A Systematic Study on the Analysis of the Emission of CO, CO$_2$ and HC for Four-Wheelers and Its Impact on the Sustainable Ecosystem

Rohit Sharma $^{1*}$, Raghvendra Kumar $^{2}$, Pradeep Kumar Singh $^{3,*}$, Maria Simona Raboaca $^{4,5,*}$ and Raluca-Andreea Felseghi $^{5}$

$^1$ Departments of Electronics & Communication Engineering, SRM Institute of Science and Technology, NCR Campus, Ghaziabad 201204, India; rohitapece@gmail.com
$^2$ Department of Computer Science and Engineering, GIET University, Gunupur, Odisha 765022, India; raghvendraagrawal7@gmail.com
$^3$ Department of CSE, ABES Engineering College, Ghaziabad, Uttar Pradesh Pin-201009, India
$^4$ National Research and Development Institute for Cryogenic and Isotopic Technologies—ICSI Rm. Valcea, Uzinei Street, No. 4, P.O. Box 7 Rauneni, 240050 Valcea, Romania
$^5$ Faculty of Electrical Engineering and Computer Science, Stefan cel Mare University of Suceava, Universității Street, No.13, 720229 Suceava, Romania; Raluca.FELSEGHI@insta.utcluj.ro
* Correspondence: pradeep_84cs@yahoo.com (P.K.S.); simona.raboaca@icsi.ro (M.S.R.)

Received: 14 June 2020; Accepted: 9 August 2020; Published: 19 August 2020

Abstract: The urbanization in Delhi NCR has led to a rapid increase in the vehicle count concerning the rise in population and mobilization. The emissions from the vehicles are currently counted amongst the main sources of air pollution in Delhi. This affects the quality of air. The emission criterion of various pollutants that are emitted from vehicles is evaluated through various International models, which include various vehicles, their modes of pollutants emitted while driving and other factors that are affecting the weather. The approximate emission of pollutants such as Carbon Monoxide (CO) and/or Particulate Matter (PM), from a variety of vehicles and different fuel types, has undergone diurnal variation over the years, depending on the time of the day. This study presents the emission factor of gaseous pollutants Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO$_2$) of 181 four-wheeler cars from different companies containing different types of fuels. The measurement of gaseous pollutants is performed for Delhi, the most polluted city in India. The various facts and data were calculated and analyzed with reference to the standard values set by the national schemes of the Pollution and Environment. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned to overcome emission problems. Therefore, it is important to develop and deploy methods for obtaining real-world measurements of vehicle emissions, to estimate the pollutants. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. This study shows that many old vehicles are used in different regions of the country, regardless of many notifications of banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. The analysis stated that the diesel engine would emit less CO$_2$/km than a petrol engine if having an almost similar engine capacity.

Keywords: vehicular emissions; pollutants; Carbon Monoxide; Particulate Matter (PM)
1. Introduction

India is one of the biggest emitters of pollutants, and vehicle pollution is one of the major sources of these pollutants. Here we present an inventory of vehicle pollution for different car models and companies. This inventory is the study of major pollutants Hydrocarbons (HC), Particulate Matter (PM), Carbon Monoxides (CO) and Carbon Dioxide (CO$_2$), for the period from 2005 to 2019. These inventories play a very important role when we discuss the input for modeling of atmospheric composition, about the air and other pollution. In this paper, we study the major makers/companies of four-wheelers vehicles that emit the pollutants in the air. The maker/companies considered for this study are Toyota, Maruti Suzuki, Hyundai, Honda, Mahindra, TATA and some other luxury makers.

According to WHO, air pollution kills around seven million people worldwide every year. The data show that approximately 90% of the population breathes air containing high levels of pollution, resulting in around seven million deaths every year due to such exposure. In January 2019, the state-run Central Pollution Control Board’s air-quality index shows that the concentration of poisonous Particulate Matter, also known PM 2.5, stood at 440 and about 12 times more than the US-government-recommended level, i.e., the level of 35. Therefore, it becomes imperative for us to deeply understand and analyze the causes of air pollution in our surroundings. Vehicles are one of the major sources of emission of pollutants, especially in urban areas. The major pollutants associated with vehicular emission are Hydrocarbons (HC), Particulate Matter (PM), Carbon Monoxides (CO) and Carbon Dioxide (CO$_2$). In this paper, we analyze these major pollutants emitted by different fuel vehicles. In the next section, we detail these pollutants in brief. The fuel and air can be the source of different pollutants that can be harmful to human health. Here we discuss some of the major pollutants caused by vehicular emission.

\[
\text{Fuel} + \text{Air} \rightarrow \text{Hydrocarbons} + \text{Carbon Dioxide} + \text{Carbon Monoxide} + \text{Nitrogen Oxide} + \text{Sulfur Dioxide} + \text{water}. 
\]

Hydrocarbons (HC) are considered to be specks of molecules of fuel that are not fully burned. These react when sunlight and oxides of Nitrogen are present, and the reaction results in the formation of ground-based ozone. The ozone so formed majorly contributes to smog and irritates the eyes and nose and also damages the lungs. Some exhausts’ HCs are harmful, too, with the potential to cause cancer. Carbon Monoxide (CO) is the product of the incomplete burning of Hydrocarbons-based fuels. It is a colorless, odorless and poisonous gas. Mostly, when cars are about to start, and if they are not tuned in a proper way or at higher altitudes, where the fraction of oxygen that is available for combustion decreases, then the CO formed has a low air-to-fuel ratio in the engine. Two-thirds of the CO emissions arise from the sources of transport, cars being the largest contributor. In some areas, the contribution of on-road vehicles to Carbon Monoxide pollution may rise up to 90%. The affinity of CO to hemoglobin is about 250 times more than the oxygen. This may cause mild-to-severe poisoning, depending upon the concentration of CO and its exposed length. The symptoms include headache, dizziness, nausea, vomiting and loss of consciousness. Carbon Dioxide (CO$_2$), as per the US Environmental Protection Agency (EPA), initially inspected CO$_2$ as a result of “complete” combustion, but now suspects Carbon Dioxide as the concern of pollution. CO$_2$ is a greenhouse gas that traps the heat of the earth and contributes to the change in the climate.

We have seen that the new vehicles are comparatively less polluting than before, but the number of vehicles and the overall distances traveled by them has considerably increased, and the people, especially while commuting, are heavily exposed to such pollutants. One such region which has an air-quality level of criticism is the Delhi National Capital Region. Delhi, also being the capital, is undergoing rapid development, with an ever-increasing number of vehicles, reaching more than 10 million now. Delhi NCR has been given the worst position among the 14 major cities of the country, on the basis of vehicular emissions, according to a study conducted by the Centre for Science and Environment (CSE). A survey conducted by IIT-Kanpur has revealed that such emissions from vehicles contribute 9% of the total Particulate Matter 10 (PM10) and 20% of the total PM2.5 in the national capital. Recently there have been some initiatives taken to curb or reduce vehicular pollution,
including public-awareness campaigns, registration of only those first-sale four-wheeled petrol-driven vehicles which have catalytic converters installed, the expansion of the rapid public transport system, the phasing out of old commercial vehicles, compliance of tightened emission standards and improvement in fuel quality by completely phasing out leaded petrol, and introduction to low Sulfur diesel. However, despite all of these measures taken, the problem still persists, and there is a large and excessive need for studies and analyses, to understand the problem at a deeper level, and with those results, a more practical approach can be strategized. Hence, our paper analyses the different types of pollutants emitting from distinct vehicles, at different periods of time, and gives an overall view of the most current situation in this region.

Timely differences in vehicle emissions are influenced by many inter-mixing factors in the real world. Post tailpipe emission the particles go through a change as they come into the contact with atmosphere, as observed when we see two times the increase in emission factors from summer to winter [1]. Taking cost-effectiveness into account is one of the major things when it comes to implementing policies for the reduction of vehicular emissions. It was seen that implementing a policy of limited driving was less cost-effective than a policy of elimination of old cars [2]. Pollutants such as SO$_2$, HC, CO$_2$, CO and PM are emitted by vehicles in very high quantities [3]. Detailed specifications of the compound of gases where the particles are studied at different stages, such as cooling, equilibrating to current conditions, are needed for the evaluation of vehicular emissions [4–6]. Usually, the estimation of vehicular and engine emissions is done by using a chassis dynamometer and engine, but these are costly and require quite a high amount without the representation of real-life emissions [6]. Tunnel studies and remote sensing aptly represent the road fleet emissions, but traffic flow, road conditions and technology lead to varying real-life emissions [7,8].

Certain studies have been conducted for the evaluation of pollutant emission from Particulate Matter and gaseous pollutants [9]. However, mostly, these evaluations are carried out for a few specific developing countries only. Intergovernmental Panel on Climate Change (IPCC) (2007) states that activity data and emission profiles from a regional source are required for the calculation of tier-two emissions. A large dataset is required for the refined estimation of emission from the road transport sector, while encompassing the effects of all the region-specific variables.

The indoor air quality has been measured by the emission evolution of specific indoor sources. This procedure included three typical activities, namely cooking style, biofuels and different levels of toasting bread [10]. In another study [11], three different models were integrated into a hybrid model for the prediction of vehicular emission, at a specific location and time, in Malaysia. A method has been proposed for emission estimation and energy consumption based on the condition of vehicles in different regions such as Spain, Malaysia and Colombia [12]. In another study, the author discussed the delay issues and time complexity on the internet of vehicles [13]. The prediction of boiler performance in terms of mass flow rate and the temperature was performed by using Artificial Neural Networks (ANNs) [14,15].

An inventory was performed for the Bangaluru region at a grid resolution of 1 km [16]. Another study provides the PM10 and PM2.5 concentration data for a populated region in Erongo [17]. The properties of SO$_2$ adsorption have been explored and evaluated [18]. Another study investigated the combustion and emission characteristics of diesel engines [19].

Strict vehicle emission regulations make sure that vehicles are efficient during their operation [20]. For major vehicle categories, the emission limits from the late 1990s are given by Euro Path; in 2000, 2004 and 2007, they were given by National-1, N-2 and N-3 standards. However, while implementing N-3 standards, it has been observed that the vehicle degradation occurs as the vehicle emission factors reach their highest values (Zhang et al., 2008). Hence, it was seen that, only after enforcing the N-4 standards, the pollutant emission factor was decreased [20]. Findings from the American Environment Protection Agency showed that NO$_x$ emission was decreased by 5%, HC emission was decreased by 7% and CO emission was decreased by 8% when the Sulfur (S) content in fuel was decreased to...
49 mg/kg, which was almost similar to the N-4 fuel standard from 327 mg/kg, which was similar to N-3 fuel standard.

In Delhi, the road traffic increased from 128 to 191 vehicles per kilometer in the time frame from 2003 to 2009 [21]. Due to this, the availability of road space in Delhi increased by 678 lane kilometers between 2003 and 2009. In Delhi, the average annual rate of the vehicle population growth is about 9.150% for commercial and 7.40% for private vehicles. Annual growth in the vehicle population is causing severe environmental problems in Delhi [22]. Delhi occupies the fifth position when it comes to the worst traffic congestion/jams in a major city. Various models, like Spreadsheet, Long-Range Energy Alternative Planning (LEAP) and Vehicle Air Pollution Information System (VAPIS), do not take into consideration many distinguishing factors in the local environment, such as management of traffic and behavior of the driver; along with this, there is also an assumption that vehicles having lower speed increase the pollutant emission. Considering the above discussion, an IVE model which has been applied in various major cities all over the world, including cities such as Shanghai and Beijing in China, can be used for emission estimations [23]. For differently fueled vehicles, features such as meteorological variables, emission factors and different modes of driving are being used in this model, with further related studies in References [24–54].

The study by Reference [55] concentrated on the analysis of CO$_2$ emission for five NMI subsectors. Authors have studied the CO$_2$ emission for the time period of 30 years, from 2010 to 2030. In another study, authors have estimated the environmental technical efficiency and shadow prices for SO$_2$ emissions of China’s provinces, from 2001 to 2013 [56]. Authors have highlighted the incompatibility in Carbon neutrality assumptions, system boundaries, methodologies and functional units in LCA studies of paper and pulp making [57]. An analysis has also been carried out which measures the effect of acceleration and speed on the emission of HC, CO and NOX in four-stroke motorcycle exhaust [58]. Another study has discussed the prospect of ethanol as an effective substitute for gasoline and also analyzed its effect on the emissive behavior of SI engines [59].

Some initiatives have been already taken to curb or reduce vehicular pollution: public awareness campaigns, registration of only those first-sale four-wheeled petrol-driven vehicles which have catalytic converters installed, the expansion of the rapid public transport system, the phasing out of old commercial vehicles, the compliance of tightened emission standards and improvement in fuel quality by completely phasing out leaded petrol and introduction of low Sulfur diesel. However, despite all of these measures taken, the problem still persists as a large and excessive need to study this situation, and analyses are required to understand the problem at a deeper level; with those results, a more practical approach can be strategized. This study shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-years-old vehicles. This study shows that many old vehicles are used in different regions after the many notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants.

The urbanization in Delhi NCR has led to a rapid increase in the vehicle count with respect to the rise in population and mobilization. The emissions from the vehicles are currently counted amongst the main sources of air pollution in Delhi, and this affects the quality of air. The emission criterion of various pollutants that are emitted from vehicles is evaluated through various international models that include the different vehicles, their driving modes, pollutants emitted and other meteorological factors. The estimated emissions of pollutants such Carbon Monoxide (CO) and Particulate Matter (PM) from different types of vehicles and different fuel types have undergone diurnal variation over the years, depending upon the time of the day. This paper makes an attempt to study and analyze the pollutants by the emission of gases by vehicles which emit from them. The various facts and data were calculated and analyzed with reference to the standard values set by the national schemes of pollution and the environment. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems.
Therefore, it is important to develop and deploy methods for obtaining real-world measurements of vehicle emissions, to estimate the pollutants. The comprehensive review reveals whether the moving vehicles create a significant impact on air quality on specific locations or not.

The significant contribution of this paper is its presentation of the gaseous pollutants (Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO₂)) emission factor of 181 four-wheeler cars from different companies and of different types of fuels. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems. This study shows that many old vehicles are used in different regions, even after the many notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. The unauthorized installation of compressed natural gas (CNG) kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets the reduction of CO, CO₂ and HC. It will be helpful to pollution-monitoring authorities for making new and effective policies against the emission of pollutants by vehicles.

The paper is organized as follows: The methodology is discussed in Section 2, which includes the quantification of emissions, studied area, experimental setup and data collection; Section 3 presents the result analysis; and, finally, the study is concluded in Section 4.

2. Methodology

2.1. Quantification of Emissions

The estimation of the emissions from the on-road vehicles is done on the basis of a number of vehicles and distance traveled in a particular year per different vehicle. This can be expressed as follows:

\[ E_i = \sum (Veh_j \times D_j) \times E_{ijkm} \]  

(1)

where \( E_i \) = emission of compound (i); \( Veh_j \) = number of vehicles per type (j); \( D_j \) = distance traveled in a year per different vehicle type (j); and \( E_{ij} \) and \( km \) = emission of compound (i) from bottom-up approach [60] were taken into account so as to estimate gaseous and particulate emission based on annual average utilization for a different vehicle category, number of registered vehicles and the corresponding emission factors vehicle type (j) per driven kilometer. Annual utilization of cars and jeeps and taxi were assumed to be 33,500, 12,600 and 12,600 km, respectively. These values were taken on the basis of five-year planning reports of India. For other sections of vehicles, annual utilization was calculated by taking the average of all the above values. The CO₂ emission [61] is estimated by using the value of the consumption of fuel [24,62] and emission factor, as follows:

\[ E_i = \sum (Fuel_{j,k} \times EF_{i,j}) \]  

(2)

where \( E_i \) = emission of compound (i); \( Fuel_{j,k} \) = consumption of fuel (j) for transport type (k); and \( EF_{i,j} \) = emission factor for compound (i) emitted from fuel (j).

Emissions of CO and HC were estimated by using the following equation:

\[ \text{Emissions (kt)} = \text{Fuel Consumption (kt)} \times \text{NCV} \left( \frac{P1}{R1} \right) \times \text{Gas Specific Emission Co-efficients} \left( \frac{kg}{TJ} \right) \]  

(3)

Stoichiometric air–fuel ratio and equivalence air–fuel ratio or Lambda(\( \lambda \)) are the important parameters for the analysis of pollution emitted by vehicles. To understand the Stoichiometric air–fuel ratio, we need to look at the fuel combustion process. It is a process in which the mixture of fuel and water produces water, heat and Carbon Dioxide. Activation energy is also required for the occurrence of such an oxidation reaction.

\[ \text{Fuel} + \text{Oxygen} \rightarrow (\text{Activation Energy}) \frac{\text{Spark (SI)}}{\text{HighTemperature (CI)}} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Energy} \]
With the help of Stoichiometric air–fuel ratio, the value of Lambda can be calculated by using the following equation:

\[ \text{Lambda} (\lambda) = \frac{\text{AFR}_{\text{actual}}}{\text{AFR}_{\text{ideal}}} \]  

(4)

Hence, the Lambda factor can be calculated by using the actual and ideal value of air–fuel ratio.

2.2. Locations

The most appropriate region chosen for the analysis of vehicular emission and its pollutants is the Delhi Northern Central Region. Delhi, a vast metropolitan area in the northern part of the country, is India’s capital territory as shown in Figure 1. The city covers the area of 1484 square kilometers (573 sq. mi) bordered by Haryana and Uttar Pradesh. The urban area of Delhi extends afar from the national capital territory border. The National Capital Region (NCR) consists of cities like Gurgaon, Noida, Ghaziabad and Faridabad. The National Capital Region (NCR) also includes Delhi, which is considered to be an “interstate regional planning” area by the National Capital Region Planning Board Act of 1985. A survey conducted by the World Health Organization (WHO) in 2014 shows that Delhi was the most polluted city in the world. Delhi was downgraded to the eleventh-worst city in the urban air-quality database in 2016. The air quality of Delhi is usually Moderate (101–200) level between January to September, and then it becomes Very Poor (301–400), Severe (401–500) or Hazardous (500+) between October and December. There is such deterioration in air quality due to various factors like stubble burning, firecrackers burning during festivals like Diwali and cold weather. The levels of Particulate Matter (PM) in Delhi have increased by about 44%, mainly due to high industrial and vehicular emissions, construction work and crop burning in neighboring states. The level of airborne Particulate Matter is also very high, that is, around PM 2.5, which is considered as most harmful to health. Increasing levels of vehicular pollution have consequently caused diseases such as asthma and lung cancer amongst the population of Delhi. The dense smog results in major air and rail traffic disruptions every year, during the winter season. The Indian meteorologists lately stated that the average peak temperature during winters has decreased in Delhi since 1998 due to rising vehicular emissions and, hence, the air pollution. Some measures have been taken to overcome air pollution in Delhi. Delhi has been ranked third amongst the other Indian cities in the count of trees. The world’s largest fleet of eco-friendly compressed natural gas (CNG) buses is controlled by Transport Cooperation of Delhi. The CSE began public interest litigation that ordered the Delhi’s transport system to switch on CNG and not to use the leaded petrol in 1998. The Department of Energy of the United States declared Delhi as its first “Clean Cities International Partner of the Year” in 2003 for its efforts to overcome air pollution by choosing eco-friendly fuel initiatives. The air pollutants in the city are also reduced by choosing Delhi metro cooperation as the main transport source in the city.

Therefore, as per various studies, many of the gains are lost. There’s a significant decrement in bus ridership due to an increment in the market share of diesel cars. The city remains assessed at basic sustainability due to the Carbon emissions of its poorer neighborhoods.
Figure 1. Selected area for on-road emission estimation in Delhi National Capital Region (NCR). Source: https://www.sketchbubble.com/en/presentation-delhi-map.html.

2.3. Experimental Setup

In this section, we discuss the test procedure used for analyzer gases. Some of the compulsory steps needed to be performed for the analysis of gas. For the gas analyzer, as per the specifications of the fabricator, the power supply is checked, and earthing also needs to be proper, in order to perform a test on vehicles. The electrical calibration should be checked. The availability and the functionality of all the components as per the fabricator need to be checked. With the help of the sample gas of suitable value for Carbon Monoxide (CO) and Hydrocarbons (HC), the span and zero calibrations are checked. We also need to check if the sampling system is leak-proof or not. Finally, it is checked if the printer is working efficiently and the print-out information is correct.

We also discuss the test procedure used for smoke meters. Some of the necessary steps needed to be carried out on smoke meters. It is checked that if the calibration of the meter is at zero and midscale point while the neutral density filter is available, after the warm-up of the meter. The ideal value must lie within 0.1 m⁻¹. The components, such as the sample hose, internal pipes, etc., are checked if they are deteriorated or have damages, to ensure that there are no leakages. The functionality of the heating system for the optical chamber is checked. The purge air system and visual displays should also be checked, to see if they are working correctly. The function of the oil temperature and Revolutions Per Minute (RPM) sensor also needs to be checked. Finally, it is checked if the printer is working efficiently and the print-out information is correct, and the instrument casing should be proper, with a proper electrical earthing.

The prescribed standard for different fuel-type vehicles consists of the appropriate values of Carbon monoxide (CO), Hydrocarbon (HC) and Lambda in the different Bharat stage norms as shown in Table 1. Here, CO and HC have emitted pollutants, and Lambda indicates the optimum condition needed for the proper functioning of catalytic converters. The estimation of the pollutants emitted is also based on the prescribed Hartridge Smoke Unit (HSU) and measured HSU. HSU (Hartridge
Smoke Unit) is a unit of measurement used to measure the capacity of exhaust gases of emissions, especially in diesel engines. The HSU limit for pre-Bharat Stage 4 norms was 65. The prescribed values for petrol vehicles consisting of pollutants and Lambda are stated as follows:

Prescribed Standard for Petrol Vehicles in Bharat Stage 4 norms:
- Carbon Monoxide (CO): −0.3 ppm.
- Hydrocarbon (HC): −200 ppm.
- Lambda (λ): Should be in the range of 0.97–1.03.

Prescribed Standard for Petrol Vehicles in Bharat Stage 3 norms:
- Carbon Monoxide (CO): −0.5 ppm.
- Hydrocarbon (HC): −750 ppm.

Table 1. Air-quality standards for national ambient [24–54].

| S. No. | Pollutant | Time Weighted Average | Concentration in Ambient Air | Methods of Measurement |
|--------|-----------|-----------------------|-------------------------------|------------------------|
|        |           |                       | Industrial, Residential, Rural and Other Areas | Ecologically Sensitive Area (Notified by Central Government) |
| 1      | Sulfur Dioxide(SO$_2$), µg/m$^3$ | Annual * 24 h ** | 50 | 20 | Improved West and Gaeke Ultraviolet Fluorescence |
| 2      | Nitrogen Dioxide(NO$_2$), µg/m$^3$ | Annual * 24 h ** | 40 | 30 | Modified Jacob and Hochheiser (Na-Arsenite) Chemiluminescence |
| 3      | Particulate Matter(size less than 10µm) or PM10 µg/m$^3$ | Annual * 24 h ** | 60 | 60 | Gravimetric TOEM Betal attenuation |
| 4      | Particulate Matter(size less than 2.5µm) or PM2.5 µg/m$^3$ | Annual * 24 h ** | 40 | 40 | Gravimetric TOEM Beta attenuation |
| 5      | Ozone(O$_3$) µg/m$^3$ | 8 h ** 1 h ** | 100 | 100 | UV Photometric Chemical Method |
| 6      | Lead(Pb) µg/m$^3$ | Annual * 24 h ** | 0.50 | 0.50 | AAS/ICP method after sampling on EPM 2000 or equivalent filter paper ED-XRF using Teflon filter |
| 7      | Carbon Monoxide(CO) mg/m$^3$ | 8 h ** 1 h ** | 0.2 | 0.2 | Non-Dispersive Infrared (NDIR) spectroscopy |
| 8      | Ammonia(NH$_3$) µg/m$^3$ | Annual * 24 h ** | 100 | 100 | Chemiluminescence Indophenol blue method |

* Annual arithmetic mean of minimum 104 measurements in a year, ** 24 hourly monitored values shall be complied with 98% of the time.

The emission estimation rate for petrol vehicles is evaluated using the prescribed values and the measured values of various pollutants and other different factors. The values of Carbon Monoxide (CO), Hydrocarbon (HC) and Carbon Dioxide (CO$_2$) ppm. These measured values are then compared with the prescribed values based on various factors such as Bharat Stage norms, Manufacturer of the vehicle, Model of the vehicle, Year of Registration of the vehicle.

Similar to the emission evaluation of petrol vehicles is the emission estimation of petrol/CNG fuel type vehicles. It consists of the estimation of emission of pollutants from petrol/CNG vehicles by collecting the appropriate values of pollutants emitted with reference to the prescribed values as per the Bharat Stage norms. Here, we consider the prescribed standards of the petrol fuel type vehicles in Bharat Stage Norm 3 and Norm 4. Moreover for the CNG/petrol fuel type vehicles, the Carbon Monoxide (CO) and Hydrocarbon (HC) are considered only (in ppm) and not Carbon Dioxide and Lambda. The values of CO and HC are measured from vehicles which are then compared with the prescribed values of the petrol type vehicles based on various factors such as Bharat Stage norms, Manufacturer of the vehicle, Model of the vehicle, Year of Registration of the vehicle.
The estimation of the emission of various pollutants in diesel type vehicles is done by comparing the prescribed and measured values of HSU. HSU is the unit of estimation to evaluate the capacity of exhaust gases of emissions in diesel engines. HSU stands for Hartridge Smoke Unit. The prescribed standard of HSU (Hartridge Smoke Unit) for diesel vehicles in Bharat Stage 3 norm and Bharat Stage 4 norm is 65 and 50, respectively. The HSU values of different diesel vehicles are collected. The comparison is then made between diesel vehicles with respect to different comparable factors, such as Bharat stage norms, a manufacturer of the vehicle, vehicle model number, year of registration of the vehicle, prescribed values of HSU and measured values of HSU.

2.4. Data Collection

The following data were collected from pollution certificate centers of Delhi NCR. A total data of 181 vehicles were used and analyzed collectively, to reach the following outcomes. Table 2 showcases the characteristics of the different vehicles which were analyzed by displaying varying vehicle maker/companies having different models and registration dates. It also shows the varying or similar engine capacities between two fuel types (diesel and petrol) from different vehicle models. Engine capacity of a vehicle simply depicts the area in which any engine’s pistons work/operate; hence, a larger amount of fuel and air is being processed when a vehicle is moving with a larger engine capacity. The average engine capacity calculated from the given table is 1778 cm$^3$ (approximately) for diesel engines and 1295 cm$^3$ (approximately) for petrol engines; hence, we can observe that vehicles having a diesel engine have a larger engine capacity, on average, than vehicles having a petrol engine, meaning that it is processing more fuel than its counterpart. A major difference between diesel and petrol engines is that the diesel engine uses more air and less fuel than the petrol engine to operate at the same level, hence emitting less CO$_2$ despite having a larger concentration of Carbon in it than petrol. The analysis stated that the diesel engine would emit less CO$_2$/km than a petrol engine if having an almost-similar engine capacity.

### Table 2. Characteristics of selected cars [24–54].

| Maker/Company          | Model    | Registration Date | Fuel Type | Engine Capacity (cm$^3$) * |
|------------------------|----------|-------------------|-----------|---------------------------|
| Toyota                 | Innova   | 2009              | Diesel    | 2494                      |
| Toyota                 | Fortuner | 2010              | Diesel    | 2982                      |
| Toyota                 | Altis    | 2014              | Diesel    | 1364                      |
| Maruti Suzuki          | Dzire    | 2009              | Diesel    | 1248                      |
| Maruti Suzuki          | Sx4      | 2011              | Diesel    | 1248                      |
| Maruti Suzuki          | Swift    | 2012              | Diesel    | 1248                      |
| Maruti Suzuki          | Ciaz     | 2015              | Diesel    | 1248                      |
| Maruti Suzuki          | Ritz     | 2016              | Diesel    | 1248                      |
| Honda                  | Amaze    | 2014              | Diesel    | 1498                      |
| Honda                  | Mobilio  | 2015              | Diesel    | 1498                      |
| Honda                  | City     | 2018              | Diesel    | 1498                      |
| Mahindra               | Scorpio  | 2010              | Diesel    | 2179                      |
| Mahindra               | XUV      | 2014              | Diesel    | 2179                      |
| Mahindra               | Thar     | 2017              | Diesel    | 2523                      |
| BMW                    | X1       | 2011              | Diesel    | 1995                      |
| BMW                    | 520D     | 2013              | Diesel    | 1995                      |
| Maruti Suzuki          | Zen      | 2004              | Petrol    | 993                       |
| Maruti Suzuki          | Wagonr   | 2005              | Petrol    | 1061                      |
| Maruti Suzuki          | Alto     | 2006              | Petrol    | 796                       |
| Maruti Suzuki          | Esteem   | 2007              | Petrol    | 1298                      |
| Maruti Suzuki          | Ritz     | 2009              | Petrol    | 1197                      |
| Maruti Suzuki          | Swift    | 2010              | Petrol    | 1298                      |
| Maruti Suzuki          | EECO     | 2011              | Petrol    | 1196                      |
| Maruti Suzuki          | Ertiga   | 2013              | Petrol    | 1373                      |
| Maruti Suzuki          | Dzire    | 2014              | Petrol    | 1197                      |
Table 2. Cont.

| Maker/Company | Model | Registration Date | Fuel Type | Engine Capacity (cm³) * |
|---------------|-------|-------------------|-----------|------------------------|
| Maruti Suzuki | Ciaz   | 2015              | Petrol    | 1373                   |
| Maruti Suzuki | Celerio| 2017              | Petrol    | 998                    |
| Maruti Suzuki | Ignis  | 2018              | Petrol    | 1197                   |
| Hyundai       | Santro| 2006              | Petrol    | 1086                   |
| Hyundai       | I10    | 2009              | Petrol    | 1086                   |
| Hyundai       | EON    | 2013              | Petrol    | 814                    |
| Hyundai       | Xcent  | 2015              | Petrol    | 1186                   |
| Hyundai       | Creta  | 2017              | Petrol    | 1591                   |
| Hyundai       | Grand i10 | 2018        | Petrol    | 1197                   |
| Honda         | Accord | 2006              | Petrol    | 2354                   |
| Honda         | Civic  | 2007              | Petrol    | 1799                   |
| Honda         | City   | 2009              | Petrol    | 1497                   |
| Honda         | Amaze  | 2013              | Petrol    | 1198                   |
| Toyota        | Innova | 2010              | Petrol    | 1998                   |
| Toyota        | I10    | 2018              | Petrol    | 1197                   |
| Tata          | Indica | 2007              | Petrol    | 1193                   |
| Tata          | Tiago  | 2016              | Petrol    | 1199                   |

* Inventory shows the characteristics for petrol and diesel cars registered in 2004–2019. Engine capacity also affects the environment, as high-capacity engines emit high amounts of pollutants in the air.

Tables 3–5 display the value/level of pollutants emitted by each vehicle, with its prescribed value. It also shows the Bharat stage norms each car is following, and their registration dates are in the chronological order.

Table 3. Measured Hartridge Smoke Unit (HSU) values for diesel vehicles [24–54].

| S No. | Bharat Stage | Maker/Model | Registration Date | Prescribed HSU | Measured HSU |
|-------|--------------|-------------|-------------------|----------------|--------------|
| 1     | 3            | Toyota/Innova | June 2009        | 65             | 42.21.27     |
| 2     | 3            | Toyota/Innova | July 2009        | 65             | 45.41.41     |
| 3     | 3            | Maruti Suzuki/Dzire | Sept 2009 | 65             | 44.31.36     |
| 4     | 3            | Mahindra/Scorpio | Jan 2010        | 65             | 31.70.89     |
| 5     | 3            | Toyota/Innova | Jan 2010        | 65             | 39.81.18     |
| 6     | 3            | Toyota/Scorpio | May 2010        | 65             | 31.70.89     |
| 7     | 4            | Toyota/Innova | Oct 2011        | 50             | 42.51.29     |
| 8     | 4            | BMW X1        | July 2011       | 50             | 39.91.07     |
| 9     | 4            | Maruti Suzuki/Swift | Sept 2011 | 50             | 42.51.28     |
| 10    | 4            | Hyundai/Verna | Feb 2012        | 50             | 42.71.29     |
| 11    | 4            | Maruti Suzuki/Sx4 | Aug 2012   | 50             | 38.61.13     |
| 12    | 4            | Maruti Suzuki/Dzire | July 2013 | 50             | 39.21.15     |
| 13    | 4            | BMW 520D      | Aug 2013       | 50             | 38.31.12     |
| 14    | 4            | Volkswagen/Vento | Oct 2013    | 50             | 40.01.19     |
| 15    | 4            | Ford/EcoSport | Nov 2013       | 50             | 44.61.37     |
| 16    | 4            | Volvo/XC60    | Jan 2014       | 50             | 41.41.24     |
| 17    | 4            | Maruti Suzuki/Sx4 | Feb 2014   | 50             | 44.01.35     |
| 18    | 4            | Mahindra/XUV  | April 2014     | 50             | 38.81.14     |
| 19    | 4            | Toyota/Scorpio | July 2014     | 50             | 43.01.30     |
| 20    | 4            | Maruti Suzuki/Swift | Aug 2014 | 50             | 41.51.24     |
| 21    | 4            | Toyota/Scorpio | Sept 2014     | 50             | 43.81.34     |
| 22    | 3            | TATA/Indigo   | Oct 2014       | 65             | 46.01.43     |
| 23    | 1            | Audi/A6       | Oct 2014       | 65             | 42.11.27     |
| 24    | 4            | Honda/Amaze   | Nov 2014       | 50             | 31.50.88     |
| 25    | 4            | Toyota/Scorpio | March 2015    | 50             | 42.31.28     |
| 26    | 4            | BMW           | March 2015     | 50             | 39.91.18     |
| 27    | 4            | Honda/Mobilio | April 2015     | 50             | 37.71.10     |
| 28    | 4            | Renault/Duster | June 2015     | 50             | 39.21.15     |
| 29    | 4            | Maruti Suzuki/Swift | July 2015 | 50             | 39.81.18     |
| 30    | 4            | Mahindra/Scorpio | July 2015  | 50             | 44.61.37     |
Table 3. Cont.

| S No. | Bharat Stage | Maker/Model         | Registration Date | Prescribed HSU | Measured HSU |
|-------|--------------|---------------------|------------------|---------------|--------------|
| 31    | 4            | Hyundai/Creta       | Aug 2015         | 50            | 41.21        |
| 32    | 4            | Mercedes M250       | Aug 2015         | 50            | 31.50        |
| 33    | 4            | Maruti Suzuki/Ciaz  | Sept 2015        | 50            | 30.90        |
| 34    | 4            | Mahindra/XUV        | Sept 2015        | 50            | 39.41        |
| 35    | 4            | Toyota/fortuner     | Nov 2015         | 50            | 42.41        |
| 36    | 4            | Maruti Suzuki/Dzire | Dec 2015         | 50            | 43.41        |
| 37    | 4            | Hyundai/Creta       | June 2016        | 50            | 43.51        |
| 38    | 4            | Honda/Mobilio       | July 2016        | 50            | 37.91        |
| 39    | 4            | Maruti Suzuki/Ritz  | July 2016        | 50            | 43.91        |
| 40    | 4            | FCA/Aventura        | Aug 2016         | 50            | 38.21        |
| 41    | 4            | Maruti Suzuki/Ciaz  | Nov 2016         | 50            | 41.31        |
| 42    | 3            | Toyota/Innova       | Dec 2016         | 65            | 38.91        |
| 43    | 4            | Toyota/Innova       | Jan 2017         | 50            | 42.61        |
| 44    | 4            | Maruti Suzuki/Dzire | Feb 2017         | 50            | 44.21        |
| 45    | 4            | Honda/City          | March 2017       | 50            | 39.11        |
| 46    | 4            | Mahindra/THAR       | May 2017         | 50            | 44.71        |
| 47    | 4            | Maruti Suzuki/Ciaz  | June 2017        | 50            | 39.01        |
| 48    | 4            | Toyota/Innova       | Dec 2017         | 50            | 40.01        |
| 49    | 4            | Honda/Amaze         | Dec 2017         | 50            | 39.31        |
| 50    | 4            | Ford/Endeavour      | Jan 2018         | 50            | 39.01        |
| 51    | 4            | Maruti Suzuki/Ciaz  | Sept 2018        | 50            | 43.11        |
| 52    | 4            | Honda/City          | Nov 2018         | 50            | 42.11        |

Table 4. Measurement of CO, CO₂ and λ for petrol vehicles [24–54].

| S No. | Bharat Stage | Maker/Model | Registration Date | CO (ppm) | HC (ppm) | CO₂ (ppm) | λ        |
|-------|--------------|-------------|------------------|----------|----------|-----------|----------|
| 1     | 3            | Maruti/M800 | March 2004       | 0.036    | 46       |           |          |
| 2     | 3            | Maruti/zen  | July 2004        | 0.050    | 8        |           |          |
| 3     | 3            | Maruti Versa| Sept 2004       | 0.036    | 11       |           |          |
| 4     | 3            | Maruti Zen  | Dec 2004        | 0.020    | 17       |           |          |
| 5     | 3            | Maruti Wagonr| Feb 2005       | 0.130    | 21       |           |          |
| 6     | 3            | Hyundai/Santro| Jan 2006  | 0.040    | 21       |           |          |
| 7     | 3            | Maruti/Maruti| Nov 2006   | 0.009    | 23       |           |          |
| 8     | 3            | Honda/Accord| Dec 2006       | 0.003    | 7        |           |          |
| 9     | 3            | Maruti Alto  | Dec 2006        | 0.036    | 20       |           |          |
| 10    | 3            | Maruti Wagonr| Dec 2006       | 0.020    | 129      |           |          |
| 11    | 3            | Hyundai/Santro| Jan 2007  | 0.090    | 39       |           |          |
| 12    | 3            | Honda/City   | Feb 2007        | 0.010    | 22       |           |          |
| 13    | 3            | Maruti/Maruti| April 2007   | 0.027    | 44       |           |          |
| 14    | 3            | TATA/Indica  | April 2007      | 0.010    | 20       |           |          |
| 15    | 3            | Honda/Civic  | June 2007       | 0.020    | 29       |           |          |
| 16    | 3            | Honda/City   | Sept 2007       | 0.001    | 75       |           |          |
| 17    | 3            | Maruti esteem| Sept 2007    | 0.100    | 107      |           |          |
| 18    | 3            | Maruti Alto  | April 2008      | 0.040    | 6        |           |          |
| 19    | 3            | Hyundai/Santro| May 2008  | 0.040    | 39       |           |          |
| 20    | 3            | Maruti/zen  | July 2008       | 0.003    | 19       |           |          |
| 21    | 3            | Hyundai/Santro| July 2008 | 0.110    | 60       |           |          |
| 22    | 3            | Honda/Accord| Aug 2008       | 0.017    | 23       |           |          |
| 23    | 3            | Honda/City   | Dec 2008        | 0.020    | 162      |           |          |
| 24    | 3            | Maruti Wagonr| Feb 2009      | 0.036    | 16       |           |          |
| 25    | 3            | Hyundai/10   | April 2009      | 0.140    | 24       |           |          |
| 26    | 3            | Maruti Swift | June 2009      | 0.160    | 34       |           |          |
| 27    | 3            | Maruti Alto  | Aug 2009        | 0.070    | 185      |           |          |
| 28    | 3            | Hyundai/10   | Sept 2009       | 0.100    | 17       |           |          |
| 29    | 3            | Ford/ICON    | Sept 2009       | 0.020    | 25       |           |          |
| 30    | 3            | Hyundai/10   | Sept 2009       | 0.110    | 31       |           |          |
| 31    | 3            | Honda/City   | Aug 2009        | 0.043    | 29       |           |          |
| 32    | 3            | Maruti Ritz  | Nov 2009        | 0.020    | 0        |           |          |
| 33    | 3            | Hyundai/10   | Nov 2009        | 0.003    | 88       |           |          |
| 34    | 3            | Maruti Swift | March 2010      | 0.020    | 0        |           |          |
| 35    | 4            | Hyundai/10   | March 2010      | 0.035    | 10       | 17.20     | 0.999    |
| 36    | 4            | Maruti Wagonr| May 2010       | 0.380    | 197      |           |          |
| 37    | 4            | Toyota/Innova| May 2010   | 0.004    | 3        | 15.4      | 1.005    |
| 38    | 4            | Maruti Dzire | Oct 2010       | 0.041    | 27       | 17.20     | 1.003    |
| 39    | 4            | Maruti EECA   | Feb 2011       | 0.033    | 27       | 16.70     | 1.009    |
| 40    | 4            | Maruti/Alstar | May 2011  | 0.020    | 24       | 17.30     | 1.003    |

* Pre-Bharat Stage 4 norms
### Table 4. Cont.

| S No. | Bharat Stage | Maker/Model     | Registration Date | CO (ppm) | HC (ppm) | CO₂ (ppm) | A    |
|-------|--------------|-----------------|-------------------|----------|----------|-----------|------|
| 41    | 4            | Mitsubishi/Outlander | Aug 2011       | 0.003    | 2        | 17.10     | 1.004|
| 42    | 4            | Maruti Suzuki/Dzire | Oct 2011        | 0.026    | 7        | 16.80     | 1.009|
| 43    | 4            | Volkswagen/Polo   | Feb 2012        | 0.019    | 73       | 16.70     | 1.000|
| 44    | 4            | Maruti Suzuki/Wagonr | Sept 2013    | 0.034    | 26       | 16.80     | 1.000|
| 45    | 4            | Maruti Suzuki/Ertinga | Oct 2013     | 0.020    | 18       | 16.60     | 1.003|
| 46    | 4            | Honda/Amaze       | Nov 2013       | 0.032    | 22       | 15.70     | 1.001|
| 47    | 4            | Hyundai/EON       | Dec 2013       | 0.032    | 14       | 15.70     | 1.003|
| 48    | 4            | Hyundai/Verna     | April 2014     | 0.010    | 28       | 17        | 1.007|
| 49    | 4            | Maruti Suzuki/Dzire | July 2014     | 0.003    | 5        | 15.30     | 1.009|
| 50    | 4            | Maruti Suzuki/Ciaz | Nov 2014       | 0.030    | 16       | 16.70     | 0.998|
| 51    | 4            | Toyota/Etios      | Dec 2014       | 0.025    | 17       | 17.10     | 1.003|
| 52    | 4            | Honda/Eco         | March 2015     | 0.003    | 66       | 16.60     | 1.011|
| 53    | 4            | Honda/Amaze       | April 2015     | 0.034    | 8        | 17.10     | 1.004|
| 54    | 4            | Maruti Suzuki/Ciaz | June 2015      | 0.36     | 36       | 17        | 1.001|
| 55    | 4            | Honda/City        | June 2015      | 0.042    | 13       | 16.60     | 1.002|
| 56    | 3            | Hyundai/Xcent     | Oct 2015       | 0.018    | 149      |           |      |
| 57    | 4            | Maruti Suzuki/Dzire | Jan 2016     | 0.035    | 13       | 15.50     | 1.003|
| 58    | 3            | Honda/Amaze       | March 2016     | 0.043    | 22       |           |      |
| 59    | 4            | Maruti Suzuki/Swift | July 2016     | 0.027    | 18       | 16.90     | 1.003|
| 60    | 4            | Renault/Kwid      | Aug 2016       | 0.012    | 8        | 15.40     | 1.003|
| 61    | 4            | Tata/Tiago        | Oct 2016       | 0.027    | 12       | 16.80     | 1.004|
| 62    | 4            | Honda/City        | Oct 2016       | 0.003    | 20       | 16.90     | 1.002|
| 63    | 4            | Honda/City        | Feb 2017       | 0.11     | 7        | 16.90     | 1.004|
| 64    | 4            | Hyundai/Grand i10 | Feb 2017       | 0.028    | 19       | 17        | 1.003|
| 65    | 4            | Maruti Suzuki/Swift | June 2017    | 0.003    | 8        | 17.30     | 1.003|
| 66    | 4            | Maruti Suzuki/Dzire | July 2017     | 0.043    | 38       | 17.30     | 1.002|
| 67    | 4            | Hyundai/Creta     | Aug 2017       | 0.043    | 9        | 16.80     | 1.004|
| 68    | 4            | Maruti Suzuki/Celerio | Oct 2017   | 0.033    | 22       | 17        | 1.003|
| 69    | 4            | Maruti Suzuki/EECO | Sept 2017     | 0.017    | 24       | 16.50     | 1.029|
| 70    | 4            | Maruti Suzuki/Dzire | Nov 2017      | 0.042    | 42       | 16.90     | 1.002|
| 71    | 4            | Renault/Kwid      | Jan 2018       | 0.003    | 5        | 16        | 1.003|
| 72    | 4            | Maruti Suzuki/Dzire | Jan 2018     | 0.003    | 4        | 17.10     | 1.003|
| 73    | 4            | Maruti Suzuki/Ertinga | Feb 2018     | 0.036    | 21       | 16.4      | 1.003|
| 74    | 3            | Hyundai/Grand i10 | April 2018     | 0.080    | 26       |           |      |
| 75    | 4            | Maruti Suzuki/Dzire | April 2018    | 0.026    | 18       | 16.6      | 1.003|
| 76    | 4            | Maruti Suzuki/Ignis | May 2018      | 0.042    | 13       | 15.7      | 1.002|
| 77    | 4            | Maruti Suzuki/Ignis | Aug 2018      | 0.024    | 35       | 17        | 1.003|
| 78    | 4            | Tata/Tiago        | Jan 2019       | 0.004    | 46       | 17        | 1.001|
| 79    | 4            | Maruti Suzuki/ECCO | Jan 2019      | 0.002    | 10       | 12.9      | 1.004|

* Pre-Bharat Stage 4 norms cars do not have the CO₂ and λ values.

### Table 5. Petrol/compressed natural gas (CNG) vehicles [24–54].

| S No. | Bharat Stage | Maker/Model     | Registration Date | CO (ppm) | HC (ppm) |
|-------|--------------|-----------------|-------------------|----------|----------|
| 1     | 3            | Honda/City      | Dec 2004          | 0.026    | 10       |
| 2     | 3            | Honda/City      | Jan 2005          | 0.170    | 9        |
| 3     | 3            | Maruti Suzuki/Wagonr | March 2005 | 0.050    | 34       |
| 4     | 3            | Maruti Suzuki/Esteeem | March 2005 | 0.020    | 7        |
| 5     | 3            | Maruti Suzuki/Esteeem | Oct 2005    | 0.034    | 7        |
| 6     | 3            | Ford/Ikon       | Feb 2007          | 0.310    | 35       |
| 7     | 3            | Maruti Suzuki/Esteeem | Oct 2007    | 0.020    | 12       |
| 8     | 3            | Maruti Suzuki/Esteeem | Dec 2007    | 0.020    | 16       |
| 9     | 3            | Maruti Suzuki/Swift | March 2008      | 0.100    | 9        |
| 10    | 3            | Maruti Suzuki/Alto | April 2008       | 0.020    | 0        |
| 11    | 3            | Maruti Suzuki/Wagonr | May 2008      | 0.040    | 9        |
| 12    | 3            | Maruti Suzuki/Wagonr | May 2008      | 0.020    | 3        |
| 13    | 3            | Maruti Suzuki/Wagonr | Aug 2008      | 0.010    | 14       |
| 14    | 3            | Maruti Suzuki/Omni | Aug 2008        | 0.001    | 5        |
| 15    | 3            | Hyundai/Santro  | Oct 2008         | 0.016    | 4        |
| 16    | 3            | Toyota/Altis    | December 2008    | 0.040    | 27       |
| 17    | 3            | Chevrolet/Aveo  | Feb 2009         | 0.010    | 6        |
| 18    | 3            | Hyundai/Accent  | April 2009       | 0.040    | 7        |
| 19    | 3            | Maruti Suzuki   | May 2009         | 0.004    | 8        |
| 20    | 3            | Maruti Suzuki/Alto | May 2009      | 0.100    | 44       |
Table 5. Cont.

| S No. | Bharat Stage | Maker/Model            | Registration Date | CO (ppm) | HC (ppm) |
|-------|--------------|-------------------------|------------------|----------|----------|
| 21    | 3            | Hyundai/i10            | Nov 2009         | 0.050    | 0        |
| 22    | 3            | Maruti Suzuki/Wagonr   | Sept 2009        | 0.041    | 9        |
| 23    | 3            | Maruti Suzuki/Sx4      | March 2010       | 0.040    | 7        |
| 24    | 3            | Maruti Suzuki/Sx4      | March 2010       | 0.040    | 16       |
| 25    | 3            | Maruti Suzuki/Dzire    | May 2010         | 0.001    | 31       |
| 26    | 4            | Maruti Suzuki/Swift    | Sept 2010        | 0.003    | 132      |
| 27    | 4            | Maruti Suzuki          | April 2011       | 0.027    | 77       |
| 28    | 4            | Maruti Suzuki/Eeco     | June 2011        | 0.019    | 18       |
| 29    | 4            | Hyundai/i20            | July 2011        | 0.010    | 93       |
| 30    | 4            | Maruti Suzuki/Santro   | Oct 2011         | 0.030    | 19       |
| 31    | 4            | Maruti Suzuki/Wagonr   | Nov 2011         | 0.040    | 18       |
| 32    | 4            | Maruti Suzuki/Alto     | Aug 2012         | 0.004    | 58       |
| 33    | 4            | Maruti Suzuki/Alto     | Dec 2012         | 0.027    | 42       |
| 34    | 4            | Hyundai/i10            | June 2013        | 0.018    | 12       |
| 35    | 4            | Maruti Suzuki/Sx4      | Oct 2013         | 0.041    | 88       |
| 36    | 4            | Maruti Suzuki/Wagonr   | Oct 2013         | 0.003    | 85       |
| 37    | 4            | Maruti Suzuki/Dzire    | Nov 2015         | 0.020    | 161      |
| 38    | 4            | Maruti Suzuki/Dzire    | Dec 2015         | 0.010    | 7        |
| 39    | 4            | Maruti Suzuki/Eeco     | Jan 2016         | 0.030    | 29       |
| 40    | 4            | Honda/Amaaze           | Jan 2016         | 0.028    | 69       |
| 41    | 4            | Maruti Suzuki/Wagonr   | Apr 2016         | 0.043    | 62       |
| 42    | 4            | Maruti Suzuki/Alto     | Feb 2017         | 0.027    | 128      |
| 43    | 4            | Maruti Suzuki/Eeco     | Mar 2017         | 0.020    | 22       |
| 44    | 4            | Maruti Suzuki/Celerio  | Apr 2017         | 0.027    | 58       |
| 45    | 4            | Maruti Suzuki/Tour     | Sept 2017        | 0.050    | 22       |
| 46    | 4            | Maruti Suzuki/Dzire    | Oct 2017         | 0.020    | 41       |
| 47    | -             | Bajaj Auto/Compact     | Oct 2018         | 0.026    | 21       |
| 48    | 4            | Maruti Suzuki/Tour     | Nov 2018         | 0.025    | 24       |
| 49    | 4            | TATA/Truck LPT         | Jan 2019         | 0.050    | 27       |
| 50    | -             | Bajaj Auto/Compact     | Jan 2019         | 0.001    | 187      |

Table 3 displays the value/level for vehicles using diesel as a fuel type. Emission from diesel vehicles is measured on the basis of HSU (Hartridge Smoke Unit), which is a unit of measurement used to measure the capacity of exhaust gases during emission. The HSU limit for pre-Bharat Stage 4 norms was 65, and for Bharat Stage 4 norms, it has been reduced to 50. Some of the major maker/companies being showcased through the table are Toyota, Maruti Suzuki, Hyundai, Honda, Mahindra, Tata and some luxury makers. As can be seen from the information mentioned above, we used vehicles from both indigenous and foreign makers/companies, thus adding another dimension to the analysis. The given data of HSU range from the value of 30.90.86 to 46.01.43, leading to the conclusion that most of the diesel vehicles are well below the current prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we can also conclude that some of the old cars are well maintained and not emitting a large number of pollutants; it may be because the regular maintenance and service by car owner. Many old-car owners followed the pollution-under-control norms introduced by the Government of India. They always adopt new steps for reducing the pollution emission, while driving their cars. The following are the steps that can be helpful for someone for reducing the maintenance cost of vehicles, as well as the emission of pollution, too. Everyone needs to keep vehicles well-tuned and inflate the tires regularly, use biofuels such as CNG for regular derive, kept regular maintenance and test vehicles every 3 months by nearby installed pollution-under-control-norms center.

Details about the petrol type fuel are presented in Table 4, in which emissions are measured from three different pollutants which are CO (Carbon Monoxide), HC (Hydrocarbons) and CO\(_2\) (Carbon Dioxide). Another parameter that is being measured for petrol driven vehicles is Lambda (\(\lambda\)), indicating the optimum conditioning needed for the proper functioning of catalytic converters. The vehicles registered during the pre-Bharat Stage 4 norms are only tested for CO and HC, having a prescribed limit of 0.5 and 750 ppm. For Bharat Stage 4 norms which were adopted in 2010 the
prescribed limit for CO and HC are 0.3 and 200 ppm; Lambda should be in the range of 0.97 to 1.03.
The given data of CO ranges from 0.001 to 0.380 ppm, and for HC, the data range from 0 to 197 ppm.
The given data for both the pollutants have a large range, which shows that there are many parameters
which give any vehicle its emission results, e.g., the distance traveled and the terrain on which the
vehicle has been driven, the maintenance of the vehicle and the maker/company of the vehicle.

Table 5 showcases the details about vehicles that operate/run on petrol/CNG. For such vehicles,
only CO and HC are measured with the same prescribed limit as according to pre-BS4 and BS4 norms;
Lambda (λ), as a parameter, is not measured for such vehicles. In the data collected for petrol/CNG,
the value of CO ranges from 0.001 to 0.310 ppm, and the value of HC ranges from 0 to 187 ppm. We can
also notice that the data for petrol and petrol/CNG driven vehicles almost have the same range.

Tables 6–8 displays the average emissions over different years of HSU for diesel-driven vehicles
and CO, HC and CO₂ for petrol and for petrol/CNG-driven vehicles. Calculating the average emission
over different years helps in realizing how a change in technology over the year can affect vehicular
emissions. The average emissions in chronological order for vehicles operating from a diesel engine
are given by Table 6. The average HSU emission is calculated from the year of 2009 to 2018. The lowest
HSU emission average (38.53.36) is calculated from the year 2015, and the highest average (43.31.35) is
calculated from the year 2009. Table 7 displays the average emissions of three pollutants (CO, HC and
CO₂) for vehicles operating on a petrol engine. The average values of pollutants are calculated from
the year of 2010 to 2019.

Table 6. Average emissions over different years of HSU for diesel-driven vehicles [24–54].

| Year | HSU | HSU | HSU | HSU |
|------|-----|-----|-----|-----|
| 2009 | 42.21.27 | 31.70.89 | 42.51.29 | 38.61.13 |
|      | 45.41.41 | 39.81.18 | 39.81.18 | 39.81.18 |
|      | 44.31.36 | 42.51.28 | 42.51.28 | 42.51.28 |
| Average * | 43.31.35 | Average * | 36.77.41 | Average * | 41.64.21 | Average * | 40.66.21 |

| Year | HSU | HSU | HSU | HSU |
|------|-----|-----|-----|-----|
| 2013 | 39.21.15 | 41.21.39 | 43.51.33 |
|      | 38.31.12 | 39.81.18 | 39.91.10 |
|      | 40.01.19 | 43.91.34 | 43.91.34 |
|      | 44.61.37 | 46.01.43 | 43.91.34 |
|      |       | 42.11.27 | 41.31.24 |
|      |       | 31.50.88 | 38.91.14 |
| Average * | 40.29.21 | Average * | 41.35.35 | Average * | 38.53.36 | Average * | 40.63.21 |

| Year | HSU | HSU | HSU | HSU |
|------|-----|-----|-----|-----|
| 2017 | 42.61.29 | 43.11.31 | 41.28.24 | 41.08.24 |
|      | 44.21.36 | 42.11.27 | 41.28.24 | 41.08.24 |
|      | 39.11.15 | 39.01.15 | 41.08.24 | 41.08.24 |
|      | 44.71.37 | 43.11.31 | 41.08.24 | 41.08.24 |
|      | 39.01.15 | 42.11.27 | 41.08.24 | 41.08.24 |
|      | 39.31.19 | 39.31.19 | 41.08.24 | 41.08.24 |

* The average values are calculated by using data collected for diesel cars. * The results demonstrate that the new
advancement in automobile industries is not very concerned about maintaining the HSU level for vehicles.
Table 7. Average emissions over different years of CO, HC and CO$_2$ for petrol-driven vehicles [24–54].

| Year | CO (ppm) | HC (ppm) | CO$_2$ (ppm) | CO (ppm) | HC (ppm) | CO$_2$ (ppm) | CO (ppm) | HC (ppm) | CO$_2$ (ppm) |
|------|----------|----------|--------------|----------|----------|--------------|----------|----------|--------------|
| 2010 | 0.035    | 10       | 17.20        | 0.033    | 27       | 16.70        | 0.034    | 26       | 16.80        |
|      | 0.004    | 3        | 15.4         | 0.020    | 24       | 17.30        | 0.020    | 18       | 16.60        |
|      | 0.041    | 27       | 17.20        | 0.003    | 2        | 17.10        | 0.032    | 22       | 15.70        |
|      |          |          |              | 0.026    | 7        | 16.80        | 0.032    | 14       | 15.70        |
|      | Average * | 0.026    | 13.33        | Average * | 0.0205   | 15          | 16.975   | Average * | 0.0295       | 20          | 16.20        |
| 2014 | 0.010    | 28       | 17           | 0.003    | 66       | 16.60        | 0.035    | 13       | 15.50        |
|      | 0.003    | 5        | 15.30        | 0.034    | 8        | 17.10        | 0.027    | 18       | 16.90        |
|      | 0.030    | 16       | 16.70        | 0.36     | 36       | 17           | 0.012    | 8        | 15.80        |
|      | 0.025    | 17       | 17.10        | 0.042    | 18       | 16.60        | 0.027    | 12       | 16.80        |
|      |          |          |              |          |          |              | 0.003    | 20       | 16.90        |
|      | Average * | 0.017    | 16.5         | Average * | 0.10975  | 32          | 16.825   | Average * | 0.0694       | 14.20       | 16.3         |
| 2017 | 0.11     | 7        | 16.9         | 0.003    | 5        | 16           |         |          |              |
|      | 0.028    | 19       | 17           | 0.003    | 4        | 17.10        |         |          |              |
|      | 0.003    | 8        | 17.30        | 0.036    | 21       | 16.40        |         |          |              |
|      | 0.043    | 38       | 17.30        | 0.026    | 18       | 15.70        | 2019    | 0.004    | 46          | 17           |
|      | 0.043    | 9        | 16.80        | 0.042    | 13       | 17           |         |          |              |
|      | 0.033    | 22       | 17           | 0.024    | 35       |              |         |          |              |
|      | 0.017    | 24       | 16.50        |          |          |              |         |          |              |
|      | 0.042    | 42       | 16.90        |          |          |              |         |          |              |
|      | Average * | 0.0398   | 21.125       | Average * | 0.022    | 16          | 16.46    | Average * | 0.003        | 28          | 14.95       |

* The average values are calculated by using data collected for petrol cars. * The table demonstrates the emission of CO, HC and CO$_2$. * The average values for HC are rapidly growing every year. This is a matter of concern. New advancement in automobile industries do not take this into consideration to maintain these values.
Table 8. Average emissions over different years of CO and HC for petrol/CNG-driven vehicles [24–54]

| Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) |
|------|----------|----------|------|----------|----------|------|----------|----------|
| 2005 | 0.026    | 10       | 2007 | 0.31     | 35       | 2008 | 0.1      | 9        |
|      | 0.17     | 9        |      | 0.02     | 12       |      | 0.02     | 0        |
|      | 0.05     | 34       |      | 0.02     | 16       |      | 0.04     | 9        |
|      | 0.02     | 7        |      | 0.02     | 7        |      | 0.02     | 3        |
|      | 0.034    | 7        |      | 0.05     | 34       |      | 0.01     | 14       |
|      |          |          |      | 0.04     | 4        |      | 0.016    | 4        |
|      |          |          |      |          |          |      | 0.04     | 27       |

Average * | 0.06 | 13.4 | Average * | 0.116 | 21 | Average * | 0.0308 | 8.875 |

| Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) |
|------|----------|----------|------|----------|----------|------|----------|----------|
| 2009 | 0.01     | 6        | 2010 | 0.04     | 7        | 2011 | 0.027    | 77       |
|      | 0.04     | 7        |      | 0.04     | 16       |      | 0.019    | 18       |
|      | 0.004    | 8        |      | 0.001    | 31       |      | 0.03     | 19       |
|      | 0.1      | 44       |      | 0.003    | 132      |      | 0.04     | 18       |
|      | 0.05     | 9        |      |          |          |      |          |          |
|      | 0.041    |          |      |          |          |      |          |          |

Average * | 0.0408 | 12.33 | Average * | 0.021 | 46.5 | Average * | 0.0252 | 45        |

| Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) |
|------|----------|----------|------|----------|----------|------|----------|----------|
| 2012 | 0.004    | 58       | 2013 | 0.018    | 12       | 2015 | 0.02     | 161      |
|      | 0.027    | 42       |      | 0.041    | 88       |      | 0.01     | 7        |
|      |          |          |      | 0.003    | 85       |      |          |          |
|      |          |          |      |          |          |      |          |          |
|      |          |          |      |          |          |      |          |          |

Average * | 0.0155 | 50 | Average * | 0.0206 | 61.66 | Average * | 0.015 | 84 |

| Year | CO (ppm) | HC (ppm) | Year | CO (ppm) | HC (ppm) |
|------|----------|----------|------|----------|----------|
| 2016 | 0.03     | 29       | 2017 | 0.027    | 58       |
|      | 0.028    | 69       |      | 0.05     | 22       |
|      | 0.043    | 62       |      | 0.02     | 41       |
|      |          |          |      |          |          |
|      |          |          |      |          |          |
|      |          |          |      |          |          |

Average * | 0.0336 | 53.33 | Average * | 0.0323 | 40.33 |

* The average values are calculated by using data collected for diesel cars. * The average values are calculated by using data collected for petrol/CNG cars. * The cars registered in 2017 are emitting higher pollutants compare to the cars registered in 2005. * This is due to the easy availability of unauthorized installation of CNG kits in the Delhi NCR region.

The lowest average of CO (0.003 ppm) is derived from the year 2019, and the highest average (0.10975 ppm) is derived from the year 2015. The lowest average of HC (13.33ppm) is derived from the year 2010, and the highest average (32 ppm) is derived from the year 2015. The lowest average of CO$_2$ (14.95 ppm) is from the year 2019, and the highest average (19.975 ppm) is from the year 2011. Table 8 displays the average emissions of just two pollutants (CO and HC) for vehicles operating on petrol/CNG. The average values of pollutants are calculated from the year 2005 to 2017. The lowest average of CO (0.0150 ppm) is from the year 2015, and the highest average (0.116 ppm) is from the year 2007. The lowest average of HC (8.875 ppm) is from the year 2008, and the highest average (84 ppm) is from the year 2015.

3. Result Analysis

Our analysis is based on the data collected from the different pollution tracker nodes installed across the different locations in Delhi NCR. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. In Table 2, we can track out that a large number of old vehicles are used in different regions after the various notifications in regard to banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants (Figures 2–4).
In Table 2, we can track out that a large number of old vehicles are used in different regions after the various notifications in regard to banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants (Figure 2–4).

**Figure 2.** Trend of HSU over an eight-year period for diesel vehicles [24–54].

This situation can be handled by introducing the low survival rate for vehicles. It would correspond to easy replacement or breakdown of old vehicles. Thus, after introducing this, the pollutants share of old vehicles would be low. Lowering the survival rate will down the percentage of pollutants emission by old vehicles.

Lowering the mileage can also result in low fuel consumption and reduce emissions, too. The vehicles can be categorized in different mileage levels. For new vehicles, the mileage should be high, and for old vehicles, those having a high emission, the mileage level should be low. Major enforcement is also needed for reducing vehicle pollution. Time to time, vehicle services and enforcement are very important to reduce the pollutants emission by vehicles (Figure 5). The current study can make significant correlations with the impact of emission components toward sustainable development. We can further investigate in terms of green ICT and pollution, as well. In the future, based on several available studies found from the work done by several researchers, we may try to further explore the solutions for reducing pollutants. We can find some IoT sensor-enabled technologies to raise alarms if the pollution level or emission of specific gases, such as CO, CO2 and HC, go beyond the acceptable limits [63–68].

**Figure 3.** Different emission trend for petrol vehicles: (a) CO trend for petrol vehicles, (b) HC trend for petrol vehicles and (c) HC and CO2 combined trend for petrol vehicles. [24–54].
a
ed installation on
2
Major
gas
2
ing,

prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we
4. Conclusions

can also conclude that some of the old cars are well maintained and not emitting a large number of
Mahindra, TATA and some luxury makers. The given data of HSU range from the value of 30.90.86
unit of measurement used to measure the capacity of exhaust gases during emission. Some of the major
fuel type. Emission from diesel vehicles is measured based on HSU (Hartridge Smoke Unit), which is a
for Delhi, the most polluted city in India. Table 3 displays the value

for old vehicles. Those having a high emission,
vehicles can be categorized in different mileage levels.

a fuel type. Emission from
diesel vehicles are well below the
level for vehicles. The
currently prescribed limits of HSU emission

Lowering the mileage can also result in low fuel consumption and reduce emissions
This situation can be handled by introducing the low survival rate for vehicles. It would

This study presents the gaseous pollutants (181) emission factors of 181four-wheeler cars from
different companies and of different types of fuels. The measurement of gaseous pollutants was done
for Delhi, the most polluted city in India. Table 3 displays the value/level for vehicles using
diesel as a
fuel type. Emission from diesel vehicles is measured based on HSU (Hartridge Smoke Unit), which is a
unit of measurement used to measure the capacity of exhaust gases during emission. Some of the major
makers/companies being showcased through the table are Toyota, Maruti Suzuki, Hyundai, Honda,
Mahindra, TATA and some luxury makers. The given data of HSU range from the value of 30.90.86
to 46.01.43, leading to the conclusion that most of the diesel vehicles are well below the currently
prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we
can also conclude that some of the old cars are well maintained and not emitting a large number of
pollutants; it may be because of the regular maintenance and service by the car owner. This study is

4. Conclusions

This study presents the gaseous pollutants (181) emission factors of 181four-wheeler cars from
different companies and of different types of fuels. The measurement of gaseous pollutants was done
for Delhi, the most polluted city in India. Table 3 displays the value/level for vehicles using diesel as a
fuel type. Emission from diesel vehicles is measured based on HSU (Hartridge Smoke Unit), which is a
unit of measurement used to measure the capacity of exhaust gases during emission. Some of the major
makers/companies being showcased through the table are Toyota, Maruti Suzuki, Hyundai, Honda,
Mahindra, TATA and some luxury makers. The given data of HSU range from the value of 30.90.86
to 46.01.43, leading to the conclusion that most of the diesel vehicles are well below the currently
prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we
can also conclude that some of the old cars are well maintained and not emitting a large number of
pollutants; it may be because of the regular maintenance and service by the car owner. This study is

Figure 4. Different emission trends for petrol/CNG vehicles: (a) CO trend for petrol/CNG vehicles and
(b) HC trend for petrol/CNG [24–54].

Figure 5. Average emissions for petrol vehicles over nine years [24–54].
also demonstrating the different HSU values emitted by the different companies’ cars. The results also demonstrate that the new advancement in automobile industries is not very much concerned about maintaining the HSU level for vehicles.

Details about the petrol-type fuel show that the cars registered in 2015 emit higher amounts of pollutants as compared to those emitted by the cars registered in 2004. However, in the cars registered after 2015, the CO and HC values come down rapidly. On the other side, if we will look at the emission of CO\textsubscript{2} by the vehicles registered in 2010, 2015 and 2019, we see the same value of CO\textsubscript{2} emitted by the old and new cars. The results also demonstrate that the new advancement in automobile industries is not very much concerned about maintaining the CO\textsubscript{2} level for vehicles. The outcome for petrol/CNG cars indicates that few petrol/CNG cars are emitting a large number of pollutants. The cars registered in 2019 are emitting higher pollutants compared to the cars registered in 2005. This is due to the easy availability of unauthorized installation of CNG kits in the Delhi NCR region. Yes, to reduce the expenses on travel, everyone is now adopting the easy installation of CNT kits from an unauthorized dealer. No one cares about the effect of unauthorized installation on pollutant emission.

Overall, the analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. The unauthorized installation of CNG kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets to reduce CO, CO\textsubscript{2} and HC. This study shows that many old vehicles are used in different regions after the various notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. These old vehicles need to be banned immediately. This study will also help pollution-monitoring authorities make new and effective policies against the emission of pollutants by the vehicles. The significant contributions that were made by the work in this paper are summarized below:

1. Presents the gaseous pollutants (Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO\textsubscript{2})) emission factor of 181 four-wheeler cars from different companies and of different type of fuels.
2. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems.
3. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles.
4. This study shows that many old vehicles are used in different regions after the many notification regards to banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants.
5. The unauthorized installation of CNG kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets the reduction of CO, CO\textsubscript{2} and HC.
6. It will be helpful to pollution-monitoring authorities for making new and effective policies against the emission of pollutants by the vehicles.

**Author Contributions:** Conceptualization, R.S., R.K., R.-A.F. and P.K.S.; methodology, R.S., M.S.R. and P.K.S.; software, R.K.; validation R.-A.F., R.S., P.K.S., M.S.R. and R.K.; formal analysis, investigation, resources, data curation, writing—original draft preparation and writing—review and editing, R.-A.F., M.S.R., P.K.S. and R.K.; visualization and funding acquisition, M.S.R. and R.-A.F. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Acknowledgments:** This work was supported by a grant from the Romanian Ministry of Research and Innovation, CCCDI-UEFISCEDI, project number PN-III-P1-1.2-PCCDI-2017-0776/No. 36 PCCDI/15.03.2018, within PNCDI III.

**Conflicts of Interest:** The authors declare no conflict of interest.
References

1. Wang, J.M.; Jeong, C.-H.; Zimmerman, N.; Healy, R.M.; Evans, G.J. Real-World vehicle fleet emission factors seasonal and diurnal variations in traffic related air pollutants. Atmos. Environ. 2018, 184, 77–86. [CrossRef]

2. Xiao, C.; Chang, M.; Guo, P.; Chen, Q.; Tian, X. Comparison of the cost-effectiveness of eliminating high-polluting old vehicle sand imposing driving restrictions to reduce vehicle emissions in Beijing. Transp. Res. Part D Transp. Environ. 2019, 67, 291–302. [CrossRef]

3. Ramachandra, T.V.; Shwetmala. Emissions from India’s transport sector: Statewise synthesis. Atmos. Environ. 2009, 43, 5510–5517. [CrossRef]

4. Lipsky, E.M.; Robinson, A.L. Design and evaluation of a portable dilution sampling system for measuring fine particle emissions. Aerosol Sci. Technol. 2005, 39, 542–555. [CrossRef]

5. Giechaskiel, B.; Maricq, M.; Ntziachristos, L.; Dardiotis, C.; Wang, X.; Axmann, H.; Bergman, A.; Schindler, W. Review of motor vehicle particulate emissions sampling and measurement: From smoke and filter mass to particle number. J. Aerosol Sci. 2014, 67, 48–86. [CrossRef]

6. Wang, X.; Watson, J.G.; Chow, J.C.; Gronstal, S.; Kohl, S.D. An efficient multi-pollutant system for measuring real-world emissions from stationary and mobile sources. Aerosol Air Qual. Res. 2012, 12, 145–160. [CrossRef]

7. Chen, C.; Huang, C.; Jing, Q.; Wang, H.; Pan, H.; Li, L. On-road emission characteristics of heavy-duty diesel vehicles in Shanghai. Atmos. Environ. 2007, 41, 5334–5354. [CrossRef]

8. Fontaras, G.; Kouridis, H.; Samaras, Z.; Elst, D.; Gense, R. Use of a vehicle-modelling tool for predicting CO₂ emissions in the framework of European regulations for light goods vehicles. Atmos. Environ. 2007, 41, 3009–3021. [CrossRef]

9. Choudhary, A.; Gokhale, S. Urban real-world driving traffic emissions during interruption and congestion. Transp. Res. Part D Transp. Environ. 2016, 43, 59–70. [CrossRef]

10. Canha, N.; Lage, J.; Galinha, C.; Coentro, S.; Alves, C.; Almeida, S.M. Impact of Biomass Home Heating, Cooking Styles, and Bread Toasting on the Indoor Air Quality at Portuguese Dwellings: A Case Study. Atmosphere 2018, 9, 214. [CrossRef]

11. Azeez, O.S.; Pradhan, B.; Shafri, H.Z.M. Vehicular CO Emission Prediction Using Support Vector Regression Model and GIS. Sustainability 2018, 10, 3434. [CrossRef]

12. Osorio-Tejada, J.L.; Llera-Sastresa, E.; Hariza Hashim, A. Well-to-Wheels Approach for the Environmental Impact Assessment of Road Freight Services. Sustainability 2018, 10, 4487. [CrossRef]

13. Kamal, M.; Srivastava, G.; Tariq, M. Blockchain-Based Lightweight and Secured V2V Communication in the Internet of Vehicles. IEEE Trans. Intell. Transp. Syst. 2020, 1–8. [CrossRef]

14. Sha, A.P.; Singamsetti, M.S.; Tripathy, B.K.; Srivastava, G.; Bilal, M.; Nkenyereye, L. Performance Prediction and Interpretation of a Refuse Plastic Fuel Fired Boiler. IEEE Access 2020, 8, 117467–117482. [CrossRef]

15. Srivastava, G. Brand Positioning of Automotive Lubricant in Indian Market. Int. J. Manag. 2014, 11, 43–55. [CrossRef]

16. Guttikunda, S.K.; Nishadh, K.A.; Gota, S.; Singh, P.; Chanda, A.; Jawahara, P.; Asundi, J. Air quality, emissions, and source contributions analysis for the Greater Bengaluru region of India. Atmos. Pollut. Res. 2019, 10, 941–953. [CrossRef]

17. Liebenberg-Enslin, H.; van Oertzen, D.; Mwananaw, N. Dust and radon levels on the west coast of Namibia–What did we learn? Atmos. Pollut. Res. 2020. [CrossRef]

18. Weng, J.; Gao, P.; Gao, Z.; Phlh, J.; LaClair, T.; Zhang, M.; Gluesenkamp, K.; Momen, A. Nanoarray-Based Monolithic Adsorbers for SO₂ Removal. Emiss. Control Sci. Technol. 2020. [CrossRef]

19. Ganesan, N.; Masimalai, S.; Ekambaram, P.; Selvaraju, K. Experimental Assessment of Effects of n-Butanol on Performance, Emission, and Combustion Characteristics of Mahua Oil Fueled Reactivity Controlled Compression Ignition (RCCI) Engine. Emiss. Control Sci. Technol. 2020. [CrossRef]

20. Wang, Z.; Wu, Y.; Zhou, Y.; Li, Z.; Wang, Y.; Zhang, S.; Hao, J. Real-world emissions of gasoline passenger cars in Macao and their correlation with driving conditions. Int. J. Environ. Sci. Technol. 2014, 11, 1135–1146. [CrossRef]

21. Goyal, P.; Mishra, D.; Kumar, A. Vehicular emission inventory of criteria pollutants in Delhi. SpringerPlus 2013, 10, 216. [CrossRef] [PubMed]

22. GNCTD. State of Environment Report for Delhi, Department of Environment and Forests; Government of NCT of Delhi: New Delhi, Delhi, India, 2010.

23. Nagpure, A.S.; Sharma, K.; Gurjar, B.R. Traffic-induced emission estimates and trends (2000–2005) in megacity Delhi. Urban Clim. 2013, 4, 61–67. [CrossRef]
24. CMIE. *India’s Energy Sector*; Centre for Monitoring Indian Economy: Mumbai, India, 2007.
25. Goel, R.; Guttikunda, S.K.; Mohan, D.; Tiwari, G. Benchmarking vehicle and passenger travel characteristics in Delhi for on-road emissions analysis. *Travel Behav. Soc.* **2015**, *2*, 88–101. [CrossRef]
26. A Delhi Particular; The Economist: London, UK, 2012; Available online: https://www.economist.com/banyan/2012/11/06/a-delhi-particular (accessed on 12 August 2020).
27. ARAI. *Emission Factor Development for Indian Vehicles*; Automotive Research Association of India (ARAI): Pune, India, 2008.
28. ARAI. *Source Profiling for Vehicular Emission*; Automotive Research Association of India (ARAI): Pune, India, 2009; Available online: http://www.cpcb.nic.in/Source_Profile_Vehicles.pdf (accessed on 31 November 2015).
29. Bearak, M. *Desperate for Clean Air, Delhi Residents Experiment with Solutions*; New York Times: New York, NY, USA, 2014.
30. Choudhury, S.R. *Children in Delhi Have Lungs of Chain-Smokers*; India Today: Noida, India, 2014; Available online: https://www.indiatoday.in/india/north/story/pollution-in-delhi-cng-children-in-delhi-182151-2014-02-22 (accessed on 12 August 2020).
31. National Capital Region Planning Board. *Census 2011*; National Capital Region Planning Board: New Delhi, India, 2016; p. 3.
32. *Delhi’s Air Has Become a Lethal Hazard and Nobody Seems to Know What to Do About It*; Time Magazine: New York, NY, USA, 2014; Available online: https://time.com/6061/delhis-air-has-become-a-lethal-hazard-and-nobody-seems-to-know-what-to-do-about-it/ (accessed on 12 August 2020).
33. *Delhi ‘Third Greenest’ City*; Available online: https://www.ndtv.com/cities/delhi-third-greenest-city-408116 (accessed on 12 August 2020).
34. *New Delhi Blanketed in Thick Smog, Transport Disrupted*; Reuters: London, UK, 2013; Available online: https://www.scientificamerican.com/article/indian-capital-blanketed-in-thick-smog/ (accessed on 12 August 2020).
35. Fontaras, G.; Martini, G.; Manfredi, U.; Marotta, A.; Krasenbrink, A.; Maffioletti, F.; Terenghi, R.; Colombo, M. Assessment of on-road emissions off our Euro V diesel and CNG waste collection trucks for 46. *J. Environ. Sci.* **2017**, *53*, 39–47.
36. Harris, G. *Delhi Wakes Up to an Air Pollution Problem It Cannot Ignore*; New York Times: New York, NY, USA, 2015.
37. Goel, R.; Gutt Kunda, S.K. Evolution of on-road vehicle exhaust emissions in Delhi. *Atmos. Environ.* **2015**, *105*, 78–90. [CrossRef]
38. Kelkar, K. How Crop Burning Affects Delhi’s Air. *Wall Street Journal*. 2014. Available online: http://on.wsj.com/1eYDyAR (accessed on 12 August 2020).
39. Harris, G. *Beijing’s Bad Air Would Be Step Up for Smoggy Delhi*; New York Times: New York, NY, USA, 2014.
40. Habib, I. *The Agrarian System of Mughal India*; Oxford University Press: Oxford, UK, 1999; pp. 1556–1707.
41. *Impose 30% Cess on Diesel Cars*; Times of India: Mumbai, India, 2014; Available online: https://twitter.com/timesofindia/status/432978549352697858 (accessed on 12 August 2020).
42. *India’s Air Pollution Triggers Comparisons with China*; Voice of America: Washington, DC, USA, 2014; Available online: https://www.voatibetanenglish.com/a/indias-air-pollution-triggers-comparisons-with-china/1855447.html (accessed on 12 August 2020).
43. *January Days Getting Colder, Tied to Rise in Pollution*; Times of India: Mumbai, India, 2014; Available online: https://timesofindia.indiatimes.com/city/delhi/january-days-getting-colder-tied-to-rise-in-pollution/articleshow/29429495.cms (accessed on 12 August 2020).
44. Kumar, R. *Fancy Schemes for a Dirty Business*; Digital Development Debates: Berlin, Germany, 2016.
45. Ministry of Petroleum and Natural Gas. *Indian Petroleum and Natural Gas Statistics 2011–12*; The Government of India: New Delhi, India, 2012.
46. Ministry of Road Transport and Highways. *Road Transport Year Book 2009–10 & 2010–11*; The Government of India: New Delhi, India, 2012.
47. Madison, P. *Top 20 most Polluted Cities in the World*; CNN: Atlanta, GA, USA, 2016.
48. Pollution Increasing Lung Cancer in Indian Women. Available online: https://zeenews.india.com/news/health/diseases-and-conditions/pollution-increasing-lung-cancer-in-indian-women_26498.html (accessed on 12 August 2020).
49. *Rationale*; NCR Planning Board: New Delhi, India, 2012; Available online: http://ncrpb.nic.in/rationale.html (accessed on 12 August 2020).
50. Society of Indian Automobile Manufacturers; The Indian Automobile Industry: New Delhi, India, 2010; Available online: https://www.indianmirror.com/indian-industries/associations/automobile-association.html (accessed on 12 August 2020).

51. The Constitution (Sixty-Ninth Amendment) Act. 1991. Available online: https://www.india.gov.in/my-government/constitution-india/amendments/constitution-india-sixty-ninth-amendment-act-1991 (accessed on 12 August 2020).

52. Mohan, V. Usual Suspects: Vehicles, Industrial Emissions behind the Foul Play All Year. Times of India. 2018. Available online: https://timesofindia.indiatimes.com/city/delhi/usual-suspects-vehicles-industrial-emissions-behind-foul-play-all-year/articleshow/66228517.cms (accessed on 12 August 2020).

53. Narain, S. A Vicious Nexus. Down to Earth. 2018. Available online: https://www.downtoearth.org.in/blog/air/a-vicious-nexus-62475 (accessed on 12 August 2020).

54. Wang, H.; Chen, C.; Huang, C.; Fu, L. On-road vehicle emission inventory and its uncertainty analysis for Shanghai, China. Sci. Total Environ. 2008, 398, 60–67. [CrossRef] [PubMed]

55. Li, M.; Mi, Z.; Coffman, D.; Wei, Y.-M. Assessing the policy impacts on non-ferrous metals industry’s CO₂ reduction: Evidence from China. J. Clean. Prod. 2018, 192, 252–261. [CrossRef]

56. Zeng, S.; Jiang, X.; Su, B.; Nan, X. China’s SO₂ shadow prices and environmental technical efficiency at the province level. Int. Rev. Econ. Financ. 2018, 57, 86–102. [CrossRef]

57. Sun, M.; Wang, Y.; Shi, L.; Klemes, J.J. Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis. Renew. Sustain. Energy Rev. 2018, 92, 823–833. [CrossRef]

58. Iodice, P.; Senatore, A. New research assessing the effect of engine operating conditions on regulated emissions of a 4-stroke motorcycle by test bench measurements. Environ. Impact Assess. Rev. 2016, 61, 61–67. [CrossRef]

59. Iodice, P.; Senatore, A.; Langella, G.; Amoresano, A. Advantages of ethanol–gasoline blends as fuel substitute for last generation Si engines. Environ. Prog. Sustain. Energy 2017, 36, 1173–1179. [CrossRef]

60. Gurjar, B.R.; Van Aardenne, J.A.; Lelieveld, J.; Mohan, M. Emission estimates and trends (1990–2000) for megacity Delhi and implications. Atmos. Environ. 2004, 38, 5663–5681. [CrossRef]

61. Garg, A.; Bhattacharya, S.; Shukla, P.R.; Dadhwal, V.K. Regional and sectoral assessment of greenhouse gas emissions in India. Atmos. Environ. 2001, 35, 2679–2695. [CrossRef]

62. MoPNG. Annual Report 2001–2002; Ministry of Petroleum and Natural Gas, Government of India: New Delhi, India, 2002.

63. Singh, P.; Paprzycki, M.; Bhargava, B.; Chhabra, J.; Kaushal, N.; Kumar, Y. Futuristic Trends in Network and Communication Technologies. FTNCT. Commun. Comput. Inf. Sci. 2018, 958, 3–509.

64. Singh, P.; Sood, S.; Kumar, Y.; Paprzycki, M.; Pljonkin, A.; Hong, W.C. Futuristic Trends in Networks and Computing Technologies. FTNCT. Commun. Comput. Inf. Sci. 2019, 1206, 3–707.

65. Singh, P.K.; Bhargava, B.K.; Paprzycki, M.; Kaushal, N.C.; Hong, W.C. Advances in Intelligent Systems and Computing. In Handbook of Wireless Sensor Networks: Issues and Challenges in Current Scenario’s; Springer: Cham, Switzerland, 2020; Volume 1132, pp. 155–437.

66. Singh, P.K.; Pawłowski, W.; Tanwar, S.; Kumar, N.; Rodrigues, J.J. Lecture Notes in Networks and Systems. In Proceedings of the First International Conference on Computing, Communications, and Cyber-Security (IC4S 2019), Cham, Switzerland, 12–13 October 2019; Volume 121, pp. 3–917.

67. Marques, G.; Saini, J.; Dutta, M.; Singh, P.K.; Hong, W-C. Indoor Air Quality Monitoring Systems for Enhanced Living Environments: A Review toward Sustainable Smart Cities. Sustainability 2020, 12, 4024. [CrossRef]

68. Singh, P.K.; Kar, A.K.; Singh, Y.; Kolekar, M.H.; Tanwar, S. Lecture Notes in Electrical Engineering. In Proceedings of the ICRIC 2019, Recent Innovations in Computing, Cham, Switzerland, 8–9 March 2019; Volume 597, pp. 3–920.

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).