Reduction in Emission by Optimizing Vehicle Operating Parameters

Dibakar Chatterji, Sudakshina Gupta and Arkopal Kishore Goswami

Abstract

The demand for mobility continues to grow as economies develop and urbanize and population and incomes increase. Transport sector emissions have grown faster than almost any other sector over the past 50 years. They are predicted to increase by 60 percent by 2050.A higher concentration of zero-emission technologies is still under development.With economic development in India, there is an increase in emission levels on the road. Dieselization in India reduces the fleet's overall fuel efficiency. Pollution levels should be the prime criteria to determine urban vehicle mobility. Three operating parameters have been considered in reducing emissions: overloading, speed, and age of the vehicle. This paper is based on a case study of an urban street in Mumbai connecting Thane to Borivali via Ghodhbunder road. The changes have resulted in a reduction in the generation of CO_2 by simply following some operating parameters.

Keywords: *HDM4, Transport Economics, Urban Mobility, Urban Emission.*

1.1 Introduction

The climate change crisis makes decarbonizing the transport sector one of our time's most pressing development challenges. The demand for mobility continues to grow as economies develop and urbanize and populations and incomes increase. With the world population projected to reach 8.5 billion by 2030, annual passenger traffic is expected to grow by 50 percent, while global freight volume is expected to grow by 70 percent over the same period. But emissions from the transport sector currently comprise approximately 24 percent of total energy-related Green House Gas (GHG) emissions. Transport sector emissions have grown faster than almost any other sector over the past 50 years. They are predicted to increase by 60 percent by 2021 if no action is taken.[1]

Transport emissions also have an impact on health locally. The transport sector is the most significant global contributor to the emissions of delicate particulate matter, strongly linked to increasing the incidence of respiratory and cardiopulmonary diseases and many forms of cancer. The transport sector is also the main contributor to CO emissions, reducing the amount of oxygen reaching the body's organs and tissues and exacerbating heart conditions. The World Health Organization's (WHO) 2018 report "Global Urban Ambient Air Pollution Database" estimated that 98 percent of cities in low and middle income countries with more than 100,000 inhabitants did not meet WHO air quality guidelines. Localized air pollution was estimated to result in 2.9 million annual premature deaths globally of which more than 85 percent occurred in low and middle-income countries.[2]

The Government of India recently updated the Nationally Determined Contribution (NDC) under the Paris Climate Agreement. According to the updated NDC, India is now committed to reducing its GDP's emission intensity by 45 percent by 2030.At the 26th session of the Conference of the Parties (COP26) on Climate Change in Glasgow in 2021, the Government of India proposed helping the world get closer to 1.5 degrees Celsius. The focus of this paper is to put a limit on air pollution which could be controlled by controlling overloading in commercial vehicles and abolition of old high-emission vehicles, that are primarily responsible for air pollution in most of the metropolitan cities in India.

1.2 Material and Methods

India has almost doubled its emissions in the past two decades, but its per capita carbon intensity remains about one-quarter of the EU's. It was more than 0.25tCO_2 per capita in 1971 and increased to 1.71tCO_2 per capita in 2019. The Indian transport sector is responsible for 13.5 percent of India's energy-related CO_2 emissions. Indian road transport accounts for 90 percent of the transport sector's total energy consumption.[3] Greenhouse gas emissions from transportation primarily come from burning fossil fuels for cars, trucks, ships, trains, and planes. Over 90% of the fuel used for transportation is petroleum-based, including diesel. Policies that promote decarbonization in road freight and passenger transportation are critical to supporting zero-emissions vehicles. The expected Net Zero Emissions by 2050 Scenario requires transport sector emissions to fall by

20% by 2030.[4]

Achieving this drop would depend on policies to encourage the least carbon-intensive travel options and operational and technical energy efficiency measures to reduce the carbon intensity of all transport modes. But there would be no compromise in the rising transport demand for economic growth. Placing the transport sector on the Net Zero pathway requires a range of government decisions and the people's cooperation.

As transport activities continue to grow, targeted policies stem rising CO_2 emissions. Under the Net Zero Emissions Scenario, direct CO_2 emissions from fossil fuel use by 2&3wheelers and light-duty vehicles will decrease by 2% and 5% per year on average by 2030, respectively. In the case of heavy trucks, CO_2 emissions decrease is suggested at only 0.5% per year on average between 2020 and 2030. A higher concentration of zero-emission technologies is still under development. As these technologies become commercially available, the average annual decrease will reach 8.5% per year from 2030 to 2050 in the Net Zero Emissions Scenario.[5] To align with the Net Zero pathway, policy efforts should continue taking advantage of mobility routines disruptions to promote lasting behavioural change. Reducing transport CO_2 and pollutant emissions will require sustained policy efforts. Priorities also include anticipating and managing demand by shaping new mobility developments in cities and formulating long-term technology and policy visions for heavy-duty subsectors such as road freight. Aligning the transport sector with Net Zero modelling will require a coordinated policy approach that facilitates decarbonization across all transport modes and expands supporting infrastructure. Measures at various levels of jurisdiction—national, subnational, within cities, and in multi-country regional blocs – must support progress in stimulating the uptake of less-emission vehicle operation under the new norms of vehicle age, gross vehicle weight, speed, etc.

The use of public transport in cities worldwide has fallen by 50-90% resulting in a modal shift to cars that would increase GHG and air pollutant emissions and congestion levels.[6] Fifty-six percent of the globe's population lives in cities and towns.[7] With urbanization on the rise, cities should now take advantage of various transport strategies to induce modal shifts. The resurgence in active modes of transport has provided governments with a policy window to improve and expand infrastructure and make road reallocation permanent. Cities can also employ measures to stem the uptake of larger vehicles.

Carbon Dioxide Emissions from Transport in India

India is experiencing rapid growth in motorization. The government and policy makers are responding to this growth by building road infrastructure. Land transportation is the third most CO_2 emitting sector, and within the transport sector, road transport contributed more than 90% of total CO_2 emissions. The greenhouse gas (GHG) emissions in India consisted of 70% CO_2 and 30% non-CO_2 (methane, nitrous oxide, F-gas) emissions.[8] With economic development in India, the vehicle ownership level has increased with a growth rate of 10.4% for two-wheelers and 11% for cars from 2001 to 2015,[9] leading to an increase in emission levels on the road. An increase in vehicle population also contributed significantly to India's air pollution. The compound annual growth rates (CAGR) in registered vehicles are 5% for Heavy Diesel Vehicles (HDV), 10% for Light Diesel goods vehicles (LDV), 4% for Buses, 8% for taxis, 8% for passenger three-wheelers (3W) autorickshaws, 9% for motorized two-wheelers (2W), and 6% for four-wheelers (4W) such as cars and jeeps in India from 1991 to 2020.[10] The vehicle population on the road is affected by their sales and survival fraction concerning age. The survival fraction of vehicles determines their age in the fleet, which affects their emission levels. The survival fraction of vehicles was determined by a policy to scrap ten years of diesel vehicles and 15 years old gasoline vehicles. Fuel efficiency measures the distance travelled per volume of fuel consumed by the vehicle on the road. Its unit is kilometres per litre (km/L). Fuel efficiency also regulates greenhouse gas emissions (such as CO_2) from vehicle exhaust.[11] There is a lack of age-wise data on fuel efficiency (corresponding to the age of the fleet vehicles) for different vehicle categories running on diesel, gasoline, and CNG at a national level.

Emission in States

Emission factors are the emission norms or standards implemented to control vehicle exhaust emissions. It depends on various factors such as the vehicle's age, usage, maintenance of the vehicle, speed, road type, vehicle category, fuel type, and fuel quality are just a few to mention. Vehicular emission is very much region-specific. In 2003-04 more than 50% of road transportation emission was contributed by six states. The highest contribution was from Maharashtra at 11.8 percent, followed by the sequence Tamil Nâdu at 10.8, Gujarat at 9.6, Uttar Pradesh at 7.1, Rajasthan at 6.22, and Karnataka at 6.19.[12] Energy consumption also varies with the modes of transport because the average energy consumption per km differs. The traffic composition of Indian cities is changing rapidly. There is a significant change from the share of slow-moving to fast-moving vehicles and from public to private transport. The emission Factor for road vehicles is gm/km.

Carbon di Oxide (CO_2) emissions are directly related to the amount of fuel burnt. With a gradual increase in the total number of in-use vehicles, the total fuel burnt and the CO_2 emissions also increased, despite the improvement in the fuel efficiency of the individual vehicles. The estimated annual total CO_2 emissions from in-use vehicles were 3.8 million tons in 1991, which increased to 6.2 million tons in 2001, and 11.2 million in 2012, approximately a threefold increase. It has been found that CO_2 emissions, only in the case of 4Ws, are proportional to their share of the total vehicular fleet and highly disproportionate for all other vehicle types (vide Table 1Pollution and Vehicle Type Shares). The share of 4Ws in the fleet is 35%, and its CO_2 emission is 37%. The share of freight modes is 4%, but the share of CO_2 is nearly 30%. The share of passenger modes is 96%, but the share of CO_2 is almost 70%.[13]Again,Table 2 shows that CO_2 emissions per 4Ws, except for light cars, are between 208.3 and 223.6 g/km. But the CO_2 emissions are 515.2g/km for the rest categories of vehicles like large buses, small buses, and heavy and medium trucks.

Table 1 : Pollution and Vehicle Type Share

	2W	4W	3W	BUS	HDV	LDV	Total	Passenger modes	Freight modes	Total
Vehicles	59%	35%	2%	1%	1%	3%	100%	96%	4%	100%
PM 2.5	8%	19%	1%	5%	38%	29%	100%	33%	67%	100%
SO_2	15%	23%	0%	1%	56%	6%	100%	39%	61%	100%
NO_X	7%	6%	9%	16%	19%	43%	100%	38%	62%	100%
CO	35%	33%	6%	5%	8%	13%	100%	79%	21%	100%
VOC	33%	19%	23%	5%	7%	12%	100%	80%	20%	100%
CO_2	17%	37%	7%	10%	11%	18%	100%	71%	29%	100%

Source : Goel, 2015, p.84

Table 2 : CO_2 Generation by Vehicle Types

	Bus	Omni buses	Two wheelers	Light Motor vehicles(Pass)	Cars and jeeps	Taxi	Trucks and Lorries	Light Motor vehicle(Goods)	Trailers & Tractors	Others*	Reference
CO_2	515.2	515.2	26.6	60.3	223.6	208.3	515.2	515.2	515.2	343.87	Mittal & Sharma 2003
CO	3.6	3.6	2.2	5.1	1.98	0.9	3.6	5.1	5.1	3.86	`CPCB,2007
NO_X	12	12	0.19	1.28	0.2	0.5	6.3	1.28	1.28	3.89	CPCB, 2007
CH_4	0.09	0.09	0.18	0.18	0.17	0.01	0.09	0.09	0.09	0.11	EEA,2001
SO_2	1.42	1.42	0.013	0.029	0.053[b]	10.3[C]	1.42	1.42	1.42	1.94	Kandlikar & Ramachandran 2000
PM	0.56	0.56	0.05	0.2	0.03	0.07	0.28	0.2	0.2	0.24	CPCB,2007
HC	0.87	0.87	1.42	0.14	0.25	0.13	0.87	0.14	0.14	0.54	CPCB,2007

Source : Ramachandra, p.3, 2009

India's share of diesel cars has almost doubled from 27% during 2002-06 to 55%. In addition, dieselization in India has occurred mainly with cars having large engine sizes. Diesel cars with an engine size less than 1600 cm^3 have 50% higher fuel efficiency than those with an engine size greater than 1600 cm^3. As a result, the overall average of all diesel cars is even lesser than their petrol counterparts (14.0 and 15.3 km/lit, respectively). Thus, the dieselization of cars in India will likely reduce the fleet's overall fuel efficiency. This is similar to China's penetration of heavy diesel cars that offsets the fuel efficiency gains achieved due to fuel efficiency standards implemented in the early 2000s. Like India, preferential tax treatment for diesel led to dieselization in Europe. As a result, the share of diesel cars in the total vehicle stock in Europe increased from 3.3% in 1980 to 32 % in 2007.[14]

Emission Factors

It will be shown that operational interventions can improve the emissions performance of vehicles. This category also includes interventions that will enhance the system's efficiency, such as optimizing speed, axle load, vehicle age, etc. Fuel consumption is a significant component of Vehicle Operating Cost (VOC), typically accounting for 20 and 40 percent of the total VOC. It is influenced by traffic congestion, road condition and alignment, vehicle characteristics, and driving style. There has been a significant change in the average fuel economy of passenger cars over 50 years, with an approximate improvement of nearly 200 percent.[15] Vehicle technology is constantly changing. Speeds influence many road user components, particularly fuel, and type of consumption. Where traffic cannot be avoided, it must be shifted to more environmentally friendly means of transport.

The demand for automobiles has increased almost endlessly in the last few years. Several world-class automobile manufacturers are working to reduce the fuel consumption of their vehicles to improve fuel efficiency and reduce air pollution. Several Japanese, European, and American automobile companies have revolutionized fuel consumption technology and redesigned their engine to meet the maximum fuel efficiency in a competitive market like India. Moreover, more fuel efficiency means more excellent greener technology, which emits lesser Carbon-monoxide (CO), Carbon-dioxide (CO_2), Hydrocarbons (HC), and Sulphur. However, only good engine quality does not ensure a more secondary emission. Still, a congestion-free road and good pavement (road) conditions are also responsible for providing a greener environment. A vehicle with new technology on a fully congested road with poor pavement conditions will behave differently than an efficient engine. However, the engine is unique in terms of age and technology. In other words, society can reap the benefits of greener technology only possible if and only if there is a congestion-free, good-quality road, which is only possible when there is an amalgamation of good Highway Engineering along with good Mechanical Engineering.

It is evident that greener the technologyis, less is the air pollution, but it is possible when road conditions and speed are optimum. Recently, air pollution has been a severe issue in metropolitan cities, which has deteriorated the quality of urban life. The primary source of air pollution in cities is fossil fuel in urban road transportation. There are government norms regarding vehicle age and conditions to minimize tailpipe emissions and regulations on vehicular speed to reduce accidents. There is a mandated retirement age of 15 years for the Taxis and 3Ws.[16] Still, nothing is specified for the other modes, except that the vehicles must obtain a "pollution under check" certificate every six months. However, restrictions on vehicle speed are not intended to reduce emissions. In general, vehicular speeds are to increase travel time savings. However, speeds correlate with vehicle operating costs and are highly sensitive to fuel consumption. The economic cost of emissions on human life is much higher than savings in travel time and vehicle operating costs. The most common reason to control vehicle speeds is to reduce road accidents rather than air pollution. Over-speed or under-speed of vehicles lead to high consumption of fuel, which further leads to air pollution an optimum level of speed should be defined or maintained to maximize fuel efficiency by minimizing fuel consumption. Hence, the paper suggests determining vehicle speed limits based on optimizing tailpipe emissions in urban road transportation.

There is much literature on vehicle speed and accidents, driving style and emission, fuel consumption, and operating. Still, no single work shows a quantitative explanation of air pollution and its relation to vehicular speed. In a single word, there is no literature related to vehicle speed and its impact on the environment in the case of urban mobility. Vehicle average pace under 70 km/h does not influence the mean Eco-index value, and the variance remains almost constant.[17] Again, all vehicle parameters were found to affect vehicle operation differently. For the engine, the speed fluctuations (due to gear changes) are primarily affected.[18] Four instrumented vehicles have been selected to measure the effect of fuel consumption on different driving conditions like accelerating, deaccelerating, cruising, and idle and their corresponding fuel consumption. It was found that diesel vans have minimum emissions, whereas double-decker buses have the maximum emissions level.[19] In a study, Spatial GPS data was used to estimate the emission level of vehicles, whereas many researchers pay attention to the spatial-temporal distribution of fuel consumption. The estimated accuracy level is almost 88.6% compared to spatial-temporal distribution, which has an accuracy level of 71.02%. Several research papers have been reviewed, but no single paper may be found on the optimum vehicle speed and its corresponding effect on air pollution. There is a considerable volume of literature on vehicle speed and road configuration to maximize time savings and road safety, reducing road accidents. Moreover, there is much literature on vehicle configuration and fuel efficiency.

However, little consideration is paid to air pollution treatment as an independent variable determining vehicle speed. In today's life, time is money, and speed is an essential factor. But rising speeds lead to a more significant number of road accidents, and pollution remains unabated in urban life. Though road safety is now being actively considered as one of the essential factors in selecting design speed, emission is not viewed in regulating vehicle speed. More straightforwardly, the authority must determine the speed of the vehicles in urban areas solely based on the pollution level, not anonymously. There is awareness among people regarding the high levels of environmental pollution caused due to the use of fossil fuels in transportation services. Their impacts, especially in the cities of developing countries like India, leave lasting effects on productivity and human health. Under the changed conditions, pollution levels should be the prime criteria to determine vehicle speed limits in urban mobility. There is a shortage of literature dealing with the relationship between assessing vehicular speed limits based on their environmental impacts.

1.3 Calculation

Carbon monoxide production has a direct relationship with the level of fuel consumption. Hydrocarbon is generated from two sources with a combustion engine. The first is from burning the fuel, while the second is from incomplete combustion.Nitric Oxides are the emissions that are least related directly to fuel consumption.The quantity of Sulphur dioxide produced is connected directly to the amount of Sulphur present in the fuel. The amount of Lead, Pb, is related directly to the amount of Lead in fuel. Catalytic converters aim to reduce certain harmful emissions into chemical compounds that are less harmful to human life and the environment. Primarily catalytic converters aim to convert any carbon (found in CO, HC, and particulate matter) into CO_2 and NO_x into ammonia, nitrogen, CO_2, and N_2O depending on the prevailing operating conditions.[20]

The Bharat Stage (BS) VI 'emission standard' came into effect for all vehicles on or after April 1, 2020. The BS VI emission standards adoption aligned Indian motor vehicle regulations with European Union regulations for light-duty passenger cars, commercial vehicles, heavy-duty trucks and buses, and two-wheeled vehicles. While not yet reaching European levels, more stringent emission standards are set for three-wheeled vehicles. The BS VI included emission limits on nitrogen oxides (NOX), carbon monoxide (CO), and hydrocarbon (HC). BS VI emission standards are defined for vehicles with gross vehicle weight (GVW) not exceeding 3,500 kg. Vehicle types in these categories include light-duty passenger and commercial vehicles.[21] It may be indicated that the HDM4 model does not consider the additional fuel consumption associated with a cold start. This is a problem for petrol vehicles on short trips where a significant portion of the journey is made under cold start conditions. In the rural area, a cold start and a short trip are random. In the urban area,a short trip is a significant factor, which is generally related to additional fuel consumption vis-à-vis high emissions. Most emissions are a function of fuel except Carbon Dioxide. It is estimated as a Carbon balance equation, which is emitted as CO_2. So, the emission standard for CO_2 is not mentioned in the BS-IV. The comparative analysis is given in Table 3.

Table 3 : Emission Standard Under BSVI and HDM4

Emission Standards (g/km)

Reference	**Vehicle Type**	**CO**	**NOx**	**CO_2**
	Light-duty	0.63	0.105	NA
BSVI	Heavy-duty	4.00	0.46	NA
	2 wheeler	0.94	0.34	NA
	3 wheeler	0.44	0.085	NA
	Light-duty	0.08	0.027	2.00
	Heavy-duty	0.08	0.027	2.00
HDM4	2 wheeler	0.2	0.02	1.8
	3 wheeler	0.1	0.055	0.8
	Car	0.1	0.055	1.8
	Bus	0.08	0.027	2.0

Source : Trade policy.Net and HDM4, CO_2 is the fuel's ratio of hydrogen and carbon

The Government of India has decided to blend 20% ethanol with petroleum from 2025. This program will be a game changer in emission standards or levels. India's net petrol imports in 20-21 were 185MT at USD 551 billion. Most petroleum products are used in transportation. A successful E20 program will save the country USD 1 billion, or Rs 30,000 crores.[22] The E20 program will cause the transition to a low-carbon economy without compromising the economic growth trajectory because it will reduce vehicular emissions, among many more benefits, as ethanol is a less polluting fuel. Different transport fuels have different caloric values. A comparison of energy content in different fuels confirms that mixing ethanol will reduce pollution and energy consumption, as stated in Table 4.

Table 4: Energy Content of Transport Fuels

Fuel	**Energy Content (MJ/litre)**
Petrol	34.7
Diesel	38.7
LPG1	25.5
CNG2	40
Ethanol	23.9
Methanol	18.1
Biodiesel	32.8

Source : Volume 7(p.318) of HDM4 Manuals 2, units are MJ/m^3

Operating Parameters

Three operating parameters have been considered in reducing emissions: axle load, speed, and kilometres driven.

Gross Vehicle Weight

Fuel consumption is primarily dependent on vehicle mass. There is a strong correlation between pavement and the carrying capacity of the vehicles due to static and dynamic forces generated during the movement of the vehicles. Because of this correlation, maximum permissible gross vehicle weight and maximum allowable axle loads are prescribed. In India, the permissible axle load is 10.2 tonnes, although most roads have been designed for an axle load of 8.16 tonnes. It is, however, a rare trucker who adheres to the prescribed norms—the rampant overloading results in extensive damage to the road network and increased emissions. For delivery-type service, the fuel consumption is 25 – 42 l/100 km. For highway driving, the fuel consumption of 42t and 60t vehicle combinations is 22 – 53 l/100 km depending on the combination's weight. The minimum specific fuel consumption was 0.04 l/ton-km over the delivery cycle and 0.015 l/ton-km over the highway cycle. The variations in fuel consumption between vehicles within the same weight class are surprisingly significant. The variation from vehicle to vehicle within the same category is 0–16%.[23] Table 5 gives the number of axles, the number of wheels, and the maximum Gross Vehicle weight in tonnes.

Table 5: Axle and Weight Combination

Vehicle axle	Wheels (No.)	Max. GVW (t)
2	3	9
2	4	12
2	6	16.2
3	10	25
	Semi-Articulated	
2	10	26.4
2	12	35.2
2	18	40.2

Source: Nylund, p. 63, 2005

Speed

The following speed bins have been used to measure emissions levels. These bins will be used to obtain CO_2 levels. These are all journey speeds.

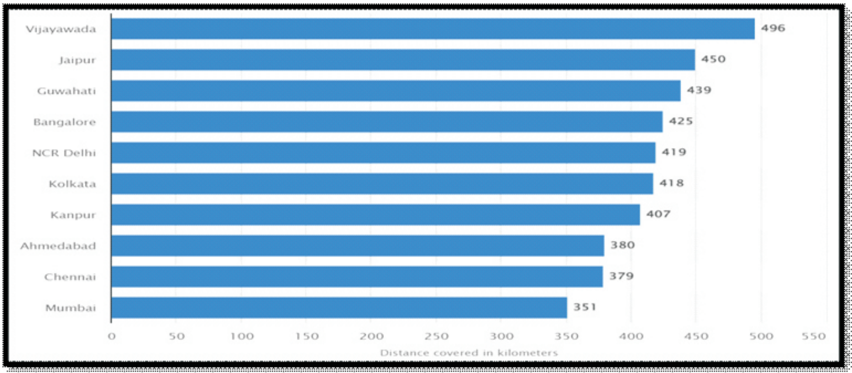
Speed Bins (Kmph)
0 to 4
5 to 15
16 to 30
Above 30

Vehicle Age

The average driving distance of 12,000 to 15,000 km annually for an Indian car; with a driver, the distance of 12,000-15,000 doubles to 25,000-30,000 km. An average car can run quite smoothly at around 3,00,000 km. The truck drivers in the country drove for about 12 hours per 24 hours. Truck drivers who owned the truck seemed to drive more hours than the trucks owned by fleet operators. Truck drivers are expected to work up to

70 hours over eight days. A total of 34 hours of rest is required after 70 hours of driving. The 70-hour limit could be reached by working 14-hour days. But one cannot drive for more than 11 hours daily[24] vide Figure 1.

Figure 1: Average Driving Range



Source: Statista,https://www.statista.com/statistics/1108993/india-average-distance-driven-by-truck-drivers-per-day-by-city/, 17.12.2022,2020

National Green Tribunal has ordered to phase out of vehicles older than 15 years. In one of the states of India, 65.01 lakh private vehicles and 69.76 lakh commercial vehicles plying on the road across the state are more than 15 years old. These vehicles fall under the BS-IV category. 1.5 lakh vehicles purchased between 1970 and 1999 are still rolling on the roads. 3.5 lakh buses purchased between 2000 and 2004 are also in service.[25] Based on these examples, three age categories considered are 5, 10, and 15 years.

Case Study

This paper is based on a case study of an urban street in Mumbai connecting Thane to Borivali via Ghodhbunder road (SH-42), which is highly congested due to high traffic intensity. Due to this traffic intensity, the distance between Thane and Borivali via SH-4 which is nearly 23 km, takes almost 1 – 1.5 hours to traverse. The Highway Development and Management (HDM) model was calibrated and configured. The road condition data were collected from the design team and used to configure the HDM4 model to reach the outcome. Annual Average Daily Traffic

(AADT) was obtained after conducting 24 hours for seven days counting. No traffic growth has been considered to optimize CO_2 levels. Table 6 provides the traffic on the project road in annual average daily traffic (AADT).The share of CO_2 in total pollutants is usually more than 95% ,[26] so the changes in CO_2 have only been considered; no other pollutants are considered. Emission and related problems are given in Table 7.

Table 6 : Traffic Volume in AADT

Traffic Volume Count (AADT) in 2017

	2W	3W	Car	LCV	Trucks	Bus	Total
Number of Vehicles	39,905	32,137	56,915	8,043	6,177	4,624	1,47,800
Composition (%)	27.0	21.7	38.5	5.4	4.2	3.1	100.0

Source : Traffic Survey, 2017

Table 7 : Emissions and Associated Problems

Emissions	Problems caused by Pollutants
Hydrocarbons	Urban ozone (smog) and air toxies
Carbon Monoxide	Poisonous gas
Nitrogen Oxides	Urban ozone (smog) and acid rain
Carbon Dioxide	Global warming

Source : Volume 7, p.124, HDM4 Manual

1.1.1 Result

Four conditions for the annual generation of CO_2 have been established. The first condition shows the project-specified base situation wherein 75 thousand tonnes have been generated. The rest three scenes show the generation of CO_2 in different cases. The changes have been made in GVW, Speed, and Age. The changes have resulted in a reduction in the generation of Co_2 and has been shown in Table 8.

Table 8: Annual Generation of CO_2

1. Project-specific Base Conditions

Vehicle Type	Axle No.	GVW(t)	Speed (km/hr)	Age (yr.)	Annual CO_2 (thousand tonnes)	CO_2 (gram/Vh-km) Bus	LCV	Truck
LCV	2	2		8				
Truck	2	16.2	23	12	75	748.02	287.9	506.0i
Bus	3	16.2		12				

2. GVW and Age Changed Conditions

Vehicle Type	Axle No.	GVW(t)	Speed (km/hr)	Age (yr.)	Annual CO_2 (thousand tonnes)	CO_2 (gram/Vh-km) Bus	LCV	Truck
LCV	2	3		5				
Truck	2	10	23	8	70	691.21	305.51	420.4
Bus	3	12		8				

3. GVW, Speed and Age Changed Conditions

Vehicle Type	Axle No.	GVW(t)	Speed (km/hr)	Age (yr.)	Annual CO_2 (thousand tonnes)	CO_2 (gram/Vh-km) Bus	LCV	Truck
LCV	2	3	30	5	67	664.7	292.5	410.55
Truck	2	10		8				
Bus	3	12		8				

4. GVW, Speed and Age Changed Conditions

Vehicle Type	Axle No.	GVW(t)	Speed (km/hr)	Age (yr.)	Annual CO_2 (thousand tonnes)	CO_2 (gram/Vh-km) Bus	LCV	Truck
LCV	2	3		5				
Truck	2	10	40	8	64	626.41	270.05	404.89
Bus	3	12		8				

Source: HDM4 model Generated outputs

1.1.2 Discussion

The HDM4 model was used to estimate CO_2 levels under different scenarios. The road deterioration sub-model was calibrated to the local conditions. The model-specified default values of vehicle engine parameters and emission standards were left unchanged since it will help to observe the changes in CO_2 levels more explicitly due to changes in selective operating parameters. Furthermore, Carbon Dioxide is not a function of fuel. It is estimated as a Carbon balance equation. Three categories of vehicles have yet to be taken for studies: Light Commercial Vehicles (LCV), trucks, and buses. A traffic survey was conducted on the road in 2017. The number of the aforementioned types of vehicles per day was collected from the traffic survey report. No traffic growth rates have been considered, the impacts of increased traffic volume are absorbed in the CO_2 levels. The entire length of 23 km of the road has been taken at a time. No improvement of the road has been considered. All base-level parametric values have been considered for analysis; for example, the existing road width of 7.5m has been maintained all over, and the actual roughness of 3.0m/km has been used. But one maintenance intervention of thin overlay at five-year intervals has been applied to arrest road surface deterioration impacts in the generation of CO_2 emission.

Changes in the values of vehicle age, Gross Vehicle Weight (surrogate of overloading), and speed have been affected step by step to capture the changes in CO_2 generation.

Firstly, the base case scenario has been developed with the actual values of the three parameters. The generation of CO_2 per unit Veh-km in the base case is as follows.

CO_2 (gm/Veh-km)

Bus	LCV	Truck
748.02	287.9	506.01

Secondly, Changes in age and GVW have been affected to see the changes in CO_2 emissions. The speed has been kept unchanged. It is found that CO_2 emissions in the case of buses and trucks are reduced by 7.6 percent and 17 percent, respectively, but in the case of LCV, the CO_2 emission increased by 6.2 percent.

CO_2 (gm/Veh-km)

Bus	LCV	Truck
691.21	305.51	420.4

Thirdly, the speed was unchanged in the first and second scenarios, and in the third scenario, the speed changed to 30km/hr. In this case, the reductions in CO_2 levels from the base level are 11.2 percent and 19 percent, respectively. But in this case, the reduction in CO_2 of LCV is 1.7 percent rather than an increase.

CO_2 (gm/Veh-km)

Bus	LCV	Truck
664.7	292.5	410.55

Fourthly, the speed has been changed to 40km/hr, in this case, leaving GVW and age unchanged. In this case, the reductions in CO_2 levels from the base level are 16.2 percent and 20 percent, respectively. But in this case, the reduction in CO_2 of LCV is 6 percent rather than an increase.

CO_2 (gm/Veh-km)

Bus	LCV	Truck
626.41	270.05	404.89

1.1.3 Conclusion

It may unequivocally be concluded that a considerable amount of emission generation may be reduced if overloading is not allowed and old, economically inefficient vehicles are not allowed to ply. Vehicle speed may be controlled by implementing modern traffic management systems like intelligent traffic management systems (ITS). It is imperative to control vehicle speed within the urban road network, which further promotes less amount of road accidents and minimum tailpipe emission simultaneously.

Endnotes :

1 International Energy Agency, Global Energy Review, pp. 2-12, 2021.

2 World Health Organization, World Health Statistics, pp. 10-15, 2018.

3 International Energy Agency, Global Energy Review, pp. 2-12, 2021.

[4] International Energy Agency, Global Energy Review, pp. 2-12, 2021.

[5] International Energy Agency, Global Energy Review, pp. 2-12, 2021.

[6] Moovit, Global Public Transport Report, https://moovit.com/press-releases/2020-global-public-transport-report/. Accessed: 17.12.2022 .

[7] International Energy Agency, Global Energy Review, pp. 2-12, 2021.

[8] J.G.J. Olivier and J.A.H.W. Peters, Trends in Global CO_2 and total Greenhouse EmissionReport, p. 43, 2020.

[9] Namita Singh, Trupti Mishra, Rangan Banerji, Emission inventory for road transport in India in 2020: framework and post facto policy impact assessment,pp.4-15, 2021.

[10] Singh, Mishra, Banerji, Emission inventory for road transport in India in 2020:pp.4-15, 2021.

[11] HDM4 Manual, vol. 3, p.312, 2000.

[12] T.V. Ramachandra, Shwetmala, Emission from India's Transport Sector: State wise Synthesis, p.1, 2009.

[13] Rahul Goel, Sarath K. Guttikunda, Evolution of on-road vehicle exhaust emissions in Delhi, p.84, 2015.

[14] Ramachandra, Shwetmala, Emission from India's Transport Sector, p.6, 2009.

[15] HDM4 Manual, vol. 3, p.47, 2000.

[16] Singh, Mishra, Banerji, Emission inventory for road transport in India in 2020,p.15, 2021.

[17] Alessandrini Adriano, Cattivera Alessio, Filippi Francesco, Ortenzi Fernando, 'Driving style influence on car CO_2emissions,' University of Rome, p.6, 2014.

[18] Giakoumis Evangelos G. and Triantafillou George, 'Analysis of the Effect of Vehicle, Driving and Road Parameters on the Transient Performance and Emissions of a Turbocharged Truck', National Technical University of Athens, p.19, 2018.

[19] H.Y. Tong and W.T. Hung 'On-Road Motor Vehicle Emissions and Fuel Consumption in Urban Driving Conditions', Hong Kong Polytechnic University, p.8, 2000.

[20] HDM4 Manual, vol. 3, p.352, 2000.

[21] HDM4 Manual, vol. 3, p.314, 2000.

[22] The Statesman, Calcutta, National Green Tribunal Judgement June 22, 2022.

[23] Nils-Olof Nylund and Kimmo Erkkilä, Heavy-Duty Truck Emissions, and Fuel Consumption, VTT Technical Research Centre of Finland, p. 63, 2005.

[24] Statista,https://www.statista.com/statistics/1108993/india-average-distance-driven-by-truck-drivers-per-day-by-city/. Accessed: 17.12.2022 .

[25] The Statesman, Calcutta, National Green Tribunal Judgement, June 22, 2022.

[26] HDM4 Manual, vol. 3, p.323, 2000.