A systematic review on real time exhaust gas sensing system for on board sensing of harmful gases in IC engine

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Abstract. Air pollution causes detrimental effects on human health and the atmosphere. The emissions associated with transport represent a major component of aerial pollution. In recent years, air pollution is becoming a very important issue in India and around the World. Conventionally, the most popular dynamometer testing has been widely used to measure vehicle exhaust emission and these measured emissions have been used as primary data for modeling transport related air quality impact. However, during such conventional emission testing, real driving conditions are not strictly considered. Nowadays, real-time vehicle emission measurement is mainly focused by the most of the researchers for analysis purposes. In the present paper, the various real-time vehicle emission measuring technologies such as vehicle emission measurement by using RFID technology, emission measurement using gas sensor technology, emission measurement using gas sensor technology with the use of IoT and emission measurement using portable emission measurement system (PEMS) is discussed.

Keywords: Air pollution, Radio-frequency identification (RFID), Internet of things (IoT), Portable emission measurement system (PEMS).

1. Introduction
Air pollution constitutes the foremost pressing environmental health risk facing our world population. It’s calculable to contribute toward seven million premature deaths a year, whereas near about ninety-two percent of the world’s population is estimated to breathe toxic air (WHO, 2016). In less-developed nations, 98 percent of children under five breathe poisonous air. As a consequence, air pollution is the biggest cause of death for children under 15 years of age, killing 600,000 every year \citep{1,2}. The World Air Quality Report 2019 presents PM2.5 data made publicly accessible during 2019, data reported in this report are focused on real-time or roughly real-time monitoring by government sources and independently controlled and validated non-governmental air quality monitors. This report concluded that according to region wise South Asia, Southeast Asia, and Western Asia bear the highest burden of fine particulate matter (PM2.5) emissions overall, with only 6 of 355 cities included meeting WHO annual goals in these areas collectively. During 2019, the study highlights the world’s top 30 most polluted cities, 21 in India, 27 in South Asia, and all the top 30 cities in Greater Asia \citep{3}. In India day by day air pollution is becoming a serious problem from both the human perspective and environmental perspective \citep{4}. Traffic-related emissions constitute a major component of airborne pollution \citep{5}, and it is largely responsible for climate change \citep{6}. Transport emissions, primarily road transport, contribute significantly to the number of greenhouse gases in the environment, so the amount of exhaust gas emissions produced by motor vehicles needs to be accurately measured. Measuring the emissions of exhaust pollutants from car engines is very important because of their adverse environmental impact \citep{7}. In urban areas the high inflow of vehicles decreasing air quality and...
causing more air pollution that leads to serious health diseases [8]. After decades of study and laboratory studies on livestock, the US Environmental Protection Agency (EPA) report concluded that the contaminants are carcinogenic and thus contribute significantly to the production of lung cancer; carmakers treat the issue of exhaust pollution with priority [9]. There is need to develop a system for measuring the emissions of exhaust pollutants from vehicle which will be simple to use and does not take a long time to learn, and that can display results in the form of parameters that people can easily understand [10]. Studies on automotive exhaust emissions under real operating conditions have clearly demonstrated that the level of natural vehicle emissions is higher than the level of laboratory test emissions [11] [12]. The Real Driving Emission (RDE) test concluded that the emission of nitrogen oxides is greater than that obtained in the laboratory test [13]. They, therefore, suggest using the test results of the RDE (Real Driving Emission) to develop the engine control system. Emissions from diesel vehicles are responsible for more air pollution related death worldwide [14] [15]. In the majority of developing countries, particularly India, the impact of diesel engine emissions is growing. In 2016, the Indian government decided to fully bypass the Bharat stage (BS) V standards and to comply with increasingly strict BSVI standards by 2020, which will reduce particulate matter (PM) and nitrogen oxide (NOx) emissions. [16]. In the BS-6 diesel engine to reduce the level of NOx and particulate matter, all vehicle manufacturers have been mainly focused on emission control devices to protect the environment from vehicular emission. One of the emission control devices used in the BS-6 diesel engine is called a "Diesel Particulate Filter (DPF)" which fixes and filter harmful carbon particles emitted during the combustion cycle in the exhaust system, preventing the release of these particles into the atmosphere. The DPF filter is designed to reduce diesel particulate matter and soot emissions up to 80% but this device also having some limited capacity after that it may be blocked so there is a need to regenerate the DPF [17-18-19]. The contribution of exhaust emissions from vehicles to the local atmosphere is many times greater than the emissions predicted by traditional emission measurement methods. The national clean air programme (NCAP Ministry of Environment, Forest & climate change, Government of India 2019) report 2019 [20] concluded that there is a need to develop techniques and methods for measuring harmful emissions in real time due to the extreme risk posed to human health and the environment. Therefore the real time sensing system must be designed to monitor air pollution through the transport sector.

2. Factors affecting vehicular emissions
Fuel intake and exhaust emission rates are closely related to engine load and vehicle speed [21]. Factors that directly affect engine load are vehicle acceleration, engine friction, wind resistance, roadway efficiency, tire-roadway friction and accessories such as air conditioning. In turn, these engine load sources are calculated by a combination of vehicle characteristics such as motor displacement, vehicle mass, transmission performance, etc. and operating conditions of vehicles. Operating conditions include vehicle speed and acceleration are influenced by traffic congestion, driver attitude, traffic signals, posted speed limits, etc. [22]. In the summer of 2016, researchers (Granié, M.A. et.al. 2011; Holmén, B.A.et.al.1998) performed an on-road emissions measurement experiment in the city of Logan, UT, USA to determine the effects of driver experience and gender and driving behaviour on vehicle emissions, where the driving of the same vehicle along the same route was measured in four different driver groups: Experienced versus Inexperienced, female versus male. The results revealed that experienced drivers and male drivers released more HC and NOx than the control driver, which was not the case with both young and female drivers [23] [24]. Jawad H. Al-rifai [25], found in his research that road grades, speed and type of vehicle had a substantial effect on gas emissions rates. Since there is no uncertainty about the fact that heavy traffic on road is more responsible for generating more pollution hence significant attention is needed to evaluate and quantify the factors which are responsible for these emissions. The following listed factors are directly or indirectly affect the emission level [26].
Type of vehicle: Vehicles in this category can be categorized into the following categories, such as vehicle brand, vehicle model, engine size, vehicle era, vehicle technology, vehicle maintenance and categories of exhaust systems, vehicle tire pressure.

Type of Fuel: Exhaust emission emitted from vehicles depends upon grade, type of fuel such as CNG, biodiesel, petrol, diesel.

External Conditions: External conditions mainly include environmental conditions such as pressure, temperature, and humidity.

Driving activity: Driving activity includes normal driving, aggressive driving, cruising, idling, accelerating, and decelerating.

The vehicular emissions also rely upon proper contact between driver and vehicle. The vehicular emissions can be minimized by identifying user optimal behavior while driving and intimate the drivers about the problems associated with the inefficient style of driving, as well as informing them about its possible solutions.

3. Implementation of Emission Norms in India

In India, as proposed by the Auto Fuel Policy and the productive development of new technologies, the Indian automotive industry is primarily working towards regulatory emissions. As Indian safety requirements are compliant with Global Technical Regulations (GTR) and UN Regulations, vehicle technology in India is now on par with international benchmarks [27]. The first concept of emission standards in India was introduced for petrol engines in 1991 and diesel engines in 1992. From April 1995, in the four metro cities Delhi, Kolkata, Chennai, and Mumbai, new petrol passenger cars with the mandatory fitting of catalytic converters were launched along with the availability of unleaded petrol [28]. The Bharat Stage–I (BS–I) emission standards for passenger cars and commercial vehicles were implemented in India in 2000 to meet the Euro I standard. In Delhi, Mumbai, Chennai and Kolkata, further Euro II equivalent Bharat Stage II standards were in place from 2001 onwards. In August 2002, the first auto fuel policy was implemented, in which four-wheeled vehicles have followed the BS III norm. In April 2010, Bharat Stage IV was introduced for 13 metro cities, and the rest of the country switched to Bharat Stage III. The criteria for Bharat Stage IV were expanded to an additional 20 cities in October 2014. India's National Capital Region (NCR) was in extreme condition due to a massive rise in levels of air pollution. This drastic situation has led the Indian Government to take the strongest decision to bypass the BS V emission standard, which was introduced in 2020, and to advance the introduction of the BS-VI emission standard from 2024 to 2020[29].

| Emission Standard | Reference | Year of Introduction | Implemented Region |
|-------------------|-----------|----------------------|--------------------|
| Bharat Stage –I(BS-I) | EURO 1 | 2000 | Nationwide |
| | | 2001 | Kolkata Chennai Mumbai NCR* |
| Bharat Stage –II(BS-II) | EURO 2 | 2003 | 11 cities#, NCR*, |
| | | 2005 | Nationwide |
| | | 2005(04) | 11 cities#, NCR* |
| Bharat Stage –III(BS-III) | EURO 3 | 2010 | Nationwide |
4. Role of On-Board Diagnostic Device (OBD)

The major automotive manufacturers have fitted their cars with an onboard diagnostic system (OBD) to monitor vehicle exhaust emission emissions according to the norm \([31]\). The system, which has stringent emission significance and its essence in the mid-90s is vehicular emissions, is used \([32]\). The on-board diagnostic is an intelligent device in which different types of sensors are embedded into the important areas of the vehicle that track the output and report the device whether those areas are working according to the specified parameters of the vehicle or not. The sensors activate a warning light on the vehicle's dashboard when any variations are detected, indicating that the area needs to be repaired. It is a computer-based system that detects failures associated with exhaust emissions in light-duty trucks, passenger cars, and even in heavy-duty vehicles from some years onwards. Although OBD-II diagnoses any emission-related fault, it does not guarantee that the driver understands the alarm of the MIL (Malfunction Indicator Lamp) fault indicator and fixes the failure of the vehicle promptly \([33]\). The OBD-III is developed as a new generation of OBD systems, featuring wireless transmission of fault information. Effective exhaust emissions control and cleaning systems are designed by original equipment manufacturers (OEMs) to meet the legal specifications of emission standards. A so called onboard diagnostic system must supervise these systems and the associated components. In 1990, OBD was first used in California to track components and parameters for pollution control. The California OBD framework specifications used in light and heavy-duty vehicles have been implemented in two stages:

**OBD I:** The California Air Resources Board (CARB) required all new vehicles sold in 1991 in California and newer vehicles to have some basic OBD capacity to monitor some of the components of pollution control. The OBD I was relatively simple and limited to only checking some of the emission control elements, and it was not calibrated to an exact emission performance level \([34]\) \([35]\).

**OBD II:** On-board diagnostics (OBD-II) second generation vehicle diagnosis norm that was developed for diagnostics and pollution control. This offers an opportunity to create new software that
provides diagnostic services for car owners with more knowledge. Improved vehicle repair and diagnostic functions and more comfortable monitoring of equipment can be provided [36].

5. Related Work

5.1 Literature Survey Based on RFID Technology

Various emission control systems have been explored in various kinds of literature over the year. Chiman vong et.al. [37], in the present paper, author mainly focused on the emission control system for developing countries is discussed. The systems are made up of RFID tags to which the lambda sensor is attached with an analogue to digital converter. The lambda sensor mounted at the exhaust pipe of the vehicle for calculating air ratio. If the air ratio is less than one then the emission of carbon monoxide and the hydrocarbons will be increased and when the air ratio more than one nitrogen oxide will be emitted. The RFID reader is used to read the value. This RFID tag passes data to the Second RFID device. The second RFID device is attached to the 3G card from which data is sent to the database server where all information is successfully modified and saved. If the actual data does not match with the standard data, then the message is generated and sent to the vehicle owner.

Anita Kulkarni et.al. [38], the onboard vehicle (OBU) device is installed, which is used to collect vehicle exhaust data and send it to the roadside unit (RSU) installed at the traffic signal point. Received data along with traffic threshold transfer to the server side unit (SSU). The author concluded that using this method would minimise CO (carbon monoxide) exhaust emission. This system stops the vehicle and generates the message and sends it to the unique contact number stored in the GSM module if vehicle emission crosses pre-set standards.

S.P.Bangal et.al. [39], this paper’s primary objective is to control road emissions and track a vehicle that causes pollution. During this process, Radio Frequency Identification (RFID) technology as an affordable and mature wireless communication technique is adopted to gather and transmit emissions data of vehicles and the Internet of Things (IoT) concept is proposed. Active RFID and active RFID tags are designed to gather emission data from the exhaust system of the car. When vehicles equipped with the RFID tag drive inspect the range, the RFID reader can receive emission data. ADC data collected will be sent to the ARM Microcontroller and then to the RFID tag via GPRS and Cloud Web Server to the Cloud Data Base Centre and the GPRS will be located in a remote location.

Ramgiri R. et.al. [40], in this proposed system, author used a wireless sensor along with active RFID monitor vehicular pollution based on IoT. IoT plays a vital role in the proposed system to address vehicular pollution in real-time applications. Given a system equipped with a CO₂ gas sensor and SOx gas sensor to monitor the pollutants continuously to maintain the quality of the air. The RFID reader, wireless gas sensors are integrated along with the microcontroller at the monitor location. The given proposed system is placed on either side of the road. The proposed system of the given paper can identify the vehicle which is attached with RFID tags passes through the sensor node. The sensor measures the exhaust emission emitted by the vehicle and the RFID reader displayed the information in the monitoring system. The real-time data detected is further sent to the microcontroller to verify the concentration of pollutants from the vehicle. The microcontroller verifies the levels of the emissions pollutant of the air emitted by the vehicle. If the amount of pollutants is greater than the threshold, the vehicle sends an alert warning message to the owner of the vehicle. The information about the RFID of the vehicle and time and date of the vehicle, the levels of CO₂ and SOx, vehicle number send to authorized agencies. This data get stored in the server database for future analysis. The microcontroller monitors the levels of emission pollutants released by the vehicle. If the amount of pollutants is greater than the threshold, the vehicle sends an alert message to the owner of the vehicle. Rajalakshmi et al. [41] proposed another system, including the Arduino board with ATmega 328 and GSM modem. The system proposed in the paper Control air pollution on roads and track vehicles that cause pollution above a certain limit. Periodic monitoring of sensor values by the vehicle unit is noted and sent to the laptop via the server. Vehicle FC details, insurance details, periodic service details are viewed on the laptop in addition to the sensor values. If any rise in sensor readings, the date of any
insurance expires, a warning will be sent to the owner by FC Service. And even the transport service with respect to the insurance of cars.

Manna S. et al \cite{42} this paper aims to control air pollution over a defined limit on roads and track vehicles that cause pollution. To resolve this problem, this paper proposes the Internet of Things (IoT). Here, system consists of the Wireless Sensor Network and Electrochemical Toxic Gas Sensors and the use of a tagging device for radio frequency identification (RFID) to track car emission records anywhere at any time. System deployed the RFID readers at a road intersection to test the prototype. It also allows the gas sensors deployed on the roadside to collect data. The vehicles that frequently drive by the intersection are equipped with a few RFID tags. The sensor data is read concurrently with data from RFID readers, and the levels of emissions from individual vehicles can be calculated in real-time over a span of five days. The vehicles that frequently drive by the intersection are equipped with a few RFID tags. This work presents the design of a device to provide a solution for the identification of environmental pollution-causing vehicles. This work seems promising to resolve the issue based on the experimental results obtained by the author. Compared to other non-RFID-based vehicle detection systems, the device has an essential significance in terms of cost and effectiveness.

![Figure 1. Proposed Emissions Control Method Using RFID technology (Source \cite{39}: Ramgiri R. et.al.IEEE, 2015)](image)

5.2 Literature Survey Based on Gas Sensor Technology

G Arun Francis et.al \cite{43}, In this system, the hydrocarbon, carbon monoxide, and nitrogen oxide amounts emitted from the exhaust are monitored by mq2, mq7, mq135 sensors mounted at the vehicle exhaust. The analogue value obtained from the sensors is analyzed by the Internet-connected Wi-Fi controller. The value of the sensors is displayed on LCD and cloud on an on-going basis. When the value obtained from the sensor exceeds the threshold limit, the controller alerts the user via the vehicle owner’s LCD and database. IoT allows the computer to change the value of the cloud.

P Arun Mozhi et.al. \cite{44}, the proposed system used in this paper consists of a microcontroller and a sensor to measure vehicle emissions in order to alert the government to monitor the AQI and to communicate emission related information through GSM. The proposed prototype system for monitoring and detecting the level of emissions of the individual vehicle and sending information to the Central pollution control board and RTO if the vehicle crosses the threshold limit. The present system capable of detecting nitrogen oxide (NO) and carbon monoxide (CO), Carbon oxide (Cox) by using gas sensors. Due to heat dissipation from exhaust emission, the sensors may be malfunctioned during working so that they placed it in the thermal Isolation Clip. The real-time data get collected in
PIC microcontroller and data analyzed using C coding. While comparing data any deviation occurs then with the help of GSM and Information regarding GPS modules is transmitted to the nearest control station also to the driver with the help of LCD display.

Ms.S.Menaga et.al.[45], the author suggested a vehicle monitoring system (VMS) consisting of different sensors, including $O_3$, NO$_2$, CO and PM2.5. The given system provides data on pollution, smoke, vibrations, and also GPS signals by driving a vehicle (car, bus, etc.) on the street. Using IoT, the various parameters sensed by different sensors are registered and transmitted to a cloud server. The transmitted data is related to GPS location, weather parameters, information about the vehicle, and information about air quality. Based on transmitted data, Government agencies are easily takes decisions on traffic planning and on taking some steps to minimise emissions. For communication purposes, a system called LoRa, which is a transmission protocol, is used in VMS and is regulated by the LoRa Alliance. In this system MQ-131 sensor is used to detect ozone, PM 2.5/10 sensor is used to detect particulate matter in exhaust emission of vehicle, MICS-4514 sensor is used to detect carbon monoxide and nitrogen oxide. The Sensor used in this system has a simplified drive circuit and long life, high sensitivity, wide range detection capacity.

Palconit, M.G.B.et.al.[46], the current study focuses on the statistical assessment of the emission of PUV CO$_2$ and its corresponding driving patterns and road grades. The CO$_2$ emission is calculated with respect to vehicle specific power (VSP). The information is obtained using the CO$_2$ NDIR (non-dispersive infrared) sensor and GPS (global positioning system) receiver, which are calibrated and tested to ensure the reliability of the reading. Two PUVs are used for five days at the San Carlos-Talamban Campus in this study in which all selected PUVs have been fuelled with gasoline. Google Earth was used for the road grade assessment. Each PUV has a built-in Wi-Fi chip microcontroller named ESP 8266 and two sensors, namely the NEO u-blox 6 Global Positioning System (GPS) receiver and a CO$_2$ NDIR rapid response sensor named COZIR-WR GC-0006. The Raspberry Pi microcontroller was used to process the received data, including road grade and acceleration measurement. The processed data is stored in CSV format and synchronised with a cloud server called Amazon Web Services, which uses the Kibana dashboard to show the synced files so that they can be accessed anytime and anywhere through the Internet. In order to interpret the collected data, statistical methods were used, such as collecting clustered data with theme values and standard deviations.

Gautam A. et.al [47], the proposed system in the present paper can be used in any moving vehicle which is responsible for air pollution in the atmosphere. The MQ2 gas sensor is placed at the exhaust pipe of the vehicle with the help of wire which is routed up to the raspberry pi, which is placed behind the dashboard. At the top of the dashboard, the LCD and buzzer are mounted and linked through wires with raspberry pi. In the proposed prototype of the device, the DC motor with the motor driver IC is just an analogy of vehicle movement. In the actual vehicle, a relay is connected in place of the engine, the output of which is used to ON / OFF the engine In the actual vehicle, a relay is connected in place of the engine, the output of which is used to ON / OFF the engine. All components used in this system get powered using the existing battery system of the car. In the python code, acceptable ppm levels of CO, LPG, and smoke are already fixed. The driver can easily monitor the ppm level of the gases on LCD. An alert in the form of a buzzer beep is given to the driver whenever the ppm level of the gases exceeds the threshold of appropriate ppm levels. This warning is an indicator to get your vehicle serviced in a given time frame by the driver. Negligence of the alarm allows the ppm level of gases to rise further. A challan is produced and sent on the email Id of the driver as the ppm level of gases crosses the predefined appropriate limits (threshold). The proposed system helps to maintain the level of gases within the specified limit. The results show that the device meets the requirement of an embedded sensor-based system that can screen and monitor air pollution using IoT with challan generation from anywhere in the world. The findings indicate that the full framework is checked and implemented effectively.
5.3 Literature Survey Based on PEMS (Portable emission measurement system) Technology.
Jerzy Merkisz et al. [48], in the present paper author emphasis on real driving emission test for the light-duty vehicle (LDV), heavy-duty vehicle (HDV). The actual driving emissions test was carried out under real traffic conditions with portable emission measurement system (PEMS) equipment. PEMS such as SEMTECH DS is used to measure CO, CO₂, NO, NO₂ emission from the exhaust of the vehicle. To measure the PM [mg / m³] concentration, PEMS AVL MSS (Micro Soot Sensor) is used. TSI 3090 EEPS™ determines the size distribution of PM [nm] is used during the test. The paper discussed the problem of measurement of CO, HC, NOx, PM emissions, and related methodologies. After the completion of the test, it was reported that the main problem is the emission of NOx and PM, which is normally higher than the level of emission, which also indicates that the actual driving emission method is very complex, but is the only way to obtain information on the actual emissions of road exhaust that cannot be obtained in the laboratory test.
O’Driscoll R, ApSimon et.al. [49], the new Euro 6 diesel passenger cars are used in this paper to calculate NOx and primary NO₂ road emissions using PEMS. Test route of Euro 6 diesel passenger vehicles, consisting of parts of the city and motorway. The vehicles used for the exhaust gas recirculation (EGR) mounted est, lean NOx traps (LNT), or selective catalytic reduction (SCR). Measurements and emission factors based on COPERT suggest that PEMS measurements are 1.6 times higher on average than COPERT estimates for NOx and 2.5 times higher for NO₂. The result shows that NOx emissions are 1 to 22 times the limit of form approval. The mean emission of NOx, 0.36 (sd. 0.36) g km⁻¹, is 4.5 times the limit of Euro 6 comparisons between PEMS.
Barouch Giechaskie et.al. [50], The RDE procedure has been described in this paper. This paper focuses on the test technique used by Portable Emissions Measurement Systems (PEMS) to check emissions of gaseous pollutants and particle numbers during a wide variety of typical road operating conditions. Total RDE test procedures are divided into the following steps such as Vehicle selection, 2 vehicle preparation, trip design, trip execution, trip verification, and calculation of emissions. Out of these mentioned steps, vehicle preparation and trip execution are described in a better way in this paper. This paper gave examples of trip verification and the calculations of emissions.
Wang H et.al. [51], in this paper study, by using plume chasing and PEMS simultaneously, comparative measurements of 12 HDDTs in China were performed. Multiple chasing tests were carried out on both freeways and local roads during the analysis for each vehicle. In this paper, different methods of data processing and key parameters are used to refine an algorithm to measure emission factors based on fuel consumption. The comparative analysis shows that NOX emissions could be satisfactorily estimated by the plume chasing process. The result shows that the relative errors of vehicle-specific emission factors for NOx were within ±20 percent compared to the PEMS results for all tested vehicles with multiple chasing results averaged.
variance in trip dynamics in the current study consists of extreme driving, softness in driving considered during the real driving test. The result obtained gave excellent insights into the possible modifications that may be needed for Indian conditions suitable for RDE testing. In this work, the PEMS instrument used was a Horiba OBS-One. The result shows that Route-1 emissions of NOx are higher compared to Route-2. This concludes that when traffic conditions are regulated, NOx emissions are lower and thus the selection of routes will probably affect the results of the RDE test. The author finally conclude that, Overall, under Indian conditions, real-world data should be collected and analysed in order to define the base procedure, rather than adjusting and adopting the EU RDE procedure. Multiple RDE tests should be performed and evaluated once the basic conditions for India are specified.

Varella R.et.al [52], three PEMS with laboratory analyzers attached to the tailpipe and the dilution tunnel were compared in this paper. The tests were performed on two Euro 6 vehicles (one petrol and one diesel) conducting the World Harmonized Light Vehicles Test Cycle (WLTC) and on a chassis dynamometer with a pre-recorded RDE cycle. The results showed that the variations between the PEMS gas analyzers and the laboratory references were generally less than 2% for CO₂ and 5% for NOx. With just a few exceptions, CO₂ and NOx mass emissions were less than 10 percent and 15 percent, respectively. The measurements of the exhaust flow rate were 10 percent at low speeds (urban conditions) and 5 percent at higher speeds.

Dinodia, H. et.al. [53] this paper explores the detailed experimental results of Real Driving Emission experiments evaluating after-treatment device configurations considering various conditions such as test paths, test days, driving behaviour etc.

Exhaust emissions emitted from vehicles get measured in real-time by various above mentioned technologies. Many of the researchers explore new technologies for measuring real-time exhaust emissions from the vehicle as given in the following table:

| Authors            | Type of vehicle | Emission measuring device | Result & conclusion                                                                 |
|--------------------|-----------------|---------------------------|-------------------------------------------------------------------------------------|
| Rohit Jaikumar et.al. (2016) [54] | Passenger Cars | AVL Digas analyzer        | The findings showed that emissions in the real world were many times higher than the traditional emission factors are compared. In addition, it is possible to use the ANN model to estimate traffic pollution under real-world conditions. |
In addition to obtaining vehicle information through OBD-II, the VMS suggested by this paper might also collect pollutants information via various gas sensor modules. In addition, the GPS module enables drivers to locate their cars on the street. And all of the data will be collected and viewed by users to browse the information in a graphical user interface.

This research presented a detailed analysis of two different approaches for in-use emissions evaluation, namely US-NTE and EU-WBW protocols for HDD vehicles. Evaluation of on-board NOx sensors along with the developed exhaust flow model is performed to calculate in-use NOx emissions within the revised NTE in-use regulatory protocol.

The linear relationship between emission pollutants and vehicle speed was found in the current paper. As vehicle speed increases, the high amount of pollutants released such as CO2, NOx, HC, and CO.

| Authors                        | Type of Vehicle | Method                  |
|--------------------------------|-----------------|-------------------------|
| Chao-Linag Hsieh et al. (2017) | Passenger Cars  | Gas sensor              |
| Berk Demirgok.(2018)           | Heavy-duty (HD) vehicles | Portable Emission Measuring device (PEMS) |
| M Lutfie et. Al.(2018)         | Heavy-duty (HD) vehicles | Gas Emission sensor Mobile gas analyzer |
This paper provides an emission data for real driving cycles of various types of vehicles by using HORIBA OBS 2200 road analysis system. The results indicate that emissions in real-world traffic can cause vehicles to exceed emission limits. The urban and highway segments had the most exceeded pollution limits, while the rural segment had the lowest. In terms of EURO 5, the THC (exceeding by 9%) and CO (exceeding by 49%) emission limits were not included in the emission limit.

6. Conclusion
A real-time emission measurement system is needed to control air pollution caused by the transport sector. Real-time emission monitoring technologies are important research tools, as various factors affecting the exhaust emission of the vehicle are significantly considered while measurement. In the Real Driving Emissions (RDE) test, real-time sensing systems are used to measure pollutants such as NOx and CO emitted by cars when driving on the road. RDE assures that vehicles produce low emissions under on-road conditions. RDE does not eliminate the laboratory test of the WLTP (Worldwide Harmonized Light Vehicles Test Procedure). RDE is used to validate the outcomes of WLTP in real life, thus ensuring that vehicle produce low emissions of pollutants, not only in the laboratory but also on the road. Europe is the world's first region to introduce such on-road tests. With the implementation of BS6 emissions standards from 1 April 2020 and Real Driving Emissions (RDE) from 1 April 2023, the Indian automotive industry is set to witness the largest emissions reforms of the last two decades. Additionally, there are still a lot of unanswered questions regarding the RDE test protocol for India. The adoption of the European RDE test procedure, as it is, maybe a challenge for India due to the significant differences between India and Europe in terms of weather, geography, demography, road infrastructure, driving behaviour, and fuel quality. In the present paper, various technologies used for real-time exhaust emission measurements have been discussed. Many researchers are giving a decent contribution to the development of new technologies using different methods for measuring vehicular emission in real-time. This paper has briefly reviewed the available literature on the real-time measurement of vehicular exhaust emissions.
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