Final Report

Strengthening the Institutional Framework for Inspection and Maintenance (I&M) Programme for In-Use Vehicles

Prepared for

Shakti Foundation

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SUSTAINABLE ENERGY
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The Energy and Resources Institute

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Executive summary

Air pollution is emerging as an important concern in India. Levels of pollutants, such as particulate matter (PM) are above the prescribed national standards in about 80% of Indian cities (CPCB 2014). Other than PM, gaseous pollutants, such as NO_x and SO_2, are found to be high at specific locations. Transport sector is one of the important contributors to pollution in cities. Sharma et al. (2013) showed that in a city, such as Bengaluru, the sector accounts for almost 50% of $PM_{2.5}$ concentrations. In studies carried out in the USA, Bishop et al. (1997) and Calvert et al. (1993) have reported that about 10% of the poorly maintained vehicles are responsible for 50% of the air pollution from the vehicular sector. TTI/DU(2013) in a study carried out in Texas, USA, found that 6.8% of in-use heavy duty diesel vehicles tested were responsible for 19.8% of total NO_x emissions. Central Pollution Control Board (CPCB 2010) attributed about 60% of vehicular air pollution in India to vehicles that are older than 10 years, though this sub-set is lesser than 30% of the total vehicular fleet. Government of India has recently announced BS-VI norms for control of emissions from new vehicles from 2020. However, in absence of an effective Inspection and Maintenance (I&M) System, the on-road reduction in emissions cannot be ensured.

Evidently, there is an urgent need to address the issue of I&M of in-use vehicular fleet. This study discusses the policies and norms regarding the criteria pollutants emitted by vehicles at different stages of life of a vehicle—type approval and conformity of production at the manufacturing stage; in-use vehicle compliance and I&M at service stage; and briefly about end of life of vehicle. With the introduction of better quality fuel and stringent emission norms India has progressed in developing norms and standards for the type approval stage, however, the policies for the in-service and end of life of the vehicle still need to be strengthened.

India has pollution under control programme for in-use vehicles at the moment. The PUC programme has institutional and technological gaps. The technology to measure emissions from the tail pipe of the vehicles has not been upgraded substantially since its introduction. The current technology measures carbon monoxide (CO)and hydrocarbons (HC) in non-diesel vehicles and smoke opacity in diesel vehicles. The technology is not appropriate for correctly measuring emissions of pollutants from new vehicles, which emit much finer particulate matter. Meanwhile, new measurement techniques and technologies, such as On-Board Diagnostic (OBD) system, have been developed and deployed in other countries for I&M. Applicability of such technologies in India is discussed in this study.

The PUC programme in India also has gaps in implementation. The operation of PUC centres is viewed as just another business venture. The centres for PUC testing are run by private operators in inadequate capacities in wayside garages and petrol pumps all over the city. The PUC operators are paid directly by the vehicle owners for testing. This leads to a conflict of interest, and PUC operators may manipulate testing results to pass the vehicles.

In this study, in-use vehicle management system was studied, and Bengaluru and Mysore were chosen as case studies for assessment of PUC programme in India. PUC operators were interviewed in the two cities. The operators were asked about the operation and maintenance costs of running the centres. It seemed that, just like any other business, PUC centres have to compete with each other to get more customers. This often leads to a conflict of interest.

The vehicle owners in Bengaluru and Mysore were interviewed to understand their perception of the PUC system in India. The main objective of this survey was to gauge the reasons why the vehicle owners lack trust in the PUC system in India; to understand how the PUC system could be improved to encourage more people to get their vehicles routinely tested; and to understand the maintenance habits that is followed by different types of vehicle owners in the two cities. In all, 3000 interviews were conducted. After analysis of the survey results, it was found that the enforcement, that is, penalization for non-compliance, was inadequate. The vehicle owners take service and maintenance of their vehicles casually and prefer local mechanics over authorized service centres.

The city of Bengaluru and Mysore maintain an online database of all the PUC tests conducted for different types of vehicles all over the city. The database is maintained by AVL technologies Pvt Ltd, Haryana. The database for the cities of Bengaluru and Mysore was collected and analysed for the purpose of this study. The objective of the analysis was to understand the pollution emission pattern displayed by the vehicle fleet in both cities. PUC database should be analysed to identify gross polluting vehicles, and then policymakers can take necessary actions to reduce emissions from these vehicles. Only 20% and 15% of the total on-road vehicles got their vehicles tested for PUC in Bengaluru and Mysore, respectively. On further analysis, it was seen that non-diesel vehicles had a higher failure rate in the PUC tests as compared diesel vehicles. Inappropriate testing techniques and easy to meet PUC standards could be the reasons why high polluting diesel vehicles pass the PUC tests. Amongst non-diesel vehicles, LPG-three wheelers were found to have the highest failure rates. The catalytic convertors in three-wheelers wear out much before these vehicles retire. Moreover, spurious LPG kits are installed in three wheelers by wayside mechanics. As a result, these vehicles run without emission control and fail the PUC tests.

Based on assessment of the current I&M regime in India, a set of recommendations have been made to strengthen the system in India.

OBD system could be a game changer for PUC testing in India. Currently, the PUC operators are required to check for the malfunctioning indicator lamp before proceeding with tail pipe emission tests in BS IV vehicles equipped with OBD. However, there are some pre-requisites before vehicles can be tested solely on the basis of OBD. The methodology to read fault codes from OBD has to be standardised in order to pass or fail vehicles. It is important to invest in anti-tampering technologies that can ensure the authenticity of OBD data. India should learn from the initiatives taken by South Korea where anti-tampering measures have been ensured to make the data obtained from OBDs more robust and reliable. The operators should also be trained to effectively use the OBD data scanners for PUC testing purpose. It is recommended that over the next 20 years, the Indian PUC system should have three kinds of testing centres. First, the existing PUC centres operating in India are needed to be strengthened in terms of technology of testing. Given the large number of vehicles without OBD in the current fleet, the potential of strengthening existing PUC centres with technologies, such as LLSP (to measure PM with higher accuracy) and NDUV (to measure NO_x) should be explored. This also requires proper standardization of technology and development of corresponding standards for the tests carried out on these technologies. These centres should be gradually phased out as new vehicles get covered with OBD technology. The second type of testing centres that needs to be gradually expanded in cities will be for analysing OBD datasets from the vehicles. The new vehicles that are fitted with OBD should be tested and certified in these centres. The vehicles failing the OBD tests for more than two times should be sent to the third type of centres (accredited inspection and certification (I&C) centres) for rigorous loaded mode testing. Presently, there are ten of these I&C centres that have been established (or in the process of being established) all over India in Nasik, Rohtak, Burari, Bengaluru, Hyderabad, Chnidwara, Railmagra, Jhuljhuli. The I&C centre in Nasik has been operational since 2015. These centres are also designed for fitness certification of commercial vehicles. Fitness testing includes testing for brakes, headlights, wipers along with PUC testing. These centres are a step forward in reducing manual manipulation of the testing results due to conflict of interest. The centre at Nasik has four lanes and can test about 175–200 vehicles in one day. To cater to a population of 10.4 million commercial vehicles, about 175 centres will be required in India assuming 200 vehicles are tested on a daily basis in a centre. Thus, the number of such testing centres has to be increased substantially, if all the commercial vehicles in the country are to be tested in these I&C centres.

This study recommends conducting annual testing of vehicles across India rather than quarterly or biannual PUC checks. The PUC standards recommended for I&M should also be tightened. It should be mandatory for all vehicles to carry a visible I&M sticker at all times, with validity period clearly mentioned on them to make it easier for traffic cops to spot defaulting vehicles. States should introduce routine checking of catalytic convertors and overall durability of vehicles to offer technologically sound, comprehensive assessment of fitness of a vehicle. The PUC certification needs to be linked and made mandatory for insurance of the vehicles.

There should be a close co-ordination between police and transport authorities to ensure that a valid PUC certificate is checked wherever papers of the vehicle are demanded. The number of checks done by the police and the RTOs should be reported periodically to the transport commissioner.

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1. Introduction

India has seen a tremendous growth in the number of vehicles. Almost 100 million new vehicles have been added to the vehicle fleet in India in the last six years (SIAM 2016). Transport sector is one of the important causes of air pollution in urban areas. The role of transport sector in the $PM_{2.5}$concentrations in cities such as Bengaluru, Delhi, Pune, and Kanpur has been 45%, 20%, 30%, and 25%, respectively (Central Pollution Control Board [CPCB], 2010).In past, the government has taken several initiatives, such as the introduction of Bharat Stage norms, to reduce the emission of pollutants from new vehicles. In this series, BS-IV norms were introduced in 13 major cities of India in 2010. The norms were then gradually implemented in other cities; it is expected that by 2017 all the vehicles in India will be manufactured according to BS-IV norms and India will move to BS-VI norms all across the country by 2020 (ICCT 2016a). These steps taken are however incomplete because even though cleaner vehicles are being introduced into the vehicle fleet, the older polluting vehicles are still plying on the road. In studies carried out in the USA, Bishop et al. (1997) and Calvert et al. (1993) have reported that about 10% of the poorly maintained vehicles are responsible for 50% of the air pollution from the vehicular sector. Study has reported that in Texas, USA 6.8% of the in-use heavy duty diesel vehicles were responsible for 19.8% of total NO_x emission from the in-use heavy duty diesel vehicles (TTI/DU 2013).

In general, the life of a vehicle can be broken down between its manufacturing, in-use or on-road, and end of life phases (Lakshmi et al. 2014; Bansal & Lloyd 2013). With regard to emission control regulations:

- The **manufacturing phase** consists of
    - Prototypes being tested against the norms prescribed for emissions of criteria pollutants and granted a Type Approval Certification
    - A subsequent Conformity of Production (COP) certification mechanism ensuring production processes are in line and continue to stay in line with Type Approval Certification (Lakshmi et al., 2014; Bansal & Lloyd, 2013).
- **Coming off the assembly line and proceeding to in-use**
    - Currently, there is no effective mechanism in India to ensure that vehicles comply with their original mass emission standards (Type Approval norms) during the useful life. The absence of a mechanism that ensures that in-use vehicles comply with TA norms (subject to deterioration factors) could lead to a situation where the introduction of better technology will not lead to expected results in emissions.
- **Inspection and Maintenance Programmes** (I&M) are designed to check for and verify fitness (or roadworthiness) of in-use private and commercial vehicles at defined periods (Walsh, 2005).

    - These are typically run by state, local government, or private agencies and tests include whether vehicles are compliant with emissions norms specifically set for in-use vehicles.
    - In general, a strong I&M programme can reduce up to 40% of vehicular pollution by effectively harnessing an integrated information management system and state of the art testing equipment to target the highest polluting vehicles that in turn can be retrofitted, repaired, or removed from roads via clear and accountable coordinating mechanisms (CPCB, 2010; Walsh, 2005).
    - This approach has a more immediate impact on emissions reduction relative to complementary policies and programmes, such as improvements in fuel quality (Lakshmi et al., 2014; CPCB, 2010).
- For vehicles approaching *end of life*, that have undergone in-use vehicle tests and failed prescribed limits,
    - Options can range from retrofitting key components of a vehicle to repairing damaged parts over specified periods of time (ICCT 2013).
    - For those vehicles that are grossly polluting, typically of older stock, incentives can be provided to discard them for recycling and scrappage purposes (A.T. Kearney & Confederation of Indian Industry 2013).
    - Discounts for purchasing new vehicles or tax incentives to scrap old vehicles are typical examples facilitating the end of a vehicle's life (A.T. Kearney & Confederation of Indian Industry 2013; Arora 2016).

Other considerations influencing variability in standards and exemptions at each phase includes the type and age of a vehicle. In principle, some semblance of harmonization in standards between manufacturing and on-road phases is desirable to achieve optimal abatement outcomes (ICCT 2013).In cases where vehicle manufacturers or owners are not able to present certification because they have not gone for testing, punitive measures can include fining drivers, withdrawing registrations, and recalling vehicles *en masse* to name a few (ICCT 2013; CPCB 2006).

It had been pointed out in the previous studies by TERI (Lakshmi et al. 2014) that the control of emissions from in-service vehicles is seriously lacking in India. While India has made some progress in improving the type approval standards and process and to an extent the COP testing of the vehicles, the in-use compliance needs to be further strengthened. At present, India only has a programme for I&M process of the vehicles, also known as PUC (pollution under control testing) in India. This study discusses in detail the current status and limitation of type approval testing, conformity of production, and the I&M System in India. Finally, the study aims to provide key suggestions for improvement of in-use vehicle emission management system in India.

2. Objective of the study

This study aims to detail out process mapping of the existing institutional arrangements for in-use vehicle testing (PUC) as well as those involved in the life cycle of vehicle ownership more generally. For the purpose of designing an appropriate institutional framework, following activities were decided to be undertaken:

- To review different in-use vehicle emission testing methodologies and overall management structure—Indian scenarios and international best practices;
- To draw conclusions from a primary survey conducted in two Indian cities in order to gauge people's awareness, perception, and opinion about in-use vehicle emission management in India;
- To understand the pollution emission pattern displayed by the vehicle fleet in Bengaluru and Mysore by analysing the PUC dataset generated in the year 2015–16.
- To prepare a position paper presenting the key recommendations and action points for the Government for revising and strengthening the institutional framework in place for in-use vehicle emissions management in India.

The proposed recommendations were discussed in a series of two workshops in Delhi and Bangalore, and the received comments have been incorporated in this report.

3. Current Institutional and Technological Framework in India

This section presents a review of institutional arrangements, technological procedures, and processes to set up emissions standards and testing procedures for different stages of life of a vehicle in India. The section presents deeper investigation of the granularities of the PUC programme.

It is also important to note that standard setting, testing, and on-road inspections are part of a broader portfolio of laws, regulations, programmes, and policies implemented by all levels of government and private actors for abatement purposes. In particular, the requirements to improve fuel quality and engine-related technologies are deeply interlinked with standard setting and testing (MoPNG 2015; National Transport Development Policy Committee 2014; ICCT 2013; Bansal & Lloyd 2013; CPCB 2010).

Interdependence has institutional implications presenting possible risks of policy overlap or conflict depending on the logistical, spatial, and temporal parameters of intended goals. In general, these interrelationships and dynamics present challenges to developing a robust framework that enables seamless navigation across multiple decision making and enforcement channels.

3.1 Type Approval and Conformity of Production (Union Government)

3.1.1 Setting emissions standards for new vehicles

Mass emissions and in-use emissions norms were first prescribed in 1990 as an amendment under Section 25 of the Environmental Protection Act (EPA), 1986. The EPA effectively afforded powers once limited to state-level governments (first articulated in the Air Act of 1981[1]) to eventually include the Central Government in the process of setting standards that would limit the rate at which various pollutants are emitted from industrial and vehicular sources (CPCB 2010).

The Motor Vehicle Act passed in 1988 and the CMVR, 1989, gave the Ministry of Road Transport and Highways (MoRTH) the authority to set and enforce standards related to vehicular emissions.

In general, MoRTH functions as a nodal agency to address an amalgam of transportation related matters (MoRTH 2014). It retains authority over a considerable range of issues pertaining to motor vehicle manufacturing and use in India. This includes policies ranging

[1] The Air (Prevention and Control of Pollution) Act, 1981 gave powers to State Pollution Control Boards to set standards in consultation with the Central Pollution Control Board (CPCB)

from safety to emissions regulation. In particular, jurisdiction is afforded to MoRTH to set mass emissions standards for vehicles preparing to be in-use along with prescription of testing procedures and equipment requirements necessary to check for and enforce compliance (ICCT 2013).

MoRTH houses two committees with involvement of multiple stakeholder that function as coordinating mechanisms between various ministries to deliberate over, develop, and decide key policies and technical revisions pertaining to vehicular emissions reduction.[2] The Standing Committee on Implementation of Emissions Legislation (SCOE) is tasked with defining and recommending mass emission standards for Type Approval and COP certification, setting test procedures and a strategy to implement the norms, and other related matters, for which it operates in advisory capacity.

The recommendations are subsequently reviewed by the Central Motor Vehicle Rule—Technical Standing Committee (CMVR-TSC), a body that is responsible for a broader set of technical inputs including safety, design, and maintenance related matters and harmonization with international standards. The MoRTH ultimately reviews and adopts or rejects the recommendations made. There is no evidence indicating that emissions standards are reviewed against a set time-period and criteria (ICCT 2013).

The SCOE is chaired by the Joint Secretary of MoRTH and is composed of officials from MoEFCC, Ministry of Heavy Industries and Public Enterprises (MoHIPE), Ministry of Petroleum and Natural Gas (MoPNG), representatives of the auto industry -the Society of Indian Automobile Manufacturers (SIAM) along with expert agencies involved with testing, such as the Automotive Research Association of India (ARAI) and the International Centre for Automotive Technology (ICAT).

The CMVR-TSC reports to MoRTH and has representatives of the Ministry of Heavy Industry and Public Enterprises (MoHI&PE), Bureau of Indian Standards (BIS), officials from Transport Departments in State Governments, Testing Agencies, such as Automotive Research of India (ARAI), Vehicle Research Development & Establishment (VRDE), Central Institute of Road Transport, SIAM, Automotive Component Manufacturers Association (ACMA), and the Tractor Manufacturers Association (TMA) (ICCT 2013).

The participation of the above-mentioned stakeholders in the CMVR-TSC suggests that setting mass emissions standards is influenced by industry specific and economic development-related goals in particular. It is notable that no environment-related ministry is represented in the CMVR-TSC.

[2] Stakeholder committees function as a coordinating mechanism to overcome institutional fragmentation and is characteristic of decision making bodies at all levels of government across India.

Other than the initiatives from the government, the judiciary has also intervened in the matters related to reduction in vehicular emissions. These interventions are derived from recommendations of additional set of committees and can include requests to submit reports, targeted mandates in select jurisdictions to make specific amendments, or sweeping policy changes (ICCT 2013; CPCB 2006).

For example, the Apex Court ordered lead-free petrol to be made available in four cities while mandating the installation of catalytic convertors into vehicles from 1995. The former decision did not take into account the risk of cross-border leakages while the latter presented coordination problems, for example, in the malfunctioning of rapidly introduced catalytic convertors given that less toxic fuels—a necessity for such convertors to function effectively—were not available in the country(ICCT 2013; CPCB 2006).

Notwithstanding such institutional hurdles, the stringency of emission standards has increased, however, at irregular intervals. Interventions in fits and starts have ultimately resulted in mandating mass emissions testing, requiring more vehicular pollutants be checked, and introduction of new vehicles to be installed with pollution-reducing technologies, such as catalytic convertors in 1995 and OBD Systems in 2013.With the recent introduction of "Bharat Stage VI" limits, the country has effectively tightened emission control norms (The Hindu 2016; MoPNG 2015; Expert Committee 2014; CPCB 2010).

Emissions standards, until recently were segregated such that stricter norms were implemented in high population metros while smaller citiescould not adopt the stricter norms due to non-availability of cleaner fuel (ICCT 2013; CPCB 2006). This decision led to highly polluting trucks from smaller cities entering into the main metropolis areas, such as the Delhi region (ICCT 2013; CPCB 2006; Roychowdhury 2015).

In India, these norms are recommended by committees set up at irregular intervals, with long gaps between the introduction of one set up of norms and the next set of more stringent norms. For example, the Mashelkar committee (in 2002) set a recommendation for a period till 2010 and suggested that another committee should be formed in 2007 for recommendations beyond 2010. However, the next committee was formed only in 2014.

3.1.2 Testing

MoRTH is largely responsible for formulating the guidelines for testing procedures of vehicles during the Type Approval and COP stage in consultation with the SCOE and CMVR-TCS (MoRTH, 2005).The general design of these mechanisms are considered to be reasonably effective given that incentives are appropriately structured for manufacturers to assume the costs and consistently submit prototypes for testing and certification (Lakshmi et al. 2014; ICCT 2013).

One drawback of the current system is that the COP inspections occur over a predictable time frame, as opposed to random checks, potentially giving manufacturers some time to superficially cover up any defaults that remain unresolved. In cases where COP tests do not match-up with Type Approval certification requirements, it appears that MoRTH submits requests to SCOE on a case-by-case basis to make appropriate recommendations for remedies (Lakshmi et al. 2014; ICCT 2013).

If 32 specimen of a particular model of a manufacturer fail, a recall procedure can be initiated although this has never happened. There appears to be no alternative in place that systematically breaks down what components of Type of Approval may not align with COP testing, and what actions are available and appropriate to remedy each type of mismatch (Lakshmi et al. 2014; ICCT 2013). The manufacturer also has the option to switch testing facilities, if it is not satisfied with the testing services offered, although a rigorous documentation procedure is to be followed to make the requested change. Limited alternatives for testing are available.

That is, there are approximately five testing facilities within which Type Approval and COP checks are conducted with two more slated to be completed by 2017 (ET Auto Bureau 2015; ICCT 2013). The centres are notable for being equipped with testing technologies capable of accurately checking newer emissions standards, the limits of which will likely continue to be tightened over the foreseeable future. Important centres involved in activities such as refining testing methodologies include the International Centre for Automotive Technology (ICAT) in Manesar and the Automotive Research Association of India (ARAI) in Pune. These facilities were and continue to be set up under the central government's National Automotive Testing and R&D Infrastructure Project (NATRiP) and are under the jurisdiction of MoHIPE (ICCT 2013).

The facilities are designed to offer a diverse set of services beyond testing, a lot of which is focused on research and development activities with the key goal of strengthening the global competitiveness of the automotive sector in India. As such, various stakeholders, including international equipment manufacturers, state level governments, various ministries from the Union government, auto representatives, among others, have are contributing both financial and non-financial support. However, such projects have seen overruns in time and cost in past, mainly due to non-availability of land for establishing these facilities.

3.1.3 Gaps: In-Use Vehicle Programmes and Recalls

The absence of IUVP may lead to a situation where vehicles continue to emit pollutants beyond prescribed limits even as Type Approval and COP measures continue to be strengthened to match international standards. That is, no effective programmes, let alone a mandate, where manufacturers check whether vehicles are functioning according to prescribed deterioration rates that allow for emission limits to incrementally increase over various stages of a vehicle's lifecycle (ICCT 2013).

One of the ways in which the likelihood of introducing an IUVP can be increased is through formalizing procedures to recalling vehicles after they have left the assembly line and are on the road (Lakshmi et al., 2014). The risk of recalls incentivizes manufacturers to make investments in IUVPs given the costs of compliance would be less than those incurred from recalls. While the Motor Vehicles Act gives MoRTH the power to initiate recalls, the decision-making apparatus has not yet allowed for formalizing any procedures.

3.2 In use vehicles – I&M

I&M of vehicles in use are largely under the jurisdiction of states in India, and consist of Pollution Under Control Checks and Fitness Tests. The main Union government legislation governing these programmes is the Motor Vehicles Act, 1988 (CPCB 2010).

3.2.1 Pollution Under Control Norms

The centre has powers to set PUC norms—distinct from mass emission standards—and key testing procedures and requirements as well (CPCB 2010). The states also have the flexibility to strengthen such norms and testing procedures while having complete jurisdiction over compliance and enforcement with respect to the functioning of PUC operators and certification of vehicle owners (CSE 2004). Although states have the authority to make PUC standards more stringent but no state has ever done it. It should be noted that tightening of norms in one state could lead to moving of commerce in the neighbouring states.

All the vehicles have to undergo the pollution under control (PUC) test; however, only commercial vehicles have to go through a fitness test on a regular basis in addition. Fitness test is needed to be undertaken by the commercial vehicles on yearly basis, starting from the second year of purchase. Besides testing the emissions, the objective of fitness test is also to ensure if the vehicle is safe to be driven on Indian roads.

The kind of tests that a vehicle will be subjected to for PUC depends upon the type of fuel used by the vehicle (or type of engine). As shown in Figure 1, the vehicles using gasoline, CNG, and LPG (spark engine) are tested for CO and HC emissions. Moreover, these vehicles are also subjected to a lambda test; which is the air-to-fuel ratio in the tail pipe. The smoke emitted from diesel vehicles (compression engine) is subjected to a smoke opacity test.

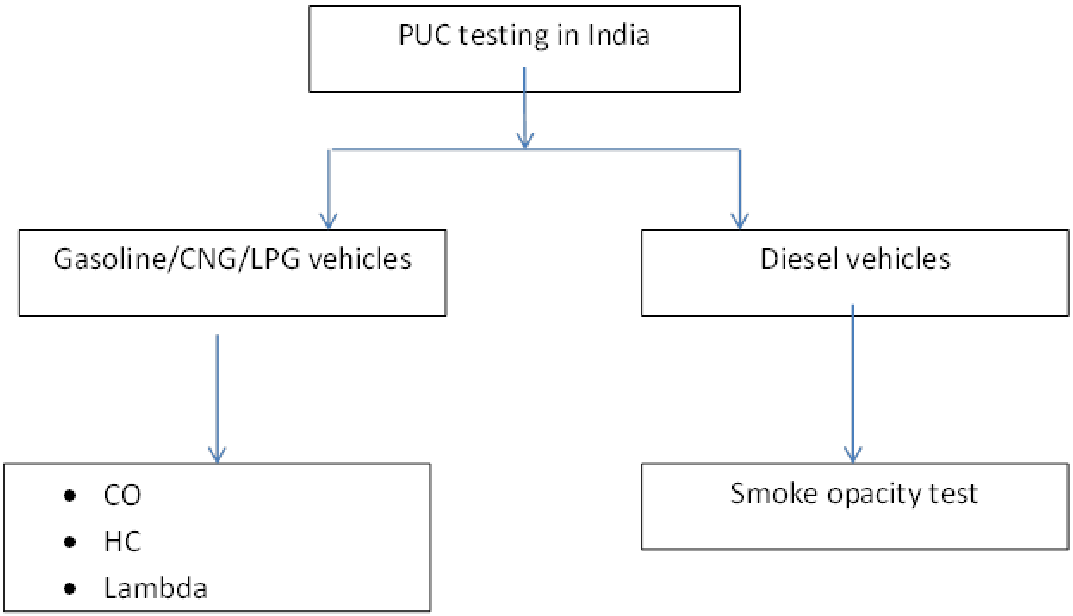

Figure 1 PUC system in India

CO and HC test: Ideally, after complete combustion, the exhaust of the vehicles must emit only carbon dioxide (CO_2) and water vapour (H_2O). Presence of CO and HC in the exhaust or the tail pipe emission is an indication of incomplete combustion and probably malfunctioning of engine and pollution control devises. Vehicles in India are tested on idle mode for I&M. Idle mode means that engine rate (in rpm) along with fuel control system—clutch and accelerator—are at rest; and the transmission is in neutral. The permissible values for CO and HC are defined according to the technology of the engine used in the vehicle. The most stringent values are for vehicles complying with BS-IV norms with maximum permissible limit for CO being 0.3% in the tail pipe emissions and corresponding value for HC being 200 ppm (Table 1).

It has been observed that one of the common practices at the PUC testing stations had been improper insertion of the probe in the tail pipe to record CO and HC lying with in the permissible limits. This anomaly has been corrected by replacing the '2 gas analyser' with '4 gas analyser' for BS-IV vehicles. The latter records values for CO_2 and O_2 in addition to CO and HC. If the probe is completely inserted inside the tail pipe of the vehicle, the O_2 percentage should not be above 15%. This keeps a check on forced dilution and malpractices at testing centres (Rogers 2002).

Another major problem associated measuring CO and HC at idle mode is that it can reduced by tuning the engine for sake of passing the test. This is called the 'late and lean' approach, in which the air fuel mixture is leaned and the spark ignition is delayed. Increased emission of NO is a problem usually associated with this approach; and oxides of nitrogen are a challenge for clean air quality today. However, introduction of lambda test (discussed later), to an extent, addresses this problem.

Table 1 Current emission limits for PUC certification in India

Vehicle Type	CO (%)	*HC (ppm)
Two or three wheelers (2/4 stroke) (vehicles manufactured before 31/3/2000)	4.5	9000
Two or three wheelers (2- stroke) (vehicles manufactured after 31/3/2000)	3.5	6000
Two or three wheelers (4 stroke) (vehicles manufactured after 31/3/2000)	3.5	4500
Bharat Stage -II compliant four wheelers	0.5	750
Four wheelers other than Bharat Stage -II compliant	3.0	1500
CNG/LPG/ Petroldriven four wheeler vehicles as per BS IV norms	0.3	200

(CPCB 2010)

Smoke opacity test: Smoke opacity test is the only test for in-use diesel vehicles in India. The main idea behind the test is to quantify the black emissions in the vehicle exhaust using the optical properties of smoke absorption. Smoke opacity is used as a proxy to measure PM emissions from diesel vehicles (DieselNet 2016).

Many studies have shown that smoke opacity test has loopholes and is not the ideal test for testing the conditions of in-use vehicles. Smoke opacity tests are also associated with high inaccuracy and lack of test to test repeatability. In a programme in Mexico, 2002, smoke samples from Mercedes Benz L1217 were simultaneously tested on smoke opacity meters of different make and operators. The results showed a variation of 30%–700%. Some of the other issues related with the smoke opacity test are listed below:

- The resolution of conventional smoke opacity tests are quite low. In fact, the highest resolution of some of the smoke opacity meters is almost the same as the emissions from Euro IV diesel engines. This makes the test unreliable for vehicles with BS-IV and higher emission standards in India.

- Nitrogen dioxide absorbs the green light in smoke opacity meters. This creates a problem because engines fitted with catalytic convertors increase the percentage of NO_2 in the total NO_x emissions resulting in higher readings on the smoke opacity meter.
- The opacity meter is sensitive to the size of the particles and may underestimate the number of particles if they are below a certain size (DieselNet 2016).

In fact, studies (Rogers 2002) have also questioned the accuracy of smoke opacity test to quantify PM emissions from the vehicle.

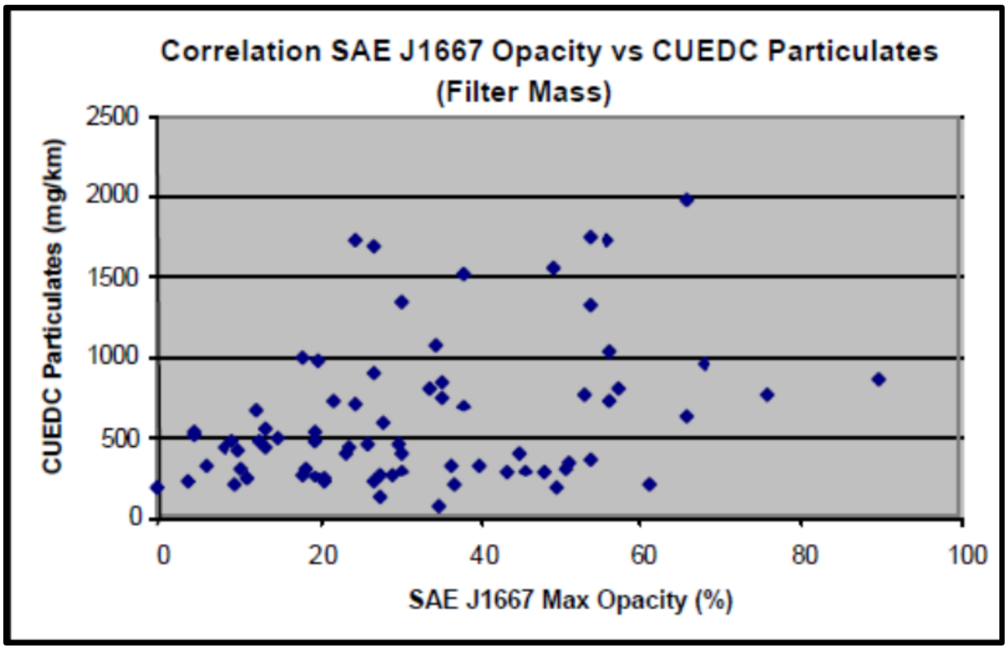

Figure 2 Correlation of smoke opacity meter test with actual filter mass test for particulate filter

Source: Rogers 2002

Studies have found poor co-relation between smoke opacity readings and PM emissions (Figure 2). Thus, as India progresses to tighter emission norms (BS-VI), smoke opacity test will not be enough to test the compliance of in-use vehicles.

Lambda test: Lambda test is the measure of air-to-fuel ratio in the exhaust. If the ratio is 1, it implies that the amount of air and fuel is optimum and the fuel is optimally burnt to CO_2. A value lesser than 1 means that the mixture is rich in fuel; that is, the quantity of air is less as compared to fuel. Such exhaust usually contains high amounts of CO and HC. Similarly, a lean mixture is one which has more air content as compared to fuel and the ratio is more than 1. A 'lean' mixture means the vehicle is more fuel efficient; however, in excess of oxygen the vehicle also emits oxides of nitrogen. Thus, EPCA (2006) recommended that lambda reading should lie between 0.97 and 1.03. EPCA (2006) also conducted lambda test on 10 767 petrol passenger vehicles in Delhi in 2006 and found out that 75% of the vehicles showed lambda test results in the range of 0.97–1.03. It was also observed that almost 88% of the vehicles not lying in this limit were on the lean mode, that is, lambda test value was more than 1.03. Manufacturers want their vehicles to have good fuel efficiency; this might be the reason why most vehicles were running on lean mode.

Vehicles complying with lambda tests in the range 0.97–1.03 should ideally have lower emissions of CO, HC, and NO_x. Currently, the lambda test is conducted at high speed (2300–2700 rpm) and the CO and HC emissions are tested on idle mode or low speed. The technician conducting the PUC test can manipulate the readings by diluting the exhaust emissions for CO and HC by removing the probe from the tail pipe and then reinserting it to get lambda readings (in case the PUC centre still uses two-probe gas analyser).

Operation of PUC centres

PUC operators belong to the private sector that function as independent units sometimes in a mobile capacity, through automotive garages, workshops and stations, and petrol pumps, and more recently, as part of servicing packages provided by manufacturers, such as Toyota and Maruti (ICCT 2013; Walsh 2005)[3].Fundamentally, PUC Centres check for whether vehicles are emitting a select number of pollutants at rates that meet or are below prescribed PUC norms. Centres may offer services exclusively to diesel- or petrol-consuming vehicles or a combination of both.

Owners are required to take their vehicles for testing one to four times a year depending on the state. A PUC certificate is issued to those who pass the tests, after which a fee is paid to the operator ranging from INR 50 to INR 150 depending on the state, vehicle, and fuel type. For those who fail, either no certificate or a failed certificate is issued after which the vehicle owner has a limited time period within which he or she is expected to take actions that can range from expensive installations of new emissions control technologies in older vehicles to minor repairs in various components of a newer vehicle likely covered within a warranty. In rarer instances, owners avail of the option to discard their vehicle entirely (ICCT 2013; Walsh 2005).

If drivers are caught without a PUC certificate, they are typically issued a challan although in some states, depending on rates of non-compliance, stricter enforcement measures can include withdrawal of registration. Local police and RTOs typically have jurisdiction over enforcement activities (CPCB 2006).

Some audits and several news reports over the years have found widespread evidence of malpractice arising from poorly trained staff, out-dated and uncalibrated testing devices,

[3]In field visits the study team found companies such as Maruti offering PUC testing as part of the overall servicing requirements

and fraud and bribery evidenced, for example, through operators issuing false passes to drivers (Vasudeva 2015; CPCB 2013, 2011; Rogers 2002).

Specific measures to resolve these issues included instituting requirements that equipment manufacturers enter into a contract (AMC) with the PUC operator in a way that requires periodic calibration on the part of the equipment manufacturer. In addition, the onus was placed on the manufacturer to train PUC operators with certification reviewed by local level governments. A code of practice effectively institutionalized these requirements (MoRTH 2010; CSE 2004).

In addition, a code of practice for functioning of the PUC Centre itself was established to resolve matters pertaining to malpractice and fraud. ARAI functions as the knowledge source at the central government level with respect to the functionality and operating procedures associated with PUCs in general (MoRTH 2010; CSE 2004).

Despite several initiatives of the government and involvement of various agencies, due to limitations in testing procedures, standards and enforcement mechanisms, the present I&M system remains weak.

3.2.2 Technologies used for I/M programmes in other countries

This section briefs about the latest technologies deployed around the world for inspection of vehicles plying on road. The improvements in the inspection programme can be sub-divided based on the area of intervention. Thus, primarily there can be two types of interventions:

Improvements in the testing mode: The mode of testing is perhaps one of the most important factors that define the accuracy and repeatability of the inspection tests conducted. The tests can be primarily divided into loaded tests and unloaded tests. The main difference between the two is the application of 'load', that is, the movement of wheels is restricted in the loaded most test. For this reason the loaded tests are performed on a chassis dynamometer, which makes it more expensive. Loaded mode testing can be further subdivided into two categories—constant acceleration and transient acceleration. The following is a brief description of some of the loaded mode tests used around the world for inspection purposes.

- **Acceleration Simulation Mode (ASM)**: In this type of testing mode, the vehicle is tested on a constant speed and the acceleration on the dynamometer is simulated using load. Used exclusively for gasoline vehicles, the tail pipe emissions tested on this mode are tested for HC, CO, and NO_x. Depending upon the used power of the engine and the tested vehicle speed, there are three kinds of ASM tests—ASM 50/15, ASM 25/25, and ASM 40/50 (ICCT 2015).

- **Transient IMxxx cycle**: IM series cycle is an upgraded version of ASM. Here vehicles are tested over various accelerations. The number following 'IM' represents the number of seconds for which the cycle continues. For example IM240 is the first 240seconds of the Federal Test Procedure (FTP) cycle. The chassis dynamometer used in IM is more complex than the one used in ASM; which makes I/M more expensive. It has been observed that testing results from IM240 are about three times more accurate than the idle testing (Faizetal 1996).
- **Lug-down testing**: Lug-down is a basic loaded testing for diesel vehicles. The vehicle is tested at a constant speed and load is applied on the vehicles till the accelerator reaches full throttle to maintain the constant speed. Alternatively, the engine starts with maximum speed and load is applied till the vehicles speed to a certain percentage of top speed (90%, 80%, 70%). Lug-down test has been proven more effective in estimating the HC and NO_x emissions. However, since the ultimate measurement is for soot through smoke opacity, which in-turn is an inaccurate proxy for PM, the results for PM emissions are inaccurate (ICCT 2015).
- **DT80:**DT80 is the testing procedure deployed in Australia for I&M testing of diesel vehicles. It is one of the most rigorous testing methods for estimating the tail pipe emissions. The vehicle is run on the chassis dynamometer—accelerated to 80km/h at maximum load of the vehicle, cruised at 80 km/h, de-accelerated to idle, repeated three times. The results obtained from DT80 are shown to have higher co-relation with on-road emissions (ICCT 2015).

Improvements in measurement techniques: The primary pollutants of concern from diesel vehicles are NO_x and PM. Testing the vehicles for PM for PUC purpose is not feasible due to complications of testing process and cost associated with it. Thus, smoke opacity has been used as a proxy method for estimation PM. In addition to the reasons mentioned in the above sections, smoke opacity meter is losing its relevance because vehicle technology is drastically changing and so are the types of emissions from the vehicles. The diesel engines used in 1998 or before (without after treatment devices) emit smoke, which contains particulate matter in the form of organic carbon (OC) or elemental carbon (EC) (also known as soot). However, engines from 2010 (with after treatment devices) emit particulate matter not only in the form of OC and EC, but majorly in the form of sulphates and nitrates (ICCT, 2015). The smoke opacity test is designed to estimate the amount of soot in the smoke emitted. Thus, there is a need for an upgraded methodology to estimate PM emissions in diesel vehicles. NO_x is another major pollutant of concern from diesel. At present, there is no means to estimate the NO_x emissions during PUC testing.

Laser light scattering photometry (LLSP): Unlike smoke opacity, which measures particulate matter through absorption of light, LLSP measures PM through scattering of light, that is, deflection in the direction of propagation of light due to irregularities in the medium. Due this principle, LLSP can record finer particle as compared to opacimeter (Norris, 2015), making it more suitable for BS-IV and beyond vehicles.

NO_x emission measurement is crucial for inspection of in-service diesel vehicles. However, traditionally it has been excluded from I&M programmes because unavailability of cost-effective and less time-consuming measuring instruments. Nonetheless, some of the techniques for NO_x measurement have been briefed in the following section.

Non-dispersive ultraviolet absorption spectroscopy (NDUV): NDUV relies on the principle that NO absorbs certain wavelength in the UV light spectrum. The quantity of NO_x is estimated through the wavelength of the light that is not absorbed by the spectrum. The major advantage of NDUV is the higher accuracy over other testing techniques, such as non-dispersive infra-red spectroscopy (NDIR) and Fourier-transform infrared spectroscopy (FTIR). In infrared spectroscopy, water molecules absorb the same wavelength of light as NO_x, which makes the result inaccurate. NDUV is shown to have a good correlation with the vehicles used for type approval purpose (Weiss et al. 2011).

Electrochemical cells

Electrochemical cells work on the principle that NO generates an electric current when oxidized. The current generated in this way gives an indication towards the quantity of NO present. This method is fairly accurate but certain cases of cross-sensitivity with CO have been observed. In fact, NO_x sensors were developed using Na^+ conductors and ZrO_2-based films. Some of these sensors are now deployed in OBD of Euro VI vehicles (ICCT 2015).

On-Board Diagnostics (OBD)

OBD is a system installed in vehicles that regularly monitors the functioning of the components, which in-turn affects the emissions from the vehicles. The monitored components usually include the engine, after treatment devices; OBDs installed in newer vehicles also monitor the functioning of the electrical components. Since functioning of all the important vehicle components is monitored by the OBD, it can be used for I&M purposes.

OBD was first deployed by General Motors in 1980s. However, OBD was not standardized until 1996, after which the technology was enhanced considerably to be used for regulatory purposes (ICCT 2016).

Due to its design and operation, OBD plays a crucial role in both I&M of the vehicle. Upon detecting malfunction in a certain area of the vehicle, the OBD stores it as a 'pending code' with detailed information about the area of malfunctioning. If in the monitoring following the generation of 'pending code' another malfunction is detected in the same area, a 'confirmation code' is generated and malfunctioning indication light (MIL) in the dashboards starts glowing. MIL plays an important role in the maintenance of the vehicle as it alerts the driver if the equipment is faulty and needs attention. The 'pending codes' and the 'confirmed codes' can be downloaded using the OBD scan tools. This downloaded data serve the purpose of inspection of vehicles.

OBDs typically do not measure the level of pollutants in the emissions. Rather, the performance of critical emission control systems is already calibrated in the lab, that is, the performances of these systems and corresponding emissions are already co-related in the laboratory. The OBD threshold limit (OTL) is said to be crossed when functioning of emission-control devices correlates with the emission level (as determined in the laboratory) above the permissible limit. At present, OBD is successfully implemented in EU, USA, and South Korea.

Remote sensing

Remote sensing (RS) is the technique used for estimating the emissions from a vehicle by measuring the attenuation of the light of a particular wavelength from the exhaust gas plume. The measurement is taken on-road and the results are estimated within 0.5 seconds. CO, NO_x, CO_2, HC, opacity, and NH_3 can be measured using RS. One of the major advantages of this technique is that it measures the emission of pollutants from the vehicle in real-world driving conditions. Along with estimation of pollutant concentration in the emission, the speed, acceleration, and photo of the number plate are also recorded. Thus, through this technique, one can easily gather important parameters, such as operating conditions, vehicle make, model, etc.

The vehicles that have horizontal tail pipe emissions are most suited for pollution estimation through RS. In order to get accurate results from RS, the traffic should ideally be single lane to avoid overlap of exhaust gases and free flowing. It is important that the vehicle is positively accelerating while the exhaust is emitted for analysis. The RS equipment should be regularly calibrated with exhaust gas plum of known concentration of pollutants.

The possible applications of RS are summarized in the following points:

- Actual fleet performance: RS can be used to gather data of on-road emissions of the vehicle fleet. The data gathered over several years can give an indication of the effectiveness of the emission control norms introduced over the period of time. Recent revelations (Volkswagen scandal) have shown that vehicles with better emission control devices are tuned to emit low emissions only in a particular test cycle. Thus, RS can be used as tool for monitoring and evaluation of the emission control technologies used in the vehicles.
- Cross checking with I&M programmes: RS can be complimented with I&M programmes in a place. The effectiveness of a new I&M programme can be evaluated

by performing a series of RS programmes before and after the introduction of the new programme.

- Identification of gross polluters: Gross polluters—the vehicles emitting the highest amount of pollutants into the air can be identified using RS programmes. The gross polluters can be according to vehicle category (HDV, LDV, 2W), type of fuel used, vehicle age, etc. Identification of gross polluters can be the first step towards introduction of an effective I&M programme in a particular area.
- Clean screening: Regular inspection of all of the vehicles in the fleet can be costly and time consuming affair. Repeated use of RS in a particular area could be deployed in order to identify vehicles that do not need regular monitoring.

Successful RS campaigns have been carried out in EU, China, USA, and Australia (Borken-kleefeld, 2013).

On-road heavy duty vehicle emission monitoring system (OHMS)

The OHMS system is a monitoring system that can deployed for monitoring of emissions from HDVs. In this system, the vehicle is accelerated (could be a defined test cycle) in a partially enclosed structure. The structure is usually open from the sides and closed from the top. The smoke emitted from the vehicle is sucked in by an exhaust installed at the top of the structure. This smoke is the analysed for PM and NO_x. The whole testing procedure does not take more than 4–5 minutes. Thus, it can be used as a standalone testing system.

OHMS can detect fine PM in the vehicle exhaust; therefore, it is suitable for vehicles installed with DPFs. However, certain studies have shown that OHMS overestimate NO_x pollutants (ICCT, 2016).

Table 2 summarizes the types of technologies in use or in development for inspection of vehicles around the world.

Table 2 Technologies used for I&M around the world

Technology	**Type**	**Expected improvement (compared to current technology in India)**	**Deployment in other regions/ countries/ cities**	**Comments**
ASM	Testing mode (loaded)	The vehicle is accelerated with load applied on it (usually tested on a dynamometer.	Beijing, Ohio, British Columbia, Georgia	ASM requires the vehicle to be placed on a chassis dynamometer. Application of

		Higher accuracy than 'unloaded' test in India.		ASM in the current (decentralized) I&M system would be challenging.
IMxxx	Testing mode (loaded)	Further improvement over ASM. Instead, of just acceleration, the vehicle follows a test cycle on chassis dynamometer.	Wisconsin, Vancouver (Canada)	Chassis dynamometer of IMxxx is much complicated and expensive than the one used for ASM.
Lug down test	Testing mode (loaded)	A loaded mode test for Diesel vehicles. Better accuracy as compared to free acceleration test mode currently used in India.	Singapore, Hong Kong, Colorado, Beijing	Requires a chassis dynamometer for testing.
DT80	Testing mode (loaded)	One of the most rigorous loaded mode tests for diesel vehicles. Results show closer correlation with on-road testing.	Australia	The vehicle is tested on a pre-defined test cycle on a chassis dynamometer, making it expensive.
LLSP	Estimation of PM particles in exhaust from diesel vehicles	Higher accuracy as compared to opacimeters used in India. Suitable for BS-IV and beyond vehicles.	-	The cost of equipment is comparable with opacimeters.
NDUV	Estimation of NO_x in exhaust from diesel vehicles	NO_x is currently not measured in diesel exhaust.	-	Higher accuracy in NO_x measurement as compared

				with other technologies,such as NDIR and FTIR.
Electrochemical cells	Estimation of NO_x in exhaust from diesel vehicles	NO_x is currently not measured in diesel exhaust.	-	Accurate results but different principle of operation from NDUV. Used as NO_x sensors in some OBDs.
OBD	Records data and alerts driver of the malfunction of emission control devices	Will play an important role both from I&M perspective. Less time consuming and more cost effective. Records the performance of the vehicles in on-road conditions.	Mandatory use in Europe, USA, South Korea	BS-IV vehicles in India are installed with OBD. More improvements in technology are expected with introduction of BS-VI vehicles.
Remote sensing	Estimation of pollutants (HC, CO, NO_x, opacity) while it is running on-road.	Possibly best technology available to evaluate the on-road performance of the vehicles. Could be used along with I&Msystem. Cannot be used as a standalone measure.	RS campaign carried out in China, Hong Kong, Taiwan, EU and USA	Expensive equipment. Pre-requisites such as single flow traffic, horizontal tail pipe needed.
OHMS	Estimation of PM and NO_x in exhaust of diesel vehicles.	High accuracy.	-	Can be implemented only if India has centralized inspection centres.

3.3 New developments in India

India has taken its first step towards changing the PUC testing system by inaugurating India's first I&C centre in Nasik, Maharashtra, in June, 2015. The facility was setup to computerize and reduce human interference in the inspection of in-use commercial vehicles. The testing facility was setup by MoRTH; however, it is operated by Rosmerta Technology Ltd.

As mentioned previously, the main shortcomings of the current inspection programmes in India are lack of regular auditing of the inspection units, improper maintenance and lack of calibration of the testing equipment, and manipulation in testing procedure and data by the staff (Lakshmi et al., 2014). I&C centres address most of these problems to an extent. The centre in Nasik has four testing lanes two for heavy commercial vehicles and two for light commercial vehicles including three-wheeler auto rickshaws. After a visual inspection, most of the inspection process is mechanized. The vehicles are tested for PUC along with other parameters such as brakes, head lights, speed limit (for school buses).

The vehicle owners have to leave the vehicle at the gates of the centre after which trained staff carry out the inspection process. Even though traditional testing equipment is used for PUC testing, the major advantage is that the inspection staff cannot access or see the readings. A pass or fail certificate is issued after the inspection process is over. This makes it difficult for the inspection staff to manipulate the readings and results. The automated machines send out signals when calibration of the equipment is needed. Moreover, ARAI has agreed to regularly audit the facility.

About 175–180 vehicles are inspected at the facility on daily basis, with each vehicle taking about 11 to 15 minutes for inspection. Still the staff believes that one such facility is not enough to cater to the commercial vehicles of the entire district. In addition, the local fleet owners have also shown resistance to this testing system, because as compared to current system, most commercial vehicles are failing the inspection test due to verylow scope for manipulation.

With advent of such testing facilities, India can aim to move towards more sophisticated testing procedures as compared to free acceleration smoke opacity tests,such as OHMS or loaded test mode on chassis dynamometer.

In addition, about 10 such I&C centres are planned to be installed in Jhuljhuli, Rohtak, Udaipur, Railmagra, Lucknow, Bengaluru, Hyderabad, Chhindwara, and Silchar. However, the number of such centres has to be increased if the government intends to test all the commercial vehicles at such centres.

OBD in India

OBD 1 system was first introduced in India for trucks and cars of BS-III standard in 2010 (Transport Policy 2016). However, a more improved system called OBD II was introduced for BS-IV vehicles. It is mandatory for all the diesel vehicles manufactured post April 2013 to be installed with OBD, which indicates the malfunction light in case vehicle component monitored by the OBD are not functioning adequately. The vehicles manufactured in future will have higher dependence on electrical equipment making OBD all the more useful. A more sophisticated version of OBD II is expected to be introduced in 2020 along with BS-VI vehicles (ICCT 2016).

OBD in India till today is only used to alert drivers and technicians of the malfunctioning in the emission control equipment in the vehicle. A circular released by MoRTH directs all the PUC testing centres to check for malfunctioning indicator lamp (MIL), in all the vehicles with OBD, before proceeding with the regular PUC testing. If the MIL is glowing, then the vehicle owner should be advised to take the vehicle to a workshop for repair (MoRTH 2012). The 'pending' and 'confirmatory' codes generated are still untapped. The technology will be used adequately if it is integrated in the PUC system.

OBD is more cost effective and less time consuming as compared to tail pipe emission tests. However, there are some pre-requisites before vehicles can be tested solely on the basis of OBD. The methodology to read fault codes from OBD has to be standardised in order to pass or fail vehicles. It is important to invest in anti-tampering technologies that can ensure the authenticity of OBD data. India should learn from the initiatives taken by South Korea where anti-tampering measures have been ensured to make the data obtained from OBDs more robust and reliable. The operators should also be trained to effectively use the OBD data scanners for PUC testing purpose. The cost of OBD data scanners starts from 20 USD; however, durable scanning tools using sophisticated user interface software cost USD1500–2500 (ICCT 2016).

3.4 Scrappage

The end of life of a vehicle is given scant attention in the overall emissions reduction framework. Given the highly decentralized apparatus of the PUC system and fragmentation evidenced in the division of state–centre responsibilities of fitness testing and Type-Approval/COP testing, respectively, numerous impediments remain to link scrappage or retrofitting strategies with the overall life of a vehicle.

In particular, vehicle registration database is not updated and not linked with other key components, such as emissions and other safety-related data of a vehicle (ICCT 2013). A number of incentive schemes are currently being tested and implemented particularly at the national level through MoRTH, but the preliminary phases of these initiatives leave outstanding gaps which are generally unaddressed (Arora 2016).

Any coordination efforts associated with recycling and scrappage will present similar structural challenges, given highly decentralized, localized, and often informal arrangements. These will likely present implementation-related challenges around emerging guidelines and rules. Further research is required to more meaningfully integrate the end of the life of vehicle in policies to reduce vehicular emissions (Confederation of Indian Industry 2013).

The MoRTH is exploring the possibilities of introducing a voluntary fleet modernization scheme in India.

4. Case Study: Bengaluru and Mysore

In order to understand the situation of I&M of in-use vehicles in India, case studies in two Indian cities—Bengaluru and Mysore—was planned. Both cities are in the state of Karnataka. While Bengaluru is the capital of the state with a vehicle population of 6 108 936 (Transport Department 2016), Mysore has a vehicle population of 650 000 (Mysore City Police 2016). The study consisted of three parts:

- Interviews conducted to get better understanding of structural and operational contours of PUC centres;
- Analysis of the PUC testing collected in the year 2015–16;
- Perception survey of the vehicle owners.

The findings from the three studies are described in the following sections.

4.1 Interviews of PUC centres in Bengaluru and Mysore

An investigation into how PUC operators carry out their day-to-day operations and the oversight related activities of a handful of RTOs in Mysore and Bengaluru offer important insights into some of the structural and operational contours and dynamics influencing and often hampering the overall effectiveness of the system. In total, eight PUC centres within five RTO jurisdictions were covered in Bengaluru and Mysore. Brief non-structured interviews were carried out with four RTO officials in the state.

4.1.1 Market incentives

Our findings broadly revealed that amongst owners and operators, PUCs are viewed as a business venture. While every individual we interviewed was aware that emissions checks were the central function, operations were run with the risks borne primarily by the business owner. That is, the initial capital investments were to be initiated by the owner. Costs primarily included testing equipment—the hardware provided by equipment manufacturers—which the field study found to range from INR300 000 to INR600 000.

Rental costs of PUC centres that operate out of petrol pumps range from INR7000 to INR10000 a month. Generally, operation (new printing papers and sticker) and labour costs (one operator) account for an additional INR10 000 to INR15 000 on a monthly basis. An estimated 20 to 30 vehicles come in for testing on a daily basis around the year, for each of the centres we visited. Certificates range from INR50 to INR125 depending on the vehicle type and fuel source (petrol/CNG or diesel).

A rough calculation that assumes the higher end of operating costs with one employee, which was typically the case (at INR180 000 annually), and certificates at INR90 (Four wheelers with petrol) at 20 vehicles per day generates annual revenues at approximately

INR650 000. In effect, it takes approximately one year to recover capital costs, after which a profit base can be sustained. This is the clearest incentive to open such a business.[4]

None of our respondents directly shared their revenue data although they referred, typically in an oblique way of the value of such ventures. That is, there was an expectation amongst owners that the "investments would" yield returns over a "reasonable time-frame."[5] One respondent in Bengaluru explained that "other businesses" around his area started emerging because of a growing population that was in need of the service. In other cases, short-lived mandates by the government to require centres to be set up in all petrol stations led to increases in PUC check centres (there is no temporal data available on this).

Except of one centre, the rest functioned as a supplementary source of income to additional services that ranged from auto workshops to driving lessons. Our visit to the Maruti facility also demonstrated a novel case where the manufacturer took the initiative to provide PUC testing whenever an owner came in for general fitness testing. Specifically, if the technician found that the owner did not have a certificate, he took the initiative to conduct the test whereby any fees were part of the broader package of services offered by the company.

4.1.2 Licensing, software, and training

The PUC operation licensing approach by the Karnataka State Transportation Department clearly indicates that market incentives are primary relied upon to set up PUC centres. It is only after the approved testing equipment is purchased and a trained operator is hired, a license is finally issued. The fairly cheap cost of licensing at a "few thousand" rupees and limited logistical requirements, for example, in providing for sufficient parking space to reduce the risk of traffic jams, functions to expedite setting up of the PUC centres over raising public revenues.

The state also introduced an online system, run by Keonics (Government of Karnataka Enterprise) that networked all the PUC operators to collate data for analysis and improve transparency. The PUC operators are provided the software and brief training of how to use the tool by the state (Transport Department 2016).

4.1.3 Implementation challenges

The conditions described above created a set of conflicting incentives and implementation roadblocks that weakened a system that already utilizes technologies that do not capture real-world emissions, which in turn are regulated, in any case, by lax norms.

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[4] These calculations are intended to give indicative values based on field interviews; however, they should not be taken as a representative sample.

[5] Conflicting reports have indicated that the certificate fees, even after hikes in Karnataka, do not allow for a profitable enterprise given maintenance costs of equipment etc. can be steep (Vasudeva, 2015). This fact points to gaps in representative analysis of cost and revenue break downs of PUC centres.

The business-oriented dynamics of the PUC centres was demonstrated consistently in both operator's and owners' references and importance placed on building customer relationships. That is, in a competitive market, these operators depended on repeat clients to come in for testing services. Some of the PUC centres leveraged their stored data from past tests to send text message reminders to drivers that their next check in was due. However, there appeared to be no action, nor any clear incentive in place beyond this for centres to initiate follow-ups in cases where vehicles failed a test.

PUC centres did not feel the need to recommend options to resolve the matter and consistently stated that it was the threat of fines that would likely lead to customers returning. It was not clear what the rate of return was. However, during specific enforcement drives, business did go up for these operators.

A key roadblock lies in the way payments are made. It appears as though the vehicle owner only makes the payment to the PUC operator only after he or she receives the certificate.[6] As such, there is an incentive for a centre that may be financially constrained, to manipulate the testing equipment or software equipment to pass the vehicle.

A variety of examples were demonstrated during field visits. It was observed how it was possible to manually plug in specific data into the software that would effectively change around the results to pass an individual. Operators also mentioned how 'false passes', in some of their neighbouring PUC Centres—now shut down—involved taking pictures of the number plate of a high polluting vehicle and rapidly inserting the gas analyser into a low polluting vehicle parked right next to the one designated for testing.

While the majority took pains to highlight their commitment to compliance and that they did not partake in the abovementioned transgressions, one operator actually demonstrated to us, in real time, how the gas analyser could deftly be manoeuvred into tail-pipes in order to yield positive readings. Through this particular case, it became evident that a captive market of grossly polluting vehicles can emerge for the benefit of select PUC centres. A disproportionate number of visibly polluting vehicles visited this centre during the one and a half hours designated to monitoring this space. Indeed, only after a certificate was produced did the operator receive payment.

One particular auto rickshaw failed three times before a pass certificate was issued. That is, the failed counts were documented and uploaded onto the centralized system. The state government, then, clearly has access to this information. However, we were unable to glean to what extent and how regularly this information was reviewed at the state level. It is true that the data, for the time being, is managed by Keonics (Government of Karnataka Enterprise). Our research failed to retrieve information about the communications processes

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[6] Based on field interviews; no publicly available procedural documents confirming whether this is prevalent across the country were found.

and data-sharing procedures in place between this third-party operator, the state, and the RTO.

In general, the relationships of the RTOs with the PUCs were variable. Their responsibilities are limited to conducting random inspections to ensure compliance and to renew licenses. However, PUC centres in only two out of the five RTOs investigated appeared to be operating as per code of conduct and regulations.

For example, one PUC centre was using testing equipment that was delisted by ARAI. In this same RTO jurisdiction, both PUC centres were being run by operators who were either trained by their owners or from another operator running a nearby PUC centre. The equipment manufacturers were not involved. Both presented the general license received to operate the centres but did not show the manufacturer approved certificates.

To renew licenses every three years, a key requirement is for manufacturing equipment being used to be approved by ARAI. In the interim, RTOs are expected to conduct two to four random inspections throughout the year to identify such red-flags. While the above-mentioned cases suggest that audits were not being conducted or such transgression went ignored.

The nature of the relationships between RTOs, the state, and existing equipment manufacturers are unclear. Clarity is required in part because of variations in the frequency with which equipment manufacturers came to inspect and calibrate machines. One approved manufacturer consistently visited while another approved manufacturer appeared to only in cases of equipment failure and malfunction. This finding warrants further understanding into whether harmonization and redressal mechanisms exist to fill this gap.

In general, conversations with the RTO representatives reflected concerns over resource limitations and the fact that management and oversight of PUCs was not a priority. In addition, the efficacy of fitness testing was not viewed as a general concern. Furthermore, there was an acknowledgment that data existed but little regard for how and whether it should be monitored or leveraged for analysis. In Mysore, the state government located in Bengaluru was referenced as a key source to seek out further information about important decision-making matters. The RTOs in this smaller jurisdiction were interpreted to have limited relevance and little input, over implementation details.

In terms of enforcement, both the RTOs and Police have the authority to fine noncompliant vehicle owners although based on our interviews; these can range between INR100 to INR1000. It appears to be the discretion of the officer issuing the fine. There is limited data publicly available on the rate of non-compliance. However, it was clear from multiple conversations that the RTOs and police do not communicate or share compliance-related data.

The extent of coordination tends to be limited to intensive enforcement drives carried out by the police and other state-level authorities (CPCB 2006). They are typically publicized and lead to a surge in testing and subsequent revenue boost for PUC centre owners. However, it was unclear to what extent data are compiled from these efforts or lessons learned are integrated into longer term strategic plans for improving on-road compliance. In general, police are poorly equipped to carry out enforcement and oftentimes find difficulty identifying noncompliant drivers given that there are no visible stickers on a vehicle (ICAMP 2014).

4.1.4 Decentralization

In a city such as Bengaluru, a combination of enforcement drives, increase in frequency of testing at specific points in time, coupled with stopgap measures such as mandating petrol pumps to house a PUC centre (the mandate was later withdrawn), has progressively led to haphazard spikes in demand for testing. With population growth and the associated revenue potential of PUC centres, new centres have mushroomed over the past decade or so.

While specific data is unavailable, it is clear that general increase in the number of PUC centres has rendered comprehensive monitoring of such a decentralized emissions control apparatus ineffective. Marginal actions involving interventions to slightly increase fines or introduce newer codes of practice reflect how problem-solving capacities are limited to incentive re-structuring or policy re-design. However, the above-mentioned discussion has shown that greater focus is needed to improve channels of communications and better leverage technology to improve transparency and accountability, all of which should set the foundation for systematic change.

4.2 Perception Survey

Due to ineffective implementation and infrastructural constraints, the current PUC system fails to effectively control emissions from in-use vehicles. Despite a provision of heavy penalties, merely 21% of total registered vehicles appear for PUC testing in Delhi (Lakshmi et al. 2014). Similarly, situation in other Indian cities are also not very promising. Moreover, the current system is not fool-proof and allows pass-through without proper testing in a number of cases. Lack of well-trained and dedicated personnel at the PUC testing centres, improper maintenance, and irregular/no calibration of equipment used for emission testing, presence of only a modest threat of enforcement, etc. are some of the major drawbacks of the existing PUC system across the country.

The vehicle owners in Bengaluru and Mysore were interviewed to understand their perception of the PUC system in India. The main objective of this survey was to gauge the reasons why the vehicle owners lack trust in the PUC system in India; to understand how the PUC system could be improved to encourage more people to get their vehicles routinely tested; and to understand the maintenance habits that is followed by different types of vehicle owners in the two cities. In all 3000 interviews were conducted.

The primary variation in the response of the vehicle owners could depend on four primary reasons:

- Vehicle type, that is, the category of the vehicle, two wheelers, three wheelers, trucks, buses, passenger cars, etc.
- Fuel used in the vehicle: diesel or gasoline.
- Age of the vehicle
- City: Bengaluru or Mysore

The data collected is used to understand the perspective of the vehicle owners regarding three important aspects:

- **Compliance with PUC**: This section details out the number of people who get their vehicles regularly tested; the frequency at which the vehicles are tested; the reasons why the vehicle owners restrain from PUC testing; and the perception of the vehicle owners regarding the appropriateness of the current PUC system.
- **Enforcement of PUC**: This section discusses the degree of enforcement experienced by the vehicle owners to get their vehicles routinely tested.
- **Service of the vehicles**: The trend followed in maintenance of the vehicles—frequency of service, preferred service station (authorized, wayside), and the perceived benefits the vehicles owners seek to reap from regular service of the vehicle.

4.2.1 Description of data

The following factors were believed to govern the responses to the main questions asked about PUC testing, perception, and vehicle service preference:

Ownership of the vehicle: If the respondent was also the owner of the vehicle. For the purpose of analysis, it was assumed that the person responding to the questions was also responsible for the maintenance of the vehicle. Figure 3 shows the percentage distribution of the respondents in the two cities. As it can be seen, almost 75% of the respondents in both the cities owned the vehicle they were driving.

Age of the vehicle: The age of the vehicle was divided into four categories—less than 3 years old, 4 to 6 years old, 7 to 10 years old, and more than 10 years old vehicle (Figure 4). It should be noted that age is also an important indicator of vehicle technology. For example, BS-IV norms were introduced in Bengaluru 6 years ago.

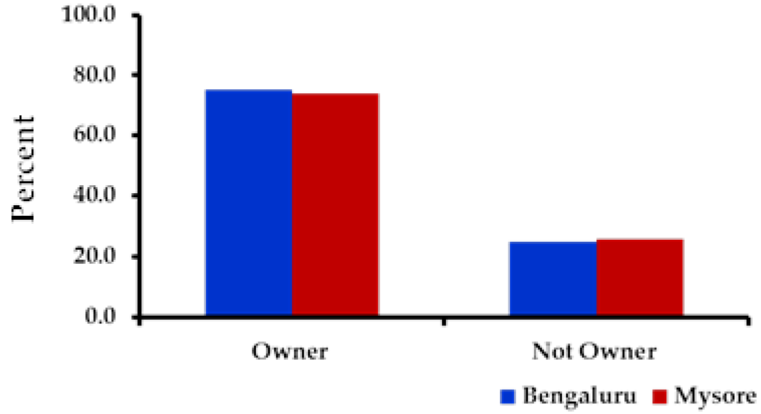

Figure 3 Distribution of respondents in the perception survey according to the ownership of the vehicle

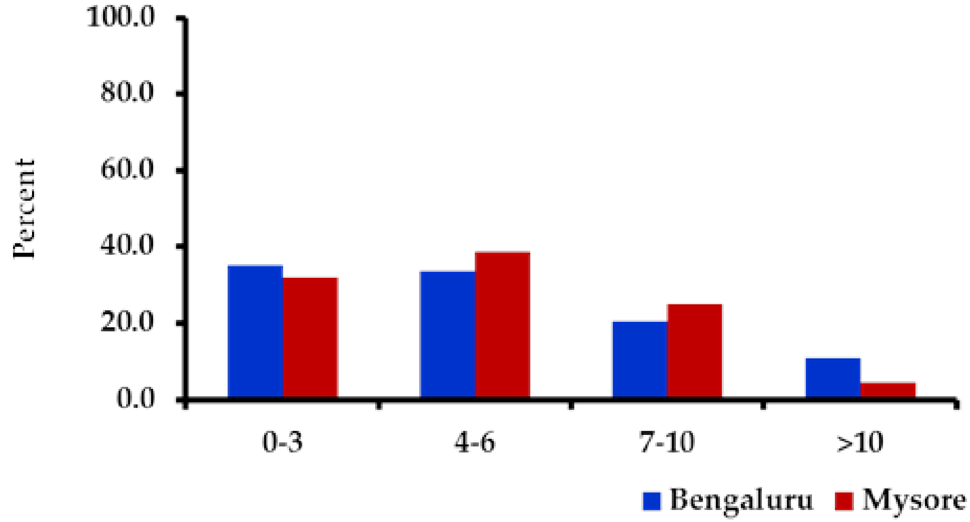

Figure 4 Vehicle registration age wise distributions of respondents in the perception survey

Fuel used by the vehicle: Of all the respondents the fuel used in the vehicles was one of CNG, LPG, gasoline, and diesel. However, the number of respondents with CNG and LPG vehicles was too insignificant to be included in the analysis.

Type of the vehicle: The vehicles were divided into six categories—four-wheeler cars, four-wheeler SUV, three wheelers, two wheelers, trucks, and buses. Figure 5 shows distribution of respondents according to the type of vehicle.

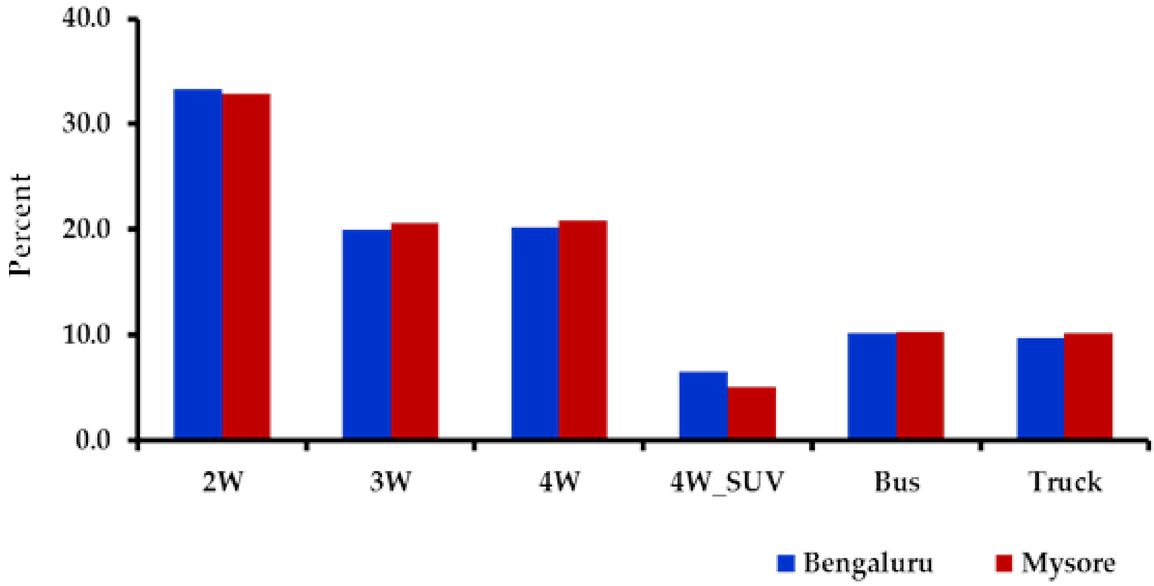

Figure 5 Distribution of respondents in the perception survey according to the type of vehicle

4.2.2 Compliance with PUC

The vehicle owners were asked questions to understand the level to which they feel responsible for getting their vehicles routinely tested and maintained. The first question they were asked was whether they had a PUC certificate, and if not, what the reasons for not getting their vehicle were tested on time.

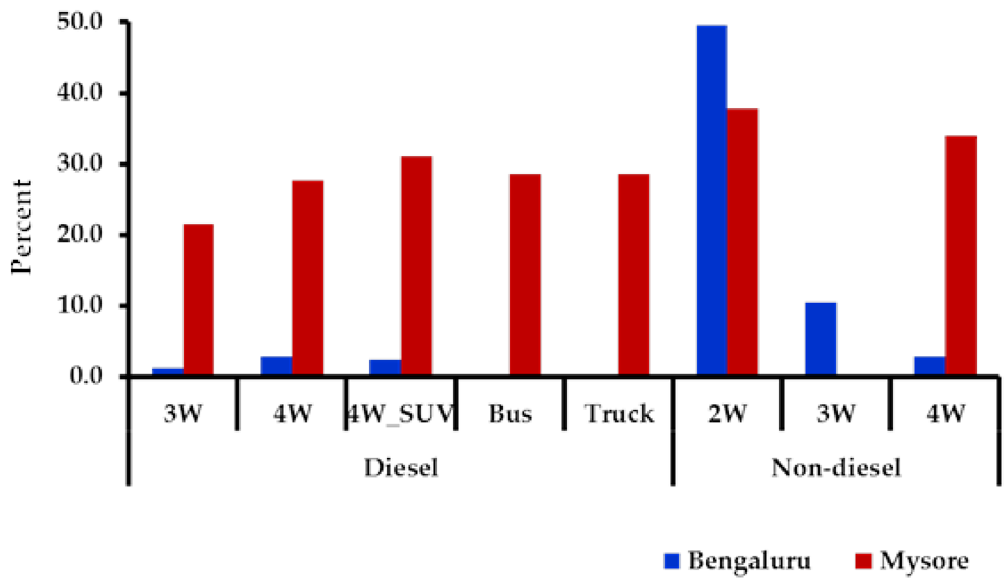

Figure 6 Non-availability of valid PUC certificates among different types of vehicles in the survey

4W: four-wheeler; 2W: two-wheeler; 3W: three-wheeler

As seen in Figure 6, about 30% of the vehicle owners did not have a valid PUC certificate in Mysore as compared to the vehicle owners in Bengaluru with the corresponding figure of 20%. The main cases of non-compliance were observed in two-wheelers and three-wheelers in Bengaluru. Rest, almost all of the categories of vehicle owners interviewed in Bengaluru had a valid PUC certificate. Also, more diesel vehicle owners have PUC certificate because diesel vehicles are only tested using opacimeters, which have a very low resolution, and thus, even polluting vehicles can easily pass the test.

All most all people driving trucks and buses had a PUC certificate in Bengaluru but not in Mysore. A possible reason for this could be that trucks and buses experience higher vigilance from traffic policemen as compared vehicles belonging to any other category. The owners of vehicles were further asked about the reason for non-compliance with PUC certificate, as shown in Figure 7.The responses were divided into four major categories—PUC testing process is too burdensome; the vehicle owners forget about the PUC certification; there is almost little or no legal enforcement experienced by vehicle owners to regularly get their vehicle certified; and they are not aware of PUC certification. Almost half of the respondents said that the procedure of PUC testing was too burdensome. A possible reason why vehicle owners feel PUC testing is burdensome is that they do not completely understand the greater environmental benefits associated with a regular maintenance of the vehicles. This implies that policy makers should seriously consider in investing in spreading awareness regarding the subject. PUC testing through OBD could be one of the ways in which PUC testing can be, perhaps, further simplified.

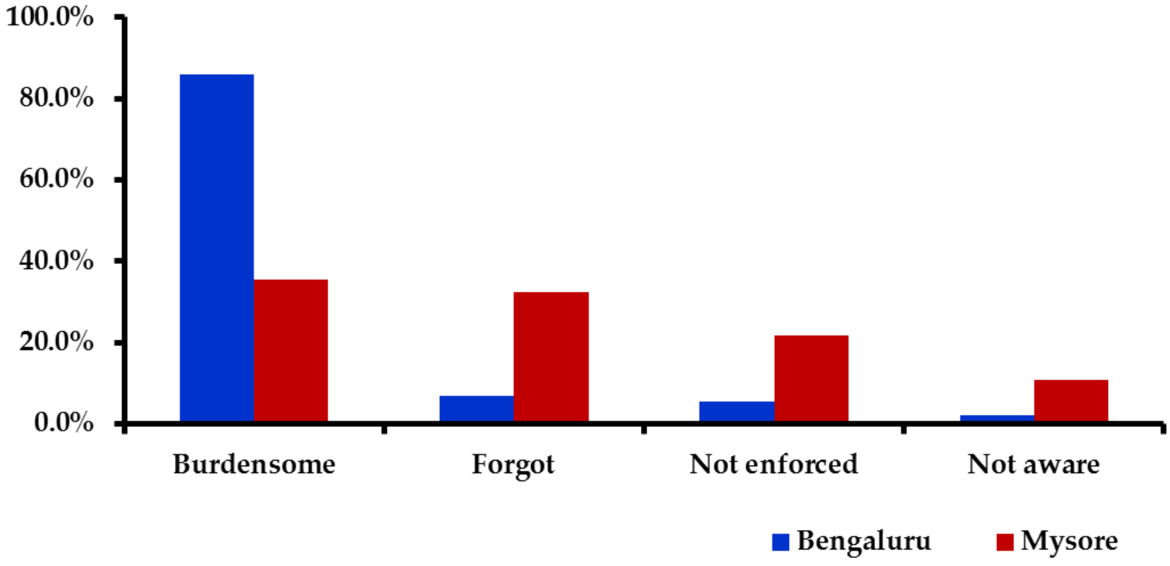

Figure 7 Non-availability of valid PUC certificates among different types of vehicles in the survey

4.2.3 Enforcement

In India, vehicles are randomly stopped on the road and are asked to produce PUC certificate. A fine has to be paid by the driver if he/she is unable to furnish a valid PUC certificate. Thus, the vehicle owners were also asked about their experience with the enforcement agencies (traffic police), which randomly stop vehicles on road and fine the vehicle owners who do not have a valid PUC certificate. Figure 8shows the response according to the category of the vehicle.

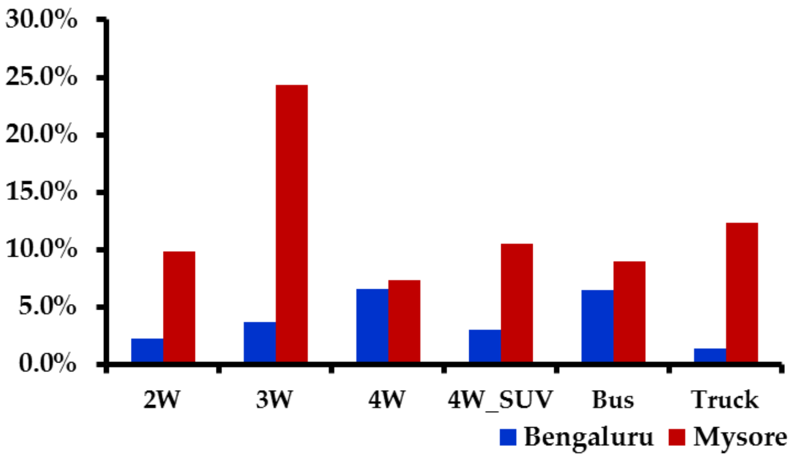

Figure 8*Percentage of different types of surveyed vehicles penalized during last year for non-compliance with PUC*

2W: two-wheeler; 3W: three-wheeler; 4W: four-wheeler

As shown, in most cases only less than 10% of the respondents had a history of being penalized for an invalid or no PUC certificate. Out of all the categories, owners of three wheelers were penalized the most for invalid PUC certificate. Our PUC data analysis also showed that three wheelers had the highest failure rate among all categories of vehicles.

4.2.4 Maintenance of vehicles

Almost 99% of the vehicles owners interviewed responded that they regularly get their vehicles serviced. Figure 9 shows the percentages of vehicle owners who prefer local wayside mechanics for getting their vehicles serviced. Almost 65% of the respondents in Bengaluru and 82% of the respondents in Mysore preferred local shops for service of their vehicles. Two- and three-wheeler vehicles in both the cities have a higher preference for local service stations as compared to other categories of vehicles. An interesting observation has been illustrated in Figure 10, as the age of the vehicles increases, the number of vehicle owners opting for local workshops increases. As the engine and vehicle technologies progresses over the years due to initiatives, such as introduction of emission norms etc., it becomes difficult for untrained servicemen at local workshops to service such vehicles.

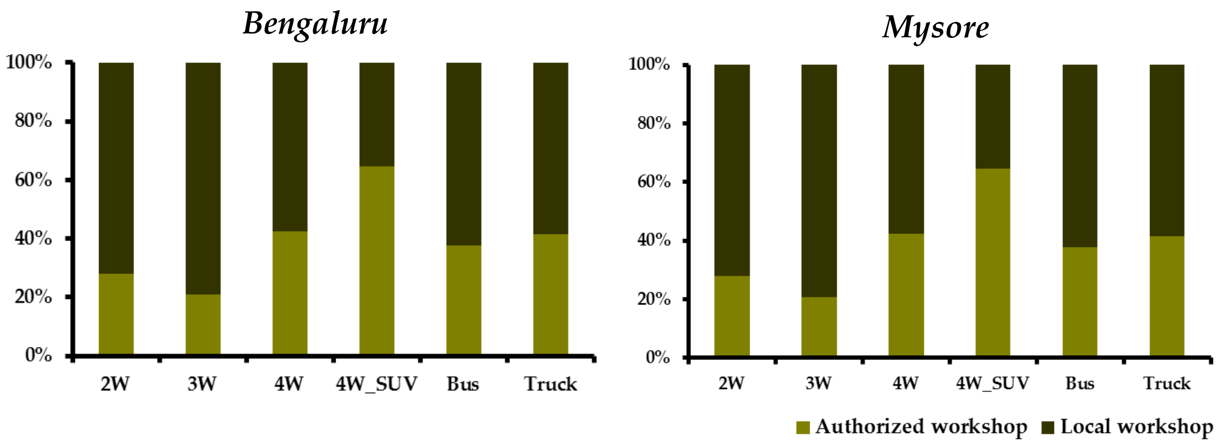

Figure 9 Percentage of different types of surveyed vehicles prefers different types of workshops for maintenance

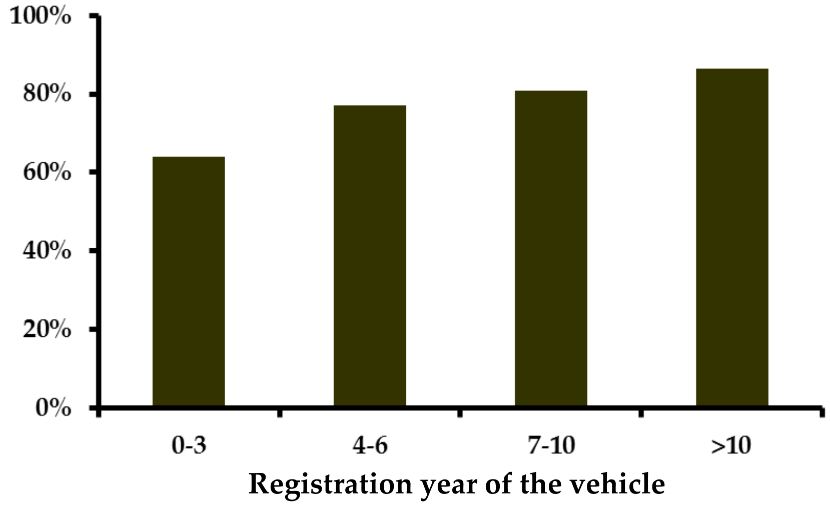

Figure 10 Percentage of total respondents in both cities of different vehicle registration age group prefers to use local workshops for vehicular maintenance

4.2.5 Salient findings of the perception survey

Bengaluru, in general, is more compliant to the PUC norms and good practices when it comes to maintenance of the vehicles—higher percentage of respondents in Bengaluru had a valid PUC certificate, more number of people opted for authorized workshop over local workshops for maintenance of the vehicles. Whereas, comparatively more numbers of respondents from Mysore were penalized in the past for not having a valid PUC certificate. Both the cities had ambivalent feelings towards the adequacy of the PUC system. However, PUC certification being more burdensome was cited as the most common reason for non-compliance in Bengaluru, whereas in Mysore it was found that a small percentage of respondents were not even aware of the need of PUC certification.

Two- and three-wheelers vehicles are a cause of concern among all the vehicle categories as it was found the highest cases of non-compliance with valid PUC certification in these two categories. Additionally, these categories also preferred local workshops the most as compared to all the other categories.

More diesel vehicles were found with a valid PUC certificate as compared to gasoline vehicles. However, as mentioned above, inappropriate technology to measure pollutants released from diesel vehicles could be a reason of higher compliance. It was also observed that less than 3 year old vehicles did not have a valid PUC. BS-IV vehicles (introduced in 2010) have much more stringent PUC standards than pre-BS-IV vehicles. This could be the reason behind high failure rate or non-compliance of vehicles less than 3 years old.

When compared with the percentage of respondents found without a valid PUC, the percentage of respondents being penalized is too low. This indicates that PUC enforcement in the two cities is less than adequate. From the analysis of the surveyed dataset, it can be concluded that the awareness of people need to be enhanced for the requirement of PUC certification system and penalties related to non-compliance to PUC system.

4.3 Analysis of PUC database

The city of Bengaluru and Mysore maintain an online database of all the PUC tests conducted for all of types of vehicle all over the city. The database is maintained by AVL Technologies. Pvt Ltd, Haryana. TERI collected this dataset for all the vehicles tested for PUC in both cities during the year 2015-16. The dataset include information on following parameters of vehicles:

- Type of vehicle: Two-wheeler, four-wheeler, etc.
- Manufacturer: Maruti, Honda, etc.
- Year of manufacturing
- Type of fuel used: Petrol, CNG, LPG, and Diesel.
- Emission norms: Pre-BS-IV, BS IV
- Engine type: 2 stroke, 4 stroke, and DIS-4S.
- Tail pipe emissions: CO, HC, NO_x, CO_2, HSU etc.
- Lambda value
- Engine rate (rpm)

The objective of the analysis was to understand the pollution emission pattern displayed by the vehicle fleet in both cities. After identifying the gross polluting vehicles from this study, one can contemplate on more appropriate I&M programme for the gross polluting vehicles.

4.3.1 Methodology followed during the analysis

The PUC database of both cities was split separately into two broad categories: (a) non-diesel vehicle and (b) diesel vehicle, to infer a better conclusion from the database. These were further divided based on the type of the vehicle, engine type, emission norm compliance, vehicle registration age, etc., as mentioned in the Table 3.

Three wheelers (diesel) and other categories of diesel vehicles were not considered in the present analysis as their individual percentage in the PUC database was very low (less than 1%). However, all categories of the non-diesel vehicles were considered in the present analysis.

Table 3 Categorization of the PUC dataset of Bengaluru and Mysore

PUC data	Vehicle type	Engine type	Fuel type	Emission norm	Registration age (Year)
Diesel	Three Wheeler		Diesel		
	Four Wheeler		Diesel	Pre-BS-IV	0–3
	SUV			BS-IV	4–6
	MMV				7–10
	Bus		Diesel		>10
	Truck		Diesel		
	Others		Diesel		
Non-diesel	Two Wheeler	2-stroke	Petrol	Pre-BS-IV	0–3
		DIS-4S	Petrol		4–6
		4-stroke	Petrol		7–10
					>10
	Three Wheeler	2-stroke	Petrol	Pre-BS-IV	0–3
		DIS-4S	Petrol		4–6
		4-stroke	Petrol		7–10
			CNG		>10
			LPG		
			Petrol+CNG		
			Petrol+LPG		
	Four Wheeler		Petrol	Pre-BS-IV	0–3
			CNG	BS-IV	4–6
			LPG		7–10
			Petrol+CNG		>10
			Petrol+LPG		

The PUC database of Bengaluru and Mysore was analysed using the SPSS-23 package. All outliers were removed from the database before analysing it, which were less than 0.5%. The database was first analysed to identify the failure rate of broad categories of vehicles (diesel and non-diesel). Then the analysis was further narrowed to identify the gross polluting vehicles based on the fuel type, emission norm, and registration age of the vehicles. Linear regression analysis was used to estimate the increasing rate of the tail pipe concentration of HSU with the increase of the vehicle registration age. The difference of mean was calculated employing the ANOVA and Tukey's HSD test. All results were tested at a significant level of 5% (p< 0.05).

4.3.2 Vehicular profile in the PUC database

Study indicates that the percentage of on-road vehicles undergo PUC test in Bengaluru (20.2%) is comparatively higher than that in Mysore (15.3%) (Figure 11).The figures were arrived at by considering the total number of vehicles in the present analysis in the PUC dataset of Bengaluru was 1 588 688 and that of Mysore was 125 770 (Table 4). As mentioned above, the total registered number of vehicles in Bengaluru were 6 108 936 (Transport Department, 2016) and the registered number in Mysore was 650 000 (Mysore City Police 2016). It was assumed that number of on-road vehicles is about 67% of the total registered vehicles (TERI 2014).

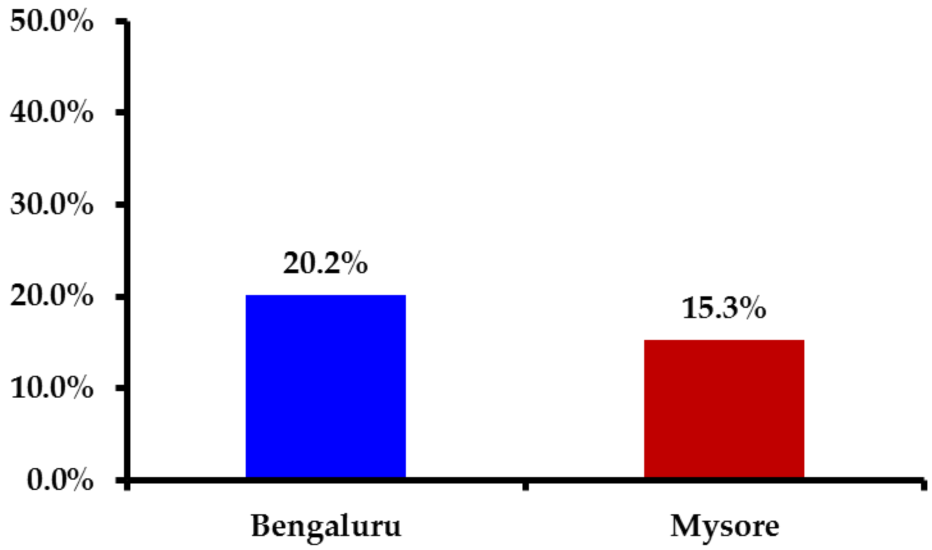

Figure 11 Percentage of total on-road vehicles undergoes PUC test according to the PUC database of Bengaluru and Mysore

The major vehicular type under the diesel vehicle category in both cities was the four-Wheeler SUV (60.0% in Bengaluru and 53.9% in Mysore); whereas two wheelers comprise the highest population of vehicles among the non-diesel vehicles (68.8% in Bengaluru and 49.7% in Mysore) (Table 4).

Table 4 Total number of vehicles (N) under different categories in the PUC database of Bengaluru and Mysore

Vehicle category	Bengaluru (*N*=1 588 688)		Mysore (*N*=125 770)	
	Diesel (*18.5%*)	Non-Diesel (*81.5%*)	Diesel (*33.5%*)	Non-Diesel (*66.5%*)
Two wheeler (2W)		890 910*(68.8%)*		41 552*(49.7%)*
Three wheeler (3W)		69 657*(5.4%)*		12 851*(15.4%)*
Four wheeler (Pre-BS-IV) (4W-P)	140 765*(47.9%)*	328 462*(25.4%)*	17 239*(40.9%)*	28 345*(33.9%)*
Four wheeler-MMV-(Pre-BS-IV) (MV-P)	23 274*(7.9%)*		3680*(8.7%)*	
Bus (Pre-BS-IV) (Bu-P)	20 665*(7.0%)*		2517*(6.0%)*	
Truck (Pre-BS-IV) (Tr-P)	50 534*(17.2%)*		8525*(20.2%)*	
Four wheeler (BS-IV) (4W-B)	38 357*(13.1%)*	5943*(0.5%)*	5489*(13.0%)*	908*(1.1%)*
Four wheeler-MMV-(BS-IV) (MV-B)	6138*(2.1%)*		1271*(3.0%)*	
Bus (BS-IV) (Bu-B)	3451*(1.2%)*		492*(1.2%)*	
Truck (BS-IV) (Tr-B)	10 532*(3.6%)*		2901*(6.9%)*	

Values in the parenthesis indicates percentage of each category of vehicle under different fuel type

The registration age of most of the vehicles in both PUC database were 0–6 years (Figure 12). However, more than 50% of the non-diesel three wheeler and pre-BS-IVfour wheelers in the PUC database of Mysore was more than 6 years old (Figure 12).

In the PUC database of two cities, all two wheelers and almost all non-diesel four wheelers were petrol fuelled (Figure 12). Only a few of the pre-BS-IV non-diesel four wheelers (less than 1%) were used fuels other than petrol (Figure 14).Nearly 60% (exactly 57.2%) of total non-diesel three wheelers of Bengaluru and 68.5% of non-diesel three wheelers in Mysore were LPG fuelled (Figure 13).

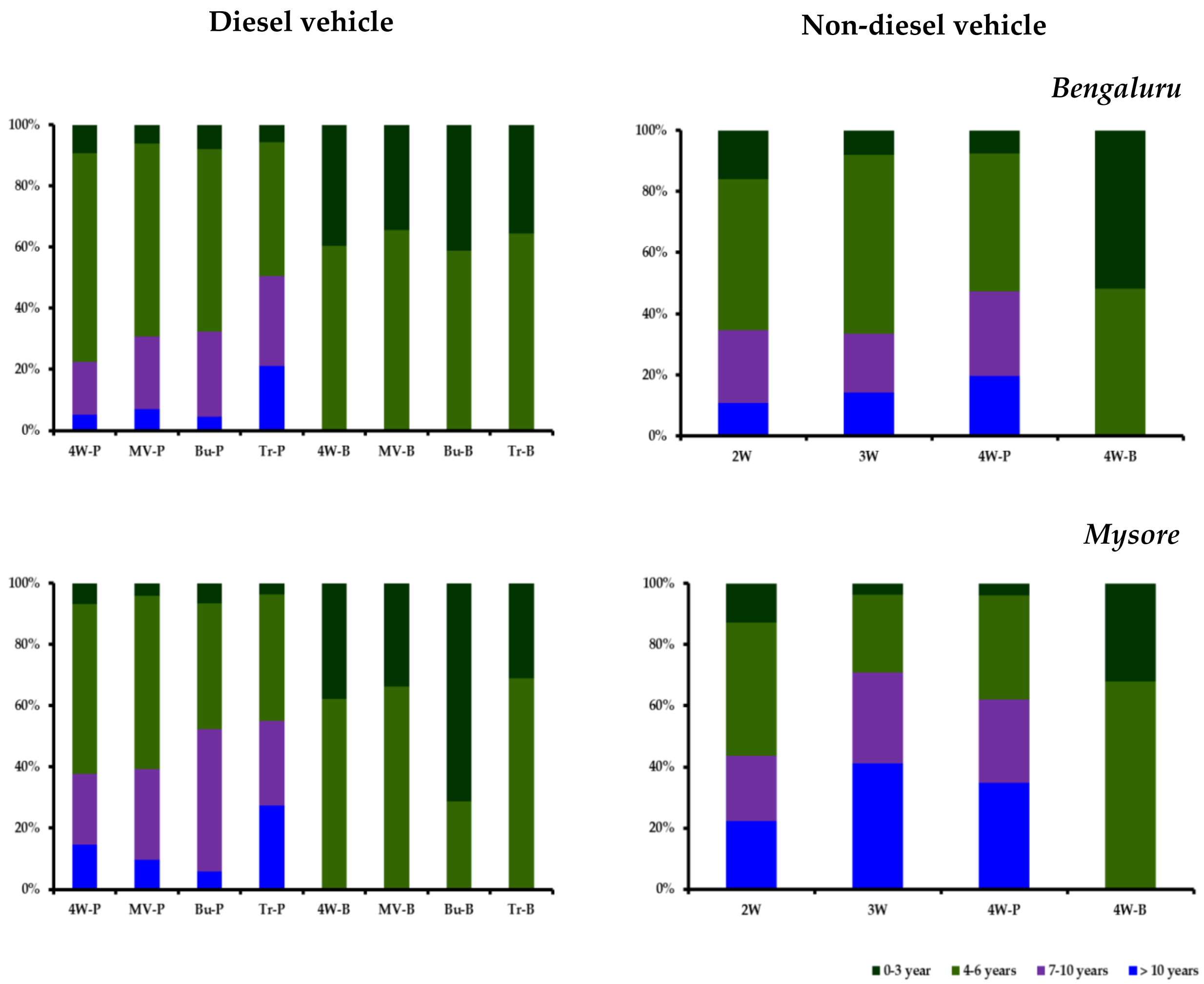

Figure 12 Registration age-wise distribution of different types of vehicles in the PUC database of Bengaluru and Mysore

2W: two-wheeler; 3W: three-wheeler; 4W-P: four-wheeler (Pre-BS-IV); 4W-B: four-wheeler (BS-IV); MV-P: 4W-MMV (Pre-BS-IV); MV-B: 4W-MMV (BS-IV); Bu-P: Bus (Pre-BS-IV); Bu-B: Bus (BS-IV); Tr-P: Truck (Pre-BS-IV); Tr-B: Truck (BS-IV).

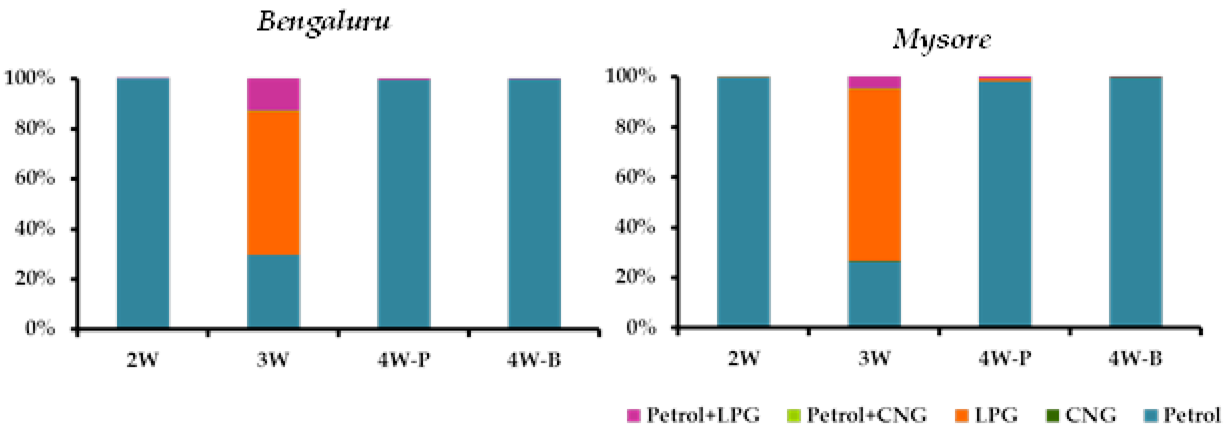

Figure 13 Fuel type-wise distributions of different categories of non-diesel vehicles in the PUC dataset of Bengaluru and Mysore

2W: two-wheeler; 3W: three-wheeler; 4W-P: four-wheeler (Pre-BS-IV); 4W-B: four-wheeler (BS-IV).

4.3.3 Results of the analysis of the PUC database

Study indicates that the PUC failure rate of non-diesel vehicles were significantly higher than that of the diesel vehicles in both cities (Figure 14). The failure rate of diesel vehicles in all types of vehicles were less than 1% in the PUC database of both cities. Diesel vehicles mainly emit fine particulates. However, as discussed above, the opacimeter testing is not suitable for modern vehicles, which emit much finer particulate matter. Thus, possibly, many high fine particulate emitting diesel vehicles go undetected in the present PUC test, resulting in lower failure rates of diesel vehicles in general.

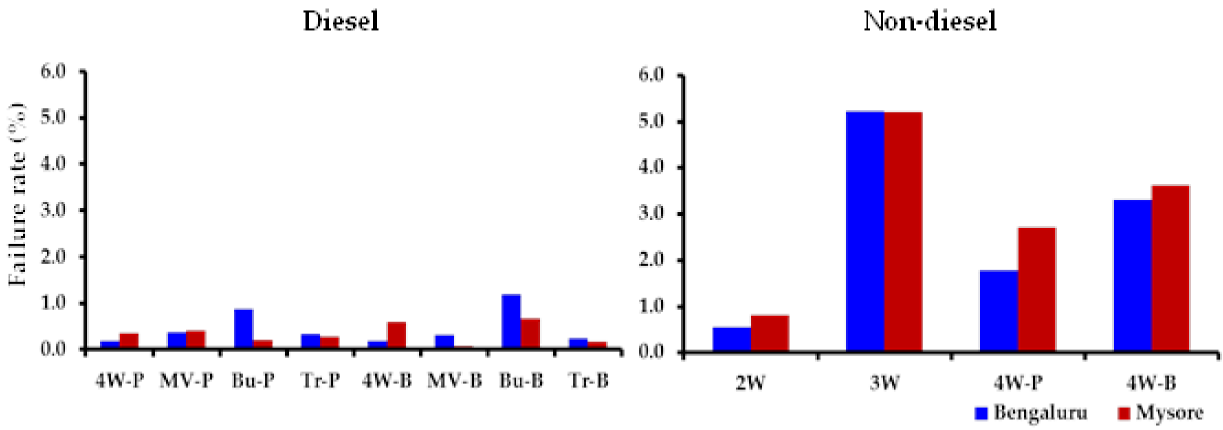

Figure 14 Failure rate of different types of diesel and non-diesel vehicles in the PUC dataset of Bengaluru and Mysore

2W: two-wheeler; 3W: three-wheeler; 4W-P: four-wheeler (Pre-BS-IV); 4W-B: four-wheeler (BS-IV); MV-P: 4W-MMV (Pre-BS-IV); MV-B: 4W-MMV (BS-IV); Bu-P: Bus (Pre-BS-IV); Bu-B: Bus (BS-IV); Tr-P: Truck (Pre-BS-IV); Tr-B: Truck (BS-IV).

The failure rate of non-diesel vehicles in both cities followed the order: three-wheeler >BS-IV four-wheeler > Pre-BS-IV four-wheeler >two-wheeler (Figure 14). Among the non-diesel vehicles, the PUC failure rate was higher in the vehicles of Mysore, whereas, the PUC failure rate of most of the type of the diesel vehicles were higher in Bengaluru. Among all types of diesel vehicles, the failure rate of BS-IV-Bus was higher in both Bengaluru (1.2%) and Mysore (0.7%) (Figure 14).

Diesel vehicles

Among all diesel vehicles in the PUC dataset of Bengaluru and Mysore, the HSU value in the tailpipe emission increases with the increase in the registration age of the vehicles. However, the increasing rate was significantly higher ($p<0.05$) in both pre-BS-IV and BS-IV emission norm compliance vehicles of Mysore compared to that in Bengaluru (Figure 15).

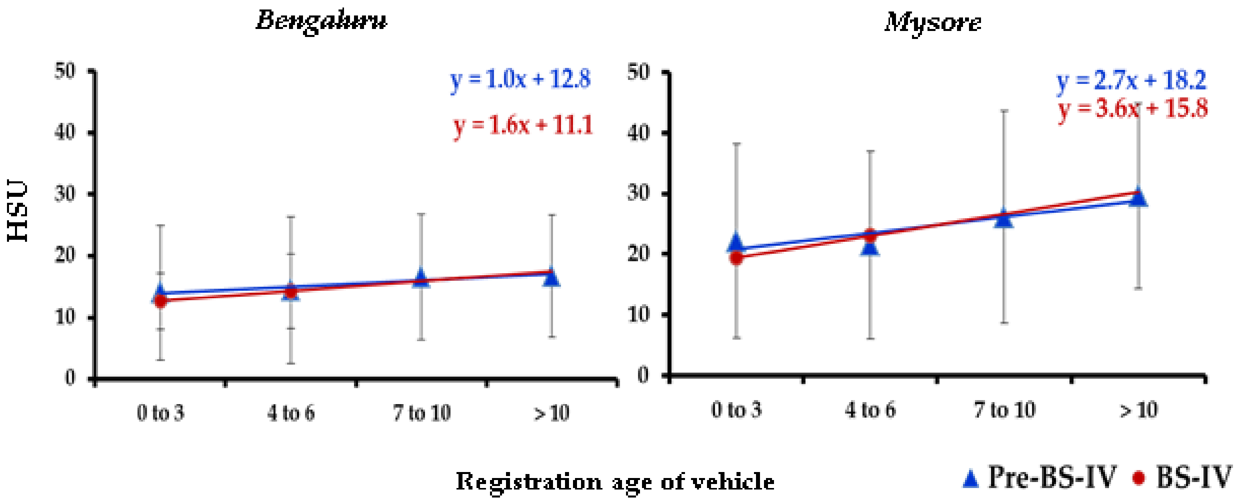

Figure 15 HSU concentration in the tailpipe emission of pre-BS-IV and BS-IV diesel vehicles in the PUC dataset of Bengaluru and Mysore

The failure rate of BS-IV bus was significantly higher (Bengaluru: 1.2%; Mysore: 0.7%) than that of the pre-BS-IV buses in both Bengaluru and Mysore (Figure 16). The HSU value in the tailpipe emission of the failed buses in both cities was significantly increased with the increase in the registration age of the vehicles (Figure 16).

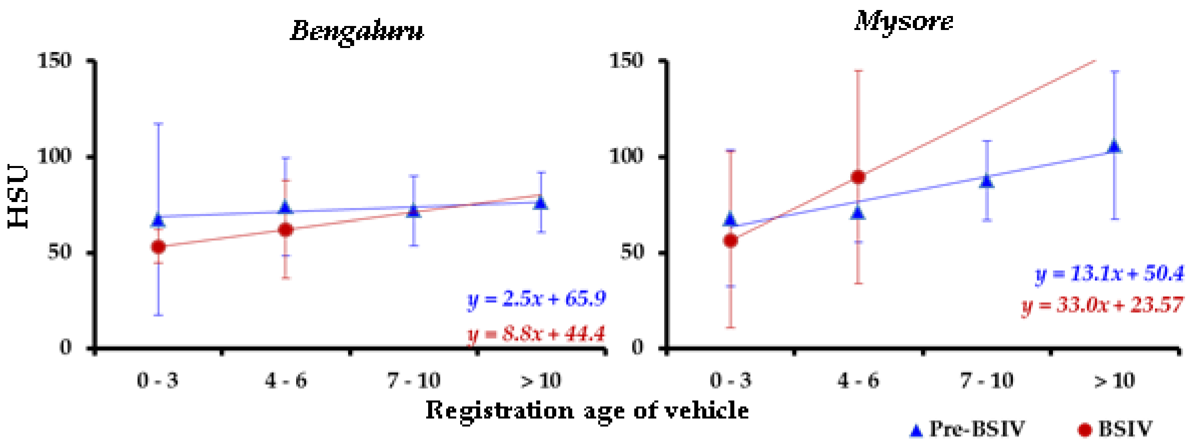

Figure 16 HSU concentrations in the tailpipe emission of the PUC failed buses in the PUC database of Bengaluru and Mysore

The increasing rate of HSU value in the tail pipe emission with the increase of vehicle registration age was significantly higher in the BS-IV buses compared to that of the pre-BS-IV buses in both cities (Figure 16). Again, as of all diesel vehicles (Figure 16), the increasing rate of the HSU value in the tailpipe emission of BS-IV buses was significantly higher in Mysore compared to that in Bengaluru.

Non-diesel vehicles

Non-diesel three wheelers belong to five different fuel classes (Figure 12) in both cities. The non-diesel three-wheeler dataset was further investigated to identify the failure rate of different fuel vehicles. Study indicates that the PUC failure rate of LPG fuelled three wheelers were significantly higher in both cities (Figure 17). Among the PUC failed three wheelers in Bengaluru and Mysore nearly 70% and more than 85% belong to the LPG fuelled vehicles respectively (Figure 17). LPG kits in three wheelers are mostly retrofitted from unlicensed vendors. Installation of inadequate kits into three wheelers could be an explanation behind the high failure rate of LPG fuelled three wheelers.

The failure rate of the LPG fuelled three-wheelers was further investigated to identify the registration age-wise failure rate of the vehicle. Study suggests that the failure rate of LPG fuelled three wheeler increases with the vehicle age (Figure 18). Again, the failure rate was

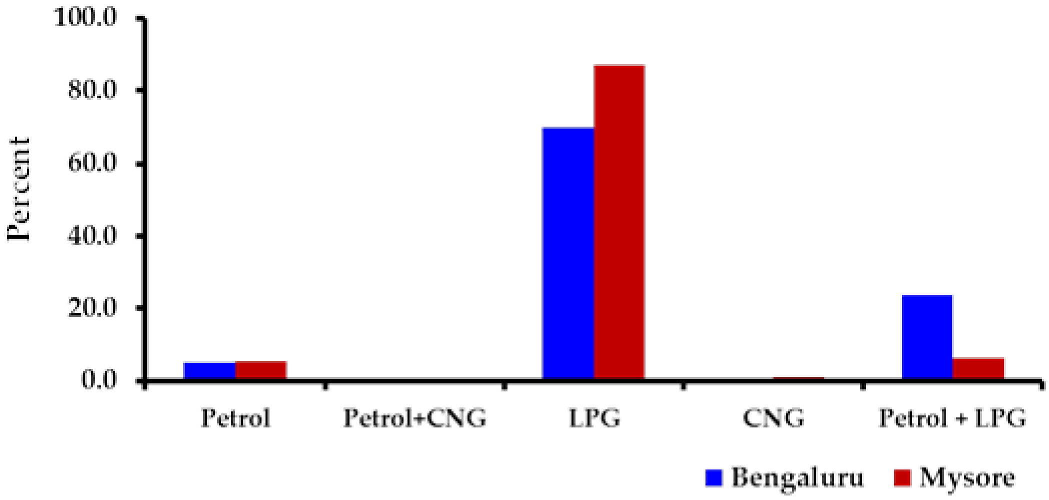

Figure 17 Distribution of failed three-wheelers according to type of fuel use in the PUC database of Bengaluru and Mysore

significantly higher in 0-6 year registration age of the vehicles in Bengaluru compared to that of Mysore (Figure 18).The life of catalytic convertors installed in three-wheeler vehicles are barely 30 000 km. In Bengaluru, the vehicle kilometre travel (VKT) of three wheelers were comparatively higher than that in Mysore, this might have attributed to higher failure rate of 0–6-year-old vehicles in the former. These vehicles run without any emission control after the life of catalytic convertors is exhausted. This could possibly explain the higher failure rate of 7–10 years of registration age of three wheelers in the PUC tests.

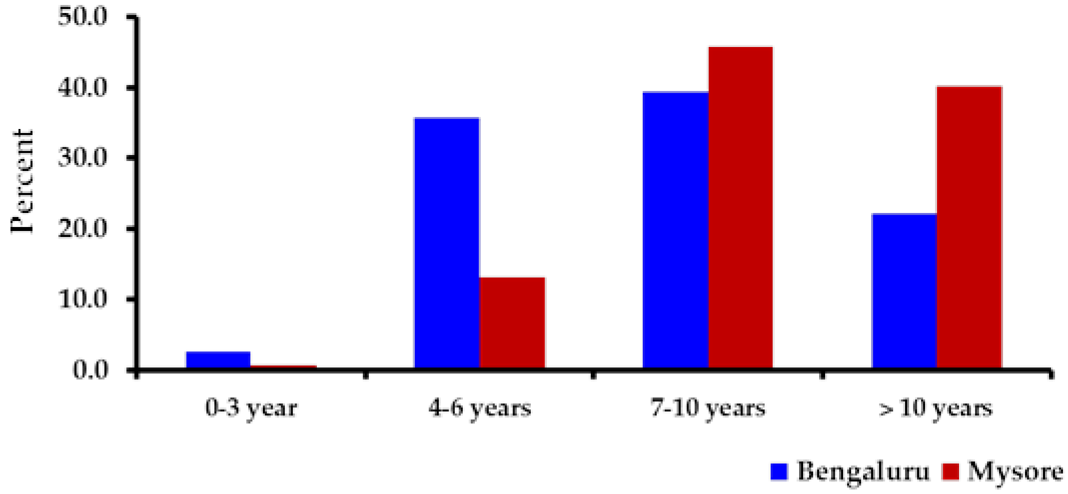

Figure 18 Vehicle registration year-wise distribution of PUC failed LPG fuelled three wheelers in the PUC database of Bengaluru and Mysore

Most of the LPG three wheelers in both cities failed in the PUC test for higher tail pipe emissions of HC and CO than the prescribed limit as mentioned in Table 1 (Figure 19). All failed three wheelers in Mysore under the registration age group of 0–3 years failed owing to higher tailpipe emission of CO (Figure 19). However, with age the failure rate due to higher emission of HC increases in both cities. This might have attributed to out-of-life catalytic converters fitted in the vehicle.

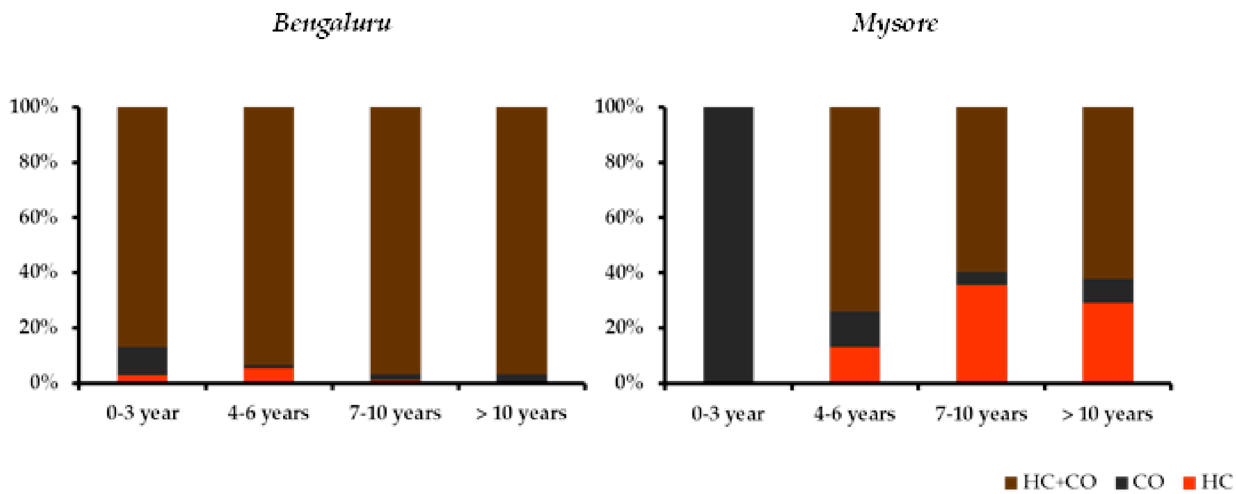

Figure 19 Registration year-wise distribution of LPG fuelled three-wheelers with higher tailpipe concentration of CO and HC than the standards

Among the non-diesel vehicles, the PUC failure rate of four wheelers (including both pre-BS-IV and BS-IV) was higher in the city of Mysore (6.3%) compared to other two categories (two-wheelers and three-wheelers) (Figure 14). Among the two cities the failure rate of four wheelers under both Pre-BS-IV and BS-IV emission norm was higher in Mysore (Figure 14). The perception survey among the vehicle owner also indicated that the PUC non-compliance rate of non-diesel four wheelers were higher in Mysore compared to Bengaluru (Figure 6). Analysis of the dataset of failed four-wheeler vehicles infers that the failure rate of BS-IV emission norm compliance non-diesel four-wheeler vehicles was higher in both cities than that of the pre-BS-IV four-wheelers (Figure 14).The tail pipe emission standard for PUC testing of BS-IV vehicles is much more stringent than that of the pre-BS-IV vehicle (Table 1); this might have attributed to higher failure rate of the BS-IV emission norm compliance four-wheeler vehicles compared to that of the pre-BS-IV vehicles. Further, non-availability of BS-IV compliance fuel (petrol) in the Mysore city or regions around might also have added to the higher failure rate of the BS-IV vehicles.

More than 99% of the non-diesel four-wheelers in both cities were petrol fuelled (Figure 13). Hence, the failure rate of non-diesel four wheelers based on the fuel type was not analysed. The failure rate of the non-diesel four-wheelers under both emission norm categories increases with the increase in registration age of the vehicle (Figure 20).

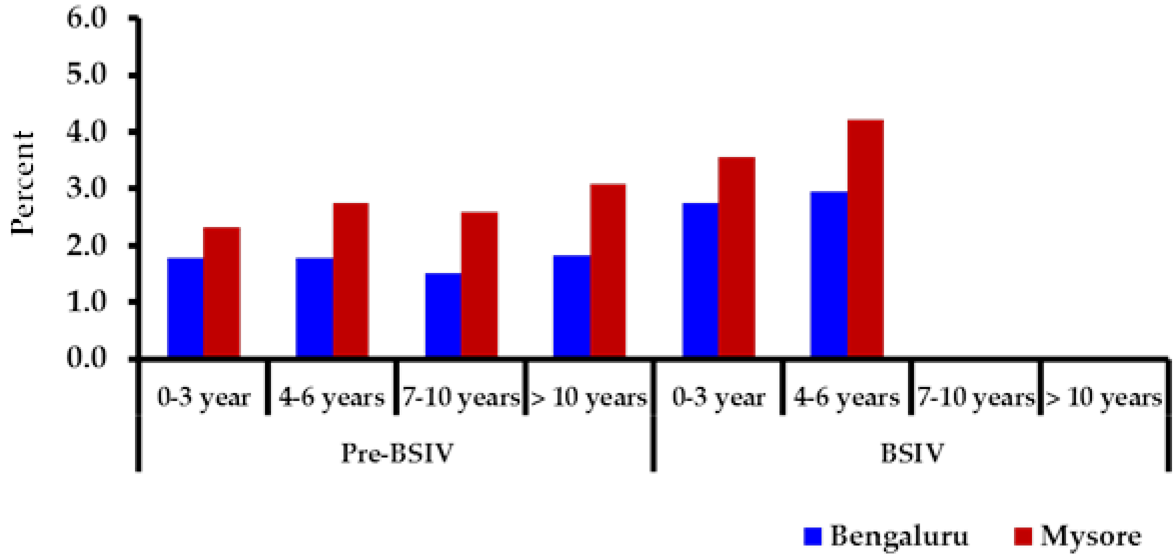

Figure 20 Vehicle registration year-wise distribution of PUC failed non-diesel four wheelers in the PUC database of Bengaluru and Mysore

Study indicates that the tail pipe emission of both CO and HC were increased significantly with the increase of the registration age of the non-diesel four wheelers in both cities (Figure 22). Average CO concentration in the tail pipe emission from failed non-diesel four-wheeler vehicles of all registration age group was higher than the prescribed standard as mentioned in Table 1.

Among the failed pre-BS-IV non-diesel four wheelers, the tail pipe concentration of CO was higher in Bengaluru compared to that of Mysore under the vehicle age group of 0–6 years. However, it reversed as the registration age of the vehicle increases (Figure 21). Significantly higher tail pipe concentration of CO was recorded in the >10 years old vehicles among all non-diesel four-wheeler vehicles in both cities (Bengaluru: 5.5%; Mysore: 7.1%). Tail pipe concentration of CO in BS-IV emission norm compliance PUC failed non-diesel four wheelers were significantly higher in the registration age group of 0–3 in the PUC database of Mysore compared to their counterpart in Bengaluru (Figure 21). This might be attributed to the non-availability of BS-IV compliance fuel in Mysore or regions around, as mentioned above. However, the average CO concentration in the BS-IV emission norm compliant non-diesel four-wheeler vehicle under the registration age group of 4–6 years was significantly higher than their counterpart under the pre-BS-IV vehicles in both Bengaluru and Mysore. The rate of increase of CO concentration in the tail pipe emission of non-diesel four wheelers from 0–3 years to 4–6 years registration age group of vehicles was higher in the BS-IV vehicles compared to that in the pre-BS-IV vehicles.

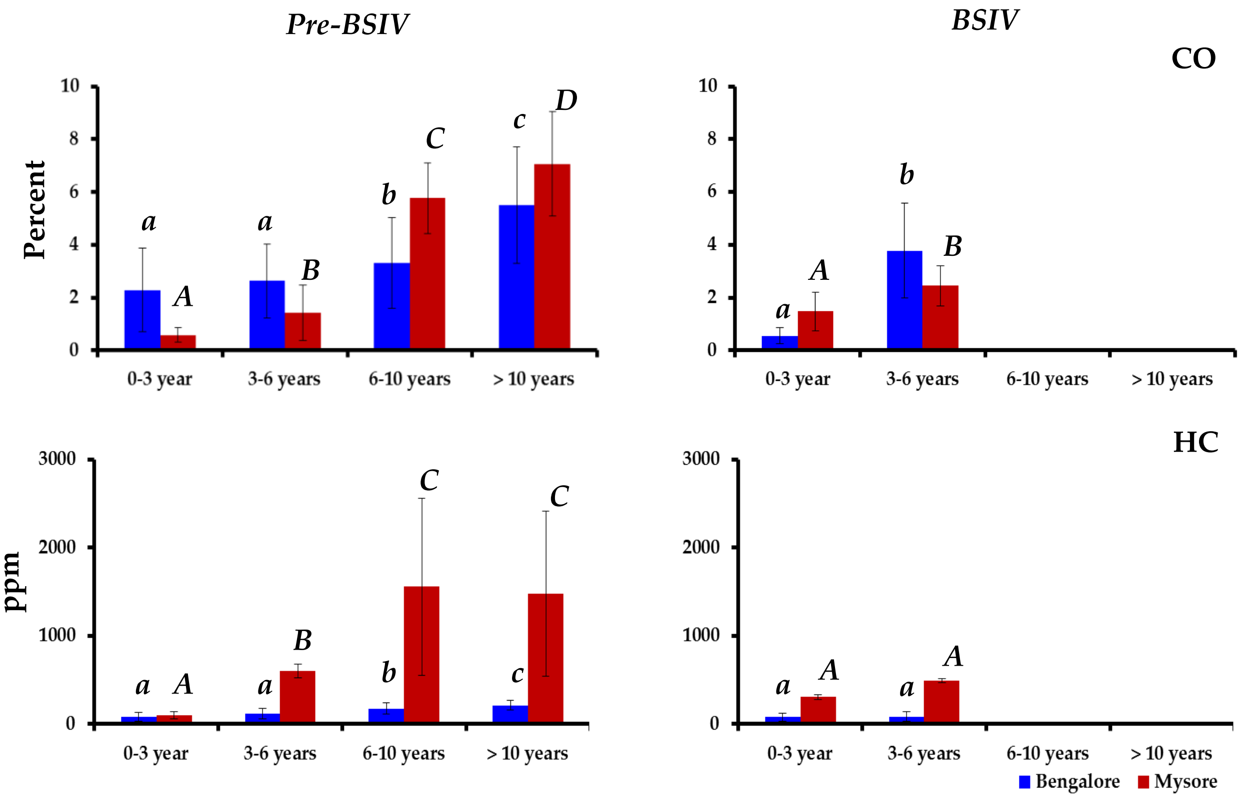

Figure 21 Vehicle registration age wise differences in the tail pipe emission of CO and HC from the failed non-diesel four-wheelers in the PUC database of Bengaluru and Mysore

Mean of all failed non-diesel 4 wheelers under each registration age group of vehicle.
Error bar indicates standard deviation of mean.
Mean of one city followed by a common lower case alphabet (Bengaluru) and upper case alphabet(Mysore) are not significantly different by Tueky'sHSD test at $p < 0.05$.

The HC concentration in the tail pipe emission of all failed non-diesel four-wheeler vehicles in the PUC database of Bengaluru was below the prescribed standard as mentioned in Table 1. This indicates that the non-diesel four-wheeler vehicles in the PUC database of Bengaluru failed in the PUC test due to higher concentration of CO in the tail pipe emission.

4.4 Salient findings of the study in Bengaluru and Mysore

The interviews conducted at PUC centres, analysis of the data collected during PUC testing, and perception survey of vehicle owners in the cities revealed interesting findings about the I&M System in Bengaluru and Mysore.

It is concluded that the PUC system in India is based on market incentives. The PUC operators are directly paid by the vehicle owners. Thus, to maintain good customer relationship, the operators have a direct incentive of manipulating the data and passing faulty vehicles in PUC tests. The interviews also revealed that PUC centres use equipment delisted by ARAI and periodicity of calibration and auditing of vehicles is irregular. It was seen that most operators were trained by the owners of the PUC centre or operators of other PUC centres.

The perception survey pointed out that three-wheeler vehicles are penalized the most for non-compliance with PUC test requirements. It was also seen from the PUC data analysis that three-wheeler LPG vehicles had the highest failure rate amongst all categories of vehicles. A possible reason could be installation of inadequate LPG kits into vehicles from local vendors. The failure rate of three-wheeler vehicles increased with increase in the age of vehicle. Three-wheelers are installed with 3-way catalytic convertors for emission control. However, the useful life of such convertors is barely 30 000 km. It was also seen that vehicle owners prefer way-side mechanics over auto-manufactures for maintenance of cars as the vehicle age. Thus, it is unlikely that cat-convertors are replaced in three wheelers after 30 000 km. This might be the reason for higher failure rate of three wheelers.

The PUC data analysis suggests that less than 1% diesel vehicles were found to fail in the two cities. The survey revealed that more diesel vehicle owners had a valid PUC test certificate as compared to non-diesel vehicles. The opacimeter is unsuitable to measure emission of finer particulate matter from modern diesel vehicles. This could be the reason behind lower failure rate and higher compliance of diesel vehicles with PUC tests.

5. Recommendations

Based on the findings from the analysis, new developments in technologies around the world and the changing scenario of the in-use vehicle management in India, following changes are recommended for the I&M in India. The recommendations are framed under four broad categories: improvement in the testing technology, changes in the institutional framework, improvements in implementations, and introduction of in-use IVCP.

5.1 Improvement in Testing Technology

It is suggested that cities in India should have three kinds of testing centres:(1) existing PUC testing centres for vehicles without OBD, (2) OBD testing centres for vehicles equipped with OBD, and (3) accredited testing centres (based on loaded tests) for vehicles failing the OBD tests. At present, petrol passenger cars and diesel vehicles manufactured post April 2013 have OBDs installed. By 2020, there would be some representation of vehicles with OBD in the total vehicular fleet. This number would then be expected to rise, assuming that all vehicles manufactured after 2020 will have OBDs installed. By 2035, almost all the vehicles without OBDs in the Indian vehicular fleet would be retiring and the need for OBD and accredited centres would gradually rise and the number of existing traditional PUC testing centres will be limited. Figure 22 represents how the numbers of traditional, OBD, and accredited testing centres are expected to change if the suggested recommendations are implemented.

(1) PUC centres with advancement in technology: The vehicles that do not have OBDs installed should be tested at the existing PUC facilities. However, the current HSU-based testing of diesel vehicles is based on the principle of absorption of light, which is not adequate to measure finer PM particles as present in the exhausts of new vehicles. This can be improved with LLSP (Laser-Light Scattering Photometry) systems, which measure PM through scattering of light. With a motive to measure NO_x from the tail pipe emissions of the diesel vehicles, the possibility of incorporating NDUV absorption spectroscopy in the PUC testing system should be explored. NDUV works on the principle that NO_x absorbs certain wavelength in the ultraviolet spectrum and transmits the rest. The vehicles failing the test at this centre should be given a chance to get serviced and get retested. If the vehicle even fails the second time, then it should be sent to accredited centre (as discussed below) for further testing.

(2) OBD based testing centres: We recommend that OBD systems should be made mandatory for all vehicles by 2020. The standards to assess the OBD datasets for desired performance of the vehicles need to be developed. Some of the existing PUC centres should be equipped with the capacity to collect and analyse OBD datasets. All the vehicles equipped with OBD should be tested at these centres. The vehicles failing the test at this centre should be given a chance to get serviced and get retested. If the vehicle fails even the second time, then it should be sent to accredited I&C centre (as discussed below) for further testing based on loaded mode tests. A pilot of OBD-based I&M programme should be implemented in Delhi. This pilot programme can test the vehicles that already have OBD system installed in them.

(3) Accredited I&C centres: The present initiatives taken by the government, that is, introduction of I&C centres, such as in Nasik, serve the purpose of testing the vehicles for road worthiness (PUC + testing for road safety). If such centres are to be deployed for a city like Delhi, with almost 8 million vehicles, then almost 125 centres would be needed to test all these vehicles on an annual basis. It would be a challenge for the state governments to allot land for so many centres. Therefore, it needs to be considered whether fewer centres can be set up only to test vehicles (only for emissions), which have failed OBD tests. Hence, lesser number of centres and corresponding amount of land would be required in each city. These centres would be equipped with facilities to test the vehicles on the rigorous loaded mode tests. Moreover, being few in number, these centres can be properly maintained and audited regularly. It could also be considered whether these facilities could be established and managed by automobile manufacturers who could take responsibility of the integrity of these tests. Possibility of introducing a policy where the government offers testing franchises on a minimum subsidy bidding basis can also be explored. These facilities should be regularly monitored by the respective state pollution control boards (SPCBs). Vehicles found with deranged parameters in OBD systems will be asked to carry out further loaded mode testing using advanced technologies like OHMS (On-road Heavy Duty Vehicle Emission Monitoring Systems) or Lug down testing for diesel vehicles. Gasoline vehicles if found to be deranged as per the OBD standards, will need to go for advanced loaded mode testing, based on advanced testing procedure, such as ASM. Selecting a specific and suitable loaded mode test for vehicles requires further investigation.

(4) Use of RS: In addition to in-use vehicle testing proposed in previous steps, RS techniques need to be employed as a check which models of vehicles emit more pollutants as compared to others. These tests can be carried out on selected roads where a significant number of vehicles are passed and their emission signals are detected remotely by the monitoring device.

(5) Catalytic convertors: It was seen from the analysis that failure rate of vehicles increases with age. A possible reason could be that vehicles might have exhausted the useful of life of the catalytic convertors installed. Thus, a regulation should be passed that requiring fitness testing to include catalytic convertors and overall durability of a vehicle.

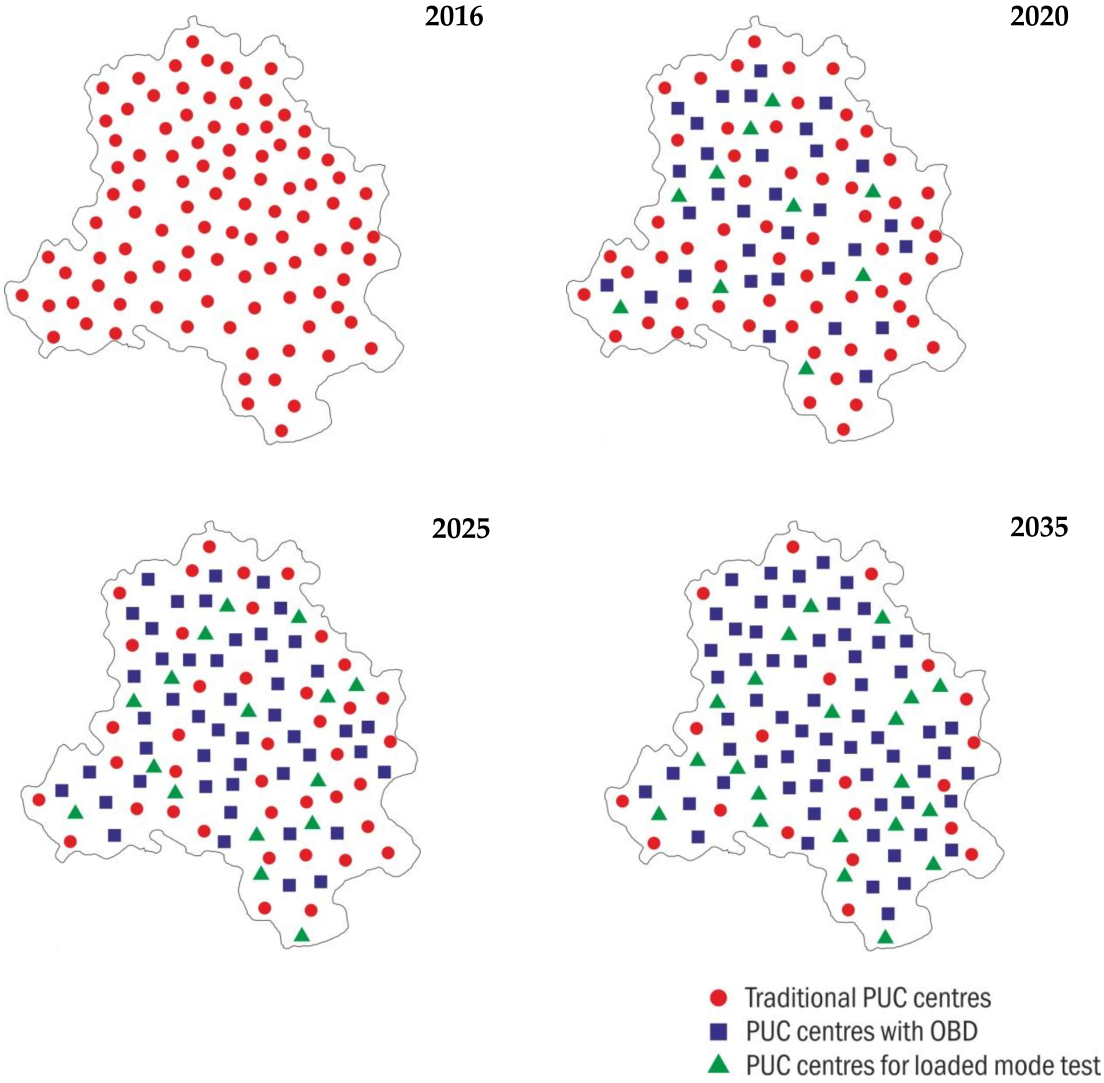

Figure 22 Diagrammatic representation of proposed changes in the PUC centres in a city.

5.2 Changes in the Institutional Framework

As such, MoRTH should make recommendations to Cabinet to legislate a new technical board consisting of environmental and transportation experts who are empowered to set and review testing standards for Type-Approvals and COP within a clear and predictable time frame. States should also be represented with an advisory capacity in the scientific board recommending CMVR committee.

MoRTH should direct approved testing agencies, such as ICAT and ARAI, to conduct surprise COP tests of the vehicles manufactured.

While technology should be used to the extent possible to review PUC data and check its veracity, the RTOs/audit agencies should be required to conduct surprise audits of PUC centres on regular basis; a target for the number of surprise audits should be prescribed to each RTO for this purpose.

States should also carry out independent checks of manufacturing equipment and provide data to ARAI about the proportion of operators using approved technology. This should help with research about feasibility of technological uptake. States can also provide harmonized training manuals developed in collaboration with the equipment manufacturers so that practices do not vary from one equipment manufacturer to another.

Both state and union government can build on developing incentives targeted at grossly polluting, older vehicles to scrap their vehicles. Policies also need to formalize scrap yards and recycling facilities through community mobilization efforts and titling initiatives. In this regard, the MoRTH is already planning a voluntary fleet modernisation programme for old vehicles.

5.3 Suggested Improvements in Implementation

Testing frequency: It is recommended to conduct annual testing of vehicles across India rather than quarterly or biannual PUC checks. Annual checks rather than quarterly or biennial checks can ensure that higher percentage of the vehicular fleet actually appear for inspections.

Tightening of standards: The PUC standards recommended for I&M should also be tightened. There is a need to improve capacity of existing PUC centres over time to become a part of an enhanced overall I&M system; centres that do not meet more stringent requirements over time may be phased out, ultimately resulting in fewer PUC centres that will be easier to audit and verify.

Visible stickers: It should be mandatory for all vehicles to carry a visible I&M sticker at all times, with validity period clearly mentioned on them to make it easier for the traffic police officers to spot defaulting vehicles. As a suggestion, the sticker should have the number of the month and the last two digits of the year in which the PUC certificate will expire. For example, a vehicle with a valid PUC certificate till 31st January 2017 should carry have a sticker saying 1/17.

States should introduce routine checking of catalytic convertors and overall durability of vehicles to offer technologically sound, comprehensive assessment of fitness of a vehicle.

There should be a close co-ordination between police and transport authorities to ensure that a valid PUC certificate is checked wherever papers of the vehicle are demanded. The number of checks done by the police and the RTOs should be reported periodically to the Transport Commissioner.

It is suggested that all cities in India move to computerized testing centres. The test data collected in each of these centres is submitted on a real-time basis to a centralized location managed by the state transport department. This data is the key to understanding the vehicular fleet in each city; and hence, the results from analysis of this data can provide insights that can be used to frame city-specific policies for better I&M of vehicles. This will result in introducing cost-effective and city-specific measures to identify high emitters. This can also act as input information for selecting models to be tested under the IVCP.

This data should be published routinely and biannual announcements should be made about progress made with respect to compliance levels and emissions reduced by the state government. Public awareness is imperative; therefore the announcement should be implemented strategically, with a campaign, in partnership with the media to highlight the importance of the efforts.

In addition, vehicle owners can be encouraged to leverage existing innovations, such as through text notifications, to exercise vigilance over the quality of PUC services offered. Broadly, it is worth considering investments in awareness campaigns to engage the public in notifying authorities of grossly polluting vehicles.

It is clear from the perception survey that majority of the vehicle owners prefer way-side mechanics for service of their vehicles. Thus, programmes can be launched by the Union Government under to National Skill Development Scheme to build the capacity and certify the way-side mechanics.

PUC integration with insurance: In many countries, integrating both vehicle insurance and vehicle inspection has worked effectively in curbing emissions from in-use vehicles, such as in Costa Rica, the EU, and many states of US.

5.4 Introduction of IVCP

The goal of this programme would be to ensure that vehicles actually comply with their original emission standards (Type Approval standards) throughout their useful life. Presently, there are no tests or screening done in India to check whether the vehicles are actually meeting their Type Approval standards throughout their useful life, provided the vehicle is maintained optimally. This can be initiated by the SCOE, which could initially target one vehicle model from all different automobile manufacturing companies operating in India. Two vehicles representing each model at two stages of their life-cycles (one new vehicle and one old vehicle) can be recruited for in-use compliance testing. Suitable vehicles would need to be recruited directly from consumers and the Regional Transport Office (RTO) database can play an important role for screening the on-road vehicles and pick out possible candidates. Vehicles found to be emitting greater than their stipulated norms as per the Type Approval standards, would go in for more comprehensive testing at the expense of the manufacturer. For the comprehensive tests, a new set of samples could be recruited from the in-use fleet, which should be tested after adequate maintenance and servicing. Manufacturers usually claim that vehicles perform inadequately in the real world due to poor maintenance. Thus, for the purpose of IVCP, it is important that adequately maintained vehicles are selected for testing purposes. If those vehicles are also found to be failing the norms, the manufacturer should be given time to look into the possible cause and submit a detailed report to SCOE. SCOE will look into the matter and decide on further actions deemed necessary, which may ultimately lead to recall. For testing of vehicles under the IVCP, it is suggested that the R&D centres, which have come up under the National Automotive Testing and R&D Infrastructure Project (NATRIP), could be roped in. A pilot programme for PEMS (portable emission measurement system) based in-use testing on a few high volume vehicles should be taken up. Even if testing agencies such as ICAT/ARAI test 8–10 cars and 8–10 trucks/buses each year in lab and on-road, it will reveal a lot in terms of the state of compliance with the standards.

Durability (deterioration) factors presently prescribed in TA norms are also questionable and need to be developed for local conditions in India, based on scientific assessments. Mass emission testing has to be carried out when the durability mileage claimed by the manufacturer is exhausted. Necessary correction in the durability factor should be made based on the evaluation carried out.

Bibliography

AT Kearney & Confederation of Indian Industry. 2013. Cost-Effective Green Mobility. Jain, S., Kidambi, R., &Mathur, M. Gurgaon: AT Kearney.

Anon. 2015. No Pollution-under-control certificate? No fuel for your vehicle. News Karnataka. Retrieved from <http://www.newskarnataka.com/Bengaluru/no-pollution-under-control-certificate-no-fuel-for-your-vehicle>

Anon. 2015. PUC test centres worsen air quality. The Statesman. Retrieved from <http://www.thestatesman.com/mobi/news/delhi/-puc-test-centres-worsen-air-quality/104416.html>

Arora, R. 2016. Government may offer up to 15% discount on new vehicles if you junk your old ones. The Economic Times. Retrieved from <http://economictimes.indiatimes.com/news/economy/policy/government-may-offer-up-to-15-discount-on-new-vehicles-if-you-junk-your-old-ones/articleshow/51232451.cms>

Automotive Research Association of India (ARAI). 2014. Keeping the Wheels of Progress in Motion (44th Annual Report). ARAI, Pune.

Automotive Research Association of India (ARAI). 2009 Certification: PUC Equipment. ARAI, Pune. Retrieved from <https://www.araiindia.com/services_certification_PUC_equipment.aspx>

Automotive Research Association of India (ARAI). 2009 PUC Equipment (FAQ's). ARAI, Pune. Retrieved from <https://www.araiindia.com/faqs_PUC_equipment.asp>

AVL. 2011. Strengthening of In-Use Vehicle Pollution Enforcement through Online Network Based System (Power Point Slides). Shimla: AVL.

Bandivadekar, A. 2015. Auto Fuel Policy Roadmap for India – What Next?(Power Point Slides). Kolkata: International Council on Clean Transportation.

Bandivadekar, A, & Bansal, G. 2013. Overview of India's Vehicle Emissions Control Program: Past Successes and Future Prospects. Washington: The International Council on Clean Transportation..

Banerjee, R. 2012. Govt proposes fitness tests for private vehicles. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/delhi/Govt-proposes-fitness-tests-for-private-vehicles/articleshow/13400391.cms>

Banerjee, R. 2015. Delhi's stricter emission norms only on paper. Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/delhi/Delhis-stricter-emission-norms-only-on-paper/articleshow/47103209.cms>

Bansal, G, & Lloyd, AC. 2013. Emissions from transportation and fuels: The importance of initial and real world measurements for policy making in India. Journal of Metrology Society of India 28(3), 227–34.

Bansal, R. 2014. India's draft road safety bill focuses more on penalty and technology. Down to Earth. Retrieved from <http://www.downtoearth.org.in/news/indias-draft-road-safety-bill-focuses-more-on-penalty-and-technology-47122>

Bert, F, & Bosu, P. 2012. Vehicle I&M in Asia: Status and challenges (Power Point Slides). Hong Kong: Clean Air Asia.

Bhanot, B. 2015. Towards Improved Vehicular Safety on Road & Roadworthiness of In-Service Vehicles (Power Point Slides). New Delhi, Delhi: Centre for Science and Environment.

Bhatt, A. 2015. Pollution certificates compromised at many places. Deccan Herald. Retrieved from <http://www.deccanherald.com/content/504331/pollution-certificates-compromised-many-places.html>

Bhattacharjee, P. 2014. Too ambitious for own good, new road safety bill lies in mishap zone. Governance Now. Retrieved from <http://www.governancenow.com/news/regular-story/new-road-safety-bill-loaded-over-ambitious-law-india-accident>

Bishop, G, Aldrete, P, & Slott, R. 1997. On-road evaluation of an automobile emission test program. Environmental Science and Technology 31, 927–31.

Borken-Kleefeld, J. 2013. Guidance note about on-road vehicle emissions remote sensing. Report prepared for the International Council on Clean Transportation. Retrieved from <http://www.theicct.org/sites/default/files/publications/RSD_Guidance_BorKlee.pdf>

BS B2B Bureau. 2016. Government revises cost estimate for NATRIP project. Business Standard. Retrieved from <http://www.business-standard.com/content/b2b-manufacturing-industry/government-revises-cost-estimate-for-natrip-project-116072800663_1.html>

Business Standard. 2009. SIAM sets up 2200 Free Pollution Check Camps on World Environment Day. Business Standard. Retrieved from <http://www.business-standard.com/article/press-releases/siam-sets-up-2200-free-pollution-check-camps-on-world-environment-day-109060400102_1.html>

Business Today. 2016. BS-VI will not improve air quality, may push car prices: Maruti Suzuki. Business Today. Retrieved from <http://www.businesstoday.in/sectors/auto/bs-vi-will-not-improve-air-quality-may-push-car-prices-says-maruti/story/227903.html>

Calvert, J, Heywood, J, Sawer, R, & Seinfeld, J. 1993. Achieving acceptable air quality: Some reflections on controlling vehicle emissions. Science 261, 37–45.

Central Pollution Control Board (CPCB). 2006. Air Quality Trends and Action Plan for Control of Air Pollution from Seventeen Cities. New Delhi, Delhi: Ministry of Environment & Forests.

Central Pollution Control Board (CPCB). 2010. Status of the Vehicular Pollution Control Programme in India. East Arjun Nagar, Delhi: Ministry of Environment &Forests.

Central Pollution Control Board (CPCB). 2011. Source Apportionment Study for Six Cities, Central Pollution Control Board, New Delhi.

Central Pollution Control Board. (2011). Report on Emission Testing Centers, PUC Auditing in Jaipur, Rajasthan 2010-11. Bhopal: CPCB Central Zonal Office.

Central Pollution Control Board (CPCB). 2013. Auditing of Authorised Vehicular Pollution Checking Centres in Delhi. Delhi, India: Ministry of Environment & Forests.

Central Pollution Control Board (CPCB). 2014. National Ambient Air Quality Status and Trends in India – 2012, New Delhi.

Centre for Science and Environment. (2004). A Primer: On Implementation Of The In-Use Emission Norms As Amended By the Union Government in February 2004 (Right to Clean Air Campaign.)

Das, S. 2014. Delhi PUC 'plan' to curb pollution hits roadblock. India Today. Retrieved from <http://indiatoday.intoday.in/story/puc-certificate-l-g-najeeb-jung-air-pollution-water-pollution-delhi-motorists-asg/1/394461.html>

Deb, K, & Sundar, S. 2003. A regime for inspection and certification for in-use vehicles in India. New Delhi: The Energy and Resources Institute.

Delhi Transport Department. 2016 Frequently Asked Questions (FAQ) about P.U.C Certificate. Retrieved from http://www.delhi.gov.in/wps/wcm/connect/doit_transport/Transport/Home/Pollution+Control/P.U.C.

Delhi Transport Department. n.d. Procedure to open an Authorized Pollution checking Centre. Retrieved from <http://www.delhi.gov.in/wps/wcm/connect/doit_transport/Transport/Home/Pollution+Control/Pollution+checking+centers/Procedure+to+open+an+Authorized+Pollution+checking+Centre>

DieselNet. 2016. Technology Guide, Measurement of Emissions. DiselNet. Retrieved from <https://www.dieselnet.com/tech/measure_opacity.php>

DoMV. 2016. Exhaust Emissions Testing. Department of Motor Vehicles. Retrieved from <http://dmv.dc.gov/node/1119028>

DOT. 2014. Inservice exhaust emission standards for road vehicles. Department of Transport.

DTE Staff. 2015. Current PUC norms for diesel are too lenient, says CSE. Down to Earth. Retrieved from <http://www.downtoearth.org.in/news/current-puc-norms-for-diesel-are-too-lenient-says-cse-51792>

Environmental Pollution (Prevention & Control) Authority for the National Capital Region. 2006. A progress report on audit of PUC centers and networking of PUC centres in Delhi (EPCA Report No. 23). New Delhi: Central Pollution Control Board.

EPCA. 2006. Implementation of Lambda measurement in Pollution Under Control (PUC) certification programme in Delhi. New Delhi. Environment Pollution (Prevention & Control) Authority.

ET Bureau. 2016. Road transport ministry releases concept paper to take off old vehicle from the roads. The Economic Times. Retrieved from <http://articles.economictimes.indiatimes.com/2016-05-26/news/73365330_1_transport-ministry-road-transport-finance-ministry>

ETAuto Bureau. 2015. NATRIP Project's deadline extended by 3 years. ET Auto. Retrieved from <http://auto.economictimes.indiatimes.com/news/policy/natrip-projects-deadline-extended-by-3-years/47375543>

European Union. 2012. Road safety: The roadworthiness package – Tougher vehicle checks to save lives. EU. Retrieved from <http://europa.eu/rapid/press-release_MEMO-12-555_en.htm>

Expert Committee. 2014. Auto Fuel Vision and Policy 2025. New Delhi, Delhi: Government of India.

Faiz, A, Weaver, C S, and Walsh, M P. 1996. Air Pollution from Motor Vehicles: Standards and Technologies for Controlling Emissions. Washington, DC: World Bank.

Feedback Infrastructure Pvt Ltd. 2012. Pre-feasibility Report: Development of Vehicle Fitness Centres (Sector Specific Inventory & Institutional Strengthening for PPP Mainstreaming Transport Department). Karnataka: Infrastructure Development Department, Government of Karnataka.

Gaur, K. 2015. Bar association protests against no fuel for vehicles without PUC certificate. The Times of India, City. Retrieved from <http://timesofindia.indiatimes.com/city/jaipur/Bar-association-protests-against-no-fuel-for-vehicles-without-PUC-certificate/articleshow/47873461.cms>

Geeta, G, Neeta, S, & Shrivastava, R K. 2013. Air Pollution Due to Road Transportation in India: A Review on Assessment and Reduction Strategies (Review Paper). Journal of Environmental Research and Development, 8(1), 69–77.

Ghatge, S V, Goyal, S K, Nema, P, & Tamhane, S M. 2006. Understanding Urban Vehicular Air Pollution Problem Vis-à-vis Ambient Air Quality – Case Study of A Megacity (Delhi, India). Environment Monitoring and Assessment 119, 557–69.

Ghoshal, A. 2015. Automatic vehicle testing centre to open in Nashik. AutocarIndia. Retrieved from <http://www.autocarindia.com/auto-news/automatic-vehicle-testing-centre-to-open-in-nashik-395522.aspx>

Goel, R, & Guttikunda, S K. 2015. Evolution of on-road vehicle exhaust emissions in Delhi. Atmospheric Environment 105, 78–90.

Goel, R, Guttikanda, S, Mohan, D, & Tiwari, G. 2013. Methods to Estimate Vehicular Characteristics in Indian Cities (Power Point Slides). Udaipur: United Nations Environmental Programme.

Gundal, S S, Kanawade, M T, & Katariya, S S. (2014). Automatic PUC detection System. ITSI Transactions on Electrical and Electronics Engineering 2(3), 30–32.

Guttikunda, S K, & Mohan, D. 2014. Re-fueling road transport for better air quality in India (Communication). Energy Policy, 68,556–61.

Honaganahalli, P, & Raju, K V. 2004. Air Quality Management in Bengaluru, India: A Preliminary Assessment (Working Paper, 154). Bengaluru, Karnataka: Institute for Social and Economic Change.

India-California Air Pollution Mitigation Program (ICAMP). 2014. Options to reduce road transport pollution in India. Delhi: The Energy and Resources Institute (TERI) India; , California: University of California at San Diego (UCSD), California Air Resources Board (CARB).

Indian Institute of Technology Kanpur (IITK). 2015. Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi. Kanpur: Indian Institute of Technology Kanpur.

International Council foron Clean Transportation (ICCT). 2013. Policy Summary: India's Vehicle Emissions Control Program (Briefing). Washington: ICCT.

International Council for Clean Transportation (ICCT). 2016a. India Bharat Stage 6 emission standards. Washington. D. C International Council for Clean Technology. Retrieved from <http://www.theicct.org/sites/default/files/publications/India%20BS%20VI%20Policy%20Update%20vF.pdf>

International Council for Clean Transportation (ICCT). 2016b. On-Board Diagnostic (OBD) Checks for Inspection and Maintenance in India. Washington.D. C. International Council for Clean Technology.

Jadav, D. 2014. Vehicle Fitness Certificate by RTO – Fitness Process | Fees | Penalties | Vehicle Types (Web log), Mumbai 77. Retrieved from <http://www.mumbai77.com/city/3678/travel/certificate-vehicle-fitness-by-rto/>

Jadhav, R. 2015. Call to overhaul vehicle PUC system. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/pune/Call-to-overhaul-vehicle-PUC-system/articleshow/49837783.cms>

Jagadeesh, V. 2014. Fitness certification centre to come up at Nelamangala. The Hindu. Retrieved from <http://www.thehindu.com/news/cities/Bengaluru/fitness-certification-centre-to-come-up-at-nelamangala/article6033707.ece>

Janwalkar, M. 2015. Monitoring of vehicles without PUC delayed. The Indian Express. Retrieved from <http://indianexpress.com/article/cities/delhi/monitoring-of-vehicles-without-puc-delayed>

Kathuria, V. 2002. Vehicular pollution control in Delhi. Transportation Research Part D 7,373–87.

Kumar, A. 2016. Vehicle pollution check centres on the radar. The Hindu. Retrieved from <http://www.thehindu.com/news/cities/Delhi/vehicle-pollution-check-centres-on-the-radar/article8052424.ece>

Lakshmi, C S, Sharma, S, Sundar, S, & Bhanot, B. 2014. Establishing a national in-use vehicle testing programme in India. Shakti Sustainable Energy Foundation. Retrieved from <http//www.shaktifoundation.in/wp-content/uploads/2014/02/National-in-use-vehicle-testingprogramme-in-India.pdf>

Ministry of Petroleum & Natural Gas. 2015. National Auto Fuel Policy (Fifth Report). New Delhi: Lok Sabha Secretariat.

Ministry of Road Transport & Highways (MoRTH) 2005 MoRTH/CMVR/ TAP-115/116, Issue no.4, Volume II, standards for petrol and diesel engine vehicles, Ministry of Road Transport & Highways, Government of India.

Mysore City Police. 2016.Number of registered motor vehicles in Mysore. Available at http://mysorecitypolice.gov.in/contentpage.aspx?id=53.

Ministry of Road Transport & Highways (MoRTH). 2013 Standards and Test Procedures for Idling MoRTH/CMVR/TAP-115/116 document (Issue 4), Chapter 8. ARAI India [online] , Ministry of Road Transport & Highways, Available at https://www.araiindia.com/CMVR_TAP_Documents/Part-15/Part-15_Chapter08.pdf [accessed 11 December 2013].

Ministry of Road Transport & Highways, O&M Section. 2013. Induction Material in respect of the Ministry of Road Transport & Highways (Office Memorandum). New Delhi. MoRTH

Ministry of Road Transport & Highways. 2012. Visual Check for Malfunction Indicator Lamp. New Delhi. MoRTH http://morth.nic.in/showfile.asp?lid=828

Ministry of Road Transport & Highways. 2014. Project for Establishment of Inspection and Certification Centre for Motor Vehicles. New Delhi: Government of India. Retrieved from <http://morth-roadsafety.nic.in/WriteReadData/LINKS/440ba28ef-a041-4c7e-97ce-25123f2b3f0f.pdf>

Ministry of Road Transport & Highways. n.d. Standards and Test Procedures for Idling (Issue 4.)

Ministry of Road Transport and Highways. 2004. Testing of Smoke Meters and Gas Analysers (Central Motor Vehicle Rules, Issue 4.). p. 218-227.

Ministry of Road Transport and Highways. 2010. Document on Test Method, Testing Equipment and Related Procedures for Testing Type Approval and Conformity of Production (COP) of Vehicles for Emission as Per CMV Rules 115, 116 and 126. Pune: Automotive Research Association of India. Retrieved from <https://www.araiindia.com/pdf/TAP_Document_Issue_4_Volume_I.pdf>

Ministry of Road Transport and Highways. 2011. Review of the Motor Vehicles Act, 1988 (Report of the Expert Committee). New Delhi. MoRTH

Ministry of Urban Development. 2009. Action Taken by the Government on the Recommendations Contained in the Thirty-Seventh Report of the Standing Committee on Urban Development. (Fifteenth Lok Sabha, Fourth Report). New Delhi: Lok Sabha Secretariat.

Mishra, P M. 2015. Centre proposes regular fitness test of private vehicles. DNA India. Retrieved from <http://www.dnaindia.com/india/report-centre-proposes-regular-fitness-test-of-private-vehicles-2050281>

Mohan, D. 2015. Road safety in India could end up in a mess. The Hindu Business Line. Retrieved from <http://www.thehindubusinessline.com/specials/auto-focus/road-safety-in-india-could-end-up-in-a-mess/article6887605.ece>

Mukherjee, S. 2015. Dump old vehicle, earn up to INR 1.5 lakh. The Indian Express. Retrieved from <http://indianexpress.com/article/india/india-others/financial-incentives-upto-rs-1-5-lakh-on-surrender-of-old-vehicles-nitin-gadkari/>

Muller, G. 2013. Changes in vehicle supervision in emerging markets: example India (Power Point Slides). Seville: TUVSUD

Mysore City Police. 2016. Number of registered motor vehicles in Mysore. Retrieved from <http://mysorecitypolice.gov.in/contentpage.aspx?id=53>

Nandi, J. 2015. Current PUC regime of no use: Experts. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/delhi/Current-PUC-regime-of-no-use-Experts/articleshow/47103189.cms>

National Bureau. 2016. Road Ministry proposes policy on scrapping vehicles. The Hindu. Retrieved from <http://www.thehindu.com/business/Economy/road-ministry-proposes-policy-on-scrapping-vehicles/article8116894.ece>

National Institute for Automotive Inspection, Maintenance and Training (NIAIMT). n.d. Inspection & Maintenance Station (IMS).

National Transport Development Policy Committee. 2014. India Transport Report: Moving India to 2032 (Executive Summary). New Delhi, Delhi: Planning Commission, Government of India.

Norris, J O W. 2005. Low Emission Diesel Research—CP17/18/770: Phase 3—Report to Vehicle and Operator Services Agency (VOSA). Report AEAT /ENV/R/1873/Issue1. AEA Technology—Environment, Didcot, U.K. February. Retrieved from <http://www.transportoffice.gov.uk/crt/repository/Low%20Emission%20Diesel%20Research.pdf>

Pandey, A. 2015. ARAI to set up inspection and certification test centres. Autocar Professional. Retrieved from <http://www.autocarpro.in/news-national/arai-set-inspection-certification-test-centres-7520>

PTI. 2014. Soon motorists will require 'pollution under control' certificate to buy petrol, diesel. The Times of India. Retrieved from: http://timesofindia.indiatimes.com/city/delhi/Soon-motorists-will-require-pollution-under-control-certificate-to-buy-petrol-diesel/articleshow/40577320.cms

Pundir B P. 2001. Vehicular Air Pollution in India: Recent Control Measures and Related Issues in India Infrastructure Report 2001. New Delhi: Oxford University Press.

Rao, V K. 2013. Vehicle fitness test to go hi-tech soon. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/visakhapatnam/Vehicle-fitness-test-to-go-hi-tech-soon/articleshow/21048928.cms>

Reuters 2015. Government to ban trucks older than 15 years as cities choke on dirty air. Economic Times. Retrieved from <http://economictimes.indiatimes.com/news/politics-and-nation/government-to-ban-trucks-older-than-15-years-as-cities-choke-on-dirty-air/articleshow/50027202.cms>

Rogers, J. 2002. Assessment of the Pollution Under Control Program in India and Recommendations for Improvement (Prepared for the South Asia Urban Air Quality Management Program). Washington D.C: The World Bank.

Rokadiya, S. 2016. Cleaning up India's Transport Sector: The Fight for New Vehicle Emission Standards. The City Fix. Retrieved from <http://thecityfix.com/blog/cleaning-up-india-transport-sector-fight-new-vehicle-emission-standards-shikha-rokadiya/>

Roychowdhury, A. 2015. Urban air quality challenges and strategies to reduce emissions from in-use and new vehicles (Centre for Science and Environment Workshop, Power Point Slides). New Delhi, Delhi: Centre for Science and Environment.

Sethi, K. 2015. Motorists Will Need PUC Certificate to Buy Petrol, Diesel. Car and Bike (An NDTV Venture). Retrieved from <http://auto.ndtv.com/news/delhi-motorists-will-need-puc-certificate-to-buy-petrol-diesel-651524>

Sethi, K. 2015. Pollution Checks for Vehicles Will Become Mandatory Soon. Car and Bike (An NDTV Venture). Retrieved from <http://www.carandbike.com/news/pollution-checks-for-vehicles-will-become-mandatory-soon-748865>

Shah, A. 2015. Auto industry calls for unified emissions rules across India. Live Mint. Retrieved from <http://www.livemint.com/Industry/htzufGEj6xTACTIe7UAaKL/Auto-industry-calls-for-unified-emissions-rules-across-India.html>

Sharma, S, Goel, A, Suresh, R, Sitalakshmi, C, Mhatta, R, Sundar, S, Bansal, G, German, J, Posada, F, & Franco, V. 2013. Assessment of Emission Test Driving Cycles in India: A Case for Improving Compliance. New Delhi. The Energy and Resources Institute and ICCT.

Sharpe, B. 2015. Testing methods for heavy-duty vehicle fuel efficiency: Trends from regulatory programs around the world and implications for India (Working Paper 2015-3). Washington DC: International Council on Clean Transportation.

SIAM. 2016. Automobile Production Trends in India. New Delhi: Society of Indian Manufacturers. Retrieved from <http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=13>

Lakshmi, C S, Sharma, S, Sundar, S, & Bhanot, B. 2014. Establishing a National In-use Vehicle Testing Programme in India. New Delhi. Shakti Sustainable Energy Foundation. Retrieved from <shaktifoundation.in/wp-content/uploads/2014/02/National-in-use-vehicle-testingprogramme-in-India.pdf>

Sonawane, S. 2015. Fitness tests on trial basis begin at automatic vehicle inspection centre. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/nashik/Fitness-tests-on-trial-basis-begin-at-automatic-vehicle-inspection-centre/articleshow/48969293.cms>

Special Correspondent. 2012. ARAI plan 10 inspection, maintenance centres. The Hindu. Retrieved from <http://www.thehindu.com/todays-paper/tp-national/tp-tamilnadu/arai-plans-10-inspection-maintenance-centres/article2794980.ece>

Srivastava, A. 2015. CSE evaluation of Volkswagen emissions fraud case and current regulations for emissions control from on-road vehicles has exposed India's lack of readiness to deal with compromised emissions performance on roads (Web log). New Delhi: Centre for Science and Environment. Retrieved from http://cseindia.org/content/cse-evaluation-volkswagen-emissions-fraud-case-and-current-regulations-emissions-control

The Hindu. 2016. Odisha's first automated vehicle fitness testing centre to come up in Cuttack. Retrieved from <http://www.thehindu.com/news/cities/Bengaluru/fitness-certification-centre-to-come-up-at-nelamangala/article6033707.ece>

Sudha, A. 2014. Vehicles may soon need fitness tests every. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/pune/Vehicles-may-soon-need-fitness-tests-every-year/articleshow/37931484.cms>

Texas A&M Transportation Institute and Denver University (TTI/DU). 2013. Heavy-Duty Diesel Inspection and Maintenance Pilot Program (Report; Revised Edition). Texas. North Central Texas Council of Governments and the Texas Department of Transportation. Retrieved from <http://www.nctcog.org/trans/air/hevp/documents/NCTCOG_DieselIM_Final_Report_UpdatedOctober2013.pdf>

The Energy and Resources Institute. 2014. TERI MARKAL simulation results. New Delhi: The Energy and Resources Institute.

The Hindu. 2016. Welcome measure to clean air. The Hindu. Retrieved from <http://www.thehindu.com/opinion/editorial/welcome-measure-to-clean-the-air/article8093156.ece>

The Times of India News Service. 2013. Pollution tests under cloud. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/delhi/Pollution-tests-under-cloud/articleshow/21350416.cms>

The Times of India News Service. 2015. Advanced centre to check fitness of vehicles. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/lucknow/Advanced-centre-to-check-fitness-of-vehicles/articleshow/48429705.cms>

The Times of India News Service. 2015. Experts highlight gaps in emission norms. The Times of India. Retrieved from <http://timesofindia.indiatimes.com/city/delhi/Experts-highlight-gaps-in-emission-norms/articleshow/49808749.cms>

Transport Department. 2016. Vehicle Statistics/Annual Report. Bangalore: Government of Karnataka. Retrieved from <http://transport.karnataka.gov.in/index.php/information/details/vehicle_statistics>

Transport Policy. 2016. India: Light Duty: Emissions. New Delhi: Transport Policy. Retrieved from <http://transportpolicy.net/index.php?title=India:_Light-duty:_Emissions>

UNEP. 2014. Promoting low carbon transport in India. New Delhi: UNEP. Retrieved from <http://www.unep.org/transport/lowcarbon/PDFs/AssementMotorVehicle.pdf>

Vandanan Vandana. 2016. How to open an authorized auto pollution control checking centre in India (Weblog). Retrieved from <http://www.indiastudychannel.com/resources/168905-How-to-open-an-authorized-auto-pollution-control-checking-centre-in-India.aspx>>

Vasudeva, S S. 2015. Licences of 10 emission testing centres cancelled. Deccan Herald. Retrieved from <http://www.deccanherald.com/content/486076/licences-10-emission-testing-centres.html>

Vasudeva, S S. 2015. Hike in emission test free for vehicles 'miniscule,' say certification centres. Deccan Herald. Retrieved from <http://www.deccanherald.com/content/508466/hike-emission-test-fee-vehicles.html>

Walsh, M. 2005. Motor Vehicle Inspection and Maintenance: The Worldwide Experience (newsletter). Arlington: Car Lines.

Weiss, M, Bonnel, P, Hummel, R, Manfredi, U, Colombo, R, Lanappe, G, Le Lijour, P, & Sculati, M. 2011. Analyzing On-Road Emissions of Light-Duty Vehicles with Portable Emission Measurement Systems (PEMS). European Commission Joint Research Centre, Institute for Energy, EUR24697EN-2011, Ispra.

Yadav, U. 2014. Karnataka Government doesn't care about vehicle smoke. The New Indian Express. Retrieved from<http://www.newindianexpress.com/states/karnataka/Karnataka-Government-Doesnt-Care-About-Vehicle-Smoke/2014/06/05/article2264042.ece>

Annexure: 1 - Workshop in Delhi

Title of the workshop: Improving Inspection and Maintenance System in India

Date: October 25, 2016

Venue: Marigold Hall, India Habitat Center, New Delhi

The objective of the workshop was to initiate a discussion on the current I&M system for in-use vehicles in India and its limitations; and to contemplate on the possible solutions to improve I&M system in India. The workshop had a representation from the government, industry, research institutes and regulatory authorities.

Dr Ajay Mathur, Director General, TERI, highlighted the importance of regular I&M in India. He released the position paper prepared from the results of the study. It was made clear that improvements in both technology and implementation were necessary for a robust I&M System in India. Mr S Sundar, Distinguished Fellow, TERI, pointed out the vehicles are increasing at an exponential rate in India and steps are needed to be taken to limit the negative externalities – air pollution, associated with vehicular emissions. While India is progressing towards stricter emission standards, it also important to strengthen I&M of the vehicles plying on the roads. On-board diagnostic systems on vehicles and an IVCP is the way ahead to improve I/M system in India. The Joint Secretary of Ministry of Road and Transport, Mr Abhay Damle, talked about the position paper released by TERI. The I&M System in India is slowly developing, he said. India is a unique country so it requires new and innovative solutions to deal with complex problems. He stressed on simple solutions which are easy to implement and would have higher returns. The suggestion of visible stickers in cars for easy identification of PUC compliant vehicles is one such solution. Mr I. V. Rao from Maruti briefed about the readiness of the manufacturing industry to solutions mentioned in the position paper. He informed the audience that OBD was introduced in India in 2006 and since then India has made a lot of progress. The OBDs are now installed in all BS-IV passenger cars and all diesel vehicles manufactured post April 2013. He was also of the opinion that OBD technology requires a lot of research and development in India before it can be used for PUC testing purpose.

In the next technical session, Mr Bhanot, former ARAI Director, made a presentation about the development made in India in the field of I&M of vehicles. He said that I/M system has a more broader objective of inspecting vehicles for roadworthiness which includes testing for wipers, brakes and so on to ensure road safety. He also briefed the audience about the new I&M centres in Nasik, Rohtak, Jhuljhuli, Bengaluru, Lucknow, Railmagra, Chhindwara, Hyderabad and Silchar. Mr Jai Kishan Malik, from TERI, summarized the policy technological recommendations as made in the policy brief. He explained the three types of PUC testing centres – traditional testing centres, OBD testing centres and accredited testing centres. Dr Arindam Datta presented the findings from PUC data analysis of Bengaluru and

Mysore. It was seen that three-wheeler LPG vehicles had the highest failure rate amongst all vehicles. Ms Amber Luong, from OKAPI, talked about the institutional bottlenecks in the I/M system. She suggested that a proper co-ordination between the central government, state government, regional transport authorities and police departments is the key to an effective I/M system.

In the end, Mr Sundar concluded the workshop by stating that there is also an urgent need to initiate awareness campaigns as vehicle owners are undeniably one of the major stakeholders in the performance of vehicles on-road.

Photo. The workshop organized in Delhi

Annexure: 2 - Workshop in Bengaluru

Title of the workshop: Improving Inspection and Maintenance System in India

Date: November 18, 2016

Venue: Iris Hotel**,** Brigade Road, Bengaluru

The objective of the workshop was to initiate a discussion on the current I&M system for in-use vehicles in India and its limitations; and to contemplate on the possible solutions to improve I&M system in India. The workshop had a representation from the government, industry, research institutes and regulatory authorities.

The speakers of the inaugural session were—Mr P Dasgupta, Director, TERI-SRC; Mr Naveen Soni, Vice President, Toyota Kirloskar Motor; DrRehmanHafeez, Director, TERI-EU; MrBalrajBhanot, former director, ARAI, Pune; Technical Officer, CPCB. Additionally, DrArindamDatta, TERI, Jai Kishan Malik, TERI, Ms Amber Luong, OKAPI, Dr T V Ramchandran, Professor,IISC and Mr V Ravichandra, Feedback Consultation were a part of the technical discussion.

The workshop started with discussion of air quality problem in Bengaluru and the role of transport sector. The steps taken by the government to understand the problem like the source apportionment study conducted in Bengaluru were also discussed. It was pointed out that the implementation of I&M policies was a challenge in Bengaluru. TERI and OKAPI presented their study on the I&M system in India. In technical session it was discussed that Bengaluru has urbanized dramatically in the last two decades with minimal planning. This seems to be a root cause behind the problems of congestion and air pollution.

Photo. The workshop in Bengaluru