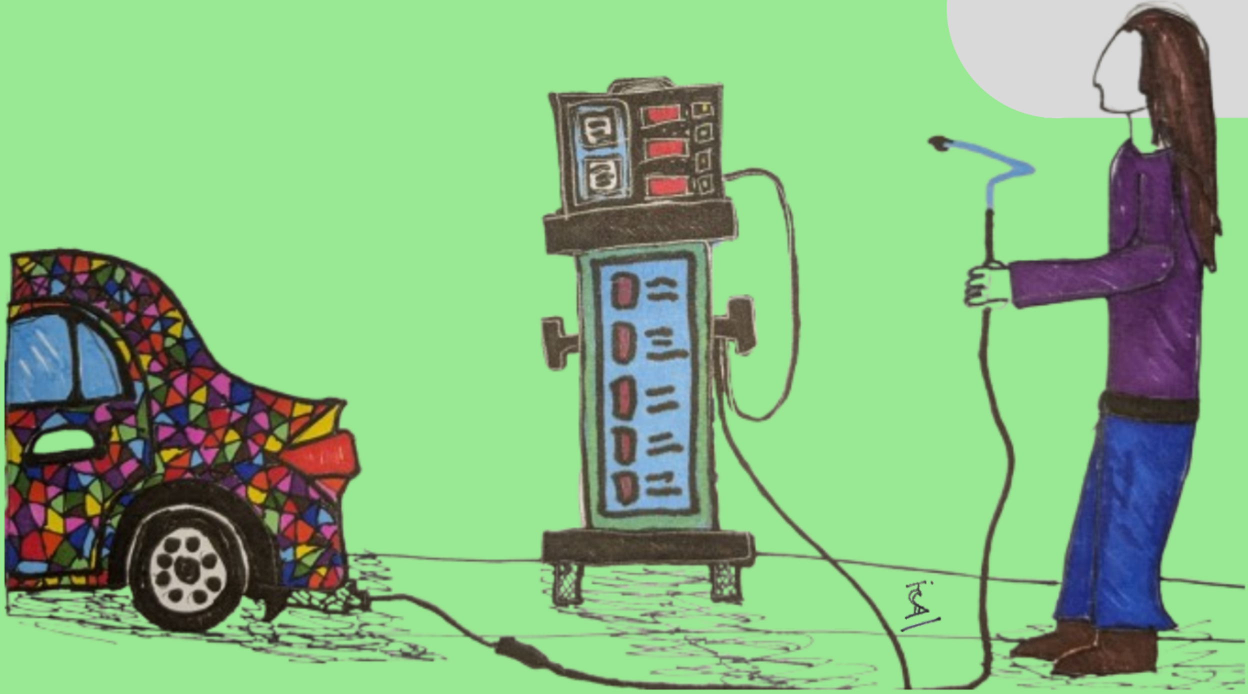

OVERHAULING INDIA'S POLLUTION UNDER CONTROL "PUC" TESTS FOR MULTIPURPOSE EMISSIONS INFORMATION

URBAN emissions .info

Sarath Guttikunda

SIM-air working paper series #53-2024

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- Sharing knowledge on air pollution
- Providing science-based air quality analysis
- Promoting advocacy and raising awareness on air quality management
- Building partnerships among local, national, and international airheads

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The working papers describe case studies where we applied the SIM-air family of tools, document general notes on emissions and pollution modeling, and present our reviews on various topics related to air pollution analysis.
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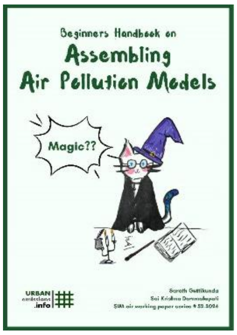

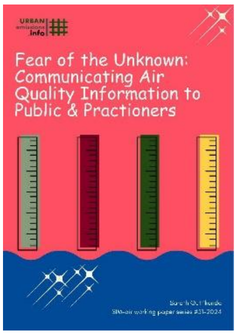

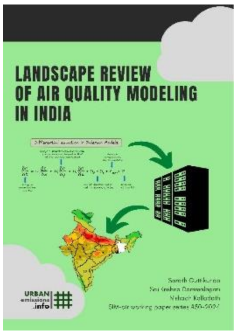

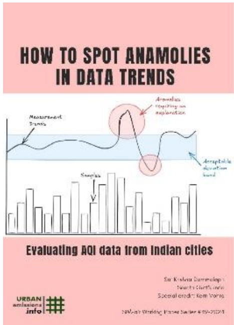

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Abstract

It is often argued that managing vehicular pollution is a numbers game—while each vehicle on the road may be deemed “clean” by emissions standards, the sheer number of vehicles collectively contributes significantly to the overall air quality problem. With millions of vehicles in operation, even small, permissible emissions from individual vehicles add up to create a substantial environmental impact. The question remains: is every vehicle on the road truly clean?

Factors such as inconsistent maintenance, aging fleets, and varying driving conditions make it unlikely that all vehicles consistently meet emission standards in real-world scenarios. This raises doubts about the effectiveness of emissions testing systems, particularly in regions where traffic congestion, poor road infrastructure, and high vehicle usage present additional challenges. The tests designed to ensure vehicles are compliant may not always be fully aligned with actual driving conditions (aka representative driving cycle), leading to discrepancies between test results and real-world emissions, thereby exacerbating the pollution problem.

The cost of a Pollution Under Control (PUC) certificate in India varies from ₹30 to ₹200 for cars and two-wheelers and is valid for six months, except for new vehicles, where the first certificate is valid for one year from the date of registration. However, concerns have been raised about the leniency of PUC certification norms, with some claiming that vehicles pass even when they emit levels worse than the prescribed environmental standards. Additionally, there have been reports of some emission testing centers issuing fake certificates or certifying vehicles without conducting any tests at all, further undermining the program’s effectiveness.

This working paper presents a critical review of India's PUC system, highlighting its current coverage and identifying key gaps, particularly in measuring on-road emissions from individual vehicles. It also examines global practices for measuring vehicle exhaust emissions, such as remote sensing, integration of on-board diagnostics, and chassis dynamometer tests, outlining their advantages and their limitations in terms of cost and implementation. To support a more effective Inspection and Maintenance (I&M) program, India’s PUC system can be overhauled by incorporating advanced technologies, standardizing equipment, training technicians, and adopting comprehensive testing methods that reflect real-world driving conditions.

This overhaul will enable a more robust assessment of vehicle emissions on India’s roads and contribute to improved air quality management nationwide.

1. Pollution Under Control (PUC)

Inspection and Maintenance (I&M) programs play a vital role in ensuring vehicle performance, enhancing fuel efficiency, and protecting the environment.

Regular inspections help detect mechanical and emission-related issues early, preventing costly failures and improving safety. Maintenance, both routine and inspection-based, keeps vehicles running efficiently, reduces wear and tear, and extends component life. A well-maintained fleet also improves fuel efficiency, as tuned engines and functioning emission systems use less fuel and emit fewer pollutants.

Keeping clean fleet records ensures regulatory compliance and can support long-term research activities. Accurate and up-to-date data from inspections and maintenance help build a reliable database of vehicle performance, which raises confidence in emissions calculations and air quality assessments. This data enables better modeling and forecasting of pollution levels, helping policymakers and researchers create more effective environmental strategies and regulations.

The **PUC program in India** is a key initiative aimed at regulating and reducing on-road vehicular emissions to combat air pollution. Under this program, vehicles are required to undergo regular emissions testing to ensure they comply with pollution standards set by the Central Pollution Control Board (CPCB). In India, the frequency of obtaining a PUC certificate depends on the age of the vehicle and, in some cases, the region:

- For new vehicles: The PUC certificate is issued at the time of purchase and is valid for the first year.
- For older vehicles (nationwide): After the initial year, the PUC certificate must be renewed every six months. Vehicle owners are required to get their vehicles tested for emissions regularly, and a new PUC certificate must be obtained to ensure the vehicle complies with emission standards.
- For older vehicles in Delhi: Due to the city's high pollution levels, the PUC certificate must be renewed every three months for vehicles older than one year, making Delhi an exception to the general six-month rule applied in other regions of India. As of October 2022, vehicles in Delhi are not allowed fuel at the stations if they do not display a valid PUC certificate on the dashboard.

While the exact start date of the PUC program is not widely documented, significant updates were made in 2004 when revised PUC norms were implemented nationwide. These revisions were introduced by the Ministry of Road Transport and Highways under the Central Motor Vehicles Rules (1989) and became effective on October 1, 2004. The revised norms standardized emissions testing for in-use vehicles, including those powered by gasoline, CNG, LPG, and diesel. The 2004 update marked an important milestone in ensuring stricter compliance and widespread enforcement of vehicle emission standards.

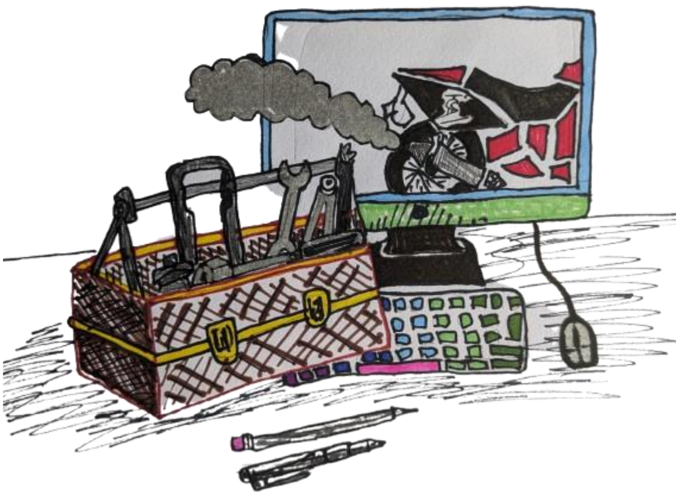
In 2013, all diesel vehicles manufactured after April 2013 were mandated to have On-Board Diagnostics (OBD) systems installed. The OBD monitors critical emission-related components and alerts the driver in case of a malfunction. Although OBD was not immediately integrated into the PUC testing procedure, its inclusion was a step toward modernizing the vehicle I&M system.

The (EPCA, 2017) highlights the low failure rate of vehicles undergoing PUC tests, raising concerns about the effectiveness of the program. In Delhi, the overall failure rate was only 4.7%, with diesel vehicles showing a failure rate of 1.7% and petrol vehicles 5.2%. In Uttar Pradesh towns, the failure rate was even lower, at 0.5%, with just 0.4% of two-wheelers and 0.6% of four-wheelers failing the tests. These low failure rates suggest that the current PUC norms and testing quality may not be sufficient to detect vehicles with high emissions, and instances of malpractices at PUC centers could be contributing to false passes.

Other issues often raised regarding the PUC program include the lack of standardization in testing protocols across different states, which results in inconsistent emission measurements. There are also concerns about the maintenance of testing equipment, with many centers operating outdated or poorly maintained machinery, leading to inaccurate readings. Additionally, the program suffers from a shortage of adequately trained personnel, which affects the quality of the tests and the ability to properly interpret emissions data.

This situation underscores the need for stricter emission standards, better quality control, and improved enforcement to ensure the program effectively reduces vehicular pollution on Indian roads.

This working paper presents a review of India's PUC program, how the tests are conducted, limitations of the use of the data from these tests, an overview of the global inspection programs, and what needs to be overhauled in the system to improve its effectiveness for use in urban air quality management.

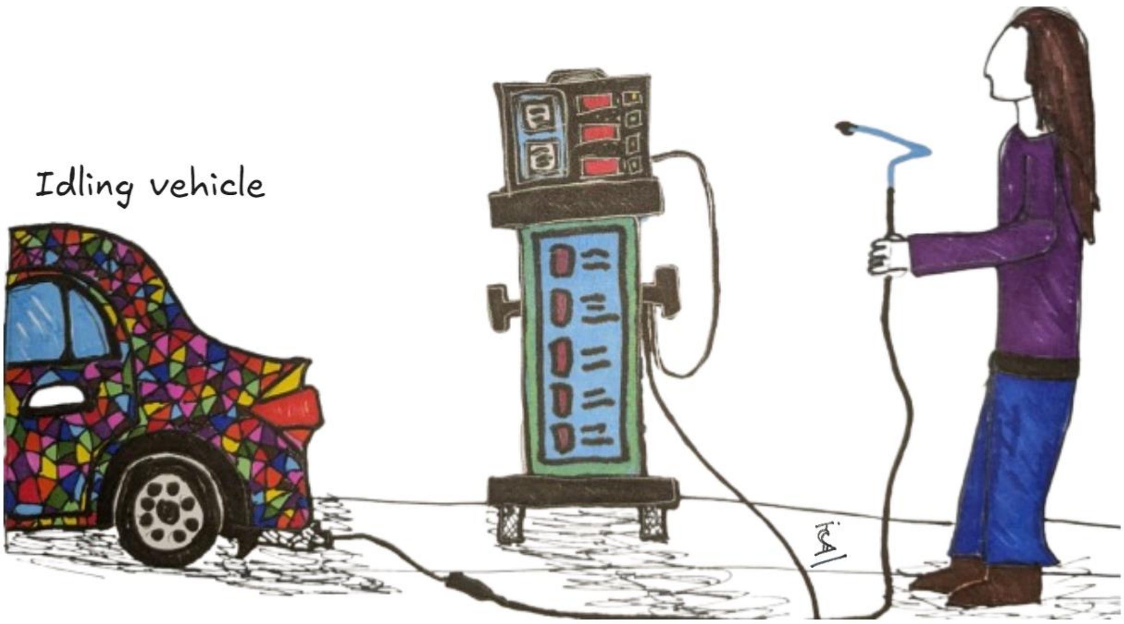


2. India’s PUC Test

The PUC certificate, issued after testing for various pollutants, certifies that the vehicle's emissions are within the permissible limits. Vehicles found violating the emissions standards are subject to penalties, and repeat offenders may face stricter consequences. This program is part of India’s broader strategy to improve air quality, especially in urban areas where vehicular pollution is a major contributor to deteriorating air standards.

What is covered in India’s PUC test

In India, **all PUC tests are conducted while the vehicle is idling**. A probe is inserted into the tailpipe to take the necessary measurements, with the engine running at idle speed near the test equipment. This method assesses the vehicle's emissions under low-load conditions, without simulating real-world driving scenarios.



Sr. No	Pollutant	Units	Emission limits	Measured Value
1	2	3	4	5
Idling Emission	Carbon Monoxide (CO)	percentage (%)	0.50	0.106
	Hydrocarbon, (THC/HC)	ppm	750.00	111.000
High idling emissions	CO	percentage (%)	N/A	
	RPM	RPM	N/A	
	Lambda	-	N/A	
Smoke Density	Light absorption coefficient	1/metre	N/A	

This PUC certificate is system generated through the national register of motor vehicles.
Note:1.Vehicle owners to link their mobile numbers to registered vehicle by logging to https://vahan.parivahan.gov.in

A screenshot of a “pollution under control” PUC certificate issued in India

For Petrol Vehicles, measurements include

- CO (Carbon Monoxide) is measured as a percentage by volume in the exhaust gases.
- HC (Hydrocarbons) is measured in parts per million (ppm), which indicates the concentration of unburnt hydrocarbons in the exhaust.
- Lambda (Air-Fuel Ratio) used for vehicles equipped with three-way catalytic converters and checks the air-to-fuel ratio (lambda value) to ensure optimal operation of the catalytic converter (this requirement has been relaxed in recent years).

For Diesel Vehicles, additional measurements include

- Smoke Density, using the Hartridge Smoke Unit (HSU) test, which measures the opacity or thickness of the smoke emitted from the exhaust.
- RPM (Revolutions Per Minute): Engine speed is measured during the smoke density test to ensure the correct acceleration for accurate readings.
- Oil Temperature: This is the engine oil temperature to ensure the engine is warmed up before conducting the test (this requirement has been relaxed in recent years).

The HSU is a scale used to measure smoke density, defined by a sampling length of 430 mm, a temperature of 100°C, and ambient atmospheric pressure, from diesel vehicle exhausts. The test involves accelerating the vehicle from idle to a specified speed under controlled conditions and measuring the amount of smoke emitted during the acceleration. A **smoke meter**, attached to the vehicle's exhaust pipe, measures the smoke's opacity by determining how much light is blocked or obscured as it passes through the exhaust gases. The result, expressed in HSU, provides a reading of the smoke density, with higher values indicating denser smoke and greater particulate matter (PM) emissions, such as soot, typically associated with diesel engines. **HSU is not a measure of PM emissions, but only a proxy**. Here's a general outline of HSU values used in diesel vehicle testing:

- 0-30 HSU: Considered low. This indicates very clean emissions, often achieved by newer diesel vehicles with modern emission control technologies.
- 30-50 HSU: Considered moderate. This range typically covers diesel vehicles that are reasonably well-maintained and have acceptable emissions.
- Above 50 HSU: Considered high. Values above 50 HSU are generally seen in older vehicles or those with poorly maintained engines. Emissions at this level fail the test. In India, the threshold for pre-BS[1] IV vehicles is set at 65 HSU, while post-BS IV are subject to 50 HSU.

[1] BS stands for Bharat Standard, which is equivalent of Euro Standard for vehicles and fuels

Countries in Europe, for instance, have historically used smoke opacity tests, including the HSU, as part of their vehicle inspection programs to ensure diesel vehicles meet emission standards. Unlike the idling test in India, the test is typically conducted on a dynamometer, which simulates road conditions and allows for precise control of the vehicle's speed and load. The test was especially relevant for older diesel engines with visible smoke emissions. However, with the introduction of stricter emission standards like Euro 6 and advancements in diesel technology[2], many countries have moved towards more advanced testing methods that assess particulate matter and nitrogen oxide (NO_x) emissions in addition to visible smoke.

What is not covered in India's PUC test

The basic equation to calculate vehicle exhaust emissions is a product of three main numbers: the number of vehicles, the vehicle kilometers traveled (VKT), and an emission factor, which represents the average emissions produced per kilometer traveled. This equation allows us to estimate the total emissions contributed by a fleet of vehicles in a particular area.

If the calculation is for a single vehicle, more specific data can be used, such as the odometer reading or an estimate of daily vehicle usage. This, combined with the vehicle's average emission rate for various pollutants, ideally derived from emissions tests like the PUC program, provides a more accurate measure of that vehicle's contribution to air pollution.

The pollutants of interest typically include PM, CO, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), volatile organic compounds (VOCs), and carbon dioxide (CO_2), which are critical indicators of air quality and related health impacts.

The current testing framework has several limitations:

- It does not measure most of the key pollutants, such as PM, NO_2, SO_2, and CO_2, except for CO and VOCs.
- The measurements for CO and VOCs are taken as idle emission rates, expressed as a fraction of the air mixture in the exhaust, rather than as an emission rate in grams per kilometer (gm/km), which is necessary for calculating total emissions from in-use vehicles.
- No odometer readings are recorded, making it impossible to build useful statistics on vehicle usage based on age, fuel type, or vehicle make.
- No information is collected on the fuel efficiency of the vehicle, which can be used to establish engine deterioration rates and to calculate CO_2 emissions.

These gaps significantly hinder the potential use of the PUC tests as an effective tool for managing and reducing vehicle emissions. While the PUC system is

[2] Vehicle and fuel standards practiced across the world are documented @ https://dieselnet.org

already in place and spread across cities, providing a comprehensive network for testing vehicles, its current limitations mean that its full potential is not being realized. The concept of testing vehicles for emissions is well understood and accepted by vehicle owners, with regular checks mandated by law. However, because the tests fail to record essential data such as odometer readings or emission rates in gm/km, much of the existing infrastructure is underutilized. As a result, valuable data that could help build accurate emission inventories, track vehicle performance over time, and inform pollution control strategies is being lost. Instead of leveraging this widespread system to gather meaningful insights into vehicle emissions and usage patterns, the current framework largely wastes its potential, leaving the country without the robust data needed to effectively tackle vehicular pollution.

3. Global Emission Testing Methods

Emissions testing is now mandatory in most countries as part of efforts to ensure vehicles meet prescribed engine and environmental standards. Despite some loopholes that allow individuals to bypass these tests, such as delaying inspections or using temporary fixes, some form of emissions inspection is typically in place. In many regions, random roadside checks by traffic inspectors help enforce compliance. Regular vehicle maintenance and securing an emissions inspection certificate have become routine tasks for many drivers, serving as necessary paperwork to confirm that a vehicle meets emission standards.

However, the methods, frequency, and requirements for these tests vary significantly from country to country. For example, in the United States, vehicle owners must renew their registration annually, and in some states, they are required to display an emissions test sticker on the registration tag. Similarly, in Germany, periodic technical inspections (PTI) include emissions testing every two years for most vehicles. In India, the PUC certificate must be renewed every six months or three months, depending on the region. In the European Union, Real-World Driving Emissions (RDE) testing complements lab tests to ensure vehicles meet emissions standards in both controlled and real-world conditions.

Here are some common ways emissions tests are conducted.

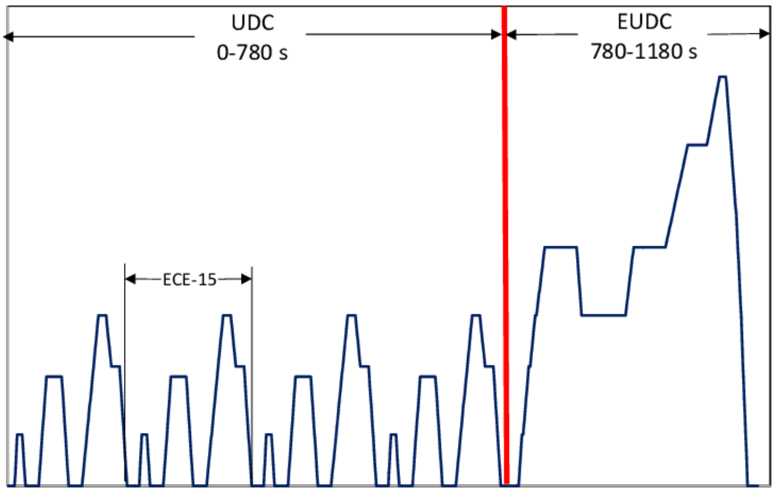
Chassis Dynamometers

The chassis dynamometer is one of the most common and effective methods used in emissions testing. In this test, the vehicle is placed on a set of rollers that simulate various road conditions while remaining stationary in the testing facility. The vehicle is driven on these rollers, which can simulate real-world driving scenarios such as accelerating, decelerating, and cruising at different speeds. By mimicking these conditions, the chassis dynamometer allows for a more comprehensive assessment of the vehicle's emissions in comparison to idle or static tests, which only measure emissions while the vehicle is stationary.

The primary pollutants measured during chassis dynamometer testing include CO, NO_x, and HC. In some cases, for research purposes, the instrumentation is extended to measure PM, black carbon (BC), and CO_2 (via fuel economy calculations). These **pollutants are monitored across different driving conditions, which is collectively referred to as “driving cycle**”. A driving cycle consists of a set of specific operating conditions that a vehicle may experience during normal use, such as city driving (stop-and-go traffic), highway cruising, and more dynamic driving behaviors like rapid acceleration or braking. Different countries use various driving cycles to reflect their typical driving behavior and road conditions. For example, Europe previously used the New European Driving Cycle (NEDC), which has been replaced by the Worldwide Harmonized Light

Vehicles Test Procedure (WLTP). The Federal Test Procedure (FTP-75) in the United States focuses heavily on urban driving conditions with frequent stops and starts. These driving cycles are typically 900 seconds (15 minutes) long. Indian Driving Cycle (IDC) is a short driving cycle formulated for vehicle manufacturers certification in India. Over time, countries adjust their driving cycles to match the evolving mix of road types, such as highways, main roads, and urban streets, as well as to better account for changing traffic patterns. This ongoing refinement ensures that emissions testing remains relevant and accurately reflects the real-world environmental impact of vehicles.

Example operations on a chassis dynamometer



New European Driving Cycle (NEDC) pattern

Driving cycles are essential because they provide a broader understanding of how a vehicle's emissions vary under different conditions. For example, a vehicle may emit low levels of pollutants when idling, but under high acceleration or cruising speeds, those emissions may spike significantly. The use of chassis dynamometers with varied driving cycles gives a more accurate and comprehensive picture of the vehicle's real-world emissions, which is critical for both regulatory compliance and environmental protection efforts.

A large set of tests using chassis dynamometers on a representative pool of vehicles can provide valuable insights into the in-use fleet's average emission factors. Such tests can also help establish relationships between vehicle speeds and emission factors, offering more precise data on how different driving behaviors influence emissions. Testing vehicles for compliance, however, is different from conducting large-scale research aimed at building patterns for policy support. Comprehensive tests, which account for all variables, can be expensive due to lab time, equipment costs, consumables, and the involvement of skilled technicians.

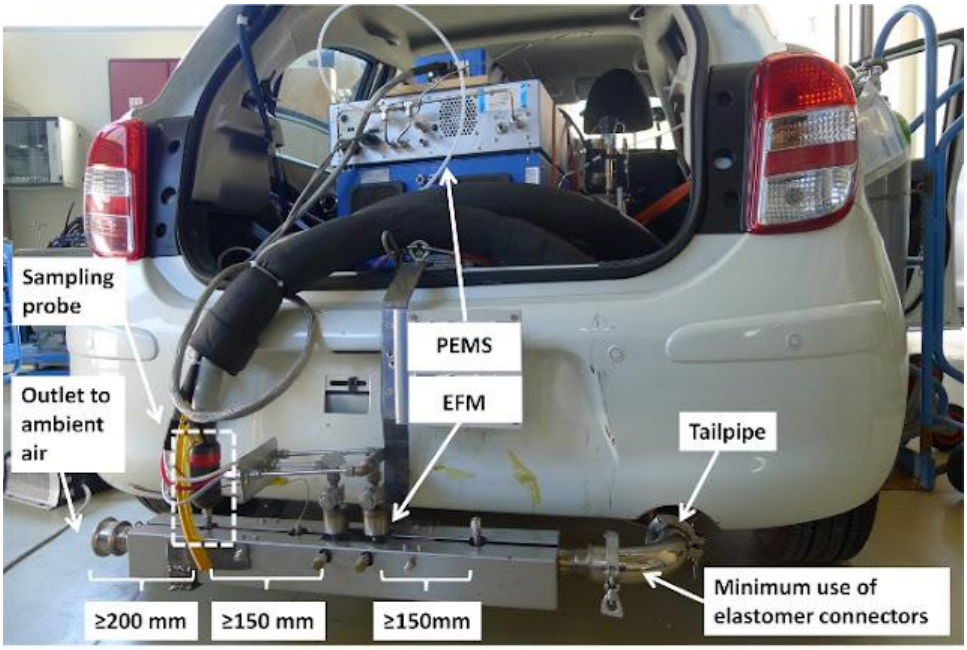
The data gathered from these tests can be used to extrapolate results to other regions within the country (or globally), helping build emission factors based on a wide array of driving cycle surveys. Though conducting large-scale surveys of driving cycles is also time-consuming, it is generally less costly and can be replicated more frequently. These surveys can cover different segments of roads and zones in a city, allowing for more specific and adaptable emission factor models, which can ultimately support more effective and targeted environmental policies.

Real-World Driving Emissions (RDE) testing

RDE is a vehicle emissions testing method designed to measure pollutants emitted by vehicles during actual on-road driving conditions, as opposed to laboratory tests, which often simulate real-world driving but can fail to capture the full range of driving environments. Introduced in the European Union as part of the Euro 6d-TEMP emissions standards, RDE testing was developed in response to the shortcomings of lab-based tests that had previously been used. The Diesel-gate scandal highlighted how vehicles could pass emissions tests in controlled environments while emitting far more pollutants under real driving conditions (Baumgärtner & Letmathe, 2020; Boretti, 2017; Zachariadis, 2016).

RDE testing involves fitting a vehicle with a **Portable Emissions Measurement System (PEMS)**, which is a small, mobile unit that records emissions as the vehicle is driven on public roads. The PEMS monitors emissions of all the critical pollutants from NO_x, PM, CO, and other harmful gases. The vehicle is driven in a variety of environments, including urban areas, highways, and rural roads, to ensure the test covers different speeds and driving behaviors like stopping, starting, and cruising. **PEMS tests cannot be repeated on all the vehicles in a city, and this is not part of inspection certification**.

This method provides a more accurate reflection of real-world emissions, as it captures data from normal vehicle use rather than simulated conditions. The introduction of RDE testing has led to stricter compliance for automakers, as vehicles must now meet emissions limits in both laboratory conditions and real-world settings. RDE has helped bridge the gap between test results and actual emissions, offering policymakers and regulators a more reliable way to ensure that vehicles contribute less to air pollution under regular use.



Video and a detailed paper on "How to measure real-world driving emissions using Portable Emissions Measurement Systems (PEMS)" (Giechaskiel et al., 2016) https://www.jove.com/v/54753/implementation-portable-emissions-measurement-systems-pems-for-real (last accessed on October 17th, 2024). This paper presents the newly adopted RDE test procedure, differentiating six steps: 1) vehicle selection, 2) vehicle preparation, 3) trip design, 4) trip execution, 5) trip verification, and 6) calculation of emissions.

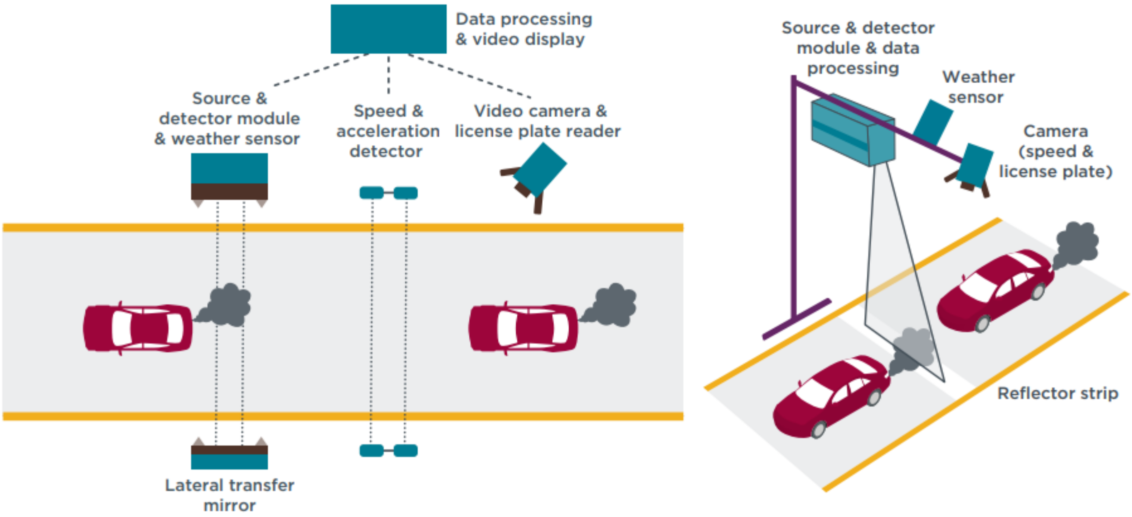
The RDE approach is now being adopted in other regions as well, as countries aim to better understand and manage the environmental impact of vehicle emissions in real-world contexts (Jaiprakash & Habib, 2018).

Remote Sensing Methods

Remote sensing methods for monitoring vehicle emissions are increasingly being used as a non-intrusive, cost-effective approach to measure real-world pollutant levels (Bernard et al., 2019). These methods involve the use of roadside sensors that detect emissions from vehicles as they pass by. Unlike traditional emissions testing, which requires vehicles to visit a testing station or undergo RDE testing with attached equipment, remote sensing collects data without disrupting normal driving behavior or requiring drivers to stop for tests.

Remote sensing is a versatile tool for monitoring vehicle emissions. It enables fleet emissions profiling (under actual driving conditions, which can be missed in lab-based or idling tests) and identifies high-emitting vehicles (aka "gross polluters"), allowing for targeted interventions to reduce pollution. It supports compliance monitoring (which is required as part of the I&M programs) by assessing emissions from thousands of vehicles in real-time without interrupting traffic. Additionally, remote sensing helps analyze emission trends and assists in air quality management by pinpointing high-pollution areas for effective action.

The data collected also provides valuable insights for research and policy development, guiding future emission standards and regulatory measures.



Schematic extracted from (Bernard et al., 2019). Schematic setup of the three units of the remote sensing device. Left, setup for crossroad remote sensing: the light source with the reflecting mirror at the other side of the road and the light detector, the speed and acceleration detectors, and the plate number recorder. Right, setup for top-down remote sensing system.

Remote sensing devices use infrared (IR) and ultraviolet (UV) beams to measure vehicle emissions through a process known as spectroscopy. When these beams interact with pollutants such as CO, NO_x, HC and PM in the exhaust, they absorb specific wavelengths of light. Each pollutant has a unique light absorption pattern, or "fingerprint", which the sensors can detect and analyze. For instance, carbon monoxide absorbs IR light at specific wavelengths, while nitrogen oxides primarily absorb UV light. By examining these absorption patterns, the sensors can accurately determine the concentration of each pollutant in real time. This **technique, using near-infrared and ultraviolet-visible spectroscopy**, provides a highly sensitive and precise method for monitoring vehicle emissions on the road.

Remote sensing has been effectively used at the Port of Oakland in California to monitor vehicle emissions, particularly from heavy-duty trucks. The California Air Resources Board (CARB) set up remote sensing equipment, including the Portable Emissions Acquisition System (PEAQS)[3], to measure real-time emissions from vehicles passing through the port area (Dallmann et al., 2012). The system utilizes infrared and ultraviolet light beams that detect pollutant concentrations in the exhaust and emission rates of trucks as they drive by. The equipment was deployed in key locations at the port, such as truck weigh stations, entrance points, and busy transport routes. The system allowed for non-intrusive emissions measurement, capturing thousands of readings over a short period. For instance, between 2016 and 2019, PEAQS captured emissions data from over 3,400 vehicles

[3] CARB deploys 'Dirty Truck Detector' along popular Fresno truck route @ https://ww2.arb.ca.gov/news/carb-deploys-dirty-truck-detector-along-popular-fresno-truck-route

at the Port of Oakland alone, with the vast majority being heavy-duty trucks used for freight transport. These measurements were crucial in identifying high-emitting trucks, which could then be flagged for maintenance or further testing.

The International Council on Clean Transportation (ICCT) conducted a remote sensing emissions study in Delhi and Gurugram between December 2022 and April 2023, collecting real-world data on vehicle emissions over 65 days at 20 locations [4]. The study captured more than 278,000 measurements, with 111,712 valid data points, covering a range of vehicle types, including two- and three-wheelers, private cars, taxis, light goods vehicles, and buses. The findings revealed that many vehicles, especially CNG-fueled ones, emitted significantly higher levels of NO_x than laboratory test results indicated, with BS VI-compliant CNG taxis and LGVs emitting 4 to 5 times more NO_x than their type-approval limits. This study provided critical insights into the gap between laboratory emissions tests and real-world emissions.

Remote sensing for vehicle emissions has several limitations. It is weather-sensitive, as factors like rain and wind can affect data accuracy. It also has limited pollutant coverage, being less effective in measuring PM and VOCs. Traffic conditions and congested roads can interfere with accurate readings, where it is difficult to isolate the signatures between vehicles or vehicles from the ambience. The high cost of equipment and maintenance is a barrier to widespread adoption. Additionally, integrating data with vehicle registration databases for enforcement can be challenging in areas with insufficient infrastructure or not open databases. Despite these challenges, it remains valuable when used alongside other methods.

[4] Real-world motor vehicle exhaust emissions in Delhi and Gurugram using remote sensing @ https://theicct.org/publication/rw-motor-vehicle-exhause-emissions-delhi-gurugram-remote-sensing-aug24

4. On-Board Diagnostics & Diesel-gate

On-Board Diagnostics (OBD) systems were not always a feature in vehicles. First introduced in the 1980s as an early attempt by car manufacturers to monitor certain engine functions, a more standardized version was introduced in 1996 in the United States as part of regulatory measures to reduce vehicle emissions. It was mandated by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act to ensure that vehicles could monitor emissions performance more effectively and that mechanics could diagnose issues more easily using universal diagnostic equipment.

Since then, OBD has become the standard in most vehicles worldwide, and many countries have adopted similar regulations to ensure that cars meet stringent emissions and performance standards.

OBD systems have the potential to provide crucial information such as direct emission rates and direct fuel consumption rates (in real-time, if necessary), when combined with vehicle usage data (e.g., odometer readings). This overlap can offer valuable insights for air quality management, allowing authorities to better track pollution sources and implement targeted interventions. Therefore, the careful management and responsible use of OBD data are essential to maximize its utility in both vehicle maintenance and environmental protection efforts.

In India, with BS-6 norms in April 2020, OBD systems became mandatory and more advanced, capable of monitoring basic engine functions and emissions equipment operations. However, emission rates monitoring and archiving is not confirmed.

While OBD systems are valuable tools for engine health checks, emissions monitoring, and vehicle safety, they are also susceptible to potential misuse or manipulation. The data collected by OBD systems, if not properly secured or regulated, could be tampered with to misreport emissions, leading to inaccurate diagnostics or even regulatory violations. This risk highlights the need for OBD data to be accessible in a structured and useful format—not just or necessarily raw data—so that it can be effectively utilized in research and policy making.

Volkswagen (VW) "Diesel-gate" scandal

Diesel-gate, uncovered in 2015, by researchers from the ICCT and West Virginia University, involved VW's use of defeat devices in its diesel vehicles to manipulate OBD systems during emissions tests[5] [6]. These devices allowed vehicles to pass regulatory emissions tests by activating a low-emission mode when testing was

[5] "EPA's notice of violation of the Clean Air Act to Volkswagen" (2015) https://theicct.org/epas-notice-of-violation-of-the-clean-air-act-to-volkswagen-press-statement

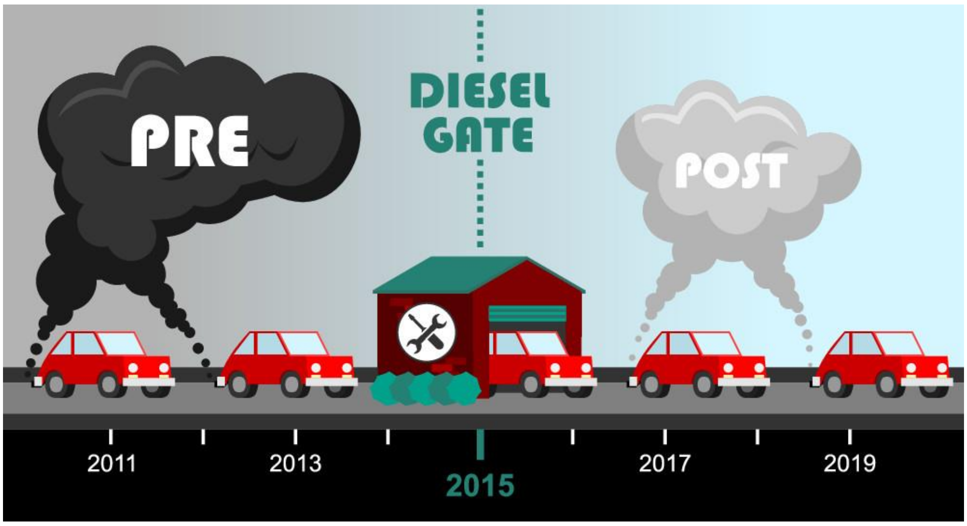
[6] "It's time for Europe to address diesel defeat devices once and for all" (2023) https://theicct.org/diesel-defeat-devices-mar23

detected (aka pre-defined driving cycles on the chassis dynamometer). However, under normal driving conditions, **the vehicles emitted up to 40 times the allowed NO_x levels**. This scandal undermined the role of OBD systems, which are designed to ensure vehicles meet emissions standards in real-world conditions.

In September 2015, The US EPA formally accused VW of installing defeat devices in nearly 11 million vehicles worldwide. Volkswagen later admitted to the deception and paid over $30 billion in fines and settlements. Various countries also launched investigations and imposed sanctions on the company, leading to its widespread financial and reputational damage.

India is one of the countries with a large VW fleet on the roads. In the absence of a valid emission testing and certification scheme, it is difficult to assess the real-world emissions and if there is an impact of the scandal on the Indian roads.

(Grange et al., 2020) used on-road remote sensing data to analyze the impact of the post-Diesel-gate fixes on NO_x emissions. The research showed that vehicles with hardware and software fixes saw a notable reduction in emissions. For example, 1.6L vehicles exhibited a 36% reduction, while the 2.0L models saw a 30% reduction. This evidence demonstrates that the fixes led to measurable improvements in NO_x control, although the reductions varied depending on vehicle model and engine size. The study also highlighted the ongoing challenge of temperature-dependent NO_x emissions, with colder ambient temperatures causing higher NO_x levels across various manufacturers. This suggests that while the fixes mitigated some of the excess emissions caused by the defeat devices, broader measures are needed to ensure long-term compliance and improved air quality.



(Grange et al., 2020) conducted the tests in the United Kingdom at 10 locations. The data were collected between 2012 and 2018 using the University of Denver's Fuel Efficiency Automobile Test (FEAT) remote sensing instrument. The test sites included both pre- and post-Diesel-gate periods, allowing for a comparison of NO_x emissions before and after VW implemented software and hardware fixes on affected vehicles. The diagram is the graphical abstract of the journal article.

5. Overhauling India's PUC for I&M and Emissions Tracking

In India, the PUC system is a well-established mechanism for managing vehicle emissions, with mandatory testing and certification required for all registered vehicles. The process of obtaining a PUC certificate is familiar to vehicle owners, who understand its importance for regulatory compliance. However, the current PUC framework relies heavily on idle-based emissions tests, which may not fully reflect real-world emissions. This leaves room for improvement in terms of testing accuracy and the overall effectiveness of the program for information gathering.

With the rise of newer vehicles equipped with OBD systems, which continuously monitor engine and emissions equipment performance, there is an opportunity to modernize the PUC system. Integration of OBD data, alongside India's digitized VAAHAN database (https://vahan.parivahan.gov.in/vahan4dashboard), which consolidates vehicle information in real-time from Regional Transport Offices (RTOs), provides a strong foundation for an enhanced emissions monitoring framework. By overhauling the PUC system to incorporate advanced technologies like OBD and remote sensing, India can create a more accurate and comprehensive emissions testing program, leading to better regulation, reduced pollution, and improved air quality.

To enhance India's PUC system, several key activities must be incorporated into the new framework.

1. **Inclusion of all criteria pollutants**: The new PUC system should measure a comprehensive range of pollutants, including PM, CO_2, SO_2, NO_2, CO, and VOCs. While pollutants like SO_2 and CO_2 can be calculated based on fuel consumption estimates, direct measurement of all key pollutants will ensure a more accurate and holistic view of vehicle emissions. This will help align the system with global emissions standards and address the full range of pollutants affecting air quality.
2. **Inclusion of odometer readings**: Odometer readings should be recorded during every PUC test to track vehicle usage over time. This data will allow regulators to assess emissions performance based on the vehicle's age and mileage, enabling a better understanding of how wear and tear affects emissions. Tracking odometer readings can also help identify high-usage vehicles that may require more frequent inspections or maintenance, particularly for older fleets.
3. **Integration with OBD systems**: The PUC system should integrate emissions measurements with the vehicle's OBD system, which already monitors vehicle's engine performance and help detect malfunctions in the emissions equipment. By linking the PUC with OBD data, emissions tests can provide deeper insights into engine health, allowing for more accurate post-processing of emission results and helping vehicle owners maintain their vehicles more effectively.

4. **Promotion of remote sensing methods**: Remote sensing should be adopted more widely as a supplementary method to monitor vehicle emissions. Remote sensing allows authorities to measure emissions from moving vehicles in real-time without requiring them to stop for testing. By linking remote sensing data to vehicle registration databases, authorities can track high-emission vehicles in real-time and identify violators more effectively. This approach will enhance enforcement, particularly in high-traffic areas, and enable better targeting of “gross polluters”.
5. **Move away from idling tests**: The PUC system needs to move away from the outdated practice of idle-based emissions tests, which only measure emissions when a vehicle is stationary. Instead, chassis dynamometer tests should be implemented to simulate real-world driving conditions, including acceleration, deceleration, and cruising at different speeds. This shift will provide a more accurate representation of how vehicles emit pollutants during typical use, ensuring compliance is assessed more realistically.
6. **Overhaul of the Indian driving cycle**: IDC should be updated to reflect current road usage patterns, which have evolved significantly since 2000. The revised cycle should account for various road types, including highways, arterial roads, and congested city streets, as well as diverse driving behaviors like frequent stops and starts. This will ensure that emissions tests are more representative of actual driving conditions, leading to more accurate emissions data and better regulatory enforcement.
7. **Standardization of PUC equipment and technician training**: The PUC system must standardize testing equipment across India to ensure consistency and accuracy in emissions measurements and improve the reliability of emissions data. Additionally, training programs for PUC technicians are essential to ensure they can accurately operate modern equipment and detect issues like tampering or malfunctioning emission control systems.

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