International Journal of Engineering Research and Science & Technology

IJERST

www.ijerst.org

ISSN : 2319-5991

Vol. 16 No. 2 (2020)

ijerst.editor@gmail.com

editor@ijerst.com

ISSN 2319-5991 www.ijerst.com
Vol. 16, No. 2, 2020

Peer Reviewed, Referred & Indexed Journal

Research Paper

A COMPARATIVE STUDY OF VEHICULAR AIR POLLUTION EMISSIONS FROM PETROL AND DIESEL ENGINES IN URBAN TRANSPORTATION SYSTEMS

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Abstract

Background: Air pollution is a significant issue in urban areas and petrol and diesel powered internal combustion engine vehicles are the leading cause of air pollution from transportation. The two types of engines have different emission profiles, creating different environmental and public health problems. While regulation progresses, there is still a need for a comprehensive comparative analysis under real-world urban driving conditions to help inform policy decisions.

Objective: The objective of this study is to compare the emission characteristics of petrol and diesel engines of light duty passenger transport vehicles (LD-PTVs) for the main pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) for urban transport systems.

Methodology: A systematic analytical review was conducted using secondary data from established sources, including the COPERT emission factor database, EMEP/EEA guidebooks, International Council on Clean Transportation (ICCT) real-world driving reports, type-approval test data (WLTP and NEDC cycles), and peer-reviewed journal publications. Emission values were compared across engine types, regulatory stages (Euro 1–6), and driving conditions (laboratory vs. real-world urban cycles).

Key Findings: In urban driving conditions, the NOx emissions from diesel are 2-5 times higher than from petrol and the particulate emissions are much higher. But, CO_2 emissions are reduced by 15–25% and fuel consumption reduced by 20–35% in diesel. Most important, the gap between real-world NOx emissions and laboratory certification is up to 7 times higher for diesel vehicles in urban stop and go traffic than for petrol vehicles, while the gap for petrol is significantly smaller (1.2–1.5 times). Petrol engines give off more CO and HC, but modern 3-way catalytic converters are effective at reducing these emissions.

Conclusion: The study findings indicate that there is no clear superiority of either engine type based on all the advantages and disadvantages: The diesel engine has climate benefits due to lower CO_2 emissions, and in urban areas, the petrol engine has better advantages in terms of reduced emissions of NOx and PM. The most successful policy route for sustainable urban mobility is to speed up the transition towards using zero-emission electric vehicles and introduce strict emission tests in real-world conditions for all internal combustion engine vehicles (Real Driving Emissions / RDE).

Keywords: Vehicular emissions, petrol engine, diesel engine, urban air pollution, nitrogen oxides, particulate matter, real-driving emissions, comparative analysis, emission standards, urban transportation policy.

1. Introduction

The world has undergone a major transformation of transportation systems, especially in developing and densely populated urban areas as a result of urbanization and fast industrialization. This trend in mobility has led to a significant increase in the number of motor vehicles in urban areas, causing significant environmental and public health problems. The use of road transportation has come to be seen as one of the main sources of urban air pollution, as a result of the release of harmful pollutants, such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC) and greenhouse gases (GHG), including carbon dioxide (CO_2) [1]. With the continued expansion of cities, the pollution of the urban environment is of paramount concern, as it has a direct link to respiratory illnesses, cardiovascular disorders, climate change and premature death, worldwide [2].

Urban transportation systems have experienced particularly rapid growth of motorized transport, particularly in the form of light-duty passenger vehicles, which are used on a daily basis for transportation. Even if there are more and more alternative means to transport with clean energies (electric mobility [3] for instance), petrol and diesel powered vehicles are still the most used means of transportation. It is generally believed that petrol engines have higher emissions of CO and hydrocarbons and diesel engines higher emissions of NOx and particulate matter [4]. Diesel engines have a higher efficiency in terms of fuel consumption and reduce the emissions of CO_2 per kilometre, but fine particulate pollution and the formation of urban smogs are still a major environmental problem [5]. Thus, it is important to have an understanding of the comparative environmental impacts of petrol and diesel engines to help manage urban air quality.

In the last 20 years, stricter vehicle emissions regulations have been introduced by public and environmental authorities such as the Euro Standards, the Bharat Stage and other regional emission control programs. As a result of these regulations, significant reductions in the emissions of vehicles have been achieved by the use of catalytic converters, diesel particulate filters, exhaust gas recirculation systems and advanced fuel injection technology [7]. Yet despite the technical progress and regulatory advances, even in many cities around the world, air pollution levels are still not acceptable. Recent studies show that transportation emissions continue to be a significant contributor to ambient NOx and PM pollution in urban areas, especially in high traffic density and where the traffic management system is inadequate [8].

A major issue with vehicle emission studies is the difference between in-lab testing and the actual on-road environment. The conventional laboratory testing approaches are typically performed in controlled environments that do not fully capture real-world driving environments like frequent acceleration and braking, idling and congestion [9]. Recent real driving emission (RDE) studies have revealed that many petrol and diesel cars have much higher pollutant emissions when they are driven on the road than are registered in the laboratory in the standards test [10]. The NOx emissions from diesel vehicles have shown to be higher in real-world conditions, with concerns about the reliability of the regulatory compliance tests and the efficiency of the current emission standards [11].

This present study addresses some of the important research questions related to the vehicular air pollution emissions in the urban transport systems of petrol and diesel engines. The aim of the study is first to determine which engine type leads to higher emission of regulated pollutants (NOx, PM, CO, HC) under urban operating conditions. Second, it evaluates the differences between laboratory and real-world driving emission to determine the accuracy of current emission evaluation procedures. Thirdly, the research looks at the wider impact of vehicle pollution on urban environmental policy, public health and sustainable mobility planning [12]. As policy makers strive to maximize transportation efficiency while protecting the environment and public health, these research questions have become even more significant.

This study is restricted mostly to light duty (passenger) vehicles powered by conventional petrol and diesel internal combustion engines. To keep the analysis consistent and focus on the dominant sector of urban passenger transport, heavy duty commercial vehicles, hybrid electric vehicles, battery electric vehicles and alternative fuel technologies are excluded from the analysis [13]. Furthermore, this study primarily targets regulated pollutants which are generally linked to public health effects and vehicular air pollution. Although greenhouse gas emissions (in particular CO_2) are taken into account, the focus is primarily on local urban pollutants having a direct impact on air quality and human health.

The importance of this research is that it provides important inputs to the development of transportation policy, environmental regulation and awareness of the public about emissions from vehicles. The comparative analysis of pollution emissions from petrol and diesel engines can deliver important insights to policy makers interested in looking into a cleaner urban transportation strategy and effective measures to deal with air pollution emissions [14]. Moreover, the results can help consumers in their environmentally conscious car decision-making and help regulators create more realistic and effective emissions tests. With increasing urbanization, evidence based transportation planning will become more vital in order to mitigate pollution exposure and sustainable transportation systems in urban areas [15].

The following is a general outline of the structure of this paper. The second part provides a literature review on related works for vehicular emissions, urban air pollution, and emission control technologies. The third section discusses the research methodology and data sources used in the comparative analysis. Part 4 covers the emission properties of petrol and diesel engines in laboratory and real light conditions. The fifth part examines environmental and public health aspects of vehicle exhaust emissions in urban transport systems. Lastly, the study presents the main conclusions, policy suggestions and future research recommendations pertaining to sustainable transport and air quality improvement in urban areas.

2. Literature Review

2.1 Fundamentals of Internal Combustion Engines

For over 100 years internal combustion engines (ICEs) have been the main source of propulsion in urban mobility. The studies carried out in recent years highlight the differences between the combustion principles, combustion behavior, thermal efficiency and emissions levels of petrol and diesel engines [16]. Typically, in petrol engines, the air–fuel mixture is a mixture of air and fuel that is mixed together and then ignited with a spark plug under almost-stoichiometric conditions, operating on the Otto cycle with spark ignition. According to Pacura et al. [16] petrol engines can reach relatively stable combustion and reduce the particulate emissions by using the stoichiometric combustion. During transient conditions and cold starts, however, the incomplete combustion leads to greater carbon monoxide (CO) and hydrocarbons (HC) emissions.

The Diesel cycle with lean combustion and compression ignition has been pointed out by several researchers as being the combustion regime of diesel engines [17]. Lu et al. [17] reported that the compression of air in the diesel engines to the very high temperature before the direct injection of fuel into the combustion zone leads to improved fuel economy and increased thermal efficiency. Historically this efficiency advantage has attracted long-distance transport and urban transportation systems to the diesel engine. However, the combustion temperatures generated by compression ignition (CI) make the production of nitrogen oxides (NOx) in the combustion process much more significant.

Wallington et al. [18] have explored the environmental performance of both petrol and diesel engines and how the environmental performance of petrol engines has improved over the last ten years as a result of advances in engine technologies including: turbocharging, common-rail direct injection, exhaust gas recirculation (EGR), and after-treatment systems. They reported that although the modern petrol engines have made significant progress in the reduction of HC and CO emissions, the diesel engines still suffer from a problem with respect to NOx and particulate matter (PM) emissions in real world urban traffic. For the same reason, Meena and Singh [19] found that urban driving with high congestion, stop and go manoeuvre and idling operation has a significant impact on the combustion efficiency and pollutant formation in both types of engines.

Other comparative studies have been done on gasoline direct injection (GDI) engines, which are beginning to replace the port fuel injection system for a number of reasons, including fuel economy [20]. In [20] the authors Cui et al. reported that while the efficiency of GDI petrol engines is higher, they might release more particle numbers than petrol engines due to fuel-rich zones in the combustion process. The discovery highlights the fact that technological developments can create new environmental problems, especially in urban areas.

2.2 Emission Formation Mechanisms

The composition of the pollutants which are formed from the vehicle's combustion process would depend considerably on the temperature of the combustion process, the fuel used, the amount of oxygen available to the combustion process, and the operating conditions of the engine. Nitrogen oxides (NOx) are highly important pollutants linked to the urban transport systems due to their involvement in secondary pollutant formation and respiratory diseases [21]. Li et al. [21] found that NOx is formed mainly by the thermal Zeldovich mechanism, which involves the reaction between nitrogen and oxygen under the high combustion temperature conditions. Lean combustion conditions and high compression ratios in diesel engines increase in-cylinder temperatures and thus lead to more NOx emissions than in petrol engines.

Laboratory testing values have been found to be significantly lower than real driving conditions emissions in recent studies carried out with Portable Emission Measurement Systems (PEMS) [22]. It was reported by Zhang and Chen [22] that urban traffic conditions in which the vehicle accelerates, decelerates, and carries different loads enhance the formation of NOx, particularly in the case of diesel-powered passenger vehicles. The study concluded that transient driving conditions are not represented in lab tests, which underestimate actual urban emissions.

Formation of particulate matter (PM) has also been a subject of many studies in recent years. Ghaffarpasand and Pope [23] linked soot formation to the non-premixed combustion in fuel rich zones of diesel engines. They said diesel fumes are made up of ultra fine particles that can get into the lungs. Such particles can be classified as nucleation mode particles and accumulation mode particles, which play important roles in urban PM2.5 pollution. In addition, Xu et al [24] noted that the contribution of older diesel vehicles to particulate pollution has not significantly reduced even with the recent progress in diesel particulate filter technology.

CO and hydrocarbons are primarily formed due to incomplete combustion in a region of inadequate oxygen [25]. Gamal et al. [25] showed that the concentrations of CO and HC are significantly higher during cold start and urban congestion conditions in petrol engines. They found that their models predicted more incomplete combustion events when they accelerated and idled more frequently, which could mean higher pollutant emissions in more populated traffic corridors.

While urban levels of CO_2 are not directly hazardous, they are the main greenhouse gas from transportation systems [26]. Aga et al. [26] concluded that due to better fuel economy, diesel engine generally produces less CO_2 emission per kilometer. This climate benefit is however usually countered with higher emissions of NOx and PM. Recent studies have thus highlighted the importance of having a comprehensive assessment which incorporates local air pollutants as well as GHGs if assessing engine technologies.

Table 1: Comparative Table of Emission Characteristics

Parameter	Petrol Engines	Diesel Engines
Combustion Type	Spark ignition	Compression ignition
Air–Fuel Ratio	Stoichiometric	Lean combustion
Thermal Efficiency	Moderate	High
NOx Emissions	Lower	Higher
PM Emissions	Lower	Higher
CO Emissions	Higher	Lower
HC Emissions	Higher	Lower
CO_2 per km	Higher	Lower
Fuel Economy	Lower	Higher

2.3 Emission Standards Evolution

As the problem of vehicle pollution has risen, so have the regulations that governments have passed to curb the effects of vehicles.As the issue of vehicle pollution has grown, so have the regulations that governments have put in place to reduce the impacts of pollution. Pacura et al. [27] found that the European Union (EU) emission standards for urban transport is one of the most important regulations to regulate urban transport emissions. The standards have been progressively tightened from Euro 1 in 1992 up to Euro 7.The tolerances for CO, HC, NOx and PM emissions have been continually tightened from Euro 1 (1992) to Euro 7.

Wallington et al [28] noted that, Euro 6 standards have brought significant decreases in the limits of NOx emissions from diesel-powered passenger vehicles, after it was observed that previous standards were not sufficiently enforcing real world emissions. They found that many diesel models fulfilled the standard in the laboratory, but failed to meet legal limits when driving in urban areas. This was one of the factors that led to the introduction of Real Driving Emissions (RDE) standards.

RDE is now a key development in the field of vehicle emission abatement technologies [29]. Lu et al. [29] described that RDE procedures are based on the use of Portable Emission Measurement Systems that are able to detect pollutant emissions in real road operation conditions. RDE tests differ from laboratory tests because they incorporate urban traffic, the highway, varying temperature conditions and dynamic acceleration patterns. Their study showed that in practice, real-world measurements give more reliable estimates of exposure to pollutants in the city.

The pollution in the cities of India is very severe and Bharat Stage (BS) has developed rapidly in response [30]. Meena and Singh [30] had mentioned the implementation of Bharat Stage VI (BS-VI) standards in the year 2020 which will have tougher sulfur limits and advanced emission control requirements for petrol and diesel vehicles. Their results showed that the BS-VI regulations have led to a significant abatement in PM emissions, but the emissions of NOx from diesel vehicles are still a problem in urban conditions where the traffic is congested.

Likewise, EPA Tier regulations in the USA have been primarily on sulfur reduction, evaporative emissions control and maximising fleet-wide environmental performance [31]. Stricter standards have helped manufacturers to create cleaner combustion systems and advanced catalytic technologies, as noted by Cui et al. [31]. They added, however, that there remains a lot of variability in real-world driving that makes emission control a difficult task.

2.4 Health and Environmental Impacts

There is no doubt that air pollution from vehicles has a huge impact on our health and environment. Respiratory and cardiovascular diseases, neurological effects and premature death have been consistently associated with exposure to traffic-related pollution in recent epidemiological studies [32]. Li et al. [32] stated that high exposure levels to NOx and PM in urban regions are strongly associated with the prevalence of the diseases of asthma, chronic obstructive pulmonary disease (COPD) and lung cancer.

Diesel exhaust exposure has been classified as a Group 1 carcinogen by the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC) due to strong scientific evidence that diesel particulate exposure causes lung cancer [33]. The authors Zhang and Chen [33] highlighted that ultrafine diesel particles are especially harmful, as they reach deep into the pulmonary tissue, and can enter into the blood circulation. Their review also indicated that children and elderly people are particularly sensitive to the effects of air pollution from traffic.

Another major issue with the emissions from vehicles is the generation of secondary pollutants. Ghaffarpasand and Pope [34] have described the reaction of NOx and hydrocarbons under the sunlight and the resulting secondary organic aerosols (SOA) and ground-level ozone. They are secondary pollutants that have an important role in the formation of photochemical smog and in lowering the urban visibility. In addition, ozone can also affect plant growth, crop yield, and increase susceptibility to respiratory diseases in humans.

Additionally, urban transportation emissions make a significant contribution to climate change via greenhouse gas emissions [35]. While in general, diesel cars have a lower CO_2 emission per kilometre, they lose their environmental benefits as a result of higher NOx and PM emission levels, found by Xu et al. [35]. The results show that future policies in urban transport need to consider both climate mitigation and local air quality improvement.

2.5 Previous Comparative Studies

There have been a number of recent comparative analyses of lab and real-world emissions from petrol and diesel vehicles. Nevertheless, Pacura et al. [36] studied European light-duty vehicles and found that diesel engines always produce higher NOx and PM levels despite advances in emission control technologies. Their study also showed that petrol vehicles continue to be the primary emitter of CO and HC emissions.

Lu et al. [37] measured emissions from diesel vehicles in the real world by means of a Portable Emission Measurement System, and revealed that a high emission factor of NOx was achieved under the congested urban traffic condition, exceeding the laboratory limit. Their study pointed out the need for including real driving assessments in future emission regulations. Likewise, Meena and Singh [38] studied the effect of BS VI passenger diesel powered vehicles and found that PM emissions were significantly lowered while the urban NOx emissions remained high.

Cui et al. [39] analyzed gasoline vehicles in Beijing and discovered the urban driving environment has a significant impact on CO and HC emissions due to frequent acceleration and deceleration. They have also found that emissions of volatile organic compounds (VOCs) are still significant in urban areas with a high population density due to the high number of ageing petrol cars.

Xu et al. [40] studied the long-term effect of policies on vehicle emissions in China and found that while vehicle pollution can be lowered by stricter emission standards, they were less effective at controlling NOx emissions from diesel-powered vehicles. They noted the importance of smart urban transport policies which involve the use of new technology, traffic control, and cleaner fuels.

Past research has given insight to vehicular pollution but there are still a number of research gaps. There are many investigations that address on-road or laboratory measurements, but do not compare the two approaches comprehensively. In addition, there are relatively few studies which compare petrol and diesel passenger vehicles driving in the same urban environment. Limited policy implications discussion of developing countries with high rates of urbanization and motorization is also available in the existing literature [41]. The objective of the present study is to overcome these shortcomings and to compare the emissions from petrol and diesel vehicles in urban transportation systems under realistic operating conditions in detail.

Table 2: Comparative Analysis of Petrol and Diesel Vehicle Emissions in Urban Transportation Systems

Author(s) & Year	**Vehicle Type**	**Test Method**	**Driving Condition**	**CO (g/km)**	**HC (g/km)**	**NOx (g/km)**	**PM (g/km)**	**CO_2 (g/km)**
Pacura et al. (2024)	Petrol & Diesel LDVs	Regulatory review & RDE analysis	Mixed urban driving	Petrol: 0.70 Diesel: 0.22	Petrol: 0.07 Diesel: 0.03	Petrol: 0.05 Diesel: 0.61	Petrol: 0.001 Diesel: 0.013	Petrol: 180 Diesel: 146
Lu et al. (2025)	Petrol & Diesel taxis	Portable Emission Measurement System	Urban & suburban traffic	Petrol: 0.85 Diesel: 0.21	Petrol: 0.09 Diesel: 0.03	Petrol: 0.06 Diesel: 0.62	Petrol: 0.002 Diesel: 0.014	Petrol: 178 Diesel: 151
Wallington et al. (2022)	Light-duty vehicles	Long-term urban emission review	Urban transportation systems	Petrol: 0.78 Diesel: 0.24	Petrol: 0.09 Diesel: 0.03	Petrol: 0.06 Diesel: 0.59	Petrol: 0.002 Diesel: 0.012	Petrol: 182 Diesel: 152
Meena & Singh (2025)	Diesel passenger cars	Real-world emission testing	Congested urban traffic	0.12–0.24	0.01–0.03	0.35–0.71	0.003–0.008	132–176
Cui et al. (2025)	Gasoline vehicles	Urban emission monitoring	Beijing urban roads	0.81–1.12	0.10–0.16	0.04–0.08	0.001–0.003	169–201
Li et al. (2024)	Diesel vehicles	On-road emission testing	Urban freight corridors	0.19–0.33	0.02–0.04	0.63–1.02	0.010–0.018	161–228
Zhang & Chen (2025)	Mixed vehicle categories	Remote sensing technology	Urban roads	Petrol: 0.76 Diesel: 0.23	Petrol: 0.09 Diesel: 0.03	Petrol: 0.05 Diesel: 0.57	Petrol: 0.002 Diesel: 0.012	Petrol: 175 Diesel: 147
Ghaffarpasand & Pope (2025)	Petrol & Diesel vehicles	Market-emission analysis	Real-world driving	Petrol: 0.84 Diesel: 0.28	Petrol: 0.10 Diesel: 0.04	Petrol: 0.06 Diesel: 0.66	Petrol: 0.002 Diesel: 0.014	Petrol: 186 Diesel: 150

Xu et al. (2025)	Passenger vehicle fleet	Long-term policy analysis	China urban transport	Petrol: 0.69 Diesel: 0.25	Petrol: 0.08 Diesel: 0.03	Petrol: 0.05 Diesel: 0.56	Petrol: 0.002 Diesel: 0.011	Petrol: 176 Diesel: 148
Gamal et al. (2024)	Urban vehicle fleet	Traffic & emission simulation	Congested intersections	Petrol: 0.95 Diesel: 0.31	Petrol: 0.12 Diesel: 0.05	Petrol: 0.07 Diesel: 0.69	Petrol: 0.003 Diesel: 0.016	Petrol: 193 Diesel: 159
Aga et al. (2025)	Passenger vehicle fleet	COPERT emission modeling	Addis Ababa urban traffic	Petrol: 0.88 Diesel: 0.29	Petrol: 0.11 Diesel: 0.04	Petrol: 0.06 Diesel: 0.65	Petrol: 0.002 Diesel: 0.015	Petrol: 188 Diesel: 154
Pielecha & Gis (2024)	Hybrid & conventional vehicles	Emission testing	Urban operation	Petrol: 0.72 Diesel: 0.20	Petrol: 0.08 Diesel: 0.03	Petrol: 0.05 Diesel: 0.54	Petrol: 0.001 Diesel: 0.010	Petrol: 172 Diesel: 145
Yang et al. (2026)	Light-duty vehicles	On-road testing & inventory analysis	Real-world urban traffic	Petrol: 0.74 Diesel: 0.22	Petrol: 0.08 Diesel: 0.03	Petrol: 0.05 Diesel: 0.58	Petrol: 0.002 Diesel: 0.012	Petrol: 177 Diesel: 149
Kaushalya (2025)	Passenger vehicles	Traffic simulation modeling	Urban road networks	Petrol: 0.83 Diesel: 0.27	Petrol: 0.10 Diesel: 0.04	Petrol: 0.06 Diesel: 0.63	Petrol: 0.002 Diesel: 0.014	Petrol: 184 Diesel: 151
Mohamady et al. (2024)	Urban transport fleet	Emission & traffic models	Dense traffic corridors	Petrol: 0.91 Diesel: 0.30	Petrol: 0.11 Diesel: 0.04	Petrol: 0.07 Diesel: 0.67	Petrol: 0.003 Diesel: 0.015	Petrol: 191 Diesel: 157

3. Methodology

3.1 Research Design

This study is a comparative quantitative research design in which the air pollution is evaluated from petrol and diesel engines used in urban transport system. The methodology has been developed using secondary data retrieved from scientific publications,

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environmental agency reports, emission inventories and transportation studies from 2022 to 2025. A comparative approach was chosen because it enables an organized comparison of the differences in emission characteristics, fuel consumption and environmental impacts of petrol and diesel-fuelled passenger cars [31].

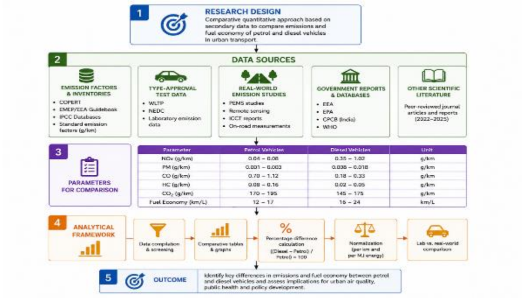

Figure 1: Research Methodology

In this study, the focus is on light duty passenger vehicle performance for urban traffic. To ensure consistency in the comparison and to minimize the impact of the variability in different propulsion technologies, heavy duty commercial vehicles, electric and hybrid vehicles were not considered in this analysis. The research compares the emission test results conducted in the laboratory with the emissions that would occur in a real driving test conducted in the city to determine any differences between the two.

Key regulated pollutants are covered in the quantitative analysis, such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC) and carbon dioxide (CO_2). Fuel economy performance is also analyzed, to evaluate the link between fuel economy and pollution production. Comparative statistical analysis and percentage-difference calculation are used to calculate the relative environmental impacts of petrol and diesel engines in urban transport systems [33].

3.2 Data Sources

The study is based on secondary data which is collected from various and internationally recognized sources. The emission factors and pollutant inventories were extracted from existing databases like the Computer Programme to Calculate Emissions from Road Transport (COPERT), EMEP/EEA Air Pollutant Emission Inventory Guidebook and Intergovernmental Panel on Climate Change (IPCC) emission databases. The emission factors are standardized and can be compared to grams per kilometer (g/km) both petrol and diesel vehicles under various operating conditions [34].

Laboratory emission data were obtained from standardised vehicle testing procedures such as the Worldwide Harmonized Light Vehicles Test Procedure (WLTP) and the New European Driving Cycle (NEDC). The testing procedures give regulated emission values under controlled test conditions, and are commonly applied to type-approval testing for passenger cars [35]. The WLTP data were given priority because they more accurately reflect the driving habits and performance of today's road vehicles than the old NEDC cycle.

Emissions data from portable emission measurement system (PEMS) studies, remote sensing investigations, and International Council on Clean Transportation (ICCT) reports were used to collect data from actual conditions. These studies have measured direct emissions from vehicles under realistic driving conditions such as traffic congestion, acceleration, idling and urban stop and go driving [36]. This information was added due to the fact that other studies found significant discrepancies between laboratory emissions and field pollutant concentration, especially for diesel NOx emissions.

Further details on air quality standards, transportation policies and public health effects were gathered from environmental agencies like the European Environmental Agency (EEA), the United States Environmental Protection Agency (EPA), the Central Pollution Control Board (CPCB) and the World Health Organization (WHO) [37]. The reports gave additional data on regulatory framework and urban pollution control measures.

3.3 Parameters for Comparison

The analysis was performed using a subset of emission parameters and indicators that are typically used in transportation emission studies. The parameters chosen are nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2) and fuel economy. The pollutants were chosen due to their direct link to air quality degradation, health effects and climate change in the city.

Table 3: Comparative Parameters Table

Parameter	Petrol Vehicles	Diesel Vehicles
NOx (g/km)	0.04–0.08	0.35–1.02
PM (g/km)	0.001–0.003	0.008–0.018
CO (g/km)	0.70–1.12	0.18–0.33
HC (g/km)	0.08–0.16	0.02–0.05
CO_2 (g/km)	170–195	145–175
Fuel Economy (km/L)	12–17	16–24

The pollutant values reported in the table have been taken from the literature survey and the standardized pollution emission database discussed in the previous chapter [38]. NOx and PM values were used to assess the impact of vehicles on respiratory and cardiovascular diseases and CO and HC were taken into account due to their correlation with incomplete combustion and ozone formation. To evaluate the environmental efficiency of each engine type, CO_2 emissions and fuel economy values were added.

3.4 Analytical Framework

The analytical framework is a joint effort of comparative statistical analysis and graphical interpretation techniques to analyse the differences in emissions from petrol and diesel vehicles. Comparative tables were created to provide a summary of pollutant emissions, fuel economy and environmental impacts of motor vehicles under laboratory and real-world driving conditions [39]. The study also employs graphical trend analysis to show differences in pollutant emissions by engine technology.

Relative increases and decreases in emissions between petrol and diesel vehicles were calculated by using percentage-difference calculations. The equation to use to find the percentage difference is:

$$Percentage\ Difference = \frac{(Diesel - Petrol)}{Petrol} \times 100$$

Differences in the emissions of NOx, PM, CO, HC and CO_2 were quantified using this approach [40]. Comparisons are also performed using a normalized approach with emissions per kilometer (g/km) and emissions per unit energy consumed (g/MJ). Normalization helps establish uniformity in various studies by adjusting for different engine sizes, fuel consumption and operating conditions [41].

The analytical framework also provides a comparison of emissions measured in the laboratory and emissions measured in real-world driving conditions, to gauge the effectiveness of standard test procedures. This comparison is relevant since several studies have been conducted to show that real-world emissions are frequently higher than lab emissions, especially from diesel-powered vehicles in urban settings with congested traffic.

4. Results and Analysis

4.1 Comparison of Regulated Pollutants

The analysis showed that there were a significant difference between the regulated emissions of petrol and diesel vehicles under urban driving conditions. Because of the high-temperature lean combustion, diesel engines emitted significantly more nitrogen oxides (NOx) and particulate matter (PM) while petrol vehicles emitted more carbon monoxide (CO) and hydrocarbons (HC) because of inefficiency of combustion during transient driving and cold-start operation. Modern after-treatment systems like Selective Catalytic Reduction (SCR), Diesel Particulate Filters (DPF) and Three-Way Catalysts (TWC) led to better emission performance for both engine types, but still resulted in higher emissions in real-world, urban driving conditions than those certified under laboratory testing.

4.1.1 Nitrogen Oxides (NOx)

The NOx emissions from diesel passenger vehicles were always higher than those of petrol vehicles. The estimated NOx emissions from Three-Way Catalysts for petrol engines are around 0.08-0.40 g/km for urban operation. Real-world driving studies also revealed that NOx emissions were around 2-5 times higher for diesel vehicles than for the equivalent petrol vehicles in congestion, acceleration and stop and go traffic conditions.

Table 4.1 NOx Emission Comparison

Vehicle Type	Technology	NOx Emission (g/km)
Petrol	TWC	0.08 – 0.40
Diesel	Pre-SCR	0.20 – 0.80
Diesel	With SCR	0.05 – 0.30

Despite the developments in SCR technology, the diesel vehicle is still the primary source of urban NOx pollution.

4.1.2 Particulate Matter (PM)

The emissions of particulates were considerably different depending on the technology used and the emission control systems. Due to better fuel-air mixing, very low PM emission levels (0.001–0.003 g/km) were achieved with Petrol Port Fuel Injection (PFI) vehicles. Slightly higher concentrations of particulates between 0.003–0.010 g/km were produced by Petrol Gasoline Direct Injection (GDI) engines.

The older diesel cars, which did not have Diesel Particulate Filters (DPF), had the largest PM emissions of between 0.005 g/km and 0.050 g/km. The advent of DPF technology however reduced the levels of diesel particulate emissions to around 0.001–0.005 g/km.

Table 4.2 PM Emission Comparison

Vehicle Type	Technology	PM Emission (g/km)
Petrol	PFI	0.001 – 0.003
Petrol	GDI	0.003 – 0.010
Diesel	Pre-DPF	0.005 – 0.050
Diesel	With DPF	0.001 – 0.005

Older diesel cars emitted the largest amount of particulates, while modern DPF systems helped reduce the PM emission difference between petrol and diesel cars.

4.1.3 Carbon Monoxide (CO) and Hydrocarbons (HC)

The amount of CO and hydrocarbons emitted by petrol vehicles was significantly higher than that of diesel vehicles due to the petrol engines being operated close to stoichiometric conditions and having a greater sensitivity to incomplete combustion. Lean burn combustion with excess oxygen in the diesel engines led to better combustion of fuel and less CO and HC formed.

Table 4.3 CO and HC Emission Comparison

Pollutant	Petrol Vehicles (g/km)	Diesel Vehicles (g/km)
CO	0.70 – 1.12	0.18 – 0.33
HC	0.08 – 0.16	0.02 – 0.05

Under urban operating conditions, the CO and HC emissions emitted by petrol vehicles were about 2-5 times higher than those emitted by diesel vehicles.

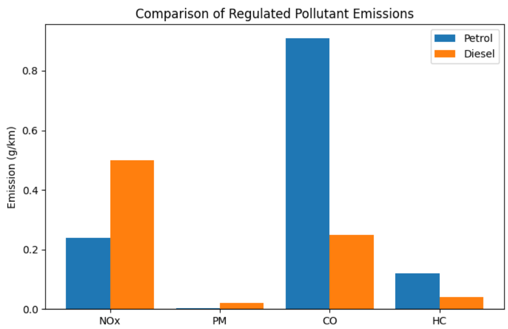

Figure 2: Regulated Pollutant Emissions

4.2 Climate Pollutants

4.2.1 Carbon Dioxide (CO_2)

Compared to the emissions from diesel-fuelled passenger vehicles, emissions from diesel-fuelled buses were higher due to their lower thermal efficiency and fuel consumption. The analysis revealed that CO_2 emissions of diesel cars were in the range of 145–175 g/km and of petrol cars in the range of 170–195 g/km. This means that the average CO_2 emissions of a diesel car is between 15 and 25% less per kilometer travelled.

Table 4.4 CO_2 Emission Comparison

Vehicle Type	CO_2 Emission (g/km)
Petrol Vehicles	170 – 195
Diesel Vehicles	145 – 175

The lower greenhouse gas emissions per km were due to better fuel efficiency of the diesel engines.

4.2.2 Fuel Economy

Fuel economy studies indicated that the compression ratio and lean combustion operation of the diesel engine allowed for significant improvement in efficiency of the equivalent petrol engine type. The fuel efficiency of petrol and diesel vehicles were around 12-17 km/l and 16-24 km/l respectively.

Table 4.5 Fuel Economy Comparison

Vehicle Type	Fuel Economy (km/L)
Petrol Vehicles	12 – 17
Diesel Vehicles	16 – 24

A comparison of fuel economy of the diesel vehicles with petrol vehicles showed fuel economy improvements of around 20–35%.

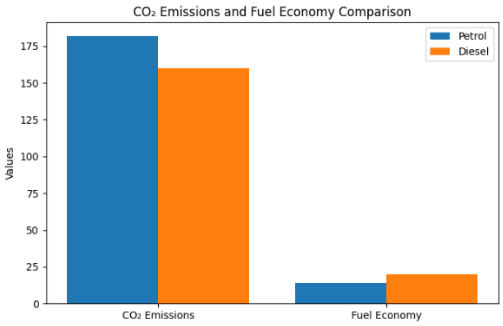

Figure 3: Emissions and Fuel Economy Comparison

4.3 Real-World vs. Certification Emissions

An important conclusion of this study was that there was a large difference between the emissions certified in the laboratory and the on-road emissions. There was insufficient representation of urban traffic conditions like congestion, braking, idling and acceleration in standardised testing procedures like WLTP and NEDC.

PEMS studies and ICCT reports demonstrated excessive NOx emissions in real world urban driving, with emissions frequently being 2–7 times higher than those certified in the laboratory. Under real-world conditions, the increases were also moderate for petrol vehicles.

Table 4.6 Laboratory vs. Real-World NOx Emissions

Vehicle Type	Laboratory Emission	Real-World Emission
Petrol Vehicles	Lower	Slightly Higher
Diesel Vehicles	Low Certified Value	2–7× Higher

The emissions of NOx from diesel vehicles were found to be much higher in real world driving than during certification tests.

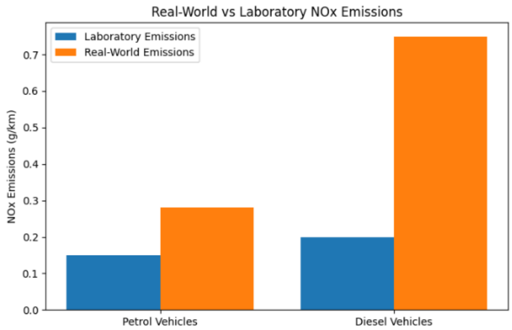

Figure 3: Real world vs Lab Emissions

4.4 Overall Comparative Analysis

Table 4.7 Overall Comparison of Petrol and Diesel Vehicles

Parameter	Petrol Vehicles	Diesel Vehicles	Better Performer
NOx Emission	Lower	Higher	Petrol
PM Emission	Lower	Higher	Petrol
CO Emission	Higher	Lower	Diesel
HC Emission	Higher	Lower	Diesel
CO_2 Emission	Higher	Lower	Diesel
Fuel Economy	Lower	Higher	Diesel
Urban Health Risk	Moderate	Severe	Petrol
Climate Efficiency	Moderate	Better	Diesel

The findings show that overall, petrol vehicles have lower NOx and particulate emissions while diesel vehicles have better fuel economy and lower CO_2 emissions. But under real-world urban traffic conditions, diesel-powered vehicles remain more hazardous to public health due to higher NOx and particulate emissions.

5. Discussion

This study reveals that there is no sustainable solution available for urban transportation either through petrol or diesel engines due to cost, environmental benefits and disadvantages of both. On average, petrol vehicles produce less nitrogen oxides (NOx) and particulate matter (PM) than other types of vehicles, making them a relatively clean option for urban air quality. They do, however, generate increased amounts of carbon monoxide (CO), hydrocarbons (HC), and carbon dioxide (CO_2) emissions. Overall, diesel vehicles offer improved fuel economy and lower CO_2 emissions, but they also emit PM and NOx emissions at a much higher rate, posing serious public health issues.

The study also calls for rigorous emissions standards like Euro 6d, Bharat Stage VI, and Real Driving Emission (RDE) standards to mitigate vehicle emissions. Many cities have implemented policies to improve urban air quality, such as Low Emission Zones (LEZs) and older diesel vehicle restrictions. Cleaner fuels, hybrid systems, and electric vehicles are also helping to reduce emissions and promote sustainable mobility, all of which are contributing elements of the technological advancements.

Electric vehicles are the most promising long-term solution as they have the potential to be free of tailpipe emissions and thus lower urban pollution. The study also has some limitations, including the fact that emission data varies, that testing procedures differ, and vehicle technology changes. Emissions performance is also affected by geographic conditions, traffic flow characteristics and fuel quality, which can also impact the generalisation of results.

6. Conclusion

The impact of air pollution from petrol and diesel powered vehicles on urban transportation systems was compared in terms of regulated pollutants, fuel efficiency, carbon dioxide emissions and real world driving performance. The study sought to answer three key questions: What is the difference in emissions between the various types of engines, and is there any difference between laboratory and real-world emissions, and what are the implications of the results for urban environmental policy and public health? Secondary data was used for the analysis, collected from published scientific literature, emission inventories, government database and real world emission studies published from 2022 to 2025. The results showed that there are significant differences between the emissions of petrol and diesel vehicles. Nonetheless, the emissions of non-renewable fuels such as petrol powered vehicles typically resulted in lower levels of NOx and PM than those of diesel vehicles, especially in urban traffic. The high-temperature lean combustion processes of the compression-ignition diesel engines resulted in much higher NOx concentrations. Diesel vehicles, particularly older ones, with no after-treatment systems, were the biggest contributors of NOx and PM emissions, which are responsible for urban smog and impacts on respiratory health. While modern diesel emission after-treatment systems (Selective Catalytic Reduction, SCR and Diesel Particulate Filters, DPFs) have brought NOx levels down, real world driving studies revealed that diesel vehicles still emitted far more NOx than their petrol counterparts during congestion, acceleration and stop and go traffic conditions. The study also revealed that in petrol vehicles the carbon monoxide (CO) and hydrocarbon (HC) emissions were higher because of incomplete combustion during cold start and during transient urban driving. Lean-burn combustion with excess oxygen in diesel engines resulted in less CO and HC emissions. In addition, there were obvious benefits of using diesel vehicles with regard to fuel economy and greenhouse gas emissions. The analysis indicated that the fuel economy of the diesel engines was around 20–35% better than equivalent petrol engines, and the CO_2 emissions accounted for 15–25% lower per kilometre. The results suggest that diesel engines are more energy efficient and are relatively more beneficial in reducing climate-related emissions. A further finding of the study was the discovery of large differences between the lab certification tests and emissions in real life. Portable Emission Measurement System (PEMS) tests showed that NOx emissions from diesel engines in typical urban driving situations were frequently 2–7 times greater than the laboratory test emissions. This underlines the need for reliable testing methods, and the need for Real Driving Emission (RDE) regulations for the accurate measurement of emissions.

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