# Enforcement of Emission Standards and I/M Programme

## Draft Report- Part 2

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0.0 Executive Summary

For improvements in air quality, the implementation of stringent emission standards for the new vehicles alone is not enough. To obtain maximum air quality benefits as a result of introduction of high technology, low emission vehicles, it is essential that these vehicles are maintained in good condition during their service life ensured through implementation of an in-use vehicle emission inspection and maintenance (I/M) programme. In this report, based on the experiences gained worldwide on implementation of vehicle I/M programmes, the practices that evolved as the best have been discussed. In roadside inspection of about 1200 vehicles by the CASE project team, the motorcycles and diesel vehicles have been found to be the worst polluters. An I/M programme that can be implemented in Dhaka has been proposed taking into consideration the ground realities. Specific measures to control smoke from diesel vehicles are recommended.

The main observations and recommendations on enforcement of emission standards and I/M programme are given below;

0.1 A Central Vehicle Emission Control Overseeing Agency

(i) A central nodal agency to oversee and supervise the enforcement of emission regulations must be established. As a separate and functionally independent unit, it may be instituted under the administrative control of BRTA/ Ministry of Communications/DoE. This agency could be named as the Vehicle Pollution Control Agency (VPCA).

(ii) Institutional design of the program is very important. The type of inspection centers, QA and QC of inspection, vehicle information system, enforcement and compliance, and management of financial resources are important issues.

0.2 Inspection Centers

(iii) Centralized, Multi-Lane, ‘Test only’ inspection centers are considered to be the best for an I/M programme. Also, the inspection centers are best operated by the private companies. For Dhaka the best practical option in view of past experiences here are considered to be, the ‘Test Only’, Decentralized Single - Lane, Privately Owned and Operated centers.

(iv) Based on once a year emission inspection, presently 54 single lane inspection centers for petrol/CNG vehicles and 9 centers for diesel vehicles are required.

(v) The inspection centers may be set up at the retail outlets of petrol/diesel/CNG in collaboration with oil companies. The centers should be well spread over the city for convenience of motorists.

(vi) Inspection centers must be equipped with analyzers that are linked to a computer for inspection data acquisition and printing of certificates and stickers. The
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inspection data is to be acquired as the test is being done. Simultaneously, a camera hooked-up to computer photographs the vehicle number plate. It is also to be printed on the inspection certificate. No hand filled certificate or sticker should be allowed.

0.3 Vehicle Database and Information System

(vii) A computerized vehicle information system networked with the inspection centers is essential for successful implementation of emission I/M programme and must be established. A central computerized database to be set-up and managed by VPCA with data portability with BRTA.
(viii) BRTA to renew registration only for the emission compliant vehicles as logged in the central database system.
(ix) Inspection data must be communicated to central database preferably in ‘real time’, or at least daily by internet.

0.4 Quality Assurance Functions

(x) QA function related to certification of test centers, inspectors and emission measurement equipment, periodic and surprise audit of inspection centers, equipment calibration to be done by VPCA through its inspectors.
(xi) VPCA to print and supply tamper-proof blank numbered certificates/stickers to the inspection centers.
(xii) The emission inspection certificate to be designed so that the photograph of vehicle restoration number plate is also printed on the certificate along with the test results.
(xiii) VPCA to organize training of inspectors of the centers in collaboration with emission equipment suppliers/technical institutes. Roadside inspection is to supplement the well-structured and implemented I/M programme. This is not a substitute of the mandatory periodic inspection.
(xiv) Roadside inspection to be conducted by VPCA or DoE along with traffic police.
(xv) Remote Sensing Devices (RSD) for roadside inspection have been tried and are being used in the several states of the USA. However, unless a sound vehicle information system is established and functioning, the use of RSD in Dhaka will be of little value as it only a tool to find quickly the high emitters. But, maintenance and repair are the separate and follow-up actions to be implemented through I/M programme.

0.5 Financial Management and Public Awareness

(xvi) VPCA to decide inspection fee that permits reasonable profits to centers and also takes into account the cost of supervision for QA, cost of stickers and certificates, roadside inspections etc.
(xvii) The portion of inspection fee per vehicle that accounts for the cost of certificates, stickers, QA functions including roadside inspections to be reimbursed by the inspection centers to VPCA.
(xviii) Suitable measures for public awareness to be taken up by VPCA through print and electronic media. The vehicle dealers may be asked to organize emission inspection camps supported by the vehicle manufacturers for the motorists.

0.6 Compliance of New Registration Vehicles

(xix) BRTA to seek clearance from VPCA before new registration of new or imported reconditioned vehicles. VPCA to examine the emission compliance certificate with mass emission regulations submitted by the vehicle dealers.

(xx) Local motorcycle manufacturers should obtain emission compliance certificate from an approved laboratory homologated with Euro regulations. Such laboratories exist in China, India, Singapore some other Asian countries.

(xx) In due course of time, as more vehicle manufacturing industries are established in the country, an Emission Testing and Certification Laboratory to certify new production vehicles as per the emission standards for new vehicles may also be established.

(xxii) Each of the imported reconditioned vehicles must also undergo idle emission inspection test as per the regulations in addition to evidence that it was manufactured according to the Bangladesh regulations or better before the clearance is given.

0.7 Measures to Control Diesel Smoke from Buses and Trucks

(xxiii) Diesel smoke emissions is a serious problem as they emit high smoke and only 26% vehicles were found to meet the current standards. To mitigate this problem specific measures suggested include:

- Henceforth, only CNG buses to be inducted in Dhaka and diesel buses to be phased out in the next 2 to 3 years’ time.
- Government as a policy should encourage use of CNG operated buses and other heavy duty vehicles in Dhaka.
- Overloading of trucks to be strictly prevented.
- Age limit of trucks and buses to be fixed for operation in the city, old vehicles to be scrapped or relocated.
- Ban import of used diesel engines for vehicle application.
- Vehicles observed giving visible smoke to be sent for inspection to a referral inspection center for test and repair and re-inspection
1.0 INTRODUCTION

The different factors that are important components of a comprehensive vehicular air pollution control program have been briefly mentioned in the Part-I (1) of the Draft Report and are again shown in Fig. 1. The emission standards, one of the four important factors are discussed in Part -I and revisions to Bangladesh emission standards are proposed. The vehicle emission inspection and maintenance (I/M) mandate is another key factor that is to be addressed concurrently to make the emission control program effective in real practice. The enforcement of vehicle emission regulations particularly for in-use vehicles is the second part of consultancy and is the subject of this report i.e., Part –II of the enforcement consultancy report.

Figure 1: Elements of a vehicle emission control strategy

The enforcement of emission regulations is the key operative part of vehicle emission control program to be overseen or accomplished by the government. After the emission standards are set, the automobile industry and oil industry perform their technical function to meet these regulations by manufacturing the low emission vehicles and providing the motor fuels of required quality. The government or its appointed agency has to ensure now that the vehicles so developed perform in real operation as required and envisaged by the standards.

Enforcement of emission regulations for the new vehicles is now well structured in the industrialized countries. Testing and approval of the vehicle prototypes and production vehicle samples is carried out as per the laid out schedule by the specialized emission test laboratories and data submitted to the government overseeing agency. In this activity, the vehicle manufacturers only are required to participate along with the testing and enforcement agencies as this is a pre-requisite for sale of vehicles to the operators.

The enforcement of regulations for the in-use vehicles is somewhat more complex to implement as it has to deal with a large number of motorists and vehicles are spread over

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the entire country. A large variety of technology and vintage vehicles are to be dealt with by the inspection agency. The social and political issues sometimes take predominance over the technical and health (difficult to quantify) issues. If an enforcement programme fails a large number of vehicles and intend to put these out of operation, it may create. This report mainly focuses on the enforcement of emission inspection and maintenance (I/M) programs of in-use vehicles.

This report first reviews the present status of enforcement of emission regulations in Bangladesh. The report then, discusses the current practices being followed elsewhere and what are generally considered the best options.

2.0 PRESENT STATUS OF ENFORCEMENT OF EMISSION REGULATIONS IN BANGLADESH

2.1 New Registration Vehicles

A laboratory that is equipped to carry out mass emission tests as prescribed by the European/US / Japan standards is very expensive to establish and run. In Bangladesh, such a laboratory would not have enough work to justify its establishment as there is no vehicle manufacturing industry in the country at present.

In absence of any mass emission measurement and certification facility in Bangladesh, it was envisaged that at the time of registration of new or the imported-used vehicles, the vehicle dealers would be asked to produce a compliance certificate with the Bangladesh standards as notified in S.R.O. No: 220-Law/2005 dated 19 July, 2005 (2). The compliance certificate with the regulations to be provided by the vehicle dealers, is to be issued by an internationally accredited Emission Testing Laboratory /Agency. Such compliance certificate is obtained by the vehicle manufacturers before the vehicle is mass produced and marketed. However, the above Bangladesh regulations do not stipulate any such requirements.

The Director (Engineering), Bangladesh Road Transport Authority (BRTA) mentioned during a meeting with him that they go by the clearance or compliance certificate given by the Department of Environment for new vehicles. And, in case of the imported –used vehicles, the BRTA goes by the details of vehicle given in the de-registration certificate of the vehicle issued in the exporting country (3).

Subsequently, it was learnt from the Director (Labs), Department of Environment that the BRTA has asked them to certify only certain models of the locally assembled motorcycles (4). The Director (Labs) further informed that they had hardly received any such request for other than locally assembled motorcycles.

The Bangladesh S.R.O. No: 220-Law/2005 stipulates emission inspection test limits i.e., idle CO and HC for petrol/CNG three- and four- wheelers and the free acceleration smoke standards for the diesel vehicles to be met at the time of new registration. It however, does not include motorcycles for compliance with any such inspection tests. Hence, DoE were certifying the new locally assembled motorcycle models as per the
1997 standards. A copy of the format in which the DoE issued these certificates is attached (Appendix 1).

It is seen that the simple inspection tests prescribed in Part- Ga of S.R.O. No: 220-Law/2005 are not yet carried out in Bangladesh either on the new or imported-used vehicles as a pre-requisite for vehicle registration.

2.2 In-Use Vehicles

The standards for emission inspection of the in-use vehicles are also given in S.R.O. No: 220-Law/2005 dated 19 July, 2005. The main observations on the status of emission inspection of in-use vehicles are as follows,

- The government notification S.R.O. No: 220-Law/2005 dated 19 July, 2005. does not specify any inspection frequency. It could be assumed that the in-use vehicle emission inspection would be part of the vehicle fitness certification. BRTA has the following schedule of fitness certification (Table 1).

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Vehicle age before fitness certification becomes due, years</th>
<th>Subsequent fitness certification frequency, years</th>
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<tr>
<td>Motorcycles</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Cars and other private vehicles</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Taxis and 3-wheeled passenger vehicles</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Buses</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Trucks</td>
<td>1</td>
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However, it is learnt that no inspection of emissions of in-use petrol/CNG vehicles is done at the time of fitness certification. For the diesel vehicles only a visual check of smoke is done.

- No emission inspection center exists in Dhaka at present where periodic emission inspection may be carried out if mandated.
- BRTA has a limited capacity (in terms of manpower only as no inspection instrumentation is used) to check vehicle fitness. For example, at Allenbury, Teigaon office their capacity is only 100 vehicles/day but they receive 300 vehicles/day for fitness certification (3). Hence, BRTA is planning to outsource fitness certification. It was informed that BRTA has already asked through a news paper notification that all the automobile repair workshops/garages are to register with BRTA under the Motor Vehicles Rules, 1984, Rule 70 (5).
• BRTA intend to authorize some selected workshops for issuing fitness certification. Emission inspection then may also be made part of fitness certification. However, if the repair workshops are authorized to issue fitness certification, experience all over the world shows that vested interests develop resulting into a lot of uncalled for repair jobs and expenses to vehicle owners. Also, false certificates may be issued as no garage would admit that they do not have capabilities to fix the problems. The inspection for fitness and repair jobs must be done by different entities to avoid such a situation.
• DoE has been conducting roadside inspection with the help of Traffic Police and sometimes accompanied also by a magistrate. They have inspected more than 1200 vehicles during the last 1-2 years in Dhaka, Chittagong and a few other large cities. These are only random checks and not part of any organized I/M programme.
• The roadside emission inspections by DoE cannot substitute the mandatory emission inspection programme. In this roadside inspection activity, if a vehicle failed the test there was no system and procedure to ensure that the vehicle is repaired and re-inspected as there exists no established emission inspection centers.
• Roadside emission inspection in absence of mandatory emission inspection would result only in creation of some type of fear among the motorists without providing them with the facilities for re-inspection after necessary repairs. This is more problematic for the petrol/CNG vehicle operators as the CO and HC are invisible gas emissions unlike the black smoke from the diesel engines.

3.0 VEHICLE EMISSION I/M PROGRAMME: ESSENTIAL COMPONENTS

A successful vehicle emission inspection and maintenance programme must address the following main issues;

• Institutional Design: What type of institutional framework can best meet the objectives of vehicle I/M?
• Emission Standards and Test Procedures: Pollutants to be monitored and the standards and test procedures to be used.
• Compliance: How to ensure that maximum number of vehicles comply with the standards?
• Management of the Programme: Financial, socio-political and institutional management by the government.

The above issues governing effectiveness of an I/M programme are discussed below in the light of experiences in other countries around the world. Several agencies like the US Agency for International Development (USAID), Asian Development Bank (ADB), CAI-Asia and independent consultants have studied the I/M programmes being implemented in the developed as well developing countries (6-11). These studies have attempted to identify what are the best possible options so that I/M programmes are cost-effective that result in maximum reduction of emissions with minimum costs to the motorists and
society as a whole. The programmes also need to be generally acceptable to public, minimize fraudulent practices and harassment to motorists.

**4.0 INSTITUTIONAL DESIGN OF I/M PROGRAMMES**

The different components of institutional design of a typical I/M programme are shown in Fig. 2. Important functions to be accomplished by the organizational structure of an I/M program include basically the;

(i) Establishment of emission inspection centres
(ii) Quality assurance and quality checks of inspection and inspection centres i.e., an auditing function of test centres, inspection staff and test equipment
(iii) Inspection data management through networking of inspection centres for identification and re-inspection of failed vehicles after repairs

![Figure 2 Components of Institutional Design of an I/M Programme](image)

**4.1 Inspection Centres- Types and Ownership**

Type of inspection centres and their ownership has been the subject of intense discussions and review by the experts worldwide. The experiences of developed countries such as the USA and European countries as well as developing countries viz., Mexico, India, and Chile etc. provide information to draw useful conclusions on the best and acceptable practices. The inspection centres depending upon the functions these perform and their ownership are classified as

- ‘Test only’ or ‘Test and Repair’ Centres
- Centralized or De-centralized centres
- Private or Public Ownership

**4.1.1 ‘Test Only’ versus ‘Test and Repair’ Centres**
Based on the experience worldwide the experts recommend the ‘Test” only centres. The ‘Test and Repair’ centres had poor performance in the developing countries where governance to ensure proper functioning of inspection centres has been generally weak. In other countries too, the experience has been far from satisfactory and some states in the US also changed to ‘Test only’ centres (6). The main advantages of the test only centres are:

- Test only centres can inspect a larger number of vehicles as their staffs are not involved in repair jobs. Mexico experience showed that ‘Test only’ centres inspect per day two times the number of vehicles compared to ‘Test and Repair’ centres.
- A higher volume of inspections results in lower inspection costs
- Due to high volume of inspections, better equipment can be installed and more skilled dedicated inspection staff may be employed
- Better overseeing of the test centres by the central supervisory authority as these will be considerably less in number.
- One of the major drawbacks of ‘Test and Repair’ Centres is development of a vested economic interest. These centres tend to recommend repairs even when not needed and also carry out excessive repairs for earning extra money.
- The Test only centres have the drawback that in case of ‘failed inspection’ the vehicle operators have to go to another place for repairs resulting in inconvenience. Further inconvenience results if the vehicle fails again on re-inspection i.e. the motorist is subjected to so-called ’ing-pong’ effect.

In Mexico, it was found that nearly 50% certificates issued by ‘Test and Repair” centres were fraudulent as no test centre is prepared to admit that they are not technically equipped to carry out the needed maintenance (6,8). The garages in turn tend to cheat on the test and issue the fraudulent certificates. In Mexico, therefore switch over to ‘Test only’ centres was made as also in Columbia and Costa Rica. In the USA, nearly half the states have adopted the ‘Test only’ type of organization. Several other countries like Sweden, Singapore, South Korea and Chile have exclusively the ‘Test only’ centres.

It is however, not a guarantee that the ‘Test only’ centres will not issue fraudulent pass certificates. These centres have been found to issue fraudulent certificates for monetary considerations as was experienced in India due to absence of good management and quality control of the test centres (8).

There should be little concern about the profitability of ‘test only’ centres. The government should decide on the appropriate test fee including the supervision and overseeing costs. The principle of “polluter pays” must apply. As the more and more new technology vehicles enter the market, more expensive tests may be required which would improve the economy of operation of the ‘test only’ centres.

It is now generally accepted that the best option for the developing countries is ‘Test Only’ centres

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4.1.2 Centralized versus Decentralized Test Centres

Centralized test only centres are multi-lane facilities. Generally 4 to 5 test lanes under one roof are built. On the other hand, a decentralized centre has only one set of test equipment and it is usually combined with repairs. India is the exception where, a large number of decentralized ‘test only’ centres exist at oil company’s retail outlets (petrol pumps). These test centres consist of a kiosk housing test equipment and the operator, situated on one side of the retail outlet at the entrance or exit. In Delhi alone more than 500 such decentralized test only centres are operating.

4.1.2.1 A Decentralized ‘Test only’ Centre

A typical decentralized ‘Test only’ centre in Delhi is in the form of a kiosk at petrol outlets. An inspection centre in the Delhi National Capital Region is shown in Figure 3. It has a computerized emission measurement system equipped with a camera to photograph the vehicle number plate when being tested and a printer to print emission inspection certificate. A typical computerized inspection test set-up used by these centres is shown in Fig. 4. The test results are communicated to the central data base maintained by the transport department of Delhi government once or twice every day.

![Figure 3 - A ‘Test only’ decentralized emission inspection centre (booth) in Delhi national capital region.](image)
Figure 4- Computerized emission test set-up of a decentralized ‘Test only’ centre in India

4.1.2.2 A Typical Centralized Multi-Lane Test Centre

Singapore has a vehicle population close to one million. It has a total of 7 centralized test only centres, five of these operated by VICOM and two centres by STA. These centres certify vehicles for roadworthiness based on which the vehicle registration is renewed. The passenger cars need to undergo roadworthiness inspection every 2 years while the commercial vehicles including taxis every year. A typical test centre has 4 inspection lanes for light duty petrol vehicles and one for diesel vehicles. A VICOM centre is shown in Fig. 5.

The inspection tests carried out on a petrol vehicle as it moves down an inspection lane are given in Table 2. The vehicle is inspected in 4-stages at 4 different inspection stations on a lane. Roadworthiness or safety inspection tests like braking test, wheel alignment, and headlight beam focus alignment, undercarriage inspection of chassis and other vehicle modules, and an emission test are carried out. A view of the light duty petrol vehicle inspection lane while the vehicle is under head light test is given in Figure 6. On an average up to 100 vehicles can be inspected every day of 10 working hours.

The tests carried out on a heavy duty diesel vehicle are given in Table 3. A full load smoke test at 100, 90 and 80 % of engine rated speed are carried out on a roller chassis dynamometer. Other tests related to safety are similar to those for the passenger cars and other light duty vehicles. A diesel truck being tested is shown on Figure 7 and the test
data displayed on instrument panel are shown in Figure 8. The test data is also being acquired on real time basis by a central data base system. As the smoke test on chassis dynamometer rollers takes longer time, a diesel vehicle inspection is completed in about 15 minutes and only 30 to 40 diesel vehicles are inspected per inspection lane per working day.

Figure 5  VICOM Sin Ming Vehicle Inspection Centre, Singapore

Figure 6  An inspection lane for petrol vehicles at VICOM, Singapore test centre
Table 2
Fitness and Emission Inspection Tests on a Petrol Vehicle in Singapore

Stage 1
**Above Carriage Check:** An inspector carries out visual checks on
- Vehicle identity (number plate, engine and chassis numbers)
- Lighting equipment (headlamps, stop lamps, front and rear lamps, direction indicators, etc)
- Bodywork, Vehicle modification/accessories
- Road wheel and tyres
- General items (seat belts, horn, windscreen, safety devices, etc)

Stage 2
**Alignment Test:** Checks front wheel alignment
The lateral movement of the front wheels is measured as the vehicle is driven over the side-slip tester.

**Brake Test:** Determines efficiency of brakes
The brake tester is used to measure brake performance, efficiency and drag force.  
*Test results are automatically registered. Test instructions and results are displayed on the overhead indicator board.*

Stage 3
**Headlight Test:** Determines proper alignment and focus of headlamps
The headlight aimer is used to measure the luminous intensity and the horizontal and vertical aim of each headlamp at high beam.

**Exhaust Emission Test:** Checks exhaust emission level of petrol driven vehicles
A probe is inserted into the exhaust pipe to collect gas sample for measurement.

**Sound Level Test**
The engine is revved and noise emission is measured to determine noise level.
*Test results are automatically registered. Test instructions and results are displayed on the overhead indicator board.*

Stage 4
**Under Carriage Check:** Checks the condition of car parts and components.
Vehicle is driven over an inspection pit for visual checks on:
- Chassis
- Exhaust system
- Suspension system
- Steering system
- Brake system
- Leakage

Test instructions and results are displayed on the overhead indicator board.
### Table 3

**Fitness and Smoke Inspection Tests on a Diesel Vehicle in Singapore**

**Stage 1**

**Above Carriage Check:** An inspector carries out visual checks on
- Vehicle identity (number plate, engine and chassis numbers)
- Lighting equipment (headlamps, stop lamps, front and rear lamps, direction indicators, etc)
- Bodywork
- Vehicle modification/accessories
- Road wheel and tyres
- General items (seat belts, horn, windscreen, safety devices, speed limiter, etc)

**Chassis Dynamometer Smoke Test:** Checks Exhaust Emission Level (Applicable for Diesel-driven Vehicles only)
- The chassis dynamometer simulates the load and inertia of the vehicle when driven on the road
- Vehicle wheel power is measured
- Smoke sample is collected from the exhaust pipe

**Stage 2**

**Alignment Test:** Checks front wheel alignment
The lateral movement of the front wheels is measured as the vehicle is driven over the side-slip tester.

**Brake Test:** Determines efficiency of brakes
The brake tester is used to measure brake performance, efficiency and drag force.

*Test results are automatically registered. Test instructions and results are displayed on the overhead indicator board*

**Stage 3**

**Headlight Test:** Determines proper alignment and focus of headlamps
The headlight aimer is used to measure the luminous intensity and the horizontal and vertical aim of each headlamp at high beam.

**Sound Level Test**
The engine is revved and noise emission is measured to determine noise level.

*Test results are automatically registered. Test instructions and results are displayed on the overhead indicator board*

**Stage 4**

**Under Carriage Check:** Checks the condition of car parts and components.
Vehicle is driven over an inspection pit for visual checks on:
- Chassis
- Exhaust system
- Suspension system
- Steering system
- Brake system
- Leakage

*Test instructions and results are displayed on the overhead indicator board.*
Enforcement of Emission Standards and I/M Programme

Figure 7  Full load Diesel Smoke test on chassis dynamometer rolls at VICOM, Singapore test centre.

Figure 8  Display of diesel smoke inspection data including engine/vehicle speeds, horse power and smoke density
4.1.2.3 Advantages of Centralized over Decentralized Inspection Centres

The centralized test only centres offer the following advantages;

(i)  A smaller number of multi-lane, centralized test-only centres would be necessary. Thus, it is far easier for the government to supervise and exercise technical audit and administrative control of the test centres

(ii) It is far easier to maintain the test equipment in good working and calibrated condition. The test results are more consistent among centres.

(iii) It is easier to employ well trained operators and keep them updated as they work in a larger group.

(iv) A small number of high volume test-only centres gives rise to easier adoption of new technology.

(v) Emission testing can be combined with fitness or roadworthy certification as is being practised in several countries like Singapore, South Korea, Hong Kong etc.

The centralized test centres are more expensive to build as these need more land in the main city area. And, if safety checks are also done then the cost of equipment and infrastructure goes up substantially. It is important to ensure profitability of the centralized test centres so that they are willing to invest in upgrading of their facilities to keep high integrity of testing and high level of quality control. It is therefore, necessary to limit the number of the centralized test centres

One complaint is however, voiced sometimes that the motorists would have to travel to long distances for inspection as a fewer number of test centres are available.

4.1.3 Public versus Private Ownership

Both examples of vehicle inspection conducted by (i) the government agencies and also (ii) private operators under government supervision exist. There is a trend world over that more and more services like transport, electricity, water etc., are being put in private sector for a better professional management. Most experts now agree that while the ‘government should regulate the I/M programmes’, actual implementation is best carried out by private operators. The reasons advanced to support it are;

(i) Budgetary pressures can hold-up maintenance and/renewal of facilities,

(ii) Fees collected are often diverted for other purposes starving the test facilities of necessary funds,

(iii) A general inability to punish poor performance or fraud by a government employee or organization, and

(iv) Setting in of complacency and incompetence due to job guarantee

It is the experience in many countries that many public services are better provided by a ‘private company accountable to the government’ rather than by a state-owned company that holds a monopoly in providing the service. Here, it must be kept in mind that by putting this service in private hands, the government is not absolving itself of
Enforcement of Emission Standards and I/M Programme

responsibility of supervision and quality assurance of the test centers. The private centers with government supervision do not automatically implement a perfect I/M programme. Government has to award contract through a transparent and competitive bidding to get a qualified and competent organization to carry out the testing. Finally, the government has to accept full accountability for supervision, quality assurance and ensuring compliance by the motorists. To quote the USAID report (6)

“There are plenty of good arguments to be made about privatization, both pro and con. Either way, outsourcing should never be viewed as the soap with which government officials wash their hands of complex issues….Government officials can privatize services. But they can’t privatize accountability....”

4.1.4 Contracting Private Companies for Inspection

The various issues to be addressed when awarding contract to private companies to implement the vehicle inspection program have been discussed in the USAID report (6). These issues are discussed briefly below. The contract has to be drafted by the contractual experts. It is important that the following factors are paid sufficient attention when awarding contract to private companies for emission inspection.

(i) Quality of inspection

The minimum qualifications set for the bidding firms should be quite stringent to ensure that the winning contractor can deliver the desired quality of inspection.

(ii) Length of contract

The length of contract should be long enough that the company recovers its investment and make some profit. With a longer contract period, the firm can amortize its investment for more years and hence reduce cost of inspection. On the other hand, a longer contract gives rise to anti-competitive effects and the firms get entrenched as the re-bidding periods are too long. The vehicle inspection should be considered by the government as a profitable business for bidding companies. Then only they will be investing in good equipment and skilled operators.
For the test only centers carrying out only no-load emission inspection tests a period of 3 to 5 years should be considered appropriate. For the centers carrying out roadworthiness tests along with emission tests a minimum contract duration of 7 to 10 years may be required as the investments would run into millions of dollars.

(iii) Single or multiple contractors

A single firm may offer lower inspection costs as it will have a high volume of business and a better quality control is possible. However, it will result into its monopoly and it may lead to poor service quality. Also, in case the contract is to be dissolved due to non-performance, it will result into complete dislocation of the inspection program until new contract is awarded which may take several months.

Multiple firms when awarded the contract would result into competition so long as each has enough business. It is likely to result in good competition and higher quality benchmarks may be set up by the government. On the other hand, it may also give rise to unhealthy practices as some contractor may become lenient in inspection to create an impression of being ‘helpful’ to get more business, resulting into passing also those vehicles which should otherwise fail.

Most of the states of the USA generally award contract to one company only (6). Singapore has two firms for one million vehicles. The entire Germany had six companies to carry out emission inspection. It is perhaps better to award contract to two or at the best three companies in one region. It will not unduly increase the work of supervision by the government and will ensure competition among the service providers. Another important advantage is that in case of failure of a company to provide good service and its contract is cancelled there are other companies who can share the load of inspection without dislocation of the I/M programme.

(iv) Cost of Inspection /Inspection fee

The government may set a band of minimum and maximum test fee when inviting bids. Setting of the lowest test fee in the bid is required to ensure a minimum level of quality and the highest level so as not to discourage the compliance. The fee should also include the cost of overseeing by the government for ensuring quality of inspections. This part of the fee is to be transferred by the contractor to the government. In a long term contract provision for inflation also need to be made.

(v) Fair competition at re-bid

This issue is important for multi-lane test only centers where huge investments are required. The companies who get the contract right in the
beginning of the programme would have an unfair advantage at the time when the rebid are invited as they already own infrastructure and can offer a low inspection fee. In this type of facilities government either provides land and general infrastructure to start with and the contractor has to provide test equipment. Alternatively, at the end of first contract the government buys the land and infrastructure which can be transferred to the new contractor. All these factors are to be included in the tender document. For decentralized type of inspection centers land etc. required is not too high and these issues are not very important.

(vi) Management of financial risk for contractors

When awarding the contract some forecasts are to be done on the number of inspections that would be done annually. This has to be derived from the number of vehicles actually under operation and the frequency of inspection as per the regulations. One has to make some provisions for noncompliance by some vehicle owners as well as the number of re-inspection of the failed vehicles. Some financial reimbursement provisions may be required if the inspections fall below the minimum target. On the other hand in case of excess inspections some part of revenue may be shared by the contractor with the government. In case of shortfall some lump-sum compensation may be paid and the test charges may be suitably increased for the next year. Provision may be made that part of test fee is kept by the government for management of risk due to shortfall in inspections.

4.2 Quality Assurance and Supervision of Inspection Program

The importance of role of overseeing by the government of the inspection stations for ensuring the quality of inspection cannot be overemphasized. An expert put it as below (8);

“implement a vehicle emissions program... [if] you are willing and able to invest the resources, manpower, and effort in auditing and supervising the program to guarantee its objectivity and transparency.”

The auditing and supervision of the test centers is a technical task that should not be taken lightly. A cadre to inspect the inspectors is to be created. Some of the important functions in this task are;

(i) Certification of test centers
(ii) Certification of inspection staff
(iii) Certification of test equipment: Ensure that only certified test equipment is used. Also, periodic as well as surprise checks on the equipment calibration are required to be done
(iv) Control of I/M Certificates: Provision and distribution of tamper-proof I/M certificates to inspection centers, and control of its inventory.
(v) Data Management: Receipt and analysis of inspection data reported by the test centers on real-time basis

(vi) Audit: Audit of test centers based on the inspection data received, audit of test procedure, calibration audits of the test equipment along with a law enforcement agency if required. Secret audit of the test centers by getting a known vehicle inspected may also be done.

(vii) Assist Roadside Inspections: Provide technical manpower to carry out roadside vehicle inspection along with police.

The above tasks may be performed by the government or by a government appointed agency of repute. Some of the tasks may be given to a technical university or NGO.

4.3 Vehicle Inspection Information System

The inspection information system is used to perform the following functions;

(i) Acquisition of vehicle inspection data in a prescribed format preferably on real-time basis or at least on daily basis
(ii) Creation of central database on the status of compliance for all vehicles
(iii) Auditing of the inspection quality for each inspection centre,
(iv) Tracking of non-compliant vehicles

Success of I/M programme in the countries outside the US and Europe such as Mexico is attributed to a large extent to a fool proof vehicle inspection information system that was put in place. In Mexico the vehicle inspection is done at the ‘test only, centralized’ inspection centres. In these centres, test results are seen only in a control room and the operator conducting the test does not see the results while conducting the test i.e., he is ‘blind’ to the test results. It prevents any manipulation of the results. All the test centres are networked with the central database system operated by the central supervising agency of the government. The test data collection has the following features;

- Tests are computer controlled, and all data are recorded electronically. No recordkeeping on paper is done as it may result into fraud or inadvertent error.
- Test data is transmitted from the test centers to a central authority in real time as the test is being conducted. Electronic security measures are used to prevent/discourage data tampering.

Electronic data transmission is essential for the central authority to always have fresh data to analyse and, supervise and audit the test operations effectively. The real time data allow remote electronic auditing of test centers and even of individual inspectors.

In the test only decentralized system a large number of test centers are to be networked, which is more difficult to implement and control. This is happening to some extent in India in cities like Delhi. The test data is transmitted daily on internet. It is not on real-
time basis but the data collected is available on daily basis to the central authority for analysis and supervision.

The central authority has to prescribe the format in which the data is to be transmitted in a uniform manner by all the test centres. Necessary electronic security measures are also to be built in to prevent tampering of the test results during and subsequent to inspection. All the data registers are to be encrypted.

A typical flow of inspection information is shown schematically in Fig. 9.

![Information Flow Diagram]

Figure 9  Information Flow in a vehicle information data base system

**5.0 EMISSION STANDARDS AND TEST PROCEDURE**

A brief review of the different type of test procedures followed in other countries is given in this section. The standards and test procedures for Bangladesh have already been
discussed in Part -1 of the consultancy report (1). However, for ready reference of the reader and completeness of this part of the report, the in-use vehicle emission standards being implemented in some Asian countries and in Europe are again discussed here. Also, the proposed emission standards for Bangladesh are given in this section.

5.1 Test Procedures

5.1.1 Petrol/ CNG Vehicles

The test procedures can be divided into:

(i) Loaded tests, e.g., US EPA IM 240, TUV 50 km/h at 7 kW load, or ASM (Acceleration Simulation Mode) test.
(ii) No load test when engine is operated at no load conditions: Low Idle or High Idle Speed Tests.

5.1.1.1 Loaded Test

The loaded tests require that the vehicle operates on a roller dynamometer, also called as chassis dynamometer. The vehicle driving wheels turn the rollers against which a resistance or load is applied. These tests are usually carried out in a well-equipped centralized centre. Vehicle is tested under a steady speed test or follows a simple cycle compared to the one used for certification of compliance of new vehicles with the mass emission standards. The well-known IM-240 test cycle is shown in Fig. 10. This test is run for 240 seconds on a roller chassis dynamometer and the complete test may take close to 15- 20 minutes for completion. The loaded test has the advantage that all the three pollutants viz., CO, HC and NOx can be evaluated. The cost of equipment is high and such inspection centers need high investments. Loaded tests also require highly skilled staff for operation.

![Figure 10](chart.png)  The IM-240 Inspection and Maintenance driving cycle used in the USA
5.1.1.2 No Load Idle Test

Excepting I/M programs in some states of the USA, all other countries by and large use no load, engine idle tests for inspection of in-service petrol and CNG vehicles. The ‘Idle Test’ is preferred over the loaded test due to its:

- Simplicity
- Low cost of equipment
- Low cost of the tests
- Acceptably effective in identifying gross polluters

The idle test is used to measure CO and HC only as the NO\textsubscript{x} under no-load conditions are in any case negligible. Now, ‘Two Stage Idle Test’ is employed for the vehicles equipped with the three way catalytic converters. In addition to the usual low idle speed test at the normal engine idle speed of 700-1200 rpm, a high speed idle test at 2500 – 3000 rpm is also conducted. At the high idle speed the engine runs hotter, the exhaust gas temperature increases and the catalytic converter starts functioning.

The idle speed test has its limitations as the engine in real life runs under load and it gives no data on NO\textsubscript{x} emissions. However, long experience has shown that this test gives a good idea of the status of maintenance of the vehicle, which has a high effect on engine emissions. The test takes only a few minutes (< 5 minutes) and incurs far lower costs than a loaded test. The idle test has been observed to discriminate fairly well between the vehicles which can be identified as ‘gross polluters’ and the ones with acceptable emission levels. It has been found to be a highly cost-effective procedure.

The detailed test procedure for measurement of idle CO and HC emissions based on European regulations ECE- R 15 is given in Annexure 1. Typical specifications of an exhaust gas analyzer and data acquisition system are also given in the annexure.

5.1.2 Motorcycles

Loaded test have not been considered anywhere for motorcycles. The motor cycle engine technology is not as advanced as of passenger cars. Motorcycles are still powered overwhelmingly by a carbureted petrol engines. The idle CO and HC emissions of carbureted engines have been seen to be good indicators that can be used to identify ‘gross polluters’. Presently, the no-load idle CO and HC emission test is used for inspection of in-use motorcycles throughout the world.

For the motorcycles powered by 2-stroke engines an acceleration smoke test was once contemplated an additional test. This test was to evaluate blue smoke emissions resulting from induction of engine lubricating oil along with the petrol or intake petrol-air mixture into the engine. As now due to stringent mass emission norms for the new motorcycles, the 2-stroke engine has been nearly phased out from use in motorcycles, inclusion of smoke test is no more relevant.
5.1.3 Diesel Vehicles

The diesel vehicles emit CO, HC, NO\textsubscript{x}, PM and smoke. However, the main pollutants of concern from the diesel engines are smoke, PM and NO\textsubscript{x}. No simple test for NO\textsubscript{x} and PM has been devised so far, which can be applied for inspection of a large number of in-service diesel vehicles in the repair garage environment.

Diesel black smoke is a visible nuisance that is objectionable to public at large. Moreover, smoke emissions reflect readily any fault with the calibration or malfunctioning of engine fuel injection system. The faulty injection system has a direct adverse effect on the fuel efficiency of the engine. Due to these considerations, almost everywhere the measurement of smoke has been adopted for I/M programmes for diesel vehicles. Two types of smoke emission inspection tests are being employed;

- No Load Smoke Test: ‘Free Acceleration’ or ‘Snap Acceleration’ Smoke Test
- Loaded Smoke Test: Full load at Maximum Torque Speed or Lug-down Test i.e., full load deceleration from rated engine speed.

5.1.3.1 Free Acceleration Smoke Test

The most common procedure for testing smoke emissions from in-use diesel vehicles is the Free Acceleration (also called Snap Acceleration) test defined according to ECE R-24 standards in EU countries and by the Society of Automotive Engineers’ SAE J1667 in the USA. In this test, with the engine idling and transmission in neutral, the accelerator pedal is pushed rapidly but not abruptly to its fully depressed position, accelerating the engine from low idle to its maximum governed speed. During the engine acceleration, peak smoke density (opacity) is recorded. This process is repeated several times and the average of the maximum exhaust gas opacity in each test is computed. This test suffers from the following drawbacks;

(i) Reproducibility of the test is poor when the test is conducted by a number of inspectors or using different designs of smokemeters.
(ii) Small differences in the time taken to accelerate the engine from low idle to maximum governed speed may give significantly different exhaust opacity readings.
(iii) The test does not correspond to any real life operating condition of the engine.

These drawbacks assume high significance especially where financial incentives may be offered to testers to pass the smoking vehicles. A well trained inspector is capable of performing controlled and uniform rate of engine acceleration and achieve good repeatability of the test. Dilution of the exhaust gas by air is also to be prevented which would otherwise result in low smoke readings.
5.1.3.2 Loaded Test

To overcome the drawbacks of Free Acceleration test and to improve reproducibility and repeatability of the smoke test, a loaded test has been employed in some countries notably in Singapore, South Korea, Chile and Hong Kong. The test is carried out on a roller/chassis dynamometer either at full engine load and steady engine/vehicle speeds or in a lug down test mode. Maximum smoke opacity observed is compared with the standards.

This test although reflects better correspondence with actual engine operation and has good reproducibility, but it is expensive to carry out. The roller dynamometer is an expensive piece of equipment; the facilities require a much higher level of infrastructure and highly skilled operators.

The European Countries have still not adopted loaded smoke tests and use the free acceleration test for inspection.

PM emissions composed of fine and ultra-fine particles are of major health concern. Studies have shown that the smoke opacity, more specifically measured under free acceleration has a poor correlation with mass of particulate emissions. Even in a test conducted on an inclined slope where the vehicle was operating under load, only 32% vehicles that had high smoke also gave high PM emissions measured in the laboratory. The correlation becomes poorer for the advanced technology vehicles with electronically controlled fuel injection as the soot content of the PM emissions for these engines is very low compared to the other components of particulate matter such as the condensed heavy hydrocarbons and inorganic matter. Although, the free acceleration smoke tests cannot be relied upon as a test for identifying a vehicle with high particulate emissions but still it can serve as a diagnostic test to identify malfunctioning engines among vehicles with mechanically controlled fuel injection systems. For this category of vehicles, the smoke tests may be specifically helpful for identifying tampered fuel injection system to increase power by over-fuelling. In conclusion, to quote a World Bank note of the year 2004 (11) that still appears to be valid,

"Given the technical problems associated with measuring particulate emissions in a garage setting, smoke testing will continue to play an important role in emission testing programs...."

The detailed procedure for measurement of smoke using free acceleration test based on European regulation ECE- R24 and SA J1667 procedure is given in Annexure 2. Typical
specifications of a partial flow smokemeter and data acquisition system are also given in the annexure.

5.1.4 Comparison of I/M Tests

The pollutants monitored, cost and time required for carrying out various tests for emission inspection are compared in Table 4. The loaded tests require a roller/chassis dynamometer that may cost USD 100,000 to 150,000 or more for light duty vehicles and significantly higher for the trucks and buses. The mass of emissions in transient loaded tests is measured requiring more sophisticated emission analyzers and sampling system that may cost USD 150,000 to 200,000 or more.

Table 4
Comparison of Emission Inspection Tests for Petrol and Diesel Vehicles

<table>
<thead>
<tr>
<th>Test</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>PM</th>
<th>Smoke</th>
<th>Cost</th>
<th>Time*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Petrol/CNG Vehicles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idle</td>
<td>√</td>
<td>√</td>
<td></td>
<td>-</td>
<td>-</td>
<td>Very Low</td>
<td>Fast</td>
</tr>
<tr>
<td>2 Stage Idle</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>Very Low</td>
<td>Fast</td>
</tr>
<tr>
<td>Steady State Loaded (ASM)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Transient Loaded (I/M 240)</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Diesel Vehicles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Acceleration</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>√</td>
<td>Low</td>
<td>Fast</td>
</tr>
<tr>
<td>Full Load/Lug Down</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>√</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

* Time for one test per vehicle

√: pollutants measured in the test;
- : not measured
(a): pollutants that may be measured but generally not measured

5.2 In-Use Vehicle Emission Standards

5.2.1 Petrol/CNG Cars

The in-use vehicle emission standards for the petrol and CNG light duty vehicles in EU and several Asian countries are given in Table 5 Emission inspection standards for the light duty vehicles operating on petrol and CNG, are based on idle tests. Some standards including the EU standards stipulate only the idle CO limit (the member states are free to stipulate additional parameters or more stringent regulations). However, most countries today specify also the idle hydrocarbon emissions. EU specification added a high speed idle test for the vehicles fitted with the 3-Way catalytic converters. At the high idle speeds, the exhaust gas temperatures increase and the catalyst starts functioning. The high idle speed test thus, enables to know if the catalyst is functional or not. The following important remarks in relation to trends in-service vehicle emission standards may be made;
### Table 5
Inspection Test Limits for In-Use Petro l/CNG Vehicles in Europe and Asian Countries (7, 14-16).

<table>
<thead>
<tr>
<th>Country</th>
<th>Vehicle type</th>
<th>Test</th>
<th>CO % vol.</th>
<th>HC ppm</th>
<th>Other Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>Without 3-W catalysts</td>
<td>Idle</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>With 3-W catalysts</td>
<td>Idle</td>
<td>manufacturers limit or 0.5 max</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fast idle at 2000 rpm</td>
<td>0.3</td>
<td>-</td>
<td>$\lambda = 0.97 - 1.03$</td>
</tr>
<tr>
<td>UK</td>
<td>Cars Pre 1992 model year</td>
<td>Idle</td>
<td>3.5</td>
<td>1200</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>post 1992 model year</td>
<td>Idle</td>
<td>0.5</td>
<td>-</td>
<td>$\lambda = 0.97 - 1.03$</td>
</tr>
<tr>
<td></td>
<td>Idle 2500-3000 rpm</td>
<td>0.3</td>
<td>200</td>
<td>$\lambda = 0.97 - 1.03$</td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td>All petrol and CNG from 2004</td>
<td>Idle</td>
<td>1.0</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fast idle 2500-3000 rpm</td>
<td>0.5</td>
<td>300</td>
<td>$\lambda = 0.97 - 1.03$</td>
</tr>
<tr>
<td>China</td>
<td>Cars</td>
<td>Idle</td>
<td>3.5</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>India*</td>
<td>Cars other than Euro 2</td>
<td>Idle</td>
<td>3.0</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Euro 2 and later</td>
<td>Idle</td>
<td>0.5</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast idle 2500 rpm</td>
<td>To be measured</td>
<td>750</td>
<td>To be measured</td>
<td>$\lambda$ to measure and report</td>
</tr>
<tr>
<td>Japan</td>
<td>Petrol vehicles 4-stroke</td>
<td>Idle</td>
<td>4.5</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-stroke</td>
<td>4.5</td>
<td>7800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>Cars</td>
<td>Idle</td>
<td>3.5</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>cars</td>
<td>idle</td>
<td>3.5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Taiwan</td>
<td>Cars</td>
<td>Idle</td>
<td>3.5</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>Cars</td>
<td>Idle</td>
<td>4.5</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Vietnam</td>
<td>Cars</td>
<td>Idle</td>
<td>4.5</td>
<td>1200</td>
<td></td>
</tr>
</tbody>
</table>

*For CNG & LPG vehicles the measured Hydrocarbon value is converted using the following formula and then compared with the limits
- For CNG Vehicles- Non Methane Hydrocarbon, NMHC = 0.3 x HC
- For LPG Vehicles- Reactive Hydrocarbon, RHC = 0.5 x HC
(i) In Europe since the introduction of Euro 1 standards, the inspection test limits have remained the same. As the more advanced emission control systems needed by Euro 4 or Euro 5 vehicles do not necessarily reduce idle emissions any further, the limits have been retained at the levels specified for the Euro 1 vehicles.

(ii) In Europe, in addition to the emission inspection tests, use of On-Board Diagnostics (OBD) systems on the vehicles has been made mandatory. EU Directive 98/69/EC required OBD systems to be fitted from 2000 (8). An OBD system consists of a computer included in the vehicle’s electronics for detecting operational malfunctions of the engine control system. The OBD system continuously monitors the functioning of important engine parameters that affect emissions and the functioning of the emission control systems like EGR, catalytic converter etc. In case of failure of the emission control systems, the dashboard flashes the warning signal and prompts the operator to get the vehicle repaired. The OBD however, is not the substitute of inspection tests but it complements the maintenance of vehicles.

5.2.2 Motorcycles and Petrol/CNG 3-Wheelers

<table>
<thead>
<tr>
<th>Country</th>
<th>Vehicle type</th>
<th>Test</th>
<th>CO % vol.</th>
<th>HC ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Motorcycles</td>
<td>Idle</td>
<td>4.5</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>3-Wheelers Petrol</td>
<td>Idle</td>
<td>4.5</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>3-W CNG</td>
<td>Idle</td>
<td>3.0</td>
<td>-</td>
</tr>
<tr>
<td>China</td>
<td>Motorcycles Post 1996</td>
<td>Idle</td>
<td>4.5</td>
<td>2200</td>
</tr>
<tr>
<td></td>
<td>4-Stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-stroke</td>
<td></td>
<td>4.5</td>
<td>8000</td>
</tr>
<tr>
<td>India*</td>
<td>Motorcycles and 3-Wheeler</td>
<td>Idle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre 2000, 2/4-Stroke</td>
<td></td>
<td>4.5</td>
<td>9000</td>
</tr>
<tr>
<td></td>
<td>Post 2000, 4-Stroke</td>
<td></td>
<td>3.5</td>
<td>4500</td>
</tr>
<tr>
<td></td>
<td>Post 2000, 2-stroke</td>
<td></td>
<td>3.5</td>
<td>6000</td>
</tr>
<tr>
<td>Japan</td>
<td>Motorcycles</td>
<td>Idle</td>
<td>4.5</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>4-stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-stroke</td>
<td></td>
<td>4.5</td>
<td>7800</td>
</tr>
<tr>
<td>Malaysia</td>
<td>All Motorcycles</td>
<td>Idle</td>
<td>3.5</td>
<td>600</td>
</tr>
<tr>
<td>Singapore</td>
<td>All Motorcycles</td>
<td>Idle</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>Taiwan</td>
<td>All Motorcycles</td>
<td>Idle</td>
<td>3.5</td>
<td>2000</td>
</tr>
<tr>
<td>Thailand</td>
<td>All Motorcycles</td>
<td>Idle</td>
<td>4.5</td>
<td>10000</td>
</tr>
</tbody>
</table>

*For CNG & LPG vehicles the measured Hydrocarbon value is converted using the following formula and then compared with the limits.
- For CNG Vehicles: Non Methane Hydrocarbon, NMHC = 0.3 x HC
- For LPG Vehicles: Reactive Hydrocarbon, RHC = 0.5 x HC
The emission inspection limits for motorcycles and, the petrol and CNG fuelled 3-wheeler in different countries are compared in the Table 6. As the motorcycles do not use 3-Way catalysts their CO and HC limits are set at a higher level than those for the 4-wheeled vehicles. Secondly, for the 2-stroke engine motorcycles a higher HC limit is permitted due to its inherent design problems. However, in most countries the production of 2-stroke engine motorcycles is nearly stopped or is being phased-out.

5.2.3 Diesel Vehicles

Diesel smoke emission inspection standards for different countries are given in Table 7.

Table 7
In-Use Diesel Smoke Emission Standards in EU and Asian Countries (7, 14-16).

<table>
<thead>
<tr>
<th>Country</th>
<th>Vehicle type</th>
<th>Test</th>
<th>Smoke Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Opacity, %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HSU</td>
</tr>
<tr>
<td>EU</td>
<td>&gt; 3.5 ton GVW Naturally Aspirated</td>
<td>Free Accn.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Turbocharged</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Naturally Aspirated</td>
<td>Free Accn.</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Turbocharged</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>China</td>
<td>All</td>
<td>Free Accn.</td>
<td>4.0 Bosch</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>HDV</td>
<td>Full Load</td>
<td>60</td>
</tr>
<tr>
<td>India*</td>
<td>All, naturally aspirated or turbocharged HDV, diesel cars and three wheelers</td>
<td>Free Accn.</td>
<td>65</td>
</tr>
<tr>
<td>Malaysia</td>
<td>All diesel HDV</td>
<td>Free Accn.</td>
<td>50</td>
</tr>
<tr>
<td>Singapore</td>
<td>HDV</td>
<td>Full Load test on chassis rolls at 100, 90 and 80 % of rated speed</td>
<td>50</td>
</tr>
<tr>
<td>Taiwan</td>
<td>HDV</td>
<td>Free Accn. and Full Load</td>
<td>40</td>
</tr>
<tr>
<td>Thailand</td>
<td>HDV</td>
<td>Free Accn.</td>
<td>45</td>
</tr>
<tr>
<td>Vietnam</td>
<td>HDV</td>
<td>Free Accn.</td>
<td>72</td>
</tr>
</tbody>
</table>

* For CNG buses and other heavy duty vehicles the standards for the petrol/CNG cars apply. The measured Hydrocarbon value is converted using the following formula and then compared with the limits
  - For CNG Vehicles- Non Methane Hydrocarbon, NMHC = 0.3 x HC
  - For LPG Vehicles- Reactive Hydrocarbon, RHC = 0.5 x HC
The diesel smoke inspections in most countries are done using free acceleration (FA) test due to its low cost and ease of implementation. In view of the deficiency of FA test, some countries like Hong Kong and Singapore have implemented annual smoke emission inspection tests under full engine load operation on a chassis roller dynamometer. In Europe practically all countries still use FA test for diesel smoke inspection.

5.3 Frequency of Emission Inspection

Frequency at which the in-use vehicles are inspected varies quite a bit among different countries. More frequent inspections may be expected to keep vehicles in good mechanical condition and at low emission levels. On the other hand, cost of inspection increases and a large number of inspection centers are required. In Europe, a new light duty vehicle is exempted from inspection for three years. After 3 years, the cars and other light vehicles are required to submit themselves for annual inspection. On the other extreme are countries like India where all the new vehicles after one year are required to present themselves for inspection every 3 months.

The purpose of in-use vehicle emission inspection is to identify and repair the gross polluters as it is often said that 20 to 30 percent bad vehicles contribute 70 to 80% of total vehicular pollution. More frequent emission inspection needs a very large number of inspection centers. To monitor functioning of a large number of inspection requires a very well organized and technically skilled supervisory government/neutral body which in practice, has been found to be very difficult. In Table-8 frequency of emission inspection followed in EU and some other countries are given.

Table 8

<table>
<thead>
<tr>
<th>Country</th>
<th>Vehicle Type</th>
<th>Vehicle age before 1st inspection, years</th>
<th>Frequency of inspection, years (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>Cars</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LCV &lt;3.5 ton</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HDV, taxis, ambulances</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>Cars, no catalyst or oxi .cat.</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cars, 3-W catalyst</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Diesel &lt; 3.5 ton</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Diesel &gt; 3.5 ton</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>India</td>
<td>All</td>
<td>1</td>
<td>1/4(3 months)</td>
</tr>
<tr>
<td>Singapore</td>
<td>Private cars, light vehicles</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Commercial vehicles, taxis, trucks</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
5.4 Proposed Emission Inspection Standards for In-Use Vehicles for Bangladesh

The revisions to emission inspection standards have been discussed in Part -1 of the consultancy report (1). These are again given here for ready reference.

Table 9
In-Use Petrol and CNG Vehicle Emission Inspection Standards *

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Test</th>
<th>Registered before Sept 1, 2004</th>
<th>Registered from Sept 1, 2004 to June 30, 2014</th>
<th>Registered from July 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO %</td>
<td>HC, ppm</td>
<td>CO %</td>
<td>Vol.</td>
</tr>
<tr>
<td>4–Wheeled Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petrol</td>
<td>Idle</td>
<td>4.5</td>
<td>1.0</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>Fast idle at 2500-3000 rpm</td>
<td>-</td>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNG</td>
<td>Idle</td>
<td>3.0</td>
<td>1.0</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>Fast idle at 2500-3000 rpm</td>
<td>-</td>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td>2 and 3 Wheelers Petrol driven (2-stroke vehicles not allowed to register after 2004)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-stroke</td>
<td>idle</td>
<td>7.0</td>
<td>4.5</td>
<td>3000</td>
</tr>
<tr>
<td>2-Stroke</td>
<td>idle</td>
<td>7.0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>3 Wheelers CNG driven**</td>
<td>All</td>
<td>idle</td>
<td>3.0</td>
<td>1200</td>
</tr>
</tbody>
</table>

* Standards for Dhaka and Chittagong. For the rest of country relaxed standards are proposed.

Table 10
In-Use Diesel Vehicle Smoke Emission Inspection Standards

<table>
<thead>
<tr>
<th>Diesel Vehicle type</th>
<th>Test</th>
<th>Smoke Emission Limit, HSU (m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Registered before Sept 1, 2004</td>
</tr>
<tr>
<td>Naturally aspirated</td>
<td>FA</td>
<td>65 (2.5)</td>
</tr>
<tr>
<td>Turbocharged</td>
<td>FA</td>
<td>72 (3.0)</td>
</tr>
</tbody>
</table>

* Standards for Dhaka and Chittagong. For the rest of country relaxed standards are proposed.
Table 11
Frequency of Emission Inspection for In-Use Vehicles

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Age of vehicle for 1st Inspection, years</th>
<th>Frequency of inspection, years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars/Light duty vehicles</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>(Petrol/CNG)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Wheelers (CNG?Petrol)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CNG Buses</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>All Diesel Vehicles</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

6.0 COMPLIANCE AND ENFORCEMENT

Enacting laws, setting up of emission standards and test procedures and building inspection infrastructure are not enough to ensure success of I/M programme. If a significant number of vehicles do not comply with the emission standards, then the air pollution will increase and I/M programme would be considered a failure. This is a behavioral and social problem and consists of the following two aspects:

(i) **Compliance Promotion** - The vehicle owners/operators are to be encouraged to go for inspection for compliance. Mechanisms are to be put in place to ensure it.

(ii) **Enforcement** - To identify and track down the defaulters who have not complied with the norms and penalize them.

6.1 Promotion of Compliance

Different methods have been used to encourage vehicle operators to go for vehicle inspection and compliance with the standards. These are discussed below;

6.1.1 Linking with Periodic Fitness Certification

In many industrial countries such as the USA, EU and Asian countries like Singapore, Japan, South Korea etc., the detailed computerized records of vehicle registration are maintained. Each vehicle is required periodically (every 1 to 2 years for private vehicles and every 1 year for the commercial vehicles) to undergo safety inspections for renewal of its registration. Emission compliance is made another essential requirement for renewal of registration.

As the entire vehicle data is computerized and the inspection stations are also networked with the central database, this approach has been very successful in ensuring compliance with the in-service emission regulations. The defaulters can be easily identified and tracked down.
In some countries, the safety related vehicle inspection is carried out by the Department of Transport while emission inspection is done by the Department of Environment. In such cases, this mechanism requires a strong coordination between different government agencies. In Singapore, the government authorized, privately operated inspection centers to carry out both the safety and emission inspections and work under the control of a single agency, the Land Transport Authority of Singapore.

In some countries, registration of private vehicles is required to be done only when purchased for the first time. For example, in India the registration of light duty vehicles remains valid for a period of 15 years. Under such regulatory regime, many vehicles operate even without valid registration. Sometime back, such a situation was known to prevail for auto-rickshaws operating in several large cities of India and Bangladesh. Computerization of vehicle registration records and periodic renewal of registration would help in preventing it.

6.1.2 Linkage with Insurance or Fuel Purchase

Other approaches that have been attempted to promote compliance include:

(i) *Linkage with Fuel Purchase*: In order to buy petrol or diesel compliance certificate with emissions is made essential. However, the petrol pumps are operated by the private owners and they hesitate to implement such a requirement in fear of losing business.

(ii) *Linkage with Vehicle Insurance*: It has been tried in some countries. If the private insurance companies and the government come to an agreement, it has possibility of success. In Costa Rica it has been tried and also in the Canadian province of British Columbia (6).

6.1.3 Public Awareness Campaigns

The vehicle operators and owners are more interested in vehicle roadworthiness and vehicle safety than the pollution caused by it. Another factor important to vehicle operators is the vehicle fuel economy particularly in the developing countries where the fuel prices are very high in relation to the income of the people. The vehicle safety is of course related to safety of drivers, passengers and the pedestrians. To get public support and their willingness to participate in the emission control programme, public is to be made aware that it is going ultimately to benefit them and their children. Its health benefits are to be emphasized. Several public awareness campaigns have targeted the ill effects of particulates related to increase in the incidence of asthmatic attacks by several fold among children. Public should be made aware of the benefits of emission control through I/M programmes using public awareness campaigns viz.

(i) *Public Benefit*: Reduction in air pollution leads to better health, and

(ii) *Private Benefit*: Better tuned vehicle gives fuel savings. Fuel savings of 5 to 15 depending upon vehicle technology under city driving conditions have been observed.
Public awareness campaigns may be run through TV messages and commercials, public posters/bill boards, print media etc. The expositions, exhibitions and public fairs also must be used. Government should provide budget for the publicity at the time of launching the I/M programmes to encourage the drivers to submit their vehicles for inspection and certification.

The vehicle manufacturers, vehicle dealers and oil companies, all can play an important role in bringing home to vehicle drivers the need of pollution control through mandatory emission inspection and certification.

The automobile companies may be asked by the government to conduct inspection and tuning camps for vehicles. These camps may be conducted at different geographical locations in the city to encourage most vehicle operators to become aware and get benefited by such camps.

The oil companies may display at their retail outlets posters/ bill boards. Both these sectors should share some costs of advertisements in electronic and print media.

6.2 Enforcement

Enforcement requires checking whether every vehicle carries a valid compliance certificate and the vehicles are in a state of compliance with the standards. This function requires a multi prong strategy. The approaches that complement each other in this effort include;

6.2.1 Checking by the Traffic Police

Whether the vehicle carries the valid compliance certificate or not may be checked by the traffic police. An easily visible sticker is generally used on the wind screen or suitably placed on motorcycles. The sticker should have a unique number, vehicle registration number, and validity period / expiry date. It should be forgery proof with a hologram or other security measures. It should be large enough to be clearly visible to the traffic police.

Certificate of compliance issued in India is shown in Fig. 11. In addition to emission data photograph of the vehicle registration number plate is also taken while the test is done.
The test data and the photographic image of number plate is printed on the ‘Pollution Under Control Certificate’.

Stickers to signify compliance are also issued which are usually put on the front windshield. In Mexico, these are put on the rear windshield so that these are visible to policemen for a longer period.

Corruption by police is always a negative aspect of this enforcement function. It can be reduced if the penalties of non-compliance are set at a high level. In such a situation the demand of bribe by the police would also be high. The vehicle operators would find it more prudent to carry a valid compliance certificate rather than pay a high amount of penalty or bribe.

Figure 11  Emission inspection ‘Pollution Under Control Certificate’ on emission inspection issued in India

6.2.2  Roadside Inspection

Subsequent to inspection and certification in I/M programme, a vehicle may have deterioration in emission performance after operation for some time. Such a vehicle
although, carries a valid I/M certificate but in reality may not comply with the emission standards. Deterioration in emission levels could be as a result of normal and unintentional deterioration in engine components. Also, in many cases the vehicles are made ‘clean for a day’ to pass inspection and reverted back to earlier settings. This is easy for the carbureted vehicles where the air-fuel mixture is made lean to reduce CO at the cost of vehicle drivability and on passing the inspection the carburetor settings are reverted back to the earlier settings. Some repair shops could also rent a functioning catalytic converter or a new carburetor for passing the inspection test.

Roadside emission checks have been introduced in several countries to check this intentional or unintentional deterioration of emission levels.

Several cities/countries which have roadside emission checks as part of their I/M programmes include Manila, Taiwan and Chile. Singapore also used it for diesel vehicles for visual check of smoke. Some U.S. states have roadside inspection programs for diesel trucks.

Roadside inspections are carried out by teams of police and emission inspectors conducting no-load tests using portable emission analysers. Vehicles can be selected randomly for roadside testing of petrol and CNG vehicles. Visual screening of diesel vehicles for smoke is employed for inspection. The ‘failed’ vehicles in roadside inspection are sent to a referral inspection centre for further inspection and repairs if required.

Supervision of roadside teams and quality control of inspection by them is rather difficult. In several instances, high incidence of corruption during roadside inspection has resulted into strong dislike by the motorists of such inspections. Therefore, it is suggested that roadside inspection should be limited only to diesel smoke (6). A smoky vehicle on visual screening is tested for smoke opacity and if failed is sent for re-inspection and repairs.

The primary function of roadside testing should be the identification of gross polluting vehicles and not as an alternative to the well designed I/M programme conducted at the test centers.

A report by the Asian Development Bank sums up the utility of the roadside inspection as below (7):

\[
\text{Roadside testing can complement a more comprehensive Motor Vehicle Inspection System but not replace it. Policymakers should ensure that roadside testing is designed as a complement to testing in fixed stations, but not as an alternative to it.}
\]

Consultancy by Regulatory Enforcement Specialist
6.2.3 Remote Sensing

Remote sensing of emissions has been developed and used in the US and Mexico, either to complement or as a substitute of roadside inspections (6, 18-20). It thus, plays a role in enforcement of I/M programmes. Remote sensing can also be used to photograph the number plates of the inspected vehicle. Thus, the remote sensing device (RSD) can identify vehicles not meeting the in-service emission standards and these vehicles can be issued notices for further inspection and compliance. A typical remote sensing system is shown in Fig. 12. And, Fig. 13 shows an actual remote sensing set-up.

Figure 12  Schematic of a Remote Sensing Device for emission inspection (18).

The RSD has a Sensor and Detector Module (SDM). The SDM module sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road. The light beam after traveling across the lane of road falls on a lateral reflecting mirror and on reflection it travels back to a series of detectors in SDM. The beam thus travels a dual path length. IR is used to detect CO, CO$_2$ and HC while UV is used to measure NO$_x$ and smoke.

The RSD detects emissions when a car drives through an invisible light beam from SDM. The concentrations of HC, CO, CO$_2$, NO$_x$ and smoke are measured in vehicle exhaust plumes based on their absorption of IR/UV light beam as it passes two times through the exhaust plume once to the mirror and again back to SDM.

The data-recording device captures an image of the rear of the vehicle with number plate, while the speed detector measures the speed and acceleration of vehicle.
The RSD units are housed in vans suitably converted for this purpose. These vans are equipped with air conditioning, a generator, and adequate storage for all components. The vans can be equipped with additional lighting for testing during the periods when natural light is poor such as during pre-dawn and post dusk hours.

Figure 13 Typical Remote Sensing Set-up (19).

6.2.3.1 Applications of Remote Sensing

There are three specific applications for remote sensing that supplement the normal vehicle inspection and maintenance programmes. The three applications approved by the USEPA are as follows (18):

(i) **Clean Screening (CS)**: RSD is used to identify clean vehicles which may be exempted from inspection at the inspection centres to reduce the unnecessary testing.

(ii) **Gross Emitter Identification (GEI)**: RSD is used to identify highly polluting vehicles which may be sent for testing at inspection centres even before their mandatory inspection becomes due.

(iii) **I/M Program Evaluation (PE)**: RSD is used to evaluate emissions of the vehicle fleet as a whole to estimate the impact of the I/M programme. The impact is quantified by modelling the emissions generated using software such as MOBILE5a (18, 20).
6.2.3.2 Site Selection for Application of RSD

Any road side inspection or survey of this kind has to be statistically representative of the vehicle population and the traffic conditions. In addition, the remote sensing devices have other requirements too. Some of the additional important requirements for remote sensing of emissions are;

(i) One-way traffic or divided roads allowing a single lane to be effectively monitored. Otherwise, there is interference by the exhaust plumes from vehicles plying in the opposing direction. Width of road is to be about 4 to 6 m.

(ii) Traffic flow is to be relatively high, yet at moderate speeds of 30 to 60 km/hr. Vehicles operating under moderate engine load that are representative of the actual city operation. Traffic flow to be in the range of 200 to 2000 vehicles per hour. Vehicle exhaust plumes should not overlap with each other.

(iii) The road should be dust free and its side paved for the safety and proper functioning of equipment.

(iv) RSD is not to be used during rains.

6.2.3.3 Experiences with RSD

RSD is being used in several states of the USA (19). It has been applied in Mexico (6, 20) and a pilot programme was run in Sri Lanka (18). Its efficacy was studied in Europe also (6). RSD has the advantage that it is a very fast technique. Emissions from a vehicle can be measured in about 1 second. Emissions from 5000 to 6000 vehicles in a day can be measured using one set of RSD. In Sri Lanka, during 3 months duration of the project, emissions from 100,000 vehicles on 24 sites in the cities of Colombo, Kandy, Galle and Kurunegala were measured. Using the fuel consumption data of vehicle types and the emissions measured by RSD, emission inventory can be developed. However, all these benefits have some constraints during actual operation using RSD. A considerable data has to be discarded due to interference by the exhaust plume from other vehicles.

The European study (6) concluded that;

(i) RSD is suited for identification of gross polluters’ for further inspection at test centers.

(ii) The technique is best suited for petrol/CNG vehicles as the device has a better resolution for gases like CO, HC, NOx etc. For the diesel vehicles, smoke measurement has a poor resolution. Also, in the measurement of smoke, dust particles and particles from other sources also contribute to smoke measurement.

7.0 MANAGEMENT OF RESOURCES

Implementation of a successful Inspection and Maintenance programme requires financial and technical resources. The government or its appointed authority has to arrange and manage these resources. In addition, as the I/M is a socio-economic programme; the government has also to see that there is no negative backlash which may discourage the participation of motorists. These issues are briefly discussed as follows;
7.1 Economic Resources

Financial resources are required for

(i) Establishment of the inspection centers, cost of land, infrastructure and test equipment
(ii) Operating costs of inspection centers
(iii) Networking of the inspection centers and data base management
(iv) Cost of overseeing and quality insurance of inspection centers
(v) Cost of tamperproof certificate
(vi) Roadside inspection

Cost of test only inspection centers depend on whether these are centralized or decentralized and if the tests are ‘no-load’ or ‘loaded’ tests. Another factor is whether inspection for certification of ‘roadworthiness’ or renewal of registration is combined with emission inspection. The centralized inspection centers may have 4 to 6 inspection test lanes. These centers require more space and land at places which are easily accessible to the vehicle operators. The equipment cost may vary substantially if the loaded tests are required (USD 200,000 to 300,000 per test lane). Thus a multi-lane test center may cost over a million dollars. Government in Bangladesh, Delhi government created such test facilities, but unfortunately none of these facilities are working due to inherent weaknesses of a public organization. The private operators in several countries have made investments in centralized I/M inspection facilities when assured of adequate returns on their investments. Government may contract out the building and operation of the centralized inspection centers.

The decentralized ‘test only’ centers are owned and operated by private companies in India as the cost of facilities is low. Space requirement of these centers is also low and these are located mostly in a corner of petrol/diesel/CNG retail outlets owned by the dealers of the oil/gas companies. One set of emission analyzer, computer, data acquisition system, printer etc., may cost about USD 10,000 to 12,000 and total investment may be around USD 15,000, which may be easily afforded by small entrepreneurs. Engineering diploma holders may start this venture if reasonable test fees are levied.

The cost of overseeing, data base management, certificate printing has to be incurred by the government. These costs are also to be paid by the motorists. The roadside inspection supplements the implementation of I/M program. Hence, its cost is also to be borne by the motorists.

Test fees thus, should include not only the cost of inspection but also, cost of overseeing the centers by the government, cost of certificate and also roadside inspection. Cost component of inspection fee that correspond to creation of a centralized I/M database, quality assurance, auditing and, the I/M certificates and stickers should be transferred to the overseeing agency/authority.
7.2 Technical Resources

Enough number of qualified and skilled technical persons is required by the overseeing agency to carry out the following technical functions;

(i) Overseeing and quality assurance
(ii) Data base management

Adequate attention is to be paid by the central agency to the above tasks. The supervision and control, and technical audit of the test centers cannot be taken lightly as the success of the I/M program depends on how well the quality assurance and audit of the test centers is carried out. A good data base is required to conduct audit of the test centers and track the defaulters to improve enforcement.

Other technical resources that are required include;

(i) Repair workshops of good quality
(ii) Training of emission inspectors

The repair work shops should have skilled technicians to carry out the necessary maintenance job on the failed vehicles. These workshops also need the technicians who are trained in emission measurement. The vehicle manufacturers are to play an important role here through their vehicle dealers and authorized service garages.

The technicians are to be trained in emission measurements. Technical institutes or technical universities can be entrusted with this task.

7.3 Socio-Political Resources

Management of socio-political resources consists of;

(i) Winning wider support of public
(ii) Ensure willingness of motorists to undergo mandatory inspections
(iii) Support of organized fleet owners
(iv) Support of organized groups like taxi unions, bus operator unions, auto-rickshaw operator unions
(v) Test center inspection free of fraudulent tests
(vi) Corruption free roadside inspection

The program should have a wider support of public and motorists. The importance of public awareness campaigns has already been stated. For winning the support of people it is important that the public and motorists should not feel harassed.

One issue is of the’ failure rate’. If too many vehicles fail the standards and an overwhelming number is sent for repairs and re-inspection it is likely to receive bad public reaction. Hence, the standards have to be implemented in a phased manner and are
to be tightened gradually. Experience in several countries has shown that a failure rate of 15 to 25% may be considered acceptable. The buses, trucks, taxis and auto-rickshaws are organized in groups. Some of these are politically powerful groups. The standards should not target all of them at the same time which may result in strong opposition to the programme.

It is necessary to invite all important stakeholders and discuss the programme before it is launched.

The roadside inspection has been known to result in widespread corruption particularly in the developing countries. This issue has to receive enough attention of the policy makers. The detailed roadside inspection of buses may invite resentment of the passengers as some of them may be delayed for their work. The diesel buses may preferably be visually examined for smoke and in case of heavy smoke may be referred to an inspection station instead of making the passengers wait until the test is carried out.

8.0 RECOMMENDATIONS ON ENFORCEMENT OF EMISSION STANDARDS AND I/M PROGRAMME IN DHAKA

Enforcement of emission standards has two components;

(i) Implementation of standards for new registration vehicles
(ii) Implementation of standards for in-use vehicles via an I/M programme

The practices and experiences on emission I/M programmes and, the problems faced and success achieved in other countries have been discussed earlier in this report. The practices that have been found best with regard to institutional design, test procedures and, compliance and enforcement have been identified. An I/M programme that can be implemented in Dhaka to start with must keep in view several factors such as the technical and economic factors related to establishment and operation of inspection centers, governance and supervision of compliance, vehicle population composition and technology, social and political issues. Given the ground realities of a developing country, it may not be possible to always follow the best practices for emission control. Under those situations, other alternative practices/systems are to be adopted. In this section, mechanism to enforce standards for new registration vehicles and an I/M programme are being proposed as given below;

8.1 Institutional Design

8.1.1 Central Overseeing Agency

In Bangladesh presently the environment related enforcement issues are under the jurisdiction of the Department of Environment. The renewal of vehicle registration and related vehicle inspection are of course, dealt by the Bangladesh Road Transport Authority (BRTA). Dhaka Transport Coordination Authority (DTCA) has the role of planning, advice and coordination of transport development and related issues in Dhaka.
The aims and objectives of DTCA known earlier as Dhaka Transport Coordination Board are given below (21).

The aims and objectives of the Board shall be as follows, namely:

- To advise the concerned agencies on an integrated and safe traffic and transportation system for Dhaka and to make necessary arrangements with that purpose;
- To co-ordinate the traffic and transportation infrastructure development plan with the over all development strategy plan for Dhaka as envisaged in the structure plan;
- To formulate strategic planning for traffic and transport sector of Dhaka and to co-ordinate inter agency co-operation.

To improve compliance, it is best to combine the emission inspection with renewal of registration. However, the present transport rules specify the first renewal subsequent to new vehicle registration, after 10 years for motor cycles, 5 years for cars and 3 years for three wheelers and taxis (Table 1). For the buses and trucks it is after one year. Then, the fitness certification is required to be done every year. In a successful emission control program, emission inspection after the vehicle manufacture date cannot be delayed by 5 to 10 years. In Europe, this period for cars is 3 years, LCVs 4 years and for others 1 year (Table 8). Hence, to combine it with vehicle fitness certification, the motor vehicle rules have to be amended. Accordingly the manpower and facilities in BRTA are to be augmented. In most countries e.g., European countries, various states of the USA, Singapore, Hong Kong, India the inspection of in-use vehicles for emissions as well as safety features is carried out by the Department of Transport. The Ministry of Environment or its appointed agency makes the emission standards but implementation of in-use emission standards is done by the transport department. In view of the above, it is proposed that;

‘Inspection of vehicles for safety and emissions may be combined and so stipulated in the motor vehicle rules to be carried out under the supervisory control of transport department e.g., by BRTA. The BRTA presently, has to concentrate on inspection of safety features more objectively by using necessary equipment. For emission inspection of vehicles a nodal central agency may be created under administrative control of BRTA or directly under Ministry of Communications (MoC) or DoE. Compliance with in-use vehicle emission standards is to be made a mandatory requirement for renewal of registration or ‘fitness certification’. For this purpose a good coordination between this central agency/ BRTA and DoE would be essential for enforcement of compliance’.

This central agency could be suitably named such as Dhaka Vehicular Pollution Control Agency.

Based on the discussion presented in Section 4 of this report, the main functions to be carried out by the central agency are summarized in Fig. 14. Each major function and its
role are discussed and the recommendations on the mechanism of implementation of principal activities thereof are given in the following sections.

![Diagram showing functions of Dhaka Vehicular Pollution Control Agency]

**Figure 14  Functions of Dhaka Vehicular Pollution Control Agency**

### 8.2 Emission Inspection Centers

- **‘Test only’ inspection centers or stations** to be established: Test and Repair centers develop vested interests hence must be ruled out.
- **‘Decentralized single lane centers’** are the practical option for Bangladesh at present, although the best practice is centralized, multi-lane test only centers. In view of the failure of the government operated, centralized inspection centers built in Dhaka around the year 2000, this option may not be pursued in public sector. It is not very likely that local private companies would be ready to invest millions of dollars in building centralized multi-lane centers. These are to be built within the city area that is easily accessible to the motorists. But, here the land costs would be very high. The high land costs combined with the cost of equipment and infrastructure would result in high inspection fees that allow the
companies operating the centers to make reasonable profits. International companies if invited to bid would charge still higher fees. The high cost of inspection would discourage motorists to voluntarily submit vehicles for inspection.

- **Privately Owned Centers**: As only emission inspection using no load tests are to be done, the cost of equipment (approx. 1 million BDT) is not going to be high. Also, these centers may be set-up in the premises of a petrol/diesel/CNG retail outlet.
- In future, the centralized stations may be considered to augment vehicle emission and safety inspection programme.

### 8.2.1 Number of Inspection Centers for Dhaka

No-load idle emission test is a short test and ideally may be completed for a vehicle in about 5 minutes. Taking other factors like time for movement of the vehicle to and from the inspection point, checking for engine warm-up condition, feeding vehicle data on the computer etc., it may be safely assumed that a vehicle may be easily inspected within a period of 10 minutes. The diesel smoke test takes somewhat longer and the test may be very conveniently completed within 15 minutes. For a 10 –hour working day that allows the motorists to come for inspection either before or after their usual working hours, the number of inspection station required are estimated as below.

**Centers for Petrol /CNG Vehicles:**

(i) Inspection time per vehicle : 10 mins.
(ii) Number of vehicle inspected per day during 10 working hours : 60 vehicles/day
(iii) Number of vehicles inspected per year (300 working days) and the station operating at 2/3 rd of its capacity : 12,000 vehicles/year
(iv) Total number of petrol/CNG vehicles *(cars, motorcycles, 3 wheelers, LCVs, minibuses and buses) in June 2012*: 650,000
(v) Number of single lane emission inspection centers for 1 test/year/vehicle : 55 nos.

* About half of buses, minibuses and 70% of ‘others’ vehicle estimated to be CNG operated.

**Centers for Diesel Vehicles:**

In Dhaka more than 50% buses and minibuses are already converted to CNG. The trucks although registered in Dhaka must be mostly operating out side Dhaka and majority of the trucks would be diesel operated. The ‘others’ non-specified vehicles number about 60,000 consisting of the human haulers, tractors, construction vehicles. Most of these would be CNG operated. Taking 30% to be diesel operated, the total diesel vehicles registered in Dhaka are estimated to be about 72,000. The number of inspection centers estimated as below;
8.2.2 Location of Inspection Centers at Petrol/Diesel/CNG Refilling Stations

It has already been discussed that ‘Test only’ decentralized inspection centers present probably at the moment the most practical option for Dhaka. These centers may be conveniently established at the petrol/diesel/CNG dispensing stations. Presently, there are nearly 150 retail outlets for petrol, diesel and/or CNG (20.21). In Dhaka, CNG filling is done at 140 stations. Petrol and diesel is being marketed by three national oil companies viz., Padma, Meghna and Jamuna Oil Companies. The CNG is also marketed by a public sector company, the RPGCL through its dealers who are also basically the dealers of one of the three public sector petroleum marketing companies.

The government may mandate the three oil companies and RPGCL to establish the emission inspection centers through their dealers at their retail outlets. Three or four private companies in collaboration or support of the respective oil companies may be contracted to own and operate the test centers. As each of the company will operate 15 to 25 inspection centers, they will be better equipped to maintain quality of inspection. On the other hand, if the inspection centers are owned and operated by the individual dealers it will be more difficult to supervise their operation and maintain quality of inspection.

*Any fuel refilling station that also has an automobile servicing workshop attached to it may be excluded from the list of inspection centers.*

The total number of inspection centers required presently equal to 64. There are in fact, more than enough number of refueling stations where the emission inspection centers can be established. The selection of the sites may be spread over the city for the convenience of motorists. As the trucks are not allowed to enter the city during day, 4 to 5 diesel smoke test centers may be set-up on the refueling stations on the main highways at the outskirts of Dhaka city.

The type of inspection centers suitable for Dhaka keeping in mind the past experiences and present status on implementation of the emission regulations is summarized in Fig. 15.

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(i) Inspection time per diesel vehicle : 15 mins.
(ii) Number of vehicle inspected per day during 10 working hours : 40 vehicles/day
(iii) Number of vehicles inspected per year (300 working days) and the station operating at 2/3 rd of its capacity : 8000 vehicles/year
(iv) Total number of diesel vehicles : 72,000
(v) Number of single lane diesel smoke inspection centers for 1 test/vehicle/year : 9 nos.
8.3 Quality Assurance and Quality Control Mechanisms

The central supervisory agency has the task of monitoring the performance of the inspection centers. To start with, it has to do the following functions

(i) Certification of test centers  
(ii) Certification of inspectors of the test centers by checking their training documents and actual emission inspection job performance  
(iii) Certification of the test equipment whether they meet the stipulated equipment specifications in the standards or regulations

Subsequently the following functions are to be performed on a regular basis,

(i) Emission data collection through central database and its management.
(ii) Audit of test centers through analysis of emission inspection data sent by the centers to the central agency
(iii) Audit through physical inspection of test centers and equipment calibration
(iv) Audit through surprise checks and secret checks
(v) Provide tamper proof, serially numbered inspection certificate formats having a hologram or other security features.

The emission test centers in turn are to be inspected periodically for their functioning by the inspectors from the central supervisory agency.

The inspection of test centers and their equipment may be done every month or alternate month as per the specified schedule. In addition, surprise checks are also to be made.

It must establish a central computerized vehicle emission data base where the data is sent ideally in real time or at least on daily basis using internet by the inspection centers to the central agency. This data should also be analyzed for monitoring functioning of the individual test centers.

The central agency is to provide tamper proof numbered inspection certificate in printable format to the inspection centers.

This agency should also assist in roadside inspection

Three inspectors and a data base operator may be able to manage the above functions to start with.

As discussed earlier, the cost of carrying out these functions is to be met through transfer to the central agency by the inspection centers of a part of inspection fee paid by the motorists.

**8.3.1 Training of Inspectors for Inspection Centers**

Trained inspectors are required by the inspection centers and also by the central agency. The agency should lay down qualification of inspectors. A SSC (vocational) in automobile area or diploma in mechanical/instrumentation engineering would be the appropriate qualifications.

The training of inspectors may be carried out with the help of suppliers of emission analyzers and smokemeters. The training may be conducted by the central agency with the help of equipment suppliers and a technical university/institute. The training essentially to comprise of;

- Operation, calibration and general maintenance of the analyzers/smoke meters,
- the printing of data on inspection certificates/stickers,
- Emission data collection and transmission to the central data base either on real time basis or daily by internet.
- basic information on vehicle emissions

The inspectors should be called for a refresher course every alternate year or whenever there are changes in the test procedures

The QA functions of the central agency are presented in a consolidated manner in Fig. 16.

![Diagram of Quality Assurance & Supervision functions]

Figure 16 Quality assurance functions of the Vehicular Pollution Control agency

8.4 Central Computerized Vehicle Data Base

(i) All the inspection centers should be required to have internet access
(ii) The inspection centers to be networked with the central data base system
(iii) The inspection data in a standardized format to be acquired by the computer coupled to analyzer automatically as the test is being conducted. The format to be standardized by the central agency in consultations with BRTA as this data would be used both by the central pollution control agency and the transport department.

(iv) The inspection data to be transferred to the central data base system preferably on real time basis so that the inspection data is not tampered with. Until networking of the inspection centers with central data base is done, the data to be transferred by internet on daily basis.

(v) Defaulters could be identified on the data base with the use of appropriate software features and notice issued to the defaulters.

**8.5 Compliance and Enforcement Mechanism**

**8.5.1 New Registration Vehicles**

The new cars and other 4-wheeled vehicles are imported in Bangladesh. Likewise new motorcycles are also imported in large numbers. But, some motorcycles are assembled/manufactured locally. The imported new vehicles are expected to have already been certified to comply with the emission regulations in the country of their origin and the compliance certificate must be demanded before these are registered in Bangladesh. The same requirement should apply to the locally manufactured motor cycles as well. For emission control, all vehicles should comply with the national emission regulations. As no facilities for mass emission testing exist in Bangladesh, the local manufacturers can get their vehicle prototype tested for mass emissions as per the regulations in an approved laboratory operating in Singapore (VICOM Test Center), India (ARAI or ICAT), Thailand or China. As per the Euro regulations, depending upon the production volume periodically a sample of production motorcycle is required to be selected randomly and sent for full scale testing to the certification laboratory. As more vehicle manufacturing industries are established in the country, the emission testing and certification work for new vehicles would also increase. In due course of time establishment of an Emission Testing and Certification Laboratory may be required in the country.

Compliance of the new and imported reconditioned vehicles with their corresponding emission standards notified by the government may be ensured as given below before these are registered for the first time.

(i) BRTA to demand from the vehicle dealers to produce clearance given by the central vehicle pollution control agency (VPCA) at the time of registration

(ii) The vehicle dealers to submit the necessary compliance certificate to VPCA. VPCA to examine the compliance certificate for each make and model of the vehicle every year. Once a make and model is given clearance, then it is valid for all the vehicles of the same vehicle make and model during the same model year.

(iii) The dealers of new vehicles to obtain emission compliance certificate from the vehicle manufacturers. The compliance certificate is issued by a government approved agency/laboratory for each make and model of the vehicles at least once...
a year to the vehicle manufacturers. The compliance certificate is issued after
necessary mass emission testing is done by them on a sample of each make and
model of the vehicle.
(iv) The local motorcycle manufacturers must get their vehicle prototypes and
production vehicles certified by an approved laboratory homologated with Euro
regulations in Singapore, India, China or another country where such facilities
exist.
(v) VPCA to give clearance after getting satisfied with compliance certificate as in
items (ii) to (iv).
(vi) The imported reconditioned vehicles dealers also to submit the compliance
certificate for each make and model of the vehicle obtained by them from the
relevant agency in the country of import.
(vii) The reconditioned vehicles to be subjected to emission inspection by VPCA as
per the laid down emission inspection standards by the government.
(viii) VPCA to give clearance for reconditioned vehicles after getting satisfied as in
items (v) and (vi).
(ix) The clearance for the vehicle make and model under reference to be
communicated to BRTA
(x) All the information related to clearance of vehicle makes and models to be stored
in the central computerized data base.

8.5.2 In-Use Vehicles

The measures that may be adopted are discussed below and given in Fig. 17.

(i) An easily visible sticker is to be used on the wind screen of 4-wheelers and 3-
wheelers. It should be suitably placed on motorcycles. It should be large enough
to be clearly visible to the traffic police.
(ii) The sticker to have;
- a unique number,
- vehicle registration number,
- validity period / expiry date,
- forgery proof with a hologram or other security measures
(iii) Insurance companies to renew insurance only if it has a valid emission
compliance certificate
(iv) Traffic police to check whether the vehicles carry valid sticker and/or certificate
(v) Identify defaulters from the vehicle data base and issue notices
(vi) Diesel buses and other vehicles emitting visible smoke to be sent by traffic police
for inspection and repair and re-inspection.
(vii) Roadside inspection by the vehicle pollution control agency along with law
enforcement agency. Measurement of emissions may be done only for petrol/CNG
vehicles. Diesel vehicles giving visible smoke to be sent to inspection center for
testing.
8.6 Management of Financial Resources

In most countries the principle of ‘polluter pays’ is followed. The inspection fee must however, be decided by the central agency in consultation with political government as high fees may have strong public resentment. All the components of inspection fee are shown in Fig. 18 as a chart. Based on the average investments necessary for the inspection centers and taking life of test equipment equal 3 to 5 years the cost of inspection may be estimated. Presently the cost of an analyzer and computerized data acquisition and printing system is about 700,000 to 800,000 BDT. Add to this, reasonable profit for the center and cost likely to be incurred by the central agency for inspection/per vehicle. Typically cost of inspection, profit of the test center, cost of certificate and stickers, cost of quality assurance functions of the central agency and database management etc. all should be built into the inspection fee.

Figure 17: Compliance mechanism measures for in-use vehicles
8.7 Public Awareness

In addition to usual methods used such as bill boards, publicity through print media and TV,

“the vehicle dealers of big car companies, diesel vehicle manufacturers and motor cycles, three wheelers may be asked to organize emission checking camps with the help of their principals for the vehicle owners and distribute pamphlets describing benefits of emission control.”

9.0 REDUCING EMISSIONS FROM DIESEL VEHICLES

In Bangladesh, the heavy duty diesel vehicles (Buses and Trucks) are high emitters of smoke. An emission survey was conducted by the CASE Project team in Dhaka and other cities during Feb – June 2012 (22). The results on diesel smoke emissions are shown on Fig.19.
It is observed that only 26% vehicles met the stipulated limit of 65HSU. In fact, more than 55% diesel vehicles gave smoke higher than 90 HSU. It is mentioned in the Terms of Reference of this consultancy that measures to specifically control diesel smoke are to be proposed. Here it may be asked whether the standards should be relaxed so that only 20 to 25% vehicles are allowed to fail the standards. This is because, if these vehicles are temporarily disallowed from operating until repaired, the services are not dislocated. However, to meet this criterion, the emission limit of over 90HSU would be necessary which appears like an absurd proposal. Even if the standards are relaxed to 80 HSU max., only 30% vehicles pass it compared to 26% meeting the 65 HSU limit.

It was given to understand that many oil tankers are even more than 25 years old and these could not be declared obsolete and scrapped due to objections by the operators and fear of dislocating petroleum fuel supply.

To control diesel smoke some difficult and hard measures are required. The following enumerates various steps that may be taken to mitigate the diesel smoke problem;

(i) Enforcement of an improved inspection program with strict QA/QC.
(ii) Promote introduction of CNG heavy duty vehicles in the urban area
(iii) Increase the amount of fines for vehicles that emit smoke. If the fines are high than the demand of bribes sought by the roadside inspectors/traffic police would also be high. This may encourage more operators to keep their vehicles compliant with standards.
(iv) Take strict steps to stop over-loading. A number of diesel vehicle operators get their vehicle’s fuel injection system adjusted to over-fuel the engine to get more power and hence carry more load. This in turn results in a drastic increase in smoke.
(v) Improving quality of fuel at the pump. The oil companies should enforce good housekeeping measures by their dealers. The ingestion of dust in diesel fuel has to be prevented so that the content of suspended particles in the fuel is kept at very low levels. Adulterated fuel can harm the engines and increase emissions. The oil companies should be held accountable for fuel quality up to the retail outlets.

(vi) Fix maximum age of vehicles operating in urban areas. It will result in to renewal of fleet more frequently introducing at market place more of new low emission vehicles of advanced techno

(vii) Ensure good maintenance of the fleet

(viii) Educate vehicle owners about the long term financial benefits of maintaining vehicles properly that are obtained due to less number of breakdowns and higher fuel economy.

(ix) Promote training of diesel mechanics to improve their skills and the availability of better equipped workshops especially for maintenance of diesel fuel injection systems.

(x) Provide fiscal incentives to scrap old vehicles and introduce new technology vehicles

(xi) Ban import of old and used diesel engines for use in vehicles.

Most of the above measures need to be implemented to get benefits of smoke reduction as well as better vehicle fuel economy and life. As most of the diesel vehicles in Bangladesh are being used for commercial purpose, the net income generated by the vehicles is of primary concern to the operators. It also means that the operator will not like his vehicles to be impounded and withdrawn from service for non-compliance with the standards. It has been seen that at times strong punitive measures do work to ensure compliance with the standards to reduce vehicle emissions.

Significant steps like banning the import of used diesel engines for vehicle application must be taken by the government. The used diesel engines would have been scrapped due to their poor performance in the country of origin. Generally, no diesel engine being used for commercial purposes is scrapped by the operator unless its mechanical condition has deteriorated to a very bad level and its maintenance has become too expensive it to be commercially viable. Moreover, there is no mechanism and facility exists in Bangladesh to test and certify the engines or vehicles that it complies with the national standards which presently are at Euro 1 level. Hence, the only practical option is to ban their imports as existing the diesel vehicle population in the country is already of a relatively old age going beyond even 25 years.

Another significant and important measure has been related to the use of CNG buses only in the big cities. In Delhi, to tackle the problem of diesel smoke the Supreme Court of India banned operation of diesel buses starting from April 2003 allowing only the CNG fueled buses to operate. Today, entire bus fleet in Delhi of over 15,000 buses is CNG operated and it has shown a visible improvement in the pollution on the roads of Delhi. One criticism of CNG buses was advanced in Delhi that it has resulted in an increase in NO/NO₂ content of air. However, there is no acceptable evidence that the
increase in NO$_2$ content observed in Delhi since introduction of the CNG buses is due to CNG buses or due to increase in overall vehicle population. Another concern voiced is that the CNG vehicles produce ultra fine particles which may be more harmful to health. The ultra fine particle issue from the CNG vehicles however, is still being researched and debated.

Based on the above discussions the steps required to tackle diesel smoke problem in Dhaka are summarized in Fig. 20.

![Diesel Smoke Control for Buses and Trucks](image)

**Figure 20:** Measures to control smoke from buses and trucks in Dhaka.

- **Implement I/M Programme with requisite QA and QC**
- **Establish a referral inspection station for test**
- **Strict steps to prevent overloading of trucks (Weigh bridges are already in place)**
- **Time bound program to phase out diesel buses from Dhaka and new registration only of CNG buses**
- **Fix age limit for operation within the city, e.g., 12 years. Relocate the older vehicles**
- **Establish computerized data base with the central supervisory agency (VPCA)**
- **Vehicle with visible smoke to be sent to referral inspection station for test, repair & report**
- **Fine (i) In 1st year of I/M program - for 2nd offence (ii). From the 2nd year - on the first offence of visible smoke.**
- **CNG trucks for transport within and to Dhaka. Diesel trucks not destined for Dhaka to bypass the city**
- **Ban import of used diesel engines for vehicle application**
10.0 CONCLUSIONS AND RECOMMENDATIONS

For improvements in air quality, the implementation of stringent emission standards for the new vehicles alone is not enough. To obtain maximum air quality benefits as a result of introduction of high technology, low emission vehicles, it is essential that these vehicles are maintained in good condition during their service life ensured through implementation of an in-use vehicle emission inspection and maintenance (I/M) programme. In this report, based on the experiences gained worldwide on implementation of vehicle I/M programmes, the practices that evolved as the best have been discussed. In roadside inspection of more than 1200 vehicles by the CASE project team, the motorcycles and diesel vehicles have been found to be the worst polluters. An I/M programme that can be implemented in Dhaka has been proposed taking into consideration the ground realities. Specific measures to control smoke from diesel vehicles are recommended.

The main observations and recommendations on enforcement of emission standards and I/M programme are given below;

10.1 A Central Vehicle Emission Control Overseeing Agency

(i) A central nodal agency to oversee and supervise the enforcement of emission regulations must be established. As a separate and functionally independent unit, it may be instituted under the administrative control of BRTA/ Ministry of Communications/DoE. This agency could be named as the Vehicle Pollution Control Agency (VPCA).

(ii) Institutional design of the program is very important. The type of inspection centers, QA and QC of inspection, vehicle information system, enforcement and compliance, and management of financial resources are important issues.

10.2 Inspection Centers

(iii) Centralized, Multi-Lane, ‘Test only’, inspection centers are considered to be the best for an I/M programme. Also, the inspection centers are best operated by the private companies. For Dhaka the best practical option in view of past experiences here are considered to be, the ‘Test Only’, Decentralized Single-Lane, Privately Owned and Operated centers.

(iv) Based on once a year emission inspection, presently 54 single lane inspection centers for petrol/CNG vehicles and 9 centers for diesel vehicles are required.

(v) The inspection centers may be set up at the retail outlets of petrol/diesel/CNG in collaboration with oil companies. The centers should be well spread over the city for convenience of motorists.

(vi) Inspection centers must be equipped with analyzers that are linked to a computer for inspection data acquisition and printing of certificates and stickers. The inspection data is to be acquired as the test is being done. Simultaneously, a camera hooked-up to computer photographs the vehicle number plate. It is also to
be printed on the inspection certificate. No hand filled certificate or sticker should be allowed.

10.3 Vehicle Database and Information System

(vii) A computerized vehicle information system networked with the inspection centers is essential for successful implementation of emission I/M programme and must be established. A central computerized database to be set-up and managed by VPCA with data portability with BRTA.

(viii) BRTA to renew registration only for the emission compliant vehicles as logged in the central database system.

(ix) Inspection data must be communicated to central database preferably in ‘real time’, or at least daily by internet.

10.4 Quality Assurance Functions

(x) QA function related to certification of test centers, inspectors and emission measurement equipment, periodic and surprise audit of inspection centers, equipment calibration to be done by VPCA through its inspectors.

(xi) VPCA to print and supply tamper-proof blank numbered certificates/stickers to the inspection centers.

(xii) The emission inspection certificate to be designed so that the photograph of vehicle restoration number plate is also printed on the certificate along with the test results.

(xiii) VPCA to organize training of inspectors of the centers in collaboration with emission equipment suppliers/technical institutes. Roadside inspection is to supplement the well-structured and implemented I/M programme. This is not a substitute of the mandatory periodic inspection.

(xiv) Roadside inspection to be conducted by VPCA or DoE along with traffic police.

(xv) Remote Sensing Devices (RSD) for roadside inspection have been tried and are being used in the several states of the USA. However, unless a sound vehicle information system is established and functioning, the use of RSD in Dhaka will be of little value as it only a tool to find quickly the high emitters. But, maintenance and repair are the separate and follow-up actions to be implemented through I/M programme.

10.5 Financial Management and Public Awareness

(xvi) VPCA to decide inspection fee that permits reasonable profits to centers and also takes into account the cost of supervision for QA, cost of stickers and certificates, roadside inspections etc.

(xvii) The portion of inspection fee per vehicle that accounts for the cost of certificates, stickers, QA functions including roadside inspections to be reimbursed by the inspection centers to VPCA.
10.6 Compliance of New Registration Vehicles

(xix) BRTA to seek clearance from VPCA before new registration of new or imported reconditioned vehicles. VPCA to examine the emission compliance certificate with mass emission regulations submitted by the vehicle dealers.

(xx) Local motorcycle manufacturers should obtain emission compliance certificate from an approved laboratory homologated with Euro regulations. Such laboratories exist in China, India, Singapore some other Asian countries.

(xxi) In due course of time, as more vehicle manufacturing industries are established in the country, an Emission Testing and Certification Laboratory to certify new production vehicles as per the emission standards for new vehicles may also be established.

(xxii) Each of the imported reconditioned vehicles must also undergo idle emission inspection test as per the regulations in addition to evidence that it was manufactured according to the Bangladesh regulations or better before the clearance is given.

10.7 Measures to Control Diesel Smoke from Buses and Trucks

(xxiii) Diesel smoke emissions is a serious problem as they emit high smoke and only 26% vehicles were found to meet the current standards. To mitigate this problem specific measures suggested include:

- Henceforth, only CNG buses to be inducted in Dhaka and diesel buses to be phased out in the next 2 to 3 years’ time.
- Government as a policy should encourage use of CNG operated buses and other heavy duty vehicles in Dhaka.
- Overloading of trucks to be strictly prevented.
- Age limit of trucks and buses to be fixed for operation in the city, old vehicles to be scrapped and/or relocated.
- Ban import of used diesel engines for vehicle application.
- Vehicles observed giving visible smoke to be sent for inspection to a referral inspection center for test and repair and re-inspection

REFERENCES

1. Proposed Revisions to Vehicle Emission Standards for Bangladesh (Bdesh-2 and Bdesh-3), prepared by Dr. B P Pundir, Regulatory Enforcement Specialist for Clean Air and Sustainability Project (CASE), Department of Environment, Bangladesh, September 2012.
3. Personal discussions.
4. Personal discussions.
13. Personal communication with VICOM
17. Managing 2 and 3 Wheelers in Asia, CAI –Asia Centre, Phillipines, 2011
ANNEXURE 1

STANDARD TEST PROCEDURE FOR MEASUREMENT OF CO AND HC EMISSIONS FROM SPARK IGNITION ENGINES – IDLE TEST

This procedure describes standard test procedure measurement of Carbon Monoxide (CO) and Unburned Hydrocarbons (HC) emissions from spark ignition engine vehicles under engine idle conditions when operating on gasoline, CNG or LPG for the purpose of an emission inspection test. For this test NDIR gas analyzers are used. (Typical specifications of the analyzer are given at the end of this procedure)

A1.1 DEFINITIONS AND SYMBOLS

CO Carbon Monoxide
CO₂ Carbon Dioxide
O₂ Oxygen
HC Unburned Hydrocarbons
Lambda Relative air-fuel ratio
NDIR Non-Dispersive Infra-Red
RPM Revolutions per minute giving engine speed

A1.2 GENERAL

The idle CO and HC emission inspection test shall be completed in the following steps

(i) Test equipment and preparation
(ii) Vehicle preparation
(iii) Execution of idle test
(iv) Reporting of results

A1.3 TEST EQUIPMENT AND PREPARATION

A1.3.1 Exhaust Gas Analyzer

The exhaust gas analyzer employed for the test should be compliant with ISO 3930 standards. It shall measure the concentration of CO, CO₂, HC, O₂ in the exhaust gas. The analyzer would be based on NDIR principle for measurement of CO and CO₂ and electro-chemical method for O₂. It also shall determine the calculated value of the relative air/fuel ratio, λ (Lambda) for the engine and display it along with the measured values of emissions. Typical specifications for the exhaust gas analyzer are given at the end of this procedure.
A1.3.2 Test Preparation

Follow the operating procedure in the instruction manual provided by the manufacturers of analyzer;

(i) Analyzer shall be calibrated as prescribed by the manufacturers daily but no more than 4 hours before use. Every time the equipment is moved or transferred carry out zero and span checks as per the manufacturer’s instructions.
(ii) Ensure filters such as dust filter, pre-filter and strainer in the sampling lime are clean and replace them as per manufacturers instruction manual
(iii) Switch on power of analyzer and warm-up as per instructions ( normally for about 5 minutes)
(iv) Carry out leak check test for the analyzer and sampling line
(v) Conduct periodically HC hang up test to ensure that sample handling line and probe are free of contaminants. HC reading should drop to 20 ppm or below within 5 minutes when probe is removed from exhaust. If it takes more than 5 minutes replace the probe with new one.
(vi) Purge the sampling system after measurement on each vehicle as per the manufacturers’ instructions.
(vii) Key in the vehicle data, registration number, make, model, date of test etc.

A1.4 VEHICLE PREPARATION

Prior to conducting the test, the following processes shall be completed to prepare a vehicle for test:

(i) Vehicles should have been warmed up by driving it for 10 kilometers or 15 minutes before conducting the emission measurement. The warm-up condition of engine can be checked from coolant temperature gauge. If equipped so, the radiator fan should have come into operation. If oil temperature gauge is used the oil temperature shall be ≥ 70° C.
(ii) Any vehicle giving blue, white or black smoke shall not be tested and would be considered to have failed the test
(iii) In case of manual transmission vehicle, the gear lever shall be positioned in neutral position and the clutch released. For automatic transmission vehicle, the gear lever must be placed in parking position and for vehicles not having parking position in the transmission; the lever is positioned at neutral position.
(iv) Vehicle wheels shall be restrained to prevent the vehicle from moving during testing.
(v) Vehicle accessories such as air conditioner, fan, radio etc shall be turned off.
(vi) The vehicle shall be inspected for exhaust leaks. Severe leaks in the system cause air to enter into the exhaust stream, which may give erroneously low-test results.
(vii) The manual choke control should be returned to the rest position
(viii) If a vehicle is equipped with an exhaust system having multiple outlets, they shall be joined to a common pipe or the CO, CO₂ and HC content from each
of them shall be measured individually and arithmetical average of each of the pollutants taken as the test result for that vehicle.

A1.5 EXECUTION OF IDLE TEST

After preparation of the analyzer and vehicle as in Sections 2 and 3 the test shall be carried out as below:

(i) For the 4-wheeled vehicles where test at two no-load speeds (normal idle speed and a high no-load speed) is to be done, the following sequence shall be followed

(a) First the high speed test, followed by
(b) the normal idle speed test.

(ii) Engine test speed shall be recorded

(iii) Sampling probe shall be inserted into the vehicle tail pipe at least 300 mm inside from the exit of the tail pipe. If needed, an exhaust pipe extension shall be used.

(iv) Allow the exhaust measurement reading to stabilize for about 1 minute.

(v) Record any abnormalities observed

(vi) Results to be printed

A1.6 INVALID TEST

For the vehicles, where lambda, λ is not a certification parameter, the test shall be considered invalid if the measured λ is > 1.08 (8). It shows excessive dilution of exhaust gas sample due to air leakage into the exhaust pipe of the vehicle.

A1.7 Typical Technical Specifications of Exhaust Gas Analyzer and Data Processing System

<table>
<thead>
<tr>
<th>Application</th>
<th>Measurement of gaseous exhaust emissions from petrol and CNG/LPG operated vehicles automobiles for emission inspection.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Exhaust Gas Analyzer for the measurement of CO, HC, CO₂, O₂ and AFR/Lambda (λ) compliant with ISO 3930 standards and ECE R-15 regulations for emission inspection of in-service vehicles.</td>
</tr>
<tr>
<td>Features</td>
<td>Exhaust gas analyzer with LCD/LED display, Data acquisition along with computer and printer (certificate printing in letter size format), PC interface for offline data processing, sampling probe and standard accessories filters, condensed water separator, calibration gas, to make the system complete and functional.</td>
</tr>
<tr>
<td>Measurement principle</td>
<td>CO, HC, CO₂: Non dispersive Infrared (NDIR), O₂: Electrochemical</td>
</tr>
<tr>
<td>Measurement parameter</td>
<td>CO, HC, CO₂, O₂, Lambda and AFR.</td>
</tr>
<tr>
<td>Measurement units</td>
<td>% (Vol) and ppm (Vol)</td>
</tr>
<tr>
<td><strong>Measurement range</strong></td>
<td>CO: 0-10 % (Vol); CO$_2$: 0-20 % (Vol); HC: 0-20000 ppm (Vol); O$_2$: 0-25 % (Vol); Lambda: 0.5-5.0</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| **Repeatability**     | CO: within 0.01% vol, or within 2% of reading.  
                          HC: within 5 ppm vol, or within 2% of reading.  
                          CO$_2$: within 0.2% vol, or within 2% of reading. |
| **Resolution**        | CO: 0.01% vol; HC: 1 ppm; CO$_2$: 0.1% vol; O$_2$: 0.1% vol  
                          Engine Speed: rpm 10; Oil Temperature: 1$^\circ$ C |
| **Operating temperature** | +5$^\circ$C to 40$^\circ$C |
| **Calibration**       | Periodic (using certified calibration gas: calibration gas to be supplied). |
| **Power**             | 220 VAC, optional 12-24 VDC operation. |
| **Outputs**           | Printer, LCD/LED display, USB/RS-232 serial interface (PC interface), compatible with Windows 2007, XP. |
| **Water condensation removal** | Automatic and continuous. |
| **Leak test**         | Semi-automatic, with manual probe closing. |
| **Flow check**        | Automatic with minimum flow alarm. |
| **Accessories**       | - Standard Sample Probes (max. flue gas temp of 600$^\circ$C) with minimum 5m length sampling line hose/probe assembly.  
                          - Oil temperature (measurement range 20-150$^\circ$ C) with connecting cable  
                          - Engine RPM sensor (measurement range 300-6000 rpm) with connecting cable  
                          - Stores up to 100 tests  
                          - Calibration gas  
                          - Battery (option)  
                          - Filter elements for 1500 vehicle emission tests.  
                          - Standard Fuse  
                          - Instruction Manual  
                          - Any other standard accessories and parts to make the systems complete, functional and operational. |
| **Data Acquisition System** | - Data acquisition system with printer capability must be designed to capture emission test data from the gas analyzer. |
| • Compare test results to adopted vehicle emissions standards  
| • Pass/fail criteria determination.  
| • Print letter size certificate of test results. |

The system shall also have a driver/vehicle registration data input screen to link test results to a specific vehicle/driver. Provisions shall be made to prohibit inspector/operator from changing emission results or pass/fail determination. Results to be printed with serial number on a custom designed format to be provided to the vendor at the time of contract award.
ANNEXURE 2

STANDARD TEST PROCEDURE FOR MEASUREMENT OF DIESEL SMOKE - FREE ACCELERATION TEST

The procedure of measurement of smoke from diesel engine vehicles using free acceleration (FA) method is given here. This procedure is based on ECE R-24 regulations and SAE J 1667, Feb 96 procedure.

A2.1 DEFINITIONS

Diesel Smoke: Particles including aerosols, suspended in the exhaust stream of a diesel engine which absorb, reflect or refract light.

Opacity (N): The percentage of light from a source which is prevented from reaching a light detector.

Effective Path Length, L: The length in meters of the optical path obscured by smoke between smokemeter light source and light detector. The portions of optical path length between light source and detector which are not obscured by smoke do not contribute to the effective path length.

Smoke Density (k): A fundamental parameter quantifying ability of a smoke plume or a smoke sample in a tube/chamber to prevent passage of light. Smoke density is expressed on per meter basis (m⁻¹).

N, L and k are related by Beer–Lambert law as by the following equation:

\[ N = [1 - e^{-kL}] \times 100, \% \]

A2.2 GENERAL

The complete Free Acceleration Test Procedure consists of five phases as below:

(1) Vehicle preparation and safety check
(2) Smokemeter and its calibration
(3) Test conditions and smokemeter installation
(4) Vehicle preconditioning
(5) Execution of free acceleration test

A2.3 VEHICLE PREPARATION AND SAFETY CHECK

Prior to conducting free acceleration test, the following items must be checked and completed:

(i) For vehicle with manual transmission, the gear lever must be positioned in neutral position and the clutch must be released. For automatic transmission vehicle, the gear lever must be placed in parking position, if available, or otherwise in neutral
Enforcement of Emission Standards and I/M Programme

position.

(ii) Vehicle wheels must be restrained to prevent vehicle from moving during testing.

(iii) If engine is equipped with engine brake, it must be deactivated during the test.

(iv) Verify speed limiting capability of the engine governor using the following procedure: With engine at low idle slowly depress engine accelerator pedal over a period of 5 to 10 seconds to gradually increase the engine speed towards its maximum no load speed. Observe any visual or audible indications if the engine or vehicle is of questionable mechanical condition. If no problem noticed, allow the engine speed to increase to maximum governed speed and then allow decrease to the engine idle speed. In case of any speed limiting capability of governor is not functioning (engine speed goes above the rated maximum engine speed) or there could be potential engine damage or unsafe conditions of personnel or equipment could occur, the accelerator must be immediately released and the free acceleration test shall be abandoned.

(v) Vehicle should be inspected for leaks in the exhaust system. Leaks in the exhaust system result in wrongly low test readings. Vehicle with severe exhaust leaks shall not be tested.

(vi) Vehicles with blue smoke or white smoke shall not be tested.

A2.4 SMOKEMETER AND ITS CALIBRATION

For testing of smoke in this procedure a sampling type smokemeter (opacimeter) shall be used. The smokemeter shall comply with the ISO 11614- 1999 standards ‘Reciprocating internal combustion compression-ignition engines — Apparatus for measurement of the opacity and for determination of the light absorption coefficient of exhaust gas’ and/or SAE J 1667 -1996 and meeting the requirements of ECE R-24 regulations. The smoke meter shall have the following basic features;

(i) The exhaust gas to be measured shall be confined in an enclosure having a non-reflecting internal surface.

(ii) In determining the effective length of the light path through the gas, account shall be taken of the possible influence of devices protecting the light source and the photoelectric cell. This effective length shall be indicated on the instrument.

(iii) The indicating dial of the opacimeter shall have two measuring scales, one in absolute units of light absorption from 0 to 9.9 (m⁻¹) and the other linear from 0 to 100; both scales shall range from 0 at total light flux with no blockage, to full scale at complete obscuration of light beam. The 0 to 100 scale shall also be in Hartridge smoke units (HSU).

A2.4.1 Calibration of the Smoke Meter

Before conducting smoke measurements, the zero and full-scale readings of the smoke meter shall be verified for correctness using the following procedure:
(i) Prior to zero and full-scale checks the smoke meter is warmed up and stabilized according to the manufacturer’s recommendations. The smoke meter is also purged, according to manufacturer’s instruction, to clear the meter optics of soot.
(ii) The electrical circuit of the photoelectric cell and of the indicating dial shall be adjustable so that the smokemeter reading can be reset at zero when the light flux passes through the smoke chamber filled with clean air or through a chamber having identical characteristics. If necessary, adjust the smoke meter reading to 0.0% ±1.0% Opacity.
(iii) With the lamp switched off and the electrical measuring circuit open or short-circuited, the reading on the absorption coefficient scale shall be $\infty$ or maximum of scale, and it shall remain at $\infty$ with the measuring circuit reconnected.
(iv) An intermediate check shall be carried out by placing in the smoke chamber a screen representing known light absorption coefficient $k$, between 1.6 m$^{-1}$ and 1.8 m$^{-1}$. The value of $k$ must be known to within 0.025 m$^{-1}$. When the screen is introduced between the source of light and the photoelectric cell, reading on the opacimeter indicating dial shall not differ by more than 0.05 m$^{-1}$ from the specified $k$ value of neutral screen.

A.2.5 TEST CONDITIONS AND SMOKE METER INSTALLATION

The following will be followed:

(i) The test shall be carried out on an engine installed on a vehicle.
(ii) The test is carried out on a stationary vehicle; the engine shall first be brought to normal operating conditions during a road run or on a roller dynamometer. The test shall be carried out as soon as possible after completion of this warming up period.
(iii) The ratio of the cross-sectional area of the probe to that of the exhaust pipe shall not be less than 0.05. The back pressure measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).
(iv) The probe shall be a tube with an open end facing forwards in the axis of the exhaust pipe, or of the extension pipe if one is required. It shall be situated in a section where the distribution of smoke is approximately uniform. To achieve this, the probe shall be placed as far downstream in the exhaust pipe as possible or, if necessary, in an extension pipe so that, if $D$ is the diameter of the exhaust pipe at the opening, the sampling end of the probe is situated in a straight portion at least 6 $D$ in length upstream of the open end of exhaust and 3 $D$ in length downstream of extension joint. If an extension pipe is used, no air shall be allowed to enter the joint.
(v) The sampling system shall be such that at all engine speeds the pressure of the sample at the opacimeter is within the limits specified by the manufacturer of smokemeter. Depending on the characteristics of the opacimeter, control of sample pressure can be achieved by a fixed restriction or butterfly valve in the exhaust pipe or extension pipe. Whichever method is used, the back pressure
measured in the exhaust pipe at the opening of the probe shall not exceed 75 mm (water gauge).

(vi) The pipes connecting exhaust with the opacimeter shall also be as short as possible. The pipe shall be inclined upwards from the sampling point to the opacimeter, and sharp bends where soot might accumulate shall be avoided. A bypass valve may be provided upstream of the opacimeter to isolate it from the exhaust-gas flow when no measurement is being made.

A2.6 VEHICLE PRECONDITIONING

Prior to the test the vehicle should have run under load at least for 15 minutes to ensure that engine is warmed up. Vehicle coolant and oil temperature gauge may be checked to verify that the engine is within normal operating range. The oil temperature gauge provided with the test equipment may be used, if necessary to verify that the engine oil temperature is ≥ 70°C.

A2.7 FREE ACCELERATION CYCLE TEST

It is of critical importance that the operator/inspector understands the proper movement of the vehicle accelerator during testing. With the vehicle prepared as in Section 2, and engine warmed up and at running at low idle speed, the operator/inspector shall execute the free acceleration cycle as below:

(i) The operator shall move the accelerator pedal quickly but not violently so as to obtain maximum delivery from the injection pump.

(ii) This position shall be maintained until maximum engine speed is reached and the governor comes into action, plus for an additional 1 to 4 seconds.

(iii) Upon completion of the 1 to 4 seconds of operation at the maximum governed speed, the operator shall release the accelerator and allow the engine to return to the low idle speed and opacimeter reverts to the corresponding conditions.

(iv) The operator shall wait for minimum of 5 seconds and maximum of 45 seconds at the low idle speed, before initiating the next free acceleration test cycle. The time period at low idle speed had allowed the engine’s turbocharger (if so equipped) to decelerate to its normal speed at engine idle. This helps to reduce the smoke variability between free acceleration cycles.

(v) The steps (i) to (iv) shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustment of the apparatus. The maximum opacity values read in each successive acceleration shall be noted until stabilized values are obtained. No account shall be taken of the values read while, after each acceleration the engine is idling. The values read shall be regarded as stabilized when four of them consecutively are situated within a band width of 0.25 m⁻¹ and do not form a decreasing sequence. The absorption coefficient (m⁻¹) to be recorded shall be the arithmetical mean of these four values.

(vi) In cases where the engine has multiple exhaust outlets, the free acceleration tests, may be carried out on each outlet. In this case the arithmetical mean of the values recorded at each outlet is the final result, if the extreme values measured do not
differ by more than 0.15 m$^{-1}$. Otherwise the highest value of smoke observed among all outlets will be taken as the final result.

**A2.8 INVALID TEST**

The following criteria apply to consider a test to be invalid:

(i) Whenever the engine did not meet the operating engine and smokemeter temperature requirements.

(ii) Whenever improper or in-consistent depression of the accelerator paddle / throttle was suspected.

(iii) If the installation of the smoke meter or any support instrumentation was a suspect.

(iv) Whenever the post-test smoke meter zero check indicated positive zero drift, the probable cause was considered to be soot accumulation on the smoke meter optics and reading was considered invalid.

**A2.9 Typical Technical Specifications of a Smokemeter (Opacimeter) and Data Processing System**

<table>
<thead>
<tr>
<th>Application</th>
<th>Measurement of diesel vehicle smoke opacity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Partial Flow Smoke Opacity Meter compliant with the SAE J1667 / ISO 11614.</td>
</tr>
<tr>
<td>Features</td>
<td>Partial Flow Smoke Opacity Meter with large LCD/LED display, sampling line hose, measurement probe, storage battery and mains operated, connecting cables, Data acquisition system along with computer and printer (letter size certificate printing), PC interface for off line data storage and processing, standard accessories (such as calibration filter) to make the system complete and functional. To have a built in digital camera to photograph the test vehicle and the image to be acquired by the computer and printed on inspection certificate</td>
</tr>
<tr>
<td>Measurement principle</td>
<td>Light opacity /extinction.</td>
</tr>
<tr>
<td>Measurement parameters</td>
<td>Smoke opacity; oil temperature and engine speed (rpm).</td>
</tr>
<tr>
<td>Measurement units for Smoke Sampling</td>
<td>m$^{-1}$ and HSU</td>
</tr>
<tr>
<td>Measurement range</td>
<td>0-10 m$^{-1}$, 0-100 HSU</td>
</tr>
<tr>
<td>Resolution</td>
<td>Opacity:1%; Absorption (K value): 0.01 m$^{-1}$ Engine Speed: rpm 10; Oil Temperature: 1$^0$ C</td>
</tr>
<tr>
<td>Power</td>
<td>220 VAC and 12 VDC</td>
</tr>
<tr>
<td>Outputs</td>
<td>On printer, LCD user interface panel, USB/serial interface (PC interface), compatible with Windows 2007. XP.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Operational temperature range</td>
<td>+10 to +40 °C.</td>
</tr>
</tbody>
</table>
| Accessories | • Standard Sampling Probe for partial flow smokemeter about 4 meter in length sampling line hose  
• Calibration Neutral Filter of about 1.7 m⁻¹ smoke density  
• Oil temperature Sensor (measurement range 20-150 °C) with connecting cable  
• Engine RPM sensor (measurement range 300-6000 rpm) with connecting cable  
• Smoke meter stores up to minimum of 100 tests data (preferable)  
• Rechargeable battery for 20 hours continuous operation  
• Minimum 8 meter Power Supply Cable  
• AC Adapter/Charger for battery  
• Clamp – on sampling probe  
• Vertical Exhaust Extension Pole  
• Instruction Manual  
• Any other standard accessories and parts to make the systems complete, functional and operational |
| Data Acquisition System and Printer | • Data acquisition system with printer capability must be designed to capture emission test data from the smokemeter and vehicle image from the camera.  
• Convert opacity measurements to HSU units,  
• Compare test results to adopted vehicle emissions standards  
• Pass/fail criteria determination.  
• Print letter size certificate of test results.  

The system shall also have a driver/vehicle registration data input screen to link test results to a specific vehicle/driver. Provisions shall be provided to prohibit inspector/operator from changing emission results or pass/fail determination. Results to be printed with serial number on a custom designed format to be provided to the vendor at the time of contract award. |