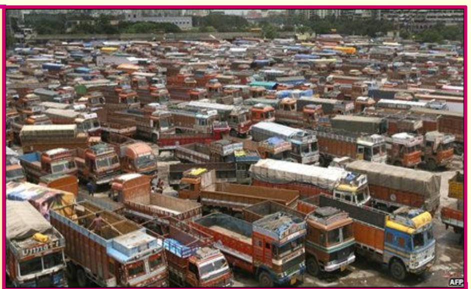
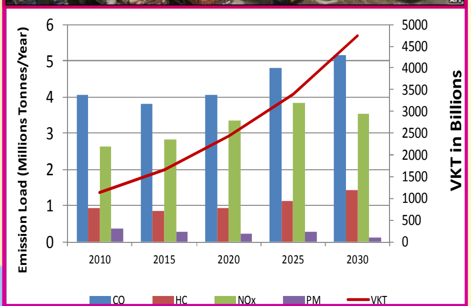
Fuel Efficiency Standards of Heavy Duty Vehicles in India

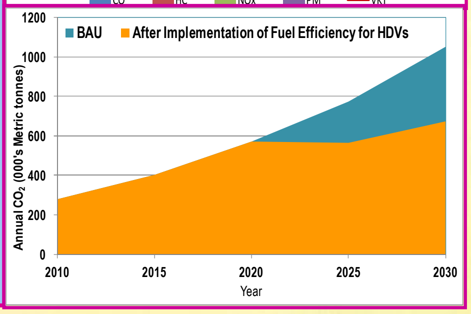
Final Report

Submitted to

SHAKTI SUSTAINABLE ENERGY FOUNDATION







April, 2014

सी एस आई आर - केंद्रीय सड़क अनुसंधान संस्थान, नई दिल्ली-110025

CSIR - CENTRAL ROAD RESEARCH INSTITUTE

NEW DELHI-110025

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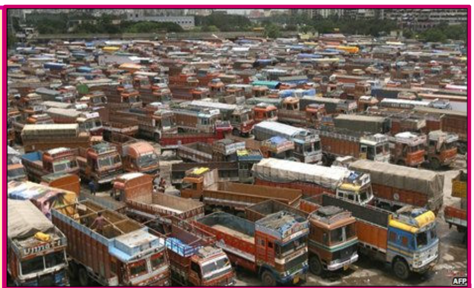

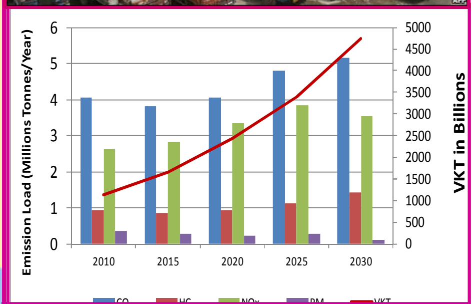

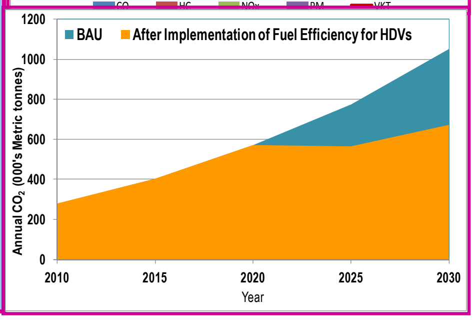

April, 2014

CSIR-Central Road Research Institute
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FOREWORD

Globally, the transportation sector is the second largest energy consuming sector after the industrial sector and accounts for 30% of the world's total delivered energy. In 2008 the transportation sector accounted for about 22% of total world CO_2 emissions. It is believed that this sector is currently responsible for nearly 60% of world oil demand. Within this sector, road vehicles dominate oil consumption and represents 81% of total transportation energy demand. Current trends in energy supply and use are unsustainable – economically, environmentally and socially. According to IINCCA (Indian Network for Climate Change Assessment-2007) the road transport, being the dominant mode of transport in the country, emitted 87% of the total CO_2 emissions from the transport sector. Hence the energy efficient road transport sector is essential to reach targeted reduction in Green House Gas (GHG) emissions by using the energy efficient technologies. In India there is rapid increase in Vehicle Kilometres Travelled (VKT) by all the road based transport modes since 2002. The per capita VKT stands at 1437 Kms (2013) is expected to increase to more than three times by 2030 which results in 1050 thousand metric tonnes of CO_2 out of which Heavy Duty Vehicles (HDVs) alone contribute to 70%. Hence, there is a very urgent need to coordinate political will and analytical research work in order to take concrete action. By identifying the steps needed to accelerate the implementation of radical technology changes, the suitable roadmaps will enable Government, industry and financial partners to make the right choices. This will in turn help the society to make the right decisions.

Hence, formulating the HDVs fuel efficient measures are very important to tackle the CO_2 emissions from the road transport sector. It is possible to reduce the CO_2 emissions over 50% of oil use around the world is for transport and three-quarters of the energy by using the very energy efficient technologies which are available in the market, also demonstrated in Japan, USA and other countries formulating fuel efficiency standards for the HDVs.

The present study attempted to propose a road map on existing low cost fuel efficiency technologies, how much they could improve efficiency, and how this potential can be realised, especially via government policies. It is crucial that government should tackle the problem of poor vehicle fuel economy, and this document provides an important guidance. The present study estimated that there is considerable reduction in CO_2 emissions of 192 thousand metric tonnes in the year 2025 and 343 thousand metric tonnes in the year 2030. About 147 billion litres in the year 2025 and 262 billion litres in the year 2030 of fuel will be saved. From the above discussion, it is very important that the fuel efficiency of the HDVs in addition to the emission norms also play very important role in reduction of the vehicular pollution. Hence it is very important to the Indian conditions to adopt the fuel efficiency of the HDVs.

Most of the technologies covered in this study are already available, commercially viable and cost-effective. To roll-out the fuel efficiency policy of the HDVs for Indian conditions all the necessary work should be started from 2015 and implement it from 2020. After the implementation necessary review of polices are also needed to change the fuel efficiency targets of HDVs. The implementation of emission norms and fuel efficiency of the HDVs polices for India is the need of the hour to reduce the vehicular pollution and to make progress towards an energy efficient road transport.

April 15th, 2014
New Delhi

(Dr. S. GANGOPADHYAY)
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EXECUTIVE SUMMARY

India is the 7th largest country in the world covering an area of 3.5million square kms and has a population of 1.2 Billion and also India is 3rd largest economies in the world by purchasing power parity. According to the Census 2011, 30 percent of India population live in urban areas and the rate of urbanisation is growing steadily. The uncontrolled and ill-planned growth of urban centers has resulted in a number of problems like traffic congestion, shortages of water and electricity, deteriorating environment and public health. The automobile population in India has increased from a mere 0.3 million in 1951 to more than 141 million in 2013. The growing cities have generated high levels of demand for travel by motor vehicles in the cities. To match the increasing travel demand, commensurate efforts have not been made to develop the mass transport systems. The increasing in purchasing power of the individuals and easy loan from the banks to buy automobiles has resulted in tremendous increase in the population of automobiles in the cities.

Due to higher income levels and greater needs for mobility in the urban areas, more automobiles are owned and operated in them. This trend is observed to be changing in the recent past mainly due to the development of better quality in road network connecting rural areas leading the communities of rural areas going in for the automobiles resulted in increase in air pollution and CO_2 emissions from the road transport sector.

The Auto Fuel Policy of 2003 laid down a road map for vehicular emission and fuel quality standards for the remainder of the new century's first decade. This road map has been largely implemented. In 2010, Bharat IV fuel quality standards and vehicle emission standards for four-wheeled vehicles were implemented in 13 major cities, while Bharat III standards took effect in the rest of the country. India has since progressively lowered its permissible vehicular pollution emission limits for vehicles.

However, there is a tremendous in increase in vehicle kilometres travelled (VKT) by each vehicle type. To tackle the significant air quality challenges that remain, a similar and more ambitious road map should be established for the next decade in addition to the emissions norms, improvement of fuel efficiency of the vehicles is very important to reduce the emissions from road transport sector. India is currently in the process of developing mandatory fuel economy standards for the Light Duty Vehicles (LDVs). However the Heavy Duty Vehicles (HDVs) are major part of VKT which is even more than 50 percent of the CO_2 emissions from road transport sector. Considering the above it is equally necessary that in addition to the emission norms, Fuel Efficiency of the HDVs necessary. To address the above the present study is aiming to focus Fuel efficiency standards regulatory frame work for Heavy Duty Vehicles (HDVs) with the following objectives:

i) To estimate vehicle kilometres travelled (VKT) by Heavy Duty Vehicles (HDVs) in India which also include fuel economy/ efficiency standards and other related performance indicators of Heavy Duty Vehicles (HDVs) in India for the existing current fleet (baseline) based on the secondary data and expected growth scenarios by 2030.
ii) To suggest robust and practical recommendations for Fuel Efficiency standards/ labelling of HDVs (both passenger and commercial by the Bureau of Energy Efficiency).
iii) To indicate the proposed policy/ technological recommendations for HDVs for the years 2015, 2020 and 2030.

In this study an attempt has been made to estimate the VKT at National level separately for intracity and intercity level traffic. Further the vintage characteristics of vehicles plying at intracity and intercity level separately estimated based on the secondary data available (CRRI, 2002, CRRI 2009). From the above about 65 percent VKT was covered by the National and State Highways together constituting about 6 percent of total road length, about 35 percent of VKT covered by the Other roads (MDR/ODR) constitute 94 percent of road network. Further out of the total VKT (1437 billion VKT) for 2013, LDVs contribute about 58 percent of VKT, whereas HDVs contribute about 42 percent of VKT. The Annual VKT estimated for the year 2013 was given in Figure ES-1. Further the future years VKT was estimated by assuming appropriate growth factors starting from 2002 to 2030 as given in Figure ES-2. Based on the VKT and Vintage characteristics, the Vehicle Emission Loads starting from 2010, 2015, 2020, 2025 and 2030 are estimated as given Figure ES-3 (Emission factors ARAI, 2009).

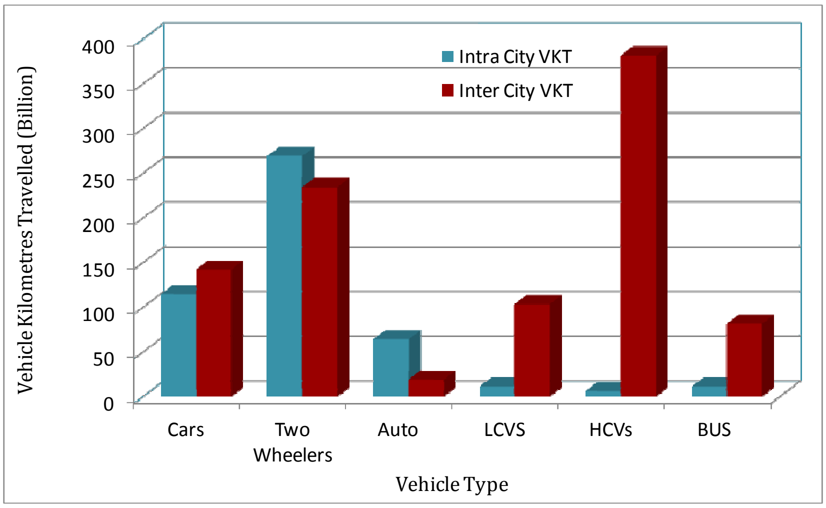

Figure ES-1: Annual Vehicle Kilometres Travelled by different Vehicle Types for Intracity and Intercity (2013)

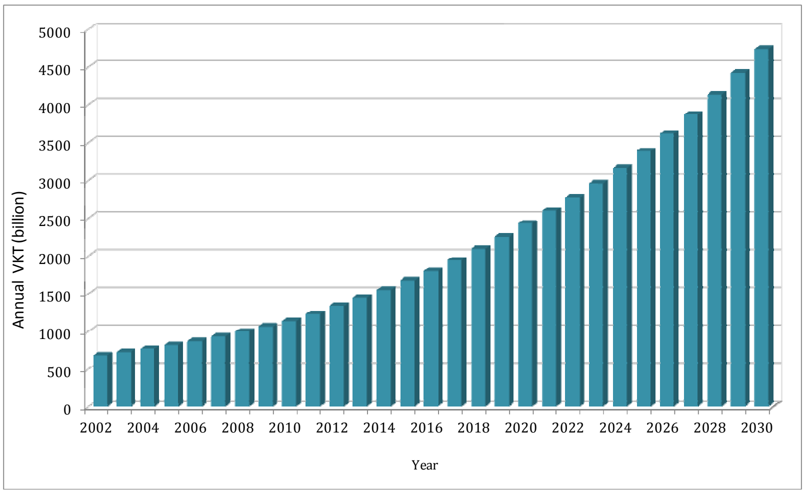

Figure ES-2: Annual VKT (Vehicle Kilometres Travelled) at National Level

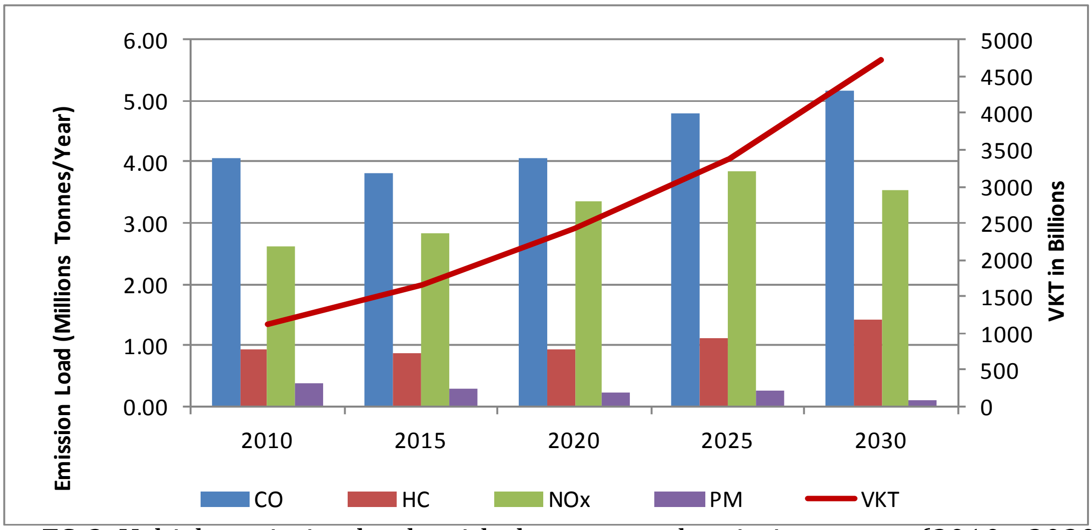

Figure ES-3: Vehicle emission loads with the proposed emission norms (2010 - 2030) along with VKT

From the above Figure ES-3 the road map laid down by the Auto Fuel Policy in 2003 able to make good progress in the reducing the emissions at the National level even at rapid increase of VKT. The future vehicular estimated were made considering the Euro V, Euro VI and Euro VII norms emissions as shown in Figure ES-4. Impact analysis based on above proposed the emissions were also carried out.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
India(LDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			
India-Cities (LDV)	Bharat IV							Bharat IV+					Bharat V					Bharat VI			
India (HDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			

Figure ES-4: Recommended vehicle emission standards

From the analysis, it can be clearly seen that there is considerable reduction in CO, NOx, HC and PM loads as shown in Figure ES-5 below.

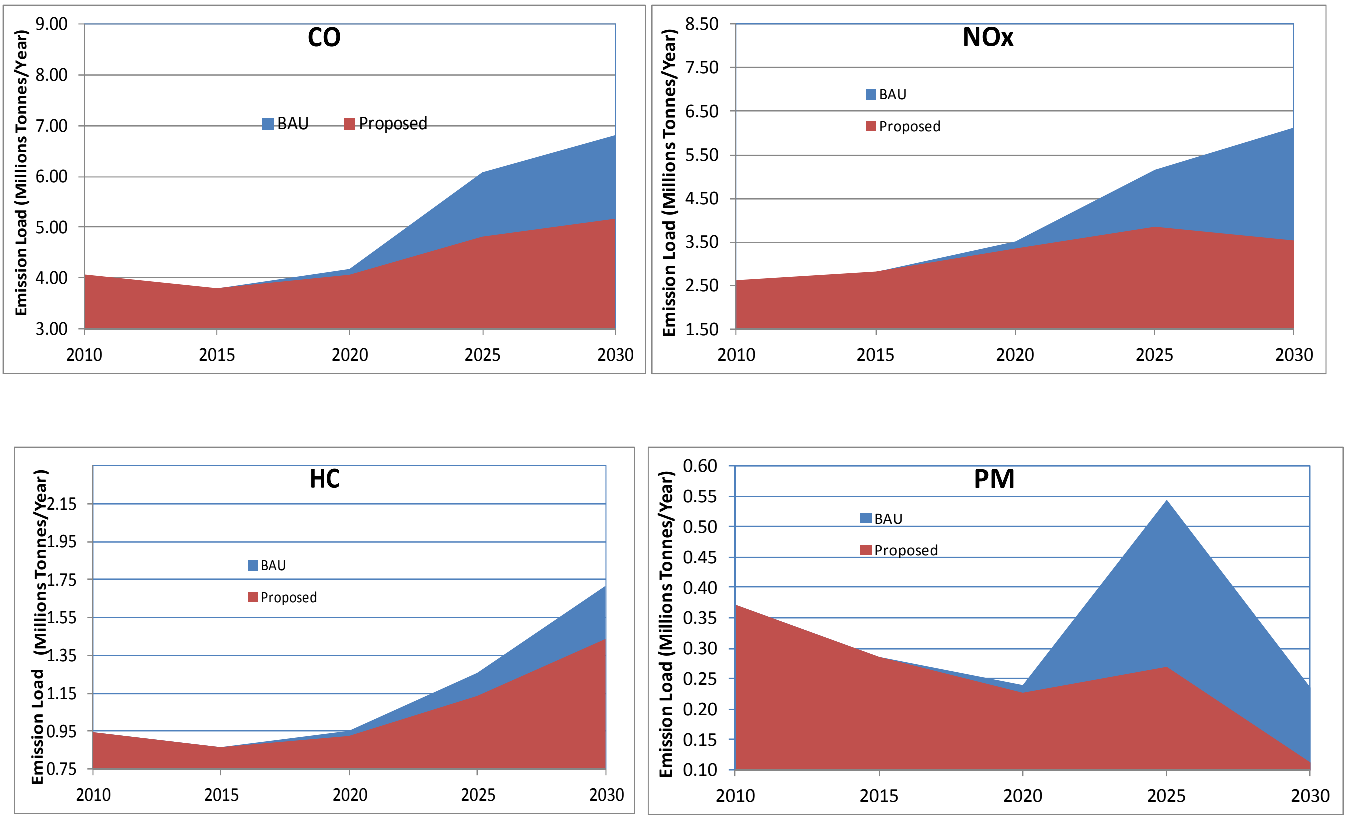

Figure ES-5: Projected Annual CO, NOx, HC and PM emissions with proposed policy action (2010–2030)

Further considering the congestion in the road network the vehicular emission loads were also estimated, the results shows that there is marginal increase. Accordingly considering the congestion in the road network the CO, NOx, HC and PM loads are estimated and it can be observed that due to congestion in the road network the reduction in CO, NOx, HC and PM is reduced. Though very primitive approach was adopted to estimate the pollution loads due to congestion, the output of the present study (pollution loads) can certainly give an idea about the quantum of pollution loads coming out of the vehicles considering prevailing congested conditions and subsequently they would help in implementing appropriate policy decisions to improve air quality, it is very pertained to note that the proposed travel demand management also very important to achieve the targeted reduction to the emission norms standards. From the above discussion there is tremendous scope to reduce the vehicle emission loads by adopting the proposed emission norms.

However still the road map beyond 2015 yet to be taken up. Further to reduce the vehicular emissions, it is not only emissions norms are important, but also fuel efficiency of the vehicles is very important. In this study an attempt has been made to study the Fuel Efficiency of HDVs where about more than 50 percent of CO_2 emissions are from the HDVs. A review of the fuel efficiency of HDVs in Japan and USA was discussed. Both countries have different approaches to achieve the Fuel Efficiency of HDVs in their respective countries. Japan established fuel efficiency of HDVs based on the Gross Weight of Vehicles (GWV) and USA established fuel efficiency of HDVs based on engine improvements and the Gross Weight of Vehicles (GWV).

To improve vehicle fuel efficiency comprises three main components which should be considered as policy options in integrated vehicle fuel efficiency: i) Information and Labelling ii) Regulatory actions and iii) Fiscal measures. For Indian conditions, these components are very important to implement in an integrated way to achieve the targeted fuel efficiency of HDVs. An attempt has been made to work out, how the fuel efficiency will help in reduction of CO_2 emissions for the Indian conditions, based on available fuel economy values for the HDVs from the different studies.

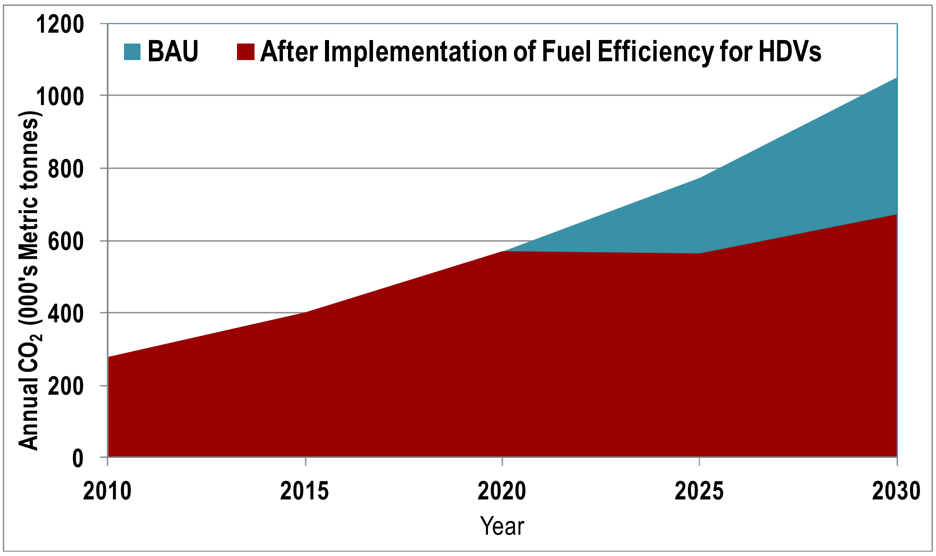

Figure ES-6: Annual CO_2 emissions under the BAU scenario cosidering all the other modes and after implementation of Fuel Effinciey for HDVs

From the above Figure ES-6, there is considerable reduction in CO_2 emissions 192 thousand metric tonnes in the year 2025 and 343 thousand metric tonnes in the year 2030 was estimated. About 147 Billion litres in the year 2025 and 262 Billion litres in the year 2030 of fuel will be saved.

From the above discussion it is very important that in addition to the emission norms, the fuel efficiency of the HDVs also play very important role in reduction of the vehicular pollution. Hence it is very important to the Indian conditions to adopt the fuel efficiency of the HDVs.

To roll-out the fuel efficiency policy of the HDVs for Indian conditions all the necessary work should be started from the 2015 and implement it from 2020. After the implementation necessary review of polices are also needed. The implementation of emission norms and fuel efficiency of the HDVs polices for India is the need of the hour to reduce the vehicular pollution and reduce the demand of fuel to road transport sector.

Fuel Efficiency Standards of Heavy Duty Vehicles in India

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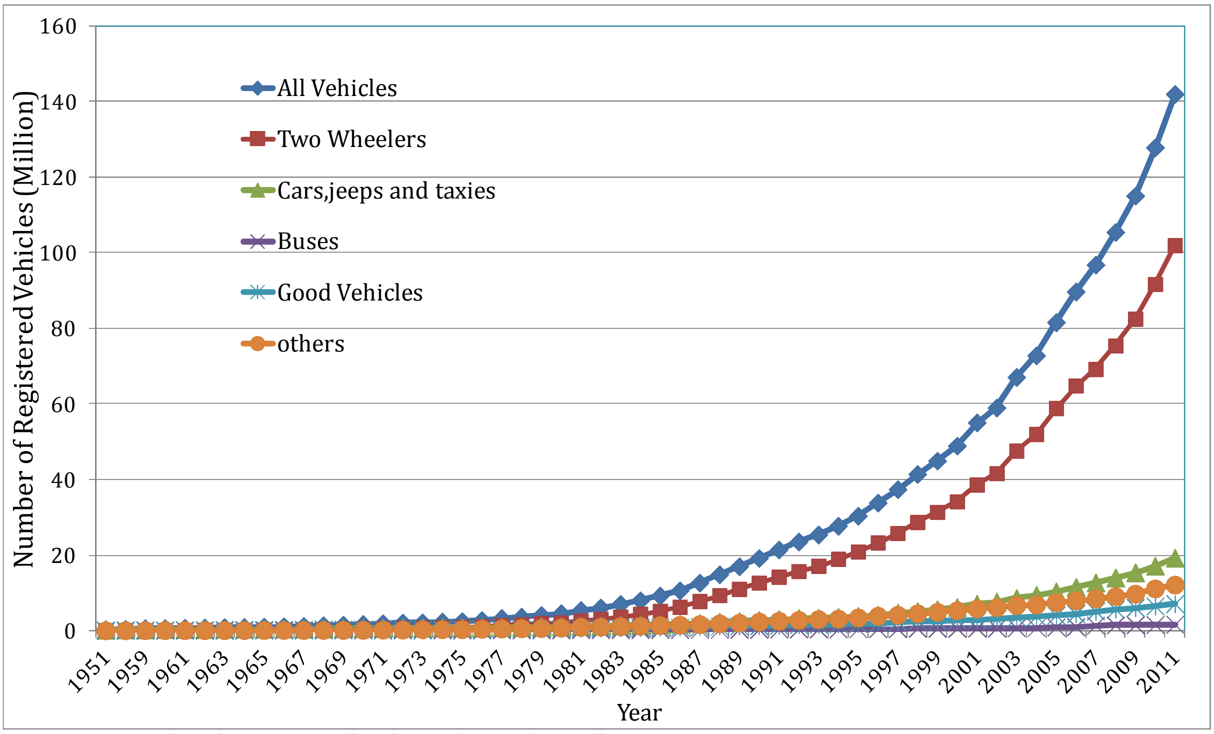
1.0 INTRODUCTION

1.1 Vehicle Growth Trends in India

The uncontrolled and ill-planned growth of urban centers has resulted in a number of problems like traffic congestion, shortages of water and electricity, deteriorating environment and public health. The growing cities have generated high levels of demand for travel by motor vehicles in the cities. To match the increasing travel demand, commensurate efforts have not been made to develop the mass transport systems. On the other hand, the Government of India has also not enforced with any restrictions on manufactures of automobiles. Moreover, the increasing in purchasing power of the individuals and easy loan from the banks to buy automobiles has resulted in tremendous increase in the population of automobiles in the cities.

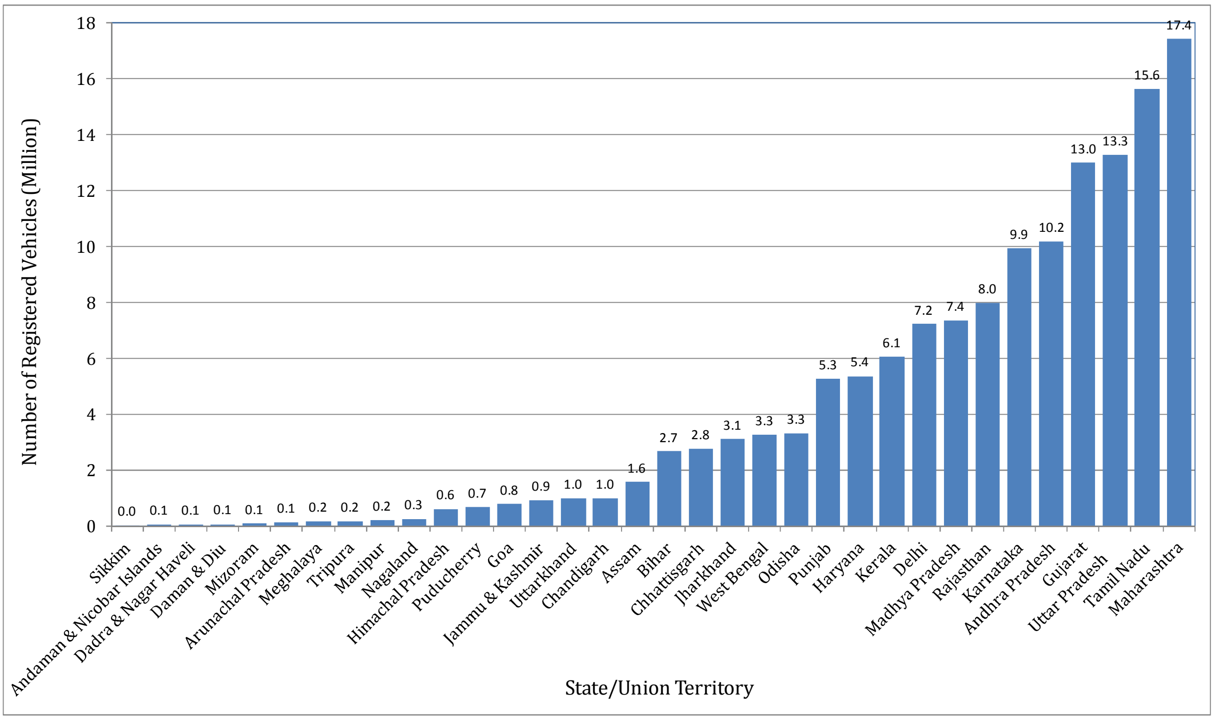
The automobile population in India has increased from a mere 0.3 million in 1951 to more than 141 million in 2013. The registered two wheelers constitute nearly 70 percent of the vehicle population in almost all the cities. Due to higher income levels and greater needs for mobility in the urban areas, more automobiles are owned and operated in them. This trend is observed to be changing in the recent past mainly due to the development of better quality in road network connecting rural areas leading the communities of rural areas going in for the automobiles.

The population of automobiles has doubled in the past 10 years and currently over 19 million are cars, jeeps and taxis which is about 14% and over 7 million and 1.6 million vehicles registered are goods vehicles and buses respectively. Two wheelers account a significant market share in the total automobiles. The low cost cars which introduced by different manufacturers attract some of the two wheeler buyers to buy a small, cheap and affordable passenger car. The total number of new vehicles registered in the 28 states and 7 union territories of India in the year 2011 were about 141,866,000. The growing trends of different vehicle types from 1951 to 2011 are presented in Figure 1.1 and Figure1.2.



Source: Ministry of Road Transport and Highways (MoRTH) Annual Report 2010-11

Figure 1.1: Total Number of Registered Vehicles in India

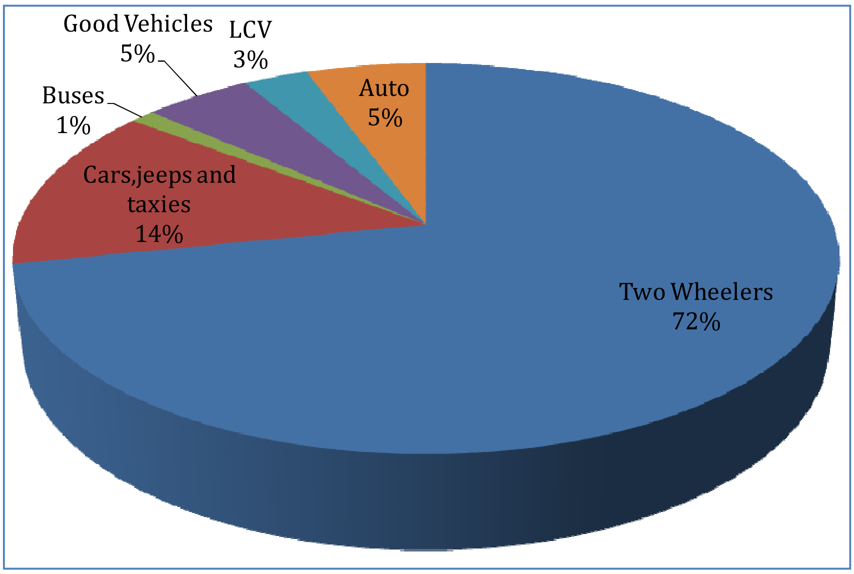


Source: MoRTH Annual Report 2010-11

Figure 1.2: Total Number of Registered Vehicles State/ Union Territory-wise in India (2011)

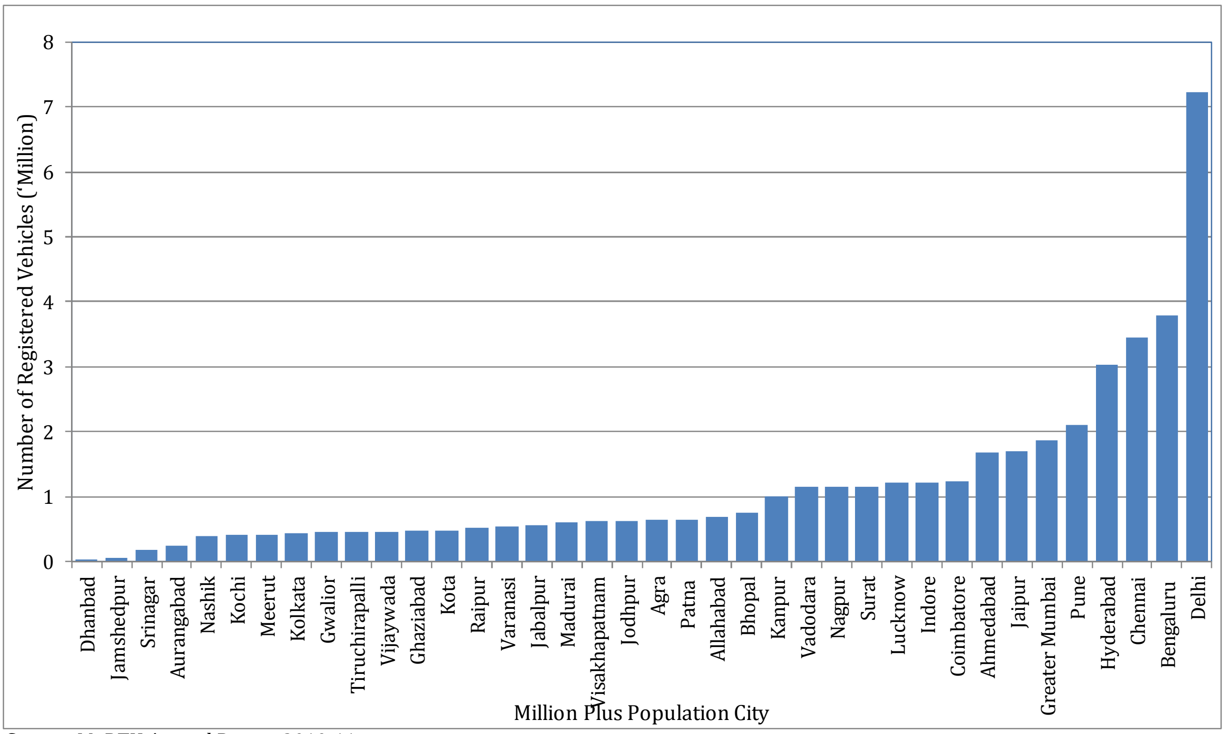
From the Figure 1.1, it can be observed that the annual growth of total vehicles is about 10% per annum which is also same for two wheelers. From the Figure 1.2, it can be seen that 15 states and 1 union territory had over a million new vehicles registered.

Maharashtra had about 17.4 million new vehicles registered, Tamil Nadu had over 15.6 million, Uttar Pradesh and Gujarat had over 13 million. About 91% of these vehicles are non-commercial vehicles purchased by households looking for a two wheeler, or a car. Only about 9% of new vehicles registered are used for commercial purposes as shown in Figure 1.3. Figure 1.4 shows the number of vehicles registered in Million Plus cities.



Source: MoRTH Annual Report 2010-11; Note: LCV-Light Commercial Vehicles (up to 7 Tonne load carrying capacity)

Figure 1.3: Composition of Total Number of Registered Vehicles in India (2011)



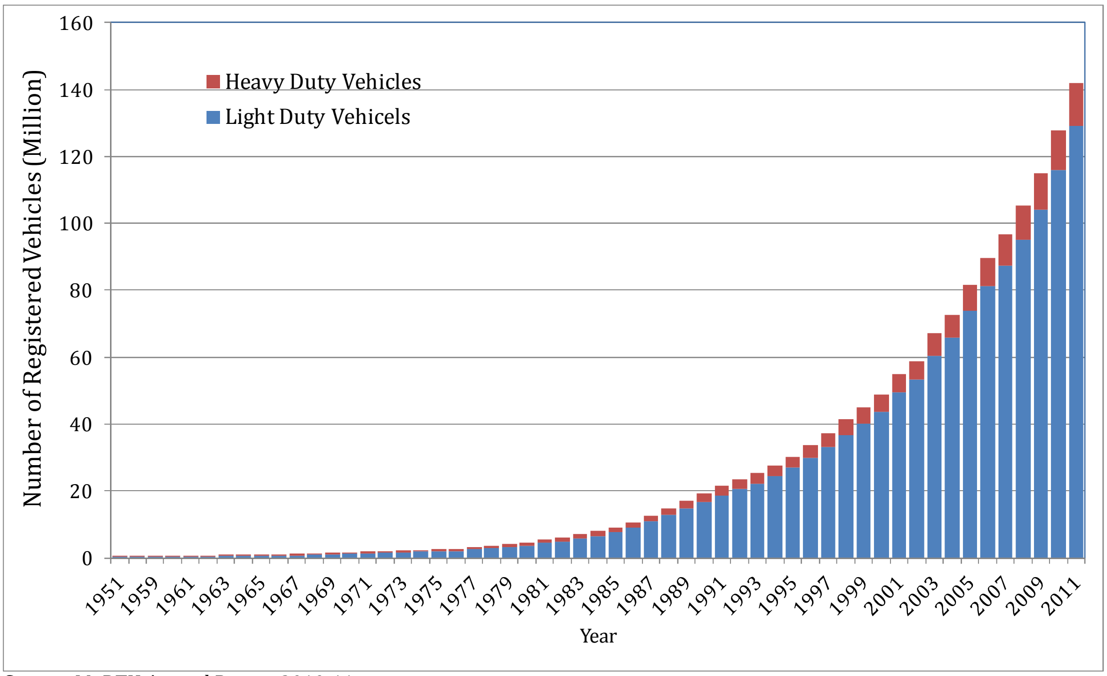
Source: MoRTH Annual Report 2010-11

Figure 1.4: Total Number of Registered Vehicles in Million Plus Population Cities in India (2011)

From Figure 1.4, it can be seen that Delhi registered about 7 million standing at maximum among all the cities followed by Bangalore, Chennai, Hyderabad. Dhanbad stands at last with registered vehicles about 0.04 Million. In 2011, Delhi was having a total registered vehicle of more than 7.3 million (more than 15% of India's Million Plus cities automobile population) with the predominance of two wheelers and cars as shown in Figure 1.4. Further, the rends of automobiles registration in Delhi city shows that motor vehicles in Delhi city have grown in multi-folds, however the road network has grown at a much slower rate leaving a huge short fall in the capacity required to carry the motor vehicles plying in the city. Furthermore, the data analysis shows that on an average about one thousand new vehicles are added on to the Delhi roads, resulting extreme congestion, ever slowing speeds, increase in road accidents, fuel wastage and environmental pollution.

1.2 Growth of Heavy Duty Vehicles and Light Duty Vehicles in India (1951-2011)

The data analysis in terms of growth of Heavy Duty Vehicles (HDV) which includes Light Commercial Vehicles (LCV), Heavy Commercial Vehicles (HCV), Multi-Axle Commercial Vehicles (MAV) and Bus and Light Duty Vehicles (LDV) from 1951 to 2011 are presented in Figure 1.5 and Figure 1.6.



Source: MoRTH Annual Report 2010-11

Figure 1.5: Growth of Heavy Duty Vehicles (includes LCV, HCV, MAV and BUS) and Light Duty Vehicles wise in India (1951 - 2011)

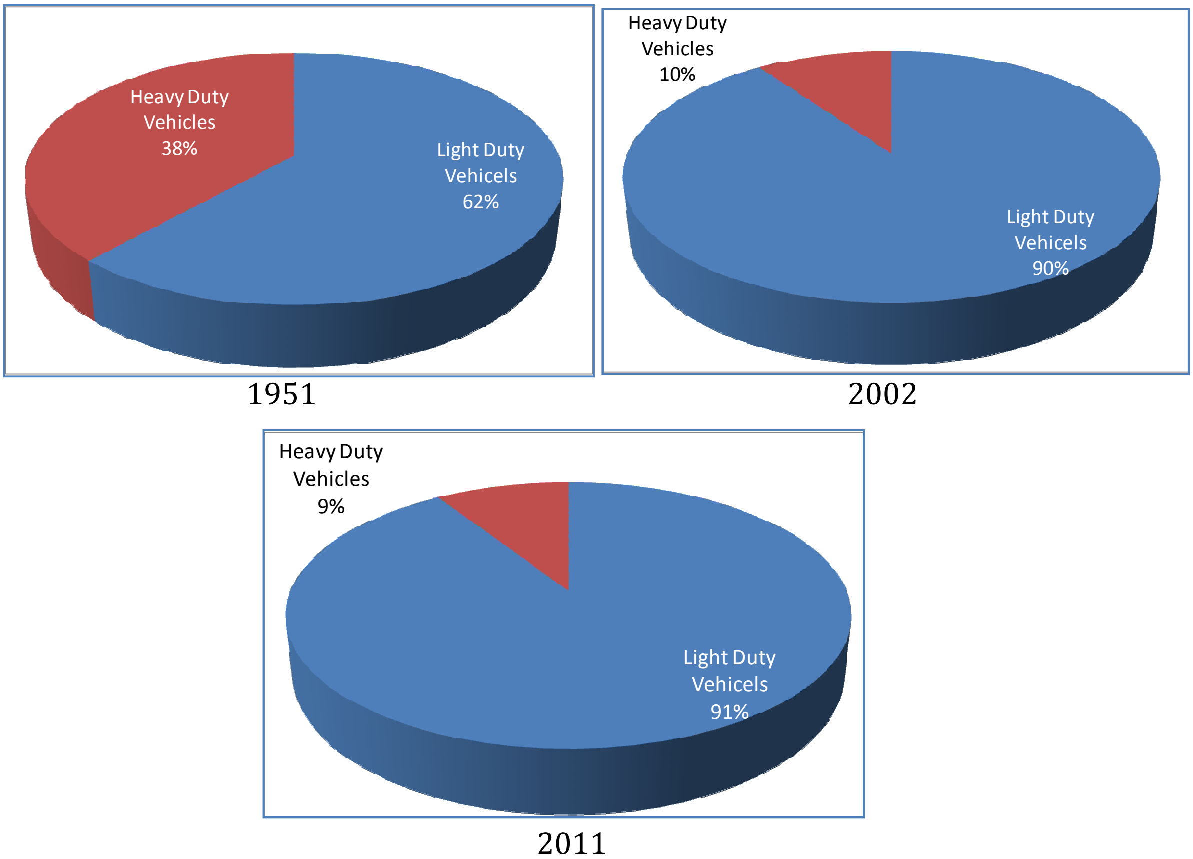
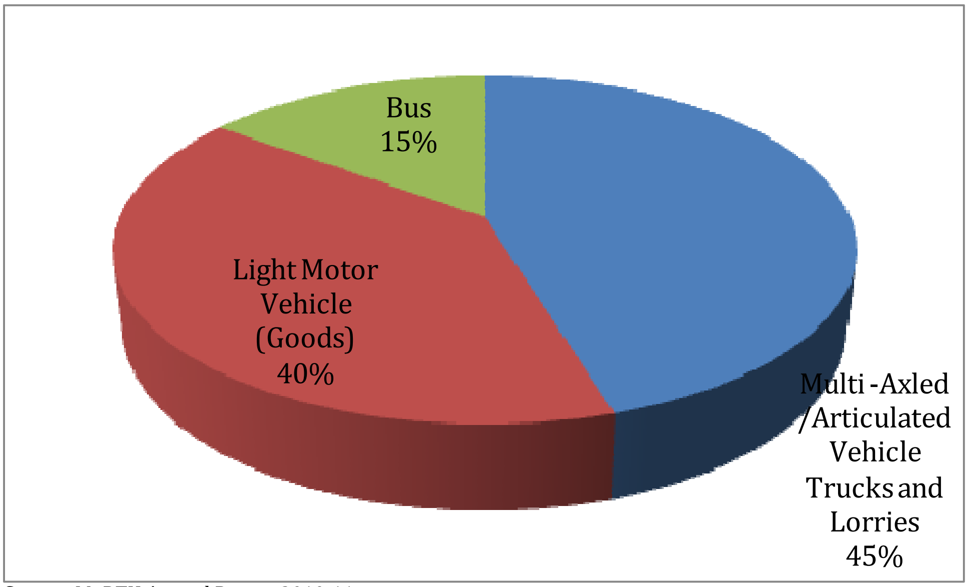


Figure 1.6: Change in Composition of Heavy Duty Vehicles and Light Duty Vehicles in India (1951 - 2011)

From Figure 1.5 and 1.6, it can be observed that HDV composition was reduced from 38 percent in 1951 to 10 percent in 2002 and further to 9 percent in 2011. Though the absolute number of HDV was increased, the increase in LDVs was more as compared to HDV. In the recent past the goods transportation competition among the road and rail mode have also been increased tremendously, this resulted in increased pressure on existing road network and also there is an increase in growth of the different commercial vehicles (Light Commercial vehicles-LCV, Heavy Commercial Vehicles-HCV and Multi Axle Commercial Vehicles-MAV), however at smaller pace. From the Road User Cost Study (RUCS, 2001 and 2010), it can be seen that the average daily kilometers travelled was increased tremendously for HDV to tackle the increase in demand of freight transportation. Furthermore, among the HDV, the Light Commercial Vehicle (LCV) are about 40 percent, Heavy Commercial Vehicle (HCV) and Multi-Axle Commercial Vehicles (MAV) are about 45 percent and Buses are about 15 percent as shown in Figure 1.7.



Source: MoRTH Annual Report 2010-11

Figure 1.7: Composition of Heavy Duty Vehicles in India (2011)

2.0 NEED FOR THE STUDY

As discussed in the previous section, the increase in passenger as well as commercial vehicles was resulted in increase in vehicular pollution loads throughout India especially at urban centres, high vehicular pollution levels are reported in Million plus cities in population. To control these pollution levels in various cities, Government of India formulated the National Auto Fuel Policy where in the vehicles emissions norms and other policy instruments are in place (source: http://petroleum.nic.in/autopolicy.pdf). Further there is rapid changes in technologies in Heavy Duty Vehicles (HDVs) like changes in engines, types of tires and spare parts etc. However after implementing over the years, the National Auto Fuel Policy norms and various policy interventions combining with change in various technologies in vehicles, no study have been conducted comprehensively to known the impacts of various measures taken, and to place the new policy initiatives.

Considering the above facts, the present study has been formulated with an aim of estimating vehicle kilometers travelled by Heavy Duty Vehicles (HDVs) in India including fuel economy/ efficiency standards, regulatory frame work of fuel standards which would eventually helps the decision making authority to frame the policy frame work on Heavy Duty Vehicles towards sustainable development considering the global changes especially in the field of heavy duty vehicles.

3.0 OBJECTIVES AND SCOPE OF THE STUDY

3.1 Objectives

As described in the previous section, after implementing the National Auto Fuel Policy and other policy interventions, there is a high need to study the impacts of the various policy measures. In view of this, the present study has been considered with an aim to focus on Fuel efficiency standards regulatory frame work on Heavy Duty Vehicles (HDVs) in India.

The main objectives of the present study are:

iv) To estimate vehicle kilometers travelled (VKT) by Heavy Duty Vehicles (HDVs) in India which also include fuel economy/ efficiency standards and other related performance indicators of Heavy Duty Vehicles (HDVs) in India for the existing current fleet (baseline) based on the secondary data and expected growth scenarios by 2030.

v) To suggest robust and practical recommendations for Fuel Efficiency standards/ labelling of HDVs (both passenger and commercial by the Bureau of Energy Efficiency).

vi) To indicate the proposed policy/ technological recommendations for HDVs for the years 2015, 2020 and 2030.

3.2 Scope of the Present Study

The scope of the present study covers following:

I. To assess magnitude of the total travel demand and travel patterns of automobiles on Indian network in terms of Vehicle Kilometres Travelled (VKT), Fuel consumption and Emissions relating to Heavy Vehicles (HDVs) include commercial passenger vehicles (Buses) and Goods Vehicles: LCV (light commercial Vehicles), HCV (Heavy Commercial Vehicles), MAV (Multi Axle Commercial Vehicles based on the secondary information available. This analysis would also include VKT over a lifetime of vehicle, VKT per vehicle type and city wise results (city type etc.).

II. Quantifying the associated pollution loads due to Impacts of Policy Interventions and technological changes pertaining to above vehicles classes. The detailed analysis and recommendations for technological and policy improvements differing in passenger vehicles and freight/ commercial vehicles from the perspective of the design, engine efficiency and loading, route or operations.

III. Investigate and report average vehicle life times and age for the various HDV types which also includes based on various weight classes. Assess VKT (as well as average age) by fleet size allowing characterization of impacts by fleet size as well as vehicle/ fleet type. Report the Government fleets, private fleets and the wide range of company/ fleet types. Important manufacturers, leading makes/ models, vehicle types, fuel use, technology in current vehicles. Sales for the last 3 to 5 years and projected growth rates of sales, typical duty cycle: average speed and loading.

IV. Information on trailers (population, ratio of truck to trailer, manufacturers, sales volume etc.), average age of vehicles by fleet types, names of the largest fleets, truck driver associations etc.

V. The detailed review of the available technologies worldwide to reduce the fuel consumption and emissions of HDVs, both commercial and passenger vehicles. Review of these technologies in Indian market as compared to international best practices.

VI. Detailed analysis and compilation of technological improvements to increase fuel economy that are expected in the next 10-15 years and their impacts. Also substantial review of the technological improvement and innovations expected in long term.

VII. Analysis of the aggregate amount of fuel savings and CO_2 emission reduction that can be expected as a result of the technological and policy changes.

VIII. In the context of South East Asian countries and best practices internationally, recommend with logic the values/ levels of fuel economy standards and policies that India should adopt, and plan to potentially improve standards (ratcheting up) over the years.

IX. Based on these and analysis, plausible fuel consumption reduction target that India should pursue for this subgroup. Detailed recommendations for FE standards for heavy duty vehicles.

X. Based on the analysis, international experience and expertise, define the detailed roadmap for implementing the FE recommendations in near, medium and long term. Developing the detailed steps involved in regulatory development for implementing the roadmap of heavy-duty vehicles. Institutional arrangements to be document for tracking various data sources (different ministries/ agencies) and their development.

XI. Various drivers/ barriers for uptake of efficiency technology. Different realistic opportunities for hybrid trucks and buses in the India market.

XII. Additional policies (apart from fuel economy standards) that government should follow to reduce and implement fuel consumption of HDV which are important in context.

However, the above scope of the work is subject to available of the secondary data and appropriate assumptions considering the anticipated growth in the HDVs.

For accomplishing the above objectives, various secondary reports of CRRI (2002 and 2009) and other available secondary reports will be utilised. In addition to the above, the Client (M/S Shakti Sustainable Energy Foundation) will also co-ordinate to get and provide the secondary data and reports.

4.0 METHODOLOGY

Considering the data availability relating to VKT, VKT by vehicle types across India has been considered most appropriate for estimating Fuel consumption and Emissions relating to Heavy Duty Vehicles both passenger vehicles and Goods Vehicles.

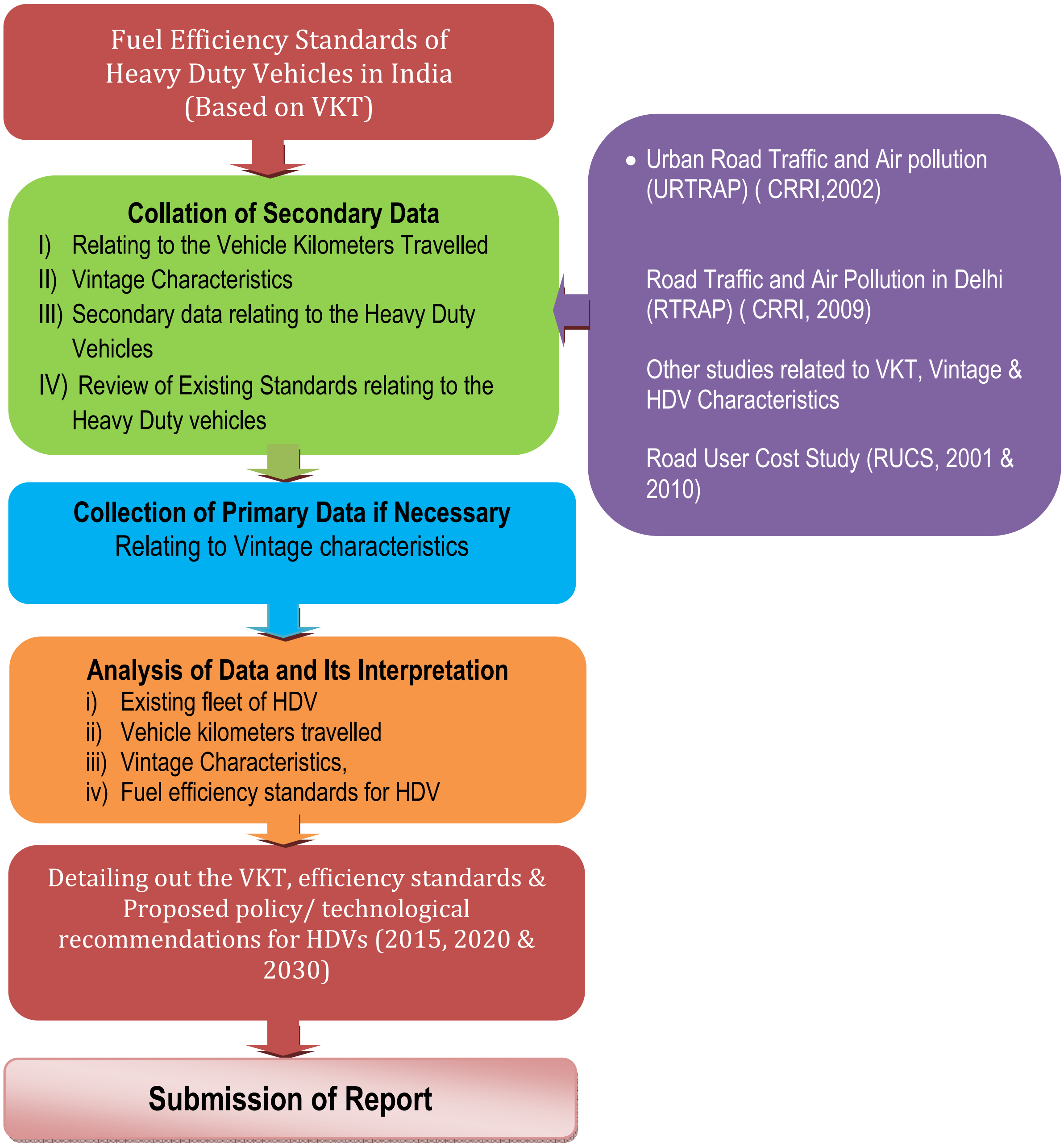


Figure 4.1: Proposed Methodology for the Study

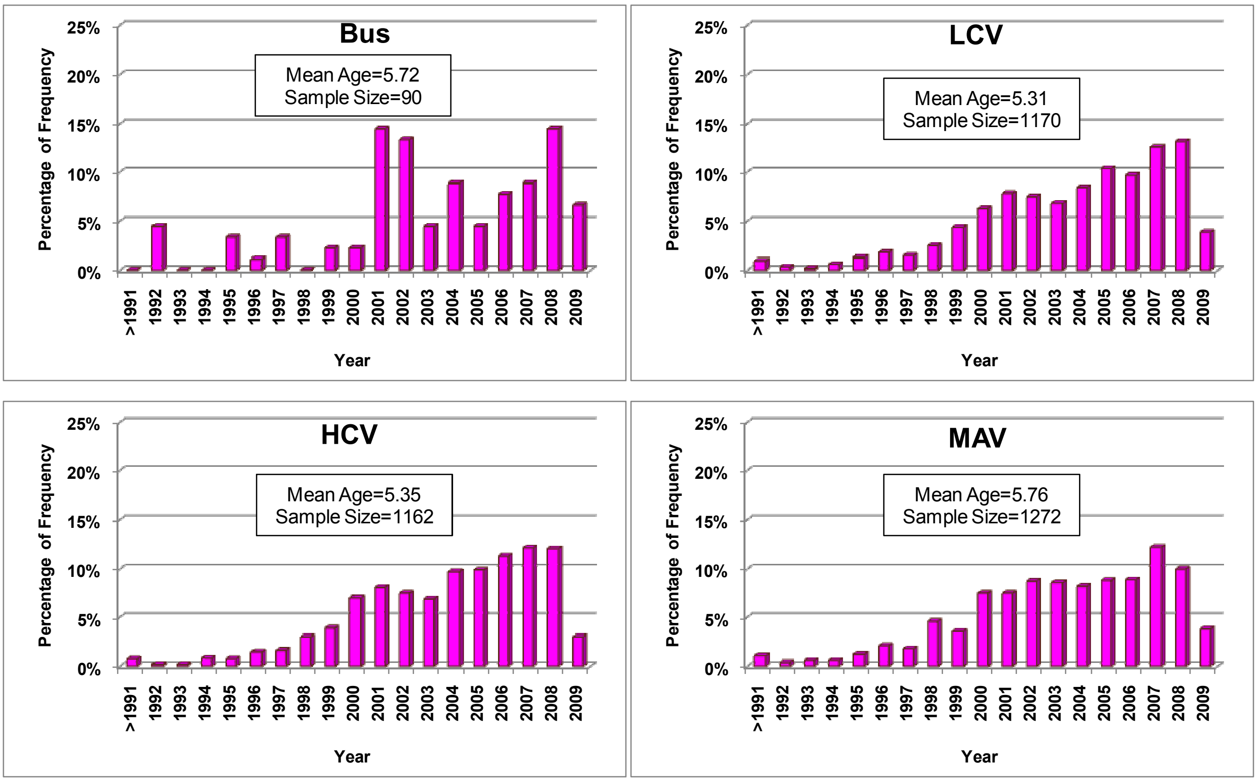
Keeping the objectives and resources allotted for the present study in view, it is proposed to utilize the traffic database generated by URTRAP study (CRRI, 2002) and RTRAP (CRRI, 2009) as the datum.

5.0 VEHICLE VINTAGE CHARACTERISTICS

Considering the data availability from the relevant studies (CRRI, 2002 and CRRI, 2009), the vintage characteristics of HDV are analysed for the cities of Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Kanpur, Agra. This vintage characteristics are will be essentially used in modeling the future vintage characteristics. The details are discussed in the subsequent sections.

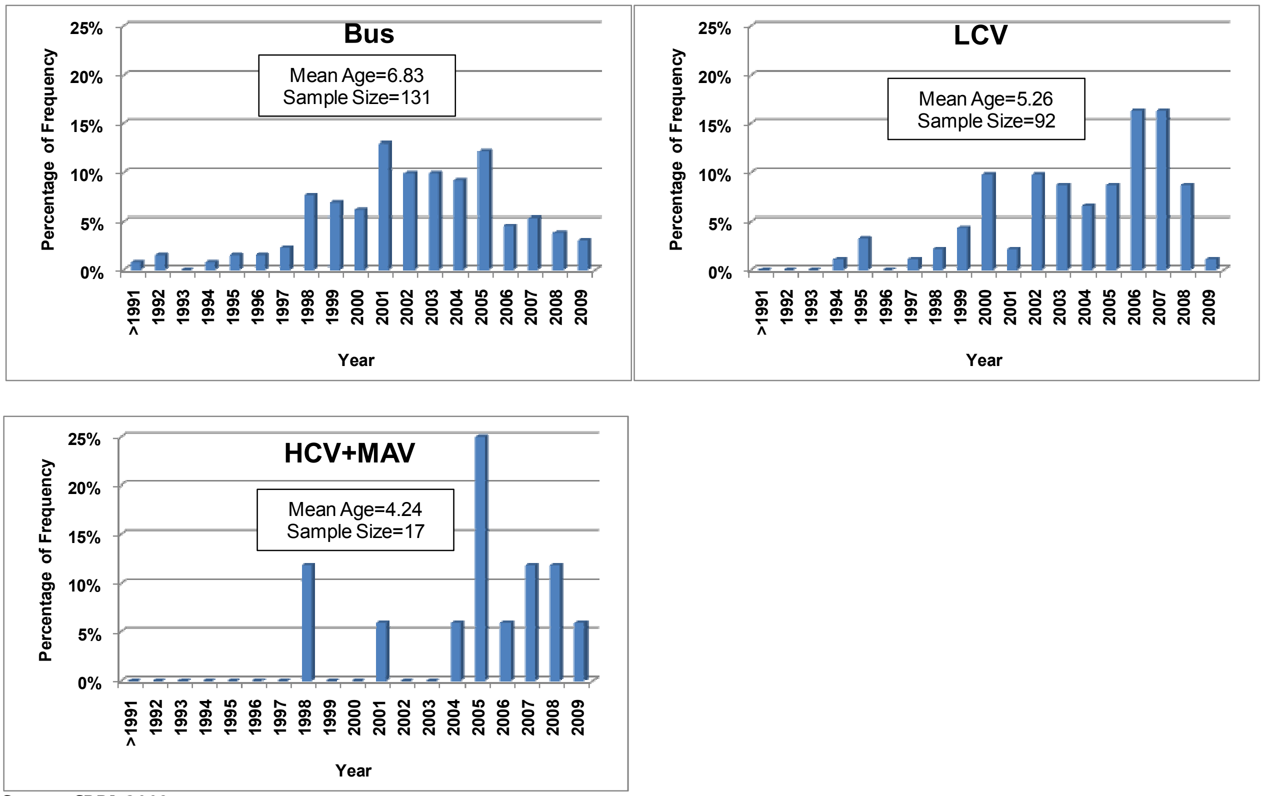
5.1 Vintage Characteristics of Delhi

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Delhi is presented in Figure 5.1. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Delhi is presented in Figure 5.2 (CRRI, 2009).



Source: CRRI, 2009

Figure 5.1: Age Distribution of HDV at Outer Cordons in Delhi (2009)



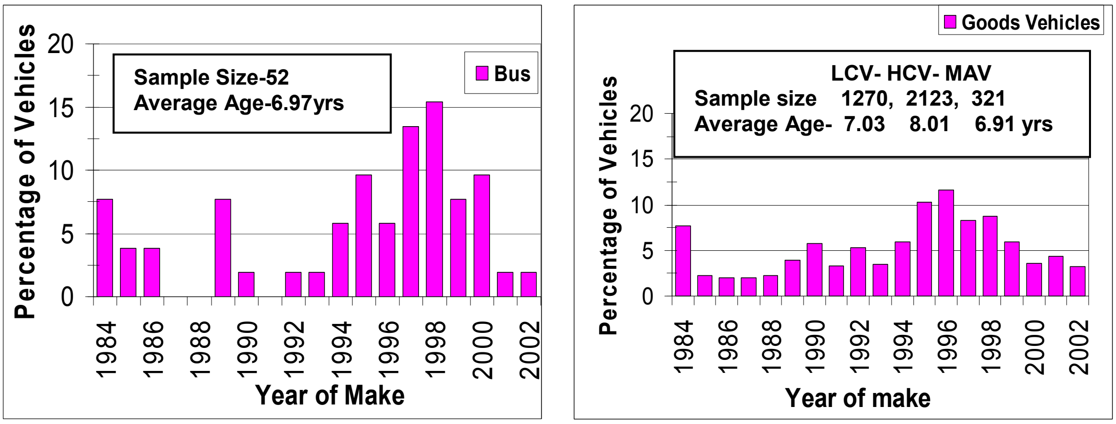
Source: CRRI, 2009

Figure 5.2: Age Distribution of HDV observed within Delhi

It can be noted from the Figure 5.1 and 5.2 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 5.31 to 5.76 at outer cordons whereas it is varying from 4.24 to 6.83 within the city.

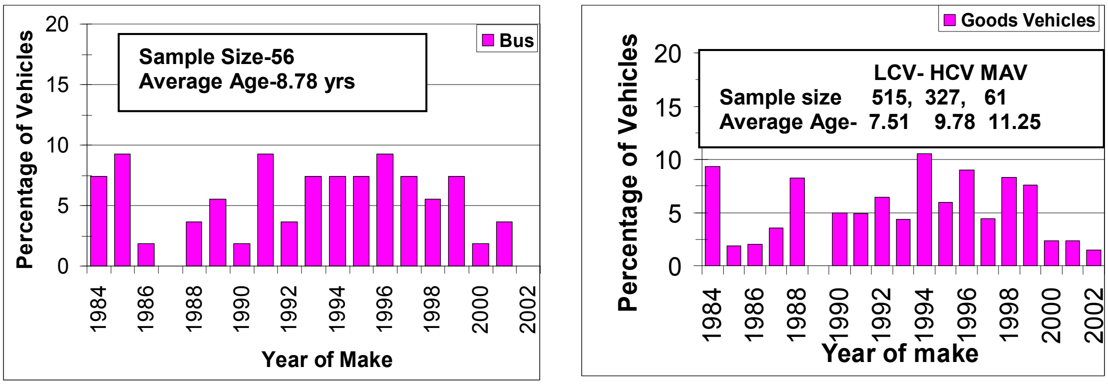
5.2 Vintage Characteristics of Mumbai

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Mumbai is presented in Figure 5.3. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Mumbai is presented in Figure 5.4 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.3: Age Distribution of HDV at Outer Cordons in Mumbai



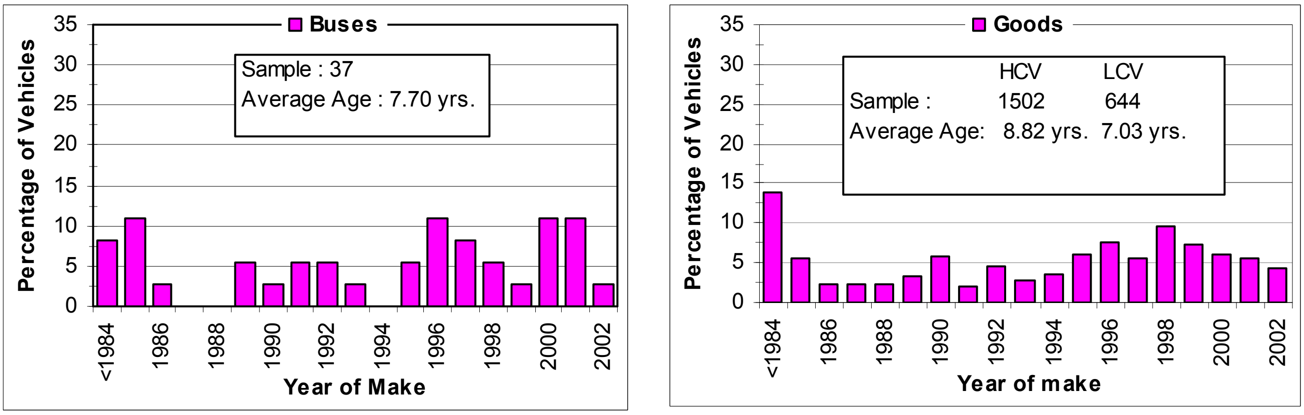
Source: CRRI, 2002

Figure 5.4: Age Distribution of HDV observed within Mumbai

It can be noted from the Figure 5.3 and 5.4 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 6.97 to 8.01 at outer cordons whereas it is varying from 7.51 to 11.25 within the city.

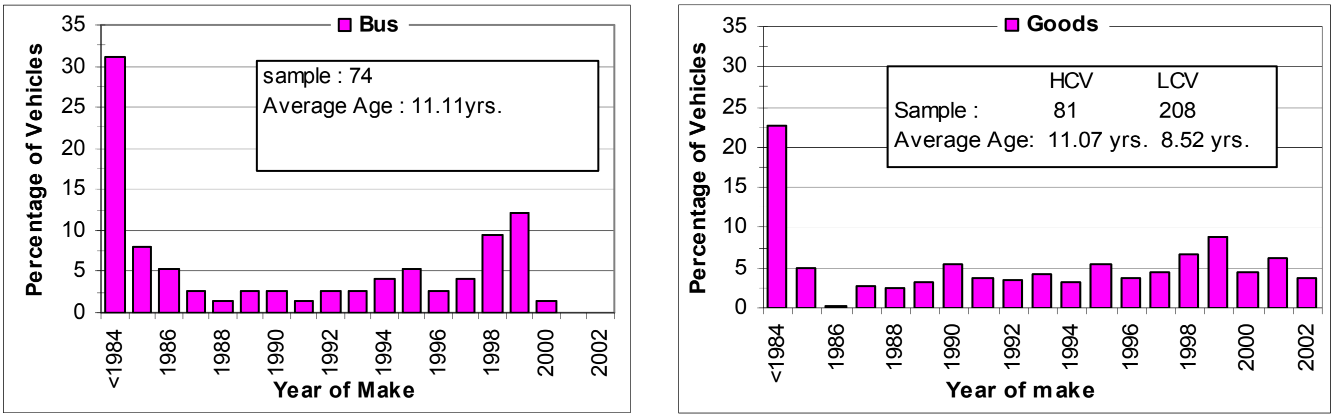
5.3 Vintage Characteristics of Kolkata

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Kolkata is presented in Figure 5.5. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Kolkata is presented in Figure 5.6 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.5: Age Distribution of HDV at Outer Cordons in Kolkata



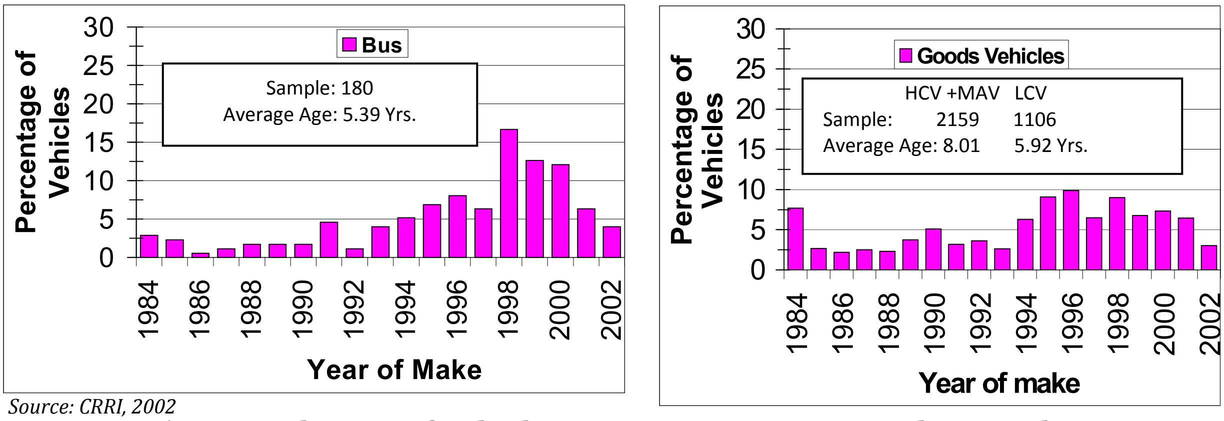
Source: CRRI, 2002

Figure 5.6: Age Distribution of HDV observed within Kolkata

It can be noted from the Figure 5.5 and 5.6 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 7.03 to 8.82 at outer cordons whereas it is varying from 8.52 to 11.11 within the city.

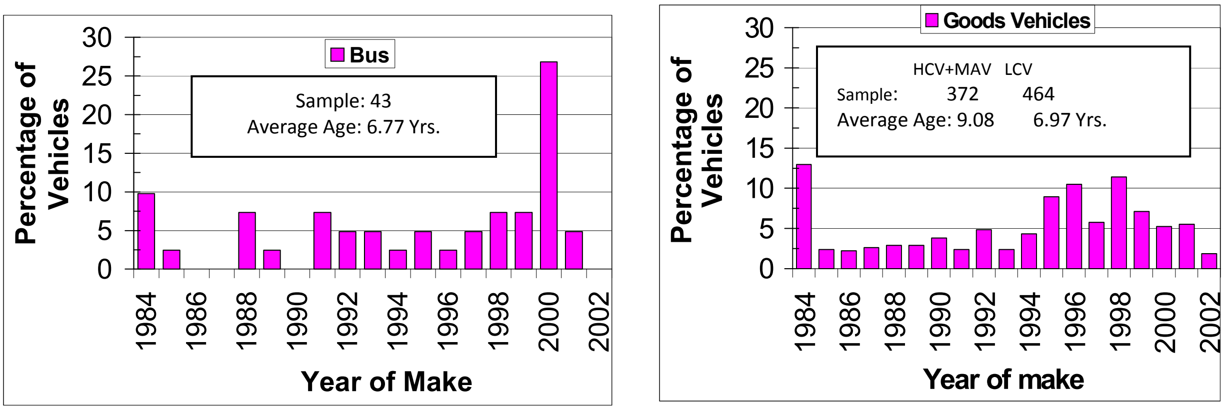
5.4 Vintage Characteristics of Chennai

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Chennai is presented in Figure 5.7. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Chennai is presented in Figure 5.8 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.7: Distribution of Vehicles as per Age at Outer Cordons in Chennai



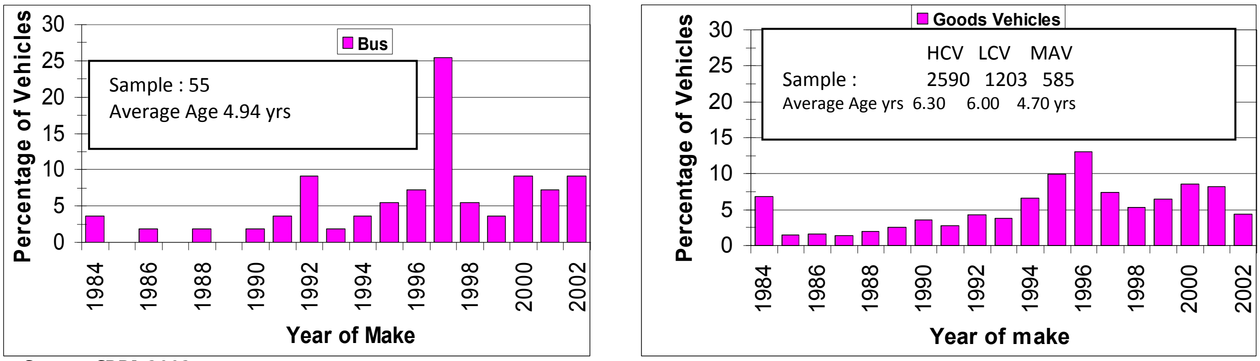
Source: CRRI, 2002

Figure 5.8: Age Distribution of HDV Observed within Chennai

It can be noted from the Figure 5.7 and 5.8 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 5.39 to 8.82 at outer cordons whereas it is varying from 6.77 to 9.08 within the city.

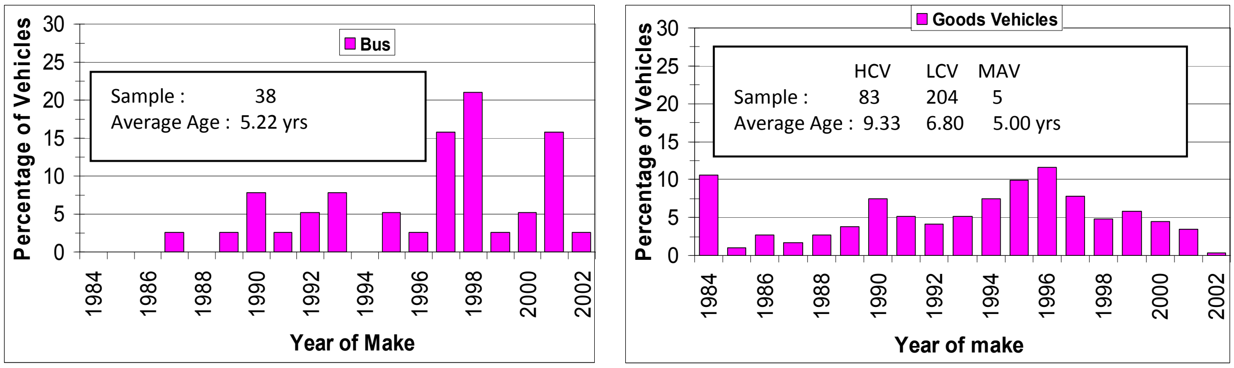
5.5 Vintage Characteristics of Bangalore

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Bangalore is presented in Figure 5.9. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Bangalore is presented in Figure 5.10 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.9: Age Distribution of HDV at Outer Cordons in Bangalore



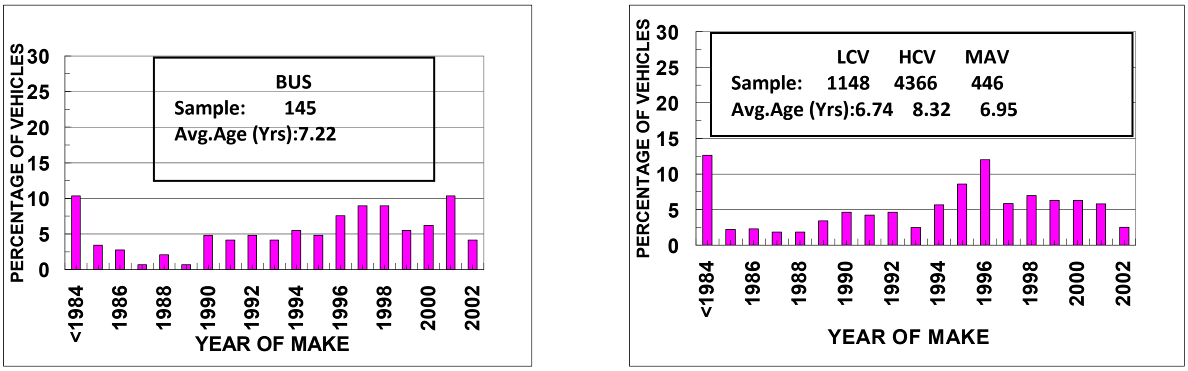
Source: CRRI, 2002

Figure 5.10: Age Distribution of HDV Observed within Bangalore

It can be noted from the Figure 5.9 and 5.10 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 4.70 to 6.30 at outer cordons whereas it is varying from 4.70 to 6.30 within the city.

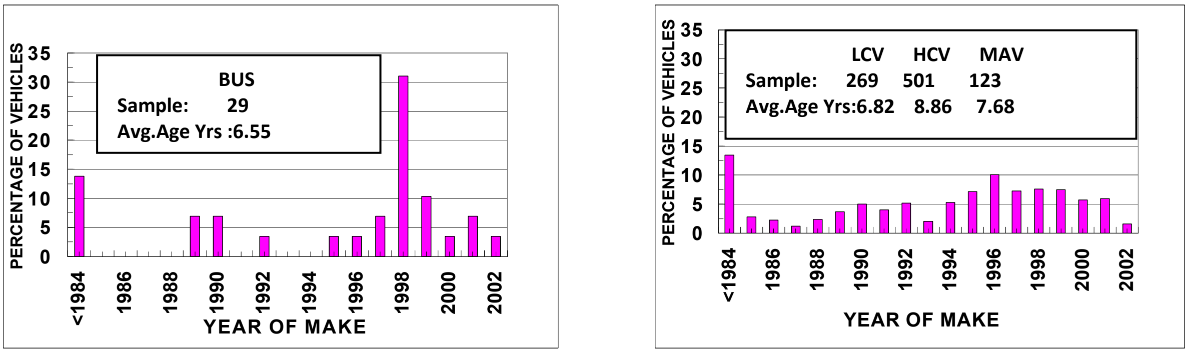
5.6 Vintage Characteristics of Hyderabad

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Hyderabad is presented in Figure 5.11. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Hyderabad is presented in Figure 5.12 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.11: Age Distribution of HDV at Outer Cordons in Hyderabad



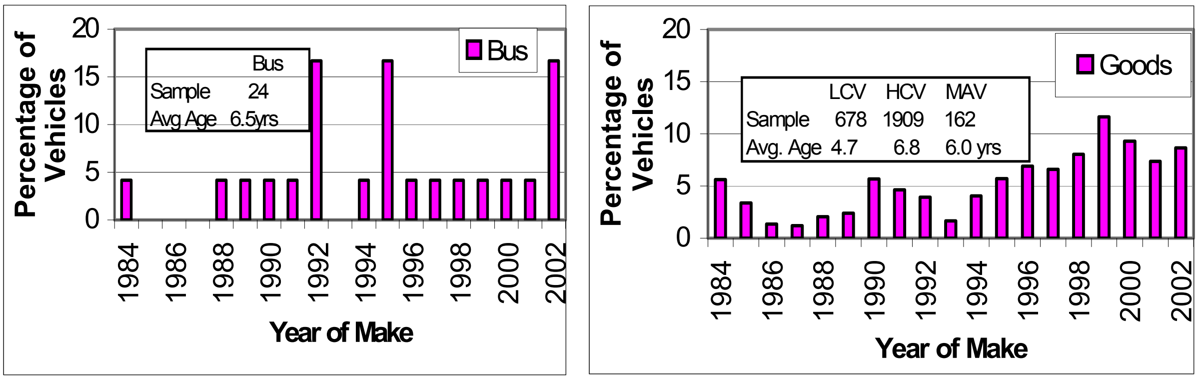
Source: CRRI, 2002

Figure 5.12: Age Distribution of HDV Observed within Hyderabad

It can be noted from the Figure 5.9 and 5.10 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 6.74 to 8.32 at outer cordons whereas it is varying from 6.55 to 8.86 within the city.

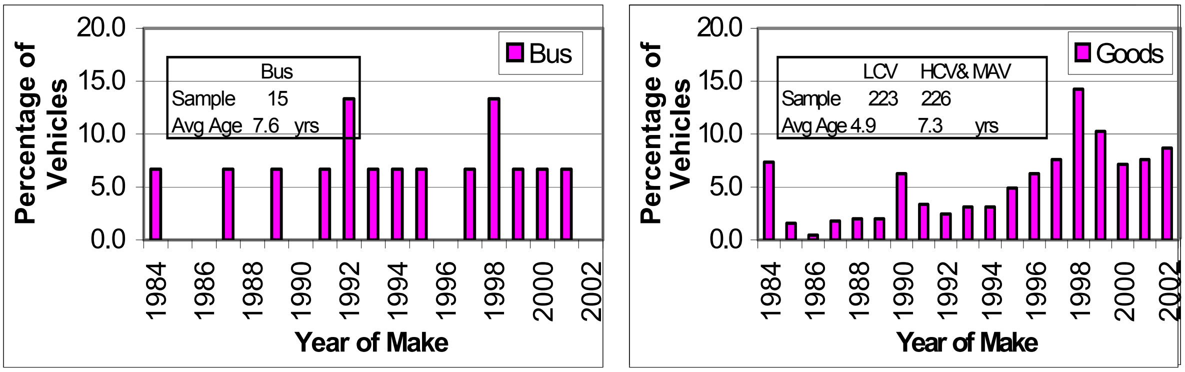
5.7 Vintage Characteristics of Kanpur

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Kanpur is presented in Figure 5.13. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Kanpur is presented in Figure 5.14 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.13: Age Distribution of HDV at Outer Cordons in Kanpur



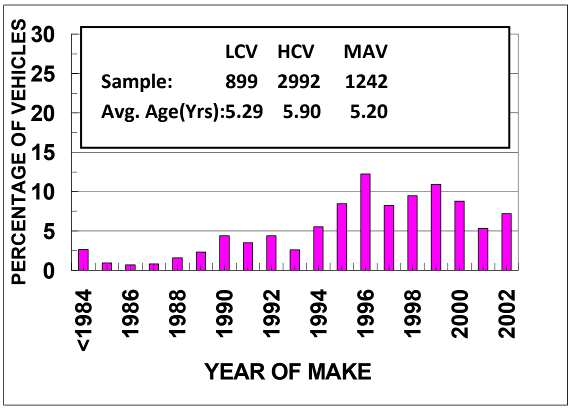
Source: CRRI, 2002

Figure 5.14: Age Distribution of HDV Observed within Kanpur

It can be noted from the Figure 5.13 and 5.14 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 4.90 to 7.60 at outer cordons whereas it is varying from 6.55 to 8.86 within the city.

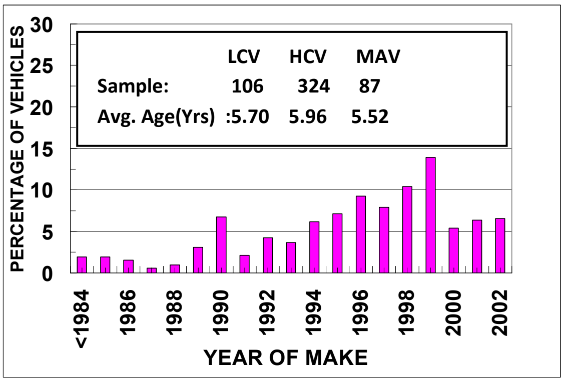
5.8 Vintage Characteristics of Agra

The distribution of vehicles as per their year of manufacture as obtained at the outer cordon points of Agra is presented in Figure 5.15. Whereas the distribution of vehicles as per the year of manufacture as obtained from the user surveys at the Fuel Stations inside the city of Agra is presented in Figure 5.16 (CRRI, 2002).



Source: CRRI, 2002

Figure 5.15: Age Distribution of HDV at Outer Cordons in Agra



Source: CRRI, 2002

Figure 5.16: Age Distribution of HDV Observed within Agra

It can be noted from the Figure 5.15 and 5.16 that the vehicles moving across the outer cordon points are relatively new compared to the vehicles plying within the city. The average age of these HDV (Bus, LCV, HCV and MAV) is varying from 5.20 to 5.29 at outer cordons whereas it is varying from 5.52 to 5.96 within the city.

5.9 Vintage Characteristics at National Level within City

Using the above vintage characteristics for different vehicle types within city the vintage characteristics for city traffic at National level was worked out and given in Figure 5.17. The same vintage characteristics are applied while calculating the pollution loads and the same shift is applied for the future year's pollution loads for 2015, 2020, 2025 and 2030.

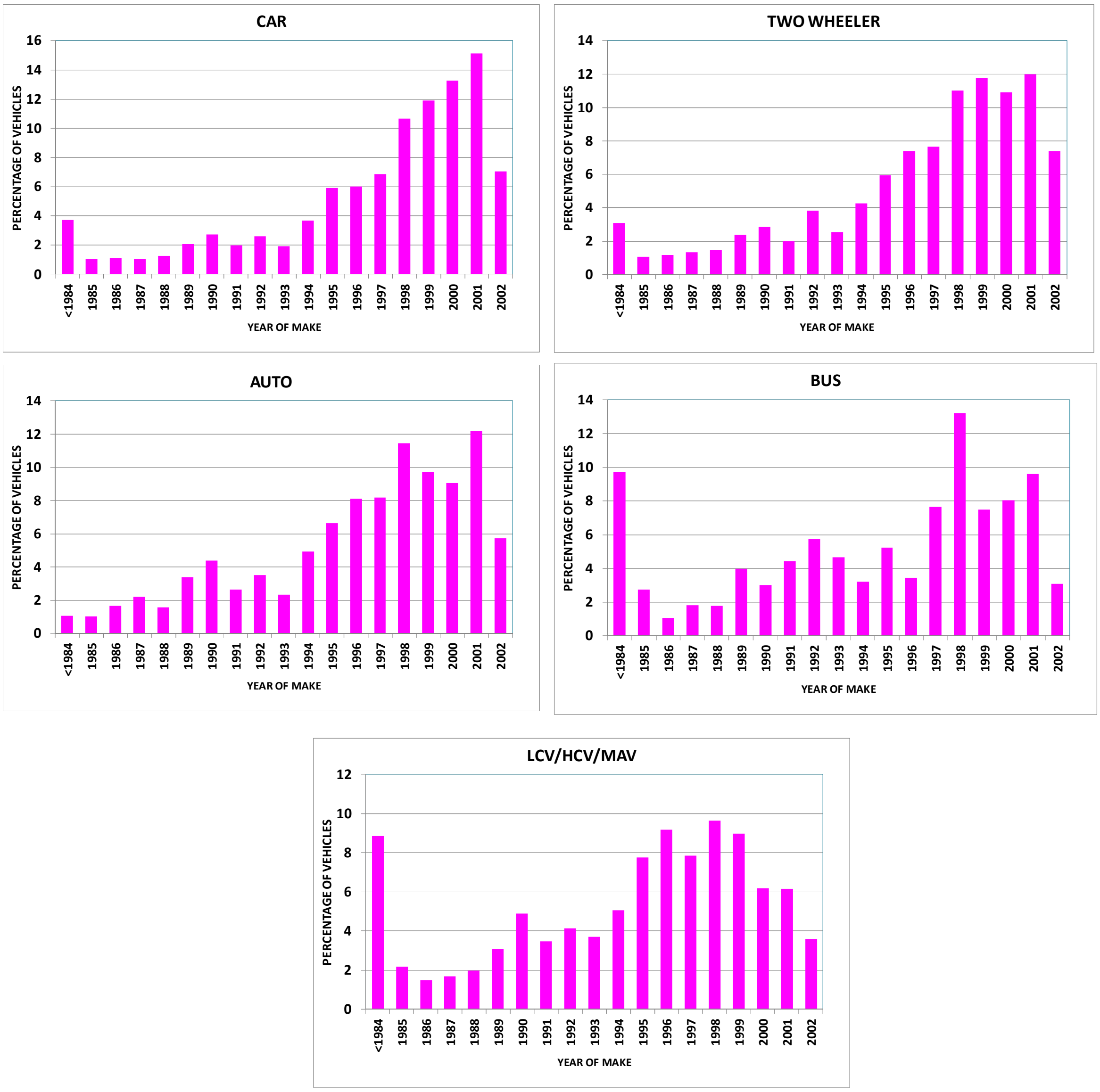


Figure 5.17: Age Distribution of Car, Two Wheeler, Auto, Bus, LCV,HCV and MAV within City at National Level

5.10 Vintage Characteristics at National Level - Intercity

Using the above vintage characteristics for different vehicle types for intercity traffic, the vintage characteristics for outer cordon traffic at National level was worked out and given in Figure 5.18. The same vintage characteristics are applied while calculating the pollution loads and the same shift is applied for the future year's pollution loads for 2015, 2020, 2025 and 2030.

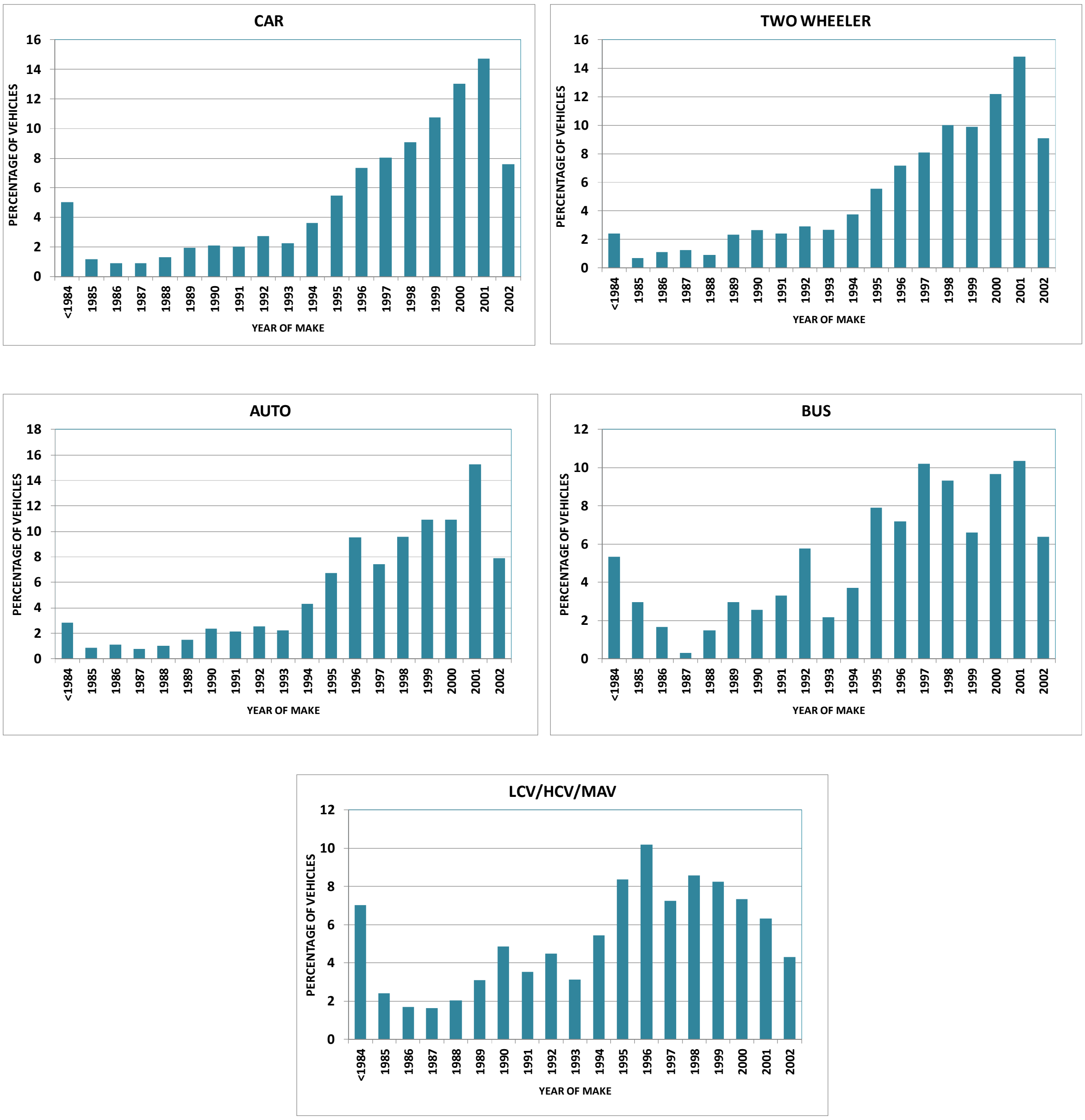


Figure 5.18: Age Distribution of Car, Two Wheeler, Auto, Bus, LCV, HCV and MAV in Inter City at National Level

6.0 VEHICLE KILOMETRES TRAVELLED (VKT)

Considering the data availability from related studies (CRRI, 2002 and CRRI, 2009) with respect to the parameters of travel by vehicle types across India, Vehicle Kilometres Travelled (VKT) has been considered most appropriate for estimating Emissions relating to Heavy Duty Vehicles (HDV) both passenger and goods vehicles. The methodology followed to estimate VKT is discussed in next section.

6.1 Methodology

The basic methodology followed for estimating the vehicle kilometers travelled covering intra city and intercity travel as shown in Figure 6.1. From the Figure 6.1, it can be seen that data review is undertaken relating the VKT studies initially. However it is to be noted that there was only one study Urban Road Traffic and Air Pollution (URTRAP, 2002) carried out at National level which is extensively carried out on VKT for eight cities (CRRI, 2002). Keeping this study as base, VKT for urban areas were arrived based on population at each of the urban centres for the intracity travel. Whereas for the VKT of intercity travel is mainly depends on the vehicles utilization per day (VUPD) for different vehicle types. For arriving the intercity VKT, the number of vehicles on road (intercity road network) was arrived first based on the number of vehicles registered at the National level and this was further multiplied with the VUPD to arrive the intercity VKT at National level. Further the estimation of VKT for intracity as well as intercity was discussed below. Further summing the intra city and intercity VKT, the total VKT is estimated. Further steps for Intracity and Intercity VKT was discussed in the subsequent subheadings in the next sections.

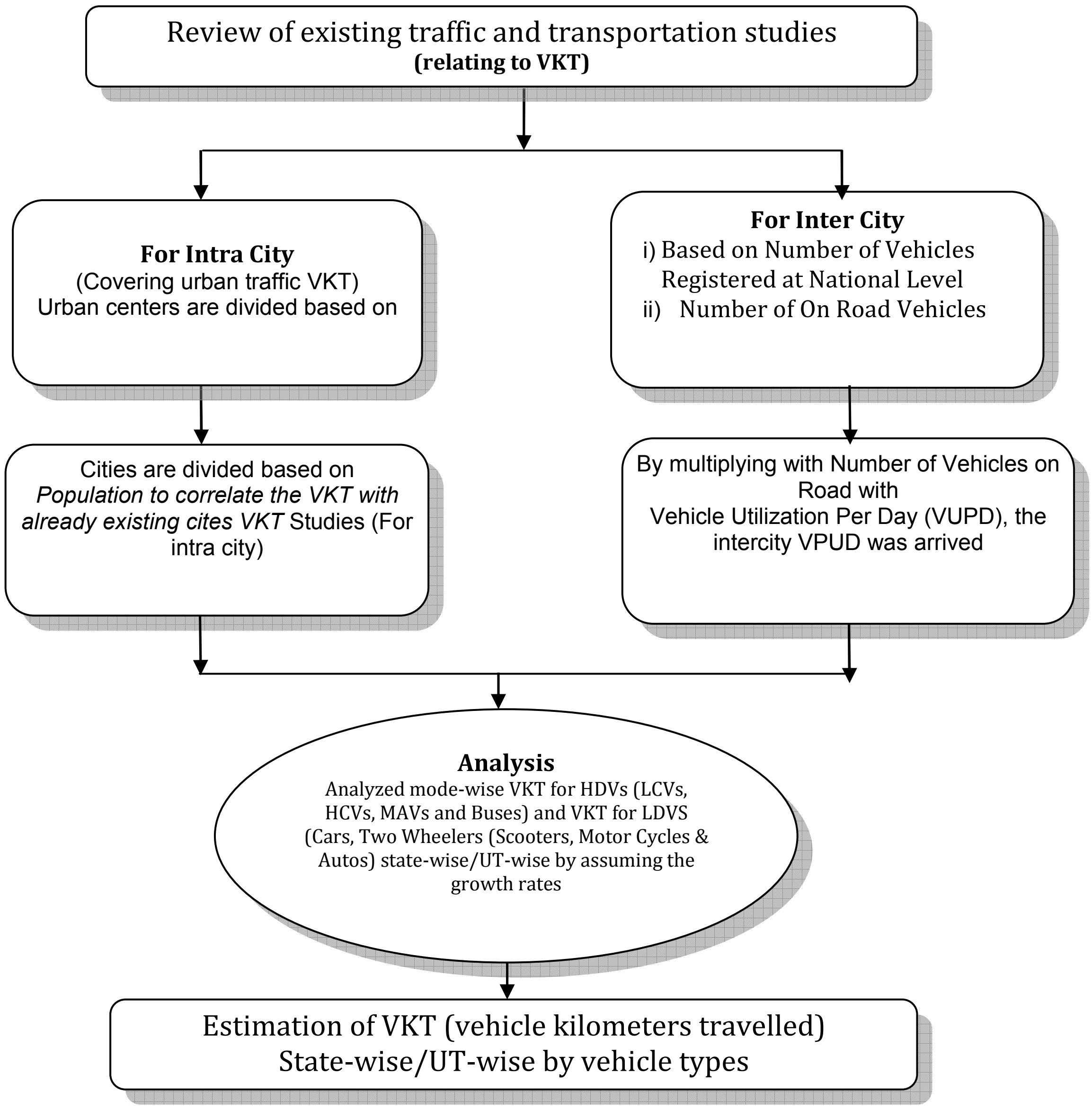


Figure 6.1: Methodology for Estimation of VKT at National Level

6.2 *Estimation of Intracity VKT*

After reviewing the literature relating to VKT, URTRAP (Urban Road Traffic and Air Pollution study by CRRI, 2002) study has been found most appropriate to adopt for VKT estimation at the national level. Thereby, URTRAP data comprising of eight cities (Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Kanpur and Agra) has been considered as basis for estimation of VKT for both intra city as well as intercity. The intracity VKT of eight cities is shown in Table 6.1.

Table 6.1: Intracity Vehicle Kilometres Travelled (VKT) in 2002

Name of the City	Population	Vehicle Kilometres Travelled (VKT, in Lakhs)							Total
		Cars	Scootters	Motor Cycles	Autos	LCVs	HVCs	Bus	
Delhi	12877470	306.89	229.39	108.84	93.57	17.46	7.68	28.51	792.34
Mumbai	16434386	120.96	64.49	30.60	53.88	12.13	13.29	10.00	305.35
Kolkata	13205697	114.14	48.29	22.92	19.45	6.76	2.98	16.18	230.72
Chennai	6560242	55.60	91.22	43.28	42.40	7.22	3.18	6.10	249.00
Hyderabad	5742036	41.93	97.45	46.24	44.60	11.13	4.90	10.52	256.77
Bangalore	5701446	53.47	138.13	65.54	50.45	7.07	3.11	8.48	326.25
Kanpur	2715555	7.87	19.74	9.37	6.55	2.72	1.20	0.73	48.18
Agra	1331339	4.26	10.19	4.84	5.49	1.32	0.58	0.81	27.49

Note: Delhi Bus VKT is the sum of CNG (10.53) + Diesel (17.98) Lakh-Kms

Source: URTRAP Study in 2002 (CRRI, 2002)

Further to estimate the intracity VKT at national level from the above eight cities, the cities in India are divided into ten categories as per the Census 2001 and the normalisation factors were devised to estimate VKT for these cities as shown in Table 6.2.

Table 6.2: Urban Cities categorized by Population and Adopted Normalization Factors

Category	Population	Number of urban agglomerations/ cities*	Normalization Factor
CLASS VI	<5000	117	0.1
CLASS V	5000 to 9999	711	0.2
CLASS IV	10000 to 19999	1119	0.3
CLASS III	20000 to 49999	907	0.4
CLASS II	50000 to 99999	289	0.5
CLASS I	100000 to 249999	169	0.6
CLASS C	250000 to 499999	46	0.7
CLASS B	500000 to 749999	17	0.8
CLASS A	750000 to 1000000	12	0.9
Million plus population cities	>1000000	35	1

**Source: Census of India, http://censusindia.gov.in/*

Since the travel intensity may not be same as a million plus cities, after dividing the population of cities from each State/ Union Territory (UT) into ten categories, the population has been normalized with a factor as described in Table 6.2. These factors are subsequently utilised to estimate VKT for each category of city based on existing VKT of cities. The million plus population cities VKT has been estimated state/ UT wise by interpolating the population with respect to the VKT has been given in Table 6.3 and the same is pictorially depicted in Figure 6.2.

Table 6.3: Estimated VKT for Million Plus Cities (2002)

State	City	Popoulation	Vehicle Kilometres Travelled (VKT, in Lakhs)								City Wise VKT Per Capita
			Cars	Scootters	Motor Cycles	Autos	LCVs	HVCs	Bus	Total	
Andhra Pradesh	Hyderabad	5742036	41.93	97.45	46.24	44.60	11.13	4.90	10.52	256.77	4.47
	Vijayawada	1039518	3.33	7.96	3.78	4.29	1.03	0.45	0.63	21.46	2.06
	Visakhapatnam	1345938	4.31	10.31	4.89	5.55	1.33	0.59	0.82	27.79	2.06
	Sub Total	***8127492***	***49.56***	***115.71***	***54.91***	***54.44***	***13.49***	***5.94***	***11.97***	***306.03***	***3.77***
Bihar	Patna	***1697976***	***5.43***	***13.00***	***6.17***	***7.00***	***1.68***	***0.74***	***1.03***	***35.06***	***2.06***
Delhi	Delhi	***12877470***	***306.89***	***229.39***	***108.84***	***93.57***	***17.46***	***7.68***	***28.51***	***792.34***	***6.15***
Gujarat	Ahmadabad	4525013	37.95	82.14	38.97	34.55	6.39	2.81	6.31	209.12	4.62
	Rajkot	1003015	3.21	7.68	3.64	4.14	0.99	0.44	0.61	20.71	2.06
	Surat	2811614	9.00	21.53	10.21	11.59	2.79	1.23	1.71	58.06	2.06
	Vadodara	1491045	4.77	11.42	5.42	6.15	1.48	0.65	0.91	30.79	2.06
	Sub Total	***9830687***	***54.93***	***122.76***	***58.25***	***56.43***	***11.65***	***5.13***	***9.54***	***318.67***	***3.24***
Haryana	Faridabad	1055938	3.38	8.08	3.84	4.35	1.05	0.46	0.64	21.80	2.06
Jharkhand	Dhanbad	1065327	2.66	6.37	3.02	3.43	0.82	0.36	0.51	17.18	1.61
	Jamshedpur	1104713	3.53	8.46	4.01	4.56	1.09	0.48	0.67	22.81	2.06
	Sub Total	***3225978***	***9.58***	***22.91***	***10.87***	***12.34***	***2.97***	***1.31***	***1.82***	***61.79***	***1.92***
Karnataka	Bangalore	***5701446***	***53.47***	***138.13***	***65.54***	***50.45***	***7.07***	***3.11***	***8.48***	***326.25***	***5.72***
Kerala	Kochi	***1355972***	***4.34***	***10.38***	***4.93***	***5.59***	***1.34***	***0.59***	***0.82***	***28.00***	2.06
Madhya Pradesh	Bhopal	1458416	4.67	11.17	5.30	6.01	1.45	0.64	0.89	30.11	2.06
	Indore	1516918	4.85	11.61	5.51	6.26	1.50	0.66	0.92	31.32	2.06
	Jabalpur	1098000	3.51	8.41	3.99	4.53	1.09	0.48	0.67	22.67	2.06
	Sub Total	***4073334***	***13.03***	***31.19***	***14.80***	***16.80***	***4.04***	***1.78***	***2.48***	***84.11***	***2.06***
Maharastra	Mumbai	16434386	120.96	64.49	30.60	53.88	12.13	13.29	10.00	305.35	1.86
	Nagpur	2129500	6.81	16.30	7.74	8.78	2.11	0.93	1.30	43.97	2.06
	Nashik	1152326	3.69	8.82	4.19	4.75	1.14	0.50	0.70	23.79	2.06
	Pune	3760636	31.54	68.26	32.39	28.71	5.31	2.34	5.24	173.79	4.62
	Sub Total	***23476848***	***163.00***	***157.88***	***74.91***	***96.12***	***20.69***	***17.06***	***17.24***	***546.91***	***2.33***
Punjab	Amritsar	1003917	3.21	7.69	3.65	4.14	0.99	0.44	0.61	20.73	2.06
	Ludhiana	1398467	4.47	10.71	5.08	5.77	1.39	0.61	0.85	28.88	2.06
	Sub Total	***2402384***	***7.69***	***18.39***	***8.73***	***9.91***	***2.38***	***1.05***	***1.46***	***49.61***	***2.06***
Rajasthan	Jaipur	***2322575***	***7.43***	***17.78***	***8.44***	***9.58***	***2.30***	***1.01***	***1.41***	***47.96***	***2.06***
Tamil Nadu	Chennai	6560242	55.60	91.22	43.28	42.40	7.22	3.18	6.10	249.00	3.80
	Coimbatore	1461139	4.68	11.19	5.31	6.03	1.45	0.64	0.89	30.17	2.06
	Madurai	1203095	3.85	9.21	4.37	4.96	1.19	0.52	0.73	24.84	2.06
	Sub Total	***9224476***	***64.12***	***111.62***	***52.96***	***53.39***	***9.86***	***4.34***	***7.72***	***304.01***	***3.30***
Uttar Pradesh	Agra	1331339	4.26	10.19	4.84	5.49	1.32	0.58	0.81	27.49	2.06
	Allahabad	1042229	3.02	7.58	3.60	2.51	1.04	0.46	0.28	18.49	1.77
	Kanpur	2715555	7.87	19.74	9.37	6.55	2.72	1.20	0.73	48.18	1.77
	Lucknow	2245509	6.51	16.33	7.75	5.42	2.25	0.99	0.60	39.84	1.77
	Meerut	1161716	3.37	8.45	4.01	2.80	1.16	0.51	0.31	20.61	1.77
	Varanasi	1203961	3.49	8.75	4.15	2.90	1.21	0.53	0.32	21.36	1.77
	Sub Total	***9700309***	***28.51***	***71.04***	***33.71***	***25.68***	***9.70***	***4.28***	***3.06***	***175.97***	***1.81***
West Bengal	Asansol	1067369	3.42	8.17	3.88	4.40	1.06	0.47	0.65	22.04	2.06
	Kolkata	13205697	114.14	48.29	22.92	19.45	6.76	2.98	16.18	230.72	1.75
	Sub Total	***14273066***	***117.56***	***56.47***	***26.79***	***23.85***	***7.82***	***3.44***	***16.83***	***252.76***	***1.77***
Grand Total VKT (Million plus Cities)		**108290013**	**885.55**	**1116.65**	**529.84**	**515.13**	**112.46**	**57.46**	**112.38**	**3329.46**	**3.07**

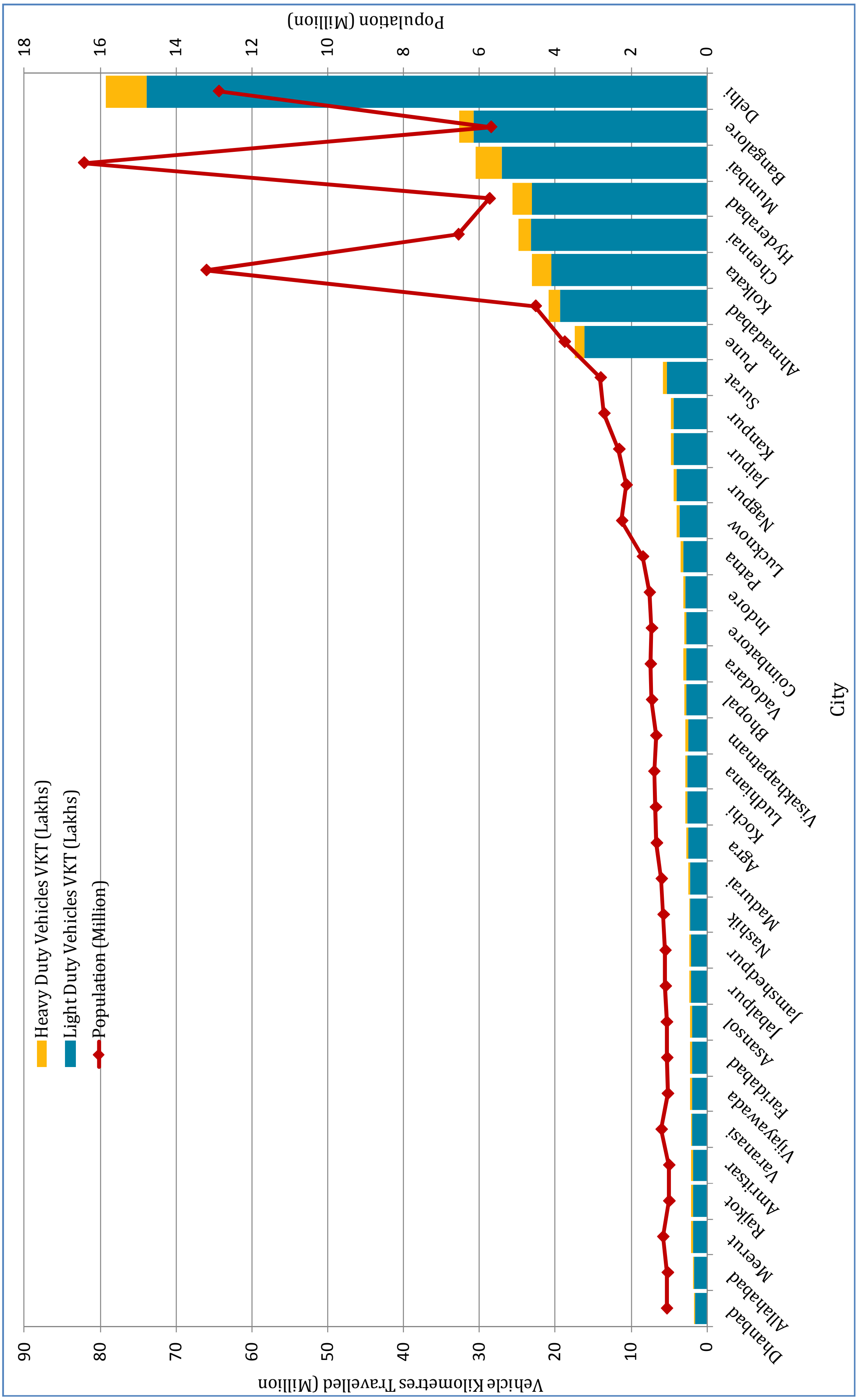


Figure 6.2: Intra city VKT for Million Plus Population Cities (2002)

From Table 6.3 and Figure 6.2, it can be observed that Delhi has highest per capita VKT/day of 6.15 km followed by Bangalore with per capita VKT/day 5.72 km and Dhanbad being lowest per capita VKT (1.61/day). Combining all the cities at national level as per the categorization given in Table 6.2, the State/ UT wise intracity VKT is estimated and presented in Figure 6.3.

From Figure 6.3, it can be observed that Delhi state has highest intracity VKT/day followed by Karnataka and Lakshadweep being lowest intracity VKT

6.3 Estimation of Intercity VKT

Based on number of vehicles registered, the on-road vehicles were appropriately worked out. Further, based on the vehicle utilized per day (VPUD) from Road User Cost Study (CRRI, 2010 and CRRI, 2001) the total VKT for the intercity was estimated for the base year 2002 for each vehicle type and presented in Figure 6.4.

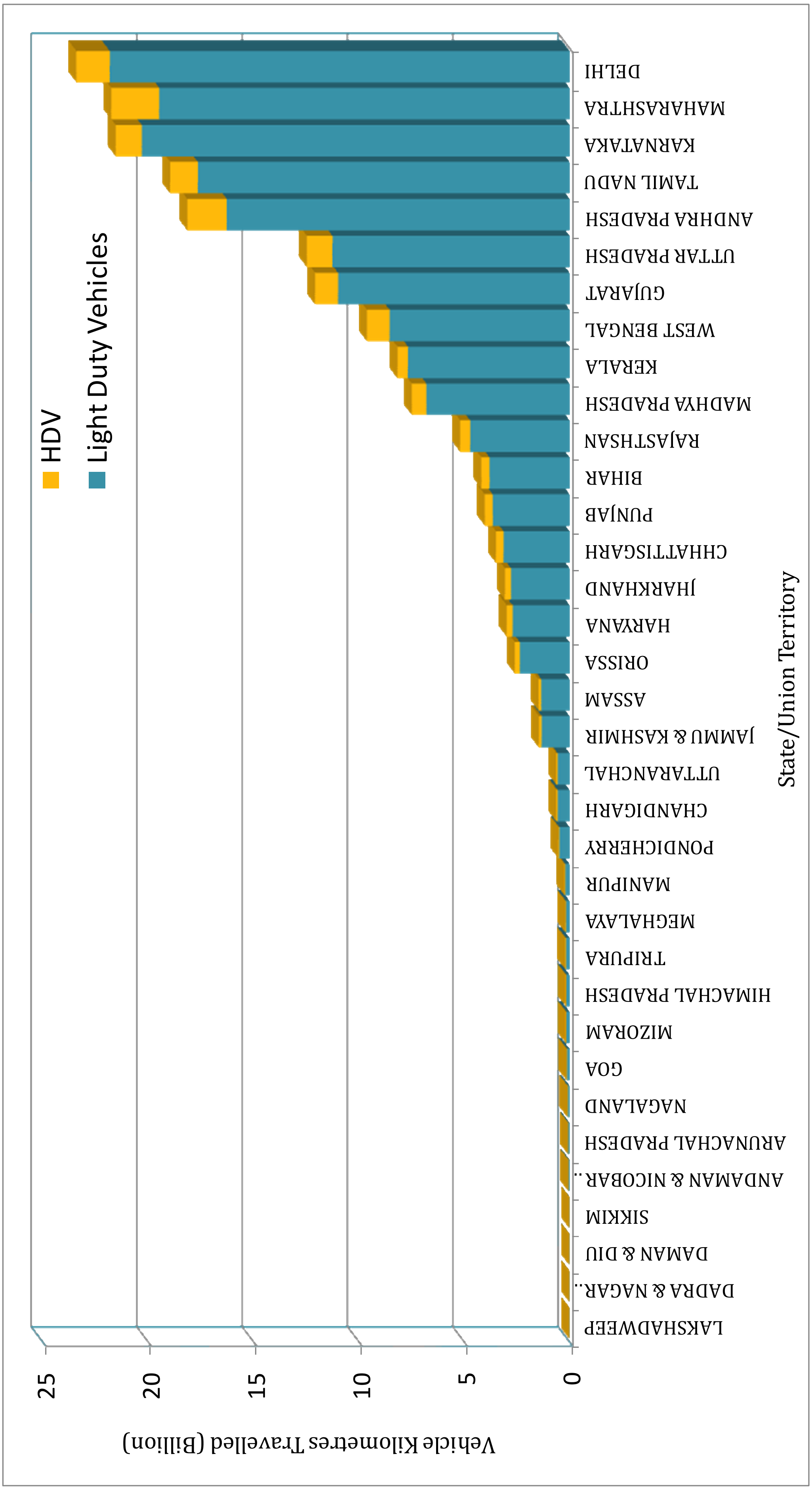


Figure 6.3: Vehicle Kilometers Travelled in State/Union Territory wise at Urban areas (2002)

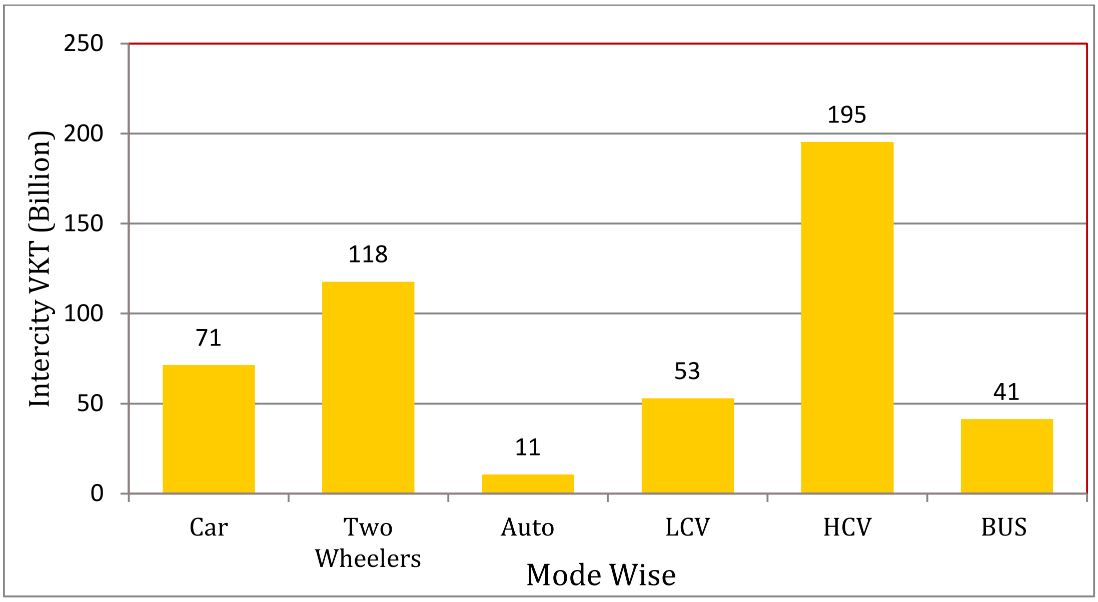


Figure 6.4: Intercity VKT estimated at National level (2002)

Further the VKT arrived was compared from the total network considering the outer cordon study data for eight major cities (URTRAP,2002), the intercity traffic has been estimated and assigned to existing National Highways/ Expressways, State Highways, Major District Roads (MDRs) and Other District Roads (ODRs) appropriately. The total length considered for various categories of roads have been given in Table 6.4. Since total network of National Highways, State Highways and MDR may not experience the same intensity of traffic, normalization based on the intensity of traffic on total network is proposed and accordingly the network is divided into three categories.

Accordingly, the VKT on intercity roads has been estimated and shown in Figure 6.5. From the Figure 6.5, it can be observed that about six percentage of National Highways and State Highways share about 65 percent of total intercity VKT, which indicates the National Highway and State Highway network is playing major role in road transportation sector.

Table 6.4: Total length considered for intercity VKT based on Road Type

Road Type	Total	Percentage
National Highways (NH)	70548	2.13
State Highways (SH)	128000	3.86
Major District Roads (MDR)	470000	14.16
Other District Roads (ODR) /Rural Roads	2650000	79.85
Total	3318548	100.00

Source: MoRT&H Annual Report 2008-09, http://morth.nic.in

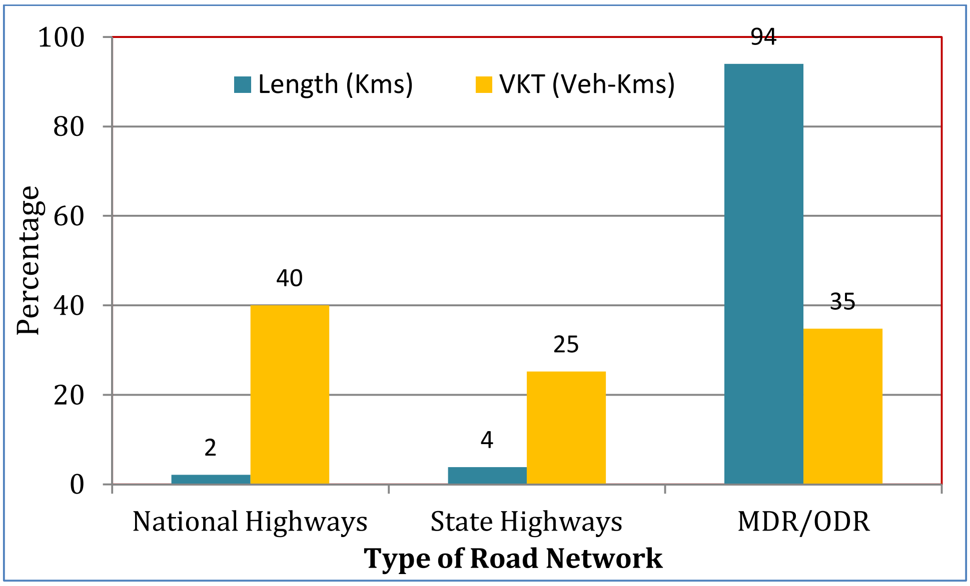


Figure 6.5: Proportion of road network and VKT based on Road Type

6.5 *Estimation of Total VKT at National Level*

By combining both intercity and intracity VKT given in Figure 6.3 and Figure 6.4 respectively, the total VKT per annum at the National level in the year 2002 has been estimated. The 2002 estimates of both intercity and intracity are considered as base year for further projections of annual VKT from 2003 to 2030. For this purpose, the growth factor for intracity between 6 and 5 percent per annum and for intercity, between 6 and 5 percent per annum has been adopted considering mainly the growth rates of vehicle population (Road Transport year book 2010-11 released in March 2011). The annual VKT at national level was arrived by combining the respective State/ UT intracity VKT and Intercity VKT, the total VKT at national level for the year 2013. Figure 6.6 shows the estimated annual intracity VKT as well as intercity VKT for the year 2013 for different vehicle types.

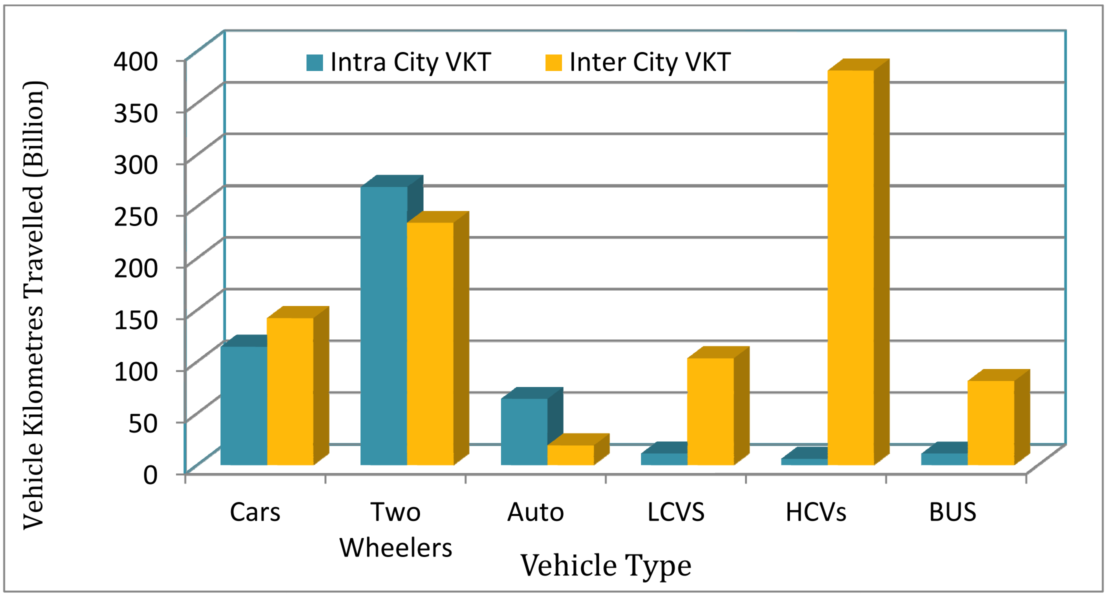


Figure 6.6: Annual Vehicle Kilometres Travelled by different Vehicle Types for Intracity and Intercity (2013)

From the Figure 6.6, it can be clearly understood that intercity VKT contribution is more than the intracity because of the higher road network as compared to the urban areas road network length. Further the main VKT contributor in intercity VKT is from the Heavy Duty Vehicles (HDVs) which travels longer lengths as compared to the urban area travel. The Total VKT in the year 2013 is around 1437 billion. The further comparison between the intercity and intracity is presented in Figure 6.7.

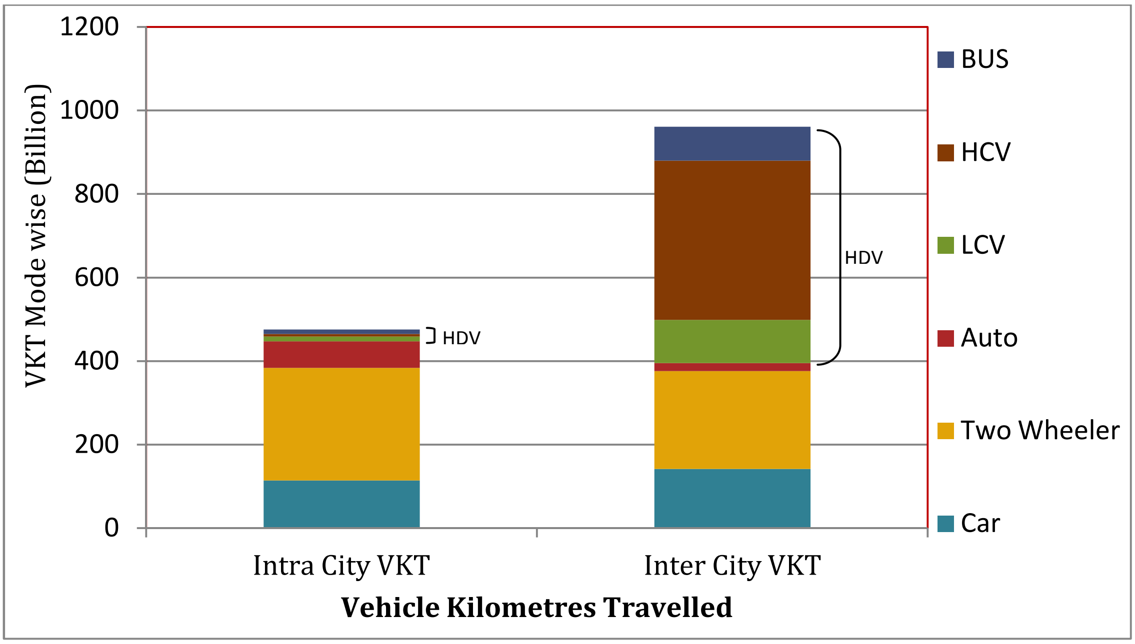


Figure 6.7: Proportion of Mode-wise VKT travelled in intracity as well as intercity at National level in 2013

From the Figure 6.7, it can be clearly seen that the intercity VKT is more than double of intracity VKT. The private vehicles (Car and Two Wheelers) contribute about 80% in intracity VKT whereas their contribution is about 40% in intercity VKT. The composition of VKT by mode wise (Heavy Duty Vehicles and Light Duty Vehicles) in intracity as well as intercity VKT is presented in Figure 6.8.

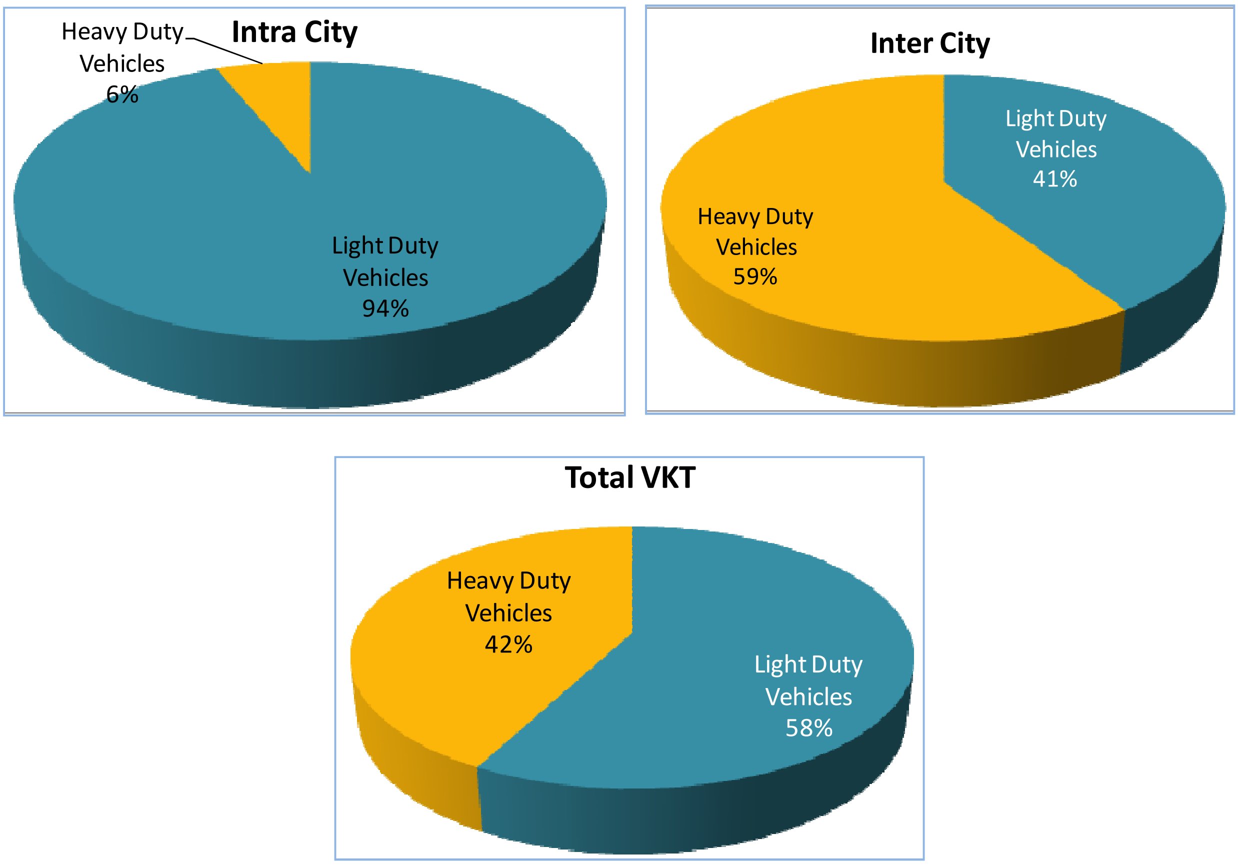


Figure 6.8: Composition of Heavy Duty Vehicles and Light Duty Vehicles in Intra City, Inter City and Total VKT (2013)

From the Figure 6.8, it can be observed that VKT of HDV (Bus, LCVs and HCVs) is around 6 percent for intracity VKT whereas it is 59% for the intercity VKT. The overall VKT of HDV is around 42 percent. Further based on the growth rates adopted for intracity and intercity VKT, the horizon years VKT for 2015, 2020, 2025 and 2030 are projected and presented in Table 6.7. The estimated annual intracity VKT based on vehicle type from the year 2002 to 2030 is presented in Figure 6.11 and 6.12. The estimated annual intercity VKT based on vehicle type from the year 2002 to 2030 is presented in Figure 6.13 and 6.14.

Table 6.5: Total Vehicle Kilometers Travelled (VKT) by vehicle type in India from 2002 to 2030

State/Union Territory	2002	2012	2013	2015	2020	2025	2030
ANDAMAN & NICOBAR ISLANDS	59606981	141482682	154650865	184827628	289037178	432587808	648652970
ANDHRA PRADESH	18130962216	42777915303	46733016279	55793246837	87057873405	130076206536	194812237683
ARUNACHAL PRADESH	74945557	175286427	191413168	228323402	355411849	529592979	790813482
ASSAM	1463652908	3423264835	3738212795	4459053023	6941033052	10342711923	15444230483
BIHAR	4169477932	9766031933	10665057906	12722992774	19811320922	29532479904	44120147326
CHANDIGARH	616397429	1441661225	1574297256	1877869271	2923121258	4355691849	6504126706
CHHATTISGARH	3490267616	8236939427	8998668345	10743665107	16765630764	25052482291	37524027199
DADRA & NAGAR HAVELI	11063897	24994560	27229099	32325918	49732859	73251096	108145248
DAMAN & DIU	12573168	28404170	30943531	36735629	56517122	83243576	122897782
DELHI	23387191003	54734175455	59784710662	71344181493	111139659863	165659842396	247349857722
GOA	144484334	326406007	355587025	422146809	649465476	956592047	1412277632
GUJARAT	12076011023	28359821969	30974914655	36962393025	57596832771	85922843089	128462075782
HARYANA	2974269963	6965232208	7606378228	9073981815	14128751671	21060454068	31461434278
HIMACHAL PRADESH	178808863	418207137	456683121	544745407	847959389	1263529451	1886762409
JAMMU & KASHMIR	1448852274	3388648371	3700411539	4413962544	6870844494	10238125181	15288056575
JHARKHAND	3059405096	7171739601	7832159296	9344021096	14552473959	21698046735	32424326162
KARNATAKA	21527109706	51953103324	56850086217	68089042723	107037750907	161016480830	242627554217
KERALA	8170256316	19667755076	21517633363	25762339591	40465236583	60825154584	91590838258
LAKSHADWEEP	5425874	12690306	13857843	16530053	25730944	38341229	57252951
MADHYA PRADESH	7484751096	17539890860	19154869654	22851840766	35587150754	53056523249	79276524766
MAHARASHTRA	21737517513	49939765669	54466109065	64807833519	100270586715	148528302564	220522178808
MANIPUR	230302273	538642507	588198813	701621293	1092154895	1627400903	2430112607
MEGHALAYA	196762285	460197502	502536693	599440932	933099315	1390394966	2076204043
MIZORAM	169070108	395429649	431810054	515076062	801775613	1194711814	1784000634
NAGALAND	97531722	228112083	249098901	297132685	462521477	689195162	1029139070
ORISSA	2586628477	6049736422	6606325595	7880224516	12266483162	18278071967	27293688383
PONDICHERRY	525447005	1247197050	1363277120	1629291090	2547918309	3813344722	5718000676
PUNJAB	4007487795	9393072003	10258004445	12238023719	19059109983	28416592296	42462496473
RAJASTHSAN	5178641998	12112067656	13226404751	15776854695	24558503641	36594196646	54644198888
SIKKIM	15423754	36073849	39392723	46988829	73143561	108989941	162748975
TAMIL NADU	18948714175	44942499018	49122164700	58699887433	91770429044	137316156627	205862277774
TRIPURA	198305432	463806690	506477934	604142163	940417327	1401299407	2092487075
UTTAR PRADESH	12456308090	29624765259	32382240940	38703699574	60555348755	90711134677	136185722851
UTTARANCHAL	626498300	1488077813	1626436872	1943582194	3039548066	4551244733	6830043674
WEST BENGAL	9614661419	21950633211	23935423252	28468173474	43993022233	65072567662	96455011447
Intra City VKT	185074813597	435423727260	475664682703	567816197091	885515597316	1321907784907	1977460551009
Inter City VKT	489301571410	898454260424	961166492335	1100034092240	1541478999889	2061073778409	2755918996189
Total VKT Vehicle Type	674376385007	1333877987683	1436831175038	1667850289331	2426994597205	3382981563316	4733379547198
Total VKT (Billion)	674	1334	1437	1668	2427	3383	4733

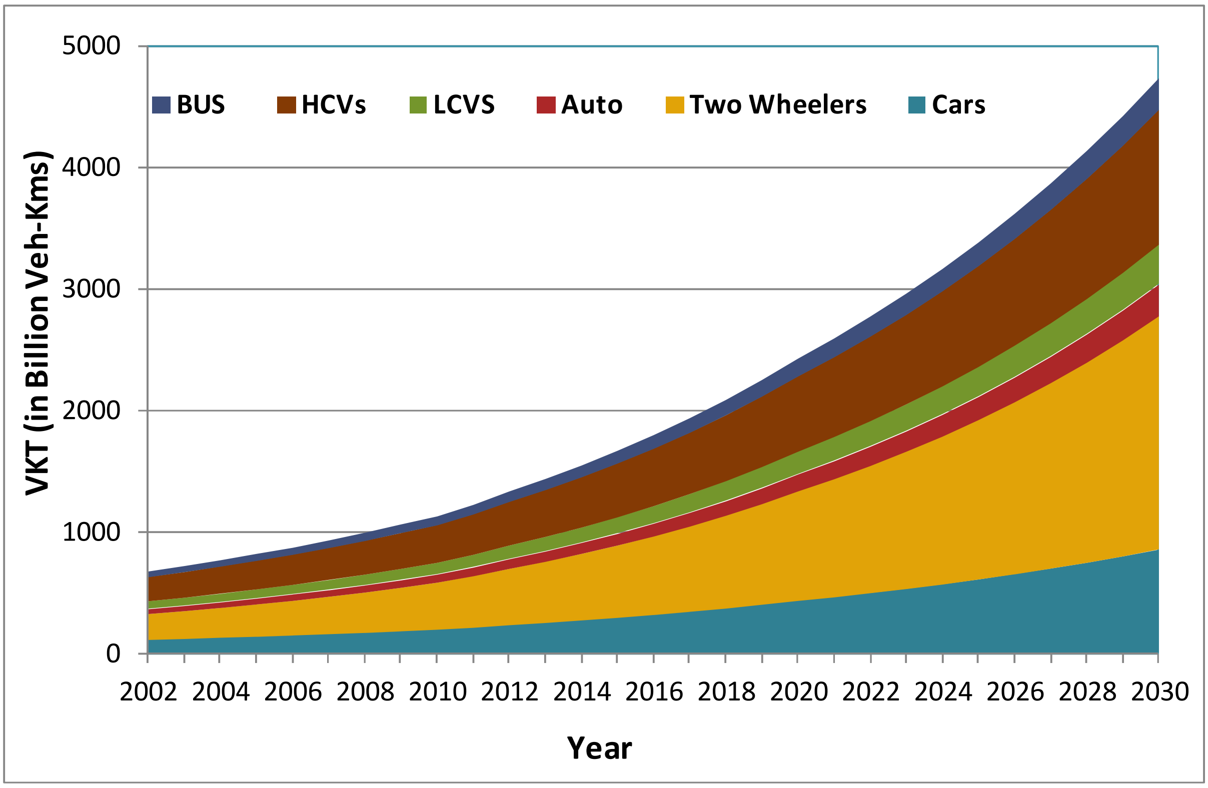


Figure 6.9: Growth of Vehicle Kilometres Travelled at National Level (2002-2030)

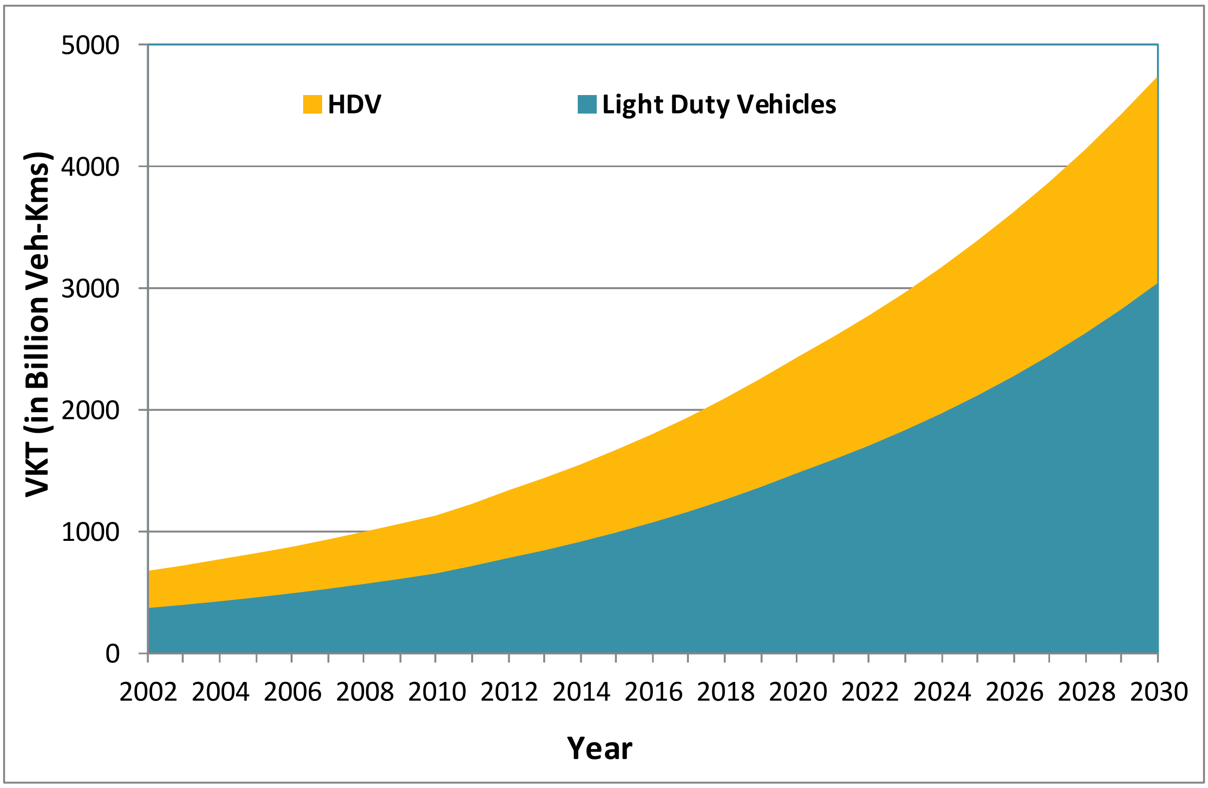


Figure 6.10: Growth of Vehicle Kilometres Travelled by Heavy Duty Vehicles and Light Duty Vehicles at National Level (2002-2030)

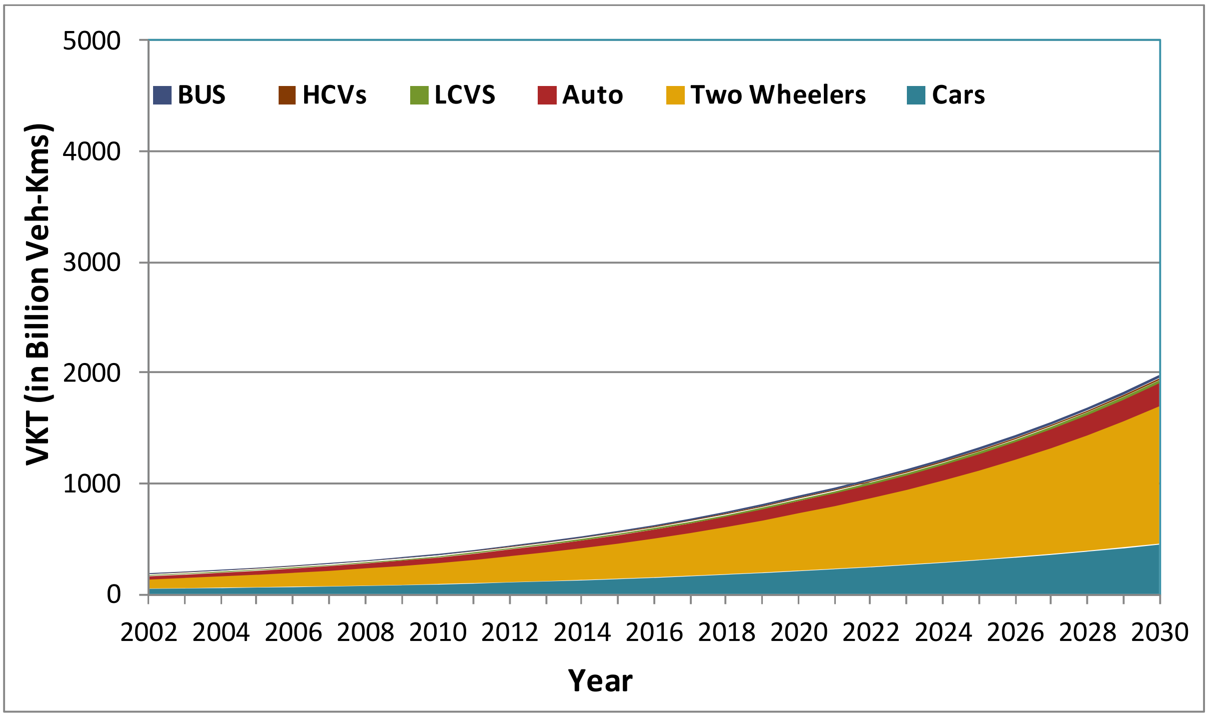


Figure 6.11: Growth of Intracity Vehicle Kilometres Travelled at National Level (2002-2030)

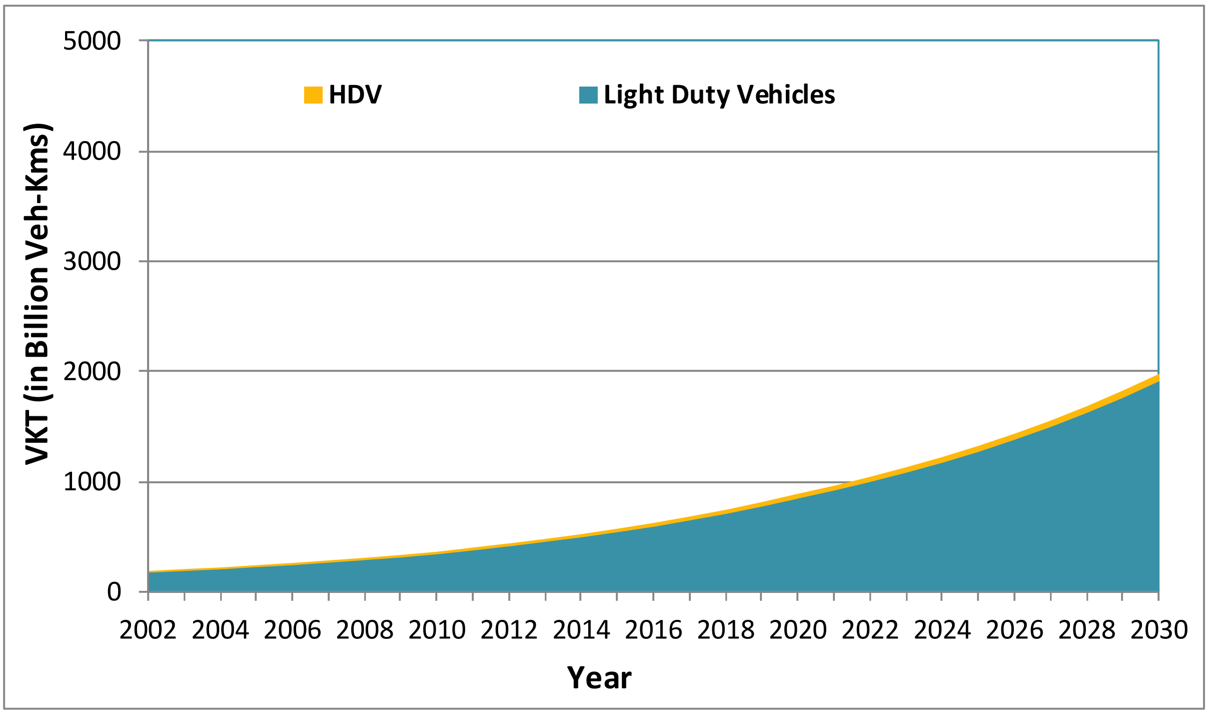


Figure 6.12: Growth of Intracity Vehicle Kilometres Travelled by Heavy Duty Vehicles and Light Duty Vehicles at National Level (2002-2030)

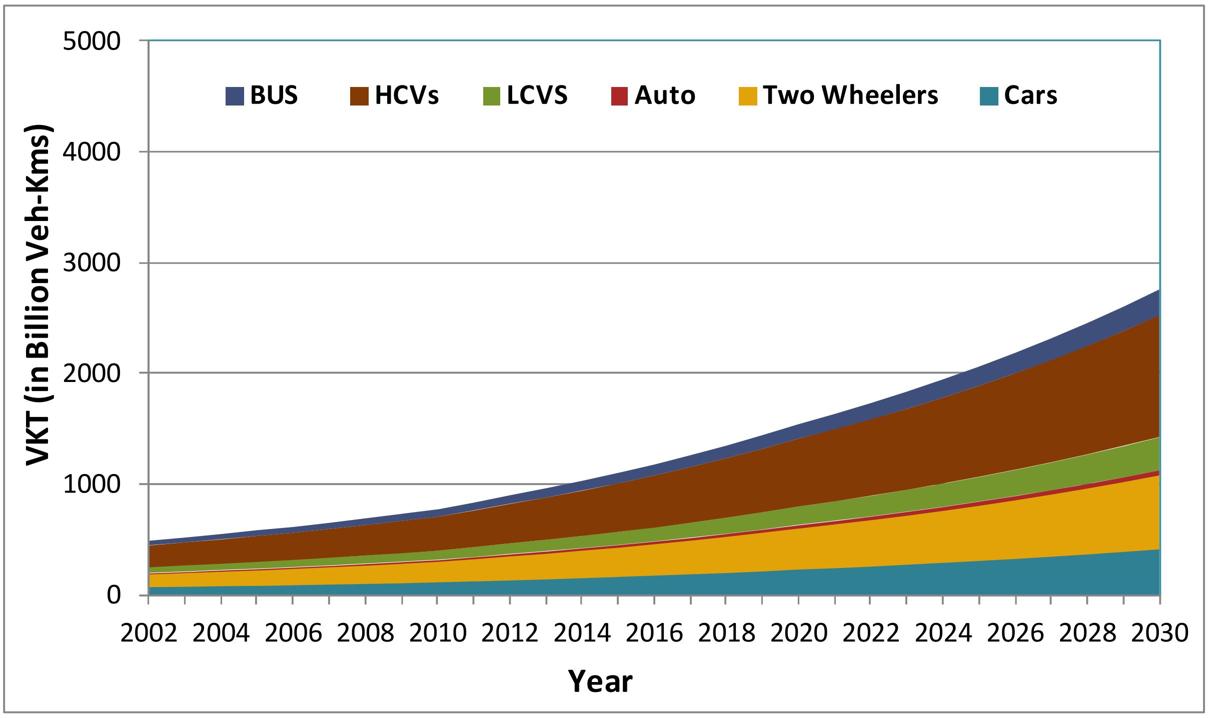


Figure 6.13: Growth of Intercity Vehicle Kilometres Travelled at National Level (2002-2030)

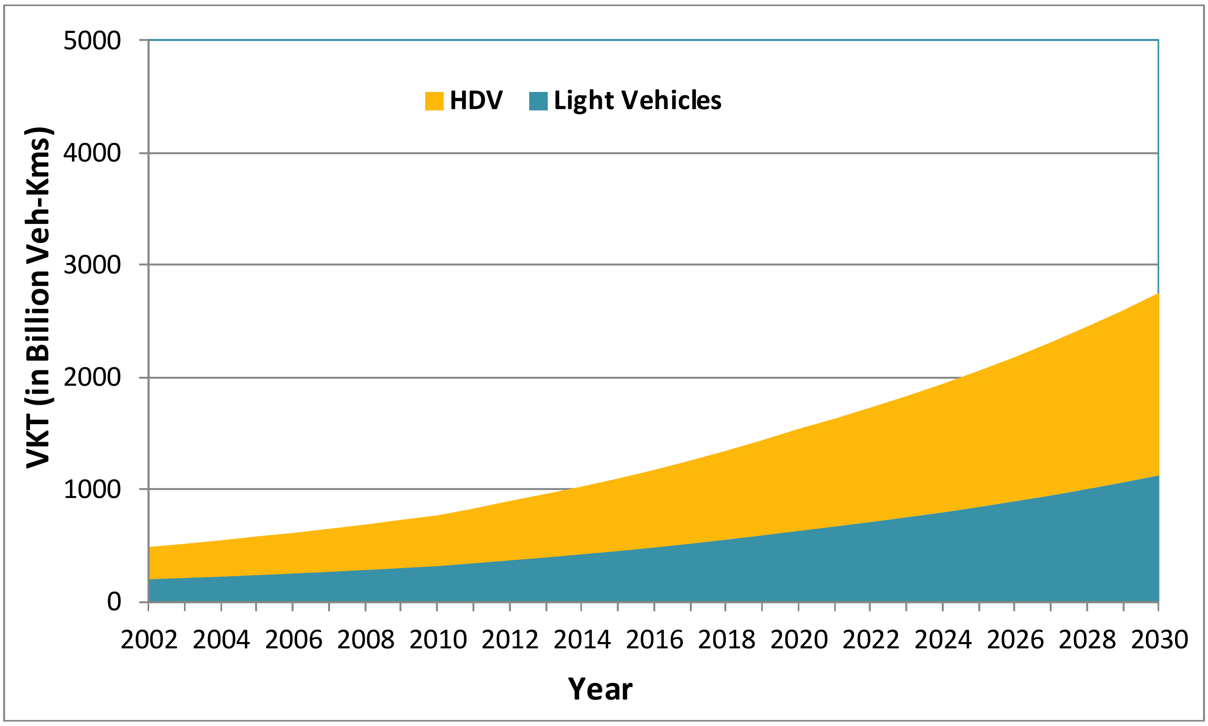


Figure 6.14: Growth of Intercity Vehicle Kilometres Travelled Intercity Heavy Duty Vehicles and Light Duty Vehicles at National Level (2002-2030)

From the Figure 6.9 to 6.14, it can be seen that the total VKT by the year 2030 would be around 4733 billion. Further it can be observed that HDV share is also steadily increasing and it would be more than 39% in total VKT at national level by the year 2030.

A close comparison of annual VKT in 2007 for the selected countries was carried out and presented in Figure 6.15. From the Figure 6.15, it can be seen that the total VKT in USA is about 5000 Billion VKT followed by 930 billion VKT in India.

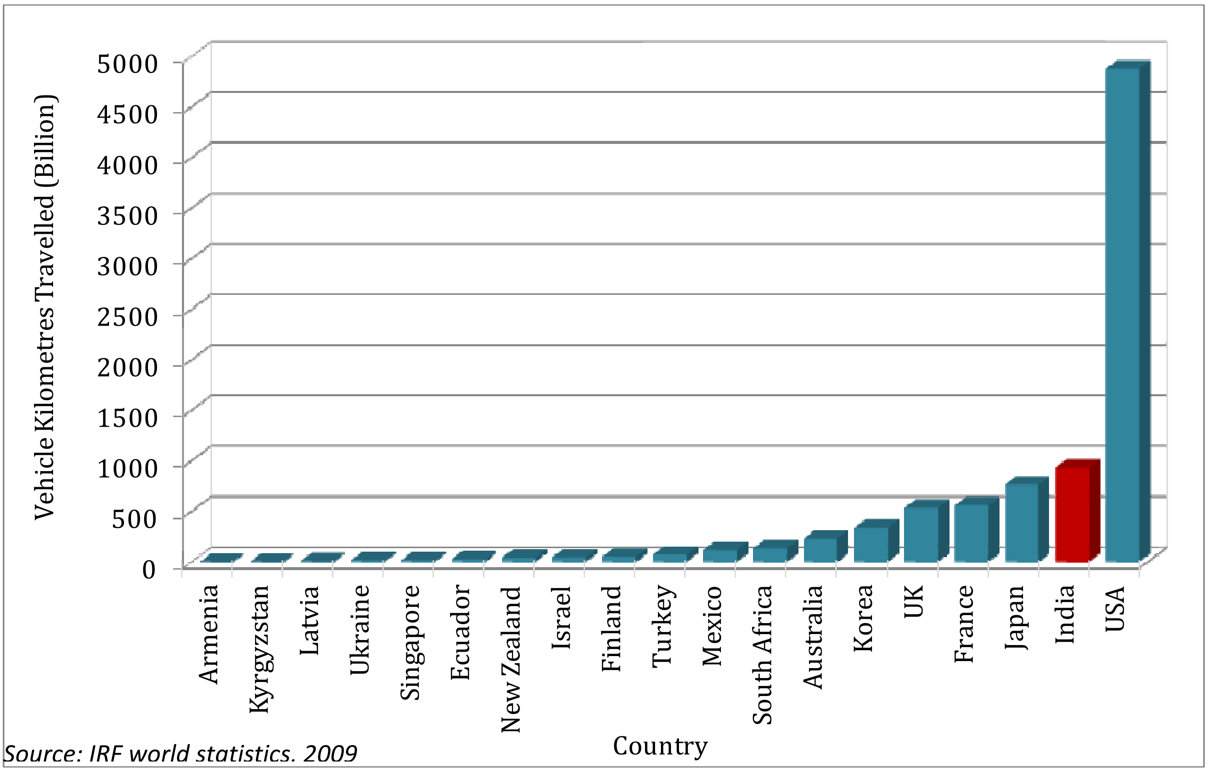


Figure 6.15: VKT of selected Countries (2007)

A comparison of per capita VKT (for year 2007) for some of the countries is shown in Figure 6.16.

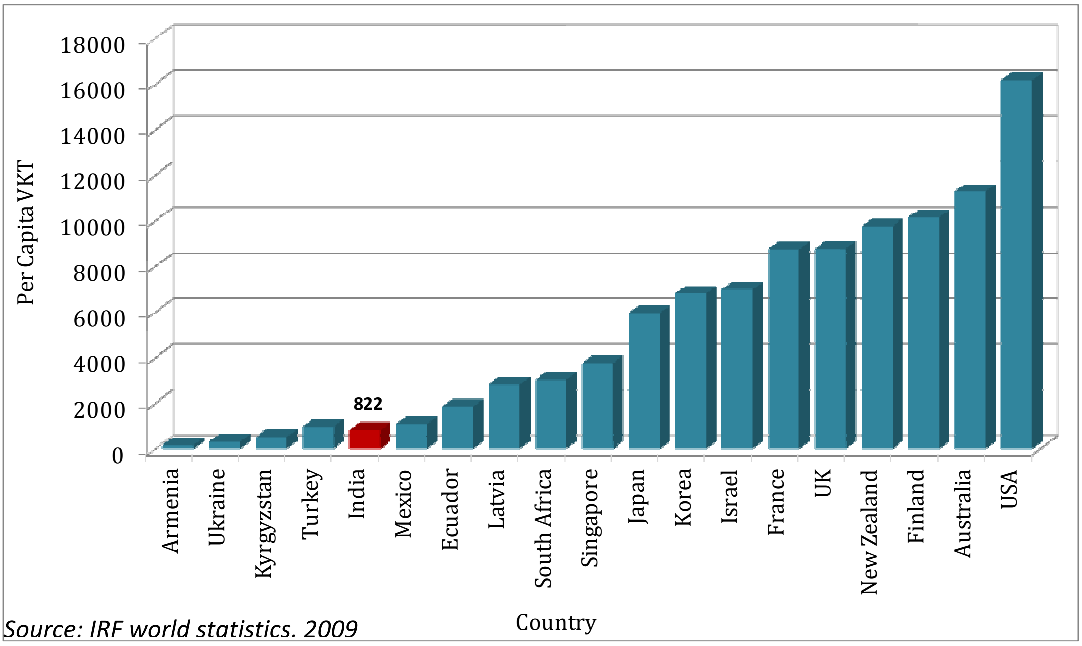


Figure 6.16: Per capita VKT of selected Countries (2007)

From the Figure 6.16, it can be observed that per capita annual VKT in USA is about 16000 km followed by 11500 km in Australia. This may be due to the geographical, high population settlements, high vehicle ownership and high income levels has contributed the highest per capita annual VKT for USA as compared to the rest of the countries. India would have about 822 km per capita annual VKT in 2007 as can be seen in Figure 6.16. Further India's per capita annual VKT is increased from 645km in 2002 to 822 km in 2007 as shown in Figure 6.17.

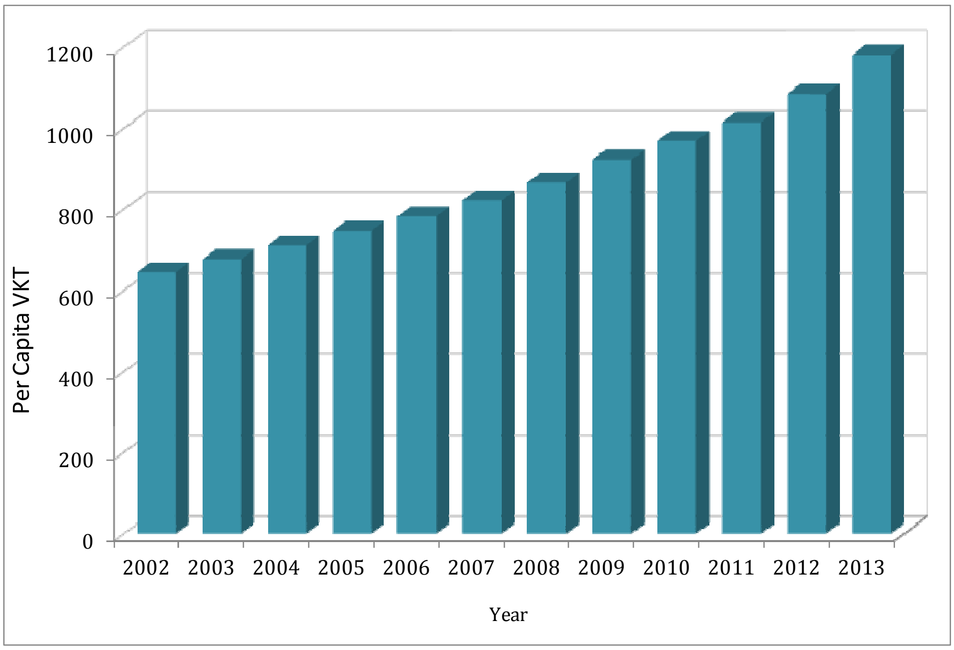


Figure 6.17: Growth of Per capita VKT at National Level (2002 -2013)

7.0 VEHICLE EMISSION LOADS AND PROPOSED EMISSION NORMS

7.1 Vehicle Emission Norms

The vehicle population in India has grown tremendously since the year 1951. The total number of vehicles registered in the 28 states and 7 union territories of India in the year 2011 were about 141 million as shown in Figure 1.1 and Figure 1.2. Further the Vehicle Kilometres Travelled has been increased tremendously from 673 Billion in year 2002 to 4733 Billion in Year 2013 as shown in Figure 6.9.

India has since progressively lowered its permissible vehicular pollution emission limits for new vehicles following the path laid out by the European Union. The Auto Fuel Policy of 2003 laid down a road map for vehicular emission and fuel quality standards for the remainder of the new century's first decade. This road map has been largely implemented. In 2010, Bharat IV fuel quality standards and vehicle emission standards for four-wheeled vehicles were implemented in 13 major cities, while Bharat III standards took effect in the rest of the country. As of January 2013, Bharat IV standards had been expanded to about ten more cities, most of which are along fuel supply routes. For two- and three-wheelers, India followed an independent path and regulated emissions in a different manner than Europe and China. This first phase of emission reductions from all on-road vehicular sources represents great progress. Further due to congestion in the road network and in absence of proper polices to tackle the Vehicle kilometres Travelled by the vehicles marginally reduced the benefits gained (CRRI, 2009).

In January 2013, the Ministry of Petroleum and Natural Gas (MoPNG) created an expert committee on "Auto Fuel Vision and Policy-2025", charged with establishing a roadmap for fuel quality and vehicle emission standards through 2025. As of now, the committee is working and no significant plans to tighten vehicle emission and fuel quality standards further have been set, apart from continuing the policy of expanding the supply of 50 ppm sulfur fuel to 60–70 cities by 2015. Aside from establishing a road map, the expert committee can make recommendations for programs to reduce emissions from in-use vehicles, institute recall policies for noncompliant vehicles and fuels, and move away from conventional gasoline and diesel to cleaner alternative fuels.

To evaluate what sort of future vehicle emissions would be possible if the Expert Committee were to make headway on these issues, an analysis of three scenarios with the proposed emission norms was done as shown in Figure 7.1. The emission norms are proposed in Figure 7.1 in the present study to reduce the vehicular pollution loads from the transport sector.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
India(LDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			
India-Cities (LDV)	Bharat IV							Bharat IV+					Bharat V					Bharat VI			
India (HDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			

Figure 7.1: Proposed Emission Norms for LDV,HDV and Diesel sulfur content standards for India and India -Cities (2015- 2030)

7.2 Estimation of Vehicle Emission Loads

The emission loads were estimated considering the proposed emission norms shown in Figure 7.2. Figure 7.2 shows the various vehicular emissions since 2002, 2010 to the future emission estimates for the year 2015, 2020, 2025 and 2030.

The pollutants emitted from tail pipe of the automobiles into the air at National are estimated on the basis of vehicle - kilometres travelled by different vehicle types and the fuel used. For determining the quantity of pollution, the emission factors are employed along with the appropriate deterioration factors to account for the age of the vehicle. The emission factors and the deterioration factors (ARAI, 2009) adopted for this exercise. Employing these emission factors, the pollution loads in terms of CO, HC, NO_x and PM were estimated for the year 2002, 2010, 2015, 2020, 2025 and 2030. The vintage of vehicles as discussed in the section 5.9 and 5.10 was adopted to arrive at the emission factors and the corresponding pollution loads. European emission factors were adopted beyond 2010.

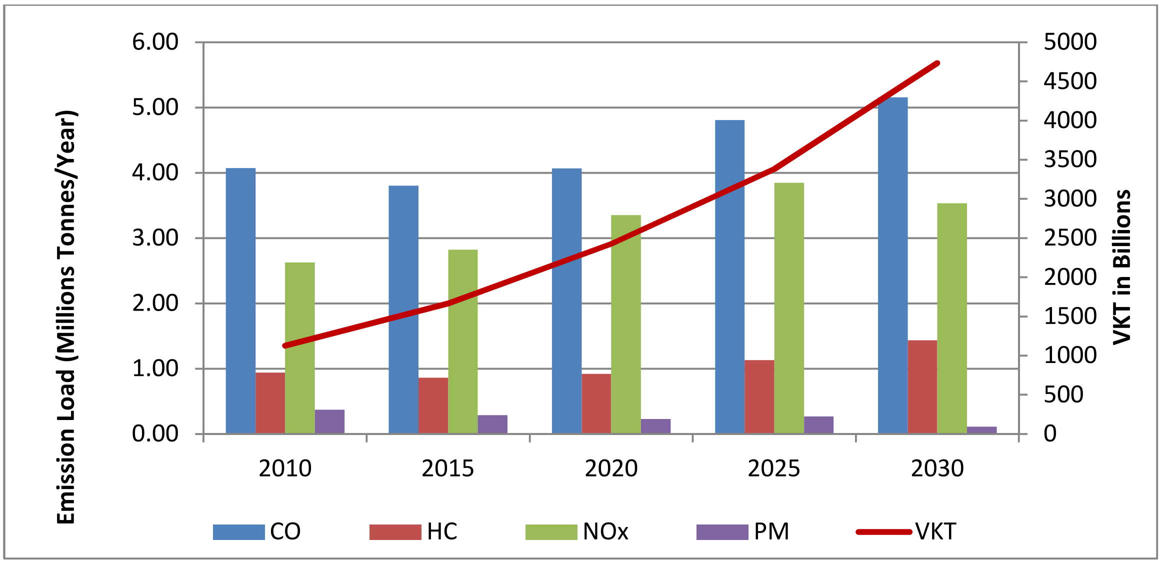


Figure 7.2: Vehicle emission loads with the proposed emission norms (2002-2030) along with VKT

The period 2002–2010 represents a successful first step in developing a motor vehicle program based on the 2003 Auto Fuel Policy. Per vehicle emissions have fallen significantly, and fleet wide emissions have dropped or slowed as well. Further, it is necessary to address the emissions loads by equally giving importance to target VKT travelled by the targeted programme. Though the Metro systems and other mass transport systems are in place in the some of the cities these are still in-adequate. Hence the National Urban Transport Policy (NUTP) should also realistically target the VKT in a phased manner. But in order to tackle the significant air quality challenges that remain a similar and more ambitious road map should be established for the next decade. Pollutant wise analysis has been carried out to see the impact from proposed norms comparing BAU (Business As Usual) case shown in Figure 7.3 to 7.6.

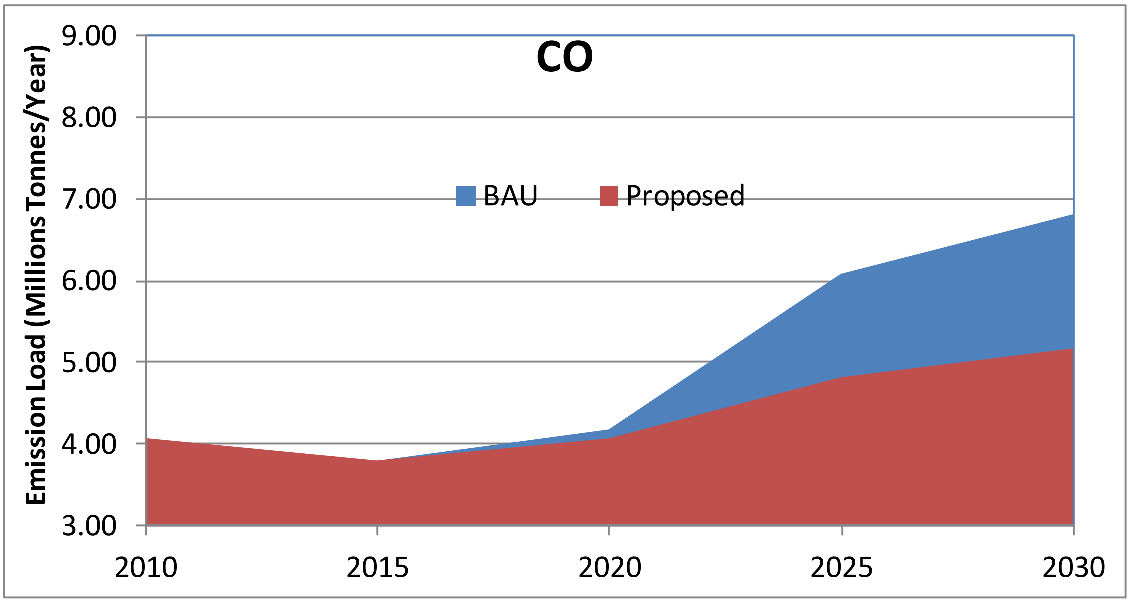


Figure 7.3: Estimated total CO Emission Loads with Proposed Norms and BAU Case (2015–2030)

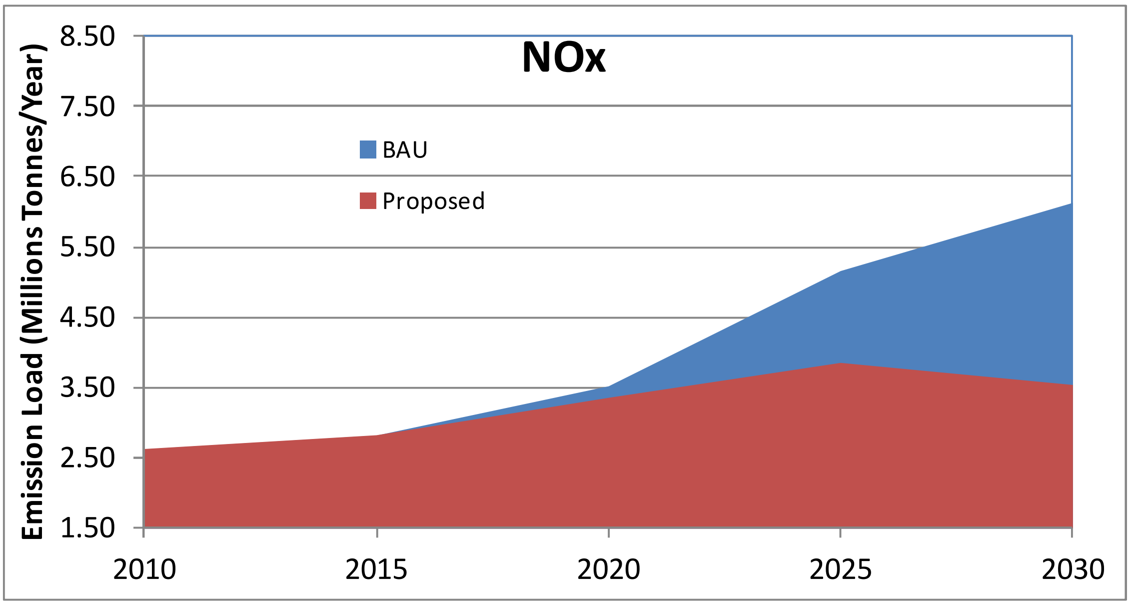


Figure 7.4: Estimated total NOx Emission Loads with Proposed Norms and BAU Case (2015–2030)

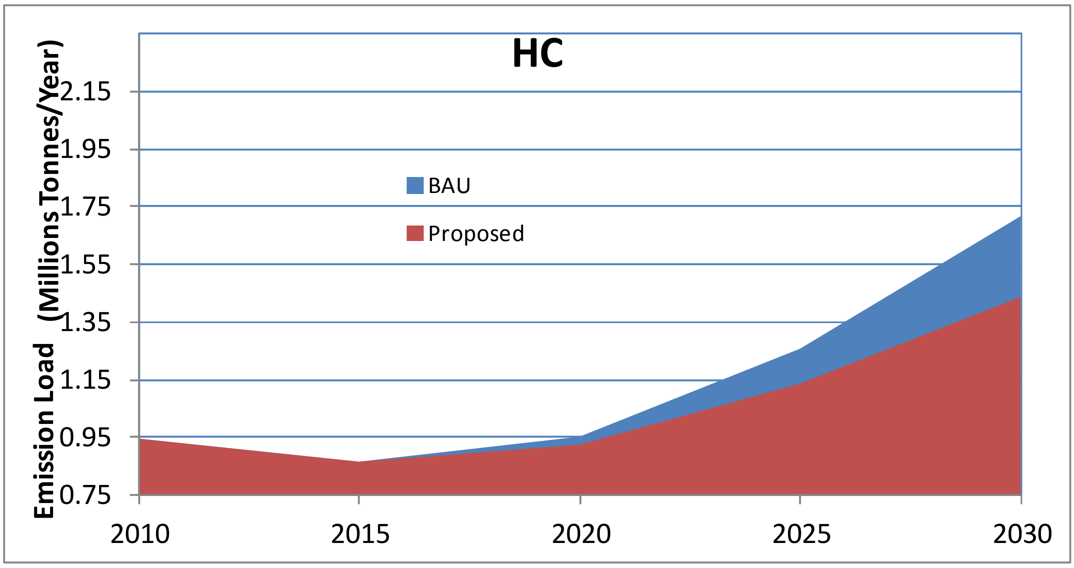


Figure 7.5: Estimated total HC Emission Loads with Proposed Norms and BAU Case (2015–2030)

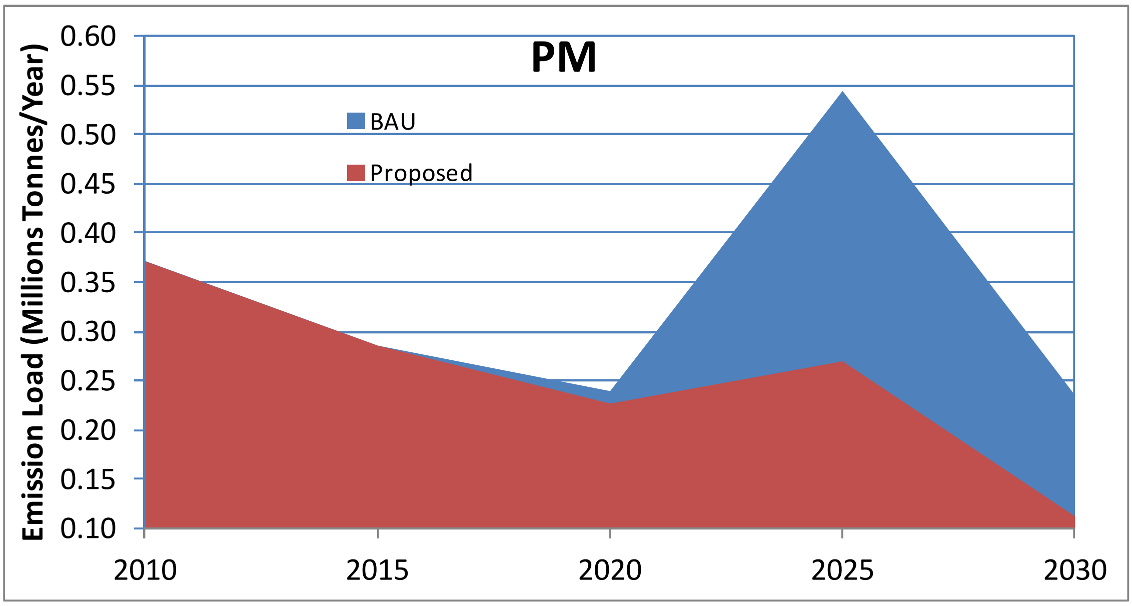


Figure 7.6: Estimated total PM Emission Loads with Proposed Norms and BAU Case (2015–2030)

From the above Figures 7.3 to 7.6 the reduction in CO, NOx, HC and PM emissions are considerable under the proposed emission norms.

7.3 Vehicle Emission Loads considering the Congestion in the Road Network

The pollution loads estimation process carried out in the present study have done by employing CPCB emission factors (ARAI, 2009). These emission factors are basically derived for the vehicles which are running under steady state conditions (with no congestion at moderate speeds). However, in reality vehicles are continuously experience congestion at many places such as mid-blocks, intersections especially on city road network. Moreover, Intersection idling also consumes extra fuel. The emission factors for such kind of situations are not available till date. Hence, whatever the pollution loads estimated in this study through CPCB emission factors (usually for steady state conditions) are certainly lower than the actual pollution loads. This can be considered as serious limitations in adopting emission factors. However, the output of the present study (pollution loads) can certainly give an idea about the quantum of pollution loads coming out of the vehicles at the moment and subsequently they will help in implementing appropriate policy decisions to improve air quality.

Further pollution loads were calculated considering the congestion on road network due to frequent bottlenecks at mid blocks, intersections and acceleration and decelerations at mouth of the flyovers during most of the day. Since 2002, the travel time of all the vehicles has increased almost twice due to congestion and since the non-availability of emission factors due to congestion in our Indian conditions, the pollution loads were estimated by increasing the pollution loads of cars and buses with separate factor as they get affected more compared to two wheeler and autos. Goods vehicles are less affected as they travel mostly during night hours. The increased factors adopted are different for different vehicle type based impact of congestion on different vehicles further the congestion factors are adopted only for the city traffic VKT leaving the inter city traffic VKT, because, intercity traffic is relatively congestion free.

Further considering the congestion in the road network the CO, NOx, HC and PM loads are estimated and shown in Figure 7.7 to 7.10 from the above Figures it can be observed that due to congestion in the road network the reduction in CO, NOx, HC and PM is reduced. Though very primitive approach was adopted to estimate the pollution loads due to congestion, the output of the present study (pollution loads) can certainly give an idea about the quantum of pollution loads coming out of the vehicles considering prevailing congested conditions and subsequently they would help in implementing appropriate policy decisions to improve air quality. From the above discussion there is tremendous scope to reduce the vehicle emission loads by adopting the proposed emission norms.

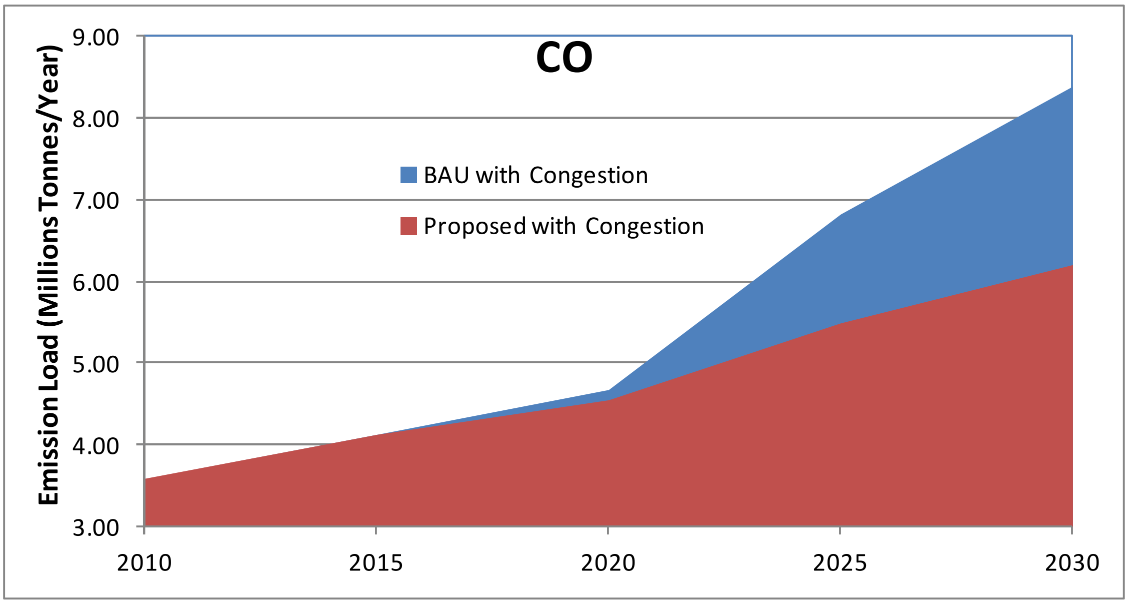


Figure 7.7: Projected total CO emissions with further policy action (2015–2030) considering the Congestion in the road network

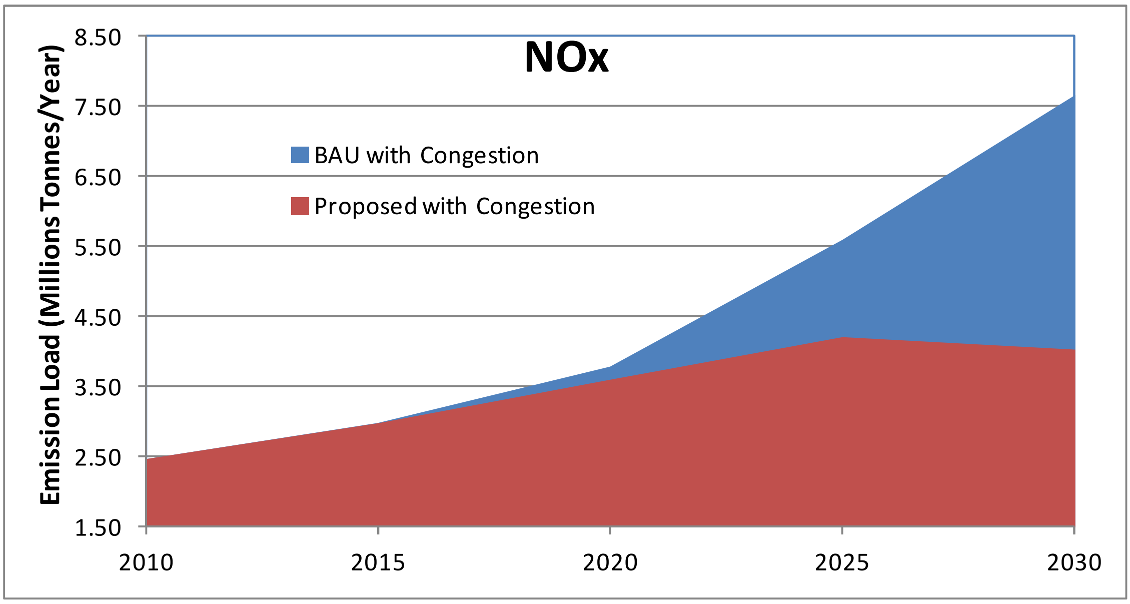


Figure 7.8: Projected total NOx emissions with further policy action (2015–2030) considering the Congestion in the road network

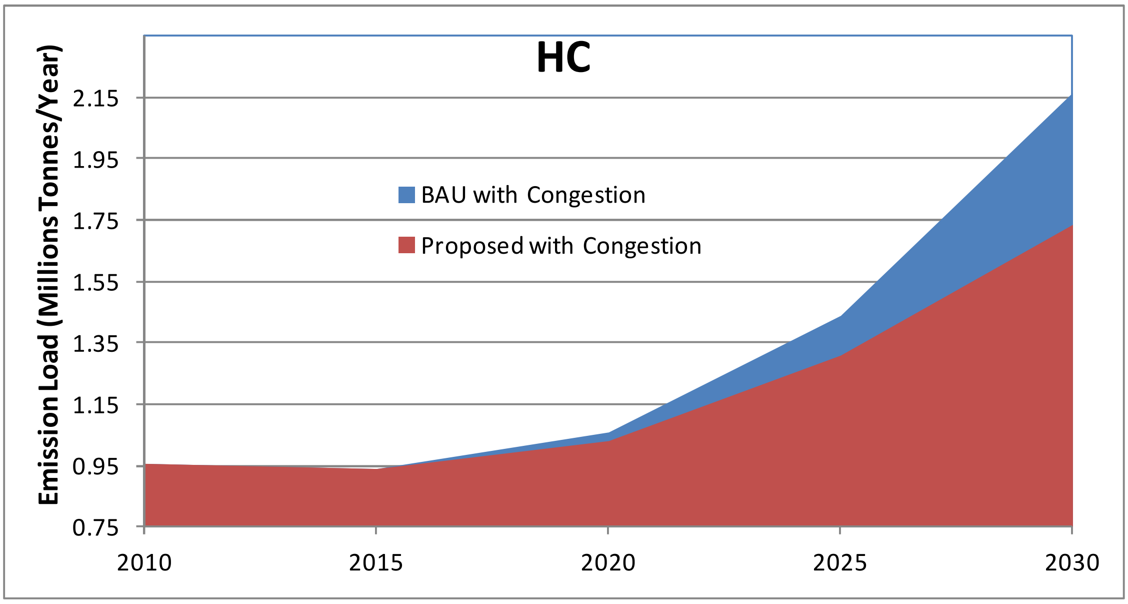


Figure 7.9: Projected total HC emissions with further policy action (2015–2030) considering the Congestion in the road network

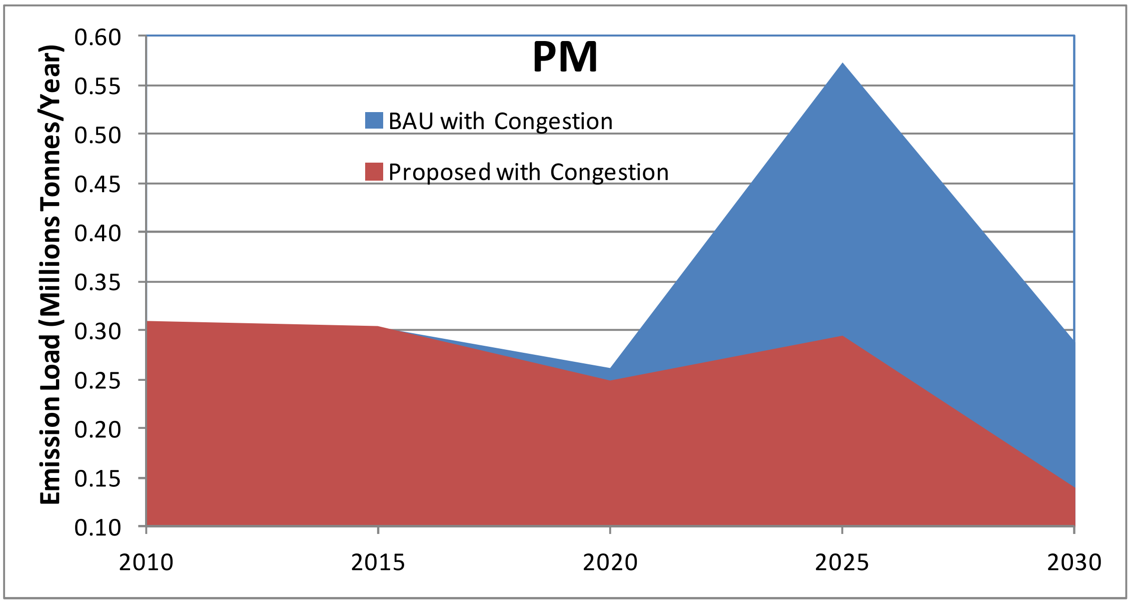


Figure 7.10: Projected total PM emissions with further policy action (2015–2030) considering the Congestion in the road network

8.0 FUEL EFFICIENCY OF HEAVY DUTY VEHICLES (HDVs)

8.1 Fuel economy, Efficiency and Intensity

Whether expressed as the ratio of the quantity of energy needed to cover a certain distance, or as the distance covered with a given quantity of energy, fuel economy of motorised vehicles represents the efficiency of the conversion of energy contained in the fuel to mechanical energy at the wheels that drive the vehicle (measured as distance travelled).

For vehicles, the term efficiency itself can have a range of meanings, such as the efficiency of an engine in converting energy into power, or the energy efficiency of moving a vehicle taking into account its weight (litres per tonne-kilometre). This report focuses on vehicle fuel economy, i.e. energy per distance moved, regardless of vehicle weight, engine power or any other factor, except where otherwise indicated.

Throughout this report, the terms “fuel economy”, “fuel efficiency”, and “fuel intensity” are used interchangeably to mean the amount of fuel consumed by a vehicle over a distance driven. the metrics used to measure it differ by region and can be litres per 100 kilometres (l/100 km) (in Europe, China, South America, Australia), kilometres per litre (in Japan, Chile, Mexico) and miles per gallon (mpg) (in the united states and the united Kingdom, though with different definitions of the gallon). Sometimes CO_2-equivalent emissions per km are measured instead of fuel economy. The EU now typically measures fuel economy in units of tailpipe CO_2 per kilometre. Although this report uses all these terms, “fuel economy” measured in litres per gasoline equivalent per 100 kilometres (Lge/100 km) is mainly used. Improving fuel economy means that Lge/100 km and gramme of CO_2 per km (gCO_2/km) decline; the fuel efficiency is better; and fuel intensity is lower. These terms encompass the technical efficiency of the engine and other vehicle attributes such as its weight and power, as well as driver behaviour, the use of the vehicle, and road conditions (IEA, 2011b and 2011c).For Indian conditions fuel efficiency/fuel economy refer to kmpl (Kilometres per litre).

8.2 Heavy Duty Vehicles Fuel Efficiency and Greenhouse Gas Regulatory Programmes in Place and Under Development

Significant fuel economy improvements (Bandivadekar, 2013) in road vehicles can be realised with technologies that are currently available but not yet widely deployed. Policies are needed to scale-up the deployment of the most fuel-efficient technologies in road vehicles. Public policy intervention to enable increased deployment of fuel-efficient vehicles is justified because the total societal benefits of more fuel- efficient vehicles significantly outweigh the costs of improvement (Societal benefits include climate change mitigation, fuel savings, energy security, and reduced air pollutant emissions). Even at an individual level, the increased cost of fuel-efficient technology is generally more than compensated by the fuel savings to the driver. However, barriers in the form of market and behavioural failures (Market failures arise when one or more of the conditions necessary for markets to operate efficiently are not met. In the context of vehicle fuel economy, a market failure would imply that more fuel is being consumed to drive a given distance than a rational allocation of resources would justify, in light of consumer and producer preferences. Imperfect competition, incomplete markets (incomplete property rights and externalities), imperfect information and asymmetric information are typical examples of market failures. Behavioural failure describes bounded rationality, among other things, where actors do not make choices rationally from the point of view of society, leading to sub-optimal outcomes for society) exist to the purchase of fuel- efficient vehicles and translate into a slow turnover of vehicle stocks compared to fuel supply price dynamics. To design effective policy packages for fuel-efficient vehicles, governments must understand the behavioural contexts and the market failures that the policies aim to address. If government intervention is justified to require and encourage better fuel economy in vehicles, the challenge is to design policies and incentives that favour societal least-cost strategies

Different countries and regions have chosen to adopt different fuel economy or GHG standards for various historic, cultural, and political reasons. These standards differ in stringency, by their apparent forms and structures, and by how the vehicle fuel economy or GHG emission levels are measured - that is, by testing methods. They also differ in terms of their implementation requirements, such as mandatory versus voluntary approaches.

Vehicle fuel economy standards can take many forms, including numeric standards based on vehicle fuel consumption, such as litres of gasoline per hundred kilometres of travel (L/100-km) or fuel economy, such as miles per gallon (mpg), or kilometres per litre (km/L). Automobile GHG emission standards are usually expressed as grams per kilometre (gCO2/km) or grams per mile (gCO2/mile). Testing methods also differ and include the US city and highway cycles, the new European drive cycle (NEDC) and newly established JC08 cycle tests in Japan

The four largest automobile markets, the US, the EU, China and Japan, each approach the regulation of fuel economy quite differently. The US is in the midst of a dramatic change regarding the way it will regulate vehicular emissions. The US used to regulate vehicles based on corporate average fuel economy (CAFE) standards, which required each manufacturer to meet two specified fleet average fuel economy levels for cars and light trucks respectively. However policy makers are now shifting to a "footprint-based" approach and looking for a way to regulate GHG emissions instead of fuel economy. In the new approach, individual vehicle fuel economy or GHG targets would be based on the size of the vehicles. As such, each automaker now has his/her own fuel economy target based on the average size of his/her own vehicle fleet.

In Japan and China, fuel economy standards are based on a weight classification system, where vehicles must comply with the standard for their weight class. Fuel economy standards in the Republic of Korea are based on an engine size classification system. China is following the New European Driving Cycle (NEDC) testing procedures developed by the EU. The Republic of Korea is following testing methods that are similar to US CAFE procedures. Japan maintains its own test procedures.

EU is also in the midst of dramatic changes in its fuel economy policies. Until 2009, the EU promoted a voluntary standard. However, as it became increasingly evident that automakers were not going to achieve the voluntary standard, it was made mandatory and is now based on a weight-based limit value curve. Table 8.1 show the Fuel Economy standards for HDVs adopted around the world.

Table 8.1: Fuel Economy and GHG emission standards for vehicles around the World

Country/region	Standard	Measure	Structure	Test Method	Implementation
United States	Fuel	mpg	Footprint-based value curve	US CAFE	Mandatory
California	GHG	g/mile	Car/LDTI	US CAFE	Mandatory
European Union	CO_2	g/km	Weight-based limit value curve	EU NEDC	Voluntary for now, mandatory by 2012
Japan	Fuel	Km/L	Weight-bin based	Japan 10-15/JC08	Mandatory
China	Fuel	L/100-km	Weight-bin based	EU NEDC	Mandatory
Canada	Fuel	L/100-km	Cars and light trucks	US CAFE	Voluntary
Australia	Fuel	L/100-km	Overall light-duty fleet	EU NEDC	Voluntary
Republic of Korea	Fuel	Km/L	Engine size	US CAFE	Mandatory

Source: Global Overview on Fuel Efficiency and Motor Vehicles Emissions Standards: Policy options and perspectives for International Cooperation (May 2011)

In February 2013, Canada adopted Heavy Duty GHG emissions standards essentially the same as the US HDVs GHG standards (Canada Gazette 2012). Mexico is developing HDVs efficiency standards as well. Ultra –low sulphur diesel and advanced emissions technologies would need to be readily available for Mexico to adopt the same standards as those adopted in the US and Canada, since engine efficiency improvements rely on these technologies. In addition, data on highway driving speeds will be required to determine whether a similar levels of investment in aerodynamics equipment is warranted in Mexico as in the US and Canada. On the whole, however, the long distances covered by over-the- road trucks in the three countries suggest important similarities in driving patterns.

8.2.1 Policies Adopted to Improve the Fuel Efficiency /Reduce the CO_2 Emissions of HVDs

The policy needed to improve vehicle fuel efficiency comprises three main components which should be considered as policy options in an integrated vehicle fuel efficiency :

i) Information and Labelling

ii) Regulatory actions; and

iii) Fiscal measures

Theoretically governments should implement a combination of these three components; however, all three components are not appropriate in all cases. In most countries, fuel economy labelling and alignment of fiscal incentives with the labels should be implemented. Fuel economy standards are most appropriate in countries with vehicle manufacturing and large markets that have the potential to influence the type of vehicles developed and brought to market.

A common element in all three components of the policy package is the measurement of vehicle fuel economy. Without reliable and replicable fuel economy testing and results, policies to improve fuel economy cannot be put in place. Policies are also needed that ensure good fuel quality (low sulphur levels) to enable use of the most advanced engines.

8.3 Vehicle Fuel Economy Information Labelling

The provision of information on vehicle fuel economy is a crucial part of the policy package needed to improve the fuel economy of vehicles. Vehicle fuel economy labelling can influence vehicle purchaser behaviour and can also be a motivational tool for manufacturers to improve vehicle fuel efficiency beyond fuel economy standard target values.

Clear, relevant information on vehicle fuel economy enables vehicle purchasers to know the fuel economy performance of different vehicle models and/or understand the implications in terms of fuel costs. Both new and used vehicles can be affixed with fuel economy labels. Many countries have introduced labelling of fuel economy for new LDVs to encourage the public to value fuel efficiency and enable consumers to easily compare vehicles among different types and different brands. There are fewer examples of HDV fuel economy labelling; in Japan, HDVs already meeting the 2015 legal requirements display a fuel economy label signifying they are eligible for fiscal incentives, in the United States the voluntary SmartWay Technology programme awards the SmartWay label to HDVs meeting the programme specifications. HDVs are very heterogeneous in their type and usage, and therefore, engine performance is normally listed without the full vehicle.

The term "labelling" is used here in the broad sense and describes the provision of a summary of the vehicle fuel economy performance used for raising industry and public awareness. This summary may be presented as an actual label, attached to the vehicle in car dealer showrooms, or a version of the "label" may be included more generally in any sales or advertising literature on vehicles in any communication medium.

Different approaches are taken to vehicle labelling in terms of the metrics, amount and type of information provided, and graphical presentation. A detailed discussion of the options in designing vehicle fuel economy labelling is provided in a recent study for the EU Commission (Brannigan *et al.*, 2011).

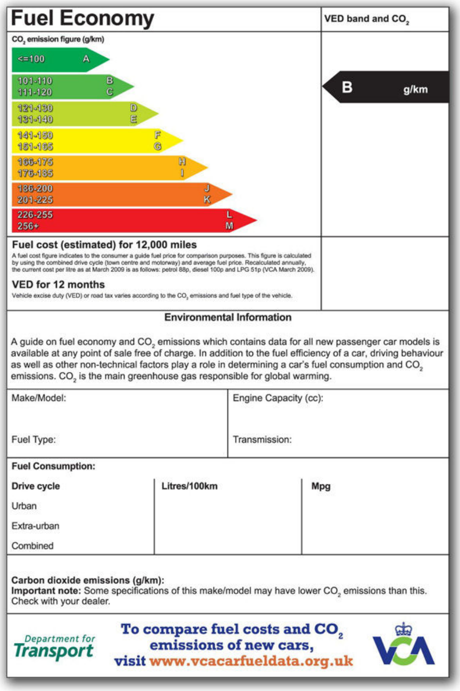
Vehicle fuel economy labels usually fall into one of three types, depending on how the information is provided:

i) Graphical rating from A to G
ii) Direct information disclosure and
iii) Relative vehicle performance compared to the fuel economy standard

Each approach has advantages and disadvantages. Although the rating-style label may provide a very clear message to vehicle purchasers, the metrics used may be unclear and even controversial, depending on how the ratings are awarded. Simple information disclosure may be more transparent but may be difficult for consumers to relate to. For this reason, many fuel economy labels include not only the fuel economy measured in testing but also the annual fuel costs associated with operating the vehicle. Portraying the vehicle fuel economy relative to the fuel economy standard may be useful for consumers to compare vehicles with each other, but is difficult for vehicle purchasers to understand the actual performance that can be expected from the vehicle.

8.3.1 Graphical Rating Labels:

Eye-catching labelling can draw the public's attention to fuel efficiency and add an environmentally-friendly expectation from purchasers for each vehicle (Figure 1). A rating- style label requires the policy maker to establish categories (usually A to G) for CO2 emissions or fuel economy, where a rating of A is awarded for the best- performing vehicle to G for the worst performing. Different criteria may be used to award this rating, and purchasers may not know the values behind the rating. The format of these labels is familiar to consumers in many countries, where they are also used to rate the energy performance of white goods. Such a label encourages people to compare vehicles in terms of fuel efficiency or environmental effects without any complicated calculation. In this method, the colouring is important. The colour of the label for most fuel-efficient vehicles should be the one that most people associate with being eco-friendly.



Source: VCA, 2012.

Figure 8.1: Graphical rating label: UK

The European Union has required passenger car CO2 emissions labelling since 2001 in all member states; however, member states are free to choose the design of the label. Many European countries have selected the graphical rating format.

The disadvantage of the graphical rating label is that it may not be very transparent and may even be controversial in some cases where the metric chosen can have a substantial impact on the rating awarded to each vehicle. In some cases the rating is awarded based on how the vehicle performs compared with vehicles in the same size class. This approach can lead to vehicles with higher absolute fuel consumption or CO2 emissions receiving a higher rating than others with lower values.

An absolute CO2 or fuel economy scale for rating provides the clearest message to vehicle purchasers. Although information about the relative position of the vehicle in its vehicle segment is useful, the overall fuel economy rating should not be awarded based on the relative position within a vehicle category. Ideally, a combination of both absolute and relative ratings information should be provided in a simple manner.

8.3.2 Direct information disclosure labels:

These labels display the actual fuel economy and/or CO2 emissions values. An example of this system is the label used in the United States, where labels for passenger vehicles include the following information: fuel efficiency in the city mode, fuel efficiency in the highway mode, combined fuel efficiency, and estimated annual fuel costs with assumptions on annual mileage and fuel price (Figure 8.2) (EPA, 2012). The label also rates the vehicle in terms of fuel economy and air pollutant attributes contributing to smog. This label allows consumers to choose a vehicle by carefully considering the benefits. Consumers can easily compare the return on investment of a fuel-efficient vehicle, taking their individual driving conditions into account. Consumers who mainly drive in urban areas, for example, are able to focus on the fuel efficiency in the city mode, not the combined fuel efficiency. In this case, the fuel efficiency on the label should be as close as possible to the fuel efficiency on actual roads, so that consumers can accurately make a calculation.

Source: EPA, 2012

Figure 8.2: Direct information disclosure label: US EPA fuel economy label

The Chinese label for vehicle fuel economy is another example of a direct information disclosure label. It displays three fuel economy values – for urban, good driving and congested city conditions – in litres per 100 km.

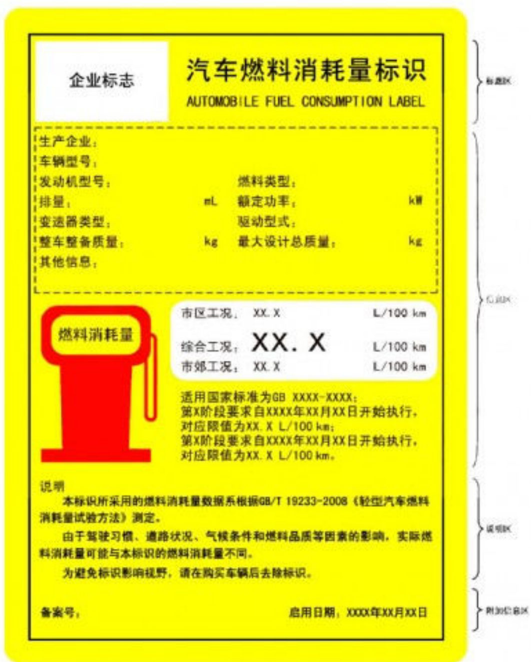


图 A.1 标识各功能区分布示意图

Figure 8.3: Direct information disclosure label: China fuel economy label

One disadvantage to providing such clear information on the fuel economy label is that, because a gap exists between the fuel economy tested on the chassis dynamometer (listed on the label) and that measured in real-life driving with air conditioning and other equipment, drivers may be misled by the difference. Thus, governments that adopt this kind of a label could consider modifying fuel efficiency information reported on the label to better reflect on-road fuel economy or at least advise consumers that their driving behaviour will affect the fuel economy they achieve. This modification could involve providing an indication of the difference between the tested value and the on-road fuel economy through collected data. The approach should be consistent for all vehicles, however, so that the comparability of chassis dynamometer testing is not compromised.

Another disadvantage to the provision of direct information is that, because consumers of passenger vehicles often do not set a high priority on fuel efficiency, they do not pay attention to detailed information. They could, therefore, be annoyed to see a label with so many numbers.

8.3.3 Relative vehicle fuel economy performance labels:

An alternative, simpler design is exemplified by the Japanese label, which is a voluntary label and is only awarded to vehicles with better fuel efficiency than the average for that vehicle class and is illustrated with one number (Figure 8.4). This type of label compares the vehicle to other similar vehicles in the same class and informs the public whether the vehicle has better fuel economy than the average for that class.

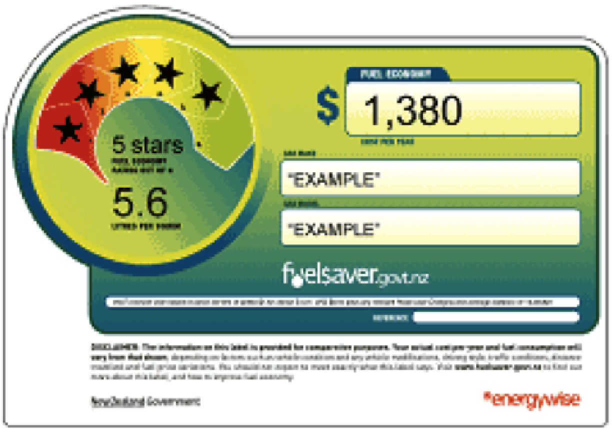
The label provides the public with an expectation that a vehicle with this label is good for the environment. The label, however, does not provide consumers with useful information on the relative fuel economy they can expect from that vehicle. Also with this method, although consumers can easily compare between vehicles with and without a label, they cannot easily compare among vehicles with a label.

Source: MLIT, 2010a.

Figure 8.4: Relative vehicle performance label: Japanese fuel economy label

In summary, the choice of approach to labelling and the metrics used depends on the objectives of policymakers and can have a significant influence on the message given to consumers. If the objective is to improve fuel efficiency incrementally within a vehicle class but without changing the proportion of vehicles sold in each vehicle class, policymakers can use vehicle labels with a rating based on the performance of the vehicle relative to other vehicles in the same vehicle class. This labelling can be confusing and misleading for consumers, however, because large, more fuel-consuming vehicles may be given a better rating than some smaller, more fuel-efficient vehicles, simply because they perform relatively better than vehicles of similar size in their class.

In New Zealand and the United Kingdom, fuel economy labels are required on used as well as new vehicles. In the United Kingdom, fuel economy labels are displayed on vehicles manufactured since 2001, while in New Zealand they are required on cars imported since 2005. Fuel economy labelling is important for used cars, as in many countries sales of used cars are much higher than new cars; for example in the United Kingdom, sales of used cars totalled 6.8 million while new cars amounted to 1.9 million in 2011. In New Zealand, fuel economy labels are developed using an algorithm allowing a comparison of test results using the European and Japanese driving cycles.



Source: New Zealand Transport Agency, 2012

Figure 8.5: New Zealand fuel economy label

A combination of the direct disclosure method with a comparative rating is likely to be the most useful for vehicle purchasers. They provide purchasers with a rating for the vehicle fuel economy as well as clear information on the fuel economy or the running costs of the vehicle to better enable comparison between vehicles. Examples are the US EPA, United Kingdom and New Zealand labels.

8.3.4 Vehicle Fuel Economy Labelling in India

In summary, the choice of approach to labelling and the metrics used depends on the objectives of policymakers and can have a significant influence on the message given to consumers. If the objective is to improve fuel efficiency incrementally within a vehicle class but without changing the proportion of vehicles sold in each vehicle class, policymakers can use vehicle labels with a rating based on the performance of the vehicle relative to other vehicles in the same vehicle class. This labelling can be confusing and misleading for consumers, however, because large, more fuel-consuming vehicles may be given a better rating than some smaller, more fuel-efficient vehicles, simply because they perform relatively better than vehicles of similar size in their class.

India has debuted a fuel economy label for new cars sold in fiscal year 2011–2012. The label is shown and described in Figure 8.6. Apart from displaying the combined fuel economy of the vehicles, the label ranks fuel efficiency by a five-star system. The current rankings are based on fleet-average fuel consumption by curb weight for fiscal year 2009–2010. Cars within 10 percent of the regression line for fuel consumption by curb weight receive three stars. Cars with fuel consumption between 10 and 30 percent less than the average receive four stars, and cars with fuel consumption more than 30 percent less receive five stars. Cars with fuel consumption greater than the average receive two stars or one in the same manner. In fiscal year 2014–2015, the ranking system will be recalibrated according to fleet-average fuel consumption in India at that time. [156]

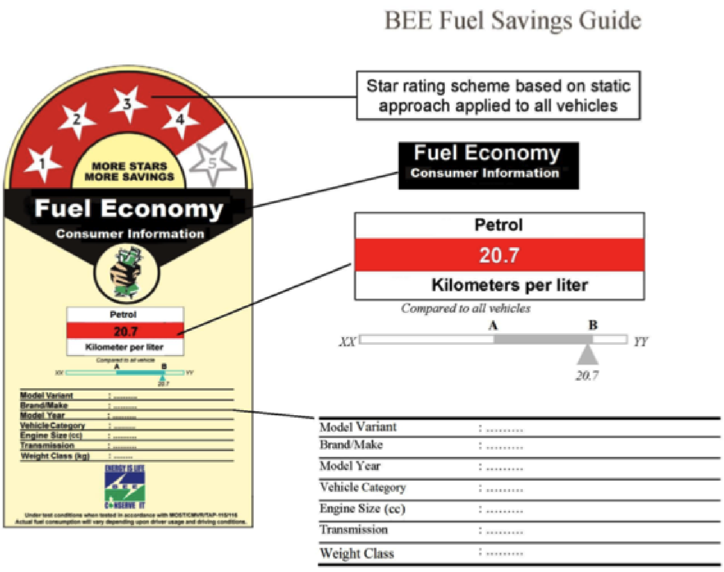


Figure 8.6: Economy label for India for LVDs

India also has another fuel economy label that the Society of Indian Automobile Manufacturers (SIAM) has issued. This label is not mandatory, and it is not available for every car. The SIAM fuel economy label, which can be obtained from a car dealership, segments the vehicles according to the weight of the car. The highlighted box from the scale as depicted below is the range of fuel economy in the appropriate weight class.

8.3.5 *Vehicle Fuel Economy Labelling Recommendations:*

From the above discussion pertaining to the each country the vehicle fuel economy labeling is very important to Indian conditions which give the choice to the vehicle users while purchasing the vehicle. Though the labeling in passenger sector was introduced in year 2011-12 still is widely practiced in India. Further for the HDVs the Weight based fuel economy and CO_2 emission base fuel economy labeling shall be made mandatory by year 2016 after the stake holders consideration.

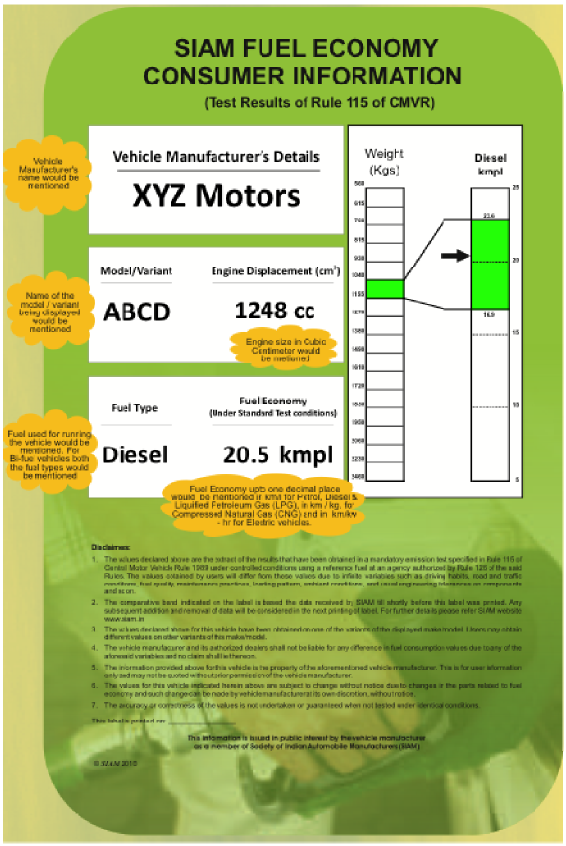


Figure 8.7: Economy label for India for LVDs as proposed by SIAM (Society of Indian Automobile Manufacturers (SIAM)

8. 4 Vehicle Fuel Economy Standards

In countries where consumers do not value fuel economy highly when purchasing vehicles, the introduction of mandatory fuel efficiency standards is an effective way to improve vehicle fuel efficiency. These standards require manufacturers to improve the annual average fuel efficiency of new vehicles up to target values set by governments. Standards for light commercial vehicles (LCVs) are also under consideration in most OECD regions. Fuel efficiency standards for HDVs have been introduced only in Japan and the United States to date (IEA, 2010a) in addition to China and Canada also under progress.

Introducing fuel economy standards for HDVs is a complex task because fuel consumption of trucks depends on many factors apart from the sheer truck weight class, such as average transported payload, typical mission profiles, road gradients, drag and rolling resistance from truck as well as trailer, engine characteristics, gear ratios and type of transmission, and auxiliary power demand. If reasonable and meaningful fuel economy standards are to be achieved, all these factors need to be taken into account for each size class and truck type. To tackle these multiple factors, programmes have been developed which combine component testing and vehicle simulation, ensuring that many if not all of these variables are taken into account.

Fuel economy standards typically set legal maximum limits for vehicle fuel use per kilometre of driving (or the inverse – kilometres or miles per litre or gallon) tested over a driving test cycle. Vehicle fuel economy standards historically have not been set as individual vehicle minimum energy performance standards, as is the case for appliances and equipment, where every product sold must meet the minimum standard. The fuel efficiency of heavier, larger vehicles is worse than that of lighter vehicles with the same technologies. Therefore fuel economy standards are set as a fleet- wide average for each manufacturer to allow for a mix of vehicle types on the market. The US CAFE (corporate average fuel economy) standards are one of the most recognised versions of this policy.

This approach gives substantial flexibility to manufacturers in achieving the target, because they can choose whether to meet their target value through significantly improving the fuel efficiency of certain kinds of vehicles or through improving most vehicles' fuel efficiency by a small amount. Mandatory standards encourage manufacturers to prioritise the improvement of fuel efficiency in vehicle development. Standards also address market failures described earlier, including split incentives and high discount rates for vehicle purchasers, by obliging all manufacturers to meet a minimum standard of fuel efficiency of vehicles sold. A comparison of fuel economy standards for HDVs worldwide shows an array of different target values, fuel economy units, test methods, and scope as shown in Tables 8.2.

Table 8.2: Status of Global HDVs fuel economy standards adopted around the world

Country or Region	Regulation Type	2010	2011	2012	2013	2014	2015	2016	2017	2018
Japan	Fuel Economy					Regulation implemented starting MY2015				
United States	GHG/Fuel Efficiency	Standard Proposal	Final Rule			Regulation implemented starting MY2014(mandatory DOT programme starts 2016)				
Canada	GHG/Fuel Efficiency		Standard Proposal	Final Rule		Regulation implemented starting MY2014				
China	Fuel Consumption	Test procedure finalized	Industry Standard proposal	Standard Proposal	Final Rule	Regulation implemented starting MY2015				
European Union	GHG	Technical Studies			Test procedure finalized	Mandatory efficiency reporting and regulator development				
California	End-user purchase requirements	Requirements for tractors and trailers (MY2011+)		Additional Requirements for existing tractors and trailors (<MY 2010)						Additional requirements for existing tractors and trailors and reefers(<MY2010)

Source: ICCT, 2011.

Note: green text illustrates planned schedule.

8. 4.1 Vehicle Fuel Economy Standards for Japan

Japan was the first country to implement mandatory fuel economy standards for HDVs. In November 2005, the Japanese government introduced its first fuel economy standards for new heavy-duty diesel vehicles, which were estimated to be responsible for approximately one-quarter of all CO2 emissions from motor vehicles in 2002. Recognizing the need for enough lead time for manufacturers to develop technologies and comply with standards, the government set 2015 as the deadline for compliance with fuel economy targets.

Japan's standards are corporate average weight–based standards. The targets for each vehicle category were set at the level of the most efficient model in 2002, which was called the "Top Runner" approach. The test procedure combines engine testing with a vehicle simulation model. This regulatory innovation is also the basis of the U.S. GHG standards test procedure. Japan made several categories and set different target values. First, passenger vehicles are separated from trucks. Trucks are divided into tractors and the other trucks (Tables 8.3 & 8.4).Then passenger vehicles are divided into city and other buses (Tables 8.5 and 8.6). Vehicles in each type are also subdivided by gross vehicle weight, because HDV fuel efficiency strongly depends on gross vehicle weight or payload. Through this process, Japan tried to minimise unfairness among manufacturers and vehicles. As the result of this categorization, the number of vehicle types in a few categories is small, which may reduce manufacturer flexibility in achieving target values. To alleviate this concern, Japan introduced a credit trade system among vehicle categories. The improvement ratio of Fuel Economy Freight Vehicles and passenger vehicles were given Tables 8.7 and 8.8.

Japan also allows manufacturers to compensate for a shortfall in fuel efficiency in some categories by an excess of fuel efficiency in another category. This system may function to give flexibility to manufacturers to achieve their goals. Japan did not introduce a credit trade system among manufacturers, possibly because Japanese manufacturers might not consider this to be reputable behaviour.

Table 8.3. Classification and Target Standard values of Freight Vehicles and other than tractor

CATEGORY	GROSS VEHICLE WEIGHT RANGE (T)	MAXIMUM LOAD RANGE(T)	TARGET STANDARD VALUES(km/l)
1	3.5<&<=7.5	<=1.5	10.83
2		1.5<&<=2	10.35
3		2<&<=3	9.51
4		3<	8.12
5	7.5<&<=8		7.24
6	8<&<=8		6.52
7	10<&<=12		6.00
8	12<&<=14		5.69
9	14<&<=16		4.97
10	16<&<=20		4.15
11	20<		4.04

Table 8.4. Classification and Target Standard values of tractor

VEHICLE CATEGORY	GROSS VEHICLE WEIGHT RANGE (T)	TARGET STANDARD VALUES(KM/L)
1	<=20	3.09
2	20<	2.01

Table 8.5. Classification and Target Standard values of passenger Vehicles (Riding Capacity :11 persons or more) (Route Bus)

VEHICLE CATEGORY	GROSS VEHICLE WEIGHT RANGE (T)	TARGET STANDARD VALUES(km/l)
1	6<&<=8	6.97
2	8<&<=10	6.30
3	10<&<=12	5.77
4	12<&<=14	5.14
5	14<	4.23

Table 8.6. Classification and Target Standard values of passenger Vehicles (Ordinary Bus)

VEHICLE CATEGORY	GROSS VEHICLE WEIGHT RANGE (T)	TARGET STANDARD VALUES(km/l)
1	3.5<&<=6	9.04
2	6<&<=8	6.52
3	8<&<=10	6.37
4	10<&<=12	5.70
5	12<&<=14	5.21
6	14<&<=16	4.06
7	16<	3.57

Table 8.7. Improvement Ratio of Fuel Economy of Freight Vehicles

	FY2002, actual values	FY2015, estimate values	Improvement ratio of fuel efficiency
Other than tractor	6.56(km/l)	7.36(km/l)	12.2%
Tractor	2.67(km/l)	2.93(km/l)	9.7%
Total	6.32(km/l)	7.09(km/l)	12.2%

Table 8.8. Improvement Ratio of Fuel Economy of Passenger Vehicles

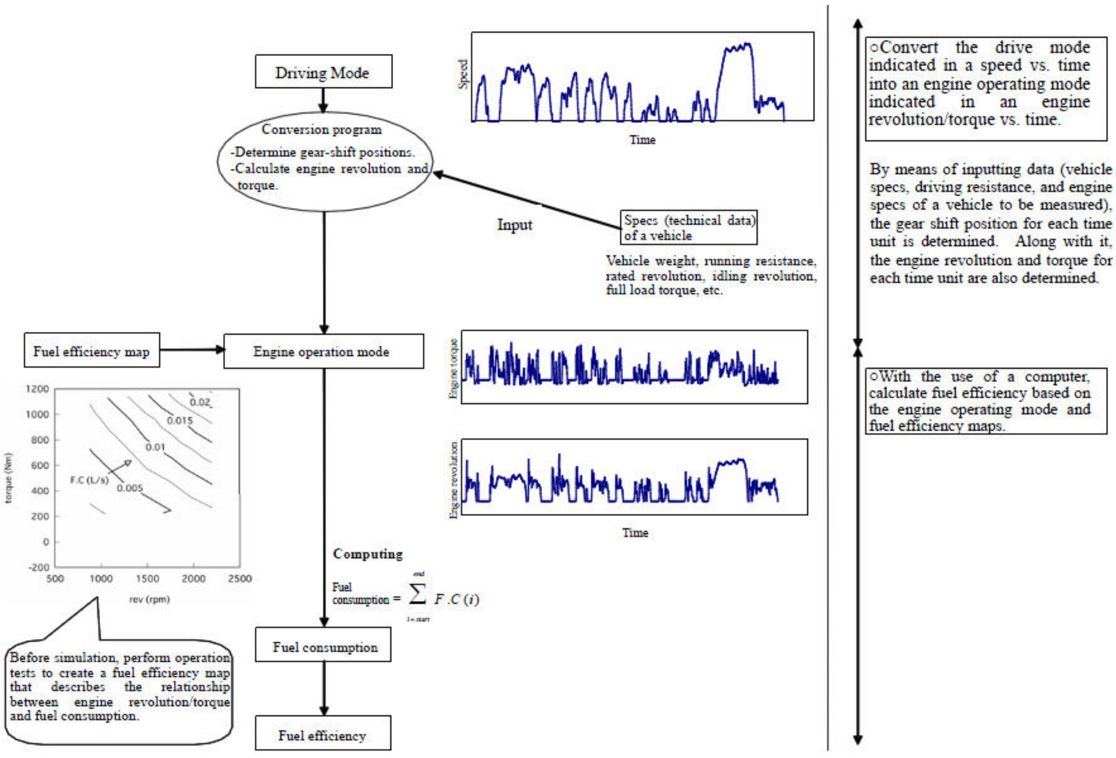
	FY2002, actual values	FY2015, estimate values	Improvement ratio of fuel efficiency
Route bus	4.51(km/l)	5.01(km/l)	11.1%
Ordinary bus	6.19(km/l)	6.98(km/l)	12.8%
Total	5.62(km/l)	6.30(km/l)	12.1%

Measurement Method:

When Japan decided to develop fuel efficiency standards for HDVs, no other government had previously developed a method to measure their fuel efficiency. Thus, Japan compared several possible methods in terms of accuracy, costs, and times, and then decided to adopt a method that was a combination of simulation and an engine-based test Figure 8.8.

First, Japan corrected the data to show how the vehicles run on actual roads. The government gathered the data on urban roads and highways, because vehicle usage was significantly different on those two types of roads. Based on the data, Japan developed two driving cycles (Figure 8.9): urban and highway modes. Then Japan developed a simulation method that could convert a vehicle- based driving cycle to an engine-based operation cycle that defines engine torque and rotation speed for each second. The engine-based test measures fuel consumption under certain engine torque and rotation speeds. With these data, the method can calculate fuel consumption for each second. Then the summation of the fuel consumption for each second indicates the total fuel consumption. Based on it, the method calculates fuel efficiency.

The fuel efficiency of a vehicle is determined as the combined fuel efficiency of two driving modes. More specifically, Japan measures the fuel efficiency of both urban and highway modes and then combines the fuel efficiency of the two modes with a weighting factor. The weighting factor for these two modes is different among vehicle types because of the difference in their usage and is decided based on the statistical data of each vehicle type on roads.



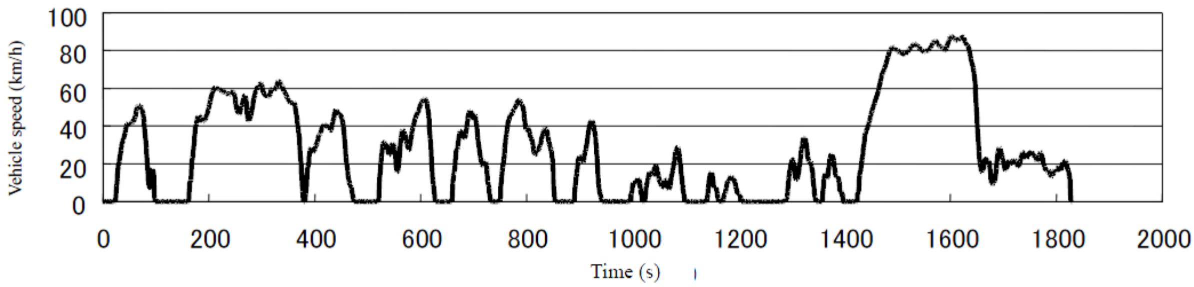
Source: Japan Automobile Research Institute: Survey Report on Evaluation Methods for Heavy Vehicles, March 2003

Figure 8.8: Simulation Method Overview adopted by Japan

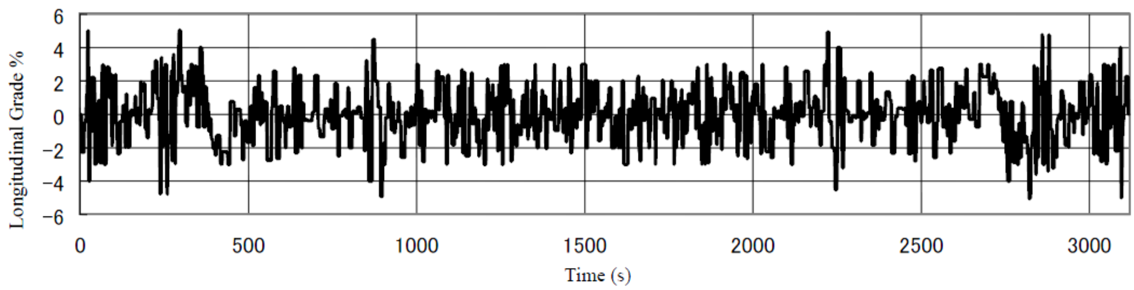
Drive modes:

Many of heavy vehicles are used mainly for interurban travel (high-speed drive). To simulate actual usage as accurate as possible, fuel efficiency evaluations shall use a combined mode of urban drive and interurban drive modes based on the proportion of usage.

Drive Mode: The exhaust gas emissions control (the new long-term control), effective since 2005, requires vehicles having a gross vehicle weight of greater than 3.5 tons to be tested in JE05 mode (a transient driving mode defined based on urban drive statistics). Therefore, fuel efficiency evaluations shall use the same principle of the driving mode. Urban Driving Mode adopted by Japan was as shown in Figure 8.9



Urban Drive Mode



Inter Urban Drive Mode

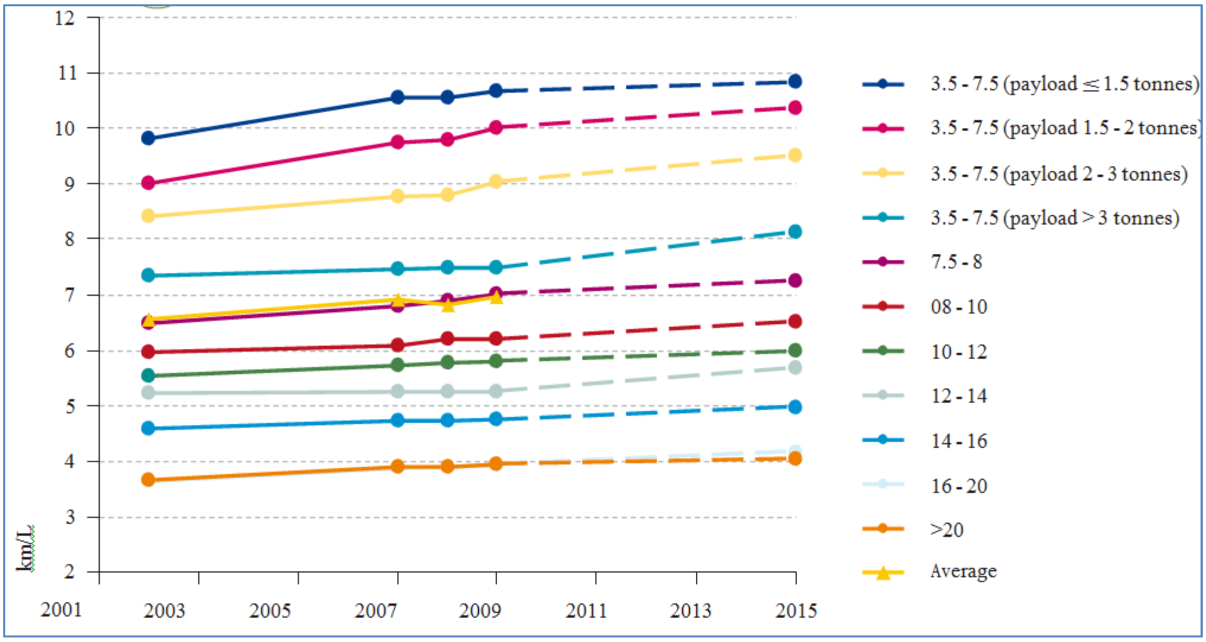
Figure 8.9: Drive Mode adopted by Japan

Proportion of the two modes: Based on surveys results on actual driving situation and frequency of expressway use, the proportion of the urban and interurban drive modes shall be determined for each vehicle type as follows (GVW= Gross Vehicle Weight)

Table 8.9. Proportion of the Urban and Inter Urban Drive Modes

	Passenger vehicles (11 persons or more)			Freight vehicles			
Vehicle type	Ordinary bus		Route bus	Other than tractor		Tractor	
GVW	14 tons or less	Over 14 tons		20 tons or less	Over 20 tons	20 tons or less	Over 20 tons
Drive proportion Upper:Urban mode Lower:Interurban mode	0.9	0.65	1.0	0.9	0.7	0.8	0.9
	0.1	0.35	0.0	0.1	0.3	0.2	0.1

Monitoring: After the regulation was developed in 2006, the Japanese government started collecting data. Since 2007, sufficient data has been available. Figure 8.10 show the improvement of the fuel efficiency of heavy-duty trucks. Compared to fuel efficiency in 2002, which was used as a base year when deciding target values, fuel efficiency in 2009 was improved in all categories. Although average fuel efficiency in some categories was continuously improved from 2007 to 2009, almost no improvement occurred in other categories in 2007-08 or 2008-09. For example, in a category whose gross vehicle weight (GVW) is 3.7t to 7.5t and payload is less than 1.5 tonne, average fuel efficiency decreased from 2007 to 2008, and then increased from 2008 to 2009. This outcome seems to suggest that the model changes of most vehicles in this category simultaneously occurred in 2008-09. (Given that the new emission regulation has applied to vehicles in this category since 2010, manufacturers changed vehicle models to adjust to the new regulation.)



Source: IEA(2012)

Figure 8.10: Fuel Efficiency Improvements in HDVs, Japan

This trend is different from that of light-duty passenger vehicles whose average fuel efficiency for all fleets is increasing every year in all categories. In the category for vehicles whose GVW is 14t to 16t, the fuel efficiency improvement rate was smaller than the improvement rate in other categories. The sales volume in this category was less than 1 000 vehicles annually from 2007 to 2009, while in some other categories, the annual sales volume was more than 10 000 vehicles. Manufacturers may face difficulty in spending sufficient resources to improve fuel efficiency in categories with small sales volumes. As a result, the Japanese credit trade system plays an important role in allowing manufacturers to cost- effectively meet target values. In addition, average fuel efficiency decreased in 2008 compared to average fuel efficiency in 2007, while fuel efficiency in each category increased. This trend was caused by the shift of the sales mix.

Overall, further efforts are necessary to achieve target values in 2015. In several categories, the current improvement rate would not be sufficient to meet the target value, but the sales volume of these categories is likely to be smaller. In categories with relatively large sales volumes, such as the category with 3.7t to 7.5t GVW and is 1.5t to 2t payload, the average fuel efficiency seemed to increase sufficiently. Thus, in Japan, the credit trade system is likely to be an important feature for meeting the targets in 2015.

8. 4.2 Vehicle Fuel Economy Standards for United States of America

On August 9th 2011, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) finalized the world's first-ever program to reduce greenhouse gases (GHGs) and improve fuel efficiency of medium- and heavy-duty vehicles. While Japan deserves full credit for establishing the world's first fuel economy program for medium and heavy-duty vehicles in 2005 that will go into effect in 2015, the US rule adds several important elements: (1) drives efficiency improvements in all aspects of the heavy-duty vehicle for the two highest fuel consumption classes: tractor trucks and pickup trucks, (2) sets separate standards for engines and vehicles, and (3) establishes standards for four major greenhouse gases in addition to fuel consumption limits.

The U.S. program differs from Japan's in several regards. While the Japanese approach was largely based on engine improvements, the United States took a more comprehensive look at improving HDV fuel economy. While the United States has separate engine only standards built into the overall requirements, it also includes aerodynamics, tires, and weight reduction in its approach to increasing overall HDV fuel economy.

The U.S. program differs from Japan's in several regards. While the Japanese approach was largely based on engine improvements, the United States took a more comprehensive look at improving HDV fuel economy. While the United States has separate engine.

The Federal Highway Administration categorizes trucks by gross vehicle weight, as shown in Table 8.10. HDVs range from class 2b large pickups and utility vans that weigh 2.5–3.2 tons when empty to class 8b large tractor trailers that weigh as much as 17 tons. When full, the smallest HDVs can about double their weight to 3.5–5 tons, while the largest can more than double their weight to 16.5–40 tons.

Table 8.10. Vehicle Weight Classes defined by US Department of Transportation

Class	Description/examples	Empty weight range	Gross weight range	Typical fuel intensities	
		Tons	Tons	Gallons per thousand	Gallons per thousand ton-miles
1c	Passenger cars	1.2-2.5	<3	30-40	67
1t	Small light-duty trucks	1.6-2.2	<3	40-50	58
2a	Standard pickups, large SUVs	2.2-3	3-4.25	50	39
2b	Large pickups, utility vans	2.5-3.2	4.25-5	67-100	39
3	Utility vans, minibuses	3.8-4.4	5-7	77-125	33
4	Delivery vens	3.8-4.4	7-8	83-140	24
5	Large Delivery vans, bucket trucks	9.2-10.4	8-9.75	83-166	26
6	School buses, large delivery vans	5.8-7.2	9.75-13	83-200	20
7	City bus, refrigerated truck, fire engine	5.8-7.2	13.16.5	125-250	18
8a	Dump/refuse trucks, city buses, fire engines	10-17	16.5-40	160-400	9
8b	Large tractor trailers, bulk tankers	11.6-17	16.5-40	133-250	7

Fuel Economy Standards:

Tables 8.11 shows the range of standards and percentage improvements in the emissions rate over the baseline for the vehicle standards for 2018. The anticipated improvement in the rate of emissions from the baseline is 7–10 percent for all categories except class 8 sleeper cabs, which are to achieve up to a 24 percent improvement in 2018. Standards are more stringent in this last category because the ground has been prepared by EPA's Smartway Program, a collaborative agency–industry program to improve the tires and aerodynamic characteristics of tractors and intercity trailers.

Table 8.11. U.S. fuel economy improvements for HDVs for 2018 over 2010 levels

Type/subclass		Percentage reduction in fuel consumption
Tractor-trailers		
Day cabs	Class 7 low roof	10.2
	Class 7 low roof	10.3
	Class 7 low roof	13
	Class 8 low roof	9.1
	Class 8 low roof	9.5
	Class 8 low roof	13.6
Sleeper	Class 8 low roof	17.5
	Class 8 low roof	18
	Class 8 low 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

8. 4.3 Vehicle Fuel Economy Standards for India

In India the major manufactures in the Bus segment is varies from 5 to 7.5 tonnes, these buses mainly used for within city travel and Heavy Commercial buses varies from 3.5tonnes to 16.2tonnes these buses mainly used for inter city travel . In truck segment Light Commercial Vehicles (LCV) varies from 3.5 tonnes to 7.5 tonnes which are mainly used for within city goods travel, Heavy Duty the commercial segmentation varies from 7.5 tonnes to upto 25 tonnes. The major manufactures are from Tata Motors Ltd, Ashok Leyland Ltd,Mahindra & Mahindra Ltd and VE CVs –Eicher and Daimler.

For Indian conditions to start with the implementing agency/Government should establish the fuel consumption standards based on engine improvements by considering extensive test producers based on i) on-road testing, ii) Engine testing iii) Chassis + Engine testing and iv) computer simulation based by adopting the standard driving test cycles to establish fuel efficiency standards help to develop and maintain a level playing field among manufacturers, as all are required to meet a fuel economy target. Further vehicle segmentation may be restricted to three categories in case of Light Duty vehicles (GVW≤7.5tonnes), Medium Duty Vehicles (7.5tonnes to 16 tonnes) and Heavy Duty Vehicles (>16tonnes). Similarly Buses category should be restricted to two category which GVW ≤7.5tonnes and more than GVW >7.5tonnes.

8.4.3.1 Vehicle Fuel Economy from previous Studies

Fuel efficiency/ fuel consumption of HDVs in terms of kilometers per litre (kmpl) was studied based on available secondary data (URTRAP, 2002, RTRAP, 2009, RUCS 2010 and RUCS 2001, RUCS 1992, & RUCS 1982). The data from various studies especially in 2002 and 2009 for urban cities and 2001 and 2010 for intercity have been considered and accordingly average fuel consumption for different HDVs are worked out and presented in Figure 7.1.

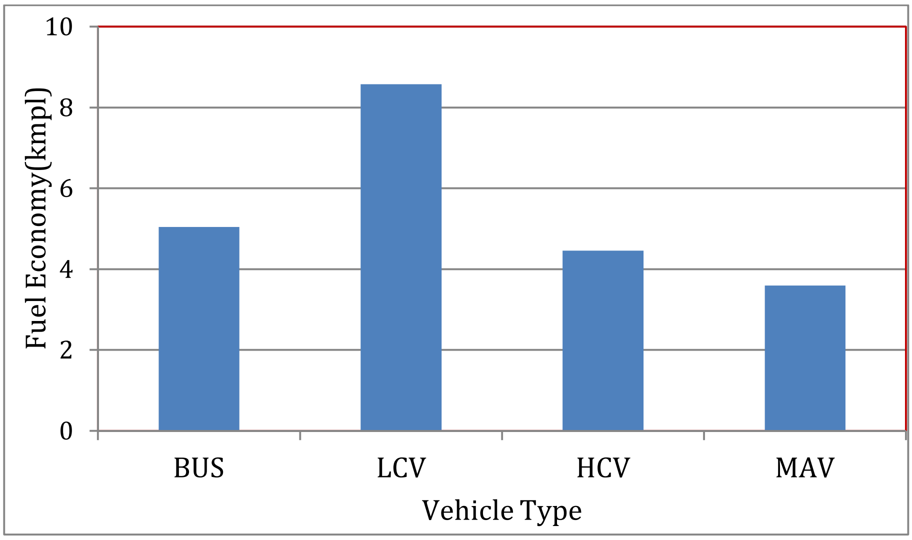


Figure 8.11: Average fuel economy per litre fuel for HDVs mode-wise

From the Figure 7.1 the average fuel consumption in terms of kilometer per litre (kmpl) for the bus is 5.05 kmpl, for LCV is 8.58 kmpl, for HCV 4.46 kmpl and for MAV 3.59 kmpl.

Assuming the above scenario for the base year fuel economy, the proposed targets to be evaluated for 2020, 2025 and 2030 as given below from Table 8.12 to 8.14.

Table 8.12. Proposed Improved Fuel Ratios of Fuel Efficiency by 2020

Category	Base Year fuel Efficiency (Kmpl)	Proposed target fuel Efficiency (Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	5.5	6.3	14.55
Light Duty vehicles (GVW≤7.5tonnes),	8.58	9.8	14.22
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	4.46	5.05	13.23
Heavy Duty Vehicles (>16tonnes)	3.59	4.0	11.42

Table 8.13: Proposed Improved Fuel Ratios of Fuel Efficiency by 2025

Category	Base Year fuel Efficiency (Kmpl)	Proposed target fuel Efficiency (Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	6.08	6.98	14.80
Light Duty vehicles (GVW≤7.5tonnes),	9.8	11.3	15.31
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	5.05	5.75	13.86
Heavy Duty Vehicles (>16tonnes)	4.0	4.48	12.00

Table 8.14: Proposed Improved Fuel Ratios of Fuel Efficiency by 2030

Category	Base Year fuel Efficiency(Kmpl)	Proposed target fuel Efficiency(Kmpl)	Improved Ratios of Fuel Efficiency (%)
Buses	6.98	8.05	15.33
Light Duty vehicles (GVW≤7.5tonnes),	11.3	13.0	15.04
Medium Duty Vehicles (7.5tonnes to 16 tonnes)	5.75	6.65	15.65
Heavy Duty Vehicles (>16tonnes)	4.48	5.1	13.84

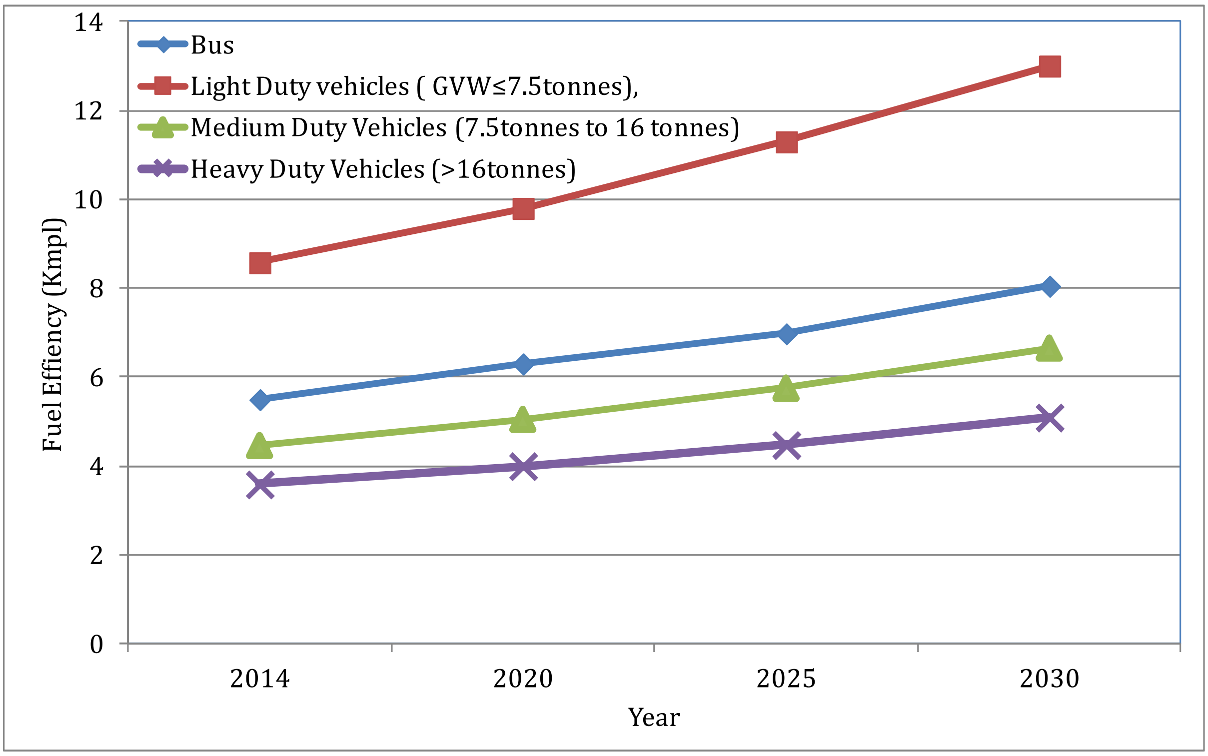


Figure 8.12: Proposed Fuel Efficney Kilometre per litre (Kmpl) for HDVs

8.4.3.2 Impact of Proposed Vehicle Fuel Economy for India

CO_2 emissions was worked out considering the above proposed targeted fuel efficiency for the four categories and shown in Figure 8.13.

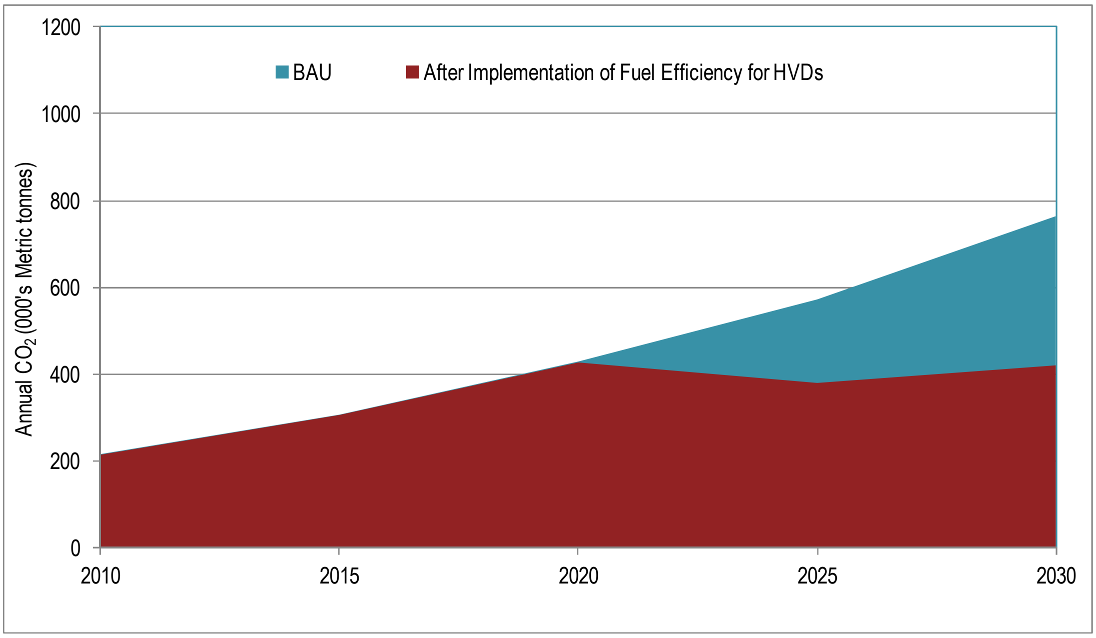


Figure 8.13: Annual CO_2 emissions under the BAU scenario and after implementation of Fuel Effinciey for HDVs

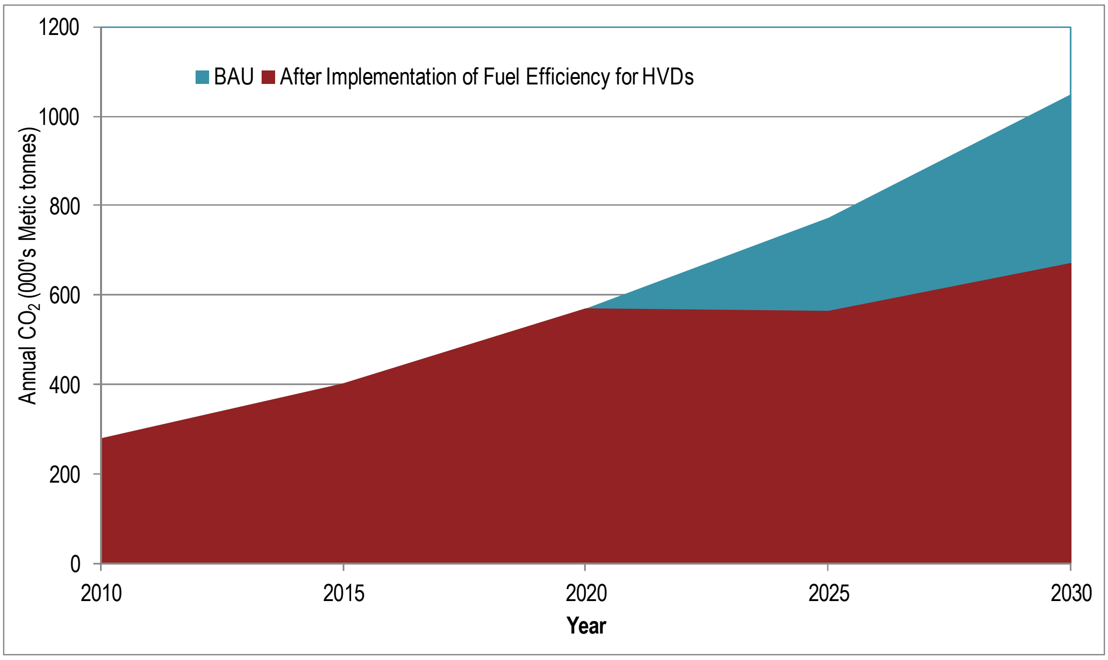


Figure 8.14: Annual CO_2 emissions under the BAU scenario cosiderong all the other modes and after implementation of Fuel Effinciey for HDVs

From the above Figures 8.13 and 8.14 there is considerable reduction in CO_2 emissions 192 thousand metric tonnes in the year 2025 and 343 thousand metric tonnes in the year 2030 was estimated. About 147billion litres in the year 2025 and 262 billion litres in the year 2030 of Fuel will be saved.

This is especially important for manufacturer innovation and the creation of new efficiency solutions. Manufacturers should be able to rely on the set up of the market to adopt new solutions, and rest assured that others will not increase their market share by producing cheaper, poor performing vehicles. Under voluntary agreements, if one manufacturer decides to ignore fuel efficiency to maximise profits, other manufacturers are forced to follow suit so as not to lose their competitiveness in the market. Fuel economy regulations provide more certainty to policymakers about vehicle fuel economy; however, their design, stringency, and form determine how much improvement in fuel economy is actually achieved. Mandatory fuel economy standards provide regulatory certainty to manufacturers, which is important because manufacturers take approximately ten years to develop a brand-new vehicle (Bastard, 2010). If these standards are compared to fiscal policy instruments such as taxes based on CO_2 values or fuel efficiency, it is evident that fuel economy standards are more likely to be fixed for longer periods. Because of various restrictions, including the necessity to make revenue stable, governments cannot determine the tax rate for a long period. The fiscal incentives in Japan, for example, have been amended every two or three years. As a consequence, manufacturers are more likely to focus on short-term investment for improving fuel efficiency in a superficial manner according to the amendment of tax rates. Therefore forward-looking fuel economy standards are needed, which can motivate manufacturers to achieve mid- and long-term technology innovation (Anderson *et al.,* 2010).

8. 5 *Fiscal Measures*

Fiscal measures represent the third component of the policy to improve the fuel economy of road vehicles. Typical fiscal measures include vehicle taxes, fuel taxes and user charges (i.e. road pricing), and are used to influence the types of vehicle purchased and their use by consumers through price signals.

8.5.1 *Vehicle taxes:*

Most countries require taxes to be paid by vehicle owners, either annually or at the time of purchase. Vehicle taxes can be aligned with fuel efficiency or CO2 emissions values of vehicles to make fuel- efficient vehicles more fiscally attractive, strongly encouraging consumers to buy such vehicles and requiring manufacturers to improve their fuel efficiency. In the current economic context, policy makers have to take the overall state of public finances into account when deciding whether to introduce new tax incentives. One advantage of vehicle tax incentives is that they are relatively easy to adopt at no extra cost, if they are designed properly and if vehicle taxes are already implemented.

In the past, vehicle taxes were based on vehicle technical characteristics such as engine capacity or power, vehicle mass, or a combination of the three. Over the last five years, however, many countries have switched their vehicle tax system to be based on vehicle CO2 emissions and/or fuel economy. This focus provides direct fiscal incentives to more fuel-efficient vehicles that can encourage manufacturers to accelerate the improvement of fuel efficiency and motivate the public to purchase such vehicles.

Vehicle taxes in many countries in Europe are directly linked to vehicle CO2 emissions, while in Japan vehicle owners to pay taxes based on a vehicle's fuel efficiency level compared to target values for each vehicle class. Vehicle tax policies in China and India are less directly linked to CO2 emissions and fuel economy and both countries. primarily link vehicle taxes to vehicle engine size. In the United States, vehicle tax disincentives in the form of the Gas Guzzler taxes only apply to a very limited number of models in the market (ICCT, 2012), however tax incentives may be available for advanced vehicle technologies such as hybrid and electric vehicles in some states.

In some countries, vehicle taxes are combined with a rebate to customers purchasing lower-emitting/ fuel-consuming vehicles, which is sometimes called a feebate. For example, in France, purchasers of a vehicle with a CO2 emission value between 91 g/km and 105 g/km received EUR 300 as a bonus in 2011 and up to EUR 5 000 for electric vehicles (IEA, 2011b). Partly as a result, average emissions of new vehicles registered in France decreased from 149 gCO2/km at the end of 2007 to about 130 gCO2/km in the first seven months of 2010 (IEA, 20112c).

To encourage the user to buy the fuel efficient vehicles this measure incentive is very much needed for the Indian conditions.

8.5.2 Fuel taxes:

Vehicle tax incentives affect only consumer choice of vehicles and cannot affect consumer driving behaviour after purchase. Fuel taxes may be ableto affect both consumer vehicle choice and driving behaviour. Most countries have introduced a tax on fuel, however on the other end of the scale there remain other countries which still subsidize fuel prices. Comparison of fuel efficiency among countries is difficult, but more fuel-efficient vehicles tend to prevail in countries with higher fuel prices and taxes (Sterner, 2007; NRC, 2010).

Fuel prices and taxes, in combination with vehicle taxes, have played an important role in determining the proportion of diesel sales and fleet CO2 emissions. While other factors such as land-use planning and public transport alternatives are also important, fuel prices are likely to play a role.

8.5.3 Complementary policies:

The targeted improvements can be enhanced by policies that influence the in-use efficiency of vehicles; how vehicles are driven, how they are used in relation to other modes, correct loading and improved freight logistics measures all complement the vehicles essential technical efficiency. Fiscal incentives can also be extended to the use of the vehicle. In some countries fuel-efficient vehicles receive discounts on motorway tolls or are exempted from congestion taxes.

Policy makers should consider the role for complementary policies to support the public response to new vehicle standards and labelling and also to assist drivers to maximise the benefits of their new efficient vehicles.

8.5.3 .1 Eco Driving:

Policies to promote eco-driving usually have two main goals: helping concerned drivers who already have an interest in energy saving, and motivating a broader audience to drive in an eco-friendly manner. Communication campaigns that directly or indirectly advertise practical tips for eco-driving can widely inform the public about eco-driving, helping drivers to have an eco-friendly behavior and to realise the importance of eco-driving. Some eco-driving techniques, such as moderate acceleration, are also useful for both reducing fuel consumption and improving safety.

In-car feedback instruments, such as gear-shift indicators, cruise controls, and onboard fuel efficiency computers that show real-time and average fuel efficiency, can more directly support eco-driving. One option is to expand the use of these devices for eco-driving among professional drivers. The average number of miles driven in a year by professional drivers greatly exceeds that of a private driver, which means that a professional driver's improvement in driving behavior has therefore a greater impact on saving fuel consumption. Japan, for example, subsidizes fleet operators for purchasing an eco-driving management system (EMS) and successfully saving energy and reducing CO_2 emissions.

Eco-driving can also be part of training courses to qualify for a driver's license. If many drivers practice eco-driving from the beginning of their driving careers due to a training course, that would lead to a considerable reduction in fuel consumption. In all cases of eco-driving training, refresher courses should be provided, because the effect can wear off (EU, 2006).

8.5.3 .2 Modal Shift:

Using more sustainable transportation modes modal shift describes the shift from private motorised vehicles to more sustainable modes of transport such as public and non-motorised transport. To motivate the public to use more sustainable transportation modes, governments need to make them more attractive by improving the public transport offering, its convenience and prices. Governments should also take co- benefits into account. Inducing motorists to use public transportation, for example, reduces traffic congestion, air pollution and noise. In some European Countries, local governments prohibit private cars from entering city centres, making these cities more attractive as tourist attractions. urban sprawl makes it difficult for governments and private companies to provide public transportation service to citizens and encourages citizens in suburban areas to use their own vehicles. governments should, therefore, adopt land use planning policies, such as zoning, to prevent sprawl. Policies that reduce urban parking options can also make it less attractive to drive into urban areas. Park-and-ride facilities can encourage drivers to leave their cars outside the city centre.

To attain the targeted CO_2 reductions all the above polices which are integrated in nature should be adopted for Indian conditions. Further the implementations and recommendations of Fuel efficiency for HDVs was discussed in the next chapter.

9.0 IMPLEMENTATION AND RECOMMENDATIONS

9. 1 Implementation

For success of any policy, planning very important, first the government should decide the rolling out the policy for the fuel efficiency of Heavy Duty Vehicles as per the time line stated below:

S.no.	Activity	Duration
1.	Implementation of Emission Norms for HDVs:	With immediate effect
2.	Planning of Implementation of Fuel Efficiency for HDVs	Start from 2015 (January/Mach)
2a)	Decide Scope , type and Schedule of Fuel Economy Polices: i) Gather information. ii) Determine scope and type of fuel economy policy measures. iii) Consult on policy schedule with stakeholders. iv) Decide target year aligned with national goals. v) Allocate fiscal and human resources.	Six Months
2b)	Decide Measurement Method of Fuel Efficiency, i) Incorporating specific traffic conditions ii) Gather information about traffic conditions. iii) Determine measurement approach. Develop driving cycle.	Six Months
2c)	Secure resources for the development and Implementation of fuel efficiency standards i) Allocate fiscal and human resources. ii) Develop system for gathering and certifying essential information. iii) Engage in broad consultation.	Six Months
3	Design of Implementation of Fuel Efficiency Polices for HDVs	2016-2020
3a)	Design Fuel Economy Policies: *Fuel Economy Label and Information* i) Decide scope of labelling scheme. Select fuel economy label design. ii) Align design of label with other measures. iii) Determine requirements for vehicle	2016-2020

	promotional and other materials.	
3b)	*Fuel economy standards* i) Decide form of fuel economy standard. ii) Determine attribute on which to base fuel economy standard. iii) Choose target values for fuel economy standard. iv) Introduce measures to avoid increasing vehicle weight. v) Design compliance policy.	2016-2020
3 c).	*Fiscal measures* i) Decide type of fiscal measures. ii) Determine level of fiscal measure. iii) Set duration of fiscal measure.	2017 onwards
4	Implementation of Fuel Efficiency Polices for HDVs i) Decide fuel economy certification process, utilising existing vehicle certification schemes. ii) Define certification vehicle family.	2020 onwards
4a).	*Certify fuel economy* i) Decide form of fuel economy standard. ii) Determine attribute on which to base fuel economy standard. iii) Choose target values for fuel economy standard. iv) Introduce measures to avoid increasing vehicle weight.	2015 onwards
4b).	*Make Information accessible to Public* i) Require manufacturers to display fuel economy information. ii) Publish fuel economy information on government website. iii) Time release of information carefully when introducing fiscal incentives.	2015 onwards
5)	*Monitoring and Reviewing* of Fuel Efficiency Polices for HDVs	2020 onwards
5a)	*Check the compliance with fuel economy policies:* i) Collect data to monitor fuel economy. ii) Check conformity of vehicles sold. iii) Check compliance with policies iv) Decide form of fuel economy standard. v) Determine attribute on which to base fuel economy standard. vi) Choose target values for fuel economy standard. vii) Introduce measures to avoid increasing	2020 onwards

	vehicle weight. viii) Design compliance policy.	
5b)	*Monitoring and Publishing the data:* i) Publish information about trend of average fuel efficiency. ii) Publish information on the most fuel-efficient vehicles to attract public's attention.	2020 onwards
6	Review and Evaluation of Fuel Efficiency Polices for HDVs	2020 onwards
6a)	*Evaluate and enforce policies:* i) Evaluate level of compliance and enforce penalties. *ii)* Evaluate impacts of fuel economy policies	2020 onwards
6b)	*Revise and Update fuel economy policies:* i) Change design and mix of fuel economy policies if needed. ii) Develop new target values as technology improves.	2020 onwards

Fuel economy labels, information should give the following information for the Indian conditions showing the star rating

i) Vehicle name and type

ii) Type, total displacement, maximum power and maximum torque of engine

iii) Vehicle kerb weight

iv) Transmission type, number of gears, and gear ratios

v) Fuel supply equipment type

vi) Major measures to improve fuel efficiency

vii) Energy consumption efficiency (fuel efficiency) (unit: km/l)

viii) Manufacturer's name

9. 3 Barriers to implement Fuel Efficiency of HVDs in India

Considering the vast variety of vehicles, different manufactures and majority percentage is of single truck owners the following are the some of the barriers to implement the Fuel Efficiency of HVDs in India:

i) Single owned HDVs are high in percentage. Many of these owners may be resistant to the imposition of HDV fuel efficiency standards due to concerns about the effect on truck prices, and new technology risk aversion.

ii) To effectively cover the entire HDV fleet any fuel efficiency regulation will of necessity be complex considering the diversity of HDVs fleet

iii) One of the pre-requisites for development of fuel consumption standards is collection of baseline data for various models of buses and trucks under pre-defined test conditions.

iv) For establishing the baseline for fuel consumption standards, fuel consumption or fuel economy data under standardised test conditions is required for each model of buses and trucks for all manufacturers for the baseline year considering the following:

a. Specification of drive cycles for various types of HDVs
b. Specification of test weight/payload for various types of HDVs
c. Specification of vehicle accessory and vocational loads for various types of HDVs
d. Specification of required tire condition for testing (tread depth, tire pressure)
e. Management of engine cooling load during dynamometer testing
f. Accounting for fuel used to regenerate active diesel particulate filters
g. Evaluating and accounting for the effect of cross-winds on aerodynamic drag

v) Developing fuel consumption standards for trucks and buses due to non-availability of any reported fuel economy data of trucks and buses yearly basis.

9. 3 Recommendations

Based on the analysis discussed in the earlier chapters, the following recommendations can be drawn:

i) Tighten the emissions standards for HDVs as discussed in Chapter -6 and also as suggested below:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
India(LDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			
India-Cities (LDV)	Bharat IV							Bharat IV+					Bharat V					Bharat VI			
India (HDV)	Bharat III							Bharat IV+					Bharat V					Bharat VI			

Figure 9.1: Proposed Emission Norms for LDV,HDV and Diesel sulfur content standards for India and India -Cities (2015- 2030)

ii) Indian consumers are very sensitive to fuel efficiency, hence while labelling, all the voluntary/mandatory limits for CO_2 g/km and fuel efficiency limits shall be fixed after thorough proper testing of the vehicles based on type of diving cycle chosen for Indian conditions as discussed in the section 8.4.

iii) Implementation of fuel efficiency of HDVs shall be taken up from 2020 as per the road map implementation given in Section 9.1.

10.0 National Workshop on Fuel Efficiency Standards of Heavy Duty Vehicles in India

As per the contractual agreement, a National Workshop has to be organised and accordingly it was organized at CSIR-CRRI on 1st April, 2014. For this, a total of 34 delegates have attended this workshop. A view of the workshop and Director CRRI was addressing the gathering as shown in Figure 10.1. The delegates included officials from Bureau of Energy Efficiency (BEE), Former member secretary, CPCB, TERI University, Voice NGO, PCRA, HART, Ministry of Health, Shakti Sustainable Energy Foundation and CSIR-CRRI.

Figure 10.1: Welcome address by Director, CSIR-CRRI, Dr. S. Gangopadhyay on Fuel Effincey Standrds of Heavy Duty Vehicles in India

Dr. Ajay Mathur, Director General, BEE (Bureau of Energy Efficiency), GoI delivered keynote address. In his address he stated that it is beginning step in dealing the Heavy Duty Vehicles in the country. He congratulated both the Shakti Sustainable Energy Foundation as well as CSIR-CRRI for conducting this study. He stressed that the study is the need of hour to reduce the emissions from Road Transport sector, and increase the Heavy Duty Vehicle fuel efficiency.

Shri. Krishan Dhawan CEO, Shakti Sustainable Energy Foundation stated the importance of the study as well as how important to take up the study results/ recommendations to implement for the Heavy Duty Vehicles for the energy efficient road transport system. A view of addresses by Dr. Ajay Mathur and Shri. Krishan Dhawan shown in Figure 10.2.

Figure 10.2: Keynote Address by Director General, BEE and address by Shri. Krishan Dhawan, CEO, Shakti Sustainable Energy Foundation on Fuel Effincey Standrds of Heavy Duty Vehicles in India

Shri. Chinmaya Acharya, Chief of Programmes, Shakti Sustainable Energy Foundation has given overview of activities of Shakti Sustainable Energy Foundation. A view of the interactions with delegates by Dr. Ajay Mathur and Shri. Chinmaya Acharya is shown in Figure 10.3.

Figure 10.3: Dr. Ajay Mathur interaction with delegates and Shri. Chinmaya Acharya, Chief of Programmes, Shakti Sustainable Energy Foundation giving the overview of activities of Shakti Sustainable Energy Foundation

Subsequently the study findings were presented by Dr. Kayitha Ravinder and Dr. Errampalli Madhu from CSIR-CRRI. Delegate Dr. B. Sengupta, Former Member Secretary, CPCB appreciated the study and he told in his remarks that it is very good attempt in this area, however the latest emission factors developed by ARAI (ICAP) can be used to estimate the emission loads and the emission norms proposed shall be taken in line with Draft Auto Fuel Policy & Vision - 2025 document. The same was incorporated in the final report. The workshop schedule was as given below.

National Workshop on
'Fuel Efficiency Standards of Heavy Duty Vehicles in India'
Sponsored by
Shakti Sustainable Energy Foundation, New Delhi
Organized by
CSIR-Central Road Research Institute, New Delhi
Date: 1st April, 2014
Venue: Council Hall , CSIR-CRRI, New Delhi

10:00-10:30	**Registration**	
10:30-11:00	**Inaugural Session**	
	Welcome address	Dr.S.Gangopadhyay, Director, CRRI
	Address by	Shri. Krishan Dhawan CEO, Shakti Sustainable Energy Foundation
	Keynote Address	Dr.Ajay Mathur, Director General, BEE (Bureau of Energy Efficiency), GoI.
11:00 – 11:30	**High Tea**	
11:30 – 11:35	Activities about Shakti Sustainable Energy Foundation	Shri.Chinmaya Acharya, Chief of Programmes, Shakti Sustainable Energy Foundation.
11:35- 12:15	Vehicle Kilometres Travelled (VKT) and Emission Loads of Heavy Duty Vehicles in India	Dr Kayitha Ravinder & Dr Errampalli Madhu, CSIR-CRRI, New Delhi.
12:15- 13:00	Fuel Efficiency Standards of Heavy Duty Vehicles in India	Dr Errampalli Madhu & Dr Kayitha Ravinder, CSIR-CRRI, New Delhi.
13:00-13:15	**Discussions & Concluding Remarks**	
13.15-14.00	**LUNCH**	

Lunch : CSIR-CRRI Cafeteria

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