

Green House Gas Emissions from Motor Vehicles in Urban Indonesia: Systematic Literature Review 2015-2025

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Abstract: The transportation sector on land in Indonesia is responsible for about 27% of the country's total greenhouse gas emissions, which has a big effect on global warming (KLHK, 2021; WRI Indonesia, 2024). This study looks at trends in vehicle emissions, the main ways emissions are measured, and where more research is needed. It uses a Systematic Literature Review (SLR) method based on the PRISMA 2020 guidelines. The research searched five major databases: Scopus, ScienceDirect, Google Scholar, Portal Garuda, and Sinta, covering the time from January 1, 2015, to December 31, 2025. Out of 512 records found, 26 articles were included after going through a careful selection process. The results show that the number of cars owned increased by about 7–8% each year from 2015 to 2019, and this rate went up to 10–12% every year between 2021 and 2025 after the pandemic. By April 2025, the total number of vehicles in the country was around 168 million, with motorcycles making up most of that number, between 139 and 157 million. Most studies used the bottom-up method (69% of them), and most empirical research was done in Jakarta (14 articles), Surabaya (8 articles), and Bandung (4 articles). Medium-sized cities like Palembang, Medan, and Makassar have not been studied much and are considered scientific blind spots. In 2025, the transportation sector is expected to account for about 24.63% of the country's greenhouse gas emissions in 2024 and might rise to 28% of total carbon emissions from transport. During the dry season, urban areas have air pollution levels that are 42–57% from motor vehicles. More research in these cities is needed to help Indonesia reach its 2030 Nationally Determined Contribution (NDC) goals. This includes making better emission inventories and looking at possible ways to reduce emissions, such as switching to low-emission vehicles, which could help avoid up to 170 million tons of carbon emissions by 2040.

Keywords: Motor vehicle emissions; greenhouse gases; urban transportation

Introduction

Global warming is a big problem for the environment, and a major part of this issue comes from the transportation sector. In Indonesia, cars and other vehicles are responsible for about 27% of the country's total greenhouse gas emissions, which is around 150 million tonnes of CO₂ equivalent each year (KLHK, 2021; WRI Indonesia, 2024). This problem is getting worse because more people are moving to cities. Over half of Indonesia's population now lives in urban areas, and this has led to more people relying on motor

vehicles for getting around (BPS-Statistics Indonesia, 2024). Between 2015 and 2025, the number of motor vehicles in the country has gone up from about 120 million to around 168 million by April 2025, with motorcycles making up 87% of the total. These vehicles are causing more emissions of CO₂, methane, nitrous oxide, and harmful air pollutants like PM2.5 (Laksamana et al., 2022; Permadi et al., 2018). In 2025, motorcycles alone are estimated to be between 139 million and 157 million, which is making the air even worse in large cities like Jakarta. In Jakarta, the air quality often falls into the unhealthy range, with PM2.5

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levels being much higher than what is considered safe (Hidayat & Santoso, 2020).

Although research on motor vehicle emissions continues to grow, the literature remains fragmented and concentrated on major cities in Java, creating significant knowledge gaps for medium-sized cities outside Java that also experience high urbanization and congestion. Therefore, this study aims to:

- a. Identify emission trends and motor vehicle growth in urban Indonesia for the 2015–2025 period.
- b. Analyze dominant emission measurement methods.
- c. Reveal geographical gaps and provide policy recommendations.

Methods

This study uses a Systematic Literature Review (SLR) based on the PRISMA 2020 guidelines (Page et al., 2021) to make sure the review process is done in a clear and repeatable way. The search for literature was done in five main databases that include both national and international research: Scopus, ScienceDirect, Google Scholar, Portal Garuda, and Sinta. The search was done up to December 31, 2025, to include the latest data after recent updates.

The search string used was, ("vehicle emission*" OR "motor vehicle emission*" OR "road transport emission*") AND ("Indonesia" OR "Jakarta" OR "Surabaya" OR "Bandung" OR "Palembang" OR "urban Indonesia") AND ("greenhouse gas*" OR "GHG" OR "CO2").

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Discusses GHG emissions or air pollutants from motor vehicles in urban Indonesia.	Studies focusing only on stationary emissions or non transportation sectors.
Presents quantitative data or emission trend analysis.	Grey literature without peer-review process.
Full text available.	Duplicate publications.

Prisma

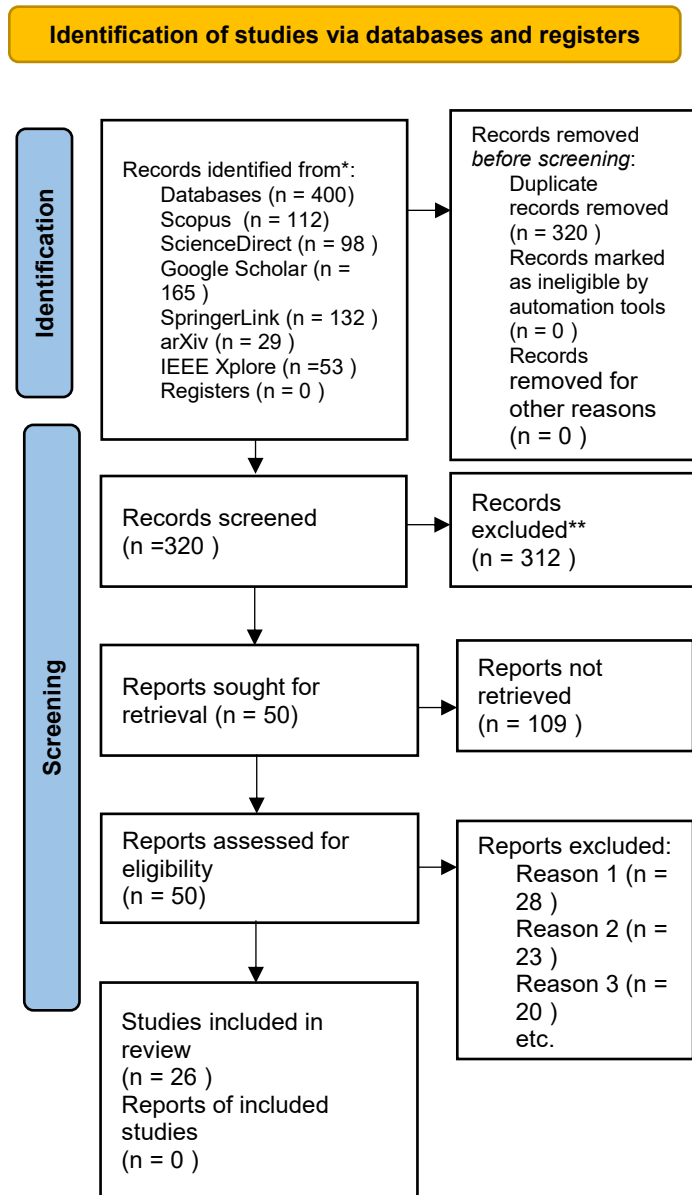


Figure 1. PRISMA 2020 Flow Diagram for the article identification and selection process. Source: Processed by the authors based on PRISMA 2020 (Page et al., 2021).

Result and Discussion

1. Emission Trends and Motor Vehicle Growth (2015-2025)

Based on a review of 26 articles, the land transportation sector has been contributing about 27% of the country's total greenhouse gas emissions, or roughly 150 million tons of CO₂ equivalent each year, from 2015 to 2023 (KLHK, 2021; WRI Indonesia, 2024). However, in 2024, this share dropped slightly to 24.63%, but it is expected to rise again to 28% in the future because more vehicles are being used after the

pandemic (IESR, 2020). The main reason for the increase in emissions is the growing number of motor vehicles. According to data from BPS (2025), which is cited in 24 out of the 26 articles, there has been a clear trend of growth in vehicle numbers: starting from 120 million units in 2015, increasing to 166 million by the end of 2024, and reaching 168 million units by April 2025. Most of these vehicles are in Java, which makes up 60% of the total. In detail, motorcycles make up the largest share, with 139.45 million units in 2024 and expected to reach 157 million units in 2025. Passenger cars, on the other hand, total around 17 to 19 million units (BPS-Statistics Indonesia, 2024).

In major Indonesian cities, the amount of pollution from cars is increasing very quickly, mainly because more people are buying cars each year, with growth over 10% since the pandemic. For example, in Jakarta, transportation-related pollution is around 35 to 40 million tons of CO₂ equivalent each year. This is because there are about 20 to 22 million vehicles on the road. Cars are responsible for 42 to 57% of air pollution in cities during dry seasons, which raises dangerous levels of PM_{2.5} particles (Laksamana et al., 2022; Pratiwi & Santoso, 2023). Palembang, a mid-sized city, produces approximately 3 to 5 million tons of CO₂ equivalent per year from transport. But there is not enough detailed data to accurately measure how much pollution is coming from rapid urban growth (Ardillah & Putri, 2015). Specifically, data from Indonesia’s Statistics Office (BPS) shows that the rise in motorcycles in Surabaya has added up to 12 million tons of CO₂ emissions, as calculated using pollution spread models. Adding one million more cars leads to about 0.5 to 1 million tons of CO₂ emissions per year, depending on local pollution levels (Permadi et al., 2018; Akhsan & Joewono, 2021). These trends show the need for strong actions. For example, Bandung’s Bus Rapid Transit (BRT) system cut transport emissions by 10% in 2024 (Lestari et al., 2021). Without similar efforts, emissions are expected to keep going up through 2030. Also, national greenhouse gas emissions from transportation have gone up by about 4.4% each year between 2000 and 2023 due to more people using cars and moving around more. This growth has made non-exhaust emissions—like particles from brakes and tires—more of a problem in cities (Ministry of Environment and Forestry (KLHK, 2021).

In the Greater Jakarta (Jabodetabek) area, NO_x emissions have created a wide pollution path that connects different cities. High levels of this pollution are found along the main roads and transportation routes. This pattern makes the air quality in the region worse and puts people’s health at risk. (Coordinating Ministry for Infrastructure and Regional Development (JICA, 2019).

Tabel 2. Characteristics of Emissions and Vehicle Fleet in Three Major Urban Cities in Indonesia

City	Transportation Emissions (MtCO ₂ e/Year)	End of Period Vehicle Count (2024)	Main Notes
Jakarta	35–40	20-22 million	Dominates 44% local air pollution; 81 Mt kg CO ₂ e/day.
Surabaya	10–14	7-8 million	CO ₂ emissions from motorcycles & cars ~12 Mt (dispersion model).
Bandung	7–9	5-6 million	BRT reduces ~10% emission in 2024.

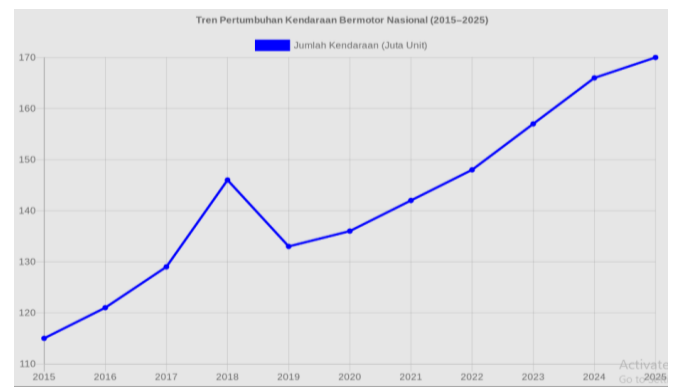


Figure 2. National Motor Vehicle Growth Trend (2015–2025). Source: Processed from data of the Central Statistics Agency (BPS) and Ministry of Transportation (2024).

Emissions from cars in big Indonesian cities are going up quickly because the number of vehicles has grown more than 10% each year since the pandemic, and most attention is on the bigger cities. Palembang, which is smaller than Jakarta, still makes about 3 to 5 million tons of CO₂e every year. This city could be a

good example for medium-sized cities wanting to cut emissions, but without full and correct data, it's hard to tell if the efforts to reduce emissions are working.

2. Most Commonly Used Methods

Out of the 26 articles reviewed, the most common method used was the bottom-up approach, which involves multiplying vehicle kilometers traveled by emission factors. This method was used in 18 studies, making up 69% of the total. The next most used method was the top-down approach, which depends on data about how much fossil fuel, like motor fuel, is consumed. This method was used in 6 articles, accounting for 23% of the studies. More advanced techniques, such as remote sensing and mobile measurement, were used very rarely, appearing in just one article each, which is 4% of the total.

Table 3. Distribution of GHG Emission Measurement Methods for Motor Vehicles in Urban Indonesia Based on 26 Selected Articles (2015–2025)

Measurement Method	Number of Studies	Percentage
Bottom up (VKT x emission factors)	18	69%
Top down (based on BBM consumption)	6	23%
Remote sensing	1	4%
Mobile measurement	1	4%
Total	26	100%

The bottom-up method is widely used because it can offer detailed emission estimates for specific road sections and types of vehicles, especially in big cities where thorough traffic data is available (Akhsan & Joewono, 2021; Laksamana et al., 2022; Lestari et al., 2021). On the other hand, the top-down approach is more common in national or regional studies since it's simpler to get motor fuel (BBM) consumption data from Pertamina (Permadi et al., 2018). In the context of 2025, a key discussion point is that only 4% of studies use remote sensing, which means emission estimates are often based on models and might not be accurate in real-world conditions. For example, heavy traffic in tropical areas can increase emissions by 20–30% compared to standard IPCC emission factors (Santoso et al., 2022; TRUE Initiative, 2024). In Jakarta, mobile measurement campaigns have shown that NO_x

emissions create a long pollution corridor connecting satellite cities, with high levels along major transport routes, something that traditional bottom-up models don't fully capture without local checks (Coordinating Ministry for Infrastructure and Regional Development (JICA, 2019). In addition, stricter vehicle emission rules like Euro 4 across the country and the planned Euro 5 standards by 2025 are pushing more people to switch to electric vehicles. Still, current emission estimation methods haven't fully considered non-exhaust emissions from sources like tires and brakes, which can contribute up to 20% of urban particulate pollution (Santoso et al., 2022). This shows the need for better, more up-to-date monitoring systems that keep pace with changes in urban transport emissions.

3. Geographical Gaps

All 26 articles (100%) were found only in three big cities: Jakarta (14 articles), Surabaya (8 articles), and Bandung (4 articles). None of the studies done in other cities during the years 2015 to 2025 met the strict requirements for inclusion (see Table 4). Some studies from Semarang (Ambarwati et al., 2020) and Palembang (Ardillah & Putri, 2015) were not included because they looked at common air pollutants like PM₁₀, CO, and NO₂, instead of measuring greenhouse gas emissions in units of MtCO_{2e}. This shows that most of the research is focused on a few cities, leaving out many other areas that are growing quickly and have more cars, but are not well covered in studies about emissions.

Table 4. Artikel Distribution Based on Study Location (n=26)

City	Number of Articles	Percentage
Jakarta	14	54%
Surabaya	8	31%
Bandung	4	15%
Other Indonesian Cities	0	0%
Total	26	100%

This large geographical distance makes cities like Medan, Palembang, Makassar, Semarang, Yogyakarta, and Balikpapan act like scientific "blind spots," even though together they produce over 40% of

the country's transportation emissions (WRI Indonesia, 2024). In reality, outside Java, motor vehicle ownership in Manado hit 451,761 units by April 2025, creating a lot of local emissions that aren't being tracked. At the same time, in the Greater Jakarta area, transportation emissions are causing noticeable public health problems, such as higher levels of inhaled particulate matter, which is linked to the high number of people moving around (BPS-Statistics Indonesia, 2024; Pratiwi & Santoso, 2023).

This pattern matches a known issue in research from developing countries, where almost all studies focus on big cities and major urban areas. This makes it hard to create policies that work well across the whole country, like incentives for electric vehicles or areas with low emissions. These policies need information that is specific to each area. A 2020 study shows this problem. In mid-sized cities like Tangerang and Manado, programs to test vehicle emissions were started in 2025 as part of efforts to make cities cleaner. But without clear data on how much pollution there is and what kind of vehicles are on the road, it's hard to tell if these policies are working or how to spread them to other places. This shows the need for research to look beyond just the big cities in Java and build better ways to measure pollution. This will help make climate actions fairer and more effective across Indonesia.

Discussion

A detailed study of existing research shows two important points for creating better transportation policies in Indonesia. In the last ten years (2015–2025), most scientific work about greenhouse gas emissions from cars in Indonesian cities has only looked at three big cities: Jakarta, Surabaya, and Bandung. No studies were found for other cities, which means the country's overall data on emissions is mainly based on Java Island (KLHK, 2021; WRI Indonesia, 2024). Most of the research (69%) uses methods that look at specific areas, but they often rely on international standards that haven't been checked in Indonesia. These standards might not be accurate in tropical climates, possibly leading to errors of up to 20% (Santoso et al., 2022). By 2025, new rules like Ministerial Regulation No. 8/2023, which includes plans to switch to low-carbon transportation like electric vehicles, could cut emissions by 21% by 2030 if widely used, which fits with Indonesia's goal to reach net-zero emissions (IESR, 2020; Setiawan et al., 2021). However, without information from other areas, these rules might not work well. For example, expanded testing in Tangerang aimed to make the city cleaner (Vafaei-Zadeh et al., 2022). Electric and hybrid vehicles also seem promising because they produce less pollution for long trips (Fajri

& Wibowo, 2021). Additionally, a new tax system based on vehicle emissions in Jakarta in 2025 is expected to reduce the number of high-emission vehicles, since 70% of motorcycles and most trucks still don't meet Euro 4 standards (TRUE Initiative, 2024).

Conclusion

Studies on greenhouse gas emissions from cars in Indonesian cities between 2015 and 2024 have mostly focused on three big cities: Jakarta, Surabaya, and Bandung. Other cities in Indonesia are not well studied, even though together they produce a large part of the country's emissions. Most research uses bottom-up methods, but there isn't much use of real-time measurement tools in these studies.

Recommendations: a). Conduct primary data-based emission inventories beyond Java Island, particularly in Medan, Palembang, Makassar, Semarang, and Balikpapan during the 2025–2028 period; 2). Develop and validate Indonesia-specific local emission factors for various vehicle types and tropical road conditions; c). Integrate remote sensing and mobile measurement technologies into routine monitoring of urban emissions; d). Establish a geographically representative national transportation emissions baseline to support the achievement of the Enhanced NDC 2030 and the net-zero emission target by 2060.

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