Establishing a National In-use Vehicle Testing Programme in India

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1. Introduction

India has observed an unprecedented growth of registered vehicles, more specifically in the last decade. A large fleet of vehicles has not only led to problems of traffic management and congestion, but has also contributed to the deterioration of air quality. According to the Central Pollution Control Board (CPCB), vehicular emissions continue to be one of the major sources of urban air pollution in Indian cities, accounting for up to 22% PM and 74% of NO_X emissions in Delhi and 16% PM and 60% NO_X in Mumbai.[1] CPCB (2011) also stated high share of road transport in prevailing PM2.5 and NOx concentrations in different cities. While, there has been some improvement in regulating the emissions from new vehicles, there is still a lot to be done to maintain the compliance throughout their useful life[2]. Older in-use vehicles often account for a major share of the current emission inventory of transport sector in India. CPCB attributed about 60% of vehicular air pollution in India to vehicles which are older than 10 years, though this sub-set is lesser than 30% of the total vehicular pool[1]. Another study by Pundir,2001 also attributes about 60% of vehicular pollution in India to about 20% of poorly maintained vehicles on the road.[3] Furthermore, as vehicles age, their emission control devices deteriorate. This can lead to a situation in which vehicles emit more than they were designed to. Therefore, comprehensive in-use testing and compliance programmes are necessary to ensure that this does not happen.

1.1 Need for in-use vehicles management

It has been reported in various studies that on-road vehicles emit much higher levels of pollutants during their lifecycle as compared to the limits set during their certification stage. This might be attributed to deterioration due to wear and tear, lack of proper maintenance, engine faults or misuse at the hands of the driver, amongst other causes.[4] This calls for robust emission control policies for in-use vehicles to bring about a significant reduction in the overall emissions. And, with air pollution continuing to be a serious health concern in all major cities of India, it is imperative to curb harmful emissions from the vehicles on road and ensure that they are not

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[1] CPCB, 2010, *Status of the Vehicular Pollution Control Program in India*, PROBES/136/2010. Central Pollution Control Board (CPCB), Ministry of Environment and Forests (MoEF)

[2] CPCB, 2011, Source Apportionment Study for six cities, Central Pollution Control Board, New Delhi

[3] B P Pundir, 2001, "Vehicular Air Pollution in India: Recent Control Measures and Related Issues", in *India Infrastructure Report 2001*. Delhi: Oxford University Press.

[4] H Jääskeläinen, 2007, "Emission Effect of Engine Faults and Service", DieselNet Technology Guide, Available at http://www.dieselnet.com/tech/emi_fault.php (accessed on 9 September 2013).

emitting more than the stipulated norms. Policies targeting in-use vehicles are acclaimed to bring about an immediate impact as compared to other policies focusing on fuel quality improvements and vehicle-emission standards, which are meant to curb emissions over time.[5]

Despite stringent emission norms at the vehicle certification stage, diesel vehicles have shown higher PM, CO, and HC emissions, particularly before the advent of strategies such as diesel particulate filters (DPF), exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and lean NOx traps (LNT) even in the US.[6]

In India, as in other countries, new vehicles have to meet emission standards and set deterioration rates at the manufacturing stage. New vehicles are tested during the type approval procedure — i.e., type approval of a vehicle model with regard to the limitation of tailpipe emissions. This involves durability testing of anti-pollution devices as well.[7] Deterioration rates apply for the useful life of these vehicles, and allow for a slight deterioration in vehicle emissions with use.[8] Still, vehicles are expected not to emit more than they are designed to over a set durability period (Table 1), taking into account their original emission norms and deterioration rates.

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[5] ICCT, 2013, Policy Summary: India's Vehicle Emissions Control Program. The International Council on Clean Transportation, Available at http://theicct.org/sites/default/files/publications/ICCT_Briefing_IndiaPolicySummary_20130703.pdf

[6] R Maxwell and H He, 2012, In-use Testing for CO_2 and Fuel Economy in the United States, Working paper 2012-1, The International Council on Clean Transportation, Available at http://www.theicct.org/sites/default/files/publications/ICCT_InUse_working_paper_2012_Eng.pdf (accessed on 12 October 2013).

[7] MoRTH, *Standards for Petrol and Diesel Engine Vehicles*, MoRTH/CMVR/ TAP-115/116, Vol. II, No. 4.

[8] Central Motor Vehicles (First Amendment) Rules, 2012.

Table 1: Durability limits for different vehicle categories applicable during ageing test

Vehicle category	Durability (km)
Two- and three-wheelers	30,000
LDVs	80,000
N1 w/GVW* ≤ 3,500 kg	100,000
N2 w/GVW <12,000 kg	125,000
N3 w/GVW < 16,000kg	125,000
N3 w/GVW > 16,000kg	167,000
M2 w/GVW < 5,000kg	100,000
M3 w/GVW 5,000–7,500kg	125,000
M3 w/GVW > 7,500kg	167,000

Source: Ministry of Shipping, Road Transport and Highways, *Central Motor Vehicles (Amendment) Rules, 2008*, G.S.R. 522 (E), Part II, Section 3(i).

Notes: *GVW: Gross vehicular weight
Vehicle categories[9]**:**
N1: Means a vehicle used for carriage of goods and having a GVW not exceeding 3.5 ton
N2: A vehicle used for the carriage of goods and having a GVW exceeding 3.5 ton but not exceeding 12 ton
N3: Means a vehicle used for the carriage of goods and having a GVW exceeding 12 ton
M2: A vehicle used for carriage of passengers, comprising nine or more seats in addition to the driver's seat, and having a maximum GVW not exceeding 5 ton
M3: A vehicle used for the carriage of passengers, comprising nine or more seats in addition to the driver's seat and having a GVW exceeding 5 ton

Currently, there is no effective mechanism in India to ensure that vehicles comply with their original mass emission standards during the working life of catalytic convertors wherever fitted and also during the working life of other types of vehicles which are not fitted with catalytic convertors if maintained properly. CMVR/TAP-115/116 Document lays down the procedure for carrying out ageing tests for verifying the durability of tail-pipe emission reduction devices of vehicles. However, these tests are not carried out on a routine basis and are carried out only on requests. In India, most of the automobile manufacturing companies comply with the emission norms with taking into account the the prescribed deterioration factors (DF) i.e. if the DF is 0.2, then the manufacturers tune their engines to emit 0.2 times lesser than the prescribed norm. There are hardly any manufacturers who go for ageing/durability test of catalytic convertor

[9] BIS, 2011, Automotive vehicles-types and terminology, First Revision, Industry Standards (IS 14272 : 2011). Bureau of Indian Standards [online]. Available at https://law.resource.org/pub/in/bis/S13/is.14272.2011.pdf (accessed on 18 December 2013).

carried out on a chassis dynamometer. For in service vehicles, instead of the loaded mode tests, stationary mode idling tests have been prescribed which do not reflect the real world situation. As a result there is no mechanism in force to check the actual functioning of catalytic convertors and therefore one has no data on how many of them fail. Consequently, there is also no mechanism to recall vehicles based on the extent of failure in the field.

Presently, the only in-use vehicle testing conducted is the Pollution Under Control (PUC) programme, which is based on idle test emission limits without any loaded mode tests. These idle mode tests do not reflect the real life situation of a vehicle running on the road. The idle mode test does not reflect the real world conditions and hence there is a possibility of higher emissions. .[10] To enforce the PUC regulations, a number of fuel-filling stations and some garages — known as PUC check centres — have been authorized to carry out these checks and the vehicles have to get the PUC check done periodically.

If the vehicles are not maintained regularly, the results of mass emission tests cannot be compared with the norms. Even in a brand new vehicle, emissions will significantly increase within a short span, if they are not maintained regularly. Therefore, there is a need to introduce loaded mode tests at given periodicities. In-use vehicle inspection and maintenance can help not only in reducing the emissions significantly from on-road vehicles, but can address other mutually reinforcing objectives as well. These include:

- Improved fuel efficiency: Improvement in kilometre run per litre of fuel
- Improved safety: Better road worthiness of vehicles

Due to ineffective implementation and infrastructural constraints, the current system is lacking in effectively controlling emissions from in-use vehicles. Despite a provision of heavy penalties, merely 21% of vehicles appear for PUC testing in Delhi. Moreover, the current system is not fool-proof and allows pass-through without proper testing. Considering, these bottlenecks, this paper analyses the present scenario of in-use vehicle testing in India, international best practices, and key recommendations for an effective inspection and maintenance system in India.

1.1.1 Age profile of on-road vehicles in India

CPCB of India reported in the year 2010, that almost 50% of two-wheeler and car populations on Indian roads were less than 5 years old, whereas about 7–11% were older than 15 years.

[10] EU, 2004, Assessment of the Effectiveness of European Air Quality Policies and Measures, Case Study 3: Comparison of the EU and US Experiences with Respect to Controlling Emissions from High Emitting Vehicles, Available at http://ec.europa.eu/environment/archives/cafe/activities/pdf/case_study3.pdf

Table 2: Age-profile of on-road vehicles in India[1]

Vehicle Type	Population (in millions)	In percentage (%)					
		< 5 yrs	6–10 yrs	11–15 yrs	16–20 yrs	20–25 yrs	> 25 yrs
2-wheelers	52	49	27	14	8	2	0.3
Cars	7	50	30	13	6	1	0.2
LCV	2	37	22	27	11	3	0.8

The Energy and Resources Institute (TERI) also conducted questionnaire-based random parking lot surveys for different categories of vehicles across six cities in India, namely: Patna, Lucknow, Ahmedabad, Kolkata, Hyderabad, and Solapur to ascertain the average age distribution of on-road vehicles in the year 2012 in these six cities. The survey revealed that Kolkata has an older fleet as compared to the rest of the cities in terms of commercial vehicles (bus, trucks, and three-wheelers), while cities such as Hyderabad and Ahmedabad have a relatively newer vehicular fleet.

1.2 Pre-production certification of vehicles in India

Prior to elaborating the policies on in-use vehicle in India, it is essential to understand the pre-production certification requirements for the vehicle manufacturers to produce a certain model of vehicle. Principal instruments in governing motor vehicles in India are the Motor Vehicle Act, 1988 and the Central Motor Vehicle Rules (CMVR), 1989.

1.2.1 Type Approval

According to the Central Motor Vehicle Rules (CMVR), all vehicle models have to acquire Type Approval with regard to the limitation of the emission of pollutants from the tailpipe, effective since April 1991. The application for Type Approval of a vehicle model with regard to limitation of the emission of gaseous pollutants from its engine needs to be submitted by the vehicle manufacturers with a description of the engine and vehicle model. Every motor vehicle manufacturer, except trailers and semi-trailers, has to also submit a prototype of the vehicle to be manufactured for testing to a test agency — under Rule 126 of Central Motor Vehicles Rules 1989 — prior to acquiring a Type Approval certificate.[11]

1.2.2 Conformity of Production

Conformity to the production clause ensures that every produced vehicle of a particular model conforms to the Type Approval norms.[11] Conformity of production testing is conducted by specified test agencies which randomly select a vehicle engine at specific periods from the factory. This selection of vehicle engines is not truly random, since the agency needs to intimate the schedule (month) for sampling/testing to the engine supplier.[12] Emission tests — mass emission and tailpipe emission — prescribed in the manual are carried out on this vehicle engine under the supervision of the test agency. If a given vehicle/engine fails the COP testing repeatedly even after corrective measures have been taken by the manufacturer, the Ministry of Road Transport and Highways (MoRTH) can withdraw the type approval certificate of the vehicles/engine.[13] Additionally, the government also has the legal authority to take further action against the manufacturer, and even order a recall. The legal procedures required to enable MoRTH to either issue mandatory recalls or levy fines on manufacturers have not been established in India though COP provisions provide for extended trials and recall in the case of repeated failures.[14]

1.2.3 Deterioration rates for emission standards for new vehicles in India

The CMVR has notified Deterioration Factors (DF) for gasoline- and diesel-driven vehicles for all BS-II onwards vehicles (Table 3).

Table 3: Deterioration factors for different vehicles in India

Vehicle category	Pollutants	TA* and COP** norms (g/km)	Deterioration Factor
Two-wheelers (Gasoline)	CO	1.0	1.2
	HC + NOx	1.0	1.2
Three-wheelers	CO	1.25	1.2

[11] 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, MoRTH/CMVR/TAP-115/116, No. 4, 2010.

[12] ARAI, Certification, Conformity of Production (COP). Automotive Research Agency of India, Available at https://www.araiindia.com/services_certification_COP.asp

[13] MoRTH/CMVR/TAP-115/116, Administrative Procedure, Part VI, No. 4.

[14] ICCT, 2013, Vehicle Emissions Compliance for Light-duty Vehicles in India, Working paper 2013-4. The International Council on Clean Transportation, Available at http://www.theicct.org/sites/default/files/publications/ICCT_COP_India_20130820.pdf

(Gasoline)	HC + NOx	1.25	1.2
Two-wheelers and Three-wheelers (Diesel)	CO	0.50	1.1
	HC + NOx	0.50	1.0
	PM	0.05	1.2

Notes: *TA: Type approval

** COP: Conformity of production

These DFs are applied to the new vehicles when they undergo durability tests (Table 1) under Type Approval and conformity of production by the specified test agencies.

1.3 Inspection and maintenance programme in India

Currently in India, the inspection and maintenance (I&M) programme consists of periodic PUC certifications for all types of vehicles and annual fitness certifications for commercial vehicles. Private vehicles need to undergo fitness tests and re-registration after 15 years from the date of the first registration. We recommend that the law should be amended and all private vehicles should be required to undergo fitness tests at given periodicities. These vehicles should be tested at computerised inspection and certification centres with facilities of carrying out loaded mode tests. Also, all in-use vehicles are mandated to undergo PUC checks which are issued based on conformity to the Idle Emission Test for gasoline vehicles and Free Acceleration Smoke Test for diesel vehicles. The current I&M system of India is presented in Figure 1.

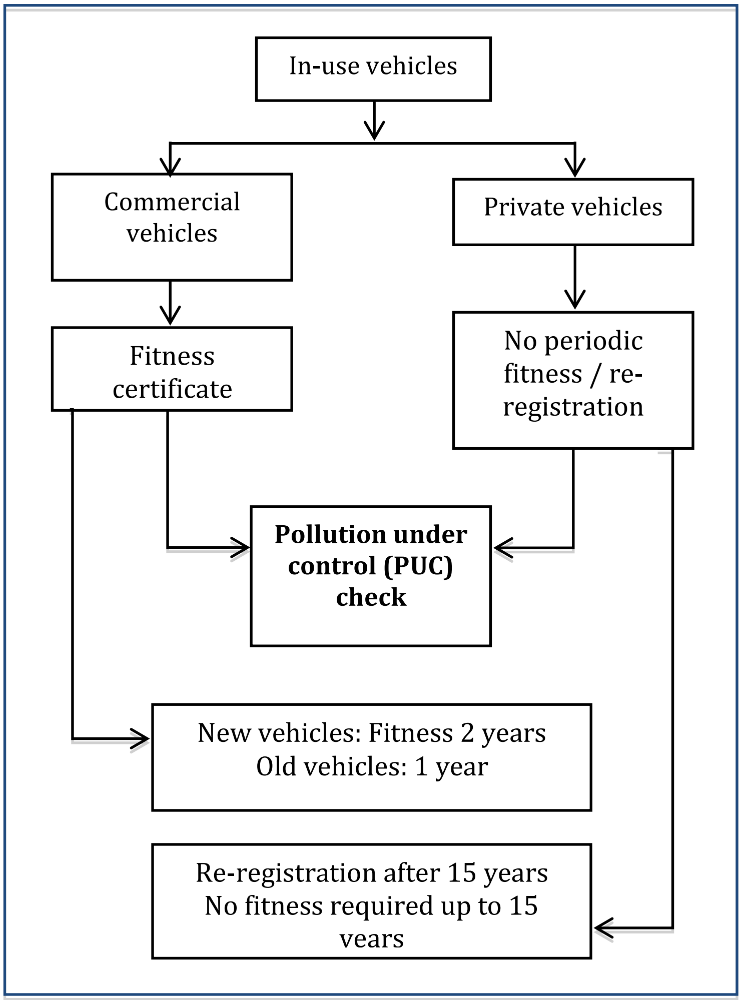

Figure 1: Existing inspection and maintenance system in India

Source: Central Pollution Control Board (CPCB), *Inspection and Maintenance Practice in India*, Parivesh, ENVIS Centre. Available at http://cpcbenvis.nic.in/newsletter/inspection/ch60503.htm (accessed 12 September 2013).

1.3.1 Structure of current Indian PUC programme

Periodic pollution under control checks are mandatory for all vehicles plying in India. The frequency of mandatory PUC checks varies from one to four times a year, depending on a state government's policies. According to the Central Motor Rules 1989, every motor vehicle is mandated to carry valid PUC certificate after one year from the date of first registration.[15] The existing norms for PUC certification, issued by Ministry of Road Transport & Highways, are based on the Idling Emission Standards for CO and HC in case of petrol vehicle and smoke density for

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[15] Transport Department, Government of NCT of Delhi. Available on http://www.delhi.gov.in/wps/wcm/connect/doit_transport/Transport/Home/Pollution+Control/P.U.C.+Certificate

diesel vehicles and dimensionless value representing burning efficiency of engine in terms of the air/fuel ratio in the exhaust gases (LAMBDA Test). The standards for in-use vehicles in India were prescribed under Rule 115 (2) of Central Motor Vehicles Rules 1989, under the Motor Vehicles Act 1988.

Revised PUC norms for in-use vehicles were notified by Ministry of Road Transport and Highway, which were implemented across the country from 1st October 2004 (Tables 4, 5, and 6).

Table 4: PUC norms for in-use petrol/CNG/LPG driven vehicles

Vehicle Type	CO (%)	*HC (ppm)
Two- and three-wheelers (2/4 stroke) (vehicles manufactured before 31/3/2000)	4.5	9,000
Two- and three-wheelers (2- stroke) (vehicles manufactured after 31/3/2000)	3.5	6,000
Two- and three-wheelers (4 stroke) (vehicles manufactured after 31/3/2000)	3.5	4,500
Bharat Stage-II compliant four-wheelers	0.5	750
Four wheelers other than Bharat Stage-II compliant	3.0	1,500

Source: ARAI[16]

* For CNG & LPG vehicles the measured Hydrocarbon value shall be converted using the following formula and then compared with the limits
· For CNG Vehicles- Non Methane Hydrocarbon, NMHC = 0.3 X HC
· For LPG Vehicles- Reactive Hydrocarbon, RHC = 0.5 X HC

Table 5: PUC norms for in use CNG/LPG/petrol driven four-wheeler manufactured as per BS-IV norms

S. No.	Vehicle type	Idle emission limits		High idle emission limits	
		CO (%)	HC (n-hexane equivalent) ppm	CO (%)	LAMBDA (RPM-2500±200)
1.	CNG/LPG driven four-wheelers as per BS-IV norms	0.3	200	-	-
2.	Petrol-driven four-wheelers as	0.3	200	0.2	1/±0.03 or as

[16] Amendment No. 1 to Doc. No.: MoRTH/CMVR/ TAP-115/116: Issue No.: 4 , URL : https://www.araiindia.com/CMVR_TAP_Documents/Amendment%201%20to%20Tap%20Issue%204_1.pdf

	per BS-IV norms				declared by vehicle manufacturer

Source : ARAI[16]

Table 6: PUC norms for in-use diesel-driven vehicles

Method of test	Vehicle type	Maximum smoke density	
		Light absorption co-efficient (1/metre)	Hartridge unit
Free Acceleration Test - for Turbo-charged engine and naturally aspirated engine method of test	Pre BS-IV	2.45	65
	BS-IV and above	1.62	50

Source : ARAI[16]

In some countries, there are mechanism where general public assists the authorities in identifying highly polluting vehicles by way of SMS, telephone, internet etc. Authorities in turn incentivise such schemes. Such vehicles have to undergo loaded mode tests for further investigations like IM240 tests in US. Some countries like Singapore have adopted stringent smoke opacity test for diesel-driven vehicles; i.e. 40 HSU,as compared to India's 50 and 65 HSU.

Beijing has also moved from Idle Testing to Accelerated Simulation Model (ASM) tests for in-use vehicles I&M in the year 2003.[17] These tests are closer to real-world conditions than idle tests. In-use vehicles are mandated to get their I&M done annually, and those which fail these tests need to reappear after repairing their vehicles. These tests are similar to I&M tests employed by some states of the US such as Texas.

If we compare the Indian standards for Idle Emission Tests (PUC norms) with other countries which also have similar testing system, it is found that CO norms are comparable to other countries; however, HC norms are quite relaxed. For example, in Thailand (gasoline-driven four-wheelers registered post 2007) and the Philippines (gasoline-driven four-wheelers post 2000), the HC norm is 100 ppm (Table 7) while in India for vehicles compliant with BS-II or higher, the HC standard is 750 ppm at idling conditions.

Table 7: PUC standards for in-use vehicles in other countries

[17] J Hao, J Hu, and L Fu. "Progress of Beijing in Control of Vehicular Emissions: Clean Air Initiative, 2004. Available at http://cleanairinitiative.org/portal/system/files/59283_hao_fullpaper.doc (accessed on 22 October 2013).

Country	Type of vehicle	CO	HC	Type of test
Thailand[18]	**Gasoline Vehicles (four-wheelers)** - Registered before 1 November 1993 - Registered since 1 November 1993 - Registered since 1 January 2007	4.5% 1.5% 0.5%	600 ppm 200 ppm 100 ppm	- Measured while parking the car at idle and no load - Equipment: Non-Dispersive Infrared Detection
Philippines[19]	**Gasoline Vehicles (four-wheelers)** Before 31 December 1996 After 1 January 1997 After 1 January 2000	4.5% 3.5% 0.5%	800 ppm 600 ppm 100 ppm	- Measured at low idle speed
Ontario[20]	**Gasoline-fuelled light vehicles (Gross vehicle weight up to 3855 kg)** 1998 and later 1988–97	0.7% 1%	150 ppm 200 ppm	- Two speed idle test
Europe [21]	**Gasoline vehicles** Registered after 1986 (without 3-way catalytic converter) Vehicles with 3-way catalytic converter - at engine idling speed - at high idle speed, 2000 rpm LAMBDA	3.5% 0.5% 0.3% 1 +/- 0,03		- At engine idling and high idle speed

[18] Pollution Control Department, Ministry of Natural Resources and Environment, Thailand
[19] URL: http://www.emb.gov.ph/laws/air%20quality%20management/dao98-46.pdf
[20] URL: http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_080001.pdf
[21] URL: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0055:en:NOT

Chongquing, People's Republic of China[22]	**Gasoline vehicles (four-wheelers)** Light duty vehicles (GVW≤3500kg) made after 1 July 1995 Heavy duty vehicles (GVW>3500kg) made after 1 July 1995 **Motorcycles made after 1.1.96**	 4.5% 4.5% 4.5%	 900 ppm 1200 ppm 2200 ppm	- Measurement method idle speed (GB/T3845)
Sri Lanka[23]	**Gasoline vehicles** Without catalytic converter - vehicles more than 5 years old from the year of manufacture - vehicles less than 5 years old from the year of manufacture With catalytic converter	 4.5% 3.5% 2.0%	 1200 ppm 1200 ppm 400 ppm	- Low idling

A USAID report on international experience and best practices of vehicle inspection and maintenance programmes mentions that policy-makers often set I&M standards by selecting "round numbers" that are not reasonable measures of whether a vehicle is a gross emitter or not.[24]

1.3.2 Failings of the existing PUC check system

Current PUC norms are based on idling emissions which is a very crude method of testing, and most often do not capture all of the high emitters. Not only this, the current PUC norms in India are weak and the quality as well as integrity of these pollution-checks remains doubtful.[25] A survey done in the year 1999 by the CPCB along with the State Transport Department audited about 20 vehicular pollution checking centres across the Delhi pertaining to their operation,

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[22] URL: http://www.unep.org/transport/pcfv/pdf/dataapchina.pdf
[23] URL: http://www.un.org/esa/gite/iandm/jayaweerapaper.pdf
[24] USAID, 2004, "Vehicle Inspection and Maintenance Programs: International Experience and Best Practices", URL: http://cleanairinitiative.org/portal/sites/default/files/articles-59065_paper.pdf (accessed on 10 August 2013).
[25] V Kathuria, 2001, Vehicular Pollution control in Delhi, India: Are the Efforts Enough?, International Institute of Ecological Economics. Available on http://www.beijer.kva.se/PDF/31729194_Disc144.pdf

maintenance, and calibration of instruments. The survey concluded that at some centres, operators were not fully knowledgeable about the operation of the instruments. It was observed at many places that the analyser instruments were exposed to dirt and heat, leaving the sampling probe dirty and choked, which affected the performance of the instruments (CPCB, 1999[26]). At many places, even calibration was not performed.

There is therefore a need for a system of carrying out surprise third party audits of the PUC centres and the technicians carrying out the tests at a regular intervals.

In another review conducted by Environmental Pollution Prevention and Control Authority (EPCA) in the year 2006, third party auditing of PUC centres in Delhi was carried out and accordingly a team was constituted with representations from the Automotive Research Association of India (ARAI), Centre for Science and Environment (CSE), Transport Department of Delhi, and Society for Indian Automobile Manufacturers (SIAM). The mandate of the audit team was to organize surprise visits to the PUC centres in different parts of Delhi and check validity of their licenses, codes of practice, integrity of the testing operations, adequacy of the facilities in the centres, and accordingly suggest improvements. This first-ever third party audit was conducted in 20 PUC centres during June 2006 and in PUC centres spread across all zones in Delhi. The report on this auditing exercise revealed that malpractices and fraudulent practices were still quite rampant in some PUC centres.[27] Some of the major lapses noted in this audit report are listed below:

- Many of the operators were not aware of important aspects of measurement protocol including the need for vehicle preparation before test, correct insertion of sampling probe, proper use of extension pipes, proper mounting of sensors, instrument preparation, etc.
- Standard accessories such as extension pipes were unavailable in a number of PUC centres.
- The sensors for checking the RPM of diesel vehicles in some of the centres was found to be working unsatisfactorily.

[26] CPCB, 1999, Parivesh, Highlights 1999, Central Pollution Control Board, New Delhi

[27] EPCA, 2006, A progress report on audit of PUC centres and networking of PUC centres in Delhi, Report no. 23. In the matter of W.P.(C) No.13029 of 1985; *M C Mehta v/s UOI & Others*. Available on http://www.cpcb.nic.in/divisionsofheadoffice/pci3/epca-report-23.pdf

The Smoke Opacity Test, which is employed to identify high emitting diesel vehicles, has been shown to have inherent problems, even if it is properly administered. The key shortcoming of the Snap Acceleration Smoke Test Method is that it is not an accurate representative of normal driving or operating conditions. In a way, it enables high smoke emitters to pass which if tested using a dynamometer on loaded mode is likely to fail.[28] The briefing note on South Asia urban air quality, (ESMAP[28]) further elaborates that no matter how well a smoke test procedure is carried out, it cannot be indicative of anything other than visible smoke. The key question is whether visible smoke or high smoke opacity can act as a reliable proxy for particulate matter, the pollutant with the most pernicious health effects. McCormick et al.2003 [29] points out that a number of vehicles with relatively high PM emissions actually exhibit low smoke opacity, emphasizing the fact that smoke opacity measurements may not be able to identify all high emitters. A possible reason for this could be emission of white smoke, which is nothing but unburned fuel.

Taking into account limitations in the existing in-use vehicle emission control system, the 2003 Auto Fuel Policy of India made a number of recommendations and plans for reduction of pollution from in-use vehicles.[30] As per the 2003 Auto Fuel Policy road map, it was suggested that an I&M system for all categories of vehicles be put in place by mid of 2010 to reduce pollution from in-use vehicles. However this has not been implemented yet. Though the *Auto Fuel Policy Report* claims that the Indian government has tried to focus on improving existing PUC system in order to make it more reliable and fool proof, however there seems to be no visible results from such initiatives.

[28] UNDP and World Bank Energy Sector Management Assistance Program (ESMAP), 2002, "Tackling Diesel Emissions from In-use Vehicles", South Asia Urban Air Quality Management Briefing Note No. 10.

[29] R L McCormick, M S Graboski, T L Alleman, J R Alvarez, and K G Duleep, 2003. "Quantifying the Emission Benefits of Opacity Testing and Repair of Heavy-duty Diesel Vehicles", *Environmental Science and Technology* Vol. 37, No. 3, pp. 630–37.

[30] MoPNG, 2003, "National Auto Fuel Policy Announced" Press release, Ministry of Petroleum and Natural Gas, Available at http://pib.nic.in/archieve/lreleng/lyr2003/roct2003/06102003/r0610200313.html (accessed 27 August 2013).

1.3.3 Detailed analysis of PUC data: Delhi

In order to bring more transparency in the PUC system, some of the state transport departments decided to make the entire system computerized. The computerised PUC test data was collected for the two metropolitan Indian cities — Delhi and Bangalore. A detailed analysis of this data for the one year (August 2012 – July 2013) for vehicles appearing in Delhi for the PUC check revealed that out of the total registered vehicles in Delhi, only 21% of vehicles appeared for PUC testing during this period.

Out of the total vehicles tested during this duration, it was observed that in case of four-wheelers (petrol/CNG/LPG) and buses (CNG), the failure rate of pre-BS-II vehicles was marginally higher than that of BS-II and above vehicles. This may be owing to the fact that older vehicles are more polluting hence fail the PUC tests more often. On the other hand, the failure rates of two- and three-wheelers registered prior to 2000 were lower as compared to those registered post 2000 (both 2 stroke and 4 stroke). This could be attributed to the fact that the norms for post 2000 vehicles are stricter, consequently the failure rates are coming out to be higher than the pre-2000 vehicles.

For diesel cars, the failure rates amongst vehicles appearing for PUC checks during this period were found to be higher in the pre-BS-IV category compared to BS-IV cars. However, in the rest of the vehicle categories, i.e., buses, trucks, and diesel vans, the vehicles belonging to pre-BS-IV category showed lower failure rates than the BS-IV vehicles. As pointed out earlier, this could be owing to the fact that BS-IV vehicles have to meet to a more stringent set of norms as compared to pre-BS-IV norms leading to a higher failure rate in these vehicles.

Analysis of 3500 failed petrol vehicles (out of 2.5 lakhs that came for testing in the August, 2013) revealed that the violations in the CO norms were significantly higher than the violations in HC norms. Almost 94% and 96% of the failing two-, three-, and four-wheelers violated the CO norms, respectively, in the analysed data, whereas, only 9% and 13% of two-, three-, and four-wheelers violated the HC norms, respectively. This again indicates the relaxed HC norms.

Analysis also shows that 10% of the vehicles failing PUC tests exceed the CO standard by almost four times. Except for a few outlier values, most of the two- and three-wheelers (failing PUC tests) violate the CO standards by 1–6 times, whereas the violation is found to be more in the case of cars which violate the CO standards by 1–10 times. LAMBDA is a dimensionless value representing burning efficiency of engine in terms of the air–fuel ratio in the exhaust gases. The permitted standard of LAMBDA value for petrol-driven four-wheelers is 1±0.3. Hence, a lower value of LAMBDA, i.e., below 1 implies a fuel mix which is rich — higher fuel concentration and lesser air. LAMBDA values below 1 and exceedence of CO values from the standard show a significant correlation (R^2=0.49), pointing to the fact that a richer fuel mixture indicates higher chances of CO emissions exceeding the given standard owing to incomplete combustion of the fuel in the engine. The correlation between LAMBDA values (less or greater than 1) and CO concentrations also showed a significant correlation (R^2=0.56), further reiterating the relationship between a rich fuel mixture and higher CO concentrations in the tailpipe emissions of the vehicles.

Analysis of the complete data set revealed that older vehicles emit a higher concentration of CO as compared to the newer vehicles. The 95th percentile values of CO concentrations observed in the newer two- and four-wheelers are much lower than the older ones implying that almost 95% of the newer vehicles emit lesser CO than older vehicles.

A one-month sample data of PUC tests of diesel-driven vehicles was also analysed to understand the failure rates and exceedence from the prescribed limits. It can be concluded that across different categories of diesel vehicles, the failures rates vary between 2–5%. Further analysis of this data again points out to the fact that a majority of the older diesel vehicles emit higher concentrations of pollutants as compared to their newer counterparts.

(Refer to Annexure-I for detailed graphs on this section)

1.3.4 Emission reduction potential of an effective I&M system in India

Effective inspection and maintenance in many countries have led to improvement in the prevailing air quality and reduction in transport related emissions. Table 8 depicts the reported percentage reduction of pollutants due to implementation of inspection and maintenance programmes in a few other countries.

Table 8: Percentage reductions in pollutants due to implementation of inspection and maintenance programme

Region	Vehicle category	Percentage reductions due to I&M implementation			
		CO	HC	NOx	PM
EU[*, #]	Petrol cars with 3-way, LAMBDA-controlled catalytic converters	17.5 to 35	12.5 to 25	2.5 to 5	
	Diesel vehicles	--	--	--	25
US[*]		13 to 74	14 to 68	6 to 40	--

Source: * Assessment of the Effectiveness of European Air Quality Policies and Measures, Case Study 3: Comparison of the EU and US Experiences with Respect to Controlling Emissions from High Emitting Vehicles; October 2004. Available at http://ec.europa.eu/environment/archives/cafe/activities/pdf/case_study3.pdf

Assessment of the Effectiveness of European Air Quality Policies and Measures, Final report on task 3.2: Case Studies Comparing the EU Experience with the Experience of USA and Other Countries; 2004. Available at http://ec.europa.eu/environment/archives/cafe/activities/pdf/task_3_2_general.pdf

A recent report on cost-effective green mobility estimates the emission reduction potential of various I&M-related actions in India as 13 to 18 million tons of CO_2-equivalent abatement; about a 0.5 million ton reduction of combined HC, NOx, and CO emissions; and 10,000 to 15,000 ton reduction of PM emissions.[31]

[31] *Confederation of Indian Industries and A T Kearney Report*, 2013, *Cost-effective Green Mobility*, Available at https://www.atkearney.com/documents/10192/1011378/Cost-Effective+Green+Mobility_FINAL.pdf/e452618b-2a19-4463-a196-8c4c4fe8ae24

Emission Reduction Potential of the I&M System

An estimate of possible CO emission reductions from two-wheelers and cars in Delhi is prepared. Percentage of failed vehicles and the extent of exceedence shown during the PUC tests have been assumed as the basis of increased emissions from the overall vehicular fleet of Delhi. Table A.1 shows that 0.9% of two-wheelers fail the PUC tests with an exceedence of an average of 39% to the prescribed standard. Similarly, 2.8% failed cars show 110% of exceedence. These numbers are applied to the overall fleet of Delhi and prescribed emission norms to arrive at increased emissions due to failed vehicles.

Increased emissions = Number of vehicle * Vehicle Kilometre Travelled (VKT) * Emission norm (EF) * (% increase in emissions)

Table A.1 CO Emission reduction potential from two wheelers and cars through an effective I&M system in Delhi

	A Percentage vehicles failed*	Estimated number of failed vehicles in Delhi (A x Registered vehicles**)	Percentage exceedence of failed vehicles (CO)*	Increased emissions (B) (Tonnes/d)	Overall emissions in Delhi (C) (Tonnes/d)#	Percentage reduction potential of I&M (B/D)
Two-wheelers	0.9%	*43467*	39%	1.2	81.56	2%
Cars	2.86%	*64671*	110%	10.5	47.92	22%

Notes: *Calculated from the PUC data obtained from the Delhi Transport Department

**Registered number of vehicles data obtained from *Road Transport Yearbook* (2010–11)

Estimated by TERI from primary surveys

The overall inventory of emissions from two-wheelers and cars in Delhi using the emission norms was estimated to be 129 tonnes per day. Hence, we assume that there can be a reduction of 11.7 tonnes from this total figure which would be a 9.1% reduction from the existing scenario, based on idle testing, in case a successful I&M system is put in place for private vehicles ensuring that all two-wheelers and cars comply with the set emission standards.

This estimation of emission reduction potential from successful implementation of I&M is highly understated since the failure rates used for the estimation are based on current PUC test results which measure idling emissions. Also, Idle Tests capture only a small amount of the high emitting vehicles. The actual reductions achieved by implementing I&M tests would be much larger if estimated based on a failure rates from loaded test mode, for which data is not available at the moment for India.

All PUC centres are supposed to carry out Lambda measurements, though each model has its own lambda limits prescribed by the manufacturers. There should be a database available from where these limits could be retrieved for testing of various models by the PUC centres.

2. National in-use vehicle testing and recall programme: The US

In the US, many problems were found with in-use vehicle emissions, despite vehicles being initially certified. When the Clean Air Act (CAA) was passed in 1970 in the US, the vehicle compliance programme only covered new vehicle certification. Eventually, with rising pollution from on-road vehicles, the programme evolved from one that focused mainly on ensuring new vehicles produced at the manufacturing end comply with standards, to the current programme that places equal, if not more, emphasis on in-use vehicle testing ensuring that vehicles comply with the set emissions standards over their entire useful lives.[32]

The in-use vehicle compliance programme (IVCP) of the US is acclaimed as one of the most comprehensive and well-implemented compliance programmes in the world. The United States Environmental Protection Agency's (USEPA's) in-use compliance activities doubles up as a feedback mechanism for the vehicle/engine certification process carried out at the manufacturing stage, hence encouraging best possible emission control technology design and durability. This also helps in ensuring engine's optimum performance throughout the vehicle's useful life.[33]

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[32] Maxwell, R., and He, H., 2012. In-use testing for CO2 and fuel economy in the United States. Working paper 2012-1, The International Council on Clean Transportation

[33] United States Environmental Protection Agency (USEPA), "Vehicle and Engine Compliance Activities", *Progress Report 2007*, October 2008. Available at http://epa.gov/otaq/about/420r08011.pdf (accessed 22 September 2013).

A feature which is quite unique to USEPA's in-use compliance programme is that instead of relying entirely on its own testing, USEPA puts the onus on vehicle manufacturers to periodically test and report the results, hence ensuring maximum coverage of the in-use compliance programme with minimal government expenditure. Though it started out initially as a programme managed mostly by EPA, it is now generally conducted by manufacturers.[34] The activities, of both EPA and the manufacturer, for vehicle certification and compliance program in the US, during its useful stage are presented in Figures 2 and 3

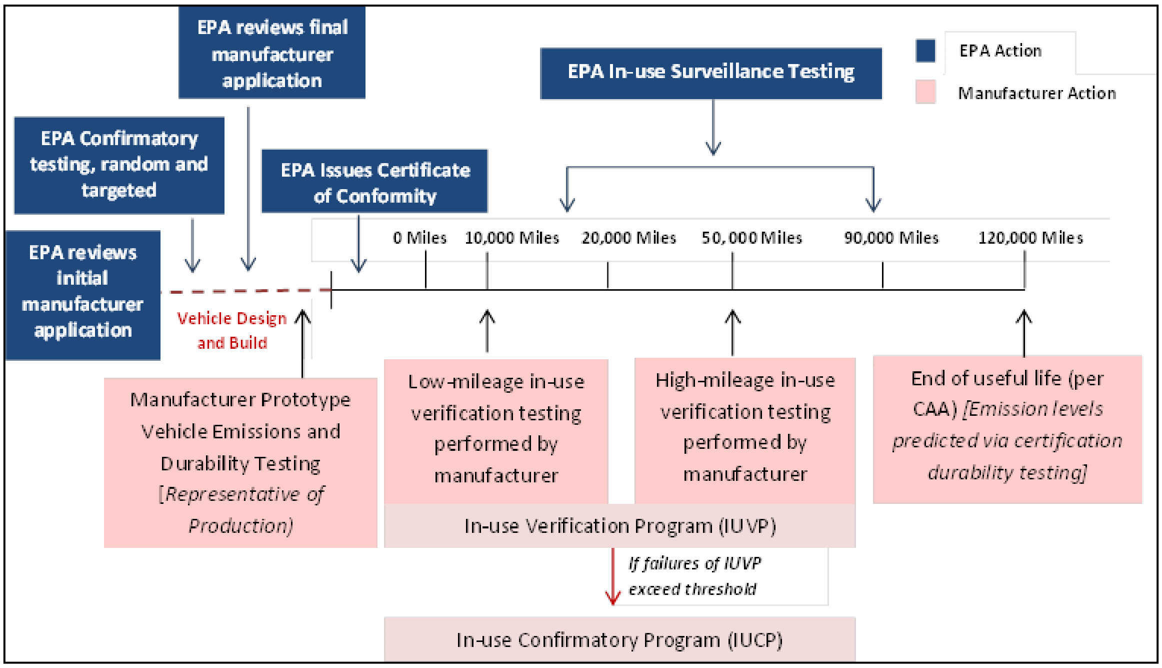

Figure 2: Compliance life of a light-duty vehicle in the US

Source: United States Environmental Protection Agency, 2007. "Vehicle and Engine Compliance Activities", *Progress Report*.

Manufacturers are mandated to monitor the compliance of the heavy-duty diesel engines by testing them during normal vehicle operation. Further investigation is required when non-compliance is witnessed so that adequate corrective measures may be undertaken eventually. Meanwhile, all the testing data is transferred to the EPA which makes independent evaluations

[34] G Bansal and A Bandivadekar, 2013, "Overview of India's Vehicle Emissions Control Program", Past Successes and Future Prospects", The International Council on Clean Transportation. Available at http://www.theicct.org/indias-vehicle-emissions-control-program (accessed 10 December 2013).

about the possible need for further actions.[35] This programme was formulated in order to enhance the manufacturer's capability to catch any impending engine problems early on, while at the same time encourage the designing of cleaner and more durable engine for the future.

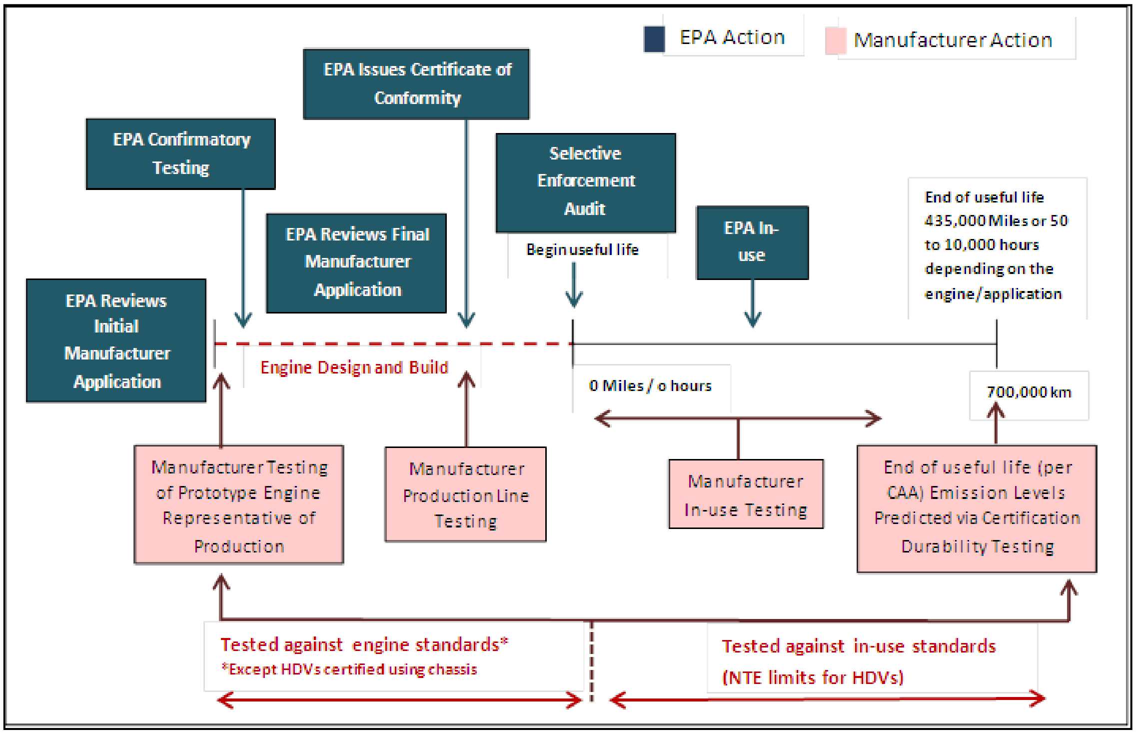

Figure 3: Compliance life of a heavy-duty highway and non-road engine in the US

Source: United States Environmental Protection Agency, 2007. "Vehicle and Engine Compliance Activities".

2.1 In-use Verification Program (IUVP)

In US, the primary screening of in-use vehicles is done through the in-use verification programme which is required both at low mileage (at least 10,000 miles) and high mileage (more than 50,000 miles) during the life of in-use vehicles. If 50% of the tested vehicles in a given test group fail, and the average emission levels are reported to be greater than 1.3 times the standard limits, the manufacturer is then mandated to conduct an In-Use Confirmatory Program (IUCP) test for that

[35] USEPA, "Regulatory Announcement", Final Rule on In-Use Testing Program for Heavy-Duty Diesel Engines and Vehicles, EPA420-F-05-021, 2005. Available on http://www.epa.gov/otaq/regs/hd-hwy/inuse/420f05021.pdf

particular test group.[36] All the IUVP test results are required to be submitted to the EPA by the manufacturers, according to set schedules. This data has so far proven to be highly helpful for the EPA to work in tandem with manufacturers to identify potential design issues for future as well as target vehicle groups that might need greater attention.

2.2 In-use Confirmatory Program

As per IUCP, vehicles are selected and tested in a more comprehensive manner. Any failure to pass these IUCP tests leads to implementation of remedies in order to rectify the excessive emissions or, in the worst case scenario, recall of the tested vehicle model.[37]

2.3 In-use Surveillance Testing

Apart from relying on the manufacturers, EPA also conducts a surveillance testing at its own facility. EPA conducts emissions testing on randomly procured in-use vehicles at the National Vehicle and Fuels Emission Laboratory in Ann Arbor, Michigan. The vehicles are screened for proper use and maintenance, and then tested for emissions compliance in the laboratory. If problems are found, discussions begin with the manufacturer on possible remedies, which may include a recall of the affected vehicles.

Generally, the EPA randomly picks up three to five vehicles, that are two or three years old, from each selected test class. These vehicles are selected for different reasons such as issues of past emissions performance or to gain deeper insights into any new technologies in the market. A test class as defined by the USEPA is a group of vehicles with very similar design characteristics from an emissions standpoint.[38] The EPA ensures that the selected vehicles have been properly maintained prior to testing.

2.4 Recall policy in the US

The US CAA authorizes the EPA "to require a manufacturer to recall vehicles or engine, at their own expense, if it is determined that a substantial number of vehicles or engines [properly

[36] USEPA, 2007, "Vehicle and Engine Compliance Activities". United States Environmental Protection Agency

[37] Maxwell, R., and He, H., 2012. In-use testing for CO2 and fuel economy in the United States. Working paper 2012-1, The International Council on Clean Transportation

[38] USEPA, 2007, "Vehicle and Engine Compliance Activities". United States Environmental Protection Agency

maintained and used] from that group do not meet the standards". This approach of linking the IUCP to a stringent recall policy ensures that manufacturers follow highest quality standards.

Vehicle manufacturers are required to design and build their vehicles to meet emission standards for the useful life of the vehicle specified by law. Under Section 207 of the CAA, if EPA determines that a substantial number of vehicles in a class or category do not meet emission standards in actual use even though they are properly maintained and used, the EPA can require the manufacturer to recall and fix the affected vehicles.[39]

Recalls or remedial actions in response to emissions related issues are normally taken as voluntary actions by the vehicle manufacturers. Though, EPA also has the authority to enforce recall on the manufacturers and ensure that they either recall the particular vehicle model or fix non-complying vehicles, the manufacturers are themselves mandated to report certain defects in the emission-related parts of the vehicle to the EPA from time to time. Recalls ordered by the EPA bring in bad publicity for the manufacturer and hamper the brand value amongst customers. As a result, manufacturers often initiate recalls at their end itself. Recalls might also be directly or indirectly influenced by the potential for EPA action.[40]

The USEPA's comprehensive in-use testing programme ensures that manufacturer's tread ever more cautiously over vehicle design and production stages to avoid expensive recalls. The recall programme had begun in the late 1970s and early 1980s; at that time, the EPA had recalled almost 30–40% of cars and light trucks produced each year while by the mid-2000s, this number had dwindled to a mere 5–10% of annually produced vehicles.[41]

3. Proposed national in-use vehicle testing in India

Taking cues from the in-use compliance programme in the US to address the shortcomings of the Indian system, a possible IVCP has been proposed in Sections 3.1-3.4.

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[39] USEPA, 2007, "Vehicle and Engine Compliance Activities". United States Environmental Protection Agency

[40] USEPA, "Cars and Light Trucks: Vehicle Recalls". Available at http://www.epa.gov/otaq/recall.htm (accessed 14 September 2013).

[41] G Bansal and A Bandivadekar, 2013, "Overview of India's Vehicle Emissions Control Program", Past Successes and Future Prospects", The International Council on Clean Transportation. Available at http://www.theicct.org/indias-vehicle-emissions-control-program (accessed 10 December 2013).

3.1 In-use Vehicle Compliance Programme (IVCP)

3.1.1 Phase-I

The proposed IVCP could be initially hosted with the Ministry of Road Transport and Highways (MoRTH) to begin with. The overarching goal of this programme would be to ensure that vehicles actually comply with their original emission standards (Type Approval standards) throughout their useful life. Currently, only I&M system is in place in India which primarily screens the vehicular fleet to pick out high emitters based on Idle Emission standards. There are no tests or screening done in India currently to check whether the vehicles are actually meeting their Type Approval standards throughout their useful life, provided the vehicle is maintained optimally.

The MoRTH 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 — low mileage and high mileage — can be recruited for in-use compliance testing. Low and high mileage testing is proposed in Table 9 mainly to test the vehicles at different stages of their life-cycle to ensure they are performing optimally throughout their useful lives. For this testing, vehicles of the given model with suitable accumulated mileage would need to be recruited directly from consumers — who can be given some incentive for enrolling their vehicles for testing. For recruitment, suitable vehicles will first need to be identified from the on-road fleet. The Regional Transport Office (RTO) database can play an important role for screening the on-road vehicles and pick out possible candidates.

Table 9: Low and high mileage based on the durability of each vehicle category

Vehicle category	Durability (km)	Low mileage in km (25% of total durability)	High mileage in km (95% of total durability))
Two/three-Wheelers	30,000	7,500	28500
LDVs	80,000	20,000	76000
N1 w/GVW* ≤ 3,500 kg	100,000	25,000	95000
N2 w/GVW <12,000 kg	125,000	31,250	118750
N3 w/GVW < 16,000 kg	125,000	31,250	118750
N3 w/GVW > 16,000 kg	167,000	41,750	158650
M2 w/GVW < 5,000 kg	100,000	25,000	95000
M3 w/GVW 5,000 to 7,500 kg	125,000	31,250	118750
M3 w/GVW > 7,500 kg	167,000	41,750	158650

Note: *GVW: Gross vehicular weight

Vehicles found to be emitting greater than their stipulated norms as per the Type Approval document, must go in for more comprehensive testing at the expense of the manufacturer since it is their responsibility that all the models manufactured by them meet their original standards throughout their useful lives, if maintained and operated optimally. 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. If those vehicles also are found to be failing the norms, the manufacturer should be given time to look into the possible cause and submit a detailed report to MoRTH. A panel/committee set up by MoRTH could look into the matter and decide on further actions deemed necessary, which may ultimately lead to recall.

Durability factors presently prescribed in TA norms are also questionable. India has adopted durability factors for mass emission testing of vehicles using catalytic convertors, based on practice existing in Europe/US. Indian situation is quite different because of maintenance practice, road conditions, driving habits and heterogeneous multi-mode traffic conditions. One is not aware if the same durability factors are applicable in our situation unless one has evaluated the functioning of such catalytic converters in field. There is therefore need to evaluate the functioning of catalytic converters of different model of vehicles based on the mileage covered by them. Mass emission testing has to be carried out after the durability mileage claimed by the manufacturer is exhausted. Necessary correction in the durability factor should be made based on the evaluation carried out.

There are examples of initiatives which can directly be taken based on existing knowledge. Public transport vehicles continuously ply on the roads and log a fixed mileage every day. Such vehicles should either replace the catalytic converter after the stated life of catalytic converter is finished or the vehicle should be scrapped after giving a reasonable margin i.e. 150,000 kms against stated life of 120,000 kms of cat. convertor.

3.1.2 Phase-II

Once the phase-I of the proposed IVCP is implemented successfully, the onus could be gradually shifted to the manufacturers who can then take over the responsibility of testing sample vehicles from in-use fleet within their own facility. This would be on a voluntary basis to avoid defaulting on the checks conducted by the MoRTH.

Meanwhile, MoRTH could continue to do random checks — on a smaller number of vehicles as compared to Phase-I of in-use surveillance — across different models and companies to catch any defaulters. This would greatly bring down the costs for MoRTH at the same time by ensuring that manufacturers are taking adequate steps to check the performance of their in-use vehicular fleet.

For testing of vehicles under the IVCP by MoRTH, 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. NATRIP is one of the largest and most important initiatives, taken by the Government of India, for developing and upgrading of automotive testing, homologation, and infrastructure facilities in the country. India has invested heavily to set up these seven national vehicle test centres across the country listed out in Table 10 — an investment of INR 1,718 crore was made under this programme.[42] An independent registered society was set up, namely the NATRIP Implementation Society (NATIS), as the apex body for implementation of NATRIP. The governing council of NATIS has representatives from the Ministry of Heavy Industries and Public Enterprises along with members of the automotive industry in its fold.

The in-use compliance tests to be carried out by MoRTH can be performed in these seven centres across India, to avoid investing huge sums of money in setting up separate centres for in-use vehicle testing. Wherever required, adequate equipment and other testing requirements need to be built in these centres to enable them to carry out exhaust emission testing based on COP standards. The centres currently carrying out Type Approval testing for new vehicle models in India can also serve as alternate centres to carry out in-use vehicle compliance testing.

Table 10: List of existing/proposed vehicle testing facilities across India

S. No.	Testing facility	
1.	iCAT, Manesar	A full-fledged testing and homologation centre within the northern hub of automotive industry
2.	NATRAX, Indore	Testing tracks on 4,098 acres of land at Indore in Madhya Pradesh
3.	GARC, Chennai	A full-fledged testing and homologation facilities
4.	East Centre, Silchar	National Specialized Hill Area Driving Training Centre at Dholchora (Silchar) Inspection and Maintenance Station for in use vehicles and

[42] NATRiP website. Available at http://www.natrip.in/ (accessed 13 September 2013).

		Mechanics Institute at Jaffirband (Silchar)
5.	ARAI, Pune	A full-fledged testing and homologation facilities
6.	NCAT, Ahmednagar	A full-fledged testing and homologation facilities
7.	Tractor Test Centre, Rae Bareilly Centre, Uttar Pradesh	Centre for Testing of Tractors and Off-Road Vehicles together with accident data analysis and specialized driving training

3.2 Strengthening inspection programmes in India

3.2.1 Key learning from best practices in I&M globally

There are a number of lessons to be learnt from I&M programmes implemented across different countries.

Test-only centres

It is a well-accepted fact across literature that 'test-only' centres provide best results across different countries, rather than 'test and repair' centres. Since, having both testing facility and a garage together discourages the personnel to fail any vehicle on grounds of faulty emissions; instead they tend to adjust the test outcome to ensure that all vehicles pass. Hence, in India as well it is recommended to establish centralized I&M system where inspections and maintenance are dealt with separately.

One-stop approach

In many countries, integrating both vehicle registration and safety inspection to emission inspection has worked effectively in curbing emissions from in-use vehicles, such as in Costa Rica, the EU, and many US states. Egypt and Sri Lanka also had plans to improve their air quality by implementing a 'one stop' approach.[43] India can also benefit from such an approach if it could be brought about successfully nationwide.

Enforcement and compliance

Law should be structured in a manner that it becomes imperative for a vehicle to have requisite emission certificate in order to operate the vehicle.

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[43] USAID, *Vehicle Inspection and Maintenance Programs: International Experience and Best Practices*, 2004.

Quality assurance

Periodic audits and quality checks must be a built-in component of the overall I&M programme to ensure effective implementation and positive results. Not even the most robust I&M mechanism can prove useful unless frauds and manual tampering is completely avoided.

3.2.2 Proposed inspection programme in India

Apart from the proposed IVCP, it is essential to strengthen the inspection procedure as well to address the menace of high emitters due to lack of proper maintenance. Currently, the system of PUC checks has proven to be in-effective in doing so, due to a number of limitations as detailed out in Section 1.3.2. Also, it has been pointed out in established literature that a centralized inspection system is better than a decentralized one.[44] Kolke,2005 reports that centralized inspection not only reduces investment cost but is also more reliable. Hence, it is proposed to modify the existing PUC system and implement a more effective inspection procedure (based on the same PUC norms).[45]

Replace existing PUC centers with fewer inspection centers

It is proposed to set up adequate numbers of inspection centres in every city, in place of the existing PUC centres. These limited number of inspection centres should be closely monitored by the respective state transport departments for quality assurance. They also must be better equipped, manned by trained personnel, and run by private agencies. However, the test data collected in each of these centres must be submitted on a real-time basis to a centralized location managed by the state transport department. This data should be analysed on a regular basis to screen out potential high emitting vehicle models which might be consistently failing these tests; this can act as input information for selecting models to be tested under the IVCP.

Testing frequency to be reduced to once a year across India

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[44] R Kolke, *Inspection and Maintenance and Roadworthiness (Sustainable Transport): A Sourcebook for Policy-makers in Developing Cities*, GIZ, Transport Policy Advisory Services. Available at http://www2.gtz.de/dokumente/bib/05-0520.pdf (accessed 19 December 2013).

[45] Kolke, 2005, *Inspection and Maintenance and Roadworthiness*. GTZ

It is proposed 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 higher percentage of the vehicular fleet actually appear for inspections. With the current system of quarterly PUC checks in Delhi just about 21% of the fleet appears for the checks. Examples of other countries where testing frequency is annual are listed below:

a) Many states in the US such as Atlanta, Louisiana, Wisconsin, Pennsylvania, Nevada, etc., the vehicle fleet is tested annually under I&M programme which requires vehicles with tailpipe emissions exceeding set standards to receive repairs before returning on road.[46]
b) China also has a Periodic Inspection and Maintenance Test (PIMT), which is again an annual inspection of in-use vehicles, employing primarily Idle Test for petrol vehicles, with a 2-speed Idle Test in some regions such as Beijing, and the Snap Acceleration Smoke Test for diesel vehicles.[47]

Link inspection/emissions certificate with vehicle insurance

To ensure that all vehicles appear for annual I&M checks and carry a valid emissions certificate, it is proposed to link it with the vehicle insurance. It should be mandated by law that insurance be given to a vehicle only if it possesses an emissions certificate valid for the next one year. It would be the responsibility of the insurance companies to check for this and any insurance company found to be insuring vehicles without a valid emission certificate should be penalized.

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 cops to spot defaulting vehicles.

In the future, on-board diagnostics (OBD) system can be linked with annual inspection checks rather than conducting tailpipe emission tests. Since OBD code-checks would be more cost-

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[46] D S Noonan, 2011. "How the Clean Air Act 'hits home' through the I&M Program", American Enterprise Institute for Public Policy Research. Available at http://www.aei.org/files/2011/12/14/-how-the-clean-air-act-hits-home-the-im-program_140927732751.pdf (accessed on 4 March 2014); Also see, Louisiana Department of Environmental Quality, Motor Vehicle Inspection and Maintenance Program. Available at http://www.deq.louisiana.gov/portal/DIVISIONS/Assessment/AirFieldServices/MotorVehicleInspectionProgram.aspx (accessed on 4 March 2014).

[47] F Lixin and M Yonglian, "Current I/M practice and a Future National I/M Regulation of China", Available at http://www.un.org/esa/gite/iandm/lixinpaper.pdf (accessed 4 March 2014).

effective along with being more accurate, it would be able to screen out vehicles having higher emissions without conducting any tests; these high emitters can be further put to detailed checks/tests. In India, OBD I has been mandated from 1 April 2010 (except LPG or CNG-fuelled vehicles and those >3500 kg GVW) and OBD II is required from 1 April 2013 for all categories.[48] However, OBD code checks should apply starting with OBD II vehicles.

Estimating cost for installing adequate inspection centres across India

The cost of installation of adequate inspection centres across India has been broadly estimated. The projected number of vehicles for the year 2020 was used to estimate number of inspecting lanes required in these centres. Based on a figure of 218 million on-road vehicles in 2020, about 4,500 lanes will be required. This is based on an assumption that vehicles go for inspection once in a year. The cost per lane has been assumed to be 1–1.5 crore for different categories of vehicles. The total investment required for establishing inspection centres for catering to all the vehicles expected till the year 2020 by this estimation is about INR 7,300 crores. Testing charges of INR 100 to 400 per vehicle — for different category of vehicles — should recover this cost within the next 2.3 years.

This is quite close to the numbers estimated in a recent report titled *Cost-effective Green Mobility* published by the Confederation of Indian Industry (CII) and AT Kearney in 2013*. The report states that an investment of about INR 8,000 to INR 10,000 crores might be required to establish I&M centres across the country. The system can lead to huge cost savings owing to improved fuel economy as a result of better maintenance of vehicles.

* CII and AT Kearny, 2013

3.3 Linking in-use testing to stronger and clear recall policy for noncompliant vehicles

For any kind of vehicle compliance programme to be fully successful it is necessary to be backed by stringent fines or penalties and effective recall policies, which in the case of India are currently missing. Though Indian laws have given the authority to establish recall policies for non-compliant vehicles, no such policy or guideline has been established so far. Currently, only the certification for vehicles can be revoked if found to be COP non-compliant. However, further instructions to remove such vehicles from the road are not defined clearly.[49]

[48] Ministry of Shipping, Road Transport and Highways, 2008, Notification, G S R 522(E), July 2008. Available at http://morth.nic.in/writereaddata/sublinkimages/GE522774676141.pdf (accessed on 10 March 2014).

[49] G Bansal, 2013, Vehicle Emissions Compliance for Light-duty Vehicles in India", Working paper 2013-3, The International Council on Clean Transportation. Available at http://www.theicct.org/sites/default/files/publications/ICCT_COP_India_20130820.pdf

In the previous sections on PUC data analysis, it is clearly illustrated that only a small percentage of on-road vehicles appear for the regular checks and those which fail the tests often exceed the set standards by manifolds. This could either be due to lack of maintenance and proper usage or that the vehicles are actually not complying with their original emission norms through their useful life. In the presence of a strong and clear recall policy linked with an effective in-use compliance system across India, the manufacturers can be held accountable in case vehicles are emitting more than they are certified to, despite proper maintenance.

There have been instances in the past where vehicles have been recalled in India owing to various safety-related and technical issues.

The Indian automobile manufacturers had introduced emission warranty programme on all BS-II compliant vehicles — including passenger cars, multi-utility vehicles (MUV), commercial vehicles, and two/three-wheelers — way back in 2001, under mounting pressure from environmental groups and consumers in Delhi, Kolkata, Chennai, and Mumbai. The warranty period of each vehicle category was set as follows[50]:

Two-wheeler: 30,000 km or 3 years whichever occurs earlier

Three-wheeler: 30,000 km or 1 year whichever occurs earlier

Passenger cars: 80,000 km or 3 years whichever occurs earlier

MUVs: 80,000 km or 3 years whichever occurs earlier

Commercial Vehicles: 80,000 Km or 1 year whichever occurs earlier

This warranty is given for every part of the vehicle, which can affect emissions including the fuel system, exhaust system, engine system, and evaporative emissions control system.[51] However, this warranty is based on the PUC check norms, and the manufacturers are required to rectify the fault if the vehicle failed to meet the PUC norms owing to some defect in the vehicle part, and not due to improper maintenance. However, this kind of warranty should be formulated on the

[50] Environment Pollution (Prevention and Control) Authority for the National Capital Region, Pollution Control Implementation Division-III. Available at http://www.cpcb.nic.in/divisionsofheadoffice/pci3/authorityforNCR.pdf (accessed on 13 December 2013).

[51] CSE, 2001. Down to Earth, "Owning Up", CSE Webnet, Available at http://www.downtoearth.org.in/node/15918 (accessed on 18 December 2013); SIAM offers emission warranty for all vehicles, *Business Line*, internet edition [online], 21 February 2001. Available at http://www.hindu.com/businessline/2001/02/21/stories/022107s5.htm (accessed 18 December 2013).

basis of the Type Approval standards and not on the un-related and lenient PUC standards. Such checks should be carried out on more number of vehicles of the given model, if a faulty vehicle comes to light, to see if it is a common problem across all vehicles of the given model. Accordingly recall must be announced, where deemed necessary, to rectify the fault at the manufacturer's end depending on the proportion of the vehicle models having faulty parts and its impact on the emissions. In the US, manufacturers are required to report warranty claim if they are above a certain threshold, as this may indicate a systemic problem with the given vehicle model.

More recently, the Society of Indian Automobiles Manufacturers (SIAM) implemented a 'voluntary code on vehicle recall' on 1 July 2012 as a pre-emptive measure to ensure safety and customer satisfaction. This code addresses potential issues that exist in a motor vehicle which does not meet the safety requirement due to manufacturing defect and the remedial actions taken in this regard. Vehicles shall be covered under safety recall for a period of seven years under this code.[52] A similar code for vehicle recalls owing to emission-related issues should also be an encouraging step by the automobile industry towards environmental protection, till the Indian government makes it mandatory.

3.4 Required institutional framework

The proposed IVCP can be initially hosted by the MoRTH with automobile manufacturers gradually taking over the responsibility of carrying out regular tests. Simultaneously I&M programmes across India should be strengthened by the respective state transport departments, which can further let private agencies run the centres. Major roles and responsibilities of different stakeholders involved in these programmes are listed out in Table 11.

Table 11: Roles and responsibilities of different stakeholders in the proposed IVCP and I&M programmes

Stakeholders	Responsibilities
Central government (MoRTH)	- Amendments in relevant Acts as well as Policy formulation - Overall co-ordination of the IVCP and I&M Program - Issue guidelines and manuals

[52] Society of Indian Automobile Manufacturers (SIAM), 2012, Media Manager, Voluntary Code on Vehicle Recall, Available at http://www.siamindia.com/Media/Release/SiamViewMediaRelease.aspx?id=316 (accessed on 12 December 2013).

State governments (state transport departments)	- Revise and update the state rules - Setting up of vehicle inspection centres - Audit performance of centres - Random checking of vehicles on road - Review of PUC and I&M database to spot vehicles which repeatedly fail tests
Traffic police	- On-road enforcement
Private agencies	- Setting up of I&M centres - Grant emissions and fitness certificates
Research institutes	- To arrive at test methodologies - Prepare emission inventories - Designing of manuals and guidelines - Design training modules and conduct training programmes
Automobile and component manufacturers	- Vehicle repair and maintenance programmes - Set up model vehicle inspection centres
Vehicle insurance companies	- Checking vehicles for possession of valid Emissions Certificate
NGOs/Media	- Creating awareness amongst consumers by means of campaigns

Source: Adapted from NATRIP, *Monitoring Compliance of Fuel Efficiency Standards*[53].

4. Conclusion

Vehicular pollution is an important concern in India and considering the steep trajectory of growth of this sector, the management of in-use vehicles becomes imperative. In the long run, stricter vehicle emission need to be implemented across the nation along with improved fuel quality standards; however, measures to check in-use vehicle-emissions can bring about an immediate impact in the transport sector emission load.[54]

This paper analysed the current scenario in India for inspection and maintenance of on-road vehicles and their compliance with the prescribed standards. The analysis suggests that the current PUC programme in India is very limited and does not seem to work effectively in the given scenario, with only a small proportion of vehicles appearing for PUC tests; the capital city

[53] PCRA, URL: http://www.pcra.org/english/transport/karuppaiah1.pdf (accessed 19 December 2013).
[54] ICCT, 2013, Policy Summary: India's Vehicle Emissions Control Program, July 2013. Available at http://www.theicct.org/sites/default/files/publications/ICCT_Briefing_IndiaPolicySummary_20130703.pdf

of Delhi portrays a grim picture of the initiative. Moreover, those vehicles which appear for testing also do not ensure compliance to the prescribed norm due to issues of manual interference, tampering, and manipulation. The paper also reviews state of the art I&M programmes in different countries bringing out best practices in the field. The potential of effective I&M programme to reduce vehicular emissions in India has been assessed and changes in the current mechanism are suggested.

An improvement in the current inspection system would not only lead to substantial reductions in emissions of different pollutants but also improvement in fuel economy. The current I&M programme is proposed to be strengthened by commissioning of improved testing centres at fewer locations. The cost of commissioning these improved inspection centres has been estimated and was found to be having a satisfactory payback period.

It was observed that a programme for compliance of in-use vehicles with their Type Approval standards is non-existent in India. On the lines of best practices across the world, a parallel IVCP is proposed along with strengthening of the inspection programme. While IVCP is about compliance of the Type Approval standards, an inspection programme ensures the emission performance of vehicles on Idle Testing standards. IVCP puts onus on the manufacturer if the vehicle is not complying with the Type Approval standards within the durability period. In-case of violation of the Type Approval standards observed during the durability period, further investigations and vehicle recall in relevant cases is recommended.

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Annexure-I Detailed analysis on Delhi's PUC data

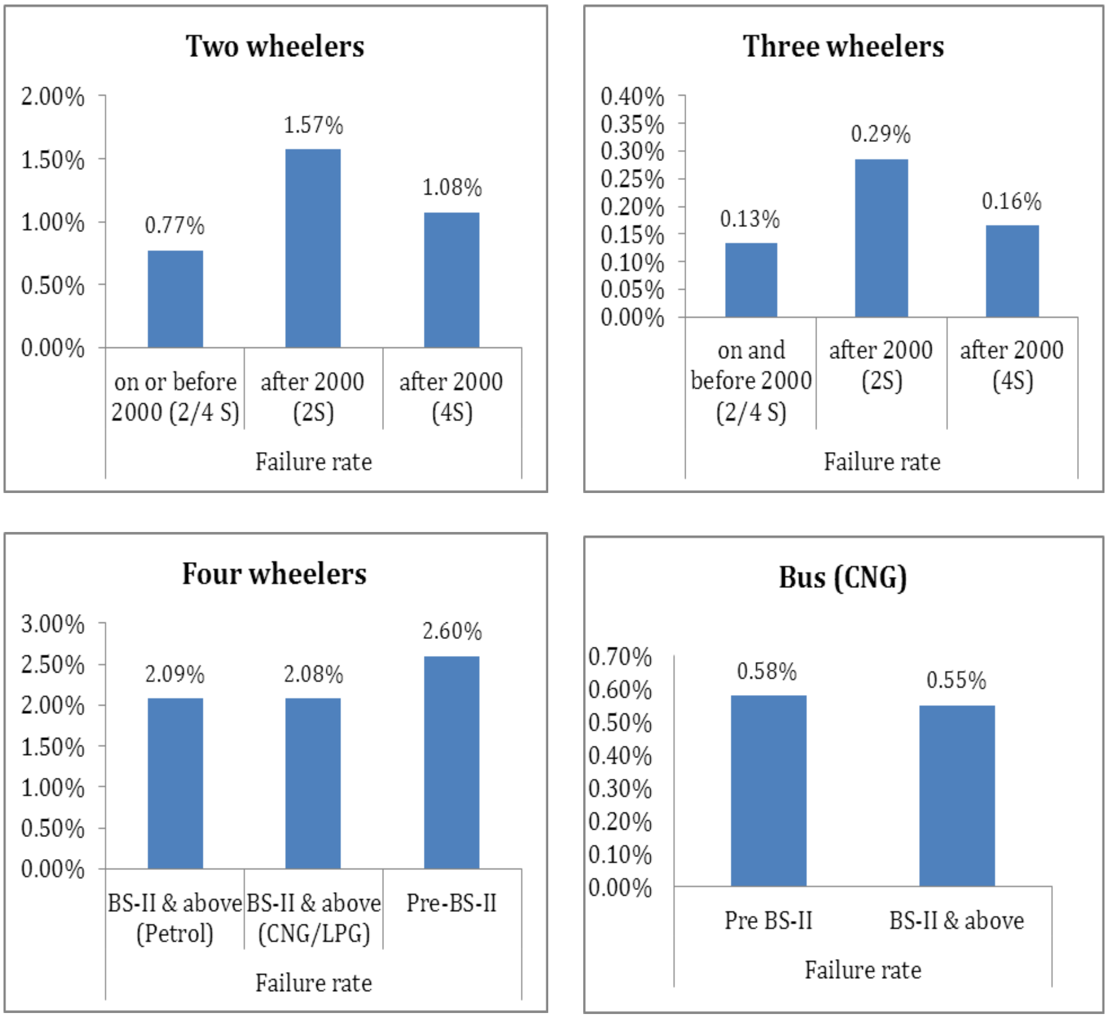

Figure A1: Vintage-wise failure rates of different categories of petrol/CNG/LPG vehicles in pollution under control checks (August 2012 to July 2013)
Source of data: Transport department, Government of NCT of Delhi

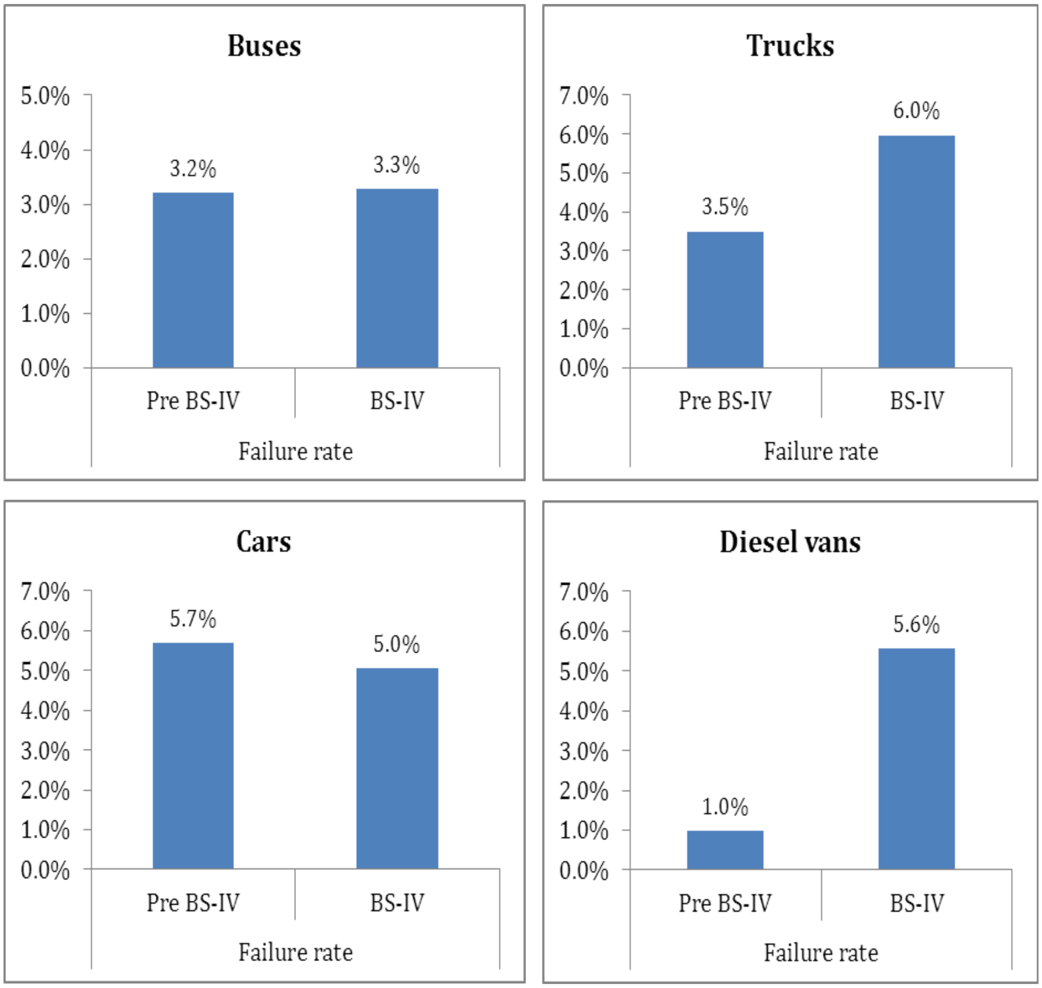

Figure A2: Vintage-wise failure rates of different categories of diesel driven vehicles in pollution under control checks (April 2013 to July 2013)
Source of data: Transport department, Government of NCT of Delhi

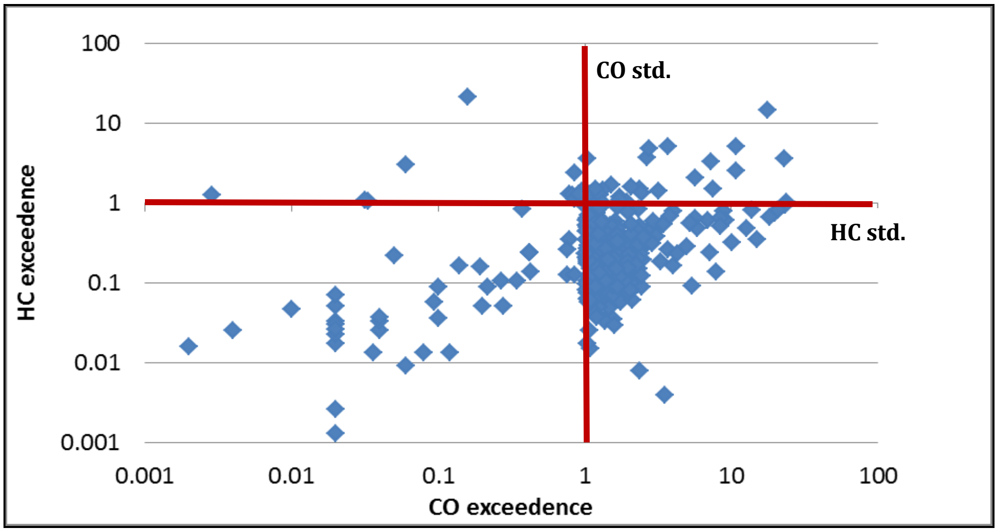

Figure A3: Hydrocarbon (HC) and carbon monoxide (CO) exceedence to the PUC norms scatter plot for all categories of petrol driven vehicles
Source of data: Transport department, Government of NCT of Delhi

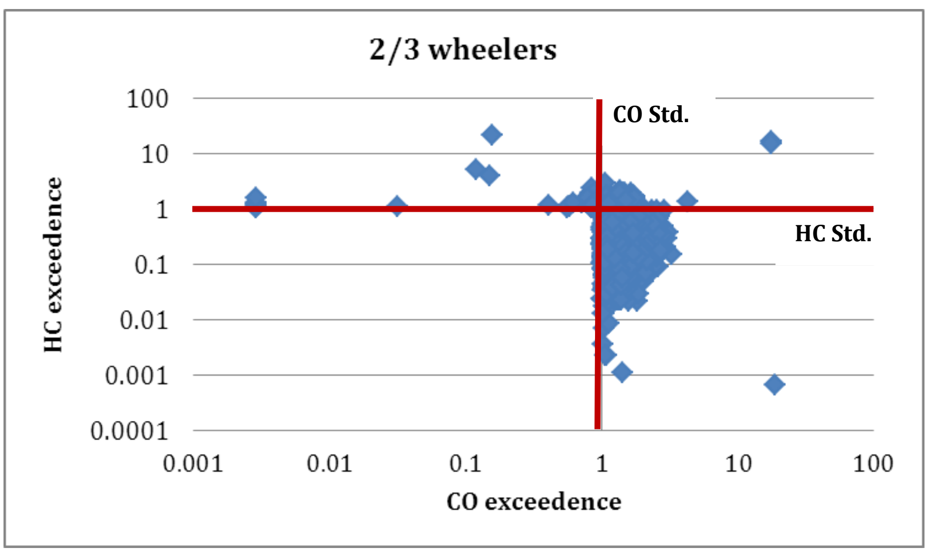

Figure A4: Hydrocarbon (HC) and carbon monoxide (CO) exceedence scatter plot for 2 and 3 wheelers
Source of data: Transport department, Government of NCT of Delhi

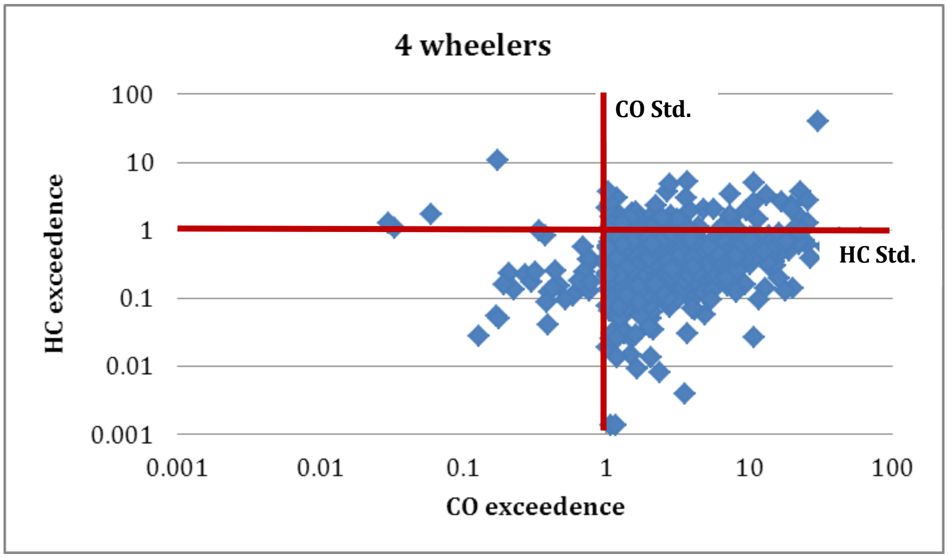

Figure A5: Hydrocarbon (HC) and carbon monoxide (CO) exceedence scatter plot for 4 wheelers
Source of data: Transport department, Government of NCT of Delhi

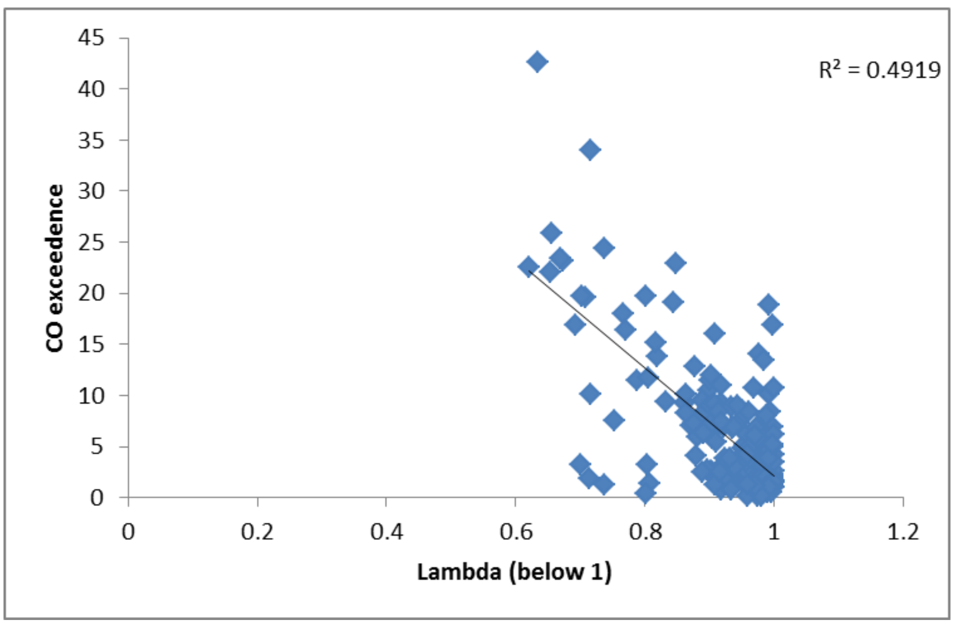

Figure A6: CO exceedence and lambda exceedence scatter plot
Source of data: Transport department, Government of NCT of Delhi

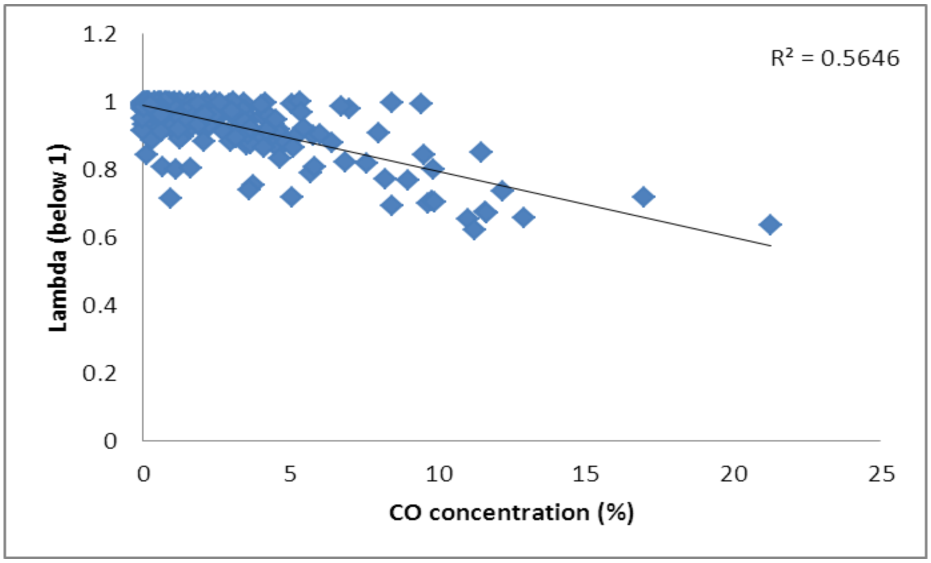

Figure A7: Correlation plot of Lambda values (below 1) and CO concentrations

Source of data: Transport department, Government of NCT of Delhi

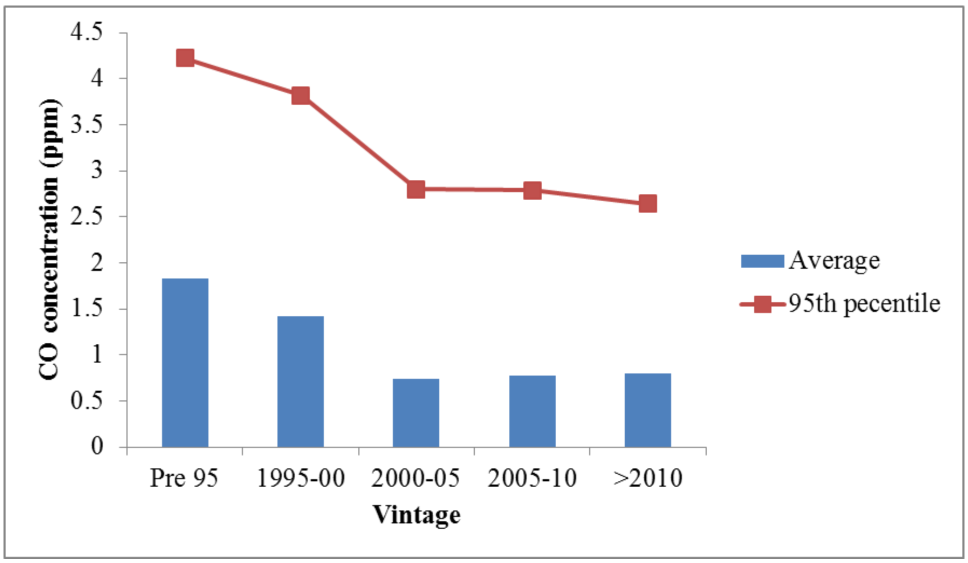

Figure A8: Vintage-wise CO concentrations of all vehicle categories

Source of data: Transport department, Government of NCT of Delhi

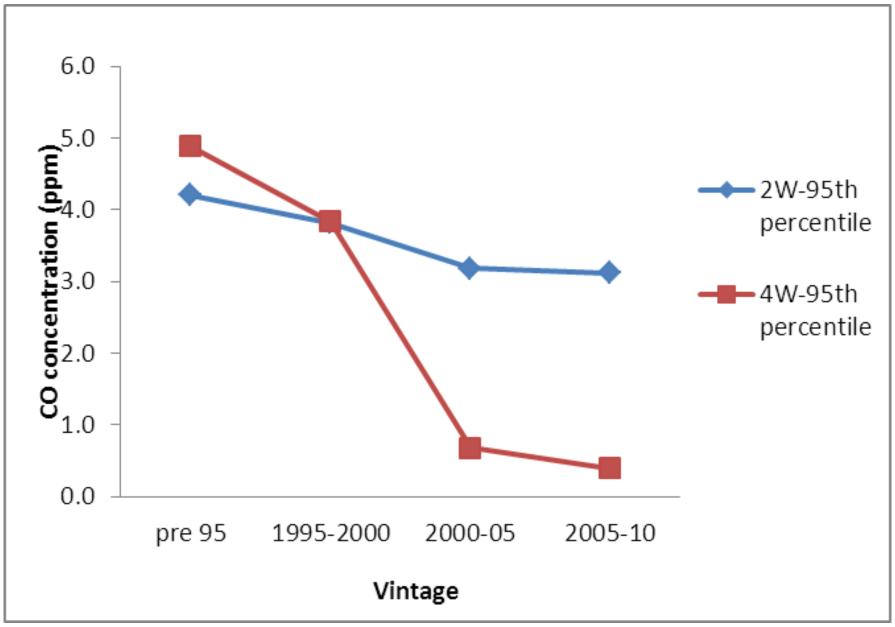

Figure A9: Vintage-wise CO concentrations for 2 and 4 wheeler categories
Source of data: Transport department, Government of NCT of Delhi

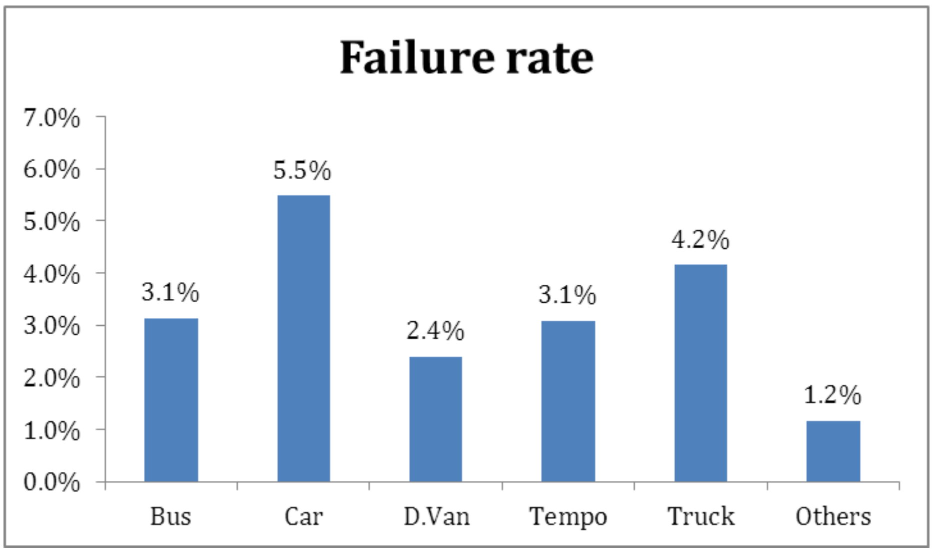

Figure A10: Percentage of vehicles failed during PUC testing in the sample analyzed for Delhi
Source of data: Transport department, Government of NCT of Delhi

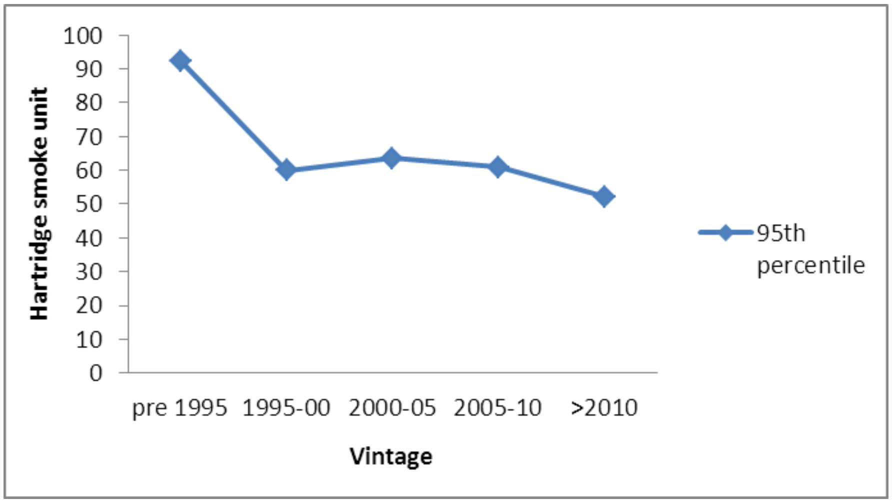

Figure A11: Trend of HSU values shown by different vintages of diesel vehicles
Source of data: Transport department, Government of NCT of Delhi