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### **A study on Effect of Inspection and Maintenance on Vehicular Exhaust Emission**

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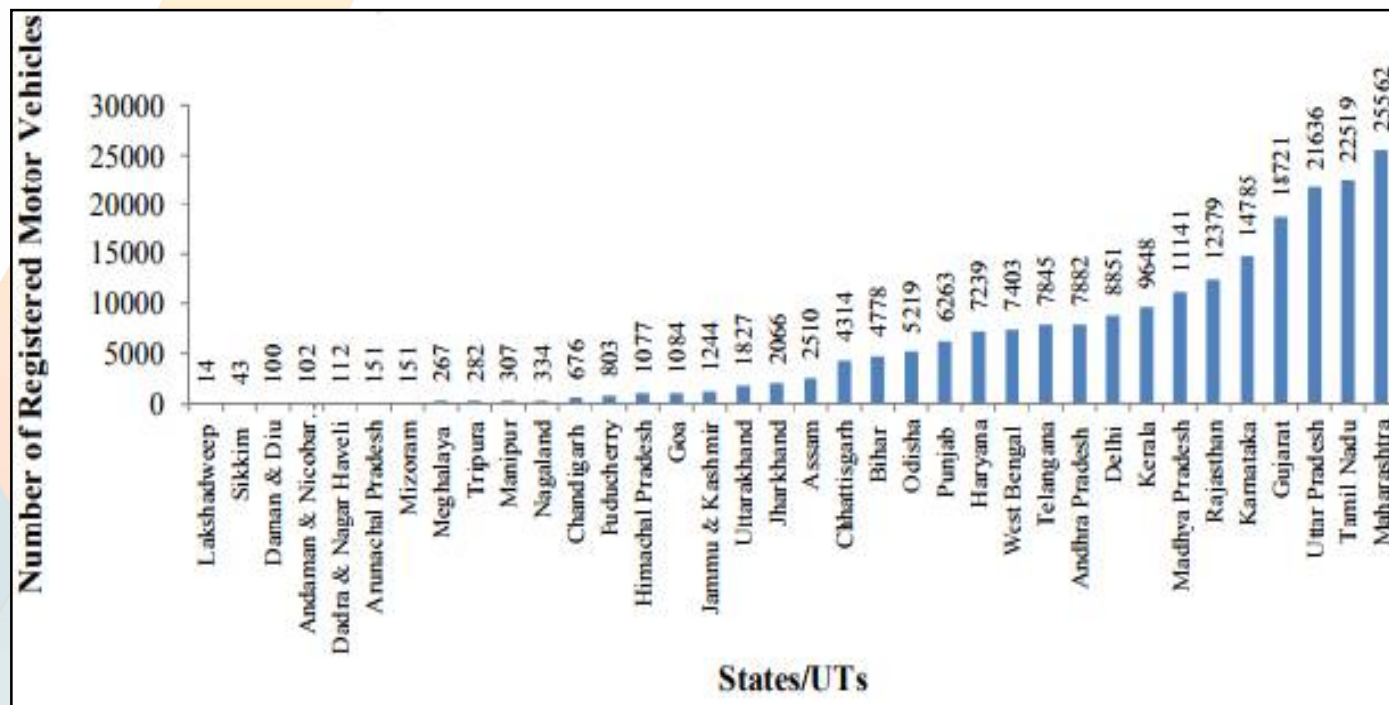


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## Introduction

- Increasing urbanization, industrialization & motorization have led to 'never-before' higher emission of Air pollutants.
- Producing about 7 million vehicles every year and major metropolitan cities recording about 15% growth rate in number of vehicles plying on its roads, India has registered about 250 million vehicles till March 2017 compared to just 80 million registered vehicles till same period of 2007.



**Fig. 1 – State-wise Vehicle population in India**

**Table 1 - Human vis-à-vis vehicular population growth and road length in Delhi**

S. No.	Parameter	1991	2001	2011	2015
1	Human population	9421167	13851000	16787000	18248290
	Decennial growth rate (%)	-	47.02	21.20	8.70
2	Vehicular population (no. of registered vehicles)	1900000	3600000	7438155	8827431
	Decennial growth rate (%)	-	89.47	106.62	-
3	Road network length (km)	21564	28508	32663	33260
	Growth rate (%)	-	32.20	14.57	1.83

## Introduction

- According to the World Health Organization (WHO) estimates, developing countries struggling with continuous ascend in urban air pollution (UAP) levels have reported more than 2 million deaths per annum along with various cases of respiratory illnesses.
- Vehicular emissions have been causing 70-80% of air pollution in almost all mega-cities of developing nations especially sourced from high rate of motorization, large number of older vehicles exhibiting poor vehicle maintenance, inadequate road infrastructure and low fuel quality.

## Introduction

- Among the criteria pollutants, CO is the major pollutant coming from the transport sector, contributing to about 90% of total emission. Hydrocarbons are next to CO. It is indeed interesting to observe that the contribution of transport sector to the particulate pollution is as less as 3-5%, most of the SPM (Suspended Particulate Matter) are generated due to re-suspension of dust out of which  $PM_{10}$  is the most prominent air pollutant.

## Literature Review

- In an effort to improve air quality resulting from the transport sector, various pollution control strategies have been adopted or proposed worldwide, such as, travel demand control, cleaner fuel standards, upgraded engine technology and stricter mandates on motor vehicle emissions.
- An important part of motor vehicle emission control relies on implementing a proper inspection and maintenance (I/M programme), since it is the best way to identify vehicles that need remedial maintenance or adjustment.

## Literature Review

- Engine maintenance has been shown to be the most significant parameter affecting the level of emissions. In a typical I/M program, motorists are required to get their vehicles periodically inspected for exhaust emissions.
- A vehicle with malfunctioning emission controls or excessive exhaust pollution may or may not be repaired. While in the case of repair, the vehicle should be retested to determine the post-repair emission rate, however, in the reverse case, the motorist should pay an emission fee.

## Literature Review

- Further, a study on emission and age distribution of vehicles in the Colorado I/M programme, reported that the vehicle age and maintenance have an impressive effect on CO emissions.
- It has also been assessed that the total amount of air pollutants, especially CO and HC, have not been decreased significantly because of continued increase of motorization whereas another reason is believed to be an increase in the annual mileage which occurs practically all over the globe and reflects the human life level.

## Literature Review

- The relationship between emissions and load is reported to be depending on the fuel delivery and emission control technology.
- Under high speed and acceleration requirements, vehicles of present times are designed to have excess fuel injected into the engine's cylinder leading to elevated CO and HC emissions.
- The high-emitter problem spans all model-years as the vehicle emissions and fuel efficiency standards are distinct entities, the relationship between fuel economy and emissions is unclear.

## Literature Review

- Vehicle type, manufacturer, country of origin, engine characteristics, and type of fuel are also critical factors and three-stage least squares regression analyses have been performed to estimate simultaneous equations for CO, CO<sub>2</sub>, and HC. The data used in such studies ranged from standard I/M testing to remote sensing and roadside pullover. I/M tests vary, from complete IM240 to idle and 2-speed (idle+cruising) tests.
- India needs such refined I/M programme.

## Research Methodology

- The present study encompassed both idle and fast idle tests attending to total number of about 300 vehicles.
- The vehicles sampled were those reporting for periodic servicing or maintenance at MSIL-authorized service stations in Gorakhpur area, India.
- Sampling was conducted in summer and under hot start conditions of engine. The instrument's sampling probe was retained inside the tailpipe for 2-3 minutes or until concentrations stabilized.

# Research Methodology

Characteristics of tested vehicles;  
registration number, model/model year, time  
since last inspection and level of  
inspection/maintenance etc.



Sampling of 300 passenger cars



Measurement of idle and fast idle concentration of  
CO (%) and HC (ppm) in vehicle's tailpipe



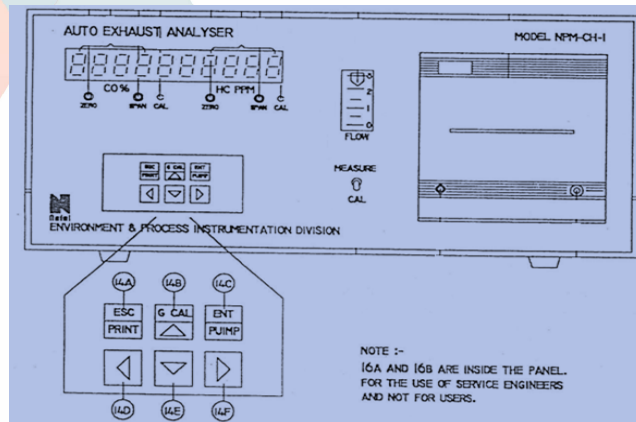
Assessment of vehicle's maintenance-related  
parameters on emission levels



Development of statistical outputs and  
discussion on vehicle's maintenance-related  
parameters on emission levels and compliance  
of standards for different vehicle models



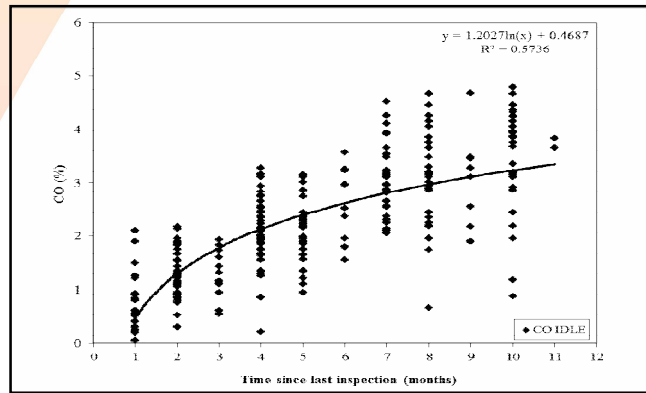
Conclusion



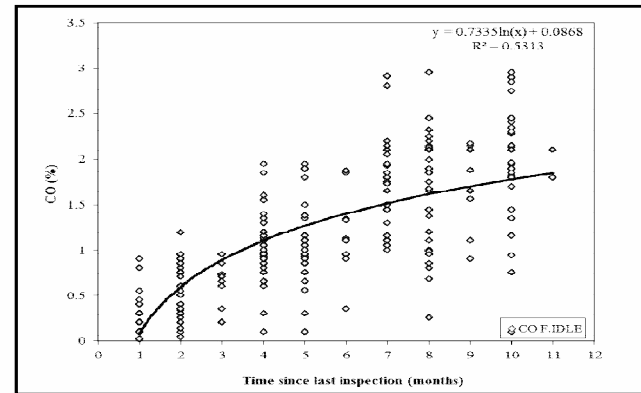
**Fig. 3 – Front view of  
Auto-exhaust analyzer**

**Fig. 2 – Schematic of research methodology**

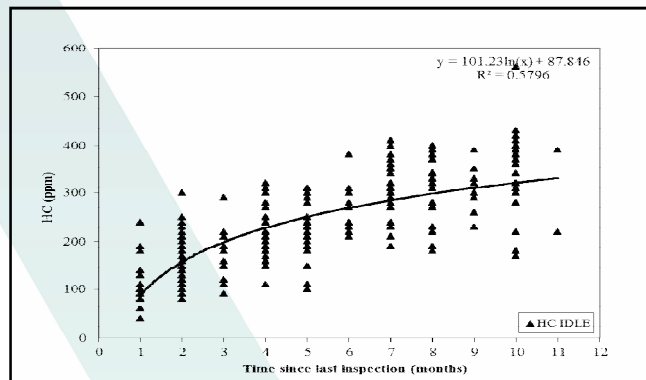
# Data Analysis, Results and Discussion



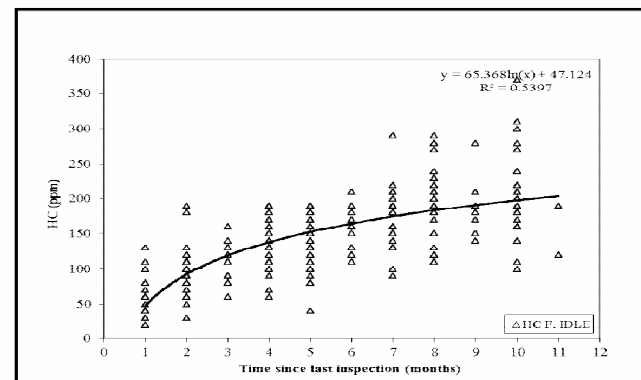
**Fig. 4: TSLI vs. CO emission (Idle)**



**Fig. 5: TSLI vs. CO emission (Fast Idle)**



**Fig. 6: TSLI vs. HC emission (Idle)**

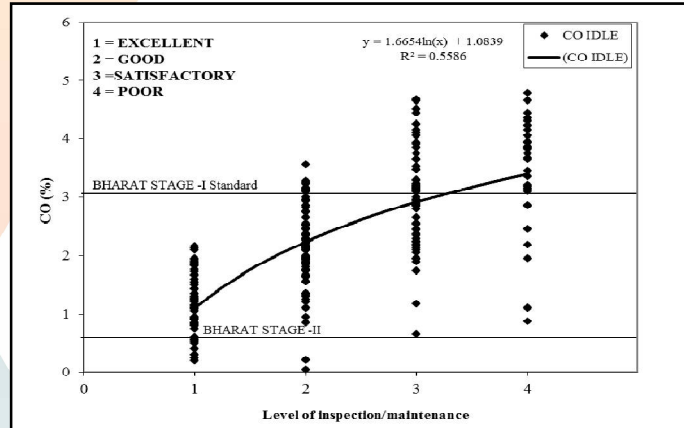


**Fig. 7: TSLI vs. HC emission (Fast Idle)**

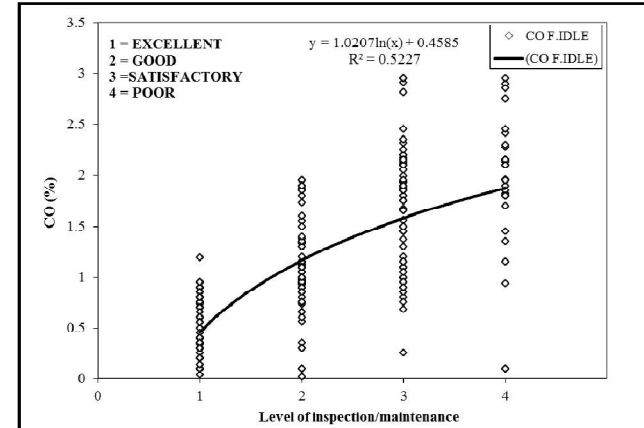
## **Data Analysis, Results and Discussion**

- The graphs show that the TSLI has a direct influence on the CO and HC emission as the CO and HC emissions are reported to increase with increase in time that has elapsed since the previous inspection/ maintenance for the vehicle was taken up.
- This increase, as evidenced by the analysis, is of logarithmic nature and it is also shown that CO and HC emissions may even exceed the existing emission norms for in-use vehicles after a certain time since previous inspection.

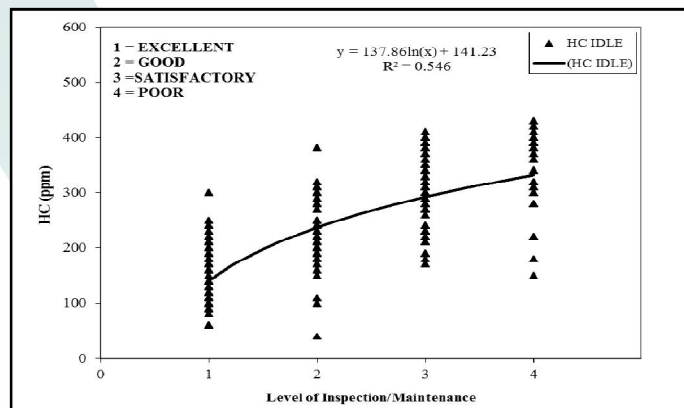
# Data Analysis, Results and Discussion



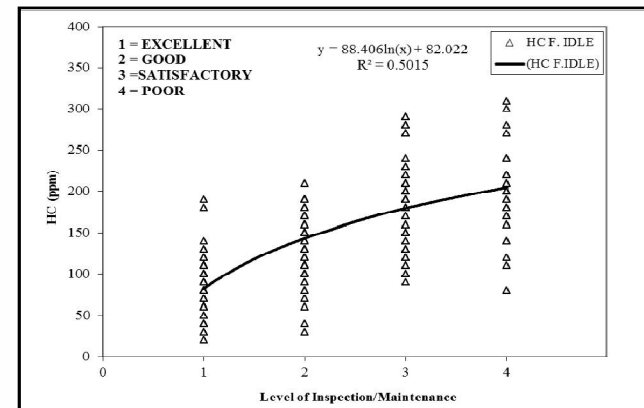
**Fig. 8: LIM vs. CO emission (Idle)**



**Fig. 9: LIM vs. CO emission (Fast Idle)**



**Fig. 10: LIM vs. CO emission (Idle)**



**Fig. 11: LIM vs. CO emission (Fast Idle)**

## **Data Analysis, Results and Discussion**

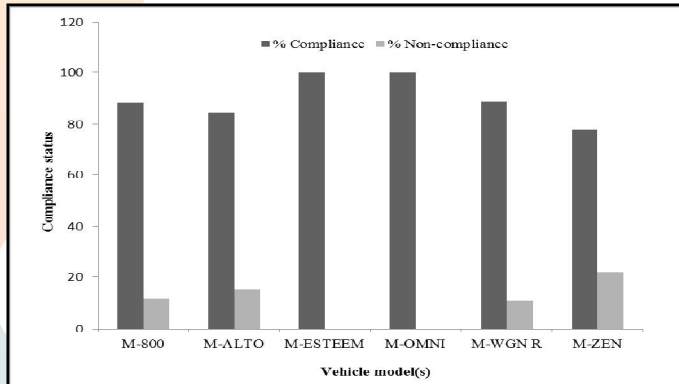
- For the purpose of understanding the variation of tailpipe exhaust levels with level of inspection/maintenance (LIM), the frequency of LIM of vehicles reporting at the exhaust monitoring station was recorded.
- Since the study covered only Bharat Stage (BS) - I and II compliant vehicles where compliance level was supposed to be low as these exhaust emission norms were relatively older, it was supposed that more and more visits would be required by the vehicles so as to be compliant to such norms.

# Data Analysis, Results and Discussion

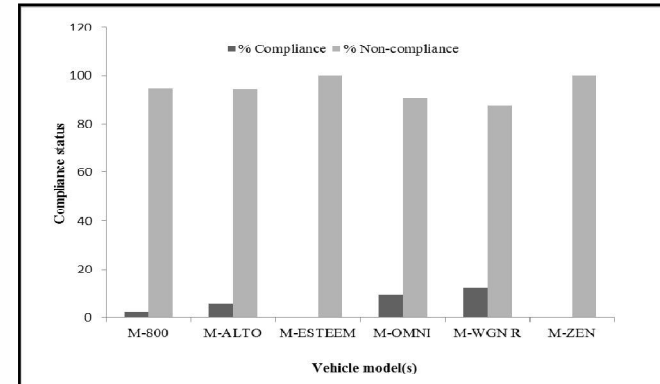
**Table 2 - Equations relating CO & HC emissions with vehicle TSLI (model-wise)**

S. No.	Model	Test mode	Equation (s)	R <sup>2</sup> value(s)	Equation (s)	R <sup>2</sup> value(s)
			CO		HC	
1.	M-800	Idle	$y = 1.3286 \ln(x) + 0.159$	0.4851	$y = 102.31 \ln(x) + 77.834$	0.4654
		F. Idle	$y = 0.7543 \ln(x) + 0.03$	0.4109	$y = 62.988 \ln(x) + 48.862$	0.4255
2.	M-ALTO	Idle	$y = 1.212 \ln(x) + 0.3065$	0.5387	$y = 108.8 \ln(x) + 64.612$	0.5733
		F. Idle	$y = 0.8745 \ln(x) + 0.1892$	0.5352	$y = 69.255 \ln(x) + 33.188$	0.4289
3.	M-ESTEEM	Idle	$y = 1.3166 \ln(x) + 0.3203$	0.6439	$y = 101.37 \ln(x) + 103.61$	0.5586
		F. Idle	$y = 0.817 \ln(x) + 0.003$	0.4338	$y = 66.227 \ln(x) + 0.003$	0.5014
4.	M-OMNI	Idle	$y = 1.4878 \ln(x) + 0.3145$	0.8298	$y = 124.42 \ln(x) + 78.62$	0.7932
		F. Idle	$y = 0.837 \ln(x) + 0.0626$	0.7337	$y = 75.522 \ln(x) + 39.846$	0.856
5.	M-WGN R	Idle	$y = 0.8171 \ln(x) + 0.0369$	0.6034	$y = 117.83 \ln(x) + 69.322$	0.6613
		F. Idle	$y = 0.817 \ln(x) + 0.0368$	0.603	$y = 77.462 \ln(x) + 34.054$	0.5708
6.	M-ZEN	Idle	$y = 1.0646 \ln(x) + 0.7571$	0.6962	$y = 97.262 \ln(x) + 98.871$	0.6805
		F. Idle	$y = 0.6807 \ln(x) + 0.2234$	0.689	$y = 63.104 \ln(x) + 51.695$	0.6698

# Data Analysis, Results and Discussion



**Fig. 12: Model-wise compliance to BS-I norms**



**Fig. 13: Model-wise compliance to BS-II norms**

**Table 3 - Relative standing of different models in respect of compliance level**

S. No	Compliance level					
	BHARAT Stage-I	% Compliance	% Non-compliance	BHARAT Stage-II	% Compliance	% Non-compliance
1.	M-WGN R	88.88	11.12	M-WGN R	12.12	87.88
2.	M-ALTO	84.62	15.38	M-ZEN	0.00	100.00
3.	M-ZEN	77.78	22.22	M-ALTO	5.88	94.12
4.	M-800	88.24	11.76	M-800	2.56	97.44
5.	M-ESTEEM	100.00	0.00	M-OMNI	9.09	91.91
6.	M-OMNI	100.00	0.00	M-ESTEEM	0.0	100.0

## Data Analysis, Results and Discussion

- M-WGN R shows best compliance to BHARAT Stage-II norms though with only 12.12% of this model's passenger cars amongst all other models being successful, while it also remains the second best performer (with 88.88% compliance) when conformance to a relatively lesser stringent Bharat Stage-I norm is reviewed.
- Further M-ESTEEM and M-OMNI were found to have 100% compliance to BHARAT Stage-I norms while no model was able to achieve the same compliance level against Bharat Stage-II norms.

## Conclusion

- Vehicle's maintenance-related parameters such as TSLI and LIM were proportional to the CO and HC emission from the tailpipe exhaust and when compared to inherent Bharat Stage norms, exhibited different failure rates.
- The results of the study can be used as the proposed line for the suitable tuning and adjustment of pollution control systems for different models petrol-driven passenger cars of MSIL complying to BHARAT Stage-I or BHARAT Stage-II standards

## References

- Road Transport Year Book, 2013-2015. Ministry of Road Transport and Highways (MoRTH), The Government of India, New Delhi, India.
- WHO (World Health Organization), 2005. Air quality guidelines for particulate matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide, Global update 2005. Geneva, 22 pages.
- Auto Fuel Policy. Report of the Expert Committee on Auto Fuel Policy-Executive Summary, Ministry of Petroleum and Natural Gases, The Government of India, 2002.

## Reference

- Faiz, A. Automotive emissions in developing countries: relative implications for global warming, acidification and urban air quality. *Transportation Research*, Vol. 27 A, No. 3, 1993, pp. 167-186.
- Anilovich, I. and Hakkert, A.S. Survey of vehicle emissions in Israel related to vehicle age and periodic inspection. *The Science of the Total Environment*, Vol. 189/190, 1996, 197-203.
- Central Pollution Control Board, 1999. *Parivesh: Newsletter*. 6(1) June, CPCB, Delhi.