Review Paper

A comprehensive assessment of transportation emissions in Nigeria: Trends, drivers, and impacts

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Abstract
This study presents an in-depth investigation into the complex dynamics surrounding transportation emissions in Nigeria against the backdrop of rapid urbanization, population growth, and economic development. Through an extensive analysis of historical trends and recent developments, the article elucidates the escalating challenges posed by emissions. Examining the drivers of transportation emissions, including population growth, economic development, and fuel choices, the study underscores the significant correlation between economic growth and emissions while scrutinizing their environmental and public health ramifications. It also explores the prevalent use of fuels in Nigeria's transportation sector, highlighting the imperative of transitioning to cleaner energy sources and leveraging technological innovations for emission reduction and sustainability. Evaluation of existing policy frameworks and regulatory mechanisms offers insights into their efficacy in emission mitigation, along with emphasizing Nigeria's commitments under international agreements like the Paris Agreement and Sustainable Development Goals. The socioeconomic impacts of transportation emissions, encompassing public health costs, economic losses from traffic congestion, and broader economic implications, are scrutinized. The study concludes with a compelling call to action for immediate policy reforms, sustainable transportation solutions, and international collaboration. As the world grapples with climate change and environmental degradation, this comprehensive assessment aims to inform policymakers, researchers, and stakeholders, serving as a crucial resource for charting a sustainable course for Nigeria's transportation sector.

Keywords: *Transportation emissions, Nigeria, trends, drivers, impacts, public health, air quality, climate change, sustainable transportation, policy recommendations*

1.0 Introduction
Nigeria, often referred to as the "Giant of Africa," boasts a vast and dynamic transportation sector that plays a pivotal role in the country's economic growth and societal development (Offiong et, al 2021). With a population exceeding 200 million people and a landmass covering 923,768 square kilometers, Nigeria's transportation system is a complex web of roads, railways, ports, airports, and inland waterways (Oluwakoya and Ogundipe, 2021). This extensive network facilitates the movement of goods, people, and services across the nation, connecting urban centers with rural areas and supporting various industries, including agriculture, manufacturing, and commerce. Understanding the nuances of Nigeria's transportation sector is essential to grasp the magnitude of its emissions challenges (Poulsen & Sampson, 2019).

The significance of studying transportation emissions in Nigeria cannot be overstated (Oyebode, 2022). In recent decades, the country has experienced rapid population growth, urbanization, and economic development, all of which have led to an exponential increase in transportation activities. While this growth has undeniable benefits, it has also contributed to escalating levels of pollution, greenhouse gas emissions, and negative impacts on public health (Adedolapo, 2022). As the world grapples with the consequences of climate change and environmental degradation, addressing transportation emissions in Nigeria has become imperative for both local and global well-being (Mei et.al., 2023).

The primary purpose of this article is to provide a comprehensive assessment of transportation emissions in Nigeria. By examining the trends, drivers, and impacts of emissions, this article aims to shed light on the complex interplay between the transportation sector and the environment, economy, and society. It seeks to contribute to a better understanding of the challenges Nigeria faces in mitigating emissions and transitioning to a more sustainable transportation system. Furthermore, this article aims to offer actionable insights and policy recommendations to guide future efforts in reducing emissions and fostering sustainable development.

2.0 Transportation emission trends in Nigeria

2.1 *Historical overview of transportation emissions*

To comprehend the current state of transportation emissions in Nigeria, it is essential to examine the historical trajectory. Over the past few decades, Nigeria has witnessed a significant transformation in its transportation sector. The country has transitioned from a primarily agrarian society to one with rapidly growing urban centers, expanding industries, and increased mobility demands.

Historically, Nigeria's transportation emissions were relatively modest. The use of traditional modes of transportation, such as bicycles and animal-drawn carts, predominated in rural areas, while cities were characterized by limited motorized transportation. However, with urbanization and economic development, there has been a substantial rise in the use of motor vehicles, particularly gasoline and diesel-powered cars, trucks, and motorcycles. This shift might have correspondingly led to a marked increase in transportation-related emissions.

The historical overview provides a critical context for understanding the challenges posed by emissions today. By tracing the growth of the transportation sector and the evolution of transportation modes, we gain insights into how emissions have become a pressing issue.

2.2 Recent developments and changes

In recent years, the transportation landscape in Nigeria has experienced significant developments and changes. Several factors have contributed to these shifts:

1. **Rapid urbanization**: Nigeria has one of the fastest urbanization rates globally, with millions of people migrating to cities in search of economic opportunities. This trend has led to increased demand for transportation services and the proliferation of vehicles in urban areas.
2. **Economic growth**: Nigeria's economic growth, particularly in sectors like manufacturing, commerce, and construction, has resulted in greater mobility requirements, leading to an upsurge in transportation emissions.

3. **Diversification of transportation modes**: The transportation sector has diversified with the introduction of new modes, including ride-sharing services, increased air travel, and expanded railway networks. Each of these modes has its own emission profile, contributing to the complexity of the issue.
4. **Shift in energy sources**: The country has witnessed shifts in the sources of energy used in transportation. While gasoline and diesel remain prevalent, there is a growing interest in alternative fuels such as compressed natural gas (CNG) and electric vehicles (EVs).
5. **Policy interventions**: The Nigerian government has introduced various policies and initiatives to address emissions, including fuel quality standards, emission controls, and incentives for cleaner transportation technologies.

2.3 Key statistics and data sources

Comprehensive research into transportation emissions requires reliable data sources and key statistics. In Nigeria, obtaining accurate emission data can be challenging due to various factors, including limited monitoring infrastructure and data collection mechanisms. However, some key sources and statistics can provide valuable insights:

1. **National emission inventories**: These inventories, compiled by environmental agencies, provide estimates of emissions from various sectors, including transportation. They are crucial for understanding the overall emissions landscape.
2. **Fuel consumption data**: Data on fuel consumption, sourced from government agencies, industry reports, and oil companies, offer insights into the volume and types of fuels used in transportation.
3. **Vehicle registration and sales data**: Information on the number and types of vehicles registered and sold in Nigeria can shed light on the growth of the automotive sector and its emissions impact.
4. **Air quality monitoring data**: Data from air quality monitoring stations in major cities can provide information on pollutant levels and their variations over time, offering insights into local emissions.
5. **Policy and regulatory documents**: Government policy documents, such as national emission reduction strategies and transportation regulations, offer valuable context and insights into the regulatory landscape.
6. **International reports**: Reports from international organizations, such as the United Nations and the World Bank, often include data and analysis on transportation emissions in Nigeria, providing a global perspective.

By examining historical trends, recent developments, and relying on these key statistics and data sources, researchers can paint a more accurate picture of transportation emissions in Nigeria. This foundation of knowledge is essential for crafting effective mitigation strategies and policies to address the environmental and societal challenges posed by these emissions.

3.0 Drivers of transportation emissions

3.1 *Population growth and urbanization*

1. **Impact on transportation demand**:

Nigeria, experiencing rapid population growth, has witnessed a significant surge in transportation demand (Ilesanmi, 2010). The burgeoning population, especially in urban centers, has led to increased mobility requirements, translating into higher vehicle usage, more public transportation

utilization, and heightened demand for goods and services. This heightened demand significantly contributes to transportation emissions as the existing infrastructure struggles to keep pace with the population's mobility needs.

2. **Urban planning challenges:**

Urbanization in Nigeria has posed substantial challenges in urban planning and transportation infrastructure development. Rapidly growing cities face difficulties in effectively organizing transportation systems, resulting in traffic congestion, inadequate public transportation, and poor road conditions. The lack of efficient urban planning exacerbates emissions by encouraging individual vehicle usage and prolonging travel times, ultimately leading to increased emissions.

3.2 Economic development and energy demand

1. **Correlation between GDP growth and emissions**:

Economic development, often measured by Gross Domestic Product (GDP) growth, is intricately linked to transportation emissions. As the economy expands, the demand for transportation services escalates. Industries, trade, and commerce flourish, necessitating transportation for the movement of goods and services. This correlation implies that economic growth can lead to a subsequent rise in transportation emissions unless coupled with efficient policies to decouple growth from emissions.

2. **Energy sources in transportation**:

The energy sources utilized in transportation significantly influence emissions. Nigeria's transportation sector primarily relies on fossil fuels, particularly gasoline and diesel. These fossil fuels are carbon-intensive, emitting greenhouse gases and air pollutants upon combustion. To mitigate emissions, a transition to cleaner energy sources such as electricity, biofuels, or compressed natural gas is imperative.

3.3 Fuel types and technology

1. **Overview of common transportation fuels used**:

The transportation sector in Nigeria predominantly relies on fossil fuels, including gasoline, diesel, and liquefied petroleum gas (LPG). Gasoline, used in cars and motorcycles, is a major contributor to emissions due to its carbon content. Diesel, widely used in trucks and buses, also emits greenhouse gases and particulate matter. LPG, although cleaner compared to gasoline and diesel, still produces emissions upon combustion.

2. **Technological advancements and efficiency gains**:

Advancements in transportation technology play a vital role in emission reduction. Modern vehicles often incorporate technologies such as fuel injection, hybridization, and electric powertrains to improve fuel efficiency and reduce emissions. Additionally, developments in vehicle design, engine efficiency, and aerodynamics contribute to lowering the carbon footprint of the transportation sector.

3.4 Policy and regulatory framework

1. **Existing policies and regulations**:

Nigeria has instituted various policies and regulations to address transportation emissions. These include emission standards for vehicles, fuel quality standards, and regulations promoting cleaner transportation technologies. However, enforcement and compliance with these policies remain a challenge, hindering their effectiveness in mitigating emissions.

2. **Policy impact on emissions reduction**:

The impact of policies and regulations on emissions reduction can be measured by assessing emission levels before and after policy implementation. Effective policies drive the adoption of cleaner fuels, encourage public transportation usage, and incentivize the adoption of low-emission vehicles. A comprehensive evaluation of the impact of policies is essential to refine and strengthen the regulatory framework for further emissions reduction.

Understanding these drivers of transportation emissions is essential for developing effective strategies and policies to mitigate the environmental impact of the transportation sector in Nigeria. By addressing population growth, economic development, fuel types, and policy frameworks, Nigeria can work towards a more sustainable and environmentally friendly transportation system.

4.0 Environmental impacts of transportation emissions

4.1 *Air quality*

1. **Effects on public health**:

Transportation emissions in Nigeria have significant and far-reaching effects on public health (Raimi et, al., 2021). The release of pollutants such as particulate matter (PM), nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO) from vehicles contributes to poor air quality, especially in urban areas. These pollutants can exacerbate respiratory diseases, increase the risk of cardiovascular problems, and have adverse effects on vulnerable populations, including children and the elderly. Prolonged exposure to polluted air is linked to higher mortality rates and a higher burden of diseases, placing considerable strain on healthcare systems (Raimi et, al., 2021)

2. **Air quality monitoring and data**:

Monitoring air quality is critical to understanding the extent of the problem. Nigeria has established air quality monitoring stations in major cities, including Lagos, Abuja, and Port Harcourt, to measure pollutant levels (Abaje, et. al.,2020). Real-time data from these stations provides valuable insights into air quality trends, allowing authorities to take corrective actions. However, challenges persist, including the need for expanded monitoring networks in smaller cities and rural areas to comprehensively assess air quality throughout the country (Abaje, et. al.,2020)

4.2. Climate change

1. **Contribution to greenhouse gas emissions**:

Nigeria's transportation sector is a significant contributor to greenhouse gas (GHG) emissions, primarily in the form of carbon dioxide (CO2) and methane (CH4). The specific percentage attributed to transportation varies depending on the source and methodology of assessment. However, estimates suggest that transportation contributes a significant share of Nigeria's total GHG emissions, with figures ranging from approximately 18% to 30% (Abam, et. al. 2021). These emissions stem primarily from the combustion of fossil fuels such as gasoline and diesel in vehicles, as well as from other sources like methane emissions from livestock and waste management practices. Globally, transportation is responsible for around 14% of total GHG emissions, making it one of the leading sectors contributing to climate change on a worldwide scale (Creutzig, et. al., 2015). Carbon emissions arise from the combustion of fossil fuels, such as gasoline and diesel, in vehicles. Methane emissions often result from leaks in natural gas pipelines used for transportation and compressed natural gas (CNG) vehicles. These emissions have regional

and global implications, as GHGs are major drivers of climate change. Nigeria's emissions contribute to the collective challenge of global warming and climate variability.

2. **Climate change impacts on Nigeria**:

The consequences of climate change are already affecting Nigeria. Rising temperatures, changing rainfall patterns, and extreme weather events like floods and droughts have far-reaching effects on agriculture, water resources, food security, and human settlements (Olaniyi et al, (2013). Vulnerable communities, particularly those in coastal areas and arid regions, face displacement and heightened risk. Addressing transportation emissions is crucial in mitigating the exacerbation of climate change impacts and building resilience in the face of these challenges.

It is evident that transportation emissions in Nigeria not only deteriorate air quality, jeopardizing public health but also contribute to global climate change, with repercussions for the country's long-term sustainability and development (Onwudiwe, 2023). To combat these environmental impacts, comprehensive strategies, including clean energy adoption, enhanced public transportation, and stringent emission standards, must be implemented to reduce emissions and promote a healthier, more climate-resilient Nigeria.

5.0 Socioeconomic impacts of transportation emissions

5.1 *Health consequences*

1. **Healthcare costs and challenges**:

The health consequences of transportation emissions in Nigeria are multifaceted and exert a significant burden on the healthcare system. The exposure to air pollutants, particularly fine particulate matter (PM2.5) and ground-level ozone (O3), contributes to respiratory illnesses, cardiovascular diseases, and other health issues (Abaje et. al. 2020). These health problems necessitate increased healthcare spending, including hospitalization, medication, and treatment. The costs associated with addressing air pollution-related health problems strain an already overburdened healthcare system, diverting resources away from other critical healthcare needs.

2. **Mortality and morbidity rates**

High levels of transportation emissions are correlated with elevated mortality and morbidity rates in Nigeria (Matthew et. al.,2018). Studies have demonstrated a direct link between air pollution and premature death, with vulnerable populations, such as children and the elderly, at heightened risk (Matthew et. al. 2018). Long-term exposure to polluted air also increases the incidence of chronic respiratory diseases, such as asthma and bronchitis, as well as heart diseases. Elevated mortality and morbidity rates not only devastate families but also undermine the nation's human capital and economic productivity.

5.2 Economic costs

1. **Traffic congestion and productivity losses**:

Traffic congestion contributes to transport emissions in Nigerian cities, resulting in substantial productivity losses (Adeyanju & Manohar 2017). Congestion leads to increased travel times, fuel wastage, and decreased efficiency in supply chains and logistics. Workers spend more time stuck in traffic, reducing their available working hours and productivity. Additionally, businesses incur higher operational costs due to delays in transporting goods. The cumulative effect of traffic congestion has a detrimental impact on Nigeria's economic competitiveness and growth potential.

2. **Economic implications of emissions**:

The economic implications of transportation emissions extend beyond congestion-related losses. Emissions can also result in increased maintenance costs for vehicles due to engine wear and tear caused by traffic congestion that leads to increased wear and tear of the vehicle including the whole drivetrain, braking system, etc. The way in which pollution may affect the wear and tear of the engine is if the emissions are abrasive or corrosive and get into the engine cylinder.) Furthermore, healthcare expenditures associated with treating pollution-related illnesses divert resources that could otherwise be invested in other essential sectors, such as education and infrastructure development. Additionally, the global community is increasingly scrutinizing the carbon footprint of products and services, potentially affecting Nigeria's international trade and market access.

Addressing the socioeconomic impacts of transportation emissions in Nigeria requires a holistic approach that not only prioritizes public health and environmental well-being but also considers the economic consequences. Implementing cleaner transportation technologies, enhancing public transportation systems, and strengthening policy frameworks can help alleviate these impacts and create a more sustainable and prosperous future for Nigeria.

6.0 Nigeria's commitments and international agreements

6.1 *Nigeria's commitment to emission reduction*

Nigeria, as a responsible global citizen, has demonstrated its commitment to addressing climate change and reducing emissions. Several key initiatives and commitments underscore the country's dedication to mitigating the impact of transportation emissions:

1. **Nationally Determined Contributions (NDCs)**: Nigeria submitted its NDCs under the Paris Agreement, outlining its commitment to reducing greenhouse gas emissions (Dioha, & Kumar. 2020). While the NDCs encompass emissions from various sectors, including transportation, they signal the country's intent to implement policies and strategies to curtail emissions.
2. **Sustainable Development Goals (SDGs)**: Nigeria has aligned its national development plans, such as the Economic Recovery and Growth Plan (ERGP) (Shaibume, & Patrick. 2023)., with the United Nations' SDGs. Several of these goals relate to climate action, sustainable cities, and clean energy, highlighting Nigeria's intention to integrate emission reduction efforts into its development agenda.
3. **African Union's Agenda 2063**: Nigeria is a member of the African Union and is actively engaged in the agenda 2063 initiative (Addaney, 2018), which envisions a prosperous and sustainable Africa. This initiative includes strategies for improving transportation and reducing the environmental footprint of the sector.
4. **Domestic policies**: Nigeria has introduced domestic policies and initiatives aimed at reducing emissions, including the National Automotive Industry Development Plan (NAIDP) (Ayetor et.al., 2021)., which encourages local production of energy-efficient vehicles.

6.2 Global agreements and targets relevant to Nigeria

Nigeria, as a signatory to various international agreements, aligns its transportation emissions goals with global efforts to combat climate change and promote sustainable development:

1. **Paris agreement**: Nigeria is a signatory to the Paris Agreement, which sets the goal of limiting global warming to well below 2 degrees Celsius above pre-industrial levels. This

agreement commits Nigeria to reducing emissions across all sectors, including transportation, to contribute to global climate stabilization.

2. **Sustainable Development Goals (SDGs)**: Nigeria endorses the SDGs, particularly Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action), which emphasize sustainable urbanization, clean energy, and the reduction of greenhouse gas emissions.
3. **African Union Agenda 2063**: Nigeria's participation in the African Union's Agenda 2063 aligns with the continent-wide aspiration to create integrated, prosperous, and sustainable economies. This includes promoting sustainable transportation systems and reducing emissions.
4. **Economic Community of West African States (ECOWAS)**: As a member of ECOWAS, Nigeria is part of regional efforts to address transportation emissions. ECOWAS has initiatives to promote energy efficiency and renewable energy adoption in the transportation sector.

Nigeria's commitment to international agreements and targets underscores its recognition of the importance of addressing transportation emissions as part of a broader effort to combat climate change and promote sustainable development. By aligning domestic policies with these global agreements and targets, Nigeria aims to play a pivotal role in mitigating the environmental impacts of transportation emissions while pursuing economic growth and social development.

7.0 Policy recommendations

7.1 *Emission reduction strategies*

1. **Short-term and long-term measures**:

Short-term measures: Implement immediate actions to reduce emissions, such as optimizing traffic flow through intelligent transportation systems (ITS), promoting ridesharing, and carpooling, and implementing vehicle emissions testing programs.

Long-term measures: Develop a comprehensive long-term strategy that includes transitioning to electric vehicles (EVs), improving fuel efficiency standards, and incentivizing the adoption of low-emission vehicles through subsidies and tax incentives. Long-term measures should also include investments in sustainable transportation infrastructure.

2. **Technological innovations**:

Research and development: Invest in research and development to support the creation and adoption of innovative technologies, such as electric and hydrogen fuel cell vehicles. Promote collaboration between academia, industry, and government to drive innovation.

Fleet modernization: Encourage the gradual replacement of older, high-emission vehicles with newer, more efficient models. Provide incentives for vehicle manufacturers to produce low-emission and fuel-efficient vehicles locally.

7.2 Sustainable transportation solutions

1. **Promotion of public transportation:**

Infrastructure investment: Invest in the development and expansion of efficient and reliable public transportation systems, including buses, trams, and commuter rail services, particularly in urban areas with high population densities.

Pricing policies: Implement congestion pricing and efficient fare structures to encourage public transportation usage and reduce the number of single-occupancy vehicles on the road.

2. **Adoption of alternative fuels**:

Diversify fuel sources: Promote the use of cleaner and more sustainable fuels, such as compressed natural gas (CNG), liquefied natural gas (LNG), biofuels, and hydrogen. Develop a comprehensive strategy for the production and distribution of alternative fuels.

Incentives for electric vehicles (EVs): Offer incentives, tax breaks, and subsidies to encourage the adoption of electric vehicles. Develop EV charging infrastructure to support widespread EV usage.

7.3 Strengthening the regulatory framework

1. **Policy reforms and enforcement mechanisms**:

Stricter emission standards: Strengthen and enforce emission standards for vehicles, ensuring that imported and locally manufactured vehicles comply with international emission norms.

Regular emission testing: Implement mandatory emission testing for vehicles at regular intervals and enforce compliance through penalties for non-compliant vehicles.

2. **International cooperation and partnerships**:

Information exchange: Collaborate with international organizations and other countries to exchange best practices, share data on emissions, and access technical expertise for emissions reduction strategies.

Climate finance: Seek international climate finance and support for implementing sustainable transportation projects and initiatives, including funding for the development of clean transportation infrastructure.

These policy recommendations aim to address transportation emissions comprehensively in Nigeria. By combining short-term and long-term strategies, promoting sustainable transportation solutions, and strengthening the regulatory framework, Nigeria can make substantial progress in reducing emissions, improving air quality, and contributing to global efforts to combat climate change while fostering economic growth and enhancing the well-being of its citizens.

8.0 Conclusion

Addressing transportation emissions is not only an environmental imperative but also a moral obligation to safeguard the well-being of present and future generations. With concerted efforts, collaborative partnerships, and informed decision-making, Nigeria can forge a path towards a sustainable, low-emission transportation future, ensuring a greener, healthier, and more prosperous nation for all.

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