MAJOR PROJECT REPORT

ON

ANALYZING THE EFFECT OF VEHICULAR VARIABLES ON TAILPIPE EMISSIONS FROM TWO- WHEELERS

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FOR THE AWARD OF DEGREE OF

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Submitted by
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CANDIDATE'S DECLARATION

I, MILDRED CHILESHE, Roll No. 2K21/ENE/17 of MTech (Environmental Engineering), hereby declare that the project Dissertation titled "**Analyzing the Effect of Vehicular Variables on Tailpipe Emissions from Two-Wheelers**" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "**Analyzing the Effect of Vehicular Variables on Tailpipe Emissions from Two-Wheelers**" which is submitted by **Mildred Chileshe, Roll No. 2K21/ENE/17**, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi**. RAJEEV KUMAR MISHRA**

Date: MAY, 2022 **SUPERVISOR**

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ABSTRACT

Countries with huge population and inefficient public transportation systems have resorted to the use of two wheelers to combat congestion, survive economic pressures and reduce traffic accidents. This includes Asian nations like India and Indonesia. African countries like Nigeria and Ghana prefer motorcycle use due to inability to afford cars, as result of high unemployment rate. In India, two-wheelers account for about 70 percent of the overall vehicular fleet. It, therefore, makes it of paramount importance to explore the key vehicular variables affecting emission from two-wheelers. From the tailpipe emission testing of 272 two-wheeled vehicles (motorcycles and scooters), we managed to get a clear comprehension of the effects of vehicular independent variables on the emission parameters. Following the data analysis, it is evident that the vehicular variables, such as mileage, age, and complying emissions standards, have a very strong influence on the tailpipe parameters CO and HC (carbon monoxide and hydrocarbon). Motorcycle and scooters' age and mileage were both significantly correlated with CO and HC (For age, R^2 = 0.846 and 0.815, respectively, and for mileage, R^2 = 0. 841 and 0.809 respectively). As regards to the engine-specific independent variables, the fuel ignition system played a significant role in CO and HC emissions, as it was discovered that more recent and sophisticated versions of two-wheeler engines had lower maximum emissions values when compared to older versions. Also, kerb weight has a poor correlation to HC and CO emissions ($R^2 < 0.3$), implying that approximately 30 percent of vehicles with the same kerb weight had the same CO and HC emissions. The logarithmic emission equations generated in the present study can reliably predict CO and HC emission levels rooted on vehicular traits. It is recommended to upgrade the phasing-out policy basis of such traits. For future studies, multivariate correlation of emissions on engine and vehicle specific parameters can be carried out, to access the level of combined impact.

Keywords: Two-Wheelers; Vehicular Variables; Ignition System; Kerb Weight, Emission Equations, Transport

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LIST OF ABBREVIATIONS

Abbreviation	Definition
ANOVA	Analysis of Variance
CAFÉ	Corporate Average Fuel Economy
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSE	Centre for Science and Environment
EPA	Environmental Protection Agency
GHGs	Green House Gases
GIS	Geographical Information System
HC	Hydrocarbons
IVE	International Vehicles Emissions
L.C. A	Life Cycle Assessment
NO_2	Nitrogen Dioxide
N_2O_3	Dinitrogen Trioxide
NO_x	Oxides of Nitrogen
O_3	Ozone
PEMS	Portable Emissions Measurement System
PM	Particulate Matter
SOA	Secondary Organic Aerosols
SPSS	Statistical Package for Social Sciences
TERI	Energy and Resources Institute
TRAP	Traffic Related Air Pollutants
UFP	Ultra Fine Particles
VECM	Vector Error Correlation Model
VOC	Volatile Organic Carbons

CHAPTER 1. INTRODUCTION

1.1 OVERVIEW

Vehicular pollution refers to the release of harmful substances known as air pollutants into the environment by automobiles. Commonly denoted as automobile emission, it has a huge negative impact on humans and the environment. Because of the exponential rise of vehicles on the roads, transportation has been the chief source of air pollution in many nations across the world. More individuals can now buy vehicles favored by the economic growth, rising income levels and auto sales policies. Because of India's rapid urban growth, pollution from automobiles has been on sharp and sustained rise at an alarming rate. Vehicular emission (VE) in metropolitan areas has become the most severe environmental issue. Vehicular air pollution is a quiet cause of death, responsible for millions of fatalities, which increase on an annual basis as the industrial revolution accelerates. Vehicular air pollution does not simply lead to respiratory illnesses like asthma, bronchitis, pneumonia, and lung cancer. It has been related to a variety of other disorders. The swelling, and impairment of the heart and blood vessels, leads to cardiovascular disorders such as ischemic stroke and heart failure. Due to exposure to cancer causing particulates, lung cancer mostly develops in immuno-suppressed or compromised individuals. Also, air pollution is known to speed up the degenerative process of Alzheimer's disease. Individuals who reside in places with significant amounts of contaminants in the air are more prone to suffer from gastrointestinal disorders like Crohn's disease. Further, accumulation of air toxins in the body culminates into chronic kidney disease.

Motorcycle ownership is almost four times greater in developing nations compared to developed countries. Furthermore, motorcycles account for 72% of vehicle fleet numbers in India. This exemplifies how crucial motorcycles' air pollution is in developing countries, particularly India [1]. Most Indian cities suffer from extremely high levels of urban air pollution, specifically Carbon Monoxide (CO), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Particulate Matter (PM). The automotive industry plays a huge share in destroying habitats (almost three-quarters). CO holds about 90% share of automobile industry pollution. HCs are next to CO [2]. Furthermore, poor air quality is closely attributed to a city's road transportation system. According to various studies, residents living close to main roads, preferably near crossways, are more prone to high ambient pollution levels than those residing further away. Automobiles in the main cities of India are believed to account for 10 % SO_2, 30 % PM, 30-40 % NO_2, 50 % HCs and 70 % CO pollution, with two-wheelers accounting for about 70 % of total pollution loads [3]. In India, two-wheelers such as scooters and motorcycles, driven by Bharat Stage (BS) IV-compliant petrol rather than compressed natural gas (CNG), emit not only black smoke on public roads on but also routinely disobey fuel quality assessments. A study by Centre for Science and Environment (CSE) discovered that the bulk of automobile pollution during the Diwali period in Delhi is from two-wheelers. According to an emissions inventory in 2018, by the Energy and Resources Institute (TERI), mobility was accountable for 28% of $PM_{2.5}$ load in Delhi's winter months of 2016. Two-wheelers contributed the most, at 7%, respectively. The reason been that two-wheelers account for a third quarters of the vehicle fleet in Delhi.

1.1.1 Causes of Vehicular Emissions

There are four major causative factors behind vehicular exhausts, such as, vehicle related factors, facility related factors, driver related factors and fuel related factors. Vehicular aspects include engine operating mode, age, mileage, engine capacity, kerb weight, fuel ignition system, emission control system etc. Facility related factors include the road design and network like acceleration /deceleration lane, road humps and traffic signals. Fuel related factors are related to the type of fuel and quality, as certain types have lower trace of contaminants such as sulphur and lead.

In the past few decades, pollutants from very old two-wheelers have been one of the key sources behind air pollution. Very old here implies these vehicles have completed their maximum allowable registration period of 15 years in Delhi. It is predicted that emission levels will increase more rapidly without an effective scrap policy concerning obsolete bikes which contribute to human health and environmental damage. The famous two-stroke scooter did not have an appropriate air-fuel ratio; hence it was responsible for increased pollutants, primarily CO and HC [4]. Research on car and motorbike emissions in Taiwan revealed that vehicle factors such as age had a significant influence on HC and CO exhaust levels. Direct correlation models were used to arrive at the conclusions [5]. Lin, et al. looked at the relationship between cancer susceptibility and mutations with motorcycles having recorded mileage of 10,000 km or more. Cancer-causing capacity and genetic modification were found to be significantly correlated with mileage. The emission factors for carcinogenicity and mutagenicity increased with distance traversed. The study also discovered that mileage had a 0.681 correlation coefficient with CO, resulting in poor combustion efficiency [6]. Nations throughout the globe have been investigating cleaner alternative fuels derived from renewable resources to combat environmental degradation. Spark ignition (SI) engine types may run on a variety of petrol blends [7]. A study on the effect of oxygenated fuel of ethanol blend on fuel use and emissions levels for SI motorbikes discovered considerable reductions in cold emission coefficients for ethanol gasoline blend compared to pure gasoline-powered bikes [8]. It is well understood that outside temperatures have a major influence on exhaust emissions, particularly cold start pollutants. A low temperature in the combustion chamber may result in partial combustion and a greater release of pollutants. Yao, et al. concluded that bikes of smaller kerb weight coupled with elevated engine heat and low combustion productivity emit elevated levels of criteria air pollutants [9].

1.1.2 Impact of Two-Wheeler-Induced Pollution

Some of the major consequences of vehicular pollution include global warming, poor air quality, health effects, declining tourism, acidic rain and damaged reputation of the country. The release of carbon emissions known as greenhouse gases (GHGs) has severely destroyed the ozone layer, which has led to an unanticipated level of global warming. Such scenario has given rise to serious environmental consequences such as drought. Also, the resultant harmful ultraviolent (UV) rays are destroying organisms, hence causing extinction of weak species. In countries with unsafe or very poor urban air quality, the citizens are forced to wear masks. Also due to huge quantity of particulate matter and other emissions, people suffer from respiratory diseases which disturb work productivity and economic growth at large. Nitrogen oxides and Sulphur dioxide, result in acidic rain which destroys the appearance of infrastructure and kills flora and fauna.

Motorbike taxi drivers hold a huge share of the workforce in African countries like Uganda and Nigeria. Since they spend most of their time on roads, they are exposed to pollutants from these two-wheelers. According to research conducted in Lokossa city of Benin, which has minimal vehicular exhaust levels, two-wheeler taxi drivers showed less respiratory symptoms compared to those in Cotonou, a more contaminated city in Benin [10]. A 2015 study in Kolkata city observed several breathing-related conditions, such as, asthma and other medical conditions, for instance, hypertension among residents due to the high rate of motorcycle exhausts [11]. In China and India, the automobile sector is a major source of greenhouse gases. A study in both countries using the spatial analysis module discovered that in Bangalore city, two wheelers powered by gasoline contributed hugely to the impacts of climate change through high CO_2 emissions [12].

1.2 PROBLEM STATEMENT

In India, vehicular pollution is a grave concern, resulting in serious diseases and high fatality rate. Given the country's large population of over a billion people and emerging industrialization, India's automobile fleet is truly massive. The two-wheeler category, which includes scooters and motorcycles, accounts for a sizable portion of the automotive fleet in both Delhi and India as a whole. Along with this substantial percentage of the fleet, yearly vehicle sales reveal that around 75% of new two-wheelers are purchased, compared to 25% of cars. The issue is exacerbated further by the fact that most two-wheelers have lower pollution regulations than other types of vehicles. The major factors behind the high rate of environmental damage from two-wheelers is because:

1. India has many registered two-wheelers, accounting for about 75 % of total annual vehicular sales.
2. Motorbikes are not a common mode of transportation in most of the industrialized nations, especially those with a medium-sized population. Consequently, the critical nature of 2-wheeler pollutants is frequently neglected in relevant transport (environmental) regulations, giving manufacturers little reason to further develop emission control technology.
3. Many outdated two-wheel autos (with registration life past) manufactured to comply to BS III and BS IV (more polluting than BS VI compliant ones) continue to clog the city's streets.
4. Even modern two-wheelers (with BS VI) have lower pollution requirements than vehicles with contemporary features.

1.3 AIM

Considering the challenges associated with air pollution from the transportation sector, particularly two-wheelers, including motorcycles and scooters, the present study investigated the effect of vehicle variables on tailpipe emissions of CO and HC from the two-wheelers. Vehicle-specific parameters included age, mileage, applicable in-use emission norms (BS III and IV), and engine-specific parameters, included kerb weight and engine ignition system.

1.3.1 Study Objectives

In line with the above stated main objective, the specific objectives included:

1. Investigation of the nature, significance, and magnitude of the impact of age and mileage on the tailpipe CO and HC emissions.
2. Evaluation of the degree of compliance of two-wheelers to recent emission standard (BS IV) in comparison to the preceding standard (BS III).
3. Assessment of kerb weight impact on lower carbon emissions partly due to less inertia.
4. Assessment of impact of different fuel ignition systems on tailpipe CO and HC emissions.

1.4 HYPOTHESIS STATEMENTS

In line with the specific objectives, the hypothesis statements, which were investigated included:

1. Age and mileage, each significantly affect the CO and HC emissions levels from 2 -wheelers positively, with an impact of high magnitude.
2. Two-wheelers are more compliant to the newer emission norms (BS IV), compared to the preceding emission norms (BS III) on account of improvement in engine combustion systems and emission control systems.
3. A two-wheeler which is lightweight, emits less tailpipe CO, as it overcomes little inertia.

CHAPTER 2. LITERATURE REVIEW

2.1 FOCUS OF REVIEW

A critique of studies and information available in connection to the problem of vehicle emissions from 2-wheelers, such as the facts, causes, affects, and remedies, has been put together. The review first summarizes the extent of 2-wheeler pollution in Asia, Africa, Antarctica, Europe, North America, Oceania, and South America. The study then reviews some literature on general vehicular pollution encompassing both 2-wheelers and 4-wheelers. Since the focus of the study is emissions in idle mode, the definition and impacts of idling emissions are reviewed, and certain remediation techniques are pointed out. The social, environmental, and health impacts of the contaminants are also described. The review illustrates the impact of vehicle and engine-specific parameters on the levels and properties of emissions.

2.2 EXTENT OF TWO-WHEELER POLLUTION

Automobiles are now a necessity for human activities, as transportation has become a basic human need. Every job necessitates the use of a vehicle for mobility. Efficient transportation systems result in time saving and good energy usage which culminates in economic development. Even though a motor vehicle has numerous advantages, it is a huge danger to the ecosystem as it contributes to increasing environmental damage. This is due to the growth in the quantity of automobiles. Motorcycle fumes are a substantial source of air contamination: these produce substantial amounts of oils (combusted or not) which may include dangerous chemical additives. Motorcycle exhaust includes significant amounts of unburnt hydrocarbons, which results in smog. Countries with a huge population and inefficient public transportation systems have resorted to the use of two wheelers to combat congestion, survive economic pressures and reduce traffic accidents. This includes Asian nations like India and Indonesia. Also, African countries like Nigeria and Ghana prefer motorcycle use due to inability to afford cars, as result of high unemployment rate.

2.2.1 2-Wheeler Tailpipe Emissions in Asia

Due to their convenience and minimal use of fuel, motorbikes are an increasingly common means of transportation in cities of all sizes. The streets of Thailand are crowded with motorcycles of all makes. In Vietnam, almost 87% of the people own a 2-wheeler. Malaysians own almost the same number of motorbikes and scooters as cars. Indonesia is the biggest exporter of 2-wheelers specifically motorcycles from the nearest country of India, which is the biggest exporter of motorbikes. In 2016, mobility pollution drivers in Tehran consisted of over 1,000,000 petrol motorbikes. In recent decades, scarce transportation choices and traffic limitations contributed to the usage of motorbikes. Motorbikes are utilized for transit instead of sports in Republic of Iran. The scenario is akin to Southeast Asian nations. Bikes are a common mode of mobility in southern Asia. In fact, in several Asian countries, such as China and Thailand, the market share of motorbikes is 70% [13].

Rana et al. estimated vehicular emissions in Dhaka using vehicle emissions with a smoke opacity meter and an automotive gas analyzer. The authors concluded that bikes were very polluting; sixty percent of the motorcycles produced CO and HC concentrations greater than the respective national emission limits [14]. In China, Lang et al. estimated the emissions from on-road vehicles from 1999 to 2011 [15]. Passenger cars and motorcycles were found to be the primary sources of CO and VOC emissions. Due to the high number of vehicles, particularly motorcycles, in the chengdu-chongqing urban agglomeration in China, a study suggested reducing the number of motorcycles to reduce carbon monoxide emissions [16].

2.2.1.1 India

Powered two-wheeled vehicles dominate the personal mobility industry in India. The manufacturing and cash flow of two-wheelers have consistently exceeded that of four-wheeled vehicles by a magnitude of five in recent years.

Motorbike turnover in India has been expanding at a double-digit rate over the years and has managed to surpass one million vehicles per month. Motorcycles still lead the passenger automobile fleet and gasoline utilization, with an annual turnover five times that of passenger cars [17]. With approximately 125,000,000 registered 2-wheel automobiles on the road, India was leading the globe in 2018; it was assumed that roughly 75,000,000 two-wheeled vehicles actually existed in the country [18]. Nagpur et al. analyzed on-road vehicle emissions in Delhi through a comparison of emission levels of automobile air toxics, volatile organic compound, and PM from non-exhaustible automobiles during the period (1991–2011) and (2011–2020). The authors concluded that two-wheelers dominated the CO, HCs, and acetaldehyde emissions [19]. Nesamani estimated the on-road vehicular emissions in Chennai through the IVE model. According to the author, two and three-wheelers emitted approximately 64% of total CO emissions. Nesamani reviewed additional mitigation options and concluded that advanced vehicular technology and increased public transportation would significantly lower vehicular emissions [20].

2.2.2 2-Wheeler Tailpipe Emissions in Africa

The African continent has abundant natural resources, but their extraction has resulted in severe contamination of the environment. Rapid urbanization and high population growth have played a key role in the pollution issue. Transportation been a key component of transforming the economies into developed status and has impacted the environment so negatively [21]. Due to factors such as expanding populace and urban growth, African two-wheeler commerce has vast growth potential. Also, the absence of dependable public transit facilities makes 2-wheelers an appealing and practical method of transit. There is massive buying of motorcycles in Nigeria and Egypt. The huge numbers of motorbike taxis in Uganda's capital, Kampala, pollute regional air. Companies are now marketing 2-wheelers with electric motors in order to mitigate environmental damage.

In 2019, Naseer Babangida Muazu conducted a study in Nigeria to determine motorcycle-related air pollution in the Katsina region. Seventy percent of respondents to the questionnaire-based analysis identified motorcycles as the primary cause of air pollution [22]. Also, Adeoti et al. analysed the impact of motorcycle emissions on climate change in Nigeria.The authors concluded that the high number of commercial motorcycles caused significant fuel consumption, which resulted in excessive greenhouse gas emissions, directly impacting weather events such as rainfall patterns [23]. Research conducted in Douala, Cameroon, discovered that motorcycle emissions were influenced by age, fuel type, and traffic conditions [24]. In Ghana, a project was conducted in 2013 to examine the issues encompassing motorcycle transport services.The researchers deduced that the growing number of motorcycles in urban areas coincided with public health and environmental issues caused by exhausts [25].

2.2.3 2 Wheeler Tailpipe Emissions in Antarctica

Being unhabited region, there have been few number of motorbikes driven in the Antarctica for expedition purposes only. According to Tin et al. review on impacts of human activities in the Antarctica , building and transportation, have affected plant and animal numbers and habitation [26].

2.2.4 2-Wheeler Tailpipe Emissions in Europe

Motorcycle buying and transit is on the rise in europe, and it is accompained by serious consequences.These repurcussions are not limited to traffic jams and environmental degradation..

Vasic & Weilenmann determined and compared CO, HCs, NO x and CO emissions from 17 gasoline-powered passenger cars to 8 powered two-wheelers. The researchers indicated that the prominence of emissions from two-wheelers was not negligible, despite the fact the two-wheeler fleet in Switzerland was comparatively small to the car fleet [27]. A study in Spain conducted the Life Cycle Assessment (L.C.A.) of an internal combustion engine motorbike to an electric battery one. The analysis revealed that the gasoline fueled counterpart contributed 5 times more in terms of global warming potential [28]. Iodice & Senatore investigated the effect of operating conditions of the engine had on emissions from a 4-stroke motorbike. The test revealed high levels of emissions under cold engine operations compared to hot operative scenario [29]. The investigation undertaken by the Swiss State Laboratories revealed that both bi and tetra-stroke bikes produced nearly sixteen times HCs and threefold the quantity of CO than conventional automobiles [30].

2.2.5 2-Wheeler Tailpipe Emissions in North America

2-Wheeler market demand has been high in North American nations,and is expected to conti ue with technological advancements such as electric batteries. Cities such as Los Angeles have congested highways which hampers time saving and productivity. Multiple states in the United States' warmer climates are witnessing a surge in 2-wheeler sales since they take up a smaller amount of area, thus curbing traffic jams [31].Policies aimed at promoting clean and energy-efficient companies can combat transportation air pollution and develop the economy in Latin America [32]. Rosenblatt et al.conducted an emissions inventory on highway motorcycle with different engine displacemnet of 296cc, 749cc and 1198cc, using a chassis dynanometer setup. The examination revealed that the these motorcycles emitted more concentrations of CO and HC in cold start mode than any other mode [33].

2.2.6 2-Wheeler Tailpipe Emissions in Oceania

Australia is home to more than 40 brands of 2-wheelers, which include as much as 50% on-road type, 40 % off-road variety and 10% lady bikes [34].Motorbikes in New zealand are owned for motor races.Motor bike races in New Zealand begun as early as the 20 th centtury.

In Australia, the motorbike mobility mode is yet to be improved in terms of reduced traffic jams and dependable transportation strategy [35] . Wardoyo et al. investigated the impact of Ultra Fine Particles (UFP) from motorbike smoke and its effect on mice. It was concluded that exposure of mice to high concentrations of UFPs for a longer period of time caused a huge number of abnormal erythrocytes compared to normal ones [36]. Abikusna et al. investigated the effect of mixing bioethanol with gasoline on emissions from a motorbike. The experiment revealed reduction in exhaust levels of CO, HC and NO_x [37].

2.2.7 2 Wheeler Tailpipe Emissions in South America

The motorbike market demand in South America has been on the rise since 2012. The market grew from 3.7 million in 2012 to the 2021 figure of 5.2 million. This is attributed to affordability, easy transit and demand for environmentally friendly automotive like electric battery 2-wheelers [38]. Grassi, Brignole & Diaz carried out an emissions inventory of on-road sources of different vehicles using the COPERT model in 2020. It was revealed that motorbikes were the main sources of CO, CO_2 , VOC and methane (CH_4) [39] .A study in Bogota in Columbia, examined the spatial distribution of black carbon and $PM_{2.5}$ along motorbike road paths. Through measurements using a micro-aethalometer, it was revealed that that the bike path users were exposed to concentrations beyond the allowable limit ; $PM_{2.5}$ average levels between 80 and 140 ug/m^3 [40].

2.2.8 Summary of Past Research

Table 2.1 below shows a summary of a few studies related to 2-wheeler emissions.

Table 2.1 – Summary of past studies on 2- wheeler vehicular pollution

Title	Aim	Methodology	Findings	Gaps
An assessment of gasoline motorcycle emissions performance and understanding their countribution to Tehran air pollution[50]. Tehran 2016	Estimation of emission rates and factors for 60 2-wheelers for CO and unburnt hydrocarbons	Chassis dynanometer laboratory . Normal stoichiometric excel spreadsheet.	40% of fuel burnt to incomplete combustion, resulting in carbon emissions	No mention of SPSS regression;
Direct and indirect factors affecting emissions of cars	Assessment of the effect of direct and indirect factors	Descriptive statistics through direct and indirect	The vehicle specific characteristics like mileage significantly affected the CO and HC levels;	No mention of emission norms, kerb

and motorcycles in Taiwan [41] Taiwan 2009	on emissions from cars and motorcycles	correlation models;	The impact of the indirect factors like driver capability was minor; Old bikes with tiny engines, mechanical transmissions, huge aggregate mileages were releasing high CO and HC fumes.	weight and ignition system impact;
Test emission characteristics of motorcycles in Central Taiwan [42] 2006 Taiwan – Asia	Determination of the impact of engine type & size, age and brand on CO and HC emissions	Correlation analysis (STATISTICA, Inc., version 6)	All the variables namely age, engine type & size and make impacted the CO and HC emissions significantly; The older the bike, the higher the emissions;but few number of bikes meant lower cumulative value;The indirect factors like driving patterns also impacted the CO and HC levels;	The correlation was not accessed on levels of magnitude of impact
Evaluating impacts of two-wheeler emissions on roadside air quality in the	Determination of effect of two-wheelers and four wheelers on	Gaussian plume model; Robust uniform world model	During congestion; the CO and NO_2 levels increased with age and fleet number of vehicles	No mention of engine specific variables relation

vicinity of a busy traffic intersection in Douala, Cameroon; Cameroon-Africa 2016	pollutants at junction			
Evaluating the emission status of light-duty gasoline vehicles and motorcycles in Macao with real-world remote sensing measurement [43] Macao- Asia 2014	Determination of the actual emission quality of small gasoline powered 4-wheelers and 2-wheelers	Remote sensing ;	Bikes were the primary contributor to carbon dioxide and unburnt hydrocarbons as a result increased proportion of traffic.	No assessment of the impact of the vehicular variables , just cumulative analysis
Development of On-Road Exhaust Emission and Fuel Consumption Models for Motorcycles and Application through Traffic Microsimulation	Determination of pollutant rates and fuel usage models for 2-wheelers in Thailand.	Onboard measurement system	Significant correlation of emission levels and fuel usage with velocity	No assessment of actors like age, mileage, kerbweight, etc.

[44] Thailand- Asia; 2017				

2.3 VEHICULAR POLLUTION SCENARIO IN DIFFERENT COUNTRIES

Automobiles are now a necessity for human activities, as transportation has become a basic human need. Every job necessitates the use of a wheeler for mobility. Efficient transportation systems result in time saving and good energy usage which culminates into economic development. Even though a motor vehicle has numerous advantages, it is a huge danger to the ecosystem as it contributes to increasing environmental damage. This is due to the growth in the quantity of automobiles. The following literature illustrates the extent of general vehicular pollution worldwide, for each of the seven continents.

2.3.1 Asia

As Asian cities continue to rise in population, they face the threat of vehicular emissions. Much of this problem is in underdeveloped nations where compliance procedures are not strictly implemented. Vehicular exhaust emissions of airborne contaminants have a significant environmental influence on air quality in several densely populated cities in eastern Asia, such as Macau [45].

2.3.1.1 China

As China became the global leader of automotive production, the quantity of automobiles increased from 49 to 220 million in 1999 to 2013 [46]. In 2008, vehicular emissions accounted for 60 % of total CO emissions in China [47]. In the year 2014, Lang accessed the contribution of region transport to exhaust emissions in Beijing-Tianjin-Hebei region of China. It was concluded that vehicular activities hugely impacted the air quality in terms of $PM_{2.5}$ and Nitrogen Trioxide (NO_3) through regional transmission [48]. A study of Langfang ; a middle size city in China, projected that the exhaust emissions in middle sized Chinese cities will rise more than in mega cities, for the period 2018 to 2025. This was due to the huge number of people and un-updated policies. To combat this vehicular pollution in both regions, it was necessary to introduce comprehensive policies such as promotion of public transportation facilities like metro lines [49].

2.3.1.2 India

India is one of the highest automobile producers, with a 10% annual growth rate. Annual automobile sales in India are expected to triple from 4 to 11 million by 2030, owing to social development and an insatiable thirst for ownership. Cars and two-wheelers will account for around 87 percent. The 53 cities of India have become a hotspot of air contaminants due to rapid growth in automobile numbers. In heavily polluted cities like Kolkata and New Delhi, this rise in vehicular population has culminated into other problems like traffic jams, poor fuel quality and so on [50]. Because of massive mobility activities, cities with air pollution levels ten times higher than advised include Ahmadabad [51]. As the center of business affairs in the country, Delhi has seen a substantial rise in traffic [52]. Increase in household income and transportation has created a disparity in the rise of vehicles and the road system. Consequently, there is a lot of congestion and limited vehicle velocity, which causes considerable pollution of the environment. Hence, Delhi has been named as one of the most polluted cities, globally [53, 54]. A study in Chembur, an industrialized area outside Mumbai, observed high emissions of NO_x near busy roads [55]. An emissions inventory in Lucknow, through use of Geographical Information System (GIS) revealed that both 2-wheelers and 4-wheelers were the primary emitters of NOx (40%) and CO (70%). In India, there is an increasing direct correlation between the mobility system and air pollution rates. Exhaust emissions are also affected by speed and years of ownership [2].

2.3.2 Africa

Rapid development in Southern Africa has resulted in more vehicle ownership, a greater consumption of fossil fuels for food preparation, and ineffective garbage disposal practices. This has led to an adverse impact on the ecosystem. Ambient air pollution has become a severe concern to human health as WHO attributed 176,000 fatalities in 2012 to it in the area [56]. A comparative study of transportation $PM_{2.5}$ pollution between Lagos city in Africa and Hong Kong city in Asia concluded that vehicular pollution contributed more to the $PM_{2.5}$ emissions in Lagos than Hong Kong. This study revealed the vehicular pollution status in most developing nations in comparison to developed nations [57] . Tarred and gravel roads in Ghana account for 96% of the mode of transportation. The country of Ghana has a huge number of aged automobiles with high mileage that affect the air environment. Additionally, there are no emission norms that establish acceptable levels of exhausts. A study by Nukpezah & Hogarh on modelling of automobile emissions in Ghana revealed that most are below Euro 2 standards as policies do not guide the importation of overaged cars [58]. A group of researchers by the name of Maina, Gachanja, Gatari, & Price examined how much heavy metals were prevalent in dust and $PM_{2.5}$ along the busy Thika highway in Kenya. The analysis indicated that most of the heavy metals studied were above the normal concentration, with Lead (Pb) being extremely beyond limit [59].

2.3.3 Antarctica

There is no direct source of vehicular pollution in Antarctica apart from manmade pollution, which is a problematic, even though no one has ever lived there permanently as it is inhabitable due to temperature issues. The Antarctic is affected by growing lead levels, more greenhouse gases, and decreasing ozone layer. The deterioration is a result of external actions like usage of fossil fuels [60]. Phillip et al. studied the condition of waterbodies and air in Puerto Williams, and observed benzene, toluene, ethylbenzene and xylene (BTEX)constituents, with anthropogenic sources [61]. A 2019 study on the effect of indirect vehicular pollution on permafrost in the Antarctica, revealed the pollutants have a drastic negative impact on fauna DNA . Also , a huge disturbance in the environmental equilibrium such as extreme temperature rise was noticed [62]. A study on terrestrial soils in King George Island on the spatial distribution of Poly Aromatic Hydrocarbons (PAHs) revealed that the high concentrations of the PAHs in areas adjacent to the Great Wall Station [63].

2.3.4 Europe

In 2022, there were 300, 000 deaths related to air pollution in Europe, and vehicle exhaust emissions took up a chunk of almost 30% of the fatality rate. To curb this problem, the European Union planned the roll out of the stricter Euro 7 norms. A literature review on impacts of vehicular air pollution in urban areas of Italy compared to rural areas concluded that epidemiologic data showed higher number of people suffering from respiratory issues in metropolitan areas due to busy roads and westernized living [64].

2.3.5 North America

The environmental rules that have existed for a span of over forty years have benefited the environment and human health in North American regions like the United States. Since 1970, the Environmental Protection Agency (EPA) has established and put into effect emissions guidelines to reduce pollution from a variety of sources like mobility. Despite an increase in economic activity and more distance covered per person, these guidelines have been a key component of pollution prevention [65]. A 2021 study in Texas in USA, examined the exposure rate of socially disadvantaged children in public schools to vehicular pollution. The results indicated that schools with larger percentages of children suffered more traffic proximity and NO_2 exposure [66].Though significant efforts had been made to curb vehicular air pollution in Mexico, delays in implementing stricter environmental regulations led to high atmospheric ozone (O_3) concentration in the year 2016 from huge number of vehicle fleet [67].

2.3.6 Oceania

Australia and other Oceania nations have enjoyed comparatively clean air compared to other parts of the world. That's because this area is made up of tiny island regions with few significant businesses and few automobiles. But there are certain places where the calibre of the atmosphere has been affected, such as big cities. Vehicle exhausts are some of the sources of key air contaminants in this region. The transportation sector is a significant contributor to pollutants in the Pacific Island nation of New Zealand. Between 1990 and 2016, Green- House Gases (GHGs) from transit by road rose by 84.3% in the region. Of all the energy subsectors in New Zealand, this growth in GHG emissions was the largest. A study in this region using the Vector Error Correction Model (VECM) revealed that the fuel usage correlates with the level of emissions. To combat this, investment in alternative greener fuel is a necessity [68].

2.3.7 South America

The region encompassing the Caribbean and Latin America is one of the developing world's most urbanized areas, with a fast-expanding automobile fleet. In many metropolitan locations, air contaminants considerably surpass norms. Aged and unmaintained motor wheelers are the principal cause of air pollution in many metropolitan areas. A study in Andean city of Manizales in Colombia assessed the contribution of vehicular activities and non-point sources to environmental degradation. More than 90% of the total projected releases of most air pollutants were attributed to transportation activity. Motorcycle use was primarily responsible for on-road vehicular CO (50 %) and VOC (81%) emissions. The biggest emitter of PM_{10} and NOx was commuter buses [69].

2.4 IDLING EMISSIONS

Idling is the practice of operating a vehicle's engine while the vehicle is stationary. This is typical when motorists are halted at traffic lights, or are waiting motionless, leaving the engine on. A vehicle idling emits toxic pollutants like soot, which change the climate drastically and deplete the ozone layer. Whilst idling, a vehicle consumes fuel than needed, increasing the level of greenhouse gases. Because of higher fuel consumption, people spend more than needed on refueling and more fossil fuels are used for petroleum products production. Also, trying to warm up your engine by idling only damages the components of your automobile.

Bhandari etal. estimated the carbon print resulting from fuel loss at signalized intersections for each mode of travel. The authors concluded that idling CO_2 emissions contribute to 9 % of total emissions from the transport sector [70]. Sharma et al. analysed the impact of a 40-day-long awareness campaign conducted at 100 signalized junctions in Delhi to educate motorists about stopping their engine's idle mode. They observed a significant reduction in fuel losses and GHG emissions after the 40-day campaign [71]. Sharma et al. estimated emissions from fuel loss using IPCC emission factors at the Ashram intersection in Delhi. The authors concluded that with almost 600 signalized junctions, fuel loss and associated emissions could affect the economy and endanger the environment [72].Sithananthan et al. studied the effect of driving variables and traffic conditions on vehicle emissions for a BS-VI motorcycle. The authors discovered higher proportion of idle state and quicker rate of change and descent rates might translate into greater CO and HC emissions in urban areas [73]. An examination of idle fuel losses and exhaust fumes at crossways in Delhi, India, revealed that as the number of vehicles and traffic congestion grew, so did these parameters [3]. Yu et al. studied the impact of an automatic idling stop device on fuel utilization and emissions on motorcycles. The researchers concluded that the fuel economy improved by about 12%, while the CO emissions dropped by almost 40 % [74]. As determined by a study that was carried out in the city of Kaen in Thailand, the authors concluded that the driving pattern, in which the majority of time was spent in idle mode due to signalized congested lanes, had a negative impact on motorcycles' fuel consumption as well as their emissions [44].

2.4.1 Control Strategy of Idling Vehicle Exhausts

Bhandari et al. suggested proper policies and mitigation measures such as switching off habits to reducing idling emissions for 2-wheelers [70]. Goel & Guttikund developed vehicle and passenger travel characteristics for road emissions in Delhi. To reduce emissions, the authors suggested that Delhi and India as a whole must soon implement stricter emission norms [75]. Sharma et al. concluded that turning off the engine when the vehicle is idling at signals can cut down on fuel consumption and emissions. The authors suggested that reducing fuel losses at intersections enhances urban air quality [76].

Sharma et al.suggested that an extensive public transportation system, comprehensive traffic management, and planning could assist in reducing fuel loss and emissions [72]. Sithananthan,suggested regulatory changes in emissions standards to control vehicular pollution [73].

Adak stated the implementation of policies to regulate traffic jams, including the development of mini-roundabouts in appropriate arterial roads, well-defined stoppages for public utility vehicles, the integration of an intelligent traffic system, a micro-controller-based highway speed checker, a cordless rash driving detector, and the creation of dedicated lanes for different car classes in developing countries like India [77]. A study by Sharma suggested that the scientific governance of road facilities like junctions and traffic is a potential solution to idling fuel consumption and emissions. These include traffic management plans like speed limits and replacing the traditional signalized intersection with a roundabout and intelligent transportation systems to increase traffic operation efficiency [3].

Regarding overall emissions from 2 wheelers in all modes, Dhital et al. discovered that emissions correspond to the emission control system. The fuel injection system performs better than the carburetor in mitigating volatile organic carbons [78].Hernández et al., concluded that the temperature, catalyst composition and engine calibration are essential in reducing emissions [79]. . Pandey et al. suggested that improving the certification technology and discarding regulations is necessary to control CO and HC emissions from cars in an idle state [80].

2.5 IMPACT OF VEHICULAR POLLUTION

In social based setups, work productivity is hampered by vehicular air pollution as it escalates sick leaves since employees tend to work few days due to diseases and also tend to take care of sick relatives.Also,some respiratory diseases affect concentration levels.Environmentally, the most challenging effect of exhaust emissions is release of green house gases which deplete the ozone layer and warm the atmsophere, culminating into global warming. Exhaust emissions impact the health of exposed humans and also damage the surroundings. The range of diseases is from mild to severe impacts in the respiratory and cardio-vascular system.Because of all these consequences, more resources and money will be spent on health care, more companies will lose on economic gains and also hire part time officers. Also, world governments will need to put in more monetary resoources into research on technological ways of reducing emisions from vehicles.

2.5.1 Environmental Negative Effects

The effects of vehicle emissions is both short and long term.Emissions include gaseous and solid contaminants which result in acidic rain, climate change and deterioration of flora and fauna.In the United States, vehicles are responsible for 20% of overall global warming due to carbonaceous emissions.In terms of air, NO_x depletes the ozone layer exposing us to ultraviolet radiation. In terms of water, sulphur dioxide becomes acidic rain which destroys flora and vegetation.Petroleum spills seep into the soil , impacting its fertility [81]. Reşitoğlu et al. studied literature on diesel engine emissions impact on environment. It was revealed that diesel engines emit a huge proportion of exhaust and degrade the environment drastically [82]. Both diesel and gasoline fuelled automobiles are huge emitters of Secondary Organic Aerosols(SOA) [83].

2.5.2 Human Health Impacs

A study in New York revealed that buses and trucks accounted for the largest share of ambient $PM_{2.5}$, resulting in huge fatality rates [84].In the region of Dhanbad of India, a thorough health impact assessment of trace elements in particulate matter was carried out. It was observed that youngsters were sickened by multi-trace components and children were 10 times prone to cancer compared to elders [85]. A study in West Bengal of India, examined the health impacts of hazardous metals present in $PM_{10.}$ It was revealed the area with the most concentration of the trace elements had evidence of daeths due to carcinogenic diseases from 2014 to 2015 [86]. A literature review by Kim et al.on Traffic Related Air Pollutants (TRAP) impact on health in congested regions concluded that 30% of PM_{10} is from automobiles, TRAP cause several sicknesses related to respiratory , cardio-vascular and organ systems. Kim, et al also learnt that street vendors are most exposed to TRAP [87].A study in Seri Kembangan (Malaysia) examined the presence of heavy metals in soils from sources like vehicles.The study discovered that areas near congested roads had an abundance of heavy metal concentrations in their soils, no wonder cancers were prevalent [88].

Table 2.2 below highlights definition, sources and efects of the main vehicular air pollutants.

Table 2.2 – Definition, sources and effect of vehicular air pollutants

Name	Definition	Sources	Health & Other Effects	Welfare Effects
Carbon Dioxide	Colourless unscented pollutant produced by insufficient burning of fuel	2-wheelers; 4-wheelers;	Headache, heart attack; disturbed mental focus climate change	Haze formation
Fine Particulates	Inhalable solid fragments released from transportable sources	Diesel engines; Industries	Respiratory problems- asthma, lung damage	Aesthetic damage

Oxides of Nitrogen	Highly reactive gas which is brownish in appearance	Oxidation of mobility sources	Difficult breathing; irritation of lungs	Ozone formation
Volatile Organic Compounds	Substances with considerable vapour pressure but little water permeability	Fuel production engines	Throat irritation; liver damage	Ozone precursor
Lead	Metallic element	Engines;	Kidney failure; cancers	Ecosystem damage
Airborne Toxins	Harmful pollutants that cause cancers	Engines	Cancers	Harmful to environment
Ozone	Very reactive photochemical oxidiser	Vehicles	Respiratory system illnesses like lung damage	Plant damage
Sulphur Dioxide	Colourless pollutant that mixes with water to form acid	Diesel engines	Lung damage	Acidic rain
Road Dust	Particulates from motion	Vehicle use	Respiratory illnesses	Aesthetic damage

2.6 VEHICLE SPECIFIC PARAMETER’S IMPACT ON EMISSIONS

Vehicle specifications highlight the characteristics and properties of automobiles. These include age, mileage, kerb weight, engine capacity, power , torque, ignition system.e.t.c. According to Pandey many studies agree that age and mileage really affect the level of CO and HC emissions, and a combination of both in high levels is a recipe for environmental disaster.Many countries have resolved to implement stricter standards on emissions levels, so that manufaturers improve the emissions treatment technology and combustion systems [80].

2.6.1 Age

Old cars usually emit more than newer cars in terms of carbon emissions because it has used up more fuel for propulsion over its longer lifetime. Even though due to mileage, a new car may emit more than an old car, still considering its lifetime, the old car has done more damage to the ecosystem.Also most newer cars due to introduction of stricter standards have updated treatment technologies, in comparison to old cars with outdated systems.

A study by the U.S urban emissions initiative concluded that though old vehicles can have less total mileage, their emissions are massive.They also realised that as cars age, the ignition and treatment systems degrade and most people do not maintain the aged cars [89]. Liu et al. studied the impact the aging process had on the properties and amount of exhaust emissions . They noted that the aerosol based emissions increased, the older a vehicle became [90]. Lin et al ompared emission levels of CO, Volatile Organic Carbons (VOCs)and Non Mobile Hydrocarbons (NMHC) for Euro III, IV and V automobiles, some powered by gasoline and some powered by bioethanol blends. It was concluded that emissions reduced for the newer cars of EURO IV and V , compared to older cars of EURO III. This points to the fact that most newer cars have updated emissions control system and ignition systems compared to older cars, so that it is easy to comply with the limits [91]. A study in Western Australia on particulate matter emissions of differently aged vehicles using a remote sending device, observed that the vehicle age is positively correlated in a non linear sense with the dust particulate emission levels and the failure of particle filters [92]. Maduekwe et al.conducted a study in lagos to understand what was really impacting the high vehicular emissions. The findings revealed that the presence of extremely aged automobiles on Lagos' roadways is the largest impediment to meeting emission reduction objective. Not until the age restriction for cars is reduced from 40 to 20 years, expansion rate is reduced and mileage is decreased annually between 2020 to 2030, Lagos may not meet its objective of curbing emissions by 2030s [93].

2.6.2 Mileage

Mileage is defined as the distance covered by a car for every litre of fuel.At times it can be defined as the total distance a vehicle has travelled from the date of its purchase to the present. In our study, the present is the date the 2-Wheeler was tested for compliance. Most times a vehicle can be old but with small mileage and vice versa. But in most cases, like developing countries, the older a vehicle is, the more mileage.

Many studies agree that the reason for high mileage vehicles having high levels of emission, is malfunction of the emission controls or the catalytic converters. He, et al.conducted a study on the emission levels of 44 gasoline and 22 bifuel taxis in China using the Portable Emission Measurement System (P.E.M.S). .It was observed that the gasoline taxis with high mileage had levels of emission of NO_x and CO far beyond the standards. However, most of these when checked , revealed malfunctioning emission controls or catalytic converters. There would be a relation between mieage and catalytic converter functioning [94]. A study in Los Angeles in America on measurement of exhausts of high mileage hydrid taxis using activity based models showed increases in CO, HC and NO_x tailpipe emissions when compared to normal vehicles [95]. Fameli & Assimakopoulos conducted an annual emissions inventory in Athens in Greece using COPERT model. It was observed that reduced usage and reduction in yearly mileage, together with the introduction of new engine anti-pollution systems resulted in low levels of CO_2, CO and VOC. The study recommended that renewing of the vehicle fleet is an effective strategy towards fighting vehicle pollutants [96].A study in the United States investigated the relationship between fuel usage and mileage as well as level of emissions. The researchers concluded that, mileage increased while the fuel economy decreased in a non linear correlation way; meaning the higher mileage the more fuel consumed. Also this resulted in more carbon emissions [97].**Table 2.3** below shows the main facts from studies on impact of age and mileage on ehaust emissions from 2-wheel autos.

Table 2.3- Studies on relation of age and mileage to exhaust emissions from 2-wheelers

Title	**Aim**	**Methodology**	**Findings**	**Gaps**
Evaluation of the Impact of Motorcycles in Urban Transport on Air Pollution: A Case of Douala City in Cameroon; Cameroon – Africa – 2018	Analysis the influence of motorbike taxis on the air quality	Tronic Test G750/A type exhaust gas analyzer used;	The level of pollutants increased as the motorbike aged and mileage index rose;further the bikes of same age were affected by the velocity	No mention of SPSS regression; No mention of engine specific impacts like kerb weight.
Analysis of Motorcycle Exhaust Regular Testing Data—A	Investigation of impact of age and mileage on exhaust fumes	Use of certification test data set (1996 – 2005)	Non compliance to norms, for bikes exceeding three years or mileages exceeding 10,000 km indicated a	No investigation of engine specific

Case Study of Taipei City [98] Taipei – Asia - 2012			steadily rising trend, and failure probabilities correlated strongly with motorbike age/mileage	variables
How Effective Are Vehicle Exhaust Standards? [99] United States 2022	Assessment of compliance of old and new motorcycles to norms	Exhaust emission data from pollution measurement centres	Used 2-wheelers older than ten years emit the bulk of the overall pollutants and automobiles beyond fifteen years emit almost half of that amount. The study concluded automobiles become dirty as they become older, and their emission control technology degrades	No assessment on how the engine specific variables related to non compliance
Effect of air pollutants and toxic emissions from various mileage of motorcycles and aerosol related carcinogenicity and mutagenicity assessment [6] Asia 2019	Investigation of the relationship between the prominence of cancer and DNA mutations with mileage from 2-wheelers	Survey Questionnaire and exhaust database from test centres	Low mileage motorbikes had reduced evidences of cancer and mutations but the impact increased with higher miles covered	No investigation of engine specific parameters impact
Air pollutants and toxic emissions of various mileage motorcycles for	Determination of emission rates and fuel usage	Pearson correlation	Tailpipe emissions and fuel usage depended on their mileage and aging. The research indicated that	No engine specific variables impact

ECE driving cycles [100] Asia 2017			mileage of 1000 km resulted in an increase of 103 mg for CO emission and 14.7 mg for hydrocarbon emission	assessment

2.6.3 Emission Noms

Emission norms are figures that set a limitation beyond which gaseous, vapour and particulate matter contaminants into environment should not exceed. In India, government established the Bharat Stage (B.S.) emission regulations, to regulate and monitor the levels of air pollutants produced by engines. In terms of adhering to the emission norms, India lags five years behind the European countries. 2017 saw the ban on marketing of automobiles that did not meet BS-IV standards.So many challenges are faced by automotive and oil companies once stricter norms are introduced such as enhancing the oil refining proceses and shifting from old to new ignition technologies [101]. Automobile exhaust fumes of particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and hydrocarbons (HCs) reduced dramatically during the last three to four decades. To satisfy more rigorous rules, advanced emission after-treatment technologies for petrol and diesel cars were nurtured, . The state of the air in cities across the United States and Europe has improved significantly [102]. Jenn et al. stated that in United States of America, to combat Greeh House Gases (GHG), and lessen petroleum fuel usage, the government introduced the Corporate Average Fuel Economy (CAFE) standards. For the year 2012 to 2025, incentives were implemented for suppliers of alternative fuel vehicles to enhance the transition to green energy and stringent standards [103]. A study on 1580 cars in delhi showed that the levels of CO and HC were reducing with introduction of stricter emission standards as technology of new vehicles was advanced and better [80].

2.6.4 India

BS IV took effect in the month of April 2016 for new kinds of clearances and in April of the following year for every wheeler transaction and licences. The rule set the initial evaporative exhaust requirements for 2- and 3-wheeled vehicles The BS VI regulations, which were rolled out in month of April 2020, linked pollution limitations for 2-wheelers with Euro standards. These rules were put in place to ensure that that motorcycles are significantly less hazardous than cars.

In 2010, the government made BS-III, also known as Euro 3 standards, mandatory. According to BSIII, the permitted amount of HC is 4500 ppm, whilst for CO is 3.5 %, for two-wheelers during a

PUC test. It additionally capped the sulphur level of gasoline to 100 ppm. BSIII also included the installation of a catalytic converter to manage emissions [104].India finalized the 4th phase of emission regulations for two-wheelers in 2014. In 2017, the (BS) IV specifications for motorbike models were adopted. The standards reduced HC+NO_X emission limits by 23% - 60% in comparison to the old BS III norms, based on motorbike type. For PUC test purposes, the limit for HC is 3000 PPM and 3.0 % @ idling for CO [105]. The Ministry of Transport published a declaration of BS VI regulations, which are equal to Euro VI in 2016. This was applicable to all vehicles manufactured on or after 1 April 2020

2.7 ENGINE SPECIFIC PARAMETER'S IMPACT ON VEHICULAR EMISSIONS

The simple definition of Kerb Weight is the total weight of a vehicle in motion.In the european union, Unless the electrical system is severely decarbonized, encouraging vehicle weight reduction might result in higher cumulative emissions savings by 2050 [106]. Reducing a vehicle's weight lessens fuel usage and leads to less carbon emissions.Most lightweight vehicles overcome little inertia and hence propelled easily. However , this increases the vehicles mileage , maybe by 6 to 8%.Majority of research is focused on use of lightweight materials like aluminium in body components and chasis of automobiles [107]. An engine ignition system is basically used to produce a spark to burn up the fuel air mixture. Recent automotive engines utilise direct-ignition system, in which a pulse of high voltage is transmitted directly to coils located on top of the spark plugs.

2.7.1 Kerb Weight

Reducing a vehicle's weight lessens fuel usage and leads to less carbon emissions.Most lightweight vehicles overcome little inertia and hence propelled easily. However , this increases the vehicles mileage , maybe by 6 to 8%.Majority of research is focused on use of lightweight materials like aluminium in body components and chasis of automobiles [107]. Zhou et al. studied the emissions from light duty gasoline vehicles in beijing through remote sensing technique. The analysis showed that old heavy duty vehicles were emitting more than light duty vehicles [108].

2.7.2 Ignition System

The prechamber ignition technology reduce emissions and fuel economy , with lean fuel mixtures [109]. A comparison investigation of laser and electric spark ignition on a hydrogen powered vehicle, discovered that the laser igntion been an advanced new system is efficient and emits less [110]. The latest advances in the combustion mechanisms of gasoline vehicles, impose heavy requirements on ignition systems than earlier. In addition to other benefits, optimisation of the ignition system allows for an expansion of combustion constraints, taking into account engine efficiency [111]

2.8 RESEARCH GAP

Given the number of intersections and vehicle congestion in countries like India, it is without a doubt that vehicular emissions from two-wheelers due to idling mode are a huge problem, as discovered in the literature review. Furthermore, the number of two-wheelers in countries with large populations, such as India, is increasing yearly. The following are the significant research gaps identified:

- The control strategy focuses on regulatory practices such as emission norms adjustment and facility-related interventions to deal with traffic management and road design.
- The fact that 2-wheeler vehicular pollution remediation techniques do not really focus on vehicle-related factors such as the impact of vehicle characteristics such as age, mileage, emission norms, kerb weight, and ignition system.
- Few studies investigate the vehicle and engine-specific parameter effects on CO and HC idling emissions.

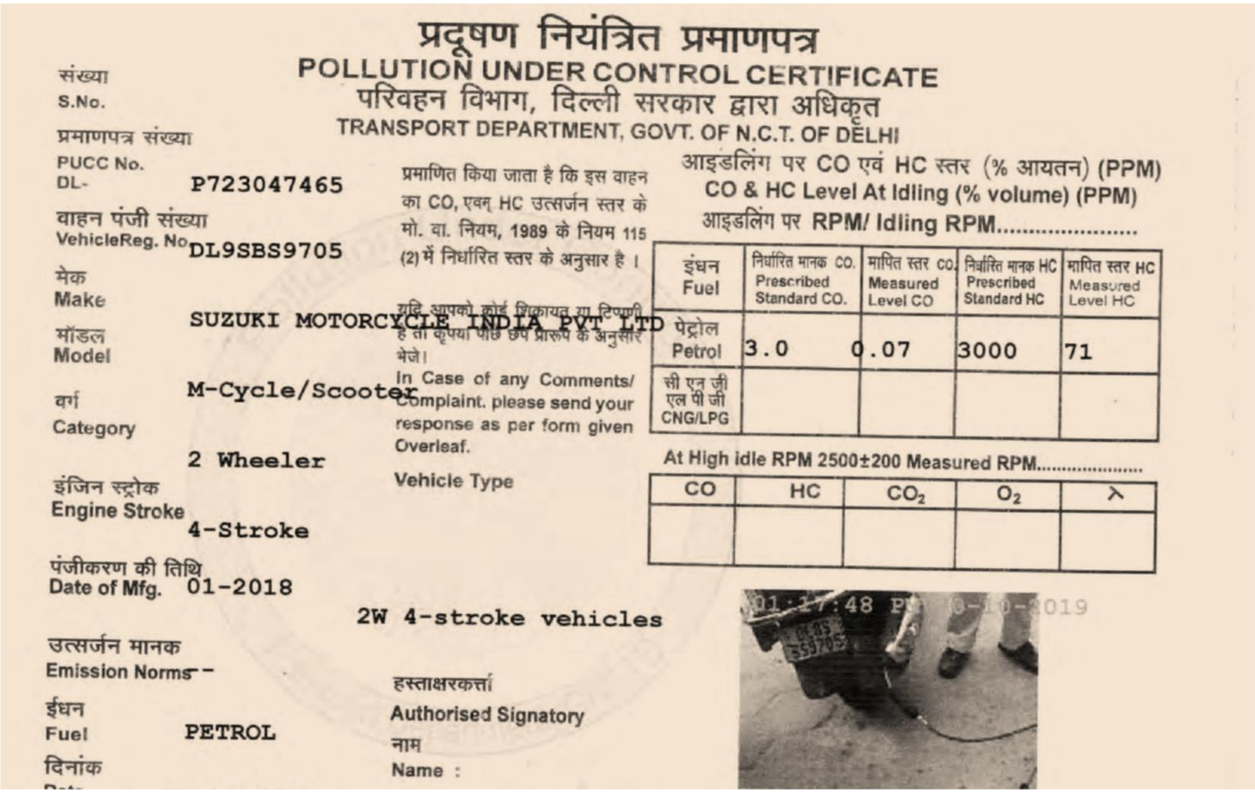
Hence, in relation to the identified research gaps, our present study may be one of the first to study the impact of vehicle parameters namely age, mileage, applicable in use emission norms and engine parameters such as kerb weight and ignition system on CO and HC idling emissions for two-wheelers. Therefore, the primary objectives of this paper included:

- Impact of vehicle specific parameters (age, mileage, and emission norms@manufacturing) on CO and HC tailpipe emissions;
- Effect of engine specific parameters (kerb weight and ignition system) on CO and HC tailpipe emissions

CHAPTER 3. MATERIALS AND METHODS

3.1 EMISSION TESTING PROGRAM -PUC CERTIFICATION

The predictor and outcome variables for the two-wheelers were gathered from the Pollution Under Control (PUC) certificates for 272 Delhi-based vehicles. A PUC certificate is proof that your two-wheeler complies with pollution guidelines. The certificate is issued by the Indian government after the emission levels of the two-wheeler have been checked. The data set only included two-wheelers from Bharat Stages (B.S.) III and IV. The two-wheelers stopped at the test platform, and their idle exhaust emissions, as well as engine and vehicle specifications, were compiled. **Fig 3.1,** below shows a typical PUC certificate for 2-wheelers that highlights essential details such as registration no., make, emission norms, measured levels of emissions of CO & HC and fuel type. For more information on the PUC certificates, refer to **Appendix 1**.


प्रदूषण नियंत्रित प्रमाणपत्र
POLLUTION UNDER CONTROL CERTIFICATE
परिवहन विभाग, दिल्ली सरकार द्वारा अधिकृत
TRANSPORT DEPARTMENT, GOVT. OF N.C.T. OF DELHI

संख्या S.No.
प्रमाणपत्र संख्या PUCC No. DL- P723047465
वाहन पंजी संख्या VehicleReg. No DL9SBS9705
मेक Make SUZUKI MOTORCYCLE INDIA PVT LTD
मॉडल Model M-Cycle/Scooter
वर्ग Category 2 Wheeler
इंजिन स्ट्रोक Engine Stroke 4-Stroke
पंजीकरण की तिथि Date of Mfg. 01-2018
उत्सर्जन मानक Emission Norms --
ईंधन Fuel PETROL
दिनांक

प्रमाणित किया जाता है कि इस वाहन का CO, एवम् HC उत्सर्जन स्तर के मो. वा. नियम, 1989 के नियम 115 (2) में निर्धारित स्तर के अनुसार है ।

यदि आपको कोई शिकायत या टिप्पणी है तो कृपया पीछे छपे प्रारूप के अनुसार भेजे।
In Case of any Comments/ Complaint. please send your response as per form given Overleaf.

Vehicle Type 2W 4-stroke vehicles

आइडलिंग पर CO एवं HC स्तर (% आयतन) (PPM)
CO & HC Level At Idling (% volume) (PPM)
आइडलिंग पर RPM/ Idling RPM......................

इंधन Fuel	निर्धारित मानक CO. Prescribed Standard CO.	मापित स्तर CO. Measured Level CO	निर्धारित मानक HC Prescribed Standard HC	मापित स्तर HC Measured Level HC
पेट्रोल Petrol	3.0	0.07	3000	71
सी एन जी एल पी जी CNG/LPG				

At High idle RPM 2500±200 Measured RPM....................

CO	HC	CO_2	O_2	λ

हस्ताक्षरकर्त्ता
Authorised Signatory
नाम
Name :

01:17:48 PM 30-10-2019

Fig 3.1 - Copy of PUC Certificate for excel data entry (Source: Transport Department, Govt. Of N.C.T. Of Delhi)

3.1.1 Procedure

The procedure for the PUC test is as illustrated in the flowchart, depicted in **Fig 3.2** on below;

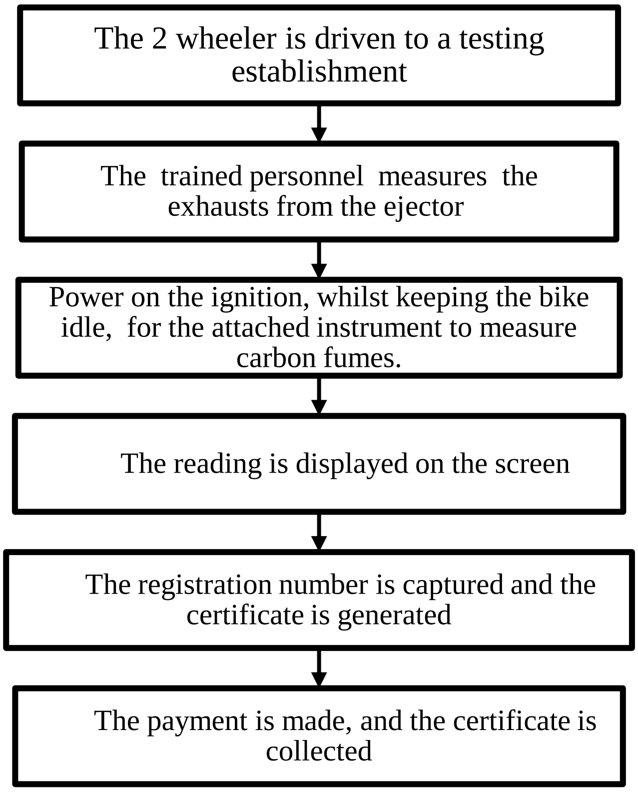


Fig 3.2– Procedure of PUC test for 2-wheelers (Source: Transport Department, Govt. of Delhi)

3.2 FIELD INSTRUMENT & DATA COLLECTION

A Di (2)-gas analyzer of Ozone make (model number Oz-Gas-02) was deployed to record the mass concentrations of tailpipe exhaust constituents from two-wheelers under the prescribed test mode. Several dependent and independent variables were compiled from the PUC certificates of different two-wheeler models. For each two-wheeler model, 16 engine-specific independent variables were studied. The independent variable comprised of vehicle-related factors such as mileage, age, and applicable in-use emission norms, in addition to engine-specific characteristics such as kerb weight, ignition type, maximum power, compression ratio, capacity, maximum torque, piston stroke, number of cylinders, cylinder bore, spark plugs, cooling system, valves per cylinder, transmission type, clutch type, and fuel delivery system. The dependent variable set included only two tailpipe emission parameters i.e., CO (%) @idling and HC (ppm) @idling. The background behind the Di (2)-gas analyzer of Ozone, including its functions, specifications and working principle is as follows.

3.2.1 About 2-Gas Analyzer

Gas analyzers are scientific instruments for measuring the quantity of a gaseous pollutant. At the PUC centres, the instruments measure the levels of CO and HC for 2-wheelers simultaneously, under idle speed, to ensure compliance with emission norms. To provide analytical findings, gas analyzers employ a wide range of sensors like electrochemical. The instrument makes most use of the Lambda coefficient model. The existence of oxygen in the emissions shows incomplete combustion. Thus, detecting these emissions may be accomplished through gauging the fraction of O_2 or O_3 . The Lambda coefficient is utilized for obtaining this calculation [112]. **Fig 3.3** below shows a 2-Gas analyzer for CO and HC, with components namely probe, cable, battery, and filter pack.

Fig 3.3 -Vehicle exhaust gas analyzer for CO/HC (Source: Bridge Analyzers Website**)**

Fig 3.4 illustrates a scooter been tested for CO and HC compliance at a refueling station.

Fig 3.4– A 2-Wheeler been tested using the 2- gas analyzer at an authorized PUC test dealer in Delhi

3.2.2 Data Collection and Entry

The raw data entered included all the valuable information from the PUC sheet like test date and registration date; the 16 vehicle and engine specific characteristics and the measured values of CO and HC. **Fig 3.5** below gives a glimpse of this raw dataset. For more information, refer to **Appendix 2**, which illustrates the raw data entries for the first 40 two- wheelers.

s.no	Manufacturing Date'	Emission Testing Date'	'Vehicle Regn. No.	Manufacturer	'Model'	Model	Applicable in-Use Emission Norm
305	Jan-14	9/28/2019	DL9SAR8148	Piaggio	M Cycle /Scooter	Piaggio BV 350 ST (2014)	BS-IV
281	Jan-06	10/12/2019	DL4SBB6170	TVS	M Cycle /Scooter	TVS Apache 150	BS-III
204	Jan-10	9/28/2019	DL4SBL8493	TVS	M Cycle /Scooter	TVS Flame (2010)	BS-III
103	Jan-13	10/20/2019	UP32FM8781	TVS	M Cycle /Scooter	TVS Star Sport 100cc 2013	BS-IV
110	Jan-14	10/6/2019	DL9SAR6866	TVS	M Cycle /Scooter	TVS Sport 100cc 2014	BS-IV
231	Jan-14	9/23/2019	DL4SBX6929	TVS	M Cycle /Scooter	TVS Star City 110cc 2014	BS-IV
273	Jan-14	9/28/2019	DL8SBH7509	TVS	M Cycle /Scooter	TVS Apache RTR 250 2014	BS-IV

Engine Capacity	Kerb Weight(Kg)	Maximum Power (bhp or HP)	Max Torque	Cylinders	Cylinder Bore (mm)	Piston Stroke (mm)
330 cc	177 kg	32.35 hpb	32.3 Nm	1	78 mm	69 mm
147.50 cc	136 kg	13.5 bhp	12.3 Nm			
124.8 cc	123 kg	10.5 Bhp	10 Nm	1	54.5 mm	53.5 mm
100 CC	109 Kg	7.40 Bhp	7.50 Nm	1		
100 CC	115 kg	7.40 Bhp	7.50 Nm	1		

n-Use Emission Norm Value		measured value		status of test (pass/fai	reason for fail	Vehicle Age (Years)	Vehicle Mileage' (KM)	Engine Capacity
3	3000	0.004	137	P		5.74	91879.45	330 cc
3.5	4500	0.013	0	P		13.79	234367.12	147.50 cc
3.5	4500	0.004	156	P		9.75	155923.29	124.8 cc
3	3000	0.008	162	P		6.80	115646.58	100 CC
3	3000	0.25	69	P		5.76	86465.75	100 CC

Fig 3.5– Raw data entry of PUC details, vehicle & engine information and levels of emission

3.3 PROPERTIES OF THE 2-WHEELERS

Due to India having a population of over a billion people as well as the necessity to decongest the road network, investment in smaller vehicles mainly two wheelers and auto-rickshaws was rampant. Thus, India is home to a diverse brand of motorcycles and scooters, suited to individual preference based on economic status, gender, road type and body morphology. India ranks just behind China in terms of global motorbike influence. Indian enterprises currently create some of the world's most recognized motorcycle brands, such as Royal Enfield, due to global partnerships, as well as substantial investments into the British and European markets. The two wheelers considered in the study were grouped in terms of 12 different brands and 2 types of emission norms (BS III and BSIV), using the Microsoft Excel summation tools.

3.3.1 Manufacturer and Emission Norms Particulars

A brief explanation of the history and reputation of the brands of two-wheelers considered in the study is as below;

1. **Honda**

Honda India Pvt. Ltd. is a division of Honda Japan, which is the globe's largest two-wheeler producer. Honda began operations in India in May 2001 and has since grown to become India's 2nd largest two -wheeler firm, with over fifty-five million happy clients [113].Recently, it launched the BS-IV compliant SP125 sports motorcycle in 2023, which has an automatic fuel injection system with less exhaust fumes.

2. **Hero-MotoCorp**

Since 2001, Hero Motocorp India has been the world's largest producer of 2-Wheelers. Over the last decade, the firm has significantly increased its research & development skills, transforming itself into a global brand. It also plays a major role in fighting environmental degradation. The centre of innovation in Jaipur, Rajasthan, is the base of Hero MotoCorp's Research, which aims to combat carbon emissions from 2- wheelers [114].

3. **Bajaj**

With over 18 million two-wheelers sold in more than 70 countries, Bajaj is 'the most popular Indian in the world'. The company is India's largest two- wheeler exporter, with two of three motorcycles sold internationally bearing the Bajaj badge. In 2023, the KTM 390 ADVENTURE with fully adjustable suspension was made [115].

4. **TVS**

TVS Motor Company, with four cutting-edge manufacturing locations in India and Indonesia, is an internationally recognized two- and three-wheeler company dedicated to developing green transportation. It produces green bikes such as the 2023 Apache RR310 [116].

5. **Royal Enfield**

Royal Enfield is in Chennai. The Royal Enfield brand is one of the world's oldest motorcycle brands. In 1901, the brand's first motorbike was manufactured. Its makes include the super-fast Hunter 350 [117].

6. **Yamaha**

Yamaha entered the Indian marketplace in 1985. The company manufactures a variety of motorbikes in India, to cater preference. Yamaha has three two-wheeler manufacturing factories and over 500 unique distributors. The YZF- R15 V3.0 is one of the most recent models to be released. It is amazing in terms of structure, efficiency, luxury, and technical features [118].

7. **Suzuki**

Suzuki Motorcycle is a division of Suzuki Motor Corporation (Japan). It produces two-wheelers most suited for precious Indian clients. Its range includes ergonomic lady type scooters like Avenis [119].

8. **Mahindra**

Mahindra and Mahindra, Inc. is part of the Mahindra Group. The company is governed by three principles: embracing zero limits, innovative reasoning, and inspiring constructive transformation. It has created a line of 2-wheelers with unique style, robust functioning, excellent mileage, and exceptional riding experience on India's difficult terrain [120].

9. **Kinetic Motor**

The Kinetic Group, with its cornerstone firm Kinetic Engineering, was created by inspirational businessman, Deceased Firodia. The company continually strives to be a consistent champion in industry and society by continuous creativity. Among its bikes included the Kinetic Blazer and Zing 80 [121].

10. **Piaggio**

Piaggio Vehicles began its activities in India in 1999 following the introduction of the Apé. Apé was an immediate triumph because it was equipped and constructed for greater fuel economy, tough performance, and remarkable weight capability. With unrivalled client service, revolutionary goods and several accolades to its name, it keeps pushing ahead. Among its revolutionary two wheelers include the electric ape [122]

11. LML

The LML Select debuted in 1993, with advanced features and visual appeal, and it was an instant hit. The LML-Piaggio partnership was dissolved in 1999. The Star, a traditionally designed steel-bodied scooter, was still made by LML.

Table 3.1 - % Share of 2-wheelers according to make

Manufacturer	**Share (%)**
1. Honda	30.51
2. Hero MotoCorp	19.12
3. Bajaj	16.18
4. TVS	11. 76
5. Royal Enfield	7.35
6. Hero	6.62
7. Yamaha	4.41
8. Suzuki	1.83
9. Mahindra	1.10
10. Kinetic Motor	0.37
11. Piaggio	0.37
12. LML	0.37

Table 3.1 above illustrates the % share of the two- wheelers according to brand. In terms of number, 83 were Honda make; 52 were Hero - Motocorp; 44 were Bajaj; 32 were TVS; 20 were Royal Enfield; 18 were Hero; 12 were Yamaha; 5 were Suzuki; 3 were Mahindra; lastly 1 each of Kinetic Motor, Piaggio and LML make.

Table 3.2 - % Share of 2 wheelers based on emission norms

Emission Norm	**Share (%)**
B.S IV	71.59
B.S III	28.41

Even though BS6 emission norms have been introduced for 2- wheelers, the majority of scooters and motorcycles are still BS3 and 4 compliant. **Table 3.2** above shows that among the 272 two-wheelers considered in the study, majority (195) are BS IV complaint, whilst 77 are BS III compliant. Brief explanation of BS III and IV is provided in the following paragraphs.

1. **Bharat Stage III (BS III)**

In 2010, the government made BS-III, also known as Euro 3 standards, mandatory. According to BSIII, the permitted amount of HC is 4500 ppm, whilst for CO is 3.5 %, for two-wheelers during a PUC test. It additionally capped the sulphur level of gasoline to 100 ppm. BSIII also included the installation of a catalytic converter to manage emissions [104].

2. **Bharat Stage IV (BS IV)**

India finalized the 4th phase of emission regulations for two-wheelers in 2014. In 2017, the (BS) IV specifications for motorbike models were adopted. The standards reduced $HC+NO_X$ emission limits by 23% - 60% in comparison to the old BS III norms, based on motorbike type. For PUC test purposes, the limit for HC is 3000 PPM and 3.0 % @ idling for CO [105]

3.4 VEHICLE SPECIFIC CHARACTERISTIC

Several vehicle specific characteristics affect the function of a motorcycle in ways such as the level of exhaust fumes and the ability to propel easily. Regarding type of fuel, according to fuel catalyst website blog on emissions from diesel and gasoline; The difference between petrol and diesel exhaust is assessed by taking into consideration fuel efficiency, formulation, and ignition features. Petrol vehicles emit at least 40% more CO_2 than diesel. Petrol automobiles also emit higher HC pollutants. Diesel vehicles generate more nitrous and SOx, in addition to more PM [123].But in this case, fuel is ruled out as all two-wheelers were using gasoline. According to Zachariadis et al. understanding the aging impact on exhaust fumes is particularly essential in developing nations when the fleet consists primarily of used and poorly maintained motorbikes [124]. The International Council on Clean Transportation (ICCT) 2017 fact sheet on footprint vs mass, concluded that because of the close connection between weight and mass, the bulkier a bike is, the higher its use of fuel and greenhouse gas emissions will be. Reduced weight is an efficient approach to minimise vehicular pollution. Yet the existing EU CO_2 goal structure provides minimal rewards to reduce automobile size: the smaller the supplier's fleet, the more achievable its allocated carbon dioxide target [125].

Table 3.3 - Distribution of 2 wheelers according to vehicle specifications

Item	**Particulars**
Number of 2 Wheelers	272
Fuel Type	All Petrol
Average Vehicle Age (Years)	5.80
Range of Vehicle Age (Years)	0.81 – 14.90
Newest / Oldest Vehicle Make Tested	Radeon TVS/ Kinetic Hero Motocorp
Average Mileage (km)	92851.22
Lowest / Highest Mileage Vehicle Tested	Hero Xtreme 160R / Honda CB 1300 (2005-06)
Kerb Weight Range (kg)	82.00 - 410.00

Table 3.3 above shows the properties of the two -wheeler dataset namely number, type of fuel, average age, range of age, newest or oldest vehicle tested, average mileage, lowest or highest mileage and the kerb weight range. A highlight of the information is as follows:

- The sample set considered is 272;
- All the 2-wheelers are powered by gasoline. According to TVS website, even though electric two -wheelers have been introduced, it simply shows majority can only afford the gasoline driven motorbikes in Delhi [126].
- The average age of the vehicles is 5.8 years. This figure is great as the phasing out policy for vehicles in India is set at 15 years. This shows that most of the 2 – wheeler owners are abiding with the regulations. The range of the ages of the two-wheelers is from 0.81 to 14.90 years; which is still within policy limits.

- The newest vehicle in terms of age was Radeon TVS, whilst the oldest was Kinetic Hero Motocorp. The TVS Radeon is a gasoline consumption efficient bike that is available in three models. The starting price is usually 80, 000 rupees, as it is BS6 limits compliant.
- With regards to mileage, the average mileage is 92851.22 km. The vehicle with the lowest mileage was Hero Xtreme 160R; whilst the vehicle with the highest mileage was Honda CB 1300 (2005-06).
- The kerb weight ranged from 82.00 - 410.00 kg. Motorbikes typically weigh 275 kg. Some varieties are bulkier, according to the material composition. Each style of motorcycle has a certain role. A dirt bike must be slim and nimble in order to navigate dirty tracks with ease. This works well if the vehicle is tiny. A touring bike is designed to have extra storage for a stereo, hot grips and a large windscreen [127].

3.5 ENGINE SPECIFIC CHARACTERISTICS

Engine effectiveness can frequently be measured by the operational behavior such as pollutants, gasoline use, sound, mechanics and thermo loads. Concerning engine capacity of a motorbike; the bigger the engine's dimensions, the more gasoline and air intake. Bigger engines, in general, consume more petrol and release more pollutants than normal-sized ones [128]. Engine torque enables a motorcycle to increase its velocity. It is simply revolving force. Torque is significantly correlated with speed in a positive way. In terms of fuel consumption, the lower the torque, the more efficient the use of petrol [129].

Table 3.4 - Engine- based properties of the 2-wheelers

Item	**Particulars**
Capacity Range (CC)	71 – 1832
Maximum Torque Range (Nm)	5.00 – 5000.00
Maximum Power Range(bhp)	3.00 – 197.26
Cylinder Bore Range (mm)	47.00- 100.00
Piston Bore Range (mm)	41.40 – 90.00
Number of Cylinders	1 -6
Valves per Cylinder	2 -16

Table 3.4 above gives information on the engine specifications of the dataset, such as capacity range, torque range, power range, cylinder bore range, piston bore range, number of cylinders and valves per cylinder. The following paragraphs highlight further these specifications.

1. **Capacity Range**

The capacity of the data ranged from 71 CC to 1832 CC. As explained on Bajaj Allianz website, the power generated by the bike's engine is measured in cubic capacity (CC). It is the amount of space in the engine chamber. The bigger the volume, the more air and fuel combination is needed to create power. This increased compaction of the air-fuel combination leads to increased power production. It ranges from 50 CC to 1800 CC on certain sports bikes. It determines horsepower and the miles travelled [130].

2. **Maximum Torque Range (Nm)**

The torque for the dataset ranged from 5.00 Nm to 5000.00 Nm. According to Bajaj auto finance website, torque is just the rotating force at the axles. In simple terms, it refers to the magnitude of rotational power that can be applied to the wheels. The lower it is, the quicker a bike moves [131].

3. **Maximum Power**

The power for the dataset ranged from 3.00 bhp to 197.26 bhp. According to bike media website blog in 2018, power is the engine's ability to propel the motorbike towards the highest possible speed [132].

4. **Cylinder Bore**

The cylinder bore ranged from 47. 00 mm to 100.00 mm. In simple terms, the bore is the diameter. A cylinder having a bore of 160 mm is 160 mm broad.

5. **Piston Bore Range**

The bore of the piston ranged from 41.40 mm to 90.00 mm. The bore is the circumference of the topmost part of the piston, instrumental in propelling the air and fuel mixing. The greater it is, the larger the circumference of the piston.

6. **Number of Cylinder**

The total number of cylinders ranged from 1 to 6. Most bikes have a single cylinder engine; however, they may possess up to six. In India, about 90 % of bikes have one cylinder.

7. **Valves Per Cylinder**

The total number of valves ranged from 2 to 16. To boost performance, an engine contains more than two valves per cylinder. Any engine requires no fewer than two valves: one for the inflow of air and the other for emitting exhaust.

3.5.1 Engine Ignition System Distribution

The ignition system's function is to ignite the gas-air combination. The ignition system comprises of spark plugs, igniting coil and plug wires [133]. The primary benefit of Capacitor Discharge Ignition (CDI) is that the capacitor may be completely recharged in less than a second of time. The major disadvantage is the limited spark period is not suitable for igniting lean combinations when utilized at minimal power settings [134]. Advantages of the Fully Transistorized Ignition system include the fact that the contact points are durable; generation of high voltage and longer timeframe of sparks. One disadvantage is that it requires a lot of mechanical spots [135].One of the advantages of an Engine Control Unit includes the fact that the technology is green; it emits fewer pollutants than other techniques. It improves engine performance and saves gasoline. The main disadvantage is motorcycles with this system are costly [136]. Inductive Discharge Ignition was invented in the nineteenth century to ignite the air-fuel combination in combustion chambers. The initial prototypes were low-tensile coils, and later high-tension magnetos, which were marketed as a more efficient replacement to the older heated-tube ignitors [137]. Advanced Microprocessor Ignition (AMI) is a technologically advanced system of ignition for motorbikes. The mechanism connects the sensor array to the throttle. Its purpose is to automatically regulate the spark progress. As a result, it differs from the manual regulation of the spark [138]. Kickstart ignition is achieved by repeatedly kicking a foot pedal to rotate the crankshaft's cranks. One advantage is that it is cost effective in comparison to other systems. The disadvantage is it is physically exhaustive as the legs get sore due to stepping on the pedal [139]. A magneto system is an older ignition technology utilized in gasoline engines. It employs a magneto and a converter to produce high-voltage pulses for the spark plugs to activate [140].

Table 3.5 - % Share of 2-wheelers based on type of ignition system

Engine Ignition System	**Share (%)**
Capacitor Discharge Ignition	40.07
Fully Transistorized Ignition	25.37
Engine Control Unit Ignition	9.93

Inductive Discharge Ignition	9.91
Advanced Microprocessor Ignition	8.82
Kick Start Ignition	6.25
Flywheel Magneto Ignition	0.37

Table 3.5 above shows the share of the two-wheeler dataset according to the type of ignition applied in the engine. 109 of the datasets used capacitor discharge; 69 were of fully transistorized system; 27 utilized engine control unit; 27 also utilized inductive discharge type; 24 were of advanced microprocessor type; 17 were of kick start ignition type and 1 was of flywheel ignition type.

3.5.2 Engine Cooling System Distribution

Air-Cooled Engines are one of the common technological advances in Indian motorcycles. For engine cooling, they utilize air for cooling. Air cooled engines are affordable and cheap in terms of manufacturing. However, the technologies are not efficient. Oil-cooled engines preserve the viscosity of oil by running at the right temperature. These are more efficient than air cooling, whilst one disadvantage is not as efficient as liquid cooling. High-capacity motorcycles employ liquid-cooled engines as it provides reliable efficiency even in rush hour traffic. This is the most efficient of all the types but expensive [141].

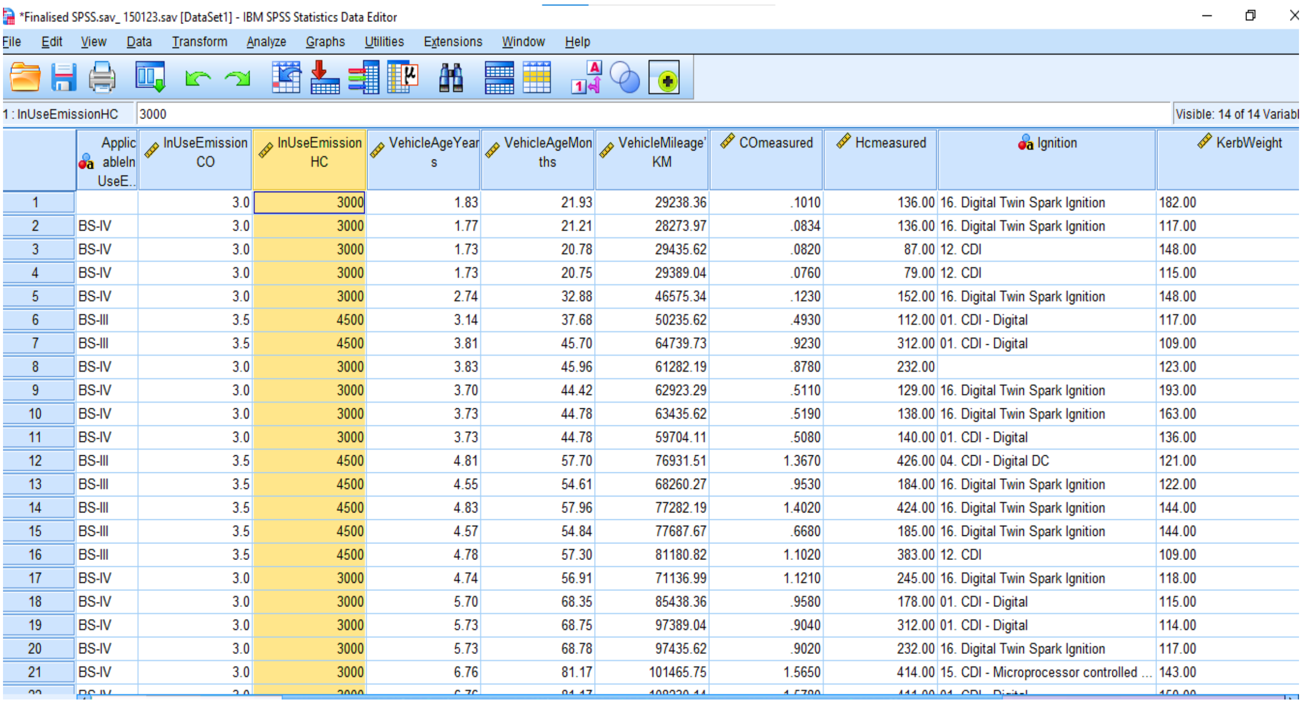
Table 3.6- % Share of 2-wheelers based on type of engine cooling system

Engine Cooling System	**Share (%)**
Air Cooling	70.48
Liquid Cooled	27.31
Oil Cooling	2.21

Table 3.6 above illustrates that 70.48% of the bikes utilize air cooling technology as these are cheaper, whilst a considerable percentage of 27.31 utilize liquid cooling, which is very efficient.

3.6 DATA EVALUATION TOOLS

IBM SPSS Statistics (version 26) was used for data evaluation, considering the enormous dataset, the number of variables gathered during the PUC testing procedure and the research objectives. In addition, the MS Excel tool was also used for quick data processing, namely calculating age and mileage, as well as investigating and entering engine-related characteristics for each unique 2-wheeler. **Fig 3.6** illustrates briefly the cleaning of the data in SPSS. For more information on the data processed, refer to **Appendix 3**.



	ApplicableInUseE..	InUseEmissionCO	InUseEmissionHC	VehicleAgeYears	VehicleAgeMonths	VehicleMileage'KM	COmeasured	Hcmeasured	Ignition	KerbWeight
1		3.0	3000	1.83	21.93	29238.36	.1010	136.00	16. Digital Twin Spark Ignition	182.00
2	BS-IV	3.0	3000	1.77	21.21	28273.97	.0834	136.00	16. Digital Twin Spark Ignition	117.00
3	BS-IV	3.0	3000	1.73	20.78	29435.62	.0820	87.00	12. CDI	148.00
4	BS-IV	3.0	3000	1.73	20.75	29389.04	.0760	79.00	12. CDI	115.00
5	BS-IV	3.0	3000	2.74	32.88	46575.34	.1230	152.00	16. Digital Twin Spark Ignition	148.00
6	BS-III	3.5	4500	3.14	37.68	50235.62	.4930	112.00	01. CDI - Digital	117.00
7	BS-III	3.5	4500	3.81	45.70	64739.73	.9230	312.00	01. CDI - Digital	109.00
8	BS-IV	3.0	3000	3.83	45.96	61282.19	.8780	232.00		123.00
9	BS-IV	3.0	3000	3.70	44.42	62923.29	.5110	129.00	16. Digital Twin Spark Ignition	193.00
10	BS-IV	3.0	3000	3.73	44.78	63435.62	.5190	138.00	16. Digital Twin Spark Ignition	163.00
11	BS-IV	3.0	3000	3.73	44.78	59704.11	.5080	140.00	01. CDI - Digital	136.00
12	BS-III	3.5	4500	4.81	57.70	76931.51	1.3670	426.00	04. CDI - Digital DC	121.00
13	BS-III	3.5	4500	4.55	54.61	68260.27	.9530	184.00	16. Digital Twin Spark Ignition	122.00
14	BS-III	3.5	4500	4.83	57.96	77282.19	1.4020	424.00	16. Digital Twin Spark Ignition	144.00
15	BS-III	3.5	4500	4.57	54.84	77687.67	.6680	185.00	16. Digital Twin Spark Ignition	144.00
16	BS-III	3.5	4500	4.78	57.30	81180.82	1.1020	383.00	12. CDI	109.00
17	BS-IV	3.0	3000	4.74	56.91	71136.99	1.1210	245.00	16. Digital Twin Spark Ignition	118.00
18	BS-IV	3.0	3000	5.70	68.35	85438.36	.9580	178.00	01. CDI - Digital	115.00
19	BS-IV	3.0	3000	5.73	68.75	97389.04	.9040	312.00	01. CDI - Digital	114.00
20	BS-IV	3.0	3000	5.73	68.78	97435.62	.9020	232.00	16. Digital Twin Spark Ignition	117.00
21	BS-IV	3.0	3000	6.76	81.17	101465.75	1.5650	414.00	15. CDI - Microprocessor controlled ...	143.00

Fig 3.6-Data cleaning of 2-wheeler engine and vehicle information in SPSS software for analysis

3.6.1 Bivariate Regression – Curve Estimation

Regression is used to determine how much one or more predictor factors influence an outcome variable. It assists in the prediction of an outcome variable's value based on any number of predictor factors. It forecasts how much change predictor factors produce in an outcome variable. Bivariate and multivariate regression are the two basic forms, although in this case, bivariate regression was employed to analyze the influence of vehicle-specific characteristics on the exhaust emissions. Bivariate regression examines the connection between one resultant variable and one predictor variable. In this case, logarithmic type of curve estimation was used. The steps for the regression were as illustrated in the **Fig 3.7** below. For step 1 of the flowchart, refer to **Appendix 4,** which shows the data qualifying process. For Step 2, refer to **Appendix 5**, for illustration of scatter plot.

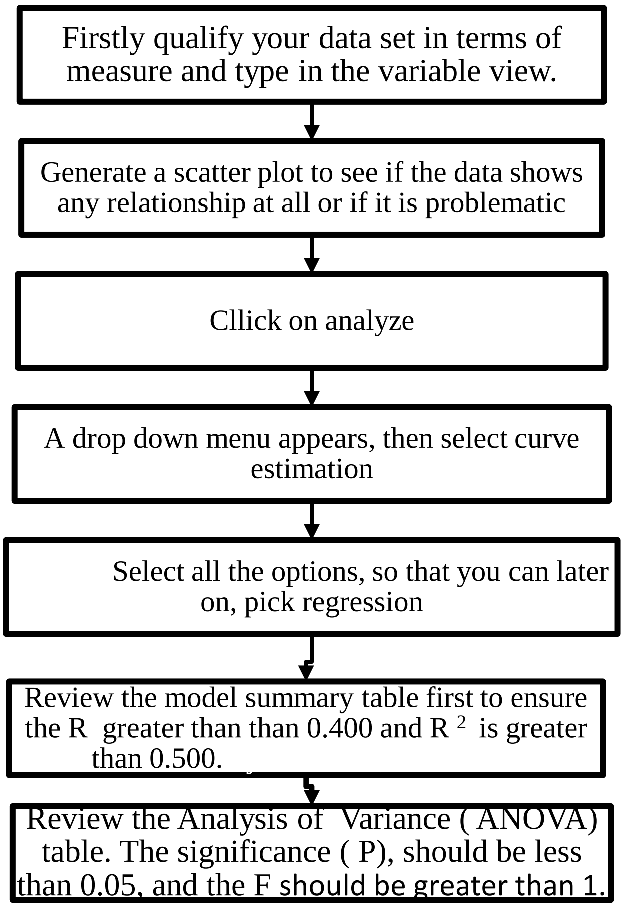


Fig 3.7 – Flowchart of SPSS regression

There were different types of curve estimation used, namely linear, loess, quadratic, cubic and logarithmic**. Fig 3.8, 3.9**, **3.10**, **3.11** and 3.12 illustrate these types of curves below;

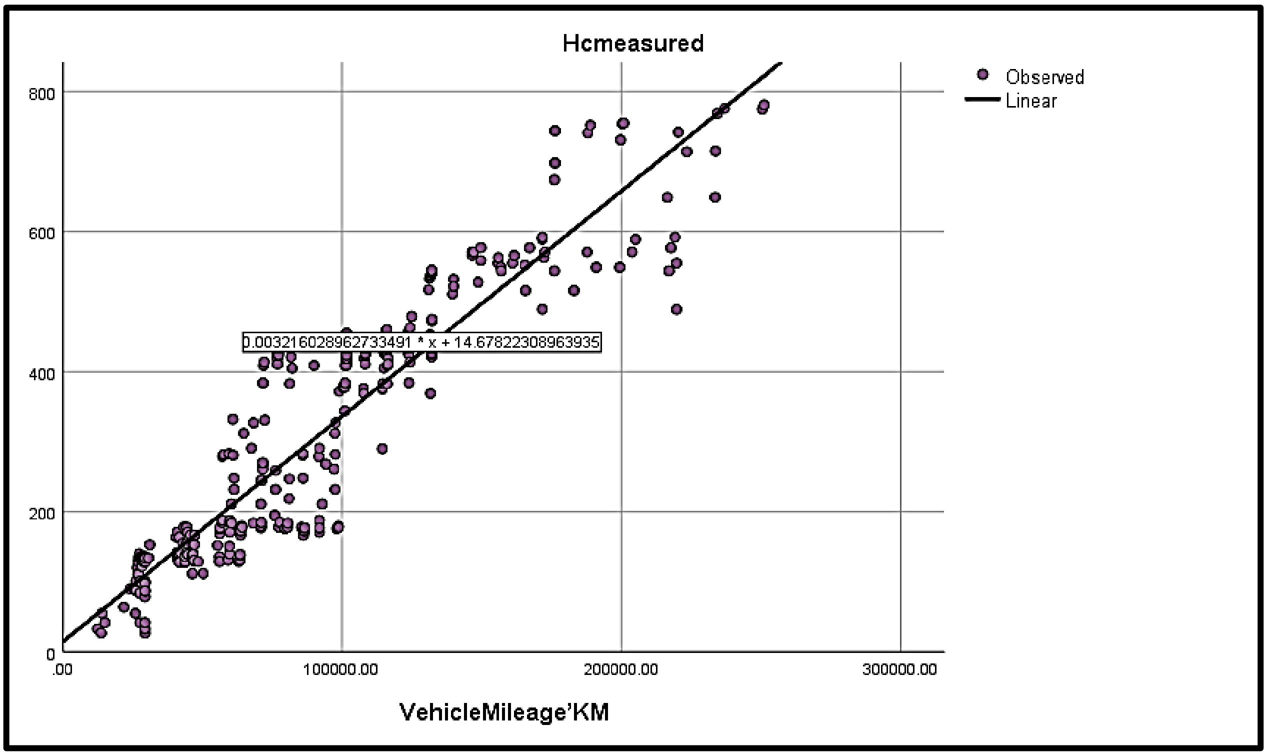


Fig 3.8 - Illustration of Linear Curve Estimation

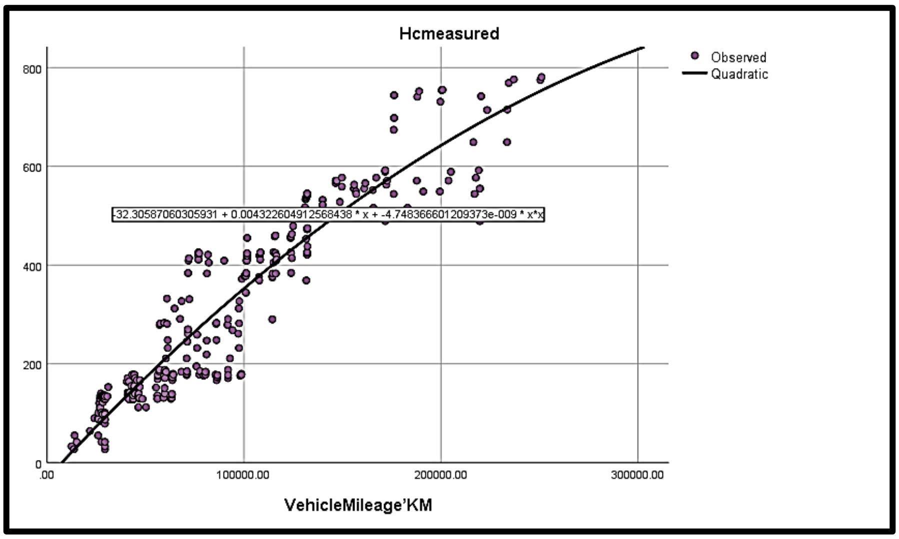


Fig 3.9– Illustration of quadratic curve estimation

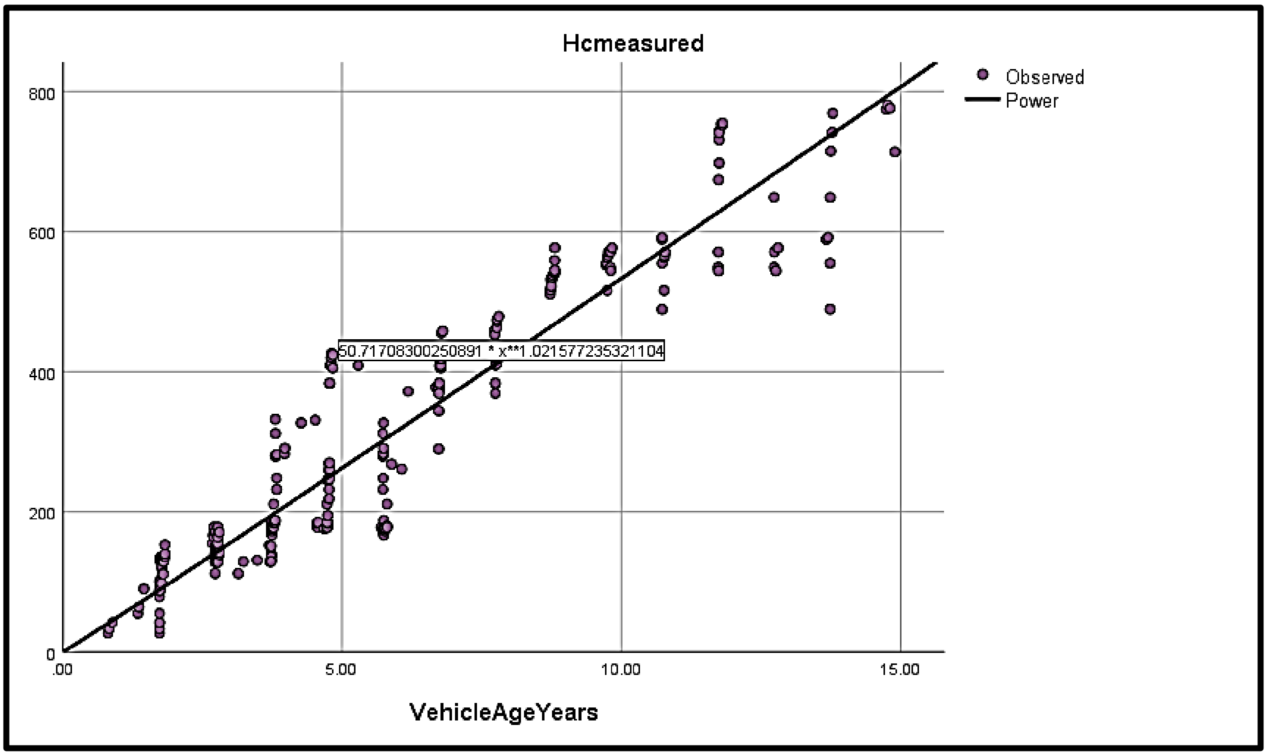


Fig 3.10 – Illustration of power curve estimation

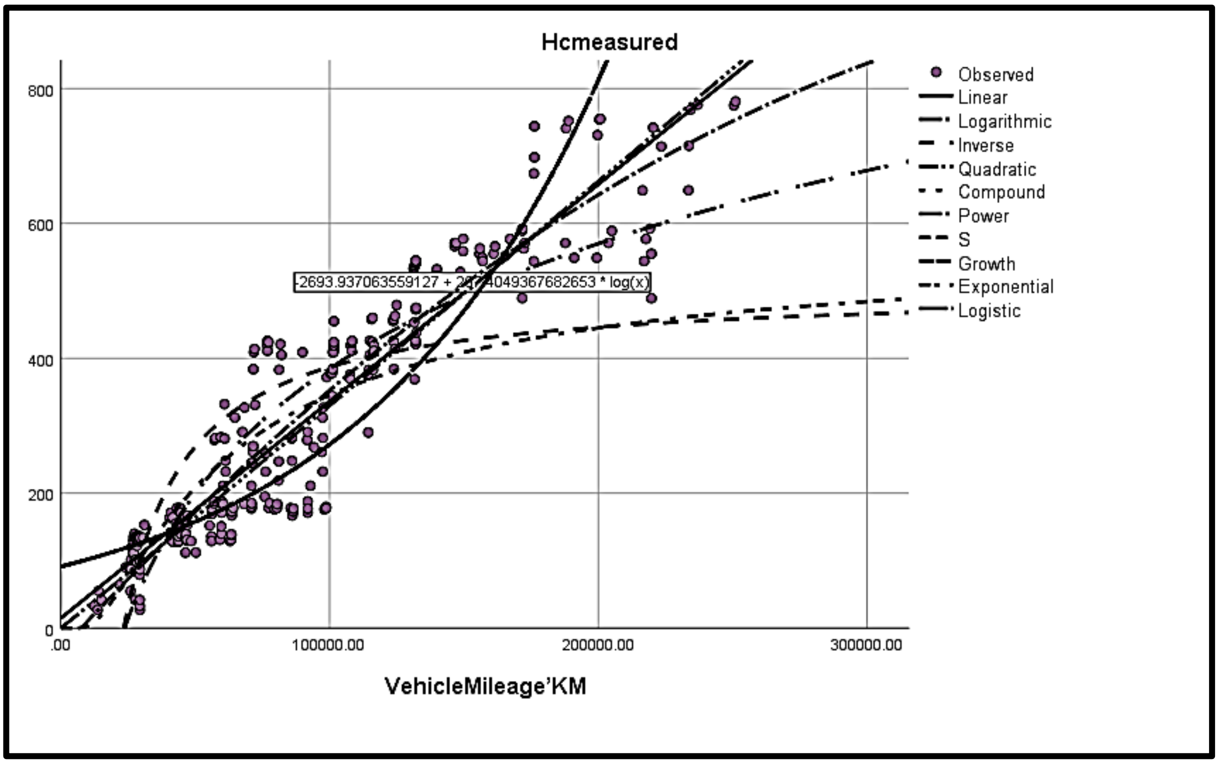


Fig 3.11 – Illustration of all the types of curve estimations

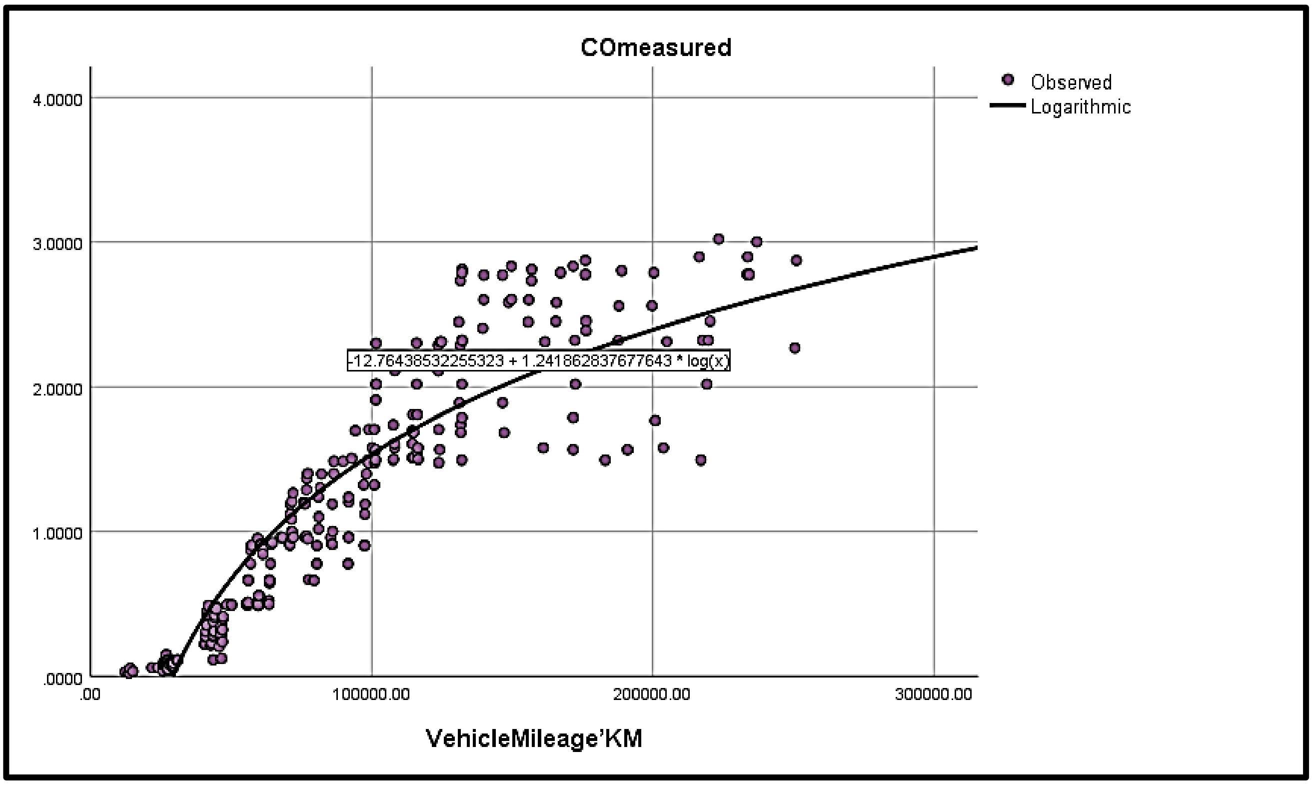


Fig 3.12 – Illustration of logarithmic curve estimation

3.6.2 Box Plot Technique

To analyses the effect of kerb weight and ignition technology, the box plot type of analysis was utilized. A boxplot is a method of graphically presenting a distribution of the numerical information utilizing the 5 summaries" - the lowest value, 1st quartile, median of all values, 3rd quartile, and highest value. It will also identify any anomalies in the information. The steps of analyzing through a box plot as illustrated in **Fig 3.14** on next page**. Fig 3.13** below shows a picture of a box plot.

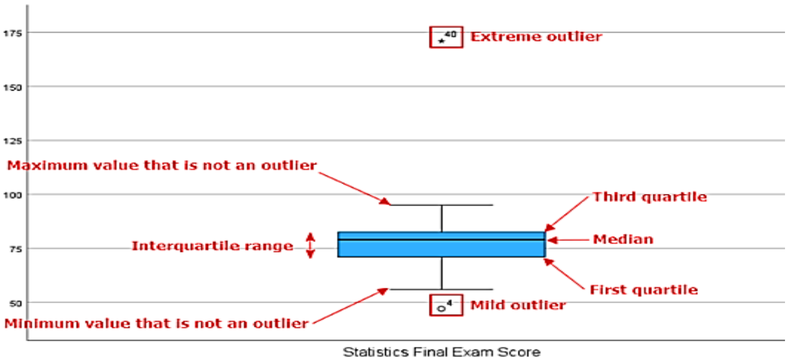


Fig 3.13 – A typical box plot

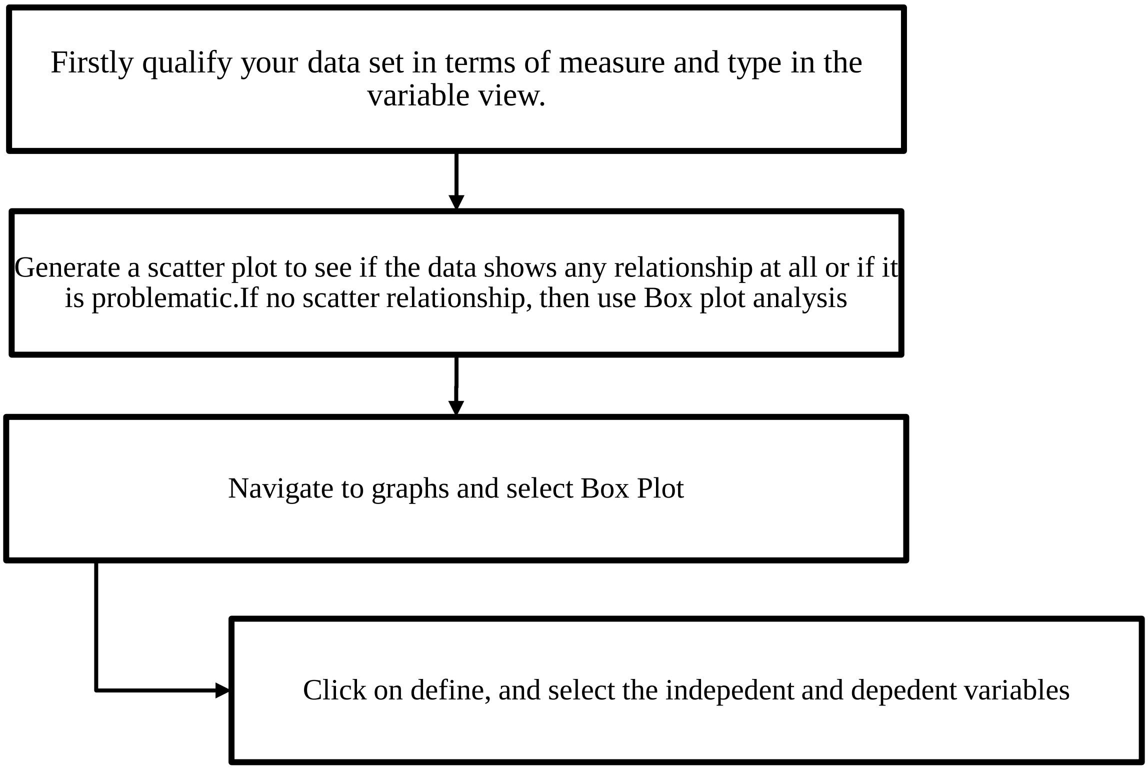


Fig 3.14 – Steps of creating a box plot in SPSS

CHAPTER 4. RESULTS AND DISCUSSION

4.1 OVERVIEW

Based on the sample size, n = 272 two-wheelers, the influence of each independent vehicle-specific parameter (age, mileage and emission standards) and engine-specific parameter (kerb weight and ignition system) on the exhaust emissions of CO and HC was examined. The influence of age and mileage on CO and HC was investigated through logarithmic curve estimation regression. Age and mileage were predictor variables in this case, while CO and HC were outcome variables. The influence was accessed in terms of model's characteristic, the variance caused in the result, the significance level of the model to predict the result, and finally the efficiency. The effects of emission standards, kerb weight and ignition system on the CO and HC were analyzed using box plots. The results, interpretations and recommendations are explained in the following sections.

4.2 VEHICLE AGE EFFECT ON CO AND HC EMISSIONS

The usage of old automobiles may result in higher levels of airborne contaminants. Numerous investigations have found that the emissions of motorbikes increase with ageing. Due to poor maintenance and outdated equipment, aged automobiles usually release more pollutants. In Taiwan, outdated hazardous motorcycles are easier to see, but very little study has been conducted to determine if local inspection and maintenance rules have any effect on the motorbike age disparities in Taiwan. Countries with inadequately administered programmes could allow obsolete bikes to continue operating, exacerbating the pollution crisis [142, 143]. A 2015 study in Tehran investigated the CO emission rates for sixty 2-wheelers using the chassis dynamometer certification program. Through the stoichiometric excel spreadsheet, more than 35% of the vehicles indicated incomplete combustion, resulting in carbon emissions [13].A 2010 study in Taiwan assessed the impact of direct and indirect variables on exhaust fumes from motorcycles and fumes. It discovered that old bikes with tiny engines, mechanical transmissions, huge aggregate mileages were releasing high CO and HC fumes [41].

4.2.1 Assessment of Effect of Age on CO Levels

Several studies have assessed the effect of 2-wheeler age on CO exhausts, using methods such as the chassis dynamometer and real-world driving tests. Very few or none have tried to interpret these results using the SPSS bivariate curve estimation regression. Akin to the aforementioned studies; in order to assess whether age has an impact on the level of CO emissions, a logarithmic curve estimation regression was run on the two variables, age as predictor variable and CO as the outcome variable. The logarithmic curve fit accurately illustrates the emission characteristics, as depicted in **Fig 4.1**, where the model is described by the equation, $-0.771 + 1.257^{*}\text{Log}(X)$. in this equation, X denotes the predictor variable, which is age in this case, 1.257 is the unstandardized B coefficient (not important here as it is bivariate regression) and -0.771 is the constant. **Tables 4.1**, **4.2** and **4.3**, illustrate specific attributes of the regression namely characteristics of the model, variance, confidence level as well as efficiency

Table 4.1 - Model summary – characteristics of the model

Regression Aspect	**Value / Particulars**
Hypothesis	Significant impact of age on levels of CO
Regression Weights	Vehicle Age (Years)→ CO@ Idling (%)
Equation	$-0.771 + 1.257^{*}\text{Log}(X)$
R	0.920
R^2	0.846
Hypothesis Supported	Yes

Table 4.1 above stipulates information on the model's characteristics. To begin with, the R value of 0.920 fulfils the criteria > 0.400, indicating that it is an optimal value for the model. R here signifies a value that symbolizes the correlation between the outcome variable and the predictor variable. In addition, the R^2 value of 0.846, is greater than 0.5, indicating that it is adequate to convey the change in CO emission levels induced by age. This means out of 100% change in CO levels, 84.6 % is associated with age. R^2 here refers to a value that indicates the amount of variance induced by the predictor variable in the outcome variable.

Table 4.2- Analysis of variance (ANOVA) table – estimation of significance level of model

	dF	**F**	**Significance(P)**
Regression	1	1485.463	0.000
Residual	270		
Total	271		

The ANOVA, that is Analysis of variance (depicted in **Table 4.2**) determines the model's level of relevance in predicting the outcome variable. As illustrated in the **Table 4.2** above, the significance (P) is 0.000, which is less than 0.05, hence there is significant correlation between the age and CO. The significance (P) here is a value that determines the confidence level of the model, and it should be less than 0.05. Also, the F value of 1485.463, is beyond 1, as a result demonstrating an extremely effective model. F here denotes an improvement in variable projection achieved by fitting the model after accounting for the error. A value greater than 1 suggests an efficient F-ratio yield model.

Table 4.3 – Coefficients table – estimation of magnitude of impact of age on CO

	Unstandardized Coefficients	**Standardized Coefficients**	
	B	**Beta (β)**	**Sig.**
ln (Vehicle Age)	1.257	0.920	0.000
(Constant)	-.771		0.000

The coefficients table (**Table 4.3** above) illustrates the intensity of the relationship; the variable's significance in the model and the magnitude with which it influences the outcome variable. The most important coefficients in **Table 4.3 are** the standardized Beta (β) and significance (P). Beta **(β)** here means a number that compares the magnitude of effects of predictors measured, be it positive or negative, increasing or decreasing. (β) is 0.920, so a change in age by 1.000 unit will bring out a change in CO by 0.920 units. The value is positive, meaning the relationship is that of increasing; if age increases by 1.000 unit, the CO levels increase by 0.920 units.

This hypothesis is supported by several past investigations, which also allude reasons for this. One such study carried out in New Delhi, India by Pandey etal. on a large dataset of 1580 cars, clearly illustrated that the age has a direct and strong influence on the tailpipe CO Idle emissions, with the regression R^2 for CO idle = 0.88 [80]. Lin et al. determined the effect of engine capacity, engine age and mileage on CO and HC of 2-wheelers from 1996 - 2002.CO and HC levels correlated positively with age; nevertheless, since there were few old bikes, the cumulative amount was not so much [42]. A study in Douala city of Cameroon investigated the impact of two- wheelers on pollution at an intersection. It concluded the positive correlation of CO and NO_2 , with age and number of vehicles [144]. Chen et al. examined the effects of motorcycle aging and mileage on pollution form 2-wheelers. The study correlated the inability to abide to the emission norms of CO and HC due to accumulation of ageing and mileage. It also observed that older motorbikes had high failure rates of engine and emission treatment systems [98]. Supporting this observation was a study also conducted in India on a Maruti Wagon R gasoline vehicle by Bindra & Vashist [145]. The study concluded improvement in CO emission levels for 2018 models compared to 2001 models, under warm idling conditions.The researchers concluded newer models were in great condition due to less ageing and improved emission control technologies. A study in The Pandey, Mishra, & Pandey allude non -compliance to CO emission norms as lack of efficient phasing out guidelines [80]. The strong influence of age on CO exhaust emissions can be attributed to the fact that as a vehicle ages, the ignition system becomes less efficient, or older cars may have outdated versions of ignition systems compared to modern vehicles. Also, as a vehicle ages, the emission control system becomes unreliable, and newer cars have better emission controls such as exhaust gas recirculation systems and evaporative emission control systems. Carbon monoxide is a byproduct of incomplete combustion, in which the ignition mechanism consumes less oxygen to fuel mass ratio, resulting in unbalanced stoichiometric ratio for a complete reaction. a large dataset of 1580 cars, clearly illustrated that the age has a direct and strong influence on the tailpipe CO Idle emissions, with the regression R^2 for CO idle = 0.88 [80]. Lin et al. determined the effect of engine capacity, engine age and mileage on CO and HC of 2-wheelers from 1996 - 2002.CO and HC levels correlated positively with age; nevertheless, since there were few old bikes, the cumulative amount was not so much [42]. A study in Douala city of Cameroon investigated the impact of two- wheelers on pollution at an intersection. It concluded the positive correlation of CO and NO_2 , with age and number of vehicles [144]. Chen et al. examined the effects of motorcycle aging and mileage on pollution form 2-wheelers. The study correlated the inability to abide to the emission norms of CO and HC due to accumulation of ageing and mileage. It also observed that older motorbikes had high failure rates of engine and emission treatment systems [98]. Supporting this observation was a study also conducted in India on a Maruti Wagon R gasoline vehicle by Bindra & Vashist [145]. The study concluded improvement in CO emission levels for 2018 models compared to 2001 models, under warm idling conditions.The researchers concluded newer models were in great condition due to less ageing and improved emission control technologies. A study in The Pandey, Mishra, & Pandey allude non -compliance to CO emission norms as lack of efficient phasing out guidelines [80]. The strong influence of age on CO exhaust emissions can be attributed to the fact that as a vehicle ages, the ignition system becomes less efficient, or older cars may have outdated versions of ignition systems compared to modern vehicles. Also, as a vehicle ages, the emission control system becomes unreliable, and newer cars have better emission controls such as exhaust gas recirculation systems and evaporative emission control systems. Carbon monoxide is a byproduct of incomplete combustion, in which the ignition mechanism consumes less oxygen to fuel mass ratio, resulting in unbalanced stoichiometric ratio for a complete reaction.

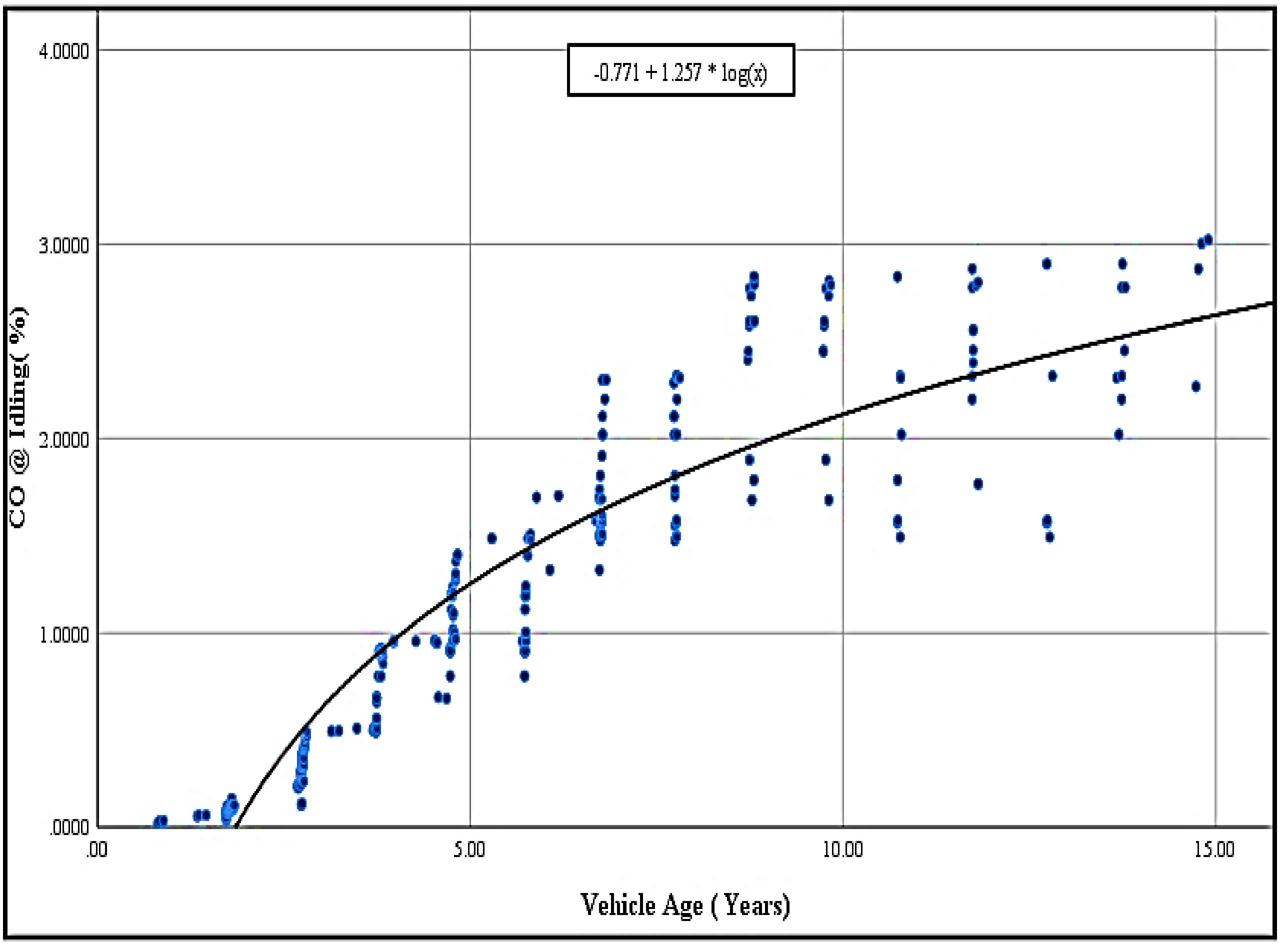


Fig 4.1- Regression of CO on age through logarithmic curve estimation

4.2.2 Assessment of Effect of Age on HC Levels

The logarithmic curve accurately depicts the emission characteristics for the parameter as shown in **Fig 4.2** below.

Table 4.4- Model summary – characteristics of the model

Regression Aspect	**Value / Particulars**
Hypothesis	Significant impact of age on levels of HC
Regression Weights	Vehicle Age (Years)→ HC @ idling (ppm)
Equation	-111.689 + 270.854 * Log (X)
R	0.903

R^2	0.815
Hypothesis Supported	Yes

From **Table 4.4** above, the (R) value of 0.903 is greater than 0.400, hence it is a satisfactory value for the model. Also, the (R^2) of 0.815 is greater than 0.5, hence it efficiently depicts the change caused in HC emission levels caused by age. This suggests that age is responsible for 81.5% of the change in HC levels.

Table 4.5- Analysis of variance (ANOVA) table – estimation of significance level of model

	dF	F	Significance (P)
Regression	1	1194.522	0.000
Residual	270		
Total	271		

From **Table 4.5** above, (P) is 0.000, which is less than 0.05, hence age and HC exhaust emissions have a significant relation. Also, the F value of 1194.522, is beyond 1, hence proving a coherent model.

Table 4.6– Coefficients table – estimation of magnitude of impact of age on HC

	Unstandardized Coefficients	Standardized Coefficients	
	B	**Beta (β)**	**Sig.**
ln (Vehicle Age)	270.854	0.903	0.000
(Constant)	-111.689		0.000

As illustrated in **Table 4.6**, β is 0.903, so a change in age by 1.000 unit will bring out a change in HC by 0.903 units. The value is positive, meaning if age rises by 1.000 unit, the HC levels rise by 0.903 units. Overall, based on **Table 4.4,4.5** and **4.6**, the hypothesis is true. Furthermore, this impact is a positive relationship, that of increasing effect, between the two variables. Apart from this study, several other past studies have examined factors that cause vehicular HC emissions and solutions to this. In a study in India, strong correlation of age on HC emissions in idle mode were found for a large and diverse dataset of 1580 cars, with $R^2 = 0.73$ [80]. Chandrappa & Kulshrestha; Heywood; Iodice

& Senatore; Maurya ; and Osman conceived that poor combustion quality in engines that is not air/fuel ratio regulated is typically responsible for excessive HC and particle emission levels [146, 147, 148, 149, 150]. A study by the Kleinman centre in the United States, discovered that used 2-wheelers older than ten years emit the bulk of the overall pollutants and automobiles beyond fifteen years emit almost half of that amount. The study concluded automobiles become dirty as they become older and their emission control technology degrades [99].To limit HC tailpipe emissions, it is required to create strict emissions guidelines that force manufacturers to upgrade the internal combustion system and after treatment systems, alongside enhancing the discarding regulations for outdated automobiles. To address scavenging losses that affect the fuel/air ratio, the market has seen the introduction of electronically regulated direct injection technology [151].

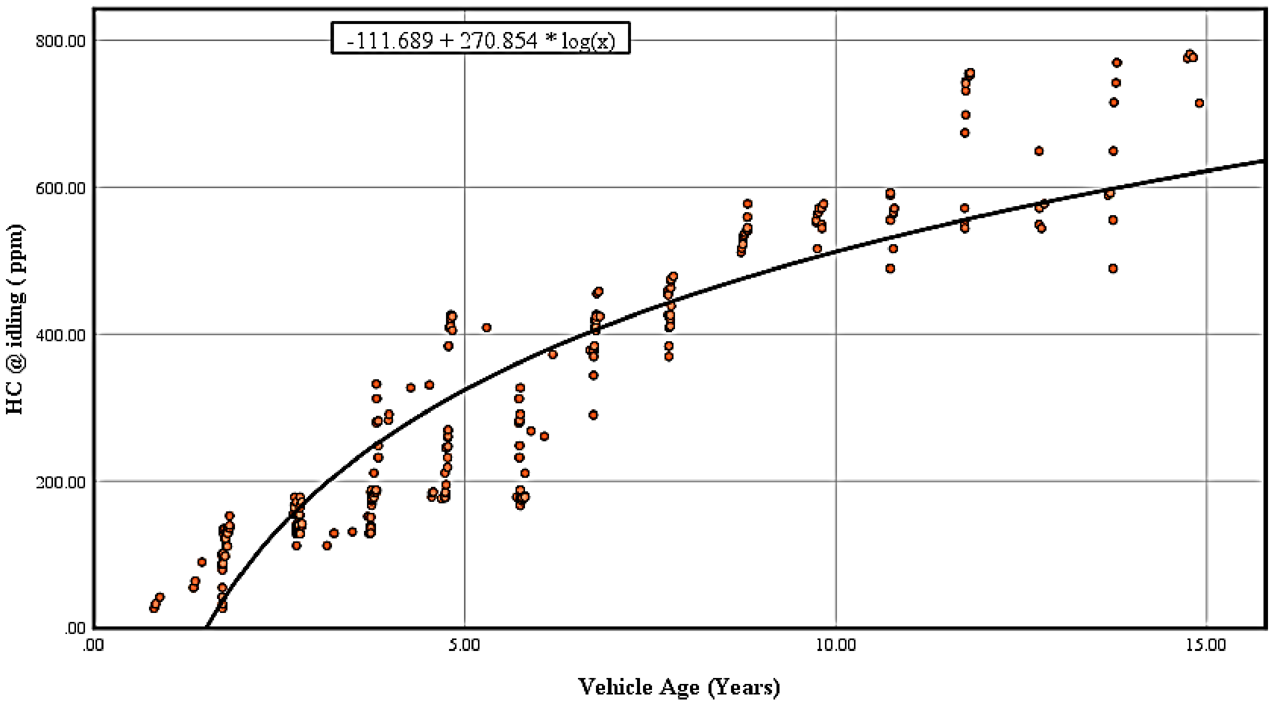


Fig 4.2 – Regression of HC on age through logarithmic curve estimation

4.3 2-WHEELER MILEAGE EFFECT ON CO AND HC EMISSIONS

Governments like the United States have set objectives for lowering automobile mileage covered in order to minimise exhaust gases in response to the climate problem. Lin et al. investigated the relationship between the prominence of cancer and DNA mutations with mileage from 2-wheelers. The study concluded low mileage motorbikes had reduced evidences of cancer and mutations but the impact increased with higher miles covered [6]. A case study of 2-wheelers in Taipei city revealed that non compliance to standards was evident in mileages greater than 10,000km, and was significantly affected by it.The study implied that the accumulation of mileage meant increased wear and tear of engine and damage in treatment components [98].

4.3.1 Assessment of Effect of Mileage on CO Levels

The logarithmic curve accurately depicts the emission characteristics for the parameter, as shown in **Fig 4.3** below.

Table 4.7- Model summary – characteristics of the model

Regression Aspect	**Value / Particulars**
Hypothesis	Significant impact of mileage on levels of CO
Regression Weights	Mileage (km)→ CO @ idling (%)
Equation	-12.764 + 1.242*Log (X)
R	0.917
R^2	0.841
Hypothesis Supported	Yes

According to **Table 4.7**, the R value of 0.917 is greater than 0.400, indicating that it is a suitable value for the model. Also, the R^2 of 0.841 is greater than 0.5, indicating that it accurately captures the change in CO induced by ageing. Hence out of 100% change in CO emissions, 84.1% is induced by mileage.

Table 4.8- Analysis of variance (ANOVA) table – estimation of significance level of model

	dF	**F**	**Significance (P)**
Regression	1	1431.745	0.000
Residual	270		
Total	271		

The significance (P) value in **Table 4.8** is 0.000, which is less than 0.05, indicating that mileage and CO exhaust emissions have a significant relationship. Furthermore, the F value of 1431.745 as indicated in **Table 4.8**, is greater than one, indicating a coherent model.

Table 4.9 - Coefficients table – estimation of magnitude of impact of mileage on CO

	Unstandardized Coefficients	**Standardized Coefficients**	
	B	**Beta (β)**	**Sig.**
ln(Mileage - KM)	1.242	0.917	0.000
(Constant)	-12.764		0.000

As seen in **Table 4.9**, β is 0.917, hence a 1.000-unit change in mileage results in a 0.917-unit change in CO. The value is positive, which means that for every 1.000 unit increase in mileage, CO levels rise by 0.917 unit. In all, the hypothesis is supported by Tables **4.7**, **4.8**, and **4.9**.

Literature supports the notion that mileage has a direct and significant influence on CO tailpipe emissions. Tsia, Hang & Chiang conducted an investigation on four stroke motorcycles that concluded that CO tailpipe emissions and fuel usage depended on their mileage and aging. The research indicated that mileage of 1000 km resulted in an increase of 103 mg for CO emission and 14.7 mg for hydrocarbon emission [100]. According to Hao et al , CO emissions usually worsen with increasing mileages due to wear and tear on automobile parts. Components such as the ignition system, which supports the fuel-air ratio for optimum combustion [152].

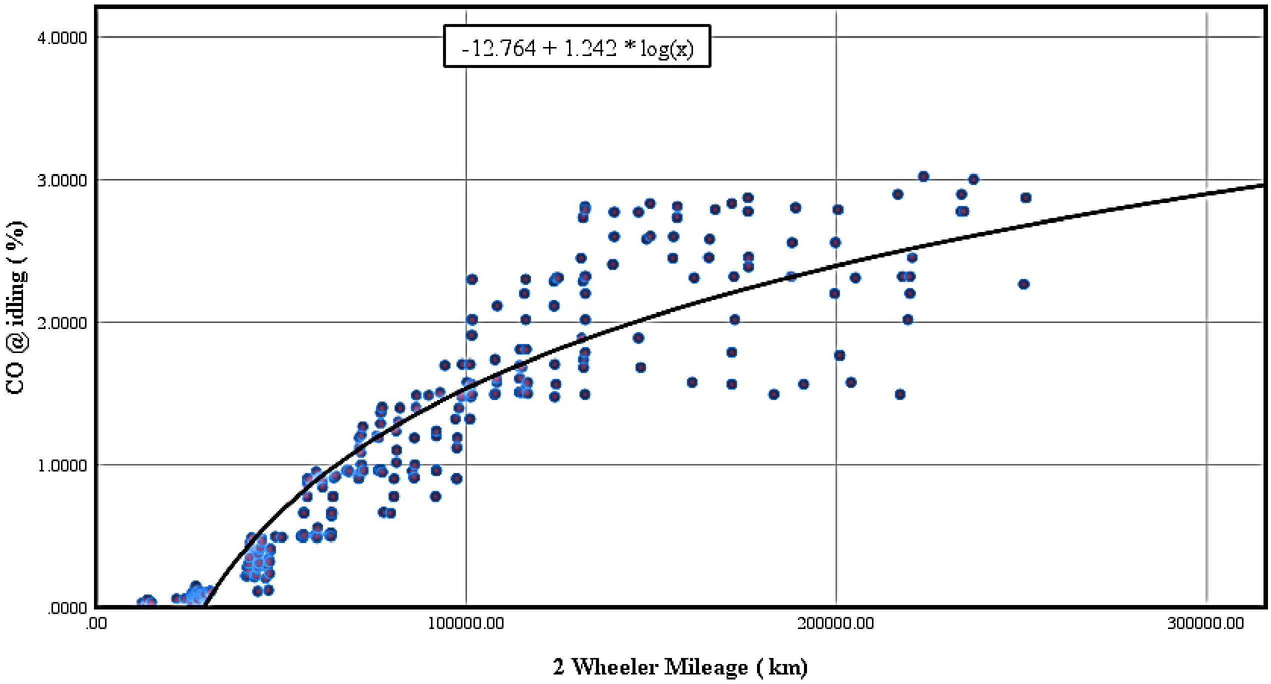


Fig 4.3- Regression of CO on mileage through logarithmic curve estimation

4.3.2 Assessment of Effect of Mileage on HC Levels

As demonstrated in **Fig 4.4**, the logarithmic curve fit accurately captures the emission characteristics for the parameter. The hypothesis test's significant findings are illustrated in Tables **4.10**, **4.11**, and **4.12**.

Table 4.10- Model summary – characteristics of the model

Regression Aspect	**Value / Particulars**
Hypothesis	Significant impact of mileage on levels of HC
Regression Weights	Mileage (km)→ HC @ idling (ppm)
Equation	$- 2693.937 + 267.405^{*}\text{Log}(X)$
R	0.900
R^2	0.809
Hypothesis Supported	Yes

Table 4.10 shows that the R value of 0.900 is greater than 0.400, indicating that it is a good fit for the

model. In the same table, R^2 of 0.809 is greater than 0.5, showing that it accurately captures the HC change caused by mileage. As a result, mileage is responsible for 80.9% of the change in HC emissions.

Table 4.11- Analysis of variance (ANOVA) table – estimation of significance level of model

	dF	**F**	**Significance (P)**
Regression	1	1150.268	0.000
Residual	270		
Total	271		

The P value in **Table 4.11** is 0.000, which is less than 0.05, showing that there is a strong correlation between mileage and HC exhaust emissions. The F value of 1150.268 is greater than one, indicating an exceptionally efficient model.

Table 4.12– Coefficients table – estimation of magnitude of impact of mileage on HC

	Unstandardized Coefficients	**Standardized Coefficients**	
	B	**Beta (β)**	**Sig.**
ln (Mileage - KM)	267.405	0.900	0.000
(Constant)	- 2693.937		0.000

As seen in **4.12**, β is 0.900, hence a 1.000-unit change in mileage results in a 0.900-unit change in HC. The number is positive, indicating that for every 1.000 units of rise in mileage, HC levels rise by 0.900 unit.

Literature states that hydrocarbons are byproducts of the incomplete combustion process [153]. Insufficient combustion has an impact on fuel use and engine operation. [154]. Moreover, the discharge of unburned HCs influences the discharge of other airborne contaminants.

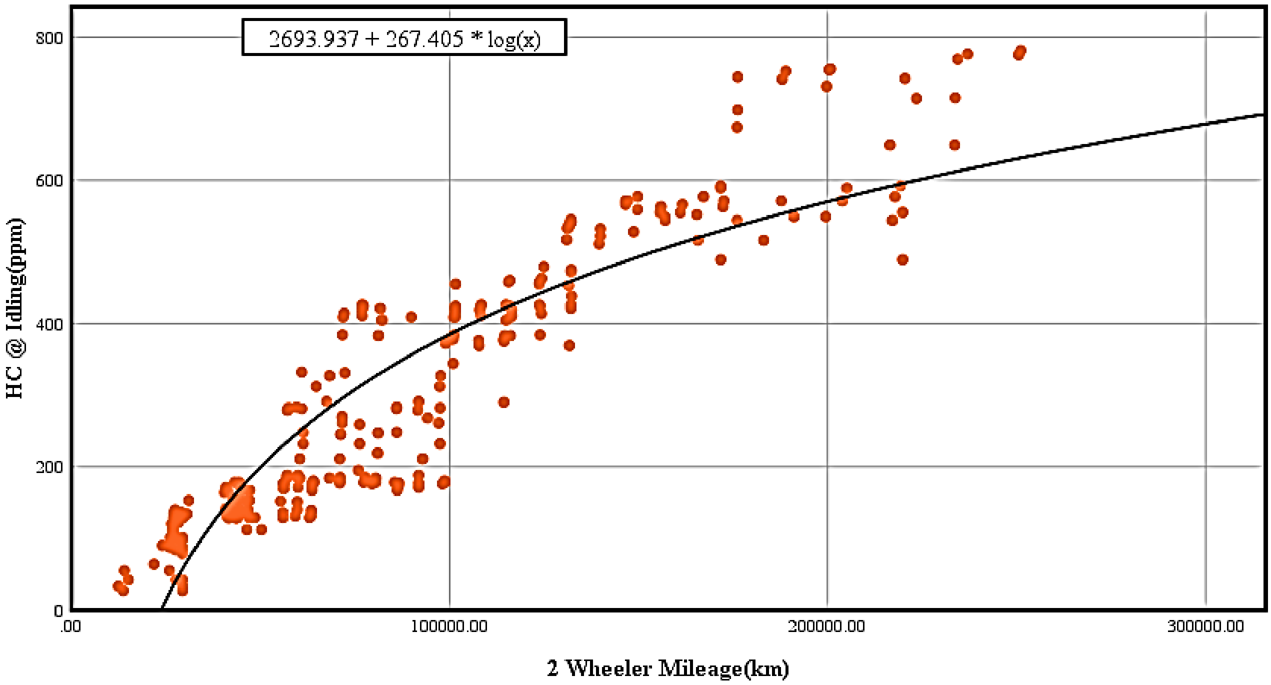


Fig 4.4- Regression of HC on mileage through logarithmic curve estimation

4.4 IMPACT OF APPLICABLE IN-USE EMISSION NORMS ON HC AND CO TAILPIPE PARAMETERS

The current study investigated the effect of BS III & IV Applicable in Use Emission Norms on CO and HC emissions. As observed from the box plots of **Fig. 4.5** and **4.6,** the CO and HC emissions levels were found to improve for BS IV compared to BS III; older emission norms. With the introduction of the BS IV norms, these parameters' emission range was decreased. Many studies support the idea that the implementation of stricter emission norms puts pressure on manufacturers to improve the ignition system for complete combustion and after treatment systems [155]. In doing so, the automobiles comply with the standards, which results in reduction of levels of exhaust emissions.

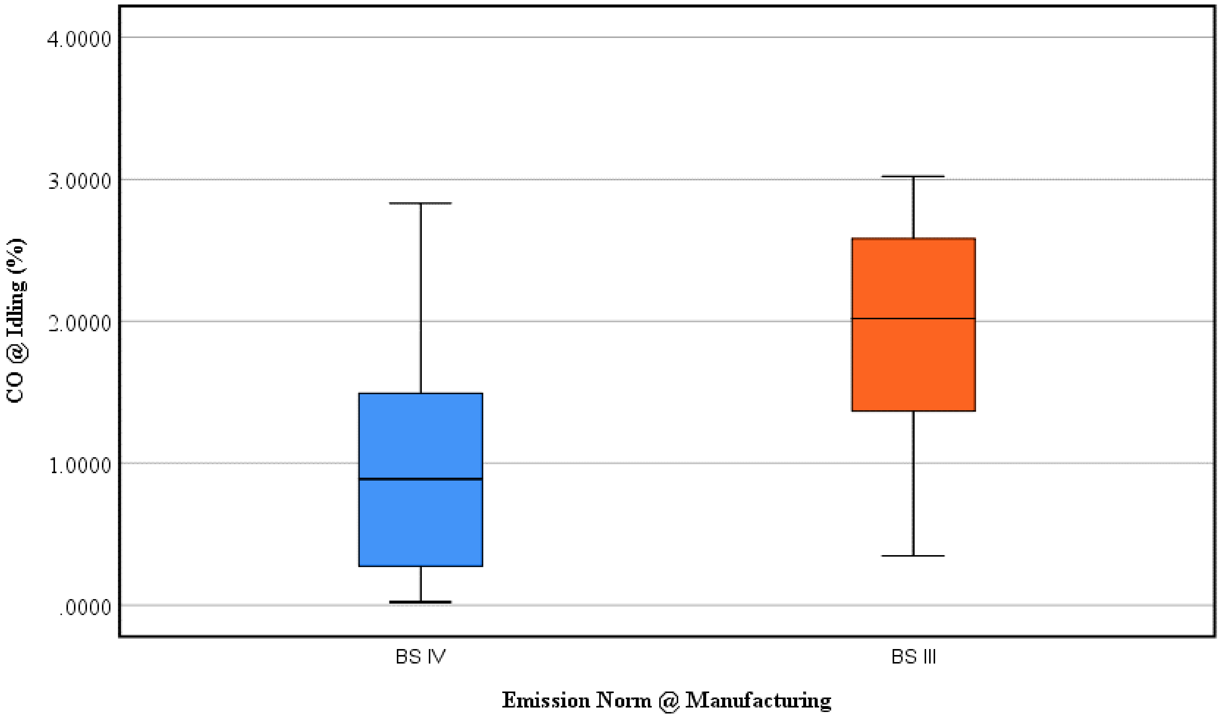


Fig 4.5- Box plot depicting the impact of emission norms on CO in idle mode

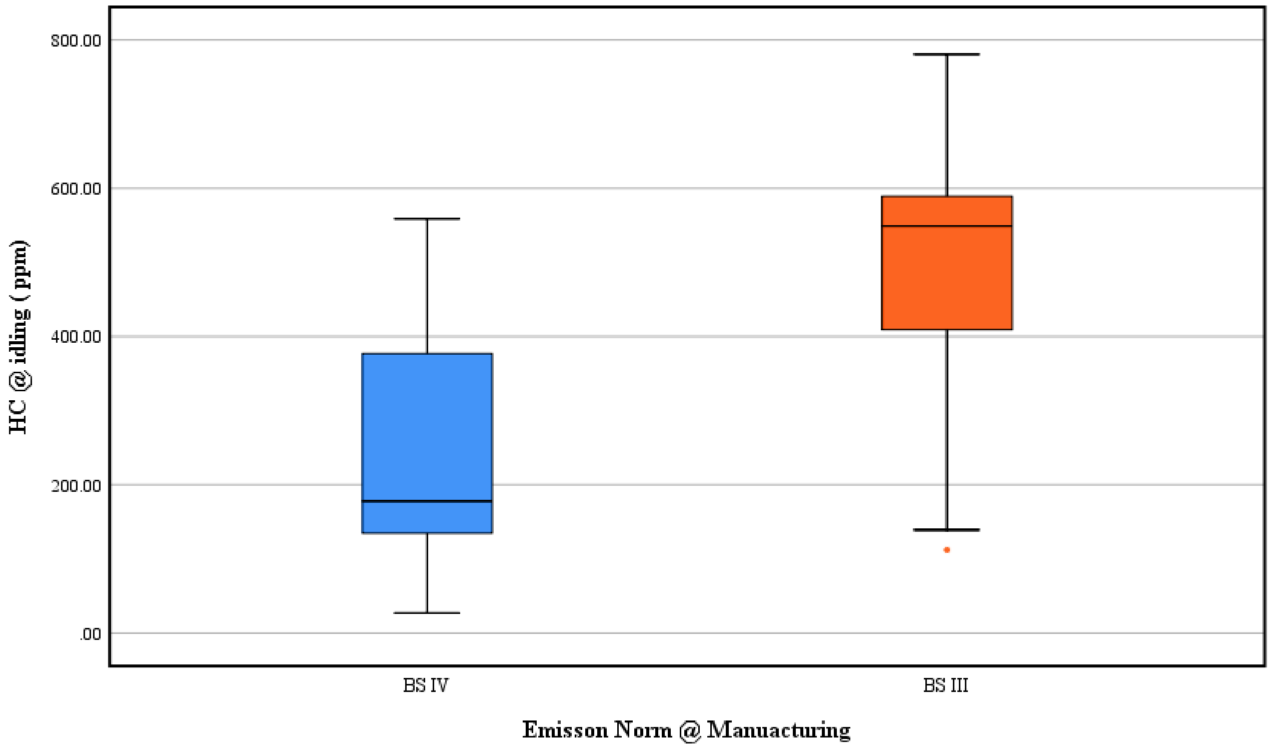


Fig 4.6 - Box plot depicting the impact of emission norms on CO in idle mode

4.5 KERB WEIGHT

Kerb weight and engine capacity are directly proportional; the heavier a wheeler is, the more fuel it burns, resulting in more carbon emissions. The current study examined the link between kerb weight and CO and HC emissions of two-wheeled vehicles when idling since the influence of kerb weight on CO and HC emissions is not well recognized. **Fig**. **4.7 and 4.8** show no relationship between kerb weight and CO or HC emissions. However, as demonstrated in the CO against kerb weight box plot, a few variables with equal kerb weight values have almost similar emission values of CO and HC. It is clear kerb weight has no direct and significant relationship with CO and HC emissions. A study on heavy duty vehicles observed HC emissions insensitive to the vehicle weight; CO emissions were influenced by weight under transient operation. Also, the study concluded that CO emissions were insensitive to weight during steady state operation [156].

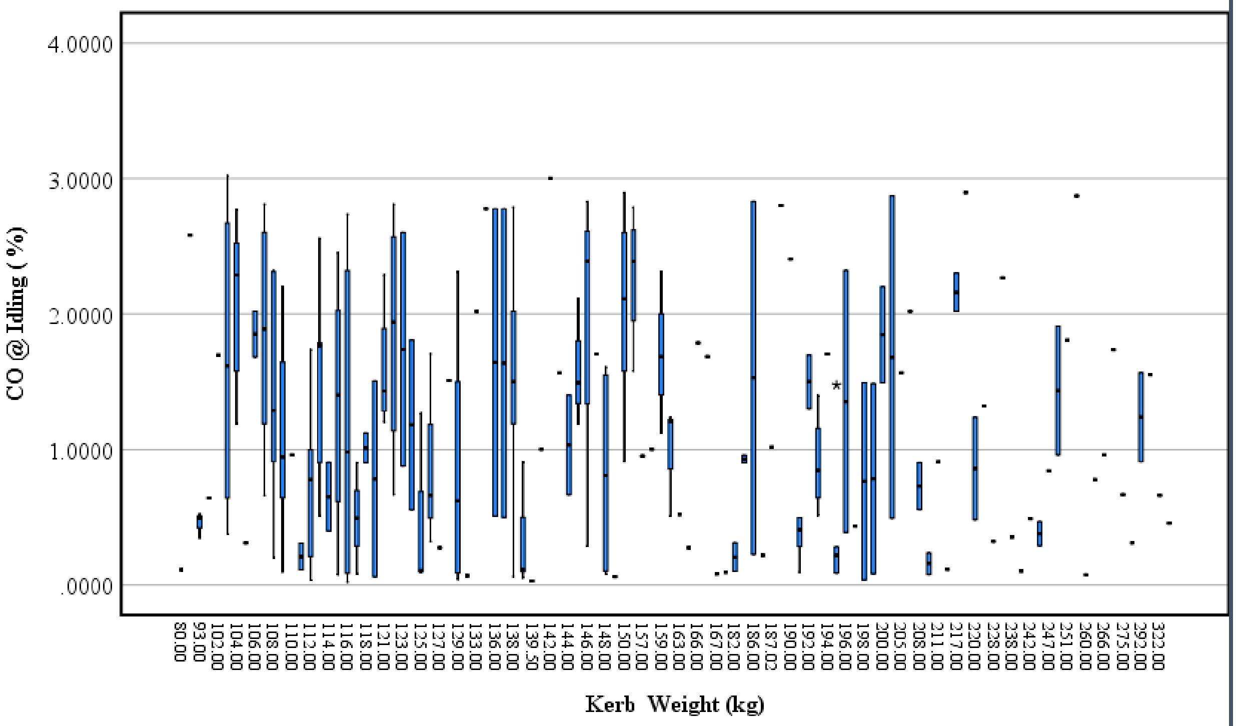


Fig 4.7 - Box plot depicting the impact of kerb weight on CO in idle mode

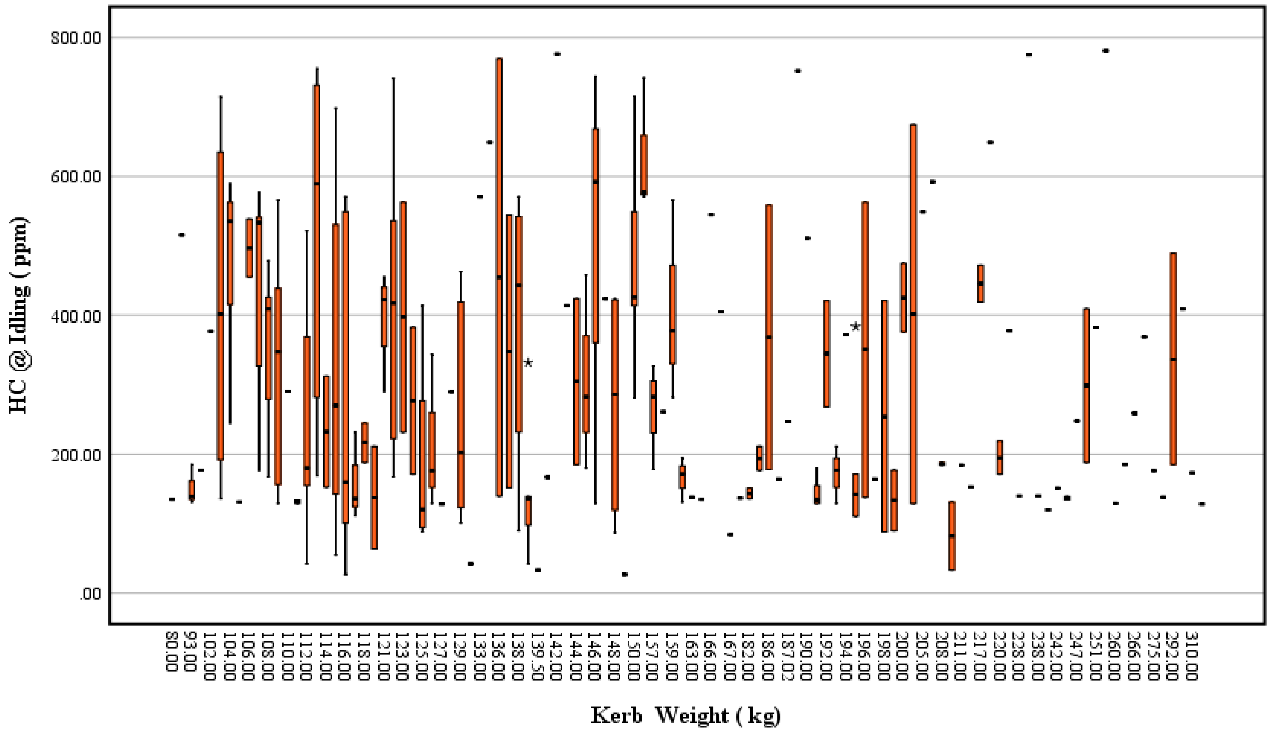


Fig 4.8- Box plot depicting the impact of kerb weight on HC in idle mode

4.6 ENGINE IGNITION SYSTEM

Future clean combustion engines will generally increase the cylinder charge to achieve higher fuel economy and lower exhaust pollutants. Excessive air entry is often combined with increased cylinder charge, resulting in unfavorable ignition conditions at the ignition point [157] . To comply with pollution policies, sophisticated ignition techniques and systems have evolved greatly in recent years; yet, just increasing the energy of the inductive ignition system does not produce the desired results.

Fig 4.9 and **4.10** show how the ignition system technology, to some extent, influences the amount of idling emissions from two-wheelers. Kick Start ignition systems have the highest CO and HC emission values. Mainly when they are cold, the Kick Start ignition system is highly mechanical and takes a while to ignite. As a result, most Kick Start ignition systems are being phased out in favor of a Kickstart/Electric combination, which is more common because Kick Start is not very effective at ensuring complete combustion. Additionally, after Kick Start, Capacitor Discharge Ignition (CDI) also recorded high CO and HC tailpipe emission values. One of the reasons is that the spark produced is strong but short (0.1 to 0.3 ms) due to the fast-capacitive discharge, resulting in ignition failure under lean mixture operating conditions. Because it is simply an electronic ignition with a spark advance feature, the Inductive Discharge Ignition (IDI) has one of the lowest maximum values. The ignition sparks have been controlled based on the engine load and speed. This improves fuel combustion and mileage while lowering pollution. Furthermore, despite the small sample size, the values of HC and CO for Fly Wheel Magneto ignition were low because it is a self-energizing type of ignition system. Thus, there is no need for an external energy source/heavy battery which is compact. Because there is no battery, it is more dependable. It produces a high-quality spark at a rapid speed. It does not require much maintenance because there is no battery. Furthermore, the Engine Control Unit (ECU) ignition had reduced HC and CO emissions since it is electronic in nature, resulting in fewer moving components that require little maintenance and boost fuel economy, leading to lesser emissions.

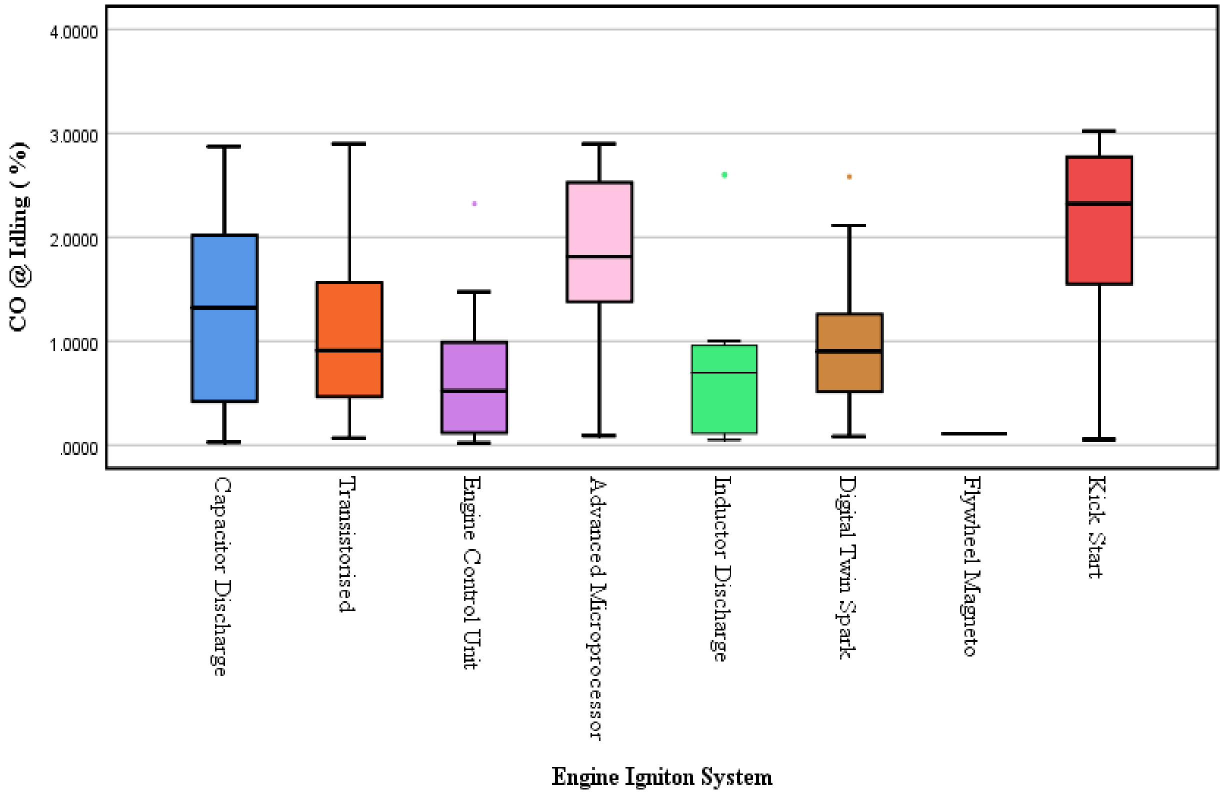


Fig 4.9 - Box plot depicting the impact of engine ignition system on CO in idle mode

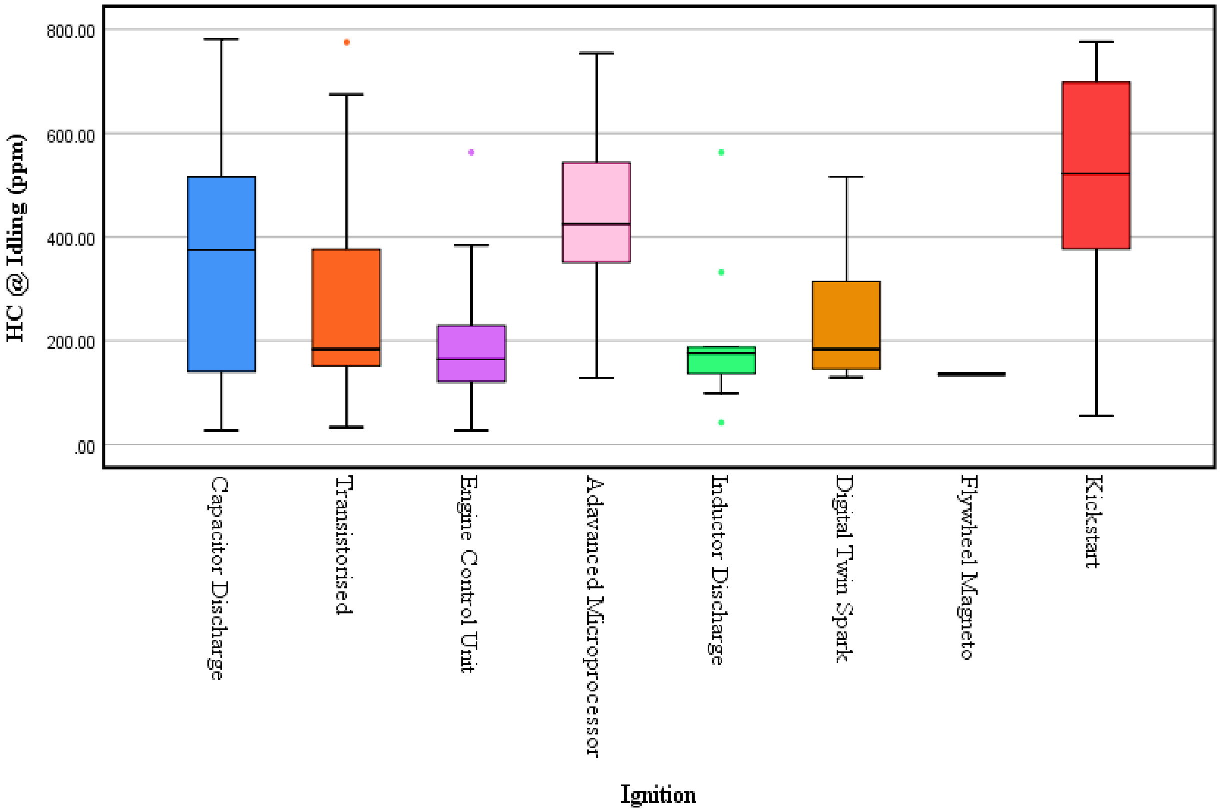


Fig 4.10- Box plot depicting the impact of engine ignition system on HC in idle mode

CHAPTER 5. CONCLUSION

5.1 SUMMARY

The present study's objective was to explore the influence of vehicle and engine-specific parameters on tailpipe CO and HC emissions from 272 two-wheelers plying on the roads of Delhi, India. The findings revealed substantial correlation values relating to age and mileage as the most significant vehicular variables influencing tailpipe emissions. The bivariate curve estimate regression based on tests of characteristics, significance, and magnitude of impact supports the notion that age and mileage each have a direct, significant, and huge positive relationship with exhaust emissions of CO and HC. The values of R, R^2, P, F and β, proved the hypothesis statements true, i.e., "There is a significant impact of age or mileage on CO and HC". Regression of age on CO and HC separately, revealed that age plays a significant role in shaping exhaust emissions as, for CO idle ($R = 0.920 > 0.400$, $F = 1485.463 > 1$ and $P = 0.000 < 0.05$) and HC idle ($R = 0.903 > 0.400$, $F= 1194.522$ and $P = 0.000 < 0.05$), respectively. The model also illustrates a positive and statistically significant magnitude of impact of age on CO and HC tailpipe parameters, for CO idle ($R^2 = 0.846$, $\beta = 0.920$) and HC idle ($R^2 = 0.815$, $\beta = 0.903$). In simpler terms, the age accounts for 84.6 % variance in CO and 81.5 % variance in HC. Also, a 1.000 unit increase in age is coupled with 0.920 unit rise in CO and 0.903 unit rise in HC respectively.

As regards mileage, the regression proved that mileage too, has a significant impact on the exhaust emissions. Regression of mileage on CO and HC separately showed that mileage plays a significant role in determining exhaust emissions. For CO idle ($R = 0.917 > 0.400$, $F = 1431.745 > 1$ and $P =0.000 < 0.05$) and HC idle ($R = 0.900 > 0.400$, $F = 1150.268$ and $P = 0.000 < 0.05$) respectively. The model also illustrates a positive and significant magnitude of impact of mileage on CO and HC tailpipe parameters, for CO idle ($R^2 = 0.841$, $\beta = 0.917$) and HC idle ($R^2 = 0.809$, $\beta = 0.900$). In plain terms the mileage accounts for 84.1 % variance in CO and 80.9 % variance in HC. Also, a 1.000-unit increase in mileage is coupled with 0.917 unit rise in CO and 0.900-unit rise in HC respectively.

BS III and IV norms illustrated a profound influence on tailpipe emissions since there was a massive improvement in complying with the standards for both CO and HC with the emergence of the much stringent BS IV norm. Many studies allude to this adherence to the latest emissions norms to the improvement in technology such as after treatment and internal combustion. The study discovered that more contemporary and complex automated ignitions systems such as Digital Inductive Discharge Ignition, Engine Control Unit, and Fly Wheel Magneto had the lowest maximum emissions' range compared to earlier versions such as the Kick Start ignition, which is more mechanical in nature.

Advanced ignition techniques have been developed in recent years to the regulatory requirements, to combat vehicular pollution and climate change. Sophisticated spark generating results in increased engine power while lowering emissions. By adjusting the spark timing, greater power is created and tailpipe emissions in idle mode are controlled. The kerb weight evidenced a weak correlation with HC and CO emissions, although kerb weight is directly proportionate to the engine capacity. However, kerb weight did affect emissions to a certain extent as a few 2-wheelers having the same kerb weight had similar CO and HC emissions levels. There is a necessity to investigate the impact of kerb weight on exhaust emissions from two-wheelers especially the heavier types, as some studies show increasing CO and HC emissions with weight of vehicle.

5.2 RECOMMENDATION

The findings gathered from this study may aid policymakers in their knowledge of the urban vehicular emission situation regarding two-wheelers and in developing better environmental regulating methods. It is necessary to investigate the real-world impact of ignition system on exhaust emissions as improper systems can lead to incomplete combustion resulting in higher levels of CO and HC. The gap that is visible in the current study is the investigation of the effects of the vehicular parameter on emissions through a combined method like multivariable regression, since most studies just focus on bi-variable correlation.

APPENDICES

Appendix 1- PUC certificate

प्रदूषण नियंत्रित प्रमाणपत्र

POLLUTION UNDER CONTROL CERTIFICATE

परिवहन विभाग, दिल्ली सरकार द्वारा अधिकृत

TRANSPORT DEPARTMENT, GOVT. OF N.C.T. OF DELHI

संख्या S.No.

प्रमाणपत्र संख्या PUCC No. DL- P723047449

वाहन पंजी संख्या VehicleReg. No. DL4SCZ1619

मेक Make HERO MOTOCORP LTD

मॉडल Model M-Cycle/Scooter

वर्ग Category 2 Wheeler

इंजिन स्ट्रोक Engine Stroke 4-Stroke

पंजीकरण की तिथि Date of Mfg. 01-2019

उत्सर्जन मानक Emission Norms --

ईंधन Fuel PETROL

दिनांक Date 30-10-2019

समय Time 10:34:09 AM

वैधता Valid Up to 29-01-2020

प्रमाणित किया जाता है कि इस वाहन का CO, एवम् HC उत्सर्जन स्तर के मो. वा. नियम, 1989 के नियम 115 (2) में निर्धारित स्तर के अनुसार है।

यदि आपको कोई शिकायत या टिप्पणी है तो कृपया पीछे छपे प्रारूप के अनुसार भेजे।

In Case of any Comments/ Complaint. please send your response as per form given Overleaf.

Vehicle Type

2W 4-stroke vehicles

हस्ताक्षरकर्त्ता Authorised Signatory

नाम Name :

अधिकृत केन्द्र कोड Authorised Centre Code P 7 2 3

SCORPIO PETRO
Community Centre, Sector 18A, Dwarka, New Delhi-110075

आइडलिंग पर CO एवं HC स्तर (% आयतन) (PPM)
CO & HC Level At Idling (% volume) (PPM)
आइडलिंग पर RPM/ Idling RPM......................

इंधन Fuel	निर्धारित मानक CO. Prescribed Standard CO.	मापित स्तर CO. Measured Level CO	निर्धारित मानक HC Prescribed Standard HC	मापित स्तर HC Measured Level HC
पेट्रोल Petrol	3.0	1.304	3000	199
सी एन जी एल पी जी CNG/LPG				

At High idle RPM 2500±200 Measured RPM....................

CO	HC	CO_2	O_2	λ

Prescribe Pollution Checking Charges : 2&3 Wheeled Vehicle = Rs : 60/-, 4 & above wheeled Vehicle = Rs. 80/-

Appendix 2 – Raw data entry of PUC information, level of measured emissions and vehicle specifications

s.no	Manufacturing Date’	Emission Testing Date’	‘Vehicle Regn. No.	Manufacturer	‘Model’
1	Dec-04	10/22/2019	DL5SN5578	hero honda	Kinetic
3	Jan-05	10/22/2019	DL3SAT1778	hero honda	CBZ star
7	Jan-08	10/22/2019	HR34C3055	Bajaj	Platina
8	Jan-08	9/28/2019	DL4SBM0536	hero honda	Hunk
9	Jan-08	9/28/2019	DL3SBA9369	hero honda	Glamour
13	Jan-10	10/22/2019	GJ18AJ4899	Bajaj	Pulsar 150es
14	Jan-10	10/21/2019	DL9SAE5974	Bajaj	Discover DTS-i
16	Jan-10	10/22/2019	DL4SBU1078	hero honda	Super splendor
17	Jan-11	10/21/2019	DL9SAF3413	Hero	CD delux
19	Jan-11	10/10/2019	HR26BM0301	Honda	Aviator
148	Jan-05	10/6/2019	UP32BL2445	Honda	M Cycle /Scooter
21	Jan-11	9/28/2019	DL6SAJ3171	Bajaj	Pulsar 135LS
22	Jan-12	10/22/2019	DL12C5926	Hyundai	I-20
23	Jan-12	10/21/2019	CH01AN8944	Honda	Activa
24	Jan-12	10/10/2019	DL4SBX2582	TVS	Wego
25	Jan-12	9/28/2019	DL4SBY7773	TVS	Wego
26	Jan-13	1/25/2019	DL9SAP4469	Honda	Shine
27	Jan-13	10/27/2019	DL9SAP4469	Honda	Shine
29	Jan-13	10/10/2019	DL5SBD5995	Honda	Aviator delux
30	Jan-13	11/20/2018	DL3SCN4559	Royal Enfield	Thunderbird
31	Jan-14	4/15/2019	DL4SCG3613	hero honda	Splendor pro GTR
32	Jan-14	10/14/2018	DL4SCG3613	hero honda	Splendor pro GTR
33	Jan-14	7/8/2018	DL4SCG3613	hero honda	Splendor pro GTR
34	Jan-14	10/22/2019	DL4SCE6281	TVS	Phoenix
35	Jan-14	10/21/2019	DL9SAy2681	Honda	Activa
36	Jan-14	10/21/2019	DL9SAP8809	Honda	Shine
38	Jan-14	9/28/2019	DL9SAP6393	Honda	Activa-I
39	Jan-15	10/22/2019	DL9SBD0345	Honda	Activa 3G
40	Jan-15	10/22/2019	DL9SAZ3765	Bajaj	Discover 100
41	Jan-15	10/21/2019	DL1SY2399	Royal Enfield	Thunderbird 350
42	Jan-15	7/20/2019	DL5SBZ2612	Bajaj	Pulsar 135LS
43	Jan-15	10/30/2019	DL9SAZ3825	Bajaj	Pulsar 150es
44	Jan-15	7/27/2019	DL9SAZ3825	Bajaj	Pulsar 150es
45	Jan-15	10/21/2019	DL9SAW4173	Hero	Glamour
46	Jan-15	10/21/2019	DL9SAY8428	Honda	Activa 3G
47	Jan-15	7/19/2019	HR26CL6118	Yamaha	YZF R-15

Appendix 2 cont'd - Raw data entry of PUC information, level of measured emissions and vehicle specification

BS compliance	measured value CO	HC	status of test (pass/fail)	reason for fail	Remark
NA	0.008	141	P		FE
Euro-2	0.873	141	P		
NA	0.11	20	P		FE
Euro-2	0.274	153	P		
Euro-2	0.864	131	P		
Euro-2	0.147	291	P		
NA	0.169	469	P		
NA	0	2	P		
NA	0.209	421	P		
Euro-2	0.15	18	P		
Euro-2	0.555	238	P		
Euro-2	0.002	0	P		
NA	NA	F	F	Excess HC	
BS-III	0.707	135	P		
Euro-2	0.272	78	P		
BS-III	0.011	9	P		
BS-III	0.182	118	P		
Euro-1	0.772	172	P		
NA	0.074	102	P		
BS-III	0.532	184	P		
BS-III	1.14	555	P		
BS-IV	0	10	P		Car
NA	0.117	95	P		
BS-III	0.049	8	P		
BS-III	1.85	97	P		
NA	0.009	187	P		
NA	0.179	1444	P		
Euro-2	1.435	255	P		
BS-III	0.002	16	P		
BS-III	0.016	53	P		
BS-III	0.766	386	P		
BS-III	1.066	217	P		
BS-III	1.662	200	P		
BS-III	0.082	1115	P		
NA	F	NA	F		

Appendix 2 cont'd – Raw data entry of PUC information, level of measured emissions and vehicle specification

Vehicle Mileage' (KM)	*Engine Capacity*	*Kerb Weight(Kg)*	*Maximum Power (bhp or HP)*
29238.36	373.3 cc	182 kg	34.5 bhp
28273.97	115 cc	117 kg	8.5 bhp
29435.62	149.5 cc	148 kg	13.8 bhp
29389.04	102 cc	115 kg	7.79 bhp
47087.67	220 cc	150 kg	21 bhp
46575.34	149.5 cc	148 kg	13.8 bhp
50235.62	102 cc	117 kg	7.9 bhp
64739.73	99cc	109 kg	7.99 bhp
61282.19	144.8 cc	123 kg	11.84 bhp
62923.29	373.3 cc	193 kg	34.52 bhp
63435.62	220 cc	163 kg	18.77 bhp
59704.11	150cc	136 Kg	11.84 bhp
76931.51	102 cc	121 kg	10 bhp
68260.27	135 cc	122 kg	13 bhp
77282.19	149.0 cc	144 Kg	14.89 bhp
77687.67	149.0 cc	144 Kg	14.89 bhp
81180.82	99.27cc	109 kg	8.1Bhp
71136.99	124 cc	118 kg	11.3 bhp
85438.36	94.38 cc	115 kg	7.59 bhp
97389.04	102 cc	114 kg	9.13 bhp
97435.62	124.5 cc	117 kg	11.34 bhp
97621.92	144.8 cc	132 kg	14.30 bhp

Appendix 2 cont'd – Raw data entry of PUC information, level of measured emissions and vehicle specification

Max Torque	*Cylinders*	*Cylinder Bore (mm)*	*Piston Stroke (mm)*
35 Nm	1	89 mm	60 mm
9.81 Nm	1	50 mm	58.8 mm
13.25 Nm	1	56 mm	60.7 mm
8.34 Nm	1	47 mm	58.8 mm
19 Nm	1	67 mm	62 mm
13.25 Nm	1	56 mm	60.7 mm
8.34 Nm	1	47 mm	58.8 mm
8.05 NM	1	53 mm	45 mm
12.26 Nm	1	56 mm	58.8 mm
35 Nm	1	89 mm	60 mm
17.55 Nm	1	67 mm	62.4 mm
13 Nm	1	57 mm	59 mm
9 Nm	1	47 mm	58 mm
11 Nm	1	54 mm	59 mm
12.5 Nm	1	56 mm	60.7 mm
12.5 Nm	1	56 mm	60.7 mm
8.1 Nm	1	53 mm	45
10.8 Nm	1	57 mm	49 mm
7.85 Nm	1	47 mm	54 mm
9.0 Nm	1	47 mm	54 mm
10.8 Nm	1	54 mm	54.4 mm
12.7 Nm	1	56 mm	58 mm
13.25 Nm	1	58 mm	56.40 mm
20 Nm	1	66.04 mm	61 mm
8.34 Nm	1	47 mm	58.8 mm
10 Nm	1	57 mm	49 mm

Appendix 2 cont'd - Raw data entry of PUC information, level of measured emissions and vehicle specification

Valves per Cylinder	***Compression Ratio***	***Spark Plugs Per Cylinder***	***Engine Cooling System***
4	11.3:1	3 Per Cylinder	Liquid Cooled
2	9.8 ± 0.5:1	1 Per Cylinder	Air Cooled
2	**9.8 +/- 0.3 : 1**	2 Per Cylinder	Air Cooled
2	9.5 + 0.5 : 1	1 Per Cylinder	Air Cooled
4	9.5 ± 0.5:1	2 Per Cylinder	Air Cooled
2	9.8 +/- 0.3 : 1	2 Per Cylinder	Air Cooled
2	9.5:1	1 Per Cylinder	Air Cooled
1	9.5:1		Air Cooled
2	9.5 ± 0.5 : 1		Air Cooled
4	12	3 Per Cylinder	Liquid Cooled
2	9.5:1	2 Per Cylinder	Oil cooled
2	9.8:1	2 Per Cylinder	Air-cooled
4		2 Per Cylinder	Air-cooled
4	9.8 ± 0.5:1	2 Per Cylinder	Air-cooled
2	9.8 +/- 0.3 : 1	2 Per Cylinder	Air-cooled
2	9.8 +/- 0.3 : 1	2 Per Cylinder	Air-cooled
2	9.5 + 0.5 : 1	1 Per Cylinder	Air-cooled
4		2 Per Cylinder	Air Cooled
	9.8:1	2 Per Cylinder	Air Cooled
4	10.5:1	2 Per Cylinder	Air cooled
4		2 Per Cylinder	Air/oil cooled
2			Air cooled
2	9.5 +/- 0.5 : 1	2 Per Cylinder	Air Cooled
	12.8:1	2 Per Cylinder	Oil-cooled
2	9.5 + 0.5 : 1	1 Per Cylinder	Air Cooled
4		2 Per Cylinder	Air Cooled

Appendix 2 cont'd - Raw data entry of PUC information, level of measured emissions and vehicle specification

Transmission	***Clutch***	***Fuel Delivery System***	***Start Type***
6 Speed Manual – Chain	Slipper Clutch	Fuel Injection	Electric Start
4 Speed Manual - Chain Drive	Wet Multiplate	Carburetor	Electric Start
5 Speed Manual- Chain Drive	Wet Multiplate	Fuel Injection	Electric Start
4 Speed Manual - Chain Drive	Wet Multiplate	Electronic Injection	Kick Start Only
5 Speed Manual – Chain	Wet multiplate	Carburetor	Electric Start
5 Speed Manual - Chain Drive	Wet Multiplate	Fuel Injection	Electric Start
4 Speed Manual	Wet Multiplate	Fuel Injection	Electric Start
5 Speed Manual – Chain	Wet Multiplate	Carburetor	Kick
4 speed constant mesh	Wet Multiplate	Carburetor – Ucal UVD20	Electric and Kick Start
6 Speed Manual - Chain Drive	Wet, Multiplate with Assist & Slipper Clutch	Fuel Injection	Electric Start
5 Speed Manual - Chain Drive	Wet Multiplate	Fuel Injection	Electric Start
5-Speed Manual - Chain Drive	Wet Multiplate	Carburettor	Kick and Self Start
5 Speed Manual - Chain Drive	Wet Multiplate	Carburettor	Electric Start
5 Speed Manual - Shaft Drive	Wet Multiplate	Carburettor	Electric Start
5 Speed Manual - Shaft Drive	Wet Multiplate	Fuel Injection	Electric Start
5 Speed Manual - Shaft Drive	Wet Multiplate	Fuel Injection	Electric Start
4 Speed Manual - Chain Drive	Wet Multiplate	Electronic Injection	Kick
5 Speed Manual - Chain Drive	Wet multiplate	Carburetor	Electric Start
4 Speed - Chain	Wet multiplate	Carburetor	Electric & kick start
4-Speed – Chain	Wet multiplate	Carburetor	Electric & kick start

Appendix 3- Data processing in excel through bivariate regression and box plots

001. Entered Data.sav [DataSet4] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Graphs Utilities Extensions Window Help

1 : s.no

	s.no	ManufacturingDate'	EmissionTestingDate'	'VehicleRegn.No	Manufacturer	'Model'
1		.	.			
2	81	1-Jan-2018 00:00.00	30-Oct-19	DL9SBS9705	bajaj	Bajaj Dominar 400 [2018]
3	129	1-Jan-2018 00:00.00	08-Oct-19	DL9SBQ7547	Bajaj	Bajaj Platina 110 [2018-2020]
4	160	1-Jan-2018 00:00.00	25-Sep-19	DL12SL9035	Bajaj	Bajaj Pulsar 150
5	238	1-Jan-2018 00:00.00	24-Sep-19	DL9SBQ7695	Bajaj	Bajaj CT100
6	175	1-Jan-2017 00:00.00	09-Oct-19	DL12SK7350	Bajaj	Bajaj Pulsar 220 F
7	272	1-Jan-2017 00:00.00	28-Sep-19	DL9SBJ3994	Bajaj	Bajaj Pulsar 150
8	64	1-Sep-2016 00:00.00	22-Oct-19	DL9SBF7929	bajaj	Platina 100ES
9	56	1-Jan-2016 00:00.00	22-Oct-19	DL9SBE2150	bajaj	CT-100 B Standard
10	87	1-Jan-2016 00:00.00	30-Oct-19	DL9SBA4054	Bajaj	Bajaj Boxer BM150
11	205	1-Jan-2016 00:00.00	13-Sep-19	DL9SAZ7187	Bajaj	Bajaj Dominar 400 (2016-2018)
12	220	1-Jan-2016 00:00.00	24-Sep-19	DL9SBA5591	Bajaj	BAJAJ AVENGER 220
13	253	1-Jan-2016 00:00.00	24-Sep-19	DL10SH6038	Bajaj	Bajaj V15
14	40	1-Jan-2015 00:00.00	22-Oct-19	DL9SAZ3765	bajaj	Discover 100
15	42	1-Jan-2015 00:00.00	20-Jul-19	DL5SBZ2612	bajaj	Pulsar 135LS
16	43	1-Jan-2015 00:00.00	30-Oct-19	DL9SAZ3825	bajaj	Pulsar 150es
17	44	1-Jan-2015 00:00.00	27-Jul-19	DL9SAZ3825	bajaj	Pulsar 150es
18	50	1-Jan-2015 00:00.00	10-Oct-19	DL8SBX8565	Bajaj	CT-100
19	203	1-Jan-2015 00:00.00	28-Sep-19	DL9SAZ4433	Bajaj	Bajaj Discover 125 M
20	155	1-Jan-2014 00:00.00	11-Sep-19	DL6SAR0679	Bajaj	Discover 100
21	190	1-Jan-2014 00:00.00	23-Sep-19	DL6SAR3698	Bajaj	Discover 100M

001. Entered Data.sav [DataSet4] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Graphs Utilities Extensions Window Help

9 : Manufacturer bajaj

	ApplicableinUs.	CONorm	HCNorm	COmeasured	HCmeasured	status	reasonforfail	VehicleAgeYears	VehicleMileage'KM
1		.	.	.	.			.	.
2	BS-IV	3.0	3000	.07	71.00	P		1.83	29238.36
3	BS-IV	3.0	3000	2.79	457.00	P		1.77	28273.97
4	BS-IV	3.0	3000	.26	369.00	P		1.73	29435.62
5	BS-IV	3.0	3000	1.37	399.00	P		1.73	29389.04
6	BS-IV	3.0	3000	.	.	F	CO not in range	2.77	47087.67
7	BS-IV	3.0	3000	.11	120.00	P		2.74	46575.34
8	BS-III	3.5	4500	.71	112.00	P		3.14	50235.62
9	BS-III	3.5	4500	1.31	420.00	P		3.81	64739.73
10	BS-IV	3.0	3000	.03	179.00	P		3.83	61282.19
11	BS-IV	3.0	3000	2.41	755.00	P		3.70	62923.29
12	BS-IV	3.0	3000	.30	202.00	P		3.73	63435.62
13	BS-IV	3.0	3000	.97	427.00	P		3.73	59704.11
14	BS-III	3.5	4500	.28	112.00	P		4.81	76931.51
15	BS-III	3.5	4500	2.56	193.00	P		4.55	68260.27
16	BS-III	3.5	4500	.28	368.00	P		4.83	77282.19
17	BS-III	3.5	4500	.03	27.00	P		4.57	77687.67
18	BS-III	3.5	4500	.58	208.00	P		4.78	81180.82
19	BS-IV	3.0	3000	.13	67.00	P		4.74	71136.99
20	BS-IV	3.0	3000	.01	.00	P		5.70	85438.36
21	BS-IV	3.0	3000	.08	148.00	P		5.73	97389.04

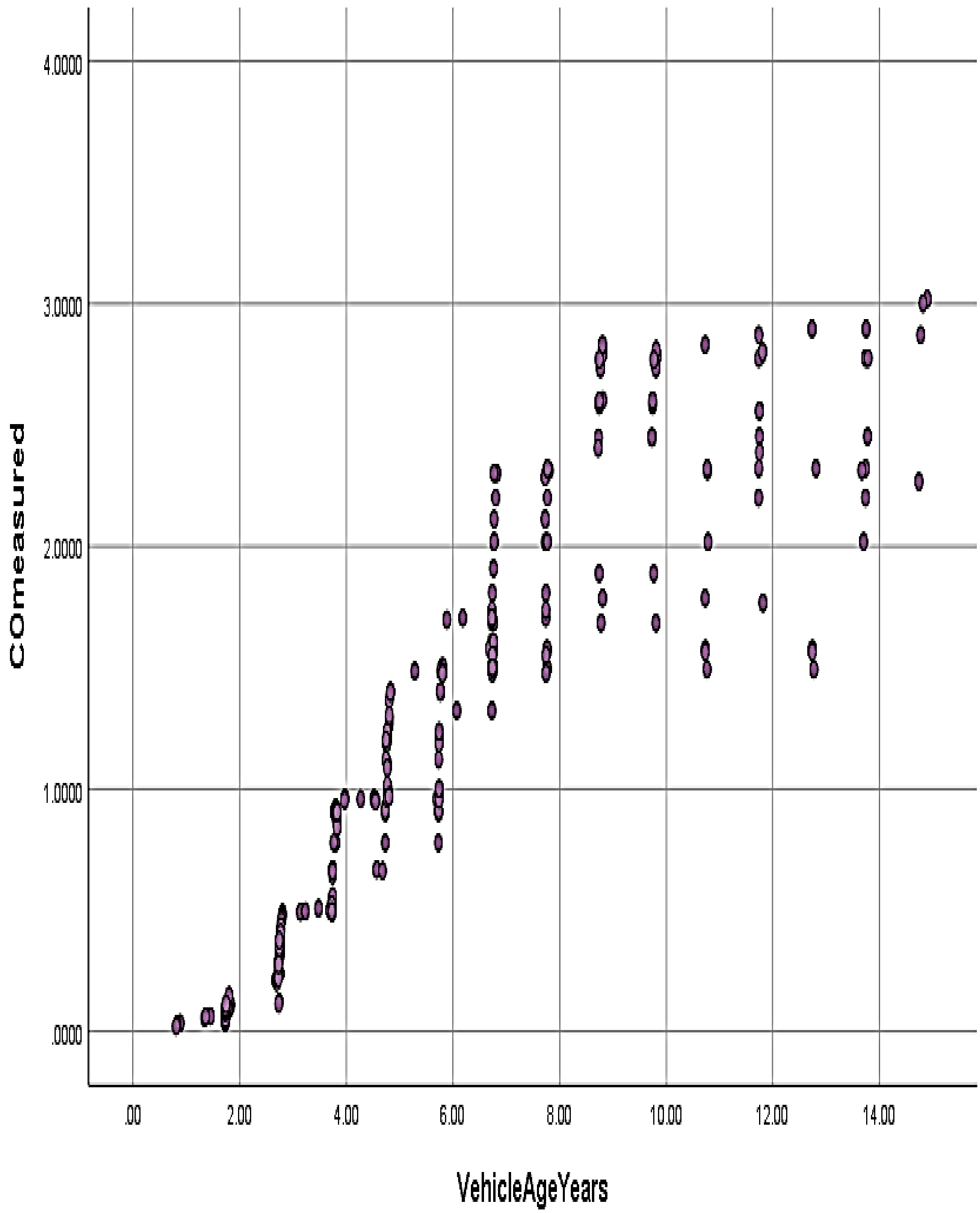
Appendix 4- SPSS data qualification and quantification

Project Analysis.sav [DataSet2] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Graphs Utilities Extensions Window Help

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	s.no	Numeric	4	0		None	None	12	Right	Scale	Input
2	Manufacturi...	Date	10	2	Manufacturing ...	None	None	23	Right	Scale	Input
3	EmissionTe...	Date	10	0	Emission Testi...	None	None	11	Right	Scale	Input
4	'VehicleReg...	String	11	0	'Vehicle Regn. ...	None	None	12	Left	Nominal	Input
5	Manufacturer	String	13	0	Manufacturer	None	None	13	Left	Nominal	Input
6	'Model'	String	51	0	Model	None	None	50	Left	Nominal	Input
7	Applicablein...	String	6	0	Applicable in-U...	None	None	6	Left	Nominal	Input
8	NormvalueCO	Numeric	3	1	In-Use Emissio...	None	None	12	Right	Scale	Input
9	NormvalueHC	Numeric	5	0	Normvalue HC	None	None	12	Right	Scale	Input
10	COIdling	Numeric	16	4	CO Idling	None	None	16	Right	Scale	Input
11	HCidling	Numeric	19	2	HC Idling	None	None	19	Right	Scale	Input
12	statusoftest...	String	2	0	Status	{1, P}...	None	2	Left	Nominal	Input
13	reasonforfail	String	15	0	reason for fail	None	None	15	Left	Nominal	Input
14	VehicleAge...	Numeric	19	2	Vehicle Age (Y...	None	None	16	Right	Scale	Input
15	VehicleMile...	Numeric	19	2	Vehicle Mileag...	None	None	13	Right	Scale	Input
16	EngineCapa...	Numeric	18	2	Engine Capacit...	None	None	18	Right	Scale	Input
17	KerbWeight...	Numeric	18	2	Kerb Weight(Kg)	None	None	18	Right	Scale	Input
18	MaximumP...	Numeric	31	2	Maximum Pow...	None	None	12	Right	Scale	Input
19	MaxTorque...	Numeric	18	2	Max Torque (N...	None	None	18	Right	Scale	Input
20	Cylinders	Numeric	1	0	No of Cylinders	None	None	12	Right	Scale	Input
21	CylinderBor...	Numeric	18	2	Cylinder Bore (...	None	None	18	Right	Scale	Input

Appendix 5- Scatter plot illustration



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