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PROMOTING LOW CARBON TRANSPORT IN INDIA

Assessment of

Heavy Duty Vehicle Characteristics in Delhi

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Assessment of Heavy-Duty Vehicle Characteristics in Delhi

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December 2015

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Technical University of Denmark

This publication is part of the 'Promoting Low Carbon Transport in India' project.
This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) supports this initiative on the basis of a decision adopted by the German Bundestag.

Supported by:

Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag

ISBN: 978-87-93130-76-0

Design and production:

Magnum Custom Publishing
New Delhi, India
info@magnumbooks.org

Photo acknowledgement:

Front cover: Aleksandr Zykov

Back cover: Eva L.

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Acknowledgements

This research has been done as part of the UNEP sponsored project on Low Carbon Transport in India. We are thankful to all our project partners for the important discussions on urban freight in India. We thank all our colleagues in the Transportation Research and Injury Prevention Programme at the Indian Institute of Technology Delhi for the necessary support in carrying out this study. We would like to acknowledge the contribution of Ashwani Kumar, final year M.Tech student, Department of Civil Engineering at IIT Delhi for carrying out the survey and assisting in analysing the survey data on freight vehicles in Delhi. We would like to thank the three reviewers Dr. Sarath Guttikunda, Dr. Ben Sharpe at ICCT and Mr. Bert Fabian at UNEP for their comments on the draft report. We are also greatful to Ms. Jospephine Basch and Ms. Surabhi Goswami for their help in language editing and proof reading of the document. Finally, we would like to thank Dr. Subash Dhar at UNEP –DTU Partnership (UDP), Denmark and Ms. Kamala Ernest for supporting the study and providing valuable feedback on earlier drafts.

Abbreviations

AMW	Asian Motor Works
ARAI	Automotive Research Association of India
BAU	Business as usual
BEE	Bureau of Energy Efficiency
BS	Bharat Stage
CAGR	Compound Annual Growth Rate
CFMTTI	Central Farm Machinery Testing and Training Institute
CIRT	Central Institute of Road Transport
CNG	Compressed Natural Gas
COP	Conformity of Production
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSE	Centre for Science and Environment
DOT	Department of Transportation
ESC	European Stationary Cycle
ETC	European Transient Cycle
EU	European Union
FE	Fuel economy
FY	Financial Year
gal/1,000 ton-mi	gallon per 1,000 tonne-mile
gal/100 bhp-hr	gallon per 100 brake horse power-hour
g/ton-mi	gallon per tonne-mile
g/mi	gram per mile
g/kWh	gram per kilowatt hour
g/tonne-km	gram per tonne kilometre
GDP	Gross Domestic Product
GHG	Greenhouse gas
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbon
HDV	Heavy Duty Vehicle
HSD	High Speed Diesel
ICAT	International Centre for Automotive Technology
ICCT	International Council on Clean Transportation

IIP	Indian Institute of Petroleum
IITD	Indian Institute of Technology, Delhi
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
km/litre	Kilometre per litre
LCT	Low Carbon Transport
LCV	Light Commercial Vehicles
LDV	Light-Duty Vehicles
LGV	Light Goods Vehicle
L/100 km	Litre per 100 kilometre
M&HCV	Medium and Heavy Commercial Vehicles
MAV	Multi Axle Vehicle
MCD	Municipal Corporation of Delhi
MoEF	Ministry of Environment and Forests
MoPNG	Ministry of Petroleum and Natural Gas
MORTH	Ministry of Road Transport
MT	Million tonnes
NA	Not available
NAPCC	National Action Plan on Climate Change
NH	National highways
NHDP	National Highways Development Project
NO_x	Nitrogen Oxide
NTKMS	Net tonne-kilometres
OEM	Original equipment manufacturer
PMGSY	Pradhan Mantri Gram Sadak Yojana
PM	Particulate Matter
ppm	Parts per million
Rs. per litre	Rupees per litre
SH	State Highways
SO_2	Sulphur Dioxide
tkm	tonne kilometre
UNEP	United Nations Environment Programme
VAT	Value Added Tax
VECV	VE Commercial Vehicles
VRDE	Vehicle Research and Development Establishment
VWCV	Volkswagen Commercial Vehicles
WHTC	World Harmonized Transient Cycle
WHSC	World Harmonized Stationary Cycle
WIM	Weigh-in-motion
YOY	Year over Year

Executive Summary

Freight demand continues to increase in India with the expansion of economy and population. ICRA Research Services (2013) has estimated long-term growth outlook for Medium and Heavy Commercial Vehicles (M&HCV) with a Compound Annual Growth Rate (CAGR) (%) of 9.5-11.5%, and for Light Commercial Vehicles (LCV) with a CAGR of 11-13% over the next five years, from 2011. This steady growth of heavy-duty vehicles has raised concerns among environmentalists and transport planners in India due to its implications on energy consumption and emissions. HDV transport has the largest share (around 55%) in fuel consumption, and it is expected that the steady growth of HDV will increase oil import dependency from 76% of 141 million tonnes (MT) to 93% by 2031 (Sharma et al., 2014). Diesel driven HDV vehicles are the major source of PM, SO_2, NO_x and CO. Thus, it has become essential to lay down a roadmap for fuel efficient HDV vehicles and encourage a sustainable policy environment for heavy-duty vehicles in India. For informed public actions extensive data is required to be collected and analysed. The preliminary data may include information regarding the current HDV market, fleet size and structure; key stakeholders likely to be affected by the policy regulations; type/size, age, mileage, fuel type, weather conditions, driving conditions, etc. for emission calculations.

This report aims to analyse fuel efficiency and the policy environment for heavy-duty vehicles in India. The report includes literature review of existing HDV studies in India, mapping of current heavy-duty vehicular technology (type of vehicle, age, fuel used) and fuel efficiency in Delhi, and discussions on policies promoting HDV modernisation and efficiency improvements. The choice of Delhi is based on the fact that many freight oriented policies like green tax, time restriction, prohibition of commercial vehicles non-destined to Delhi, use of alternative fuels, ban on commercial vehicles above 15 years and proposals of integrated freight complexes have been adopted. Additionally, fleet data captured not only includes the HDVs registered in Delhi but also data from other neighbouring states. This may at least help to understand the fleet characteristics of the neighbouring states of Delhi. The literature review includes three sections on international experiences on fuel emission and fuel economy standards, fuel efficiency policies, emission standards and market analysis for HDVs in India. The last two sections, 5 and 6, discuss the analysis of the data collected and explore the policies for improving efficiency of HDV in India, respectively.

The setting of emission standards for HDV is not easy due to the involvement of multiple manufacturers in the making of the final vehicle, and the difference in the performance of the engine, which depends on the chassis it is paired with. Thus, emissions for HDV are measured in gram per kilowatt hour. The setting of emission standards involves various testing procedures, which try to simulate different driving conditions to correctly estimate the experimental emissions as close to real world emissions. These test cycles may vary from region to region.

The fuel emission standards are complemented with fuel efficiency and GHG emission programmes to reduce energy dependency and global warming. From international experience it is found that fuel efficiency programmes either focus on improving vehicle efficiency measured by fuel consumed per unit distance travelled, or directly on GHG emissions measured by CO_2 emissions per tonne km. The GHG emission approach offers a broader view and includes not only improvement of engine efficiency but also non-engine technology improvement in vehicles.

In India, the Ministry of Road Transport (MORTH) is responsible for setting vehicle emission standards. The testing procedure of the present Bharat III and IV HDV involves two testing cycles: the European Stationary Cycle (ESC) and the European Transient Cycle (ETC). The recent report on "Auto Fuel Vision and Policy 2025" proposes to introduce Bharat Stage (BS) IV emission standards by April 2017 and BS V emission standards by April 2020. BS VI emission standards are recommended for introduction in 2025. However, it is suggested that instead of blindly following European emission standards, India should directly advance from BS IV to BS VI (Bandivadekar, 2015). The second issue that is encountered is the low sulphur content fuel that is being used during testing, compared with the commercially available fuel in the country, which is leading to poor actual emissions estimates. Apart from the fuel emission standards, the fuel efficiency policy of India includes fuel taxation and recent proposals on the introduction of pollution tax in a few states. The effect of these fuel efficiency policies on the operation is still not clear and requires further research. As far as the Indian HDV market is concerned Tata Motors represents half of truck and bus sales, followed by Ashok Leyland and VE Commercial Vehicles. The second important aspect to note is the small engine capacity of Indian HDVs, compared to other countries like China and the United States, as well as the European Union.

In order to understand the characteristics of current HDV and LDV vehicles entering and operating in Delhi, a continuous 72 hour manual cordon count and origin-destination survey based on stratified random sampling has been conducted at 14 major entry points of Delhi during the months of September and October 2015.

The Supreme Court in 2001 ordered that, "no heavy, medium or light goods vehicles will ply on inter-state routes by passing through Delhi or New Delhi. It is only those goods vehicles, which on payment of octroi/ toll tax carry goods to or from Delhi, which would be allowed to ply" (EPCA, 2004). The decision was made to control the pollution from transit vehicles in Delhi.

The survey results show that around 16% of the vehicles are non-destined to Delhi. The results obtained are statistically similar to the recently published Centre for Science and Development (EPCA, 2015) report. It is observed that the banning of non-destined vehicles may not be very useful in reducing pollution in Delhi. Another important observation is that less than 1% of vehicles are older than 15 years. Most vehicles are in the range of 2 to 10 years old. Approximately 60% of the freight vehicles entering comply with Bharat Stage III and IV norms for emissions. Thus, policies regarding the banning of vehicles older than 15 years may not have a major impact on reducing fuel emissions. Also, the average daily traffic observed at the 14 entry points is around 34,000 vehicles, which has an approximately 12% variation from the Centre for Science and Development (EPCA, 2015) report.

From the literature review it is clear that a great deal of studies and recommendations are available on testing procedures to be adopted and their implications on setting emission standards in India. However, the introduction of new emission standards in new engines may take decades to fully consolidate in the market, depending on the growth of freight vehicles. This creates a need for an integrated approach where the emission standards are to be accompanied with policies promoting HDV modernisation and improved efficiency, like the green freight programme, vehicle fuel economy labelling, vehicle taxation, fuel taxation, and eco driving. The challenges for the implementation of these policies in India are presented. Therefore, it is very important to investigate factors like projected growth, cost of operation, knowledge of vehicle characteristics, in terms of vehicle size, fuel type used and age distribution, fuel quality, etc. before implementing any freight oriented policies.

Photo credit: Dinesh Mohan

1. Introduction

1.1 Background

This study is part of a larger project on "Promoting Low-Carbon Transport in India", a major initiative of the United Nations Environment Programme (UNEP), hereafter referred to as the Low Carbon Transport (LCT) project in this document. The overall context in which the LCT project has been undertaken is the critical role of the transport sector in reducing greenhouse gas (GHG) emissions. Therefore, the focus of the project is to contribute to the efforts of the Government of India by:

- Creating an enabling environment for coordinating policies at the national level to achieve a sustainable freight transport system.
- Building capacities of cities to improve passenger and freight mobility with lower CO_2 emissions.

The LCT project has been endorsed by the Ministry of Environment and Forests (MoEF), Government of India. It is being jointly implemented by the UNEP–DTU Partnership (UDP), Denmark (URC); Indian Institute of Technology, Delhi (IIT-D); Indian Institute of Management, Ahmedabad (IIM-A); and CEPT University, Ahmedabad.

India is currently the fourth largest GHG emitter in the world, although its per capita emissions are less than half the world average. Further, India's transport sector accounts for 13% of the country's energy related CO_2 emissions. It is evident that opportunities exist to make India's transport growth more sustainable by aligning development and climate change agendas. At present, the CO_2 emission per capita in India is approximately one-fourth of the world average, with the transport sector contributing to approximately 10% of the total CO_2 emissions (IEA, 2010). At the global level the emissions from transport had been constant between 2007 and 2008, however, in India the emissions from the transport sector have been growing gradually. In addition to CO_2 emissions, the transport sector is also responsible for negative externalities like road congestion, local air pollution, noise and accidents. In urban areas, the share of freight transport is substantial and expected to grow, resulting in increasing negative externalities of the transport sector. India's National Action Plan on Climate Change (NAPCC) recognizes that Greenhouse Gas (GHG) emissions from transport can be reduced by adopting a sustainable approach -- e.g. improving energy efficiency of transport vehicles, rationalising movement of freight in cities, etc. India is aiming to reduce future CO_2 emissions per unit of GDP by 20–25%, as compared to the 2005 level, by 2020 (Energy Information Association, 2009).

This report presents a review of the characteristics of freight vehicles in India, including fuel efficiency and emission norms. The key objective of the study is to analyse the fuel efficiency of current heavy-duty vehicles and the policy environment surrounding them. The study aims to highlight the characteristics (age, fuel used, type of vehicle used and fuel efficiency) of freight vehicles in large urban areas such as Delhi. The information will assist policymakers in designing interventions and identifying appropriate policies required to address the negative externalities caused by freight transport cities.

1.2 Overview of freight traffic in India

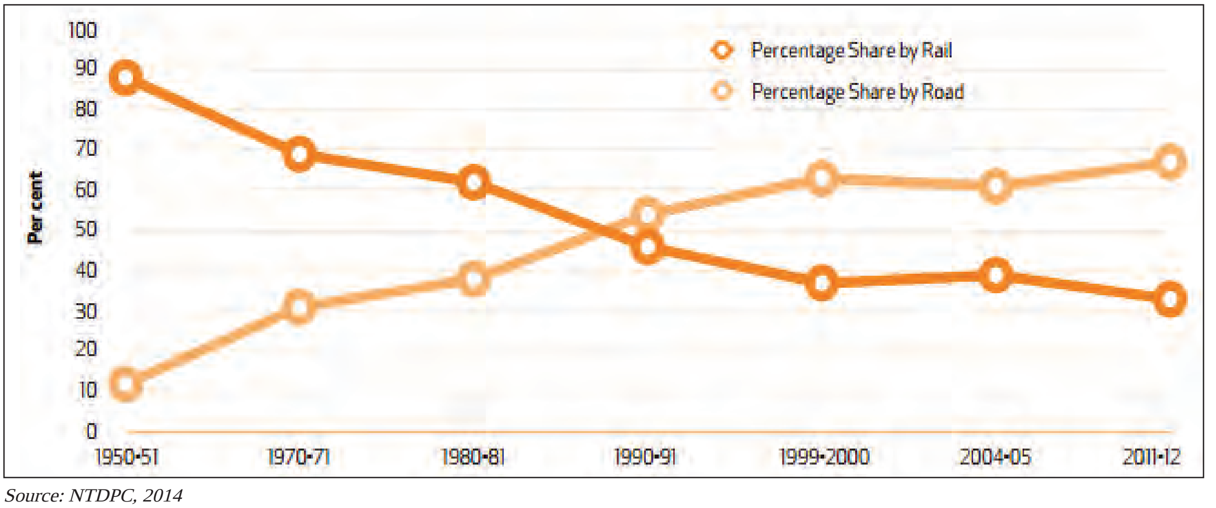
Freight transportation is an important component of the economic development of India. Growing urbanisation has led to an increase in the consumption of goods and services and, thus, an increase in freight transport services for urban areas. Freight traffic carried by rail and road has increased from 257 billion tonne km in 1980-81 to 2,053 billion tonne km in 2011-12. Out of six modes of freight transport -- i.e. rail, road, coastal shipping, airways, inland waterway, pipelines -- rail and road dominate, carrying approximately 87% of the total freight traffic in the country in 2007-08 (NTDPC, 2014). Rail was the dominant mode for freight traffic in the late 1980s. However, since the early 1990s the share of railways has decreased, dropping to 37% in 2011. Figure 1 shows the share of railways and roads in freight traffic movement. Railways lost their share in comparison with road transport around 2001. This can be attributed to many reasons, such as the changing nature of goods, increase in value added products, the sluggish capacity and infrastructure development of railways compared to those of roads. The government has invested in the expansion of the road network in the country since the formation of the National Highway Authority of India in 1997, and the introduction of various schemes like the National Highways Development Project (NHDP), Pradhan Mantri Gram Sadak Yojana (PMGSY) and Jawaharlal Nehru National Urban Renewal Mission (JnNURM). Moreover, the flexibility offered, in terms of availability, cost savings and adaptability to individual demands, has been a major factor in the dominance of the road sector. As a result, road transport was responsible for approximately 50% (RITES, 2014) of freight transport in India in 2011. Table 1 shows the shares of different transport sectors in freight traffic in India.

Table 1: Modal shares in freight traffic (2007-2008)

Mode	Share in originating traffic		Percentage share in total traffic	
	Tonnes(million)	NTKMS(Billion)	Tonnes	NTKMS
Rail	768.72	508.1	30.08	36.06
Road	1558.87	706.16	61.01	50.12
Coastal Shipping	59.1	85.7	2.31	6.08
Airways	0.28	0.29	0.01	0.02
IWT	54.88	3.38	2.15	0.24
Pipelines	113.5	105.45	4.44	7.48
Total	2555.35	1409.08	100	100

Source: RITES (2014)

Figure 1: Freight Traffic: Roads Overtake Rail



Source: NTDPC, 2014

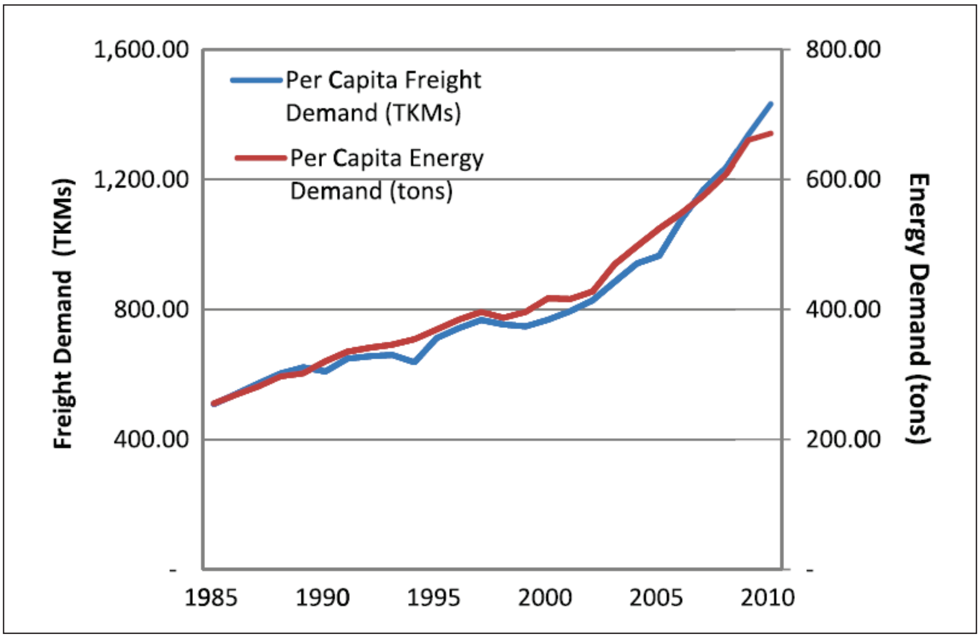
Rapid growth in the road freight traffic has, therefore, resulted in an increase in the demand for heavy-duty vehicles. Table 2 shows the growth rate of commercial vehicles in India from the fiscal years 2008 to 2012. The growth is divided into two classes: Medium and Heavy Commercial Vehicles (M&HCV), and Light Commercial Vehicles (LCV), as per the Motor Vehicles Act, 1988. ICRA Research Services (2013) has estimated long-term growth outlook for M&HCV with a Compound Annual Growth Rate (CAGR) (%) of 9.5-11.5%, and for LCV with a CAGR of 11-13% over the next five years from 2011. Although the absolute number of heavy-duty vehicles has increased, their share in comparison with light-duty vehicles has decreased. Dhar and Shukla (2015) have suggested a strong correlation between the demand of freight and that of consumable commodities within the economy. Figure 2 shows the strong correlation between freight and energy demands. The authors (Dhar and Shukla, 2015) have also suggested that, "the per capita freight in BAU is expected to increase from 1464 tkm in 2010 to 5941 tkm in 2050 and consequently the overall demand for freight transport is expected to increase from around 1793 billion tkm in 2010 to 10,052 billion tkm in 2050." According to Sessa C and Enei R (2009) the demand for freight transport by EU-27 countries is expected to increase from 3,683 billion tkm in 2005 to 6,983 billion tkm in 2050. Based on these estimates, the growth rate of the demand for freight movement transport in India is considerably higher than that of the EU-27 countries.

Table 2: Segment wise volume from 2008-2012

Segments	Volumes					YOY Growth (%)				
	FY08	FY09	FY10	FY11	FY12e*	FY08	FY09	FY10	FY11	FY12e*
M&HCVs	274,582	183,495	244,944	322,788	332,472	-12.6%	-7.0%	43.4%	22.9%	3-4%
LCVs	215,912	200,699	287,777	353,620	413,735	-0.4%	-33.2%	33.5%	31.8%	17-18%

*Source: ICRA Research Services, 2013; * computed at 3% growth for M&HCVs and 17% for LCVs*

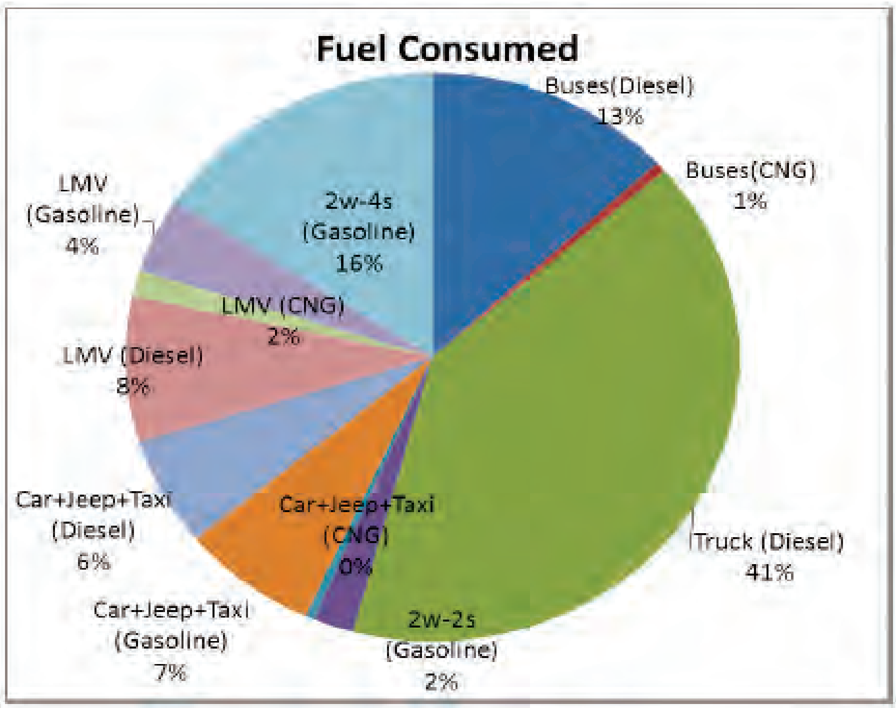
Figure 2: Per capita freight demand vs. energy demand



Source: Dhar and Shukla, 2015

Given the steady growth of the heavy-duty sector, it is expected that it will lead to an increase in oil import dependency -- from 76% of 141 million tonnes (MT) to 93% by 2031. This has further raised concerns over energy security, the environment and climate change. The estimated category-wise fuel consumption is shown in Figure 3. Since trucks and buses have the largest share of fuel consumption (55%), the largest fuel savings can be achieved by improving the efficiency and operation of the heavy-duty sector.

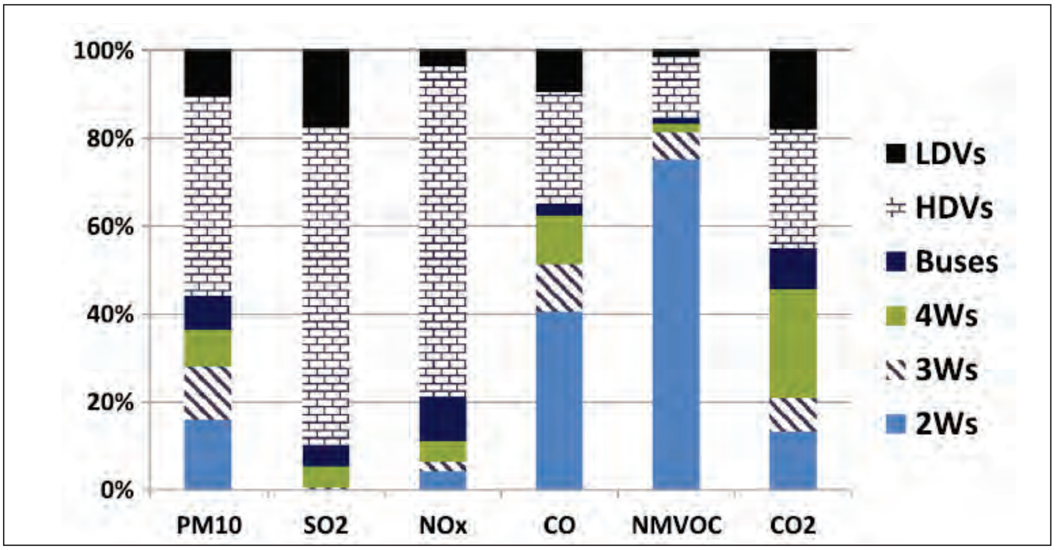
Figure 3: Vehicle category and fuel-wise distribution of energy used in the country during 2010



Source: Sharma et al., 2014

Guttikunda and Kopakka (2013) studied the emission inventory for Greater Hyderabad Municipal Corporation. They suggested that vehicle exhaust predominantly through diesel operated heavy-duty and light-duty vehicles are responsible for the emissions of PM, SO_2, NO_x, and CO (Figure 4). Dholakia et al. (2013) highlight using Delhi as a case study; that with the current policy scenario it would not be able to reach the recommended values of national air quality standards, even by 2030. Strict policy implementation combined with technology improvement and cleaner fuels are required to meet the aim. A source apportionment study of six cities (TERI, 2014) shows that the transport sector is one of the major sources of particulate matter (particularly PM2.5) and NO_x. Improvements in fuel efficiency and vehicle technology play an important role in reducing emissions.

Figure 4: Share of vehicle exhaust emissions by vehicle type for the Greater Hyderabad Municipal Corporation



Source: Guttikunda and Kopakka, 2013

Given the vital role of heavy-duty vehicles in fuel consumption and greenhouse gas emissions, it is important for India to meet its growing energy demand in an efficient manner. To cut down the energy demand for freight vehicles, it is necessary to lay down a roadmap for efficient vehicles and fuel consumption in the country.

The aim of this report is to analyse the fuel efficiency of current heavy-duty vehicles and the policy environment surrounding them. The report includes literature review of existing HDV studies in India, mapping of current heavy-duty vehicular technology (type of vehicle, age, fuel used) and fuel efficiency in Delhi, and discussions on policies promoting HDV modernisation and improved efficiency. Primary and secondary data have been analysed to understand the present scenario of freight operation and characteristics, in terms of mileage, age profile, vehicle categories, and emission standards for Delhi. The selection for Delhi is based on the fact that it was recently named one of the most polluted cities of the world (World Health Organisation, 2014), and a constant effort is being made by the city government to curb air pollution. Various freight policies, like green tax, time restriction, prohibition of non-Delhi-destined commercial vehicles, use of alternative fuels, ban on commercial vehicles above 15 years and proposal of integrated freight complexes, have been adopted. Furthermore, few studies are available for Delhi with which the results can be compared in order to develop an understanding of the city's fleet operation. Additionally, the fleet data captured includes not only the HDV registered in Delhi but also the data from other neighbouring states. Thus, the data captured may at least help to understand the fleet characteristics of the neighbouring states to Delhi. The results are discussed in later sections.

1.3 Need for study

Growing urbanisation, industrialisation and motorisation has led to increased oil dependency and high levels of GHG emissions in India over the last few decades. This necessitates systematic and sustainable approaches to develop low carbon transport plans in India addressing both passenger and freight demands. The Indian government has already finalised the country's first passenger vehicle fuel efficiency standards on 30 January 2014. It is expected to bring the regulations into effect by April 2016 (Transportpolicy.net, 2015). Similarly, the roadmap for emission standards of Light-Duty Vehicles (LDV) and Heavy-Duty Vehicles (HDV) is already under the consideration of the Ministry of Road Transport and Highways (MoRTH), India. Taking into account the above facts, the present study --in comparison to others (EPCA, 2015; CSIR-Central Road Research Institute, 2014) -- has been formulated with an aim to understand the characteristics of urban freight, specifically, and the comparisons with national freight vehicles. A comprehensive classification of the freight vehicles is adopted. Various characteristics, such as vehicle age, fuel type used, mileage by fuel type used, and kilometres travelled, as well as emission standards of current fleet have been explored. The results obtained will present a better framework for developing the emission standards and other regulatory policies for LDVs and HDVs.

The study includes six sections. Section 2 reviews international experiences on fuel emission and fuel economy standards. Section 3 presents reviews on fuel efficiency policies and emission standards for HDV in India. Section 4 provides market analysis of HDV in India. Section 5 discusses the methodology of data collection and its analysis, and section 6 explores policies for improving efficiency of HDV in India.

Photo credit: Dinesh Mohan

2. International experiences on fuel emission and fuel economy standards

2.1 International fuel emission standards

The development of HDV fuel emission standards is a new endeavour, compared to the LDV standards. According to Sharpe (2015), it is not easy setting up emission standards for HDV, compared to LDV, due to multiple manufacturers being involved in the making of the final product, and the performance of a particular engine, which differs with the type of chassis it is paired with. This leads to two methods on which the emission standards are based: (1) Full vehicle certification, and (2) Individual engine-based certification. The formulation of emission standards requires clarity in terms of three aspects -- i.e. testing method to be adopted, acceptable limit of emissions, and emission metrics. The testing method includes testing cycles, which specifies the engine or vehicle operating conditions and may vary from one region to another. Thus, the testing methods to be adopted should closely represent the actual emissions during real world conditions. For HDV emissions the tests are performed on engines, and emissions are measured in terms of gram per kilowatt hour -- i.e. emissions generated in relation to the power generated by the engine. Unlike LDV, where emissions are measured in gram per kilometre, in HDV the emissions are heavily affected by the type of vehicle in which the engine is placed and the way the vehicle is used. Thus, the measurements, in terms of gram per kilowatt hour, cannot be easily converted into gram per kilometre.

Many countries, such as Japan, USA, and China, as well as some European countries, have been involved in the formulation and implementation of the HDV related emission standards. Japan made a first move by introducing HDV fuel emission standards in 2005, followed by USA in 2011. A summary of testing procedures for Japan, the U.S. and Canada, China and the European Union is shown in Table 3.

Table 3: Summary of test procedures for Japan, the U.S. and Canada, China and the European Union

	Regulatory Categories	Certification Test Procedures
Japan	• Other trucks (11 subcategories) • Tractors (2 subcategories) • Route buses (5 subcategories) • Other buses (8 subcategories)	Simulation modelling + engine dynamometer testing
U.S. and Canada	• Tractors • Vocational vehicles • HD pickup trucks and vans • Engines (tractors, voc. vehicles)	Vehicles → simulation model Engines → dynamometer testing

China	• Tractors • Dump trucks • Rigid trucks • City buses • Other buses	"Base" vehicles → chassis dynamometer "Variant" vehicles → simulation modelling
European Union	Truck and bus categories based on GVWR, chassis configuration, and axle configuration	Simualtion modelling

Source: Sharpe, 2015

2.2 Fuel efficiency and GHG emissions programme

Bansal and Bandivadekar (2013) suggest that the emission standards mentioned above limit the rate of pollutant emissions from the vehicle but do not take into account the total emissions produced. Conversely, fuel efficiency and GHG emission programmes focus on reducing energy dependency and, consequently, global warming. Therefore, it is useful to supplement well-planned fuel efficiency programs with emission standards. The authors discuss two approaches that are generally adopted to reduce emissions: 1) related to vehicle efficiency, and 2) related to reduction in GHG emissions. The vehicle efficiency approach includes setting targets either in terms of fuel economy, measured by distance travelled per unit of fuel consumed, or in terms of fuel consumption standards, measured by fuel consumed per unit of distance travelled. The second approach is directly related to the CO_2 emissions from the operating vehicle. Policymakers must understand the difference between the two approaches, as fuel consumption may not always be directly related to GHG emissions. Due to the availability of multiple fuel options in the market, the CO_2 emissions may differ for each type of fuel. Moreover, the GHG emissions approach takes into account the non-engine technology improvements. For example, the operation of air conditioning may place extra load, and lead to more CO_2 emissions. Thus, the GHG emissions approach will also focus on improvements in the efficiency of air conditioning systems in vehicles. The GHG and fuel economy standards are further classified based on the vehicle attributes, taking into account vehicle weight and size. German and Lutsey (2010) discuss the pros and cons of weight and size-based fuel economy standards. The authors argue that it is better to adopt size-based economy standards rather than mass-based standards. They further assert that the mass-based approach discourages the use of light weight technology in vehicles, encourages heavier engines by placing less stringent standards, and is facilitated by the fact that mass is invisible while size is not. The fuel economy standards adopted by various countries are discussed below.

2.2.1 Japan

In 2005, Japan became the first country to introduce average weight-based HDV standards. An appropriate lead time was given to the manufacturers to develop technologies complying with the fuel economy standards by 2015. The targets were set according to the most efficient model in 2002 for each vehicle category. The test procedures were based on both engine testing and vehicle simulation models. Trucks and buses were separated from passenger vehicles, and a further sub-classification was done based on gross vehicle weight. Table 4 summarises the fuel economy standards for Japan. The sub-classification based on the gross vehicle weight was done to account for the changes in the fuel usage due to different payloads. Data was collected to calculate the fuel efficiency for two modes: urban and highways. The engine-based driving cycles were obtained from the vehicle-based driving cycles of urban and highways by simulation methods. From the engine-based tests, fuel consumed per second for a particular engine torque and rotation is then obtained. The sum of fuel emissions for each second, therefore, gives the total fuel consumption.

Table 4: Fuel economy standards for HDVs in Japan

Heavy-Duty Transit Buses		Heavy-Duty Non-Transit Buses		Heavy-Duty Trucks		Heavy-Duty Tractors	
GVW (tonnes)	FE target (km/L)	GVW (tonnes)	FE target (km/L)	GVW (tonnes)	FE target (km/L)	GVW (tonnes)	FE target (km/L)
6-8	6.97	3.5-6	9.04	3.5-7.5	10.83-8.12	≤20	3.09
8-10	6.30	6-8	6.52	7.5-8	7.24	>20	2.01
10-12	5.77	8-10	6.37	8-10	6.52		
12-14	5.14	10-12	5.70	10-12	6.00		
>14	4.23	12-14	5.21	12-14	5.69		
		14-16	4.06	14-16	4.97		
		>16	3.57	16-20	4.15		
				>20	4.04		

Source: Bansal and Bandivadekar, 2013

2.2.2 United States of America

The United States took a comprehensive look towards fuel efficiency standards and included separate standards in terms of vehicle and engine, concentrating on GHG emissions in addition to fuel economy standards. The U.S. not only included engine improvement standards but also improvements in aerodynamics, tires and weight reduction. Table 5 summarises the percentage reductions in fuel consumption required by the year 2018 over 2010 levels.

2.2.3 Europe

The research on the reduction of CO_2 emission by HDV began in 2009, and is still in progress. The introduction of Euro VI in 2014 includes the testing procedures to assess the fuel consumption and emissions.

2.2.4 China

In Hong Kong tax incentives were introduced to encourage the use of environmentally friendly commercial vehicles that met Euro V standards. Under this, sold vehicles that meet these standards are issued certificates and receive tax reductions of 50% (AEA, 2011). In 2012, there was a proposal for a National Fuel Consumption Standard for new commercial Heavy-Duty Vehicles (HDVs). This set the fuel consumption limits based on the gross vehicle weight for trucks, tractors, coaches, and buses weighing more than 3.5 tonnes.

Table 5: U.S. fuel economy improvements for HDVs for 2018 over 2010 levels

Type/Sub-class		Percentage Reduction in Fuel consumption
Tractor-trailers		
Day cabs	Class 7 low roof	10.2
	Class 7 mid roof	10.3
	Class 7 high roof	13
	Class 8 low roof	9.1
	Class 8 mid roof	9.5
	Class 8 high roof	13.6
Sleeper	Class 8 low roof	17.5
	Class 8 mid roof	18
	Class 8 high roof	23.4
Vocational		
Light HDV	Class 2b-5	8.6
Medium HDV	Class 6-7	8.9
Heavy HDV	Class 8	5.9
Pickups and Vans		
Gasoline		12
Diesel		17

Source: Bansal and Bandivadekar, 2013

Table 6 summarises various international fuel economy and GHG emission standards, and Table 7 shows the development of fuel efficiency standards for different countries across the world.

Table 6: Global Regulatory Landscape for GHG and fuel economy standards

Country/ Region	Regulation Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Japan	Fuel economy						Phase 1 regulation implemented starting MY 2015					
							Phase 2 under consideration					Phase 2 imple-mentation
United States	GHG/Fuel efficiency	Standard proposal	Final rule		Phase 1 regulation implemented starting MY 2014 (mandatory DOT program starts MY 2016)							
					Phase 2 regulatory development		Proposal	Final rule				Phase 2 imple-mentation
Canada	GHG/Fuel efficiency			Standard proposal	Final rule	Phase 1 regulation implemented starting MY 2014 (harmonized with US)						
						Phase 2 regulatory development		Proposal	Final rule			Phase 2 imple-mentation
China	Fuel consumption	Test procedure finalised	Industry standard (stage 1) proposal	Stage 1 imple-mentation								
				National standard (stage 2) proposal	Stage 2 final rule	Stage 2 implementation						
							Stage 3 development and proposal					Stage 3 imple-mentation
European Union	GHG	Technical studies			Impact assess-ment	Test protocol and simulation model finalisation		Monitoring and reporting policy (proposal and final rule)				
California	End-user purchase requirements	Requirements for tractors and trailers (MY 2011+)			Additional requirements for existing tractors and trailers (< MY 2010)				Additional requirements for existing trailers and reefers (<MY 2010)			
India	Fuel efficiency				Technical studies; rule proposal			Final rule		Phase 1 implementation		

Red text represents a possible timeline for new regulatory developments as identified by ICCT as of June 2015. Possible dates do not necessarily represent commitments by regulatory agencies and may be subject to change.

Source: Transportpolicy.net, 2015

Table 7: Fuel economy and GHG emission standards for vehicles around the world

	Fuel Economy (metric)		
Japan	Fuel economy (km/L)		
U.S. and Canada	Tractors, Vocational	HD Pickups	Engines
	gal/1,000 ton-mi	gal/100 mi	gal/100 bhp-hr
	g/ton-mi	g/mi	g/kWh
China	Fuel consumption (L/100 km)		
European Union	GHG (g/tonne-km)		

Source: Sharpe, 2015

2.3 Preliminary data required for the setting of fuel emission and fuel economy standards

The AEA (2011) report provides detailed analysis of initial steps required for the possible policy actions required to reduce emissions from HDVs. The steps include collecting information regarding: HDV market and fleet; technological options for reducing CO_2 emissions; current and expected fuel usage from HDVs; policies to control emissions from HDVs. The report starts from the study of HDV market and fleet. It is important to identify key stakeholders that are likely to get affected by the policy regulations. The report notes that although the vehicle emission norms target the new vehicle fleet, it is important to calculate the existing fleet size and structure to take necessary actions to control their emissions. Furthermore, it is necessary to examine the on board equipment in HDVs to estimate the energy consumption. Thorough knowledge of losses will help to design efficient equipment and reduce overall energy consumption. Moreover, the EPA (2008) report identifies various factors, such as vehicle type/size, age, mileage, fuel type, weather conditions, maintenance of the vehicle, and type of driving conditions as one of the important factors to be considered while calculating emissions from HDV. It is argued that single average speed used in the calculation of the emissions does not represent the real world case. The speed of the vehicle varies from the road type, whether it is operating on collector streets, arterial roads, or highways. Next, it is highlighted that the emissions are first calculated in terms of engine operation and are expressed in grams per brake horsepower per hour. Then these emissions are converted into grams per mile. Different conversion factors are applied on g/brake horsepower to emissions in gram/mile. Huai et al. (2006) have collected extensive data ranging from vehicle number, manufacturer, engine model, engine parameters, total distance, total fuel used, total fuel economy, total idle time, average vehicle speed, maximum vehicle speed, total cruise time, total brake time, average load factor, etc. using on board "electronic computer modules (ECM)". Results include the analysis of various vehicle operating characteristics like distance travelled, mileage; engine characteristics like model year, power, engine models; fuel economy analysis; analysis of activity data; calculation of emissions based on the activity data. Poulikakos, Heutschi and Soltic (2013) recorded data regarding "axle load, number of axles, gross vehicle mass, speed, axle distance" and vehicle category using "weigh-in-motion (WIM) sensors". The data regarding origin of vehicle, declared weight, vehicle category, photograph of the vehicle, as well as speed is collected through a road pricing system.

Therefore, analysing the results of earlier studies, it can be conclude that a comprehensive data set is required to understand the current fleet operation characteristics.

Photo credit: Dinesh Mohan

3. Fuel efficiency policies and Emission Standards for HDV in India

3.1 Fuel taxes

Fuel taxes are the excise taxes imposed on the sale of fuel. In India the fuel taxes vary across the country from one state to another. Both central and state governments make up the share in fuel pricing. The central road fund was introduced by the central government in the year 2000 under Central Road Fund Act, 2000. Under it, the union government imposed taxes on the consumption of petrol and high speed diesel. The revenue generated is to be used for the development of national highways, state roads, rural roads, and railways over/under bridges. Presently, a cess of Rs. 2 per litre on petrol and high speed diesel is being levied (Indian Economic Services, 2015). Purohit and Purohit (2010) highlight the taxes on vehicle operation in India, including "custom duty on imported petroleum and union excise duty on motor spirit and high speed diesel (HSD) levied by the central government" and "State VAT on fuel (motor spirit) and lubricants", which is levied by the States. These taxes are the major source of revenue for both central and state governments. Table 8 shows the distribution of the taxes among different states. Impacts of taxes on the operation of heavy-duty vehicles have not been studied. Although, a study by IISD (2013) discusses how non-uniform distribution of taxes leads to a considerable variation in the fuel prices from one state to another. The truck drivers on long routes fill the tanks at the beginning of the trip where the fuel is cheapest, thereby requiring higher working capital at the start. If fuel prices were to be uniform, a greater number of trucks could be operated with the same working capital.

Table 8: Taxes on fuel at the Central and State levels

State	Import Duty		Union Excise Duty		VAT Rates (in %)	
	Petrol	HSD	Petrol (in Rs. per litre)	HSD (in Rs. per litre)	Petrol	HSD
Andhra Pradesh	7.5	7.5	15.50	4.60	33	22.25
Assam	7.5	7.5	15.50	4.60	25.75	15.5
Bihar	7.5	7.5	15.50	4.60	24.5	18.36
Chhattisgarh	7.5	7.5	15.50	4.60	22	22
Delhi	7.5	7.5	15.50	4.60	48	20
Goa	7.5	7.5	15.50	4.60	18	19
Gujarat	7.5	7.5	15.50	4.60	NA	21
Haryana	7.5	7.5	15.50	4.60	20	8.8
Himachal Pradesh	7.5	7.5	15.50	4.60	25	14
Jammu & Kashmir	7.5	7.5	15.50	4.60	NA	NA

Jharkhand	7.5	7.5	15.50	4.60	20	14.4
Karnataka	7.5	7.5	15.50	4.60	25	NA
Kerala	7.5	7.5	15.50	4.60	29	24.69
Madhya Pradesh	7.5	7.5	15.50	4.60	28.75	23
Maharashtra	7.5	7.5	15.50	4.60	NA	23
Manipur	7.5	7.5	15.50	4.60	20	NA
Meghalaya	7.5	7.5	15.50	4.60	NA	NA
Orissa	7.5	7.5	15.50	4.60	18	18
Pondicherry	7.5	7.5	15.50	4.60	12.5	12.5
Punjab	7.5	7.5	15.50	4.60	27.5	8.8
Rajasthan	7.5	7.5	15.50	4.60	28	18
Tamil Nadu	7.5	7.5	15.50	4.60	30	21.43
Tripura	7.5	7.5	15.50	4.60	20	12.5
Uttar Pradesh	7.5	7.5	15.50	4.60	23.62	16.16
Uttarakhand	7.5	7.5	15.50	4.60	NA	21
West Bengal	7.5	7.5	15.50	4.60	NA	NA

Source: Purohit and Purohit, 2010; NA: Not available

Apart from the fuel tax there has been recent development on the introduction of the pollution tax/green tax by states like Maharashtra, Andhra Pradesh, Himachal Pradesh and Karnataka to reduce pollution from older vehicles (commercial vehicles older than 8 years and private vehicles over 15 years) and create better public transportation. Recently, Delhi introduced the green tax to be paid at tolls by heavy-duty and light commercial vehicles, starting from 1 November 2015. This has been introduced to reduce the burden of pollution from the non-destined trucks transiting through Delhi. According to the Supreme Court, larger trucks must pay 1,300 Rs. and small vehicles 700 Rs. as green tax upon entry into Delhi. The funds collected are to be further used for the protection of the environment.

3.2 Emission Standards

The Air (Prevention and Control of Pollution) Act, 1981, and the Environment (Protection) Act, 1986 established the authority to control the motor vehicle emissions in India. Through the Air Act, state governments obtained the power to regulate and enforce environmental standards. The Environment Act gave most of the power to central governments. The Motor Vehicle Act, 1989 fixed the emission standards and authorised state and central governments to regulate and enforce them. In India, the Ministry of Road Transport and Highways (MoRTH) is responsible for setting the vehicle emission standards. MoRTH frames the emission standards but the individual municipality is responsible for its enforcement. Apart from MoRTH, national agencies like Automotive Research Association of India (ARAI), International Centre for Automotive Technology (ICAT), Vehicle Research and Development Establishment, Ahmednagar (VRDE), Indian Institute of Petroleum, Dehradun (IIP), Central Farm Machinery Testing and Training Institute, Budhni (CFMTTI) and Central Institute of Road Transport, Pune (CIRT) are responsible for testing emission standards of new vehicles, conformity of production (COP) testing and inspection and maintenance programs. In addition to this, in 2003 the Auto Fuel Policy Committee was formed by the Ministry of Petroleum and Natural Gas (MoPNG) to establish a roadmap for fuel emissions and vehicle standards in India. In succession to this, an expert committee on "Auto Fuel Vision and Policy 2025" recently submitted its report on the roadmap for the emission standards up to 2025.

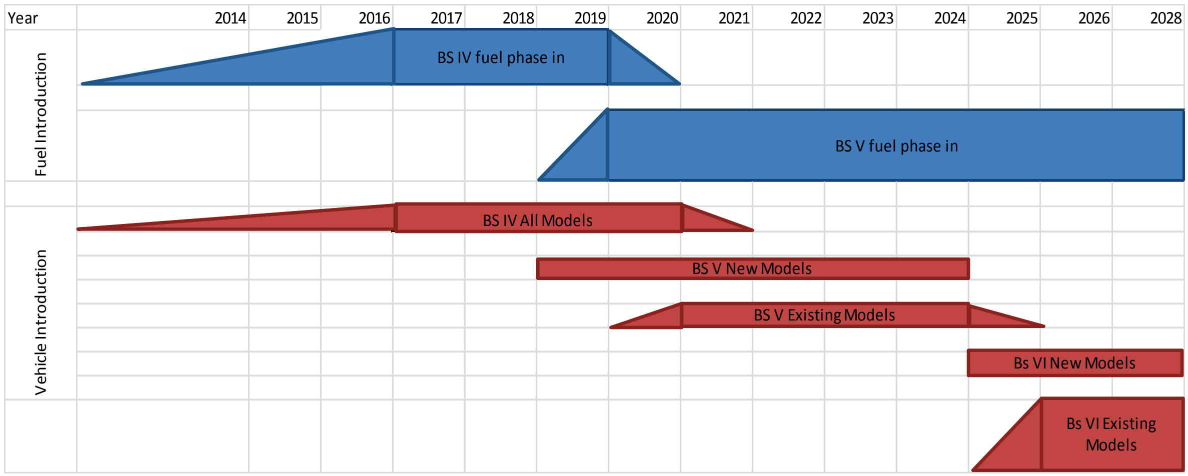
The 2014 Auto Fuel Vision and Policy 2025 report proposes to continue the existing Bharat Stage (BS) IV emissions for commercial vehicles. Emission norms corresponding to the proposed BS V have been developed and are similar to Euro V emission norms. The committee has proposed to introduce BS IV emission standards by April 2017 and BS V emission standards by April 2020. It is recommended that BS VI emission standards be introduced in 2025. Figure 5 summarises the transition of emission norms countrywide.

The emission standards for trucks and buses greater than 3.5 tonnes gross vehicle weight, is shown in Table 9.

The testing procedure of Bharat III and IV HDV involves the passing of two testing cycles: the European Stationary Cycle (ESC), where engines are tested on engine dynamometer over steady state cycles, and the European Transient Cycle (ETC) test to simulate different driving conditions – such as urban, rural and motorway driving. The main flaw of this testing is the usage of low sulphur content fuel in lab testing, compared with the commercially available fuel in the country. Thus, this leads to inaccurate real world emission estimates.

Due to the shortcomings of the present testing procedures, Bandivadekar (2015) recommends that instead of blindly following European emission standards, India should directly advance from BS IV to BS VI. Although Euro V emission norms have led to a decrease in particulate matter in the case of light-duty vehicles, less reduction has been achieved in the NO_x emissions from heavy-duty vehicles. The author suggests that advancing directly from Euro IV (Bharat IV) to Euro VI (Bharat VI) will achieve higher NO_x reductions. The testing methods adopted in BS IV and V do not simulate the real world NO_X emissions accurately. BS VI includes the World Harmonized Transient Cycle (WHTC) and the World Harmonized Stationary Cycle (WHSC) tests, which estimate NO_x emissions closer to real operating conditions. Additionally, WHTC and WHSC tests help to estimate CO_2 in gram per kilowatt hour. Moreover, there is no great technology difference required to comply with Euro V and Euro VI emission standards for heavy-duty vehicles. By 2020 the emission control technology needed to meet Euro VI standards will be in its fourth generation, thus, India can benefit from technological advancements. Furthermore, the health benefits obtained by adopting Euro VI norms will outweigh the increase in cost for the first seven years of the programme. Additionally, the author is in support of eliminating older commercial vehicles with the proper arrangement of incentives to reduce the burden of increased cost on transport operators.

Figure 5: Proposed Roll Out of BS IV, BS V and BS VI Countrywide



Source: Auto fuel policy 2025 report, 2014

Table 9: Emission Standards for diesel truck and bus engines, g/kWh

Year	Reference	Test	CO	HC	NO_x	PM
1992	-	ECE R49	17.3-32.6	2.7-3.7	-	-
1996	-	ECE R49	11.20	2.40	14.4	-
2000	Euro I	ECE R49	4.5	1.1	8.0	0.36*
2005†	Euro II	ECE R49	4.0	1.1	7.0	0.15
2010†	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010‡	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03
0.612 for engines below 85 KW † earlier introduction in selected regions ‡ only in selected regions						

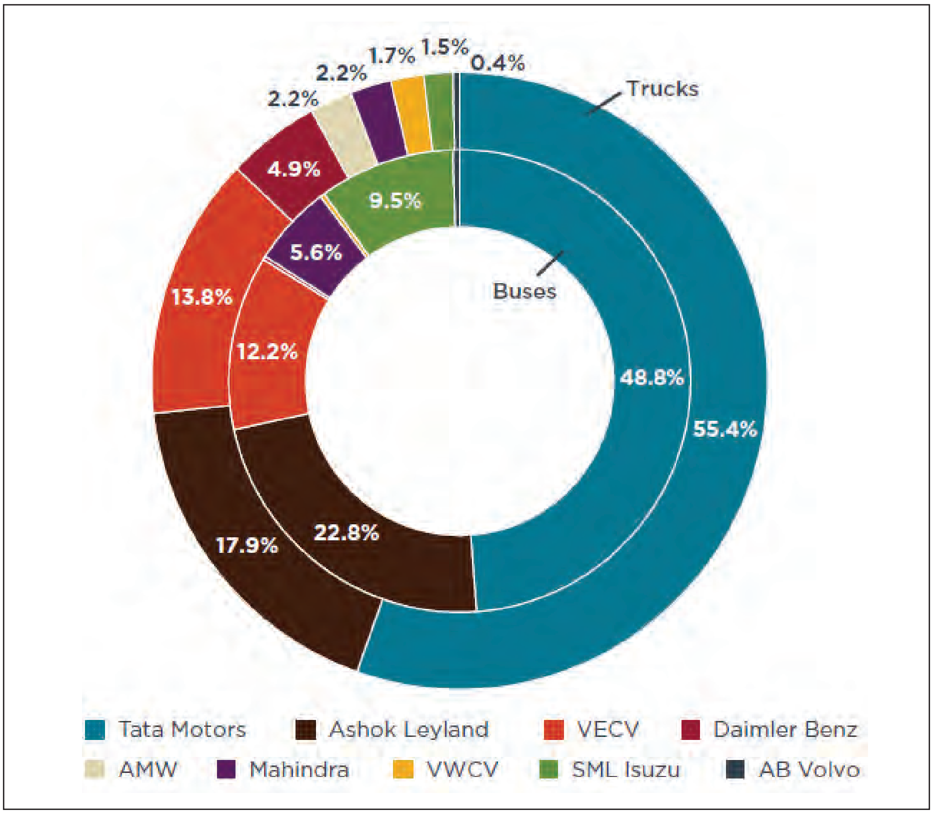
Source: https://www.dieselnet.com/standards/in/hd.php

Photo credit: Dinesh Mohan

4. Market analysis of heavy-duty vehicles in India

Sharpe (2015) highlights the importance of understanding the heavy-duty market analysis to establish fuel efficiency regulations for heavy-duty vehicles. The author analyses in detail the market shares of different heavy-duty vehicle manufacturers in India and its comparison with other major markets, such as United States, China, and the European Union. In addition to this, attributes of the Indian HDV engine is also explored to propose engine-based regulations. According to ICCT's Global Transportation Roadmap model, the sale of HDVs has increased by a factor of 2.7 since 2000. The 2013-14 sales were approximately 270,000. The Indian HDV market share is dominated by Tata Motors, as it represents almost half of truck and bus sales, followed by Ashok Leyland and VE Commercial Vehicles. These three manufactures account for approximately 85% of the sale of heavy-duty vehicles. Figure 6 shows the distribution of market shares.

Figure 6: Manufacturer market shares for new heavy-duty vehicles

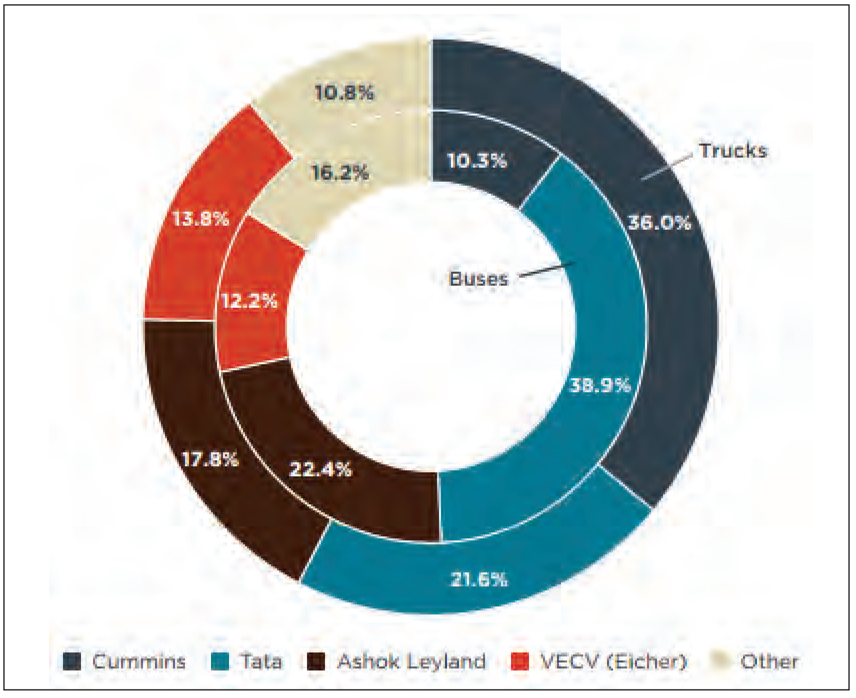


Source: Sharpe, 2015

* AMW: Asian Motor Works; VECV: VE Commercial Vehicles; VWCV: Volkswagen Commercial Vehicles

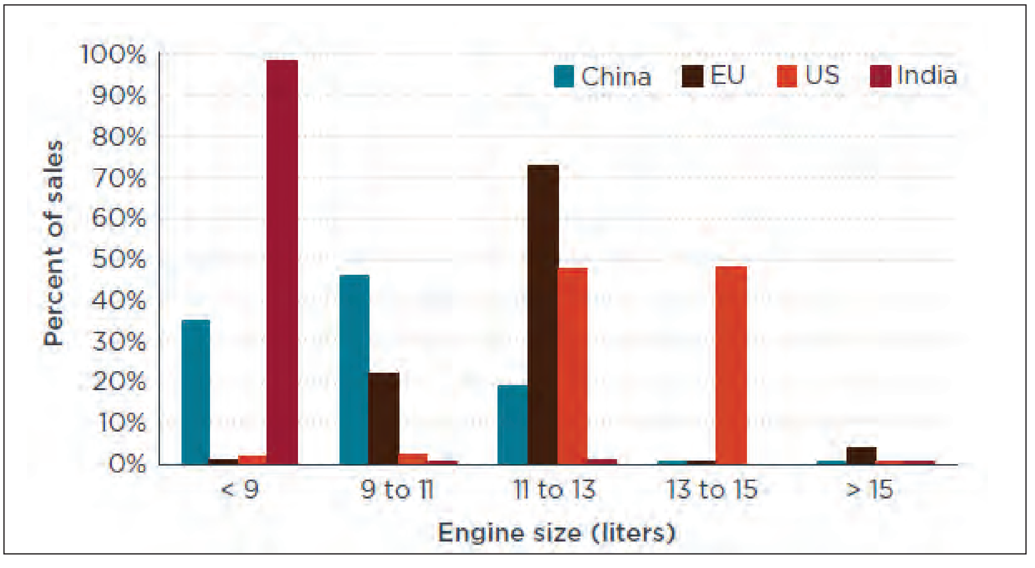
In terms of HDV engine manufacturers, figures show that Cummins, as an independent supplier, plays a significant role. Overall market share of Cummins account for approximately 30% of total HDV engines sold in India, and Tata represents 90% of Cummins' sale. Figure 7 shows the engine manufactures market share. Compared to countries like China and the U.S., as well as the European Union, the engines in India are smaller in capacity -- generally, less than 9 litres. Figure 8 shows the engine size distribution sales for different countries.

Figure 7: Engine manufacturer market shares for new truck and bus sales



*Source: Sharpe, 2015; *VECV: VE Commercial Vehicles*

Figure 8: Regional engine size distribution for vehicles over 15 metric tonnes



Source: Sharpe, 2015

Table 10 provides information regarding the top selling truck and bus models for various gross vehicle weight rating segments. It is observed that Tata models are the best-selling models in the case of heavy-duty vehicles.

Table 10: Top selling vehicle models by gross vehicle weight segment

Segment	Model	Fiscal year 2013-14 sales	Top model's % of segment sales	Top 5 models: % of sales	Top 10 models: % of sales
Trucks <7.5 tonnes	Tata LPT 407	9,078	32.0%	72.6%	87.3%
Trucks 7.5 - 12 tonnes	Tata LPT 1109	14,609	33.1%	56.6%	72.8%
Trucks 12 - 16 tonnes	Tata LPT 1613	8,262	23.1%	60.7%	80.1%
Trucks 16 – 25 tonnes	Tata LPT 2518	12,284	26.0%	41.7%	66.4%
Trucks >25 tonnes	Tata LPT 3118	11,419	36.2%	71.3%	88.4%
Tractor trucks >25 tonnes	Tata LPT 3518	2,811	16.2%	61.3%	79.1%
Buses <7.5 tonnes	Tata Winger	4,685	17.7%	48.3%	74.0%
Buses 7.5 – 12 tonnes	Ashok Leyland Lynx	2,284	13.1%	51.0%	78.9%
Buses >12 tonnes	Ashok Leyland Viking	5,424	24.9%	38.0%	60.2%

Source: Sharpe, 2015

The Environmental Protection Agency (2014) discusses the way the market characteristics of India may affect various elements of the emerging Indian freight market. This is summarised in Table 11.

Table 11: Characteristics of different market elements in the emerging truck market

Market Structure & Development	Role of domestic manufacturers in the commercial vehicle market	high/strong impact
	Impact of market cyclicality on domestic truck market sales and production	low/weak impact
Competitive Environment	Degree of market consolidation	high/strong impact
	Competitive abilities of domestic vs. foreign truck manufacturers	high/strong impact
Market Characteristics	Customer demand for more sophisticated commercial vehicles	low/weak impact
	Influence of Total Cost of Ownership on truck customer's purchase decision	very low/weak impact
	Demand for added–value services (e.g. car maintenance, repair services)	very low/weak impact
	Importance of fleet management solutions and telematics services	very low/weak impact
Globalisation Strategies	Interest of global OEMs entering the domestic market	very high/strong
	Competitive abilities of emerging OEMs to succeed on the global truck market	low/weak impact

Source: Environmental Protection Agency (EPA), 2014

Photo credit: Dinesh Mohan

5. Method: Details of freight vehicles entering Delhi

To understand the characteristics of current HDV and LDV vehicles entering and operating in Delhi, manual cordon counts and origin-destination surveys were conducted at 14 major entry points of Delhi during the months of September and October 2015. The counting was done continuously for 72 hours, capturing the data from Saturday to Monday, or Friday to Sunday. This was to ensure that data for one complete working day (either Friday or Monday), one mix day (Saturday) and one complete off day (Sunday) was captured. The details for surveyed locations are given in Table 12 and Figure 9. Data was collected for each category of freight vehicle at an interval of 15 minutes. Additionally, an origin and destination survey of the freight vehicles was conducted on a complete working day. The origin and destination survey was done at toll plazas and was based on stratified random sampling. The format for the origin and destination survey is attached in Appendix 1. The frequency of choosing vehicles for the origin and destination survey was based on volume of freight vehicles at that location. The results obtained are discussed in the following section. The analysis of the results include the count, characteristics in terms of vintage, mileage by fuel type, kilometres travelled, fuel used for various types of HDV and LDV vehicles, and emission standards for the present fleet. The results of this survey have been compared with the results obtained in previous studies for Delhi. The categorisation adopted for the analysis of HDV and LDV is shown in Table 13.

Table 12: Details of survey locations

SNo	Direction		Survey Location	Name of Road	Date and Day of Week		
	From	To					
1.	Noida	Delhi	DND flyover	DND flyover	26-Sep-15 (Saturday)	27-Sep-15 (Sunday)	28-Sep-15 (Monday)
2.	Noida	Delhi	Kalandikunj toll tax	Kalandikunj toll tax	26-Sep-15 (Saturday)	27-Sep-15 (Sunday)	28-Sep-15 (Monday)
3.	Ghaziabad	Delhi	Mandoli main toll	Mandoli main toll	19-Sep-15 (Saturday)	20-Sep-15 (Sunday)	21-Sep-15 (Monday)
4.	Mohan Nagar	Delhi	Mohan Nagar toll tax	Mohan Nagar toll tax	26-Sep-15 (Saturday)	27-Sep-15 (Sunday)	28-Sep-15 (Monday)
5.	Sonipat	Delhi	NH-1 Singhu border	NH-1	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)	14-Sep-15 (Monday)
6.	Mathura	Delhi	NH-2 Badarpur toll	NH-2	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)	14-Sep-15 (Monday)
7.	Gurgaon	Delhi	NH-8 Rajoukari toll plaza	NH-8	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)	14-Sep-15 (Monday)
8.	Tikri Border	Delhi	NH-10 Tikri Border	NH-10	11-Sep-15 (Friday)	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)

9.	Gaziabad	Delhi	NH-24 U.P Gate	NH-24	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)	14-Sep-15 (Monday)
10.	Gurgaon	Delhi	NH-236 Aaya Nagar toll tax	NH-236	12-Sep-15 (Saturday)	13-Sep-15 (Sunday)	14-Sep-15 (Monday)
11.	Noida	Akshar-dham	Noida major toll tax	Noida major toll tax	26-Sep-15 (Saturday)	27-Sep-15 (Sunday)	28-Sep-15 (Monday)
12.	Surajkund	M.B Road	Prahaldpur toll tax	Prahaldpur toll tax	19-Sep-15 (Saturday)	20-Sep-15 (Sunday)	21-Sep-15 (Monday)
13.	Saharanpur	Shadra	Loniborder SH-57	Loniborder SH-57	19-Sep-15 (Saturday)	20-Sep-15 (Sunday)	21-Sep-15 (Monday)
14.	Shahibabad	Delhi	Shahdara toll tax	Shahdara toll tax	19-Sep-15 (Saturday)	20-Sep-15 (Sunday)	21-Sep-15 (Monday)

Figure 9: List of entry points surveyed

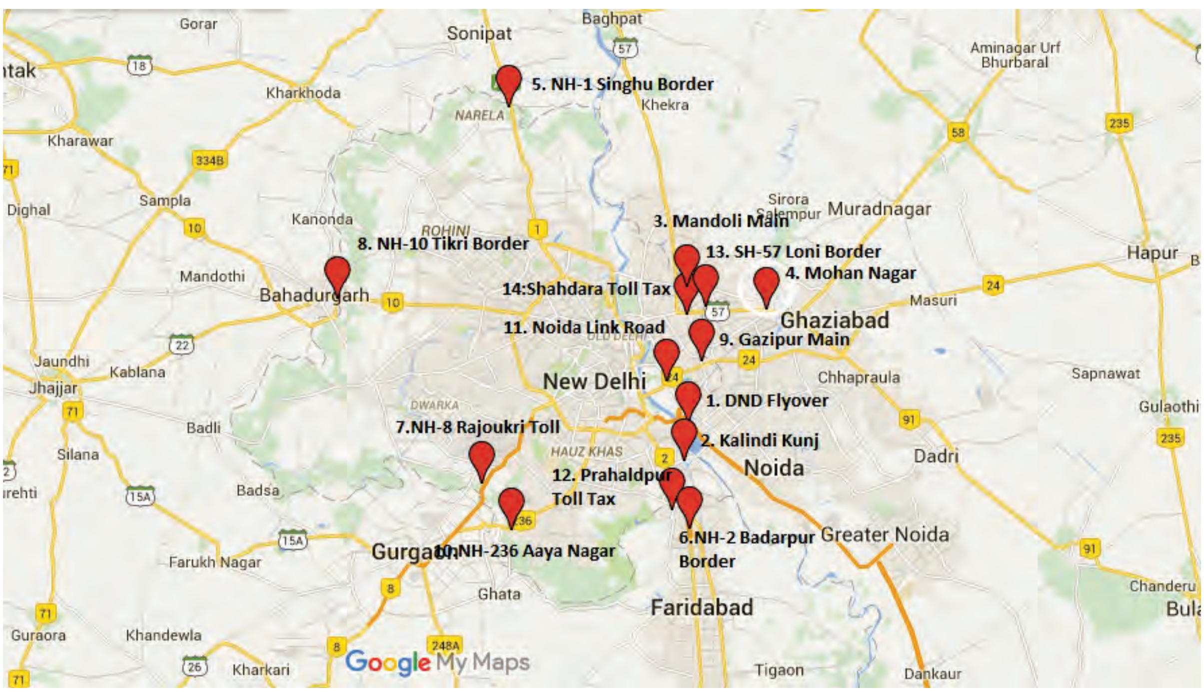


Table 13: Classification of freight vehicles for analysis

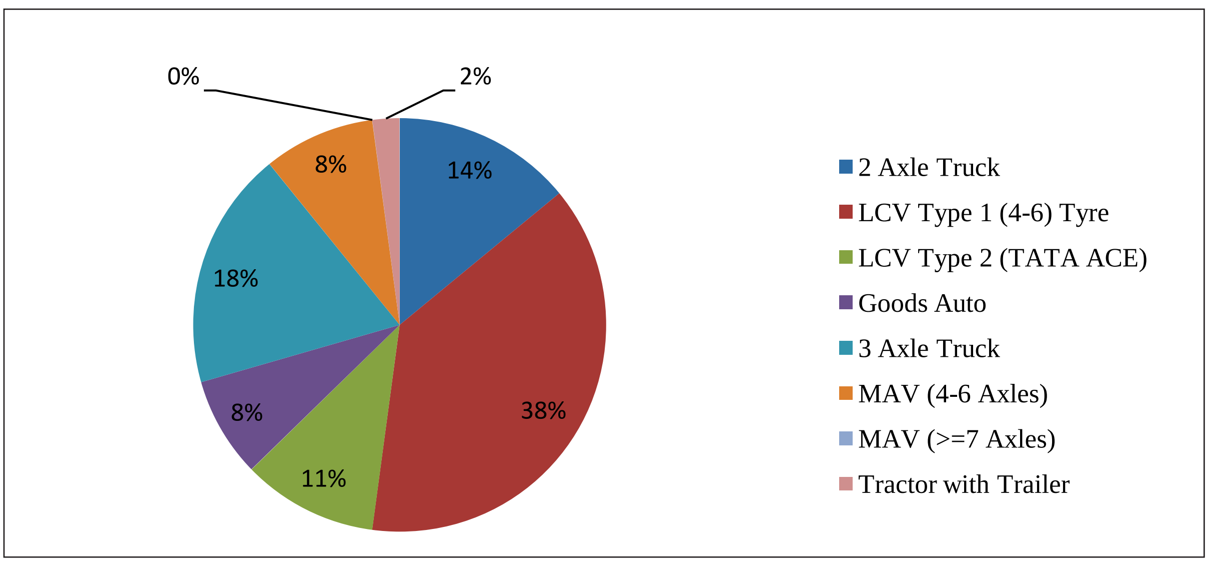
Heavy-Duty Vehicles	2 Axle Truck	
	3 Axle Truck	
	Multi Axle Vehicle (MAV) 4-6 axles	
	Multi Axle Vehicle (MAV) ≥7 axles	
Light-Duty Vehicles	Goods Auto	
	LCV Type 1 (4-6 tyres)	
	LCV Type 2 (Tata Ace)	
Tractor with Trailer	Tractor with Trailer	

5.1 Total number of vehicles entering Delhi

Figure 10 shows the total average daily traffic at 14 locations. The NH-8 Rajoukri toll has the maximum number of freight vehicles entering, followed by the NH-1 Singhu border. A total of 44,043 freight vehicles entered through all the entry points. Figure 11 shows the composition of type of freight vehicles entering the locations. Here, LCV refers to Light Commercial Vehicles and MAV refers to Multi Axle Vehicles. LCV with 4 to 6 tyres, 2 axle and 3 axle unit trucks form the dominant mode entering Delhi.

Figure 10: Count of freight vehicles entering Delhi through different entry points

Figure 11: Average Daily Traffic in percentage (in terms of number of vehicles)



5.2 Percentage of freight vehicles destined to Delhi

From an emission point of view, it is significant to note that in 2001 the Supreme Court ordered that, "no heavy, medium or light goods vehicles will ply on inter-state routes by passing through Delhi or New Delhi. It is only those goods vehicles, which on payment of octroi/toll tax carry goods to or from Delhi, which would be allowed to ply" (EPCA, 2004). The decision was made to control the pollution caused by the transit vehicles in Delhi. Table 14 summarises the results for 14 locations. As can be seen, 16% of the vehicles are non-destined to Delhi. Out of the total HDVs observed, 2 axle forms the highest percentage (8%) of non-destined vehicles, followed closely by 3 axle unit trucks (6.6%) and MAV (4-6 axle) (7%). In the case of light commercial vehicles, LCV Type-1 has the highest percentage (8.5%) of non-destined vehicles. Out of the total non-destined vehicles, it is observed that 61.8% are HDV and 38.16% are LCV.

Table 14: Percentage of different freight vehicle types destined and non-destined to Delhi

Distribution of vehicle as final destination (Percentage)			
S.No	Vehicle Type	Destined to Delhi	Not Destined to Delhi
		1	2
1	Goods Auto	97%	3%
2	LCV Type-1	85%	15%
3	LCV Type-2	91%	9%
4	2 Axle Truck	78%	22%
5	3 Axle Truck	83%	17%
6	Multi Axle Truck (4-6 Axle)	70%	30%
7	Multi Axle Truck (> 6 Axle)	100%	0%
8	Tractor with Trailer	100%	0%
Total		84 %	16%

5.3 Distribution of freight vehicles by location of registration

Registration location of freight vehicles entering Delhi, by type, has been compiled by recording the license plate numbers of the vehicles. Figure 12 shows that most of the light-duty vehicles, like goods auto and LCV Type-2 (Tata ace), are registered in Delhi. Most HDVs are registered outside Delhi. Table 15 shows the percentage contribution of each type of freight vehicle registered outside Delhi.

Figure 12: Distribution of freight vehicles as per the registration

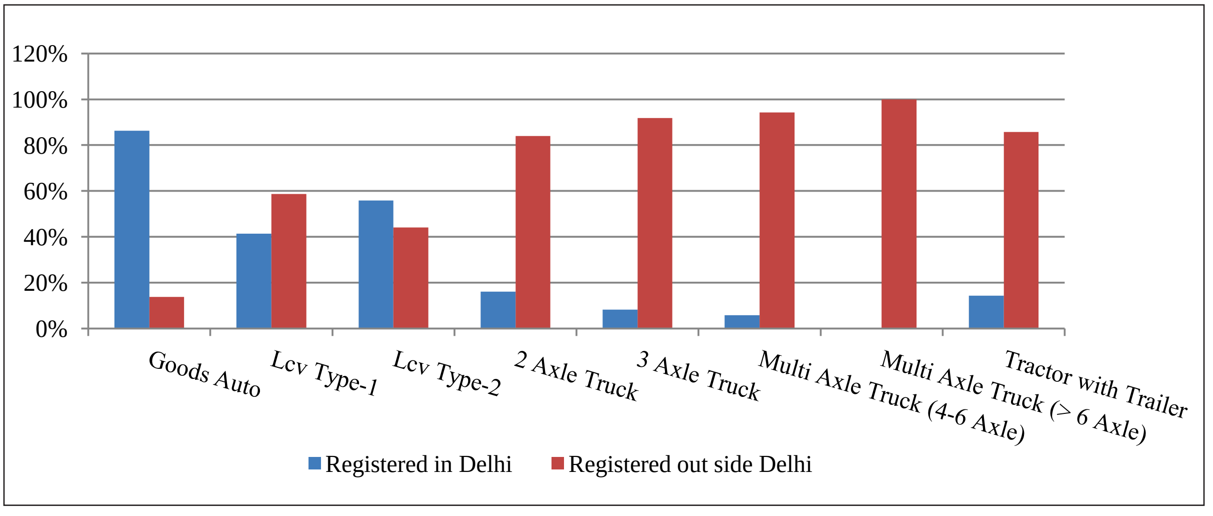


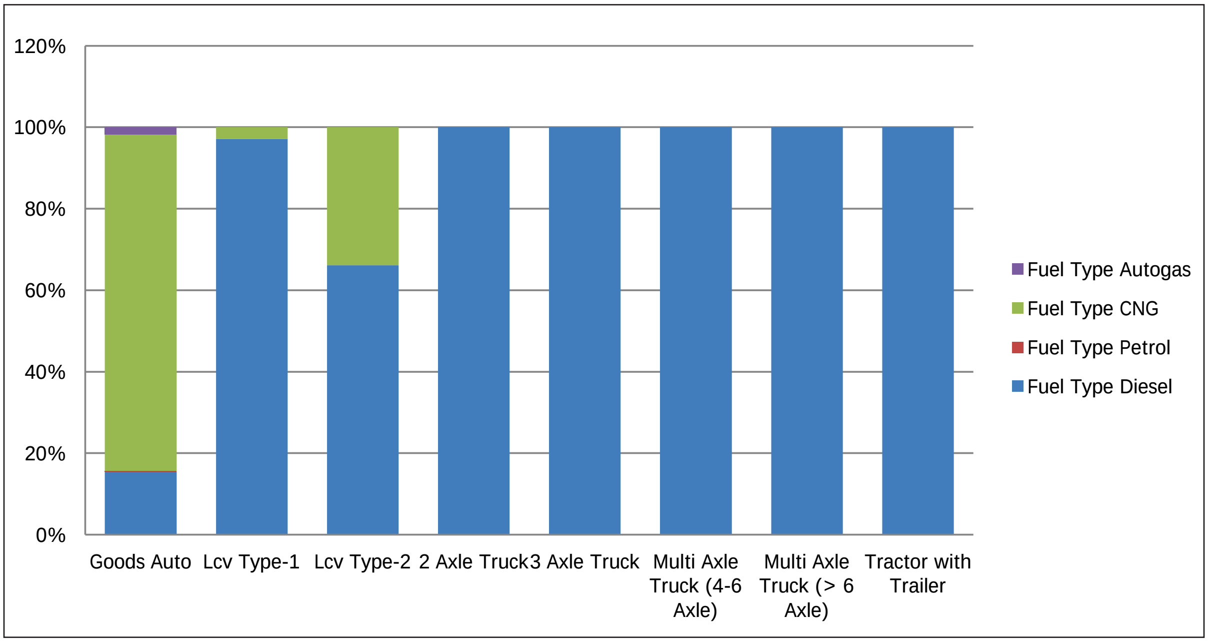
Table 15: Freight vehicles captured in survey state wise

State	Vehicle Type	Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer	Total	Total % Share
	Vehicle Code→ / ↓ State Code	1	2	3	4	5	6	7	8		
DELHI	DL	690	836	490	168	95	39	0	2	2320	33.79%
HARYANA	HR	62	697	220	621	846	345	1	9	2801	40.80%
PUNJAB	PB	1	52	4	23	19	11	0	0	110	1.60%
UTTRAKHAND	UK	0	21	1	11	2	2	0	0	37	0.54%
UTTAR PRADESH	UP	43	374	113	131	104	53	0	9	827	12.05%
RAJASTHAN	RJ	2	73	25	61	141	182	1	0	485	7.06%
HIMACHAL PRADESH	HP	0	17	6	24	12	0	0	0	59	0.86%
JAMMU KASHMIR	JK	0	9	4	16	6	5	0	0	40	0.58%
CHANDIGARH	CH	1	0	0	2	0	0	0	0	3	0.04%
BIHAR	BR	0	0	0	0	1	1	0	0	2	0.03%
KARNATAKA	KA	0	0	0	0	0	1	0	0	1	0.01%
TAMILNADU	TN	0	2	0	1	3	12	0	0	18	0.26%
NAGALAND	NL	0	3	1	1	9	12	0	0	26	0.38%
ANDRA PRADESH	AP	0	1	0	2	0	2	0	0	5	0.07%
CHHATISGARH	CG	0	0	0	0	1	3	0	0	4	0.06%
GUJRAT	GJ	1	4	1	5	3	18	0	0	32	0.47%
JHARKHAND	JH	0	1	0	1	2	1	0	0	5	0.07%
MAHARASHTRA	MH	0	7	2	1	9	9	0	0	28	0.41%
WEST BENGAL	WB	0	0	1	1	6	4	0	0	12	0.17%
MADHYA PRADESH	MP	1	11	2	9	18	9	0	0	50	0.73%

5.4 Classification of freight vehicles based on fuel type

Figure 13 shows the comparison between fuel type and freight vehicle type. Approximately 82% of goods auto use CNG as fuel. Meanwhile, 2 axle unit truck, 3 axle, multi axle truck (4-6 axle, >6 axle) and tractor with trailer run completely on diesel.

Figure 13: Fuel type vs. Freight vehicle type



5.5 Age profile of freight vehicles

Tables 16 and 17 show the age profiles of different types of freight vehicles entering Delhi. From the O&D survey the model year can be obtained, however, calculations require the month in which the vehicle was manufactured. It is assumed, for calculation purposes, that all the vehicles were registered mid-year. It is observed that less than 1% of the vehicles are older than 15 years; most of the vehicles are in the range of 2 to 10 years. Moreover, 60% of the freight vehicles entering comply with Bharat Stage III and IV norms for emissions. Thus, policies regarding the banning of such vehicles may not prove to be very useful in terms of reducing fuel emissions.

5.6 Mileage of freight vehicles

Tables 18 and 19 show the fuel consumption (km/litre) versus type of vehicle. The data is based on responses of drivers during the O&D survey and, therefore, liable to be based on drivers' experience. In general, as the age increases the fuel efficiency reduces. The mileage for diesel-run LDVs ranges from 7 to 13 km/litre, whereas for HDVs it is 3 km/litre. The mileage for LDVs running on Compressed Natural Gas (CNG) ranges from 11 to 23 km/litre. CNG is not used by HDVs.

5.7 Total kilometre travelled per year

Table 20 shows the total kilometre travelled by age and type of vehicle. The odometer reading can be at maximum five digits in the case of goods auto, and six digits for other freight categories. Thus, any response observed in the dataset with an odometer reading greater than the allowed limit is erroneous and has not been considered in the analysis while calculating mileage. The odometer reading is divided by the age of the vehicle to calculate total kilometre travelled per year. The general trend is that with the increase in age the kilometre travelled per year is decreasing. However, for LCV Type-2, 3 axle unit truck and 2 axle unit truck the total kilometre travelled per year remains constant regardless of vehicle age.

Table 16: Distribution of vehicles according to age

Distribution of vehicle according to age										
S.No	Age of Vehicle	Vehicle Type								Total
		Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer	
1	<= 2 years	26%	21%	17%	17%	14%	18%	0%	21%	19%
2	2 to 4 years	24%	20%	16%	20%	14%	21%	100%	29%	19%
3	4 to 6 years	21%	23%	23%	23%	25%	21%	0%	14%	23%
4	6 to 8 years	16%	17%	20%	17%	22%	20%	0%	7%	18%
5	8 to 10 years	8%	11%	9%	12%	14%	9%	0%	21%	11%
6	10 to 12 years	3%	5%	5%	7%	4%	5%	0%	7%	5%
7	12 to 15 years	2%	3%	9%	4%	6%	5%	0%	0%	5%
8	> 15 year (if any)	0.4%	1%	0.9%	0.6%	0.9%	0.3%	0%	0%	0.8%

Table 17: Distribution of vehicles according to emission standards implementations

Distribution of vehicle according to emission standards implementations (Percentage)										
S. No	Age of Vehicle	Vehicle Type								Total
		Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer	
1	Below India 2000	0%	0.2%	0%	0%	0.3%	0%	0%	0%	0.1%
2	India 2000	6%	8%	15%	11%	11%	10%	0%	7%	10%
3	Bharat II	24%	28%	29%	29%	36%	29%	0%	29%	29%
4	Bharat III& IV	71%	64%	57%	60%	53%	61%	100%	64%	61%

Table 18: Average fuel mileage (km/litre) of diesel vehicles according to their age

S. No	Age of Vehicle	Vehicle Type							
		Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer
1	<= 2 years	14	8	15	4	3	3	-	6
2	2 to 4 years	12	8	12	3	3	3	2	5
3	4 to 6 years	12	8	12	3	3	3	-	5
4	6 to 8 years	14	8	11	3	3	3	-	5
5	8 to 10 years	10	8	11	3	3	3	-	5
6	10 to 12 years	-	8	10	3	3	3	-	5
7	12 to 15 years	-	7	9	2	2	3	-	-
8	> 15 year (if any)	-	7	10	2	2.00	-	-	-
Total		13	8	12	3	3	3	2	5

Table 19: Average fuel mileage (km/litre) of CNG vehicles according to their age

S. No	Age of Vehicle	Vehicle Type							
		Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer
1	<= 2 years	24	12	20	-	-	-	-	-
2	2 to 4 years	23	11	19	-	-	-	-	-
3	4 to 6 years	22	11	18	-	-	-	-	-
4	6 to 8 years	20	11	17	-	-	-	-	-
5	8 to 10 years	17	9	16	-	-	-	-	-
6	10 to 12 years	21	8	15	-	-	-	-	-

7	12 to 15 years	-	6	14	-	-	-	-	-
8	> 15 year (if any)	-	-	13	-	-	-	-	-
Total		23	11	18	-	-	-	-	-

Table 20: Per year km travelled by vehicles according to age

S. No	Age of Vehicle	Vehicle Type							
		Goods Auto	LCV Type-1	LCV Type-2	2 Axle Truck	3 Axle Truck	Multi Axle Truck (4-6 Axle)	Multi Axle Truck (> 6 Axle)	Tractor with Trailer
1	<= 2 years	20131	38343	26686	52143	79574	72176	-	12134
2	2 to 4 years	20349	37415	26721	55486	78734	57171	89985	15132
3	4 to 6 years	13687	34869	24997	58102	62398	63598	-	20494
4	6 to 8 years	10083	38807	26813	54645	52703	55142	-	6075
5	8 to 10 years	7756	36102	26519	52493	63356	69526	-	9727
6	10 to 12 years	8126	42590	25520	49878	63509	68082	-	17849
7	12 to 15 years	-	40344	31326	56546	60741	62323	-	-
8	> 15 year (if any)	-	36679	33733	57979	61709	-	-	-
Total		18290	37374	26639	54705	65851	62773	89985	13181
Rounded value to nearest 500		18000	37000	26500	54500	65500	62500	89500	13000

5.8 Comparison with previous studies

The Centre for Science and Environment (EPCA, 2015) surveyed freight vehicles to quantify the number of trucks entering and exiting Delhi. The survey was conducted on nine major points of Delhi, which accounts for approximately 75% of freight vehicles entering, as per MCD data by using video camera method. The results of the study are compared with those of CSE in Table 21.

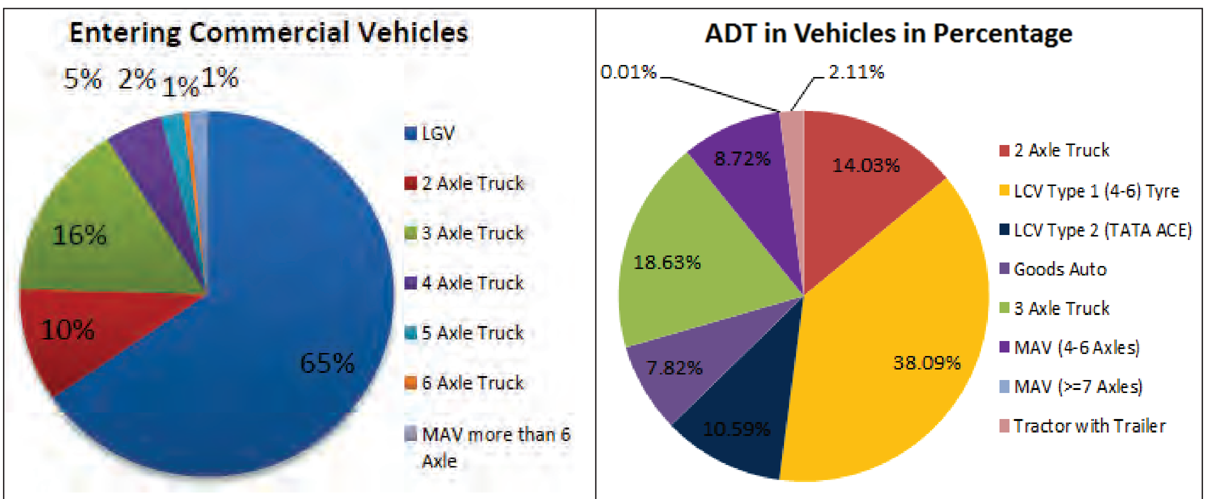
Table 21: Comparison of average daily traffic at entry points (EPCA, 2015) vs. IITD study

Entry points	Average daily traffic		Difference (%)
	CSE	IITD study	
Kundli Border/NH-1	8369	5827	30
Tikri Border on NH-10	3700	3776	2.1
Rajokari Border on NH-8	9919	8989	9.4
Badarpur	4460	4335	2.8
Kalindikunj	4271	4603	7.7
Ghazipur	3914	3355	14.2
Shahdara	3955	3003	24
Total	38,588	33,888	12

An overall variation of approximately 12% is observed from the CSE data that is not statistically significant. The difference may be attributed to seasonal variation, as the CSE study was conducted in June-July and the IITD study was conducted in September-October 2015.

It is observed that 65% light goods vehicles enter Delhi, followed by 16% 3 axle unit trucks and 10% 2 axle unit trucks. Composition of the vehicles entering Delhi, as per the CSE study, is shown in Figure 14(a). From the IITD study, Figure 14(b), it is observed that the highest share of 57% is by light goods vehicles, followed by 19% 3 axle unit trucks and 14% 2 axle unit trucks. For the number of non-destined freight vehicles, the origin and destination survey was conducted by CSE on NH1 and NH10. CSE observed that around 23% of all commercial vehicles travelling on NH1 are non-Delhi destined, which is comparable to the IITD result of 24%. Furthermore, on average, it is observed that around 16% of all commercial vehicles travelling from the 14 locations are non-Delhi destined.

Figure 14: Distribution of commercial vehicles entering Delhi (EPCA, 2015) vs. IITD study



(a) CSE study **(b) IITD study**

** LGV of CSE (65%) study is comparable to LCV Type-1, LCV Type-2 and Goods Auto of IIT study (56%)

*** 4, 5, 6, >6 axle trucks of CSE study (9%) are comparable to MAV (4-6 axles), MAV (>=6 axles) of IIT study (8.72%)

Comparison of Mileage of HDV and LDV

IISD (2013) found that "new trucks with a carrying capacity between 15 and 21 tonnes give a mileage of 3.5 to 4 km/litre and small trucks with a 2.5 tonne capacity give a mileage of 8 km/litre. After five to eight years, the mileage for large trucks reduces to 2 to 2.5 km/litre." Similarly, CSIR (2014), from the observations of secondary sources, found 5.05 km/litre for buses, 8.58 km/litre for LCVs, 4.46 km/litre for HCVs and 3.59 km/litre for multi axle vehicles. According to the classifications used of LDVs and HDVs running on diesel, it is observed that the mileage for LDVs varies from 7.86 to 13.08 km/litre, and from 2 to 3.15 km/litre for HDVs. For LDVs running on CNG the mileage varies from 11.01 to 23.13 km/litre.

Photo credit: Dinesh Mohan

6. Policies for improving efficiency of HDV

From the above discussion it is clear that a great deal of literature and recommendations are available on testing procedures to be adopted and their implications on setting emission standards in India. However, the introduction of new emission standards in new engines may take decades to fully consolidate in the market, depending on the growth of freight vehicles in the country. Furthermore, little reliable information is available in terms of fuel efficiency and amount of emissions generated by in-use vehicle fleet before the introduction of new standards. Moreover, the scepticism created by the introduction of new fuel efficient technologies, in terms of performance in real world conditions, makes fleet operators reluctant to invest in these technologies. The situation becomes critical when a single owner is associated with making decisions. This creates a need for an integrated approach where the emission standards are to be accompanied with policies promoting HDV modernisation and improved efficiency. The Clean Air Initiative for Asian Cities Center (2010) proposes the three generalised approaches of “avoid”, “shift” and “improve” in order to improve the freight operations in Asian countries. With these three approaches as the base, challenges and opportunities of various freight strategies, within the Indian context, are explored further. The “avoid” approach includes the reduction of kilometres driven by freight vehicles through proper land use planning, industrial zoning, improving the coordination among various stakeholders in the supply chain and increasing the limit of single axle load. The European Business and Technology Centre (EBTC) (2014) highlights the lack of warehousing standards, poor awareness of warehouse technologies and fragmented HDV ownership in India as major challenges that limit the coordination among various stakeholders.

The second approach of “shift” refers to an increase in the capacity of sustainable modes like railways and water borne vessels. As previously discussed, the share of Indian railways has fallen during the last decade, therefore, efforts need to be made to accelerate the investment in railways to restore its share in Indian freight transport. Significant improvements in railway infrastructure will help in realising both environmental and economic benefits. The construction of Dedicated Freight Corridors in India will serve to be a lucrative option for the efficient movement of goods.

The third approach, “improve”, includes various programmes and strategies to improve the fuel efficiency and emissions for HDVs. A few of the important strategies are discussed in detail below.

6.1 Green freight program

The green freight program particularly focuses on both the regulatory and voluntary partnerships. The regulation standards are set for new vehicles and the partnership approach takes into account the present in-use fleet of vehicles. Voluntary partnership refers to a partnership where government and private sector work together to address challenges of public policy. A legal agreement is signed where either party can withdraw at any time without fear of being penalised. The following considerations (Table 22) are to be taken into account before the development of green freight framework (Environment Protection Agency, 2014).

Table 22: Factors to be considered for the development of green freight program

Factors	Implications
Cost of operation	In expanding freight markets → Purchasing price of vehicle is important In mature freight markets → Vehicle service and maintenance is important
Projected Growth	Emerging freight markets → Greater scope of early introduction of vehicle standards In stable freight markets → Market penetration is gradual
Compilation of baseline industry statistics	• Identification of numbers and size of carriers responsible for significant fuel emissions → Important for prioritising goals • Freight vehicle activity → Measured by yearly growth in distance travelled, revenue, tonnage hauled • Knowledge of vehicle characteristics in terms of vehicle size, fuel type used and age distribution → Important for emission calculations • Fuel quality: Emission control technologies depend on sulphur content of fuel. India has high levels of sulphur in diesel ranging up to 350 ppm.

Source: Derived from Environment Protection Agency, 2014

Based on the above considerations, it is clear that being an emerging freight market offers a great opportunity for the introduction of fuel efficient technologies in India. The early introduction of fuel efficient technologies can ensure that the new fleet of vehicles will be operative for the next two decades. Furthermore, efforts are to be made to reduce the sulphur content of fuel to utilise the full potential of emission control technologies. Additionally, the use of better quality fuel will help to represent the emissions from the test cycles to the real world conditions.

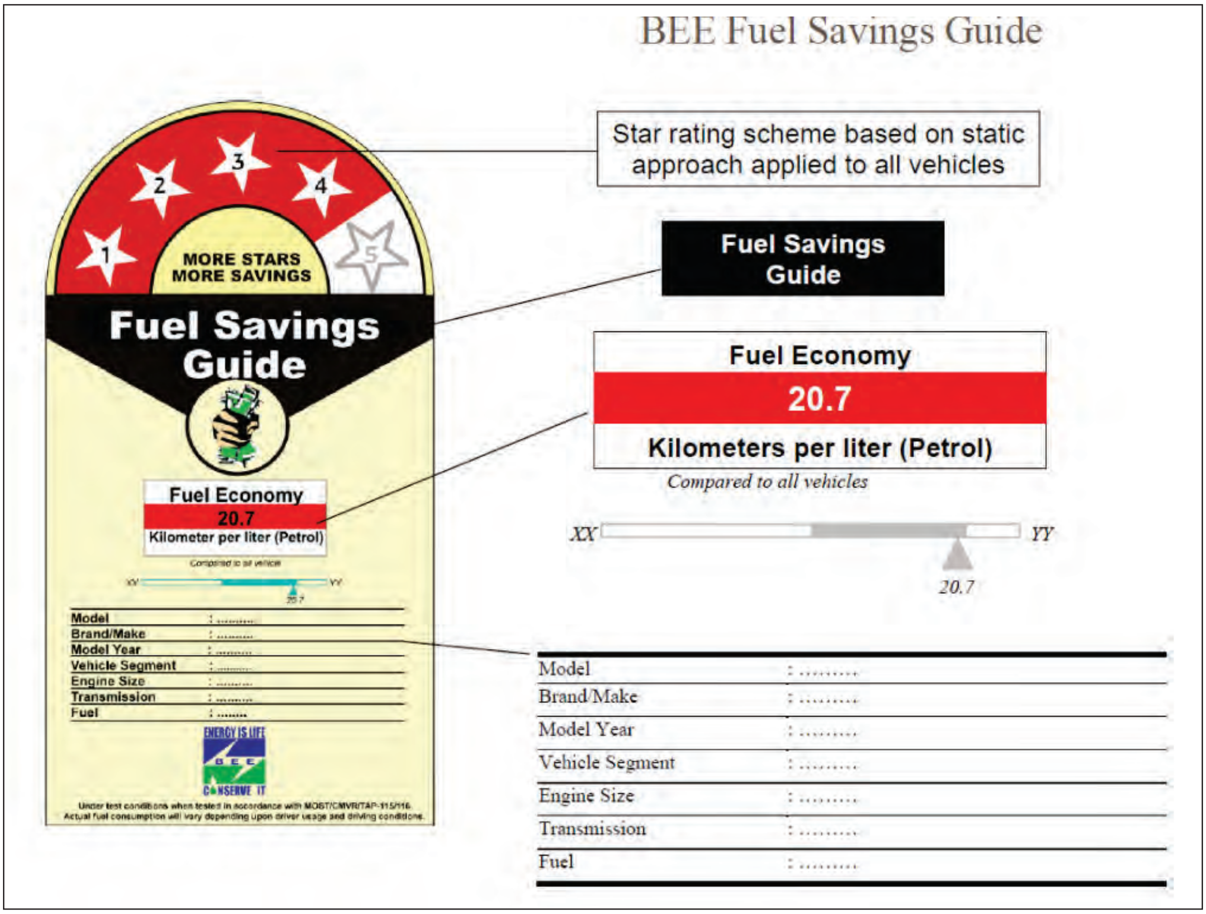
6.2 Vehicle fuel economy labelling

Vehicle labelling is used to inform the purchaser of the vehicle rating, in terms of fuel economy. It is found to have influence on the purchaser's behaviour and acts as a motivational tool to buy fuel efficient vehicles. Vehicle labelling has been adopted in various countries like the U.S., China, Japan, Brazil, and European countries. Some of the characteristics of vehicle labelling are discussed below:

- The labels can have graphical schemes, star ratings or numerical scales from 1 to 10.
- The labels may include information regarding fuel economy, CO_2 emission, fuel cost and expected savings, etc. (Figure 15).
- The labels can be absolute, i.e. based on fuel efficiency regardless of size, fuel type, weight, or labels can be class-based. The former labels help consumers choose the most efficient vehicle, whereas the latter labelling system is useful if the consumer has to choose a vehicle belonging to a particular class.

It is essential to choose the appropriate method of labelling to avoid chances of confusion and evasion. Due to diversity in composition of freight vehicles -- they carry more freight in tonnes/km -- it is observed that large and more fuel consuming freight vehicles may be rated better than small ones. It is suggested that in India weight-based and CO_2 emission-based fuel economy labelling will be made mandatory by the year 2016.

Figure 15: BEE vehicle labelling system for passenger cars in India



Source: http://www.indiaenvironmentportal.org.in/files/file/BEE%20Consultation%20Paper-21Oct2011.pdf

6.3 Vehicle taxation

Vehicle taxation is introduced to make fuel efficient vehicles fiscally attractive for the buyers, encouraging them to shift to more fuel efficient vehicles. The vehicle taxes may be based on CO_2 emissions, engine capacity or vehicle mass. Vehicle taxes in Europe are linked to CO_2 emissions, whereas in Japan they are linked to vehicle emission standards compared to target values. The vehicle taxing in India and China is based on vehicle engine size, which might lead to the purchase of smaller but not necessarily more efficient trucks. For users to buy fuel efficient vehicles in India, incentives are required.

6.4 Fuel taxation

Fuel taxes are introduced to control driving behaviour after purchase. It is found that both fuel taxing and vehicle taxing play an important role in diesel consumption and CO_2 emissions. As discussed earlier, fuel taxes in India vary from state to state. The impacts of differential taxation on HDV operation in India have not been studied.

6.5 Eco driving

The main purpose of Eco driving is to teach how to drive vehicles more efficiently. It is observed that the average miles driven by professional drivers far exceed private drivers. The Japanese government provides incentives to drivers who install eco driving management systems in their vehicles.

Table 23 summarises various legislations and policies for HDV around the world.

Table 23: Summarises various legislations and policies for HDV around the world

Policy name	Country	Start Year	Status	Type of policy	HDV (/CO_2) Relevance
Heavy-duty vehicle emissions test facility	Australia	2008	In force	Funding	HDV specific (+ve impact)
Long Combination Vehicle (LCV) Programme	Canada	2009	In force	Pilot scheme	HDV specific (+ve impact)
Hong Kong – Tax incentives for environmentally Friendly Commercial Vehicles	China (Hong Kong)	2008	In force	Tax incentive	Mention of HDV (+ve impact)
Top Runner Programme: Fuel efficiency standards for Heavy-duty vehicles	Japan	2006	In force	Regulatory	HDV specific (+ve impact)
Green Taxation and Subsidies for Automobiles	Japan	2001	In force	Taxation	Mention of HDV (+ve impact)
Heavy-Duty Vehicle Idling Emission Reduction Program	United States	2005	In force	Regulatory	HDV specific (+ve impact)
Heavy Vehicles Fee	Switzerland	2001	In force	Taxation	HDV specific (-/+ve impact)
SmartWay Transport Partnership	US	2004	Implemented	Regulatory	HDV specific (+ve impact)
FleetSmart - Natural Resources Canada	Canada	1997	Implemented	Vehicle Fee	HDV specific (+ve impact)

CARB Zero Emission Bus Programme	US	2007	In place	Training	HDV specific (+ve impact)
California Hybrid Truck and Bus Voucher Incentive Project	US			Training	HDV specific (+ve impact)
US EPA and DOT proposal on GHG Emission Standards and Fuel Efficiency Standards for medium and Heavy-Duty Engines and Vehicles	US	2010	Proposed	Regulation	HDV specific (+ve impact)

Source: AEA, 2011

7. References

AEA, (2011). Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy.European Commission – DG Climate Action. Available at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf

Arthapedia.in, (2015). Central Road Fund (CRF) - Arthapedia. [online] Available at: http://www.arthapedia.in/index.php?title=Central_Road_Fund_(CRF)

Askin, A., Barter, G., West, T. and Manley, D. (2015). The heavy-duty vehicle future in the United States: A parametric analysis of technology and policy tradeoffs. Energy Policy, 81, pp.1-13.

Auto Fuel Vision and Policy 2025 Report. (2014), Government of India. Available at: http://petroleum.nic.in/docs/autopol.pdf

Bandivadekar, A. (2015). Direct progression from Bharat IV to Bharat VI national vehicle emission standards in India, ICCT. Available at: http://www.theicct.org/leapfrogging-bsIV-to-bsVI-india

Bansal, G. and Bandivadekar, A. (2013). Overview of India's Vehicle Emissions Control Program: Past Successes And Future Prospects, ICCT. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf

Clean Air Initiative for Asian Cities Center, (2010). Challenges and Opportunities For An Environmentally Sustainable Road Freight Sector In Asia. Clean Air Initiative for Asian Cities Center., pp.1-29. Available at: http://cleanairasia.org/wp-content/uploads/portal/files/documents/Freight_Paper-_UNCRD_FINAL_Aug2010.pdf

CSIR-Central Road Research Institute, (2014). Fuel Efficiency Standards of Heavy Duty Vehicles in India, Shakti foundation. Available at: http://shaktifoundation.in/wp-content/uploads/2014/02/Fuel-Efficiency-Standards-of-HDV-in-India.pdf

Delhi Development Authority, (2010). Master Plan for Delhi - 2021. VIBA Press Pvt. Ltd. Available at: http://dda.org.in/tendernotices_docs/jan12/reprint%20mpd2021.pdf

Dhar, S. and Shukla, P. (2015). Low carbon scenarios for transport in India: Co-benefits analysis. Energy Policy, 81, pp.186-198.

Dholakia, H., Purohit, P., Rao, S. and Garg, A. (2013). Impact of current policies on future air quality and health outcomes in Delhi, India. Atmospheric Environment, 75, pp.241-248.

Dieselnet.com, (2015). Emission Standards: India: Heavy-Duty Truck and Bus Engines. [online] Available at: https://www.dieselnet.com/standards/in/hd.php

Environment Protection Agency (EPA), (2014). How to Develop a Green Freight Program: A Comprehensive Guide and Resource Manual. Enivoronment Protection Agency (EPA), pp.1-198. Available at: http://www3.epa.gov/smartway/forcountries/documents/420b14054.pdf

EPA, (2008). Average In-Use Emissions from Heavy-Duty Trucks. Available at: http://www3.epa.gov/otaq/consumer/420f08027.pdf

EPCA, (2015). Report on strategies to reduce air pollution from trucks entering and leaving Delhi. Centre for Science and Environment. Available at: http://cseindia.org/userfiles/EPCA%20Report%20(October%202015).pdf

European Business and Technology Centre (EBTC), (2014). Overview of the Demand in the Indian Transport and Logistics Industry. pp.1-69. Available at: http://ebtc.eu/index.php/information-hub/publications/transport-publications/163-market-reports-transport/264-overview-of-demand-in-the-indian-transport-and-logistics-industry

German, J. and Lutsey, N. (2010). Size or Mass?: The Technical Rationale for Selecting Size as an Attribute for Vehicle Efficiency Standards. ICCT, pp.1-16. Available at: http://www.theicct.org/sites/default/files/publications/ICCTpaper_sizewt_final.pdf

Guttikunda, S. and Kopakka, R. (2013). Source emissions and health impacts of urban air pollution in Hyderabad, India. Air Qual Atmos Health, 7(2), pp.195-207.

Huai, T., Shah, S., Wayne Miller, J., Younglove, T., Chernich, D. and Ayala, A. (2006). Analysis of heavy-duty diesel truck activity and emissions data. Atmospheric Environment, 40(13), pp.2333-2344.

ICRA RESEARCH SERVICES, (2013). Indian Commercial Vehicle Industry. Available at: http://www.icra.in/Files/ticker/Indian%20CV%20Industry-An%20Update.pdf

India Energy Security Scenarios (IESS), 2047, (2015). User Guide for India's 2047 Energy Calculator Transport Sector. Available at: http://www.indiaenergy.gov.in/

Poulikakos, L., Heutschi, K. and Soltic, P. (2013). Heavy duty vehicles: Impact on the environment and the path to green operation. Environmental Science & Policy, 33, pp.154-161.

Purohit, M. and Purohit, V. (2010). Road User Taxes in India Issues in Tax Policy and Governance. Planning Commission, Government of India. Available at: http://planningcommission.nic.in/reports/sereport/ser/ser_ruti.pdf

RITES, (2014). Total Transport System System Study on Traffic Flows and Modal Costs (Highways, Railways, Airways and Coastal Shipping). Available at: http://planningcommission.nic.in/reports/genrep/index.php?repts=rites.html

Sessa C and Enei R, (2009). EU transport demand: Trends and drivers. European Commission Directorate-General Environment, p.61. Available at: http://www.eutransportghg2050.eu/cms/assets/EU-Transport-GHG-2050-Task3-Paper-EU-Transport-Trends-and-Drivers-22-12-09-FINAL.pdf

Sharma, S., Dutta, A., Sitalakshami, C., Hiremath, R. and Sundar, S. (2014). Developing pathways for fuel efficiency improvements in HDV sector in India, Shakti foundation. Available at: http://shaktifoundation.in/report/pathways-fuel-efficiency-improvements-hdv-sector-india/

Sharpe, B. (2015). Market analysis of heavy-duty vehicles in India, ICCT. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_India-HDV-market_20150809.pdf

Sharpe, B. (2015). Testing methods for heavy-duty vehicle fuel efficiency: Trends from regulatory programs around the world and implications for India. ICCT, pp.1-20. Available at: http://www.theicct.org/sites/default/files/publications/ICCT_HDV-test-procedures_India_20150420.pdf [Accessed 4 Dec. 2015].

TERI, (2014). Advancement of Fuel Quality and Vehicle Emissions Norms to Improve Urban Air Quality in India. Available at: http://www.teriin.org/policybrief/index.php?a=15

The International Institute for Sustainable Development (IISD), (2013). The Impacts of India's Diesel Price Reforms on the Trucking Industry. The International Institute for Sustainable Development. Available at: https://www.iisd.org/gsi/sites/default/files/ffs_india_irade_trucking.pdf

Transportpolicy.net, (2015). Global Comparison: Heavy-duty Fuel Economy and GHG - Transportpolicy.net. [online] Available at: http://transportpolicy.net/index.php?title=Global_Comparison:_Heavy-duty_Fuel_Economy_and_GHG

Trends in Growth and Development of Transport. (2014), National Transport Development Policy Committee. Available at: http://planningcommission.nic.in/sectors/index.php?sectors=National%20Transport%20Development%20Policy%20Committee%20(NTDPC)

User Guide for India's 2047 Energy Calculator Transport Sector. (n.d.). India Energy Security Scenarios, 2047. Available at: http://www.indiaenergy.gov.in/

World Health Organisation, (2014). WHO's Ambient Air Pollution database Update 2014. World Health Organisation. Available at: http://www.who.int/phe/health_topics/outdoorair/databases/AAP_database_results_2014.pdf

Appendix 1: Origin and Destination format

STUDY OF TRIP GENERATION MODEL FOR URBAN FREIGHT (IIT DELHI)

ORIGIN-DESTINATION SURVEY FOR FREIGHT VEHICLES

NAME OF SECTIONS:

LOCATION: ____________

SHEET NO.

DIRECTION: FROM: ____________ TO: ____________

DATE

Time of Interview	Registration number	Vehicle Type/ Fuel used	Year/make/model	Ownership	Odometer Reading	Fuel Mileage/Kms/litre of fuel	Commodity Type	Commodity Weight	Origin Zone: District/city	Origin Zone: State	Origin Zone: Industry Type	Destination Zone: District/city	Destination Zone: State	Destination Zone: Industry Type	Exit Point via Route***	Ready to take alternate long route:** Yes/No	Trip Frequency
Codes																	
Vehicle Type							Fuel used		Frequency	Ownership		*** IF destination is outside Delhi				Name of the Enumerator:	
1- Goods Auto							D- Diesel		1- Daily	1- Owned by Driver		** IF destination is outside Delhi					
2- LCV (Type-1)							P- Petrol		2- 2 times Weekly	2- Owned by Company							
3- LCV (Type-2 Tata Ace)							C- CNG		3- Weekly	3- Owned by Other Operator							
4- Two Axle Trucks							A- Autogas		4- Fortnightly	4- On Hiring						Name of the Supervisor:	
5- Three Axle Trucks									5- Monthly								
6- Multi-Axle Vehicle (4 to 6 Axle)									6- Occasionally								
7- Multi-Axle Vehicle (> = 7 Axles)																	
8- Tractor with Trailer																	

Appendix 2: Survey site photographs

Classified Volume Count At (DND FLYWAY) During Day Time

Classified Volume Count At (NOIDA MAJOR) During Day Time


Origin / Destination Survey At (RAJALKARI) During Day Time

Classified Volume Count At (DND FLYWAY) During Night Time

Information about the project:

UNEP Transport Unit in Kenya, UNEP DTU Partnership in Denmark and partners in India have embarked on a new initiative to support a low-carbon transport pathway in India. The three-year EUR 2.49 million project is funded under the International Climate Initiative of the German Government, and is designed in line with India's National Action Plan on Climate Change (NAPCC). This project aims to address transportation growth, development agenda and climate change issues in an integrated manner by catalyzing the development of a Transport Action Plan at the national level and Low-Carbon Mobility plans at the cities level.

Key local partners include the Indian Institute of Management, Ahmedabad, the Indian Institute of Technology, Delhi and CEPT University, Ahmedabad. The cooperation between the Government of India, Indian institutions, UNEP, and the Government of Germany will assist in the development of a low-carbon transport system and showcase best practices within India, and for other developing countries.

Homepage : www.unep.org/transport/lowcarbon

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