Greening Growth: The Revealed Comparative Advantage of Indian Transport Sector Emissions

Syeeda Khatoon[1], Syed Asghar Mehdi[2]

[1] Economics Section, Women's College, Aligarh Muslim University, India
syeedaasghar@hotmail.com
[2] Department of Hospitality and Tourism Management,
Faculty of Management and Commerce, Mangalayatan University, India
syed.mehdi@mangalayatan.edu.in

Citation: Syeeda Khatoon, Syed Asghar Mehdi (2026). Greening Growth: The Revealed Comparative Advantage of Indian Transport Sector Emissions. *Journal of Environmental Management and Tourism, 17*(1), 42-54. https://doi.org/10.14505/jemt.v17.1(81).04

Article info: Received 31 January 2026; Received in revised form 9 February 2026. Accepted 17 February 2026; Published 27 February 2026.

Abstract: Greening growth requires aligning economic expansion with environmental sustainability, a challenge that is particularly acute for rapidly growing economies such as India. The transport sector plays a dual role in this transition: it is a critical enabler of productivity, mobility, and tourism-led growth, while simultaneously emerging as one of the fastest-growing sources of greenhouse gas (GHG) emissions. This study examines India's transport-sector ((Mobile combustion – road, rail, ship & aviation) emissions in a global comparative perspective by applying the Revealed Comparative Advantage (RCA) framework to transport-related GHG emissions (CO_2, CH_4, N_2O, and F-gases) for the period 1970–2023, using EDGAR data. The analysis compares India's emission intensity relative to world averages and major emitting countries, including China, the United States, Japan, Russia, and Canada, as well as international aviation and shipping. Findings indicate that while India's relative environmental burden remained below the global benchmark until the mid-2000s, its RCA in transport-sector emissions has exceeded unity thereafter, coinciding with accelerated economic growth, motorisation, urbanisation, and rising aviation demand. Road transport and aviation emerge as the dominant contributors, with international transport activities approaching global average emission intensities. The results highlight that India and China currently exhibit a revealed comparative disadvantage in greening transport growth relative to advanced economies that have begun to decouple transport emissions from economic expansion. The study underscores the urgency of integrated mitigation strategies, including rapid electrification of road transport, modal shifts towards rail, expansion of low-carbon public transport, deployment of sustainable aviation fuels, and stronger regulatory and market-based instruments. Aligning transport decarbonisation with tourism growth and broader development goals is essential for India to achieve green growth without compromising mobility and economic aspirations.

Keywords: Green growth; Transport emissions; Revealed comparative advantage (RCA); India; transport; GDP; Sustainable mobility.

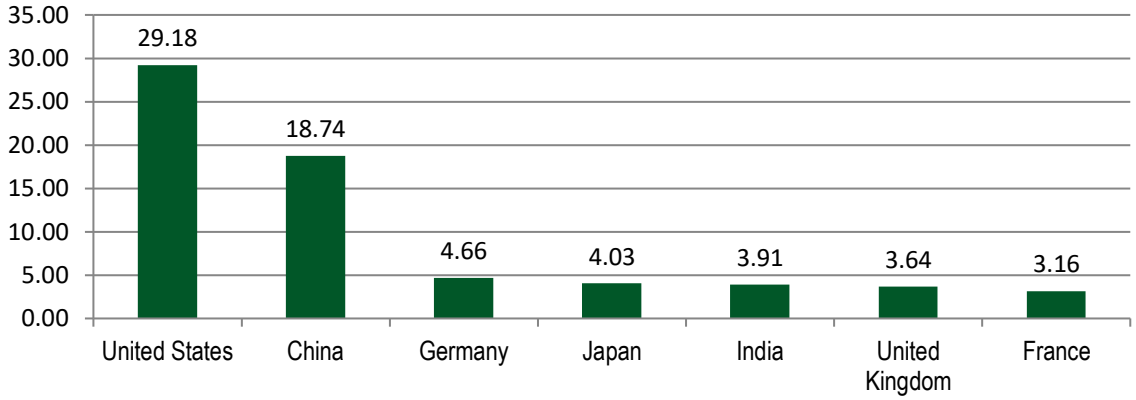
JEL Classification: O44; R11; R41; Z32.

Introduction

India is among the world's fastest-growing major economies, with sustained growth driven by industrialization, urban expansion, and rising household incomes. While this growth has lifted millions out of poverty, it has also intensified pressure on natural resources and increased environmental pollution. The transportation sector plays a dual role: it is essential for economic productivity and social mobility, yet it is a major source of air pollution and

carbon emissions. Greening growth refers to fostering economic development while ensuring that natural assets continue to provide the resources and environmental services on which human well-being depends. In India, achieving green growth is especially important given the country's development needs, high population density, and vulnerability to climate change. This paper explores how the transportation sector fits into India's green growth pathway by analyzing emission trends and future opportunities. India is among the world's fastest-growing major economies, with sustained growth driven by industrialization, urban expansion, and rising household incomes. India has overtaken France and U.K. to become the fifth largest economy of the world on the bases of GDP (Current US$) on the basis of World Bank data base of 2024, presented in the below Graph reflects that.

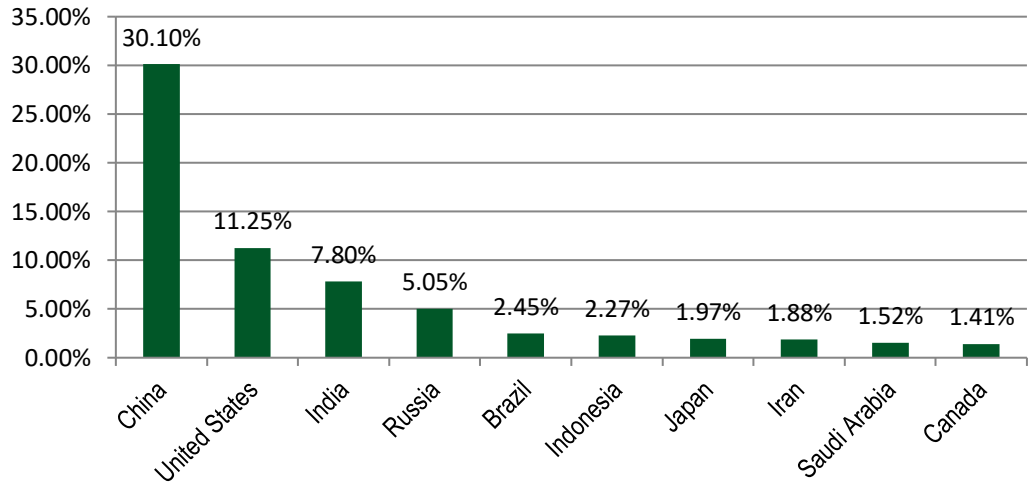
Graph 1. World's Seven Largest Economies: As Per 2024 GDP ($ trillion)



Source: World Bank Data, World Development Indicators, https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD#

However, when it comes to the emissions, India the large parts of Green House Gas (GHG) emissions are contributed by China, United States and India at the third place as shown in the below Graph

Graph 2. Share of GHG Totals in Mt. CO2 eq/yr (2023)



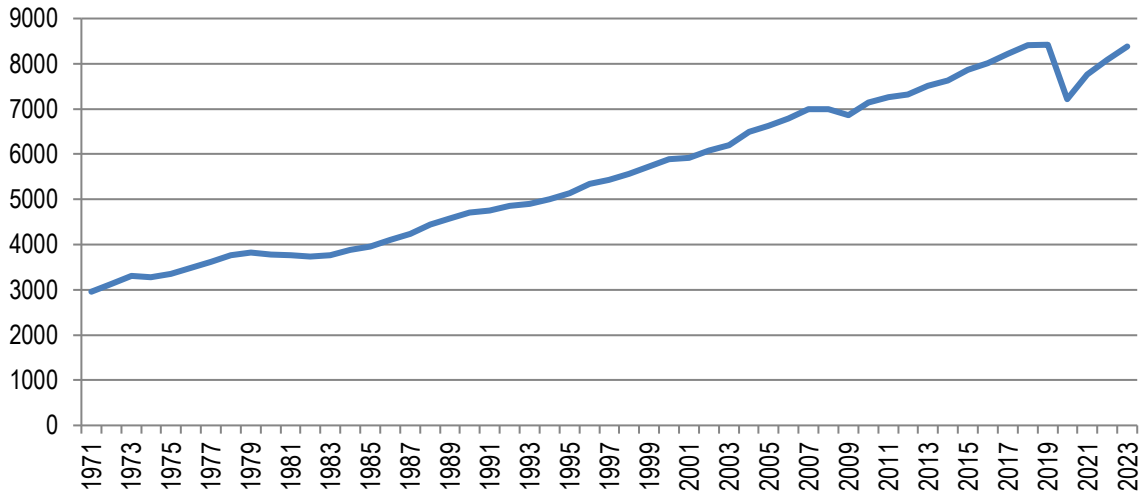
Source: EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database (a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA). https://edgar.jrc.ec.europa.eu/report_2024

While this economic growth has lifted millions out of poverty, it has also intensified pressure on natural resources and increased environmental pollution. The transportation sector is essential for economic productivity and social mobility, yet it is a major source of air pollution and carbon emissions.

In general, markets tend to overlook the environmental damage associated with economic activities. When the production or consumption of a good imposes costs on third parties who are not directly involved in the

market transaction, such impacts are referred to as externalities. Negative environmental externalities - such as air pollution, depletion of natural resources, and contamination of water bodies - adversely affect ecosystems and, ultimately, human well-being. These adverse effects necessitate timely and effective policy formulation and implementation preceded by an in-depth measured analysis of environmental impact of the transport sector – as per the scope of this paper. The global transport sector GHG Emissions (GHG emissions include CO_2 – fossil only, CH_4, N_2O and F-gases) has been continually rising since 1970s (exception being the 2020 widespread pandemic lockdowns) as shown in the below graph

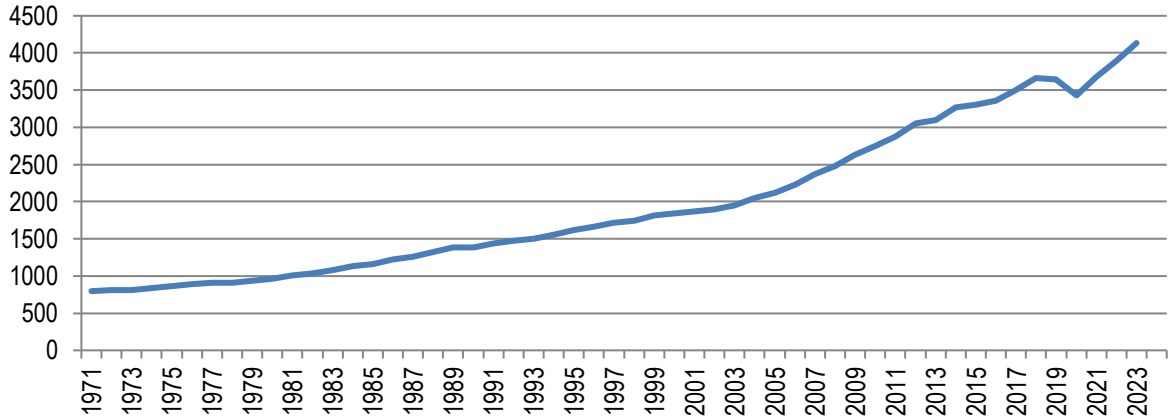
Graph 3. Global Transport Sector GHG Emissions (Mt. CO2 eq/yr.)



Source: EDGAR, 2024

The same trend is followed in case of India as well (Graph 4)

Graph 4. India Transport Sector GHG Emissions (Mt. CO2 eq/yr.)



Source: EDGAR, 2024

Travel and tourism have many connected sub-sectors out of which hospitality and transport (rail, road and aviation) are important sub sectors. So what can be the travel and tourism sector's role in controlling environmental damage? The obvious answer is twin fold (a) Adopt circular principles in hospitality sub sector, and (b) Adopt sustainable travel and transport models for the sub sector. Tourism as the sector is much needed in all the developing economies of the world as it is the largest service sector that can not only contribute to the national income but has multiplier effect on the generation of direct and indirect employment. Much has been written about the hospitality sector and much needs to be focused on transportation in terms of its rising contributions to emissions along with its vital backbone towards the economic growth of the countries. The transport sector emerges as a major contributor to emissions, with road transport and aviation playing dominant roles. The World in general and India in particular, transport accounts for a substantial share of air pollution and energy-related CO_2 emissions. The paper seeks to assess the transportation sector worldwide, including mobile

combustion across road, rail, shipping, and aviation, with particular emphasis on India through an evaluation of the country's revealed comparative advantage in transport-sector emissions. The study seeks to assess whether India's transport-sector greenhouse gas (GHG) emissions have become disproportionately concentrated relative to global trends, using the Revealed Comparative Advantage (RCA) framework as a comparative environmental benchmarking tool over the period 1970–2023. The study seeks to answer the Research Questions as below:

1.Has India's transport-sector GHG emission intensity, relative to global averages, increased over the period 1970–2023?

2.Does India exhibit a Revealed Comparative Advantage (RCA < 1) in transport-sector emissions in recent years, indicating a relative concentration of emissions compared to the world average?

3.How does India's transport-sector RCA compare with major economies such as China, USA, Japan, Russia, Canada, and international aviation/shipping?

The study innovatively repurposes Revealed Comparative Advantage (RCA) or Balassa index as the novel methodology adopted here as a relative benchmarking tool to assess a country's emission intensity in the transport sector vis-à-vis the global pattern. Although originally developed for trade competitiveness, the RCA framework is well suited for comparative environmental analysis because it normalizes a country's sectoral emissions by its overall emissions profile and compares this share with the corresponding global share. This relative scaling controls for differences in country size and total emissions, allowing meaningful cross-country comparison of sector-specific emission concentration.

1. Research Background

The Green practices are drawing attention in developed economies because the demand for environment quality is more than unity at higher stages of development. As economic power centres are shifting to Asia-Pacific region thereby increasing the importance of Asian economic development for environmental management. The large parts of CO_2 emissions are contributed by China, United States and India. Environmental emissions are global concern because its adverse impact is not limited to a country or a region, as rising global temperature is leading to melting of polar ice caps, rise in level of sea and extreme weather conditions.

As the increase in scale of economic activity has worsening impact on environment, simultaneously, maintenance of environment quality is necessary for sustainable development. Therefore, the flow of economic activity should take into consideration its environmental impact. Scientists believe that emissions from economic activities like factories, power plants, cars and trucks targeted to move to zero by 2050. Globally, Power Industry, and Transport are the major contributors to the Green House Gas emissions. In 2018, delegates from around 200 countries met in Poland and set tougher targets for cutting greenhouse gas emissions, vis-à-vis, Paris climate agreement of 2015 along with stronger transparency rules are set for countries regarding revealing their emissions (Irfan, 2018). In Paris Climate change agreement also, nearly 200 countries met and agreed to limit the global temperature rise to 2^0C by 2100; but the preferred level is set at 1.5^0C. If the emissions continue to rise with the pace of the current rise leads to more wild fires, coastal flooding, widespread food shortages and population displacement by 2040 (Pierre-Louis, 2018).

Transportation is a major source of air pollution and greenhouse gas emissions, especially in cities. In India, the sector accounts for about 40% of total air pollution, over 40% of Nitrogen Oxides **(**NOx) emissions, 12% of energy-related CO_2 emissions, and roughly 7% of combustion-linked PM2.5. In Delhi alone, transport contributes nearly 43% of PM2.5 levels. Two-wheelers, three-wheelers, and trucks are the biggest emitters within this sector. In Delhi, 2Ws and 3Ws together generate around 60% of transport pollution, followed by trucks (20%), buses (10%), and passenger cars (10%). Nationally, heavy-duty vehicles produce about 45% of CO_2 emissions, cars 25%, two-wheelers 15%, buses 9%, and light-duty vehicles 8%. India's government is aligning transport reforms with its climate commitments under the 'Panchamrit' agenda, targeting energy independence by 2047 and net-zero emissions by 2070. Electric mobility is central to this transition, with a goal of 30% EV penetration by 2030 (about 102 million EVs). There are different schemes nationally such as 'FAME scheme', and 'PLI' scheme; new initiatives like 'PM e-Bus Sewa' and 'PM e-Drive' with local incentives to push for such transitions. Although EV adoption is rising among smaller vehicles, electric buses and trucks are still in the early stages of deployment (Council for International Economic Understanding, 2025).

Aviation contributes about 2.5% of global CO_2 emissions but nearly 4% of total global warming due to additional non-CO_2 effects such as NOx, SO_2, water vapor, and contrail formation at high altitudes. Although only around 10% of people fly annually, demand has quadrupled since 1990, with improved aircraft efficiency reducing emissions per passenger-kilometer by over half. However, total emissions continue to rise as air travel expands. Non-CO_2 emissions significantly amplify aviation's climate impact, potentially tripling its warming effect.

Strategies like using cleaner jet fuels with lower aromatic content and rerouting flights to avoid contrail-prone regions can greatly reduce these effects. The EU plans to start monitoring non-CO_2 emissions in 2025, though broader global action is lacking. Future mitigation depends on transitioning to Sustainable Aviation Fuels (SAFs), e-fuels, hydrogen, and electric aircraft. While efficiency gains and technological advances have reduced energy intensity, aviation still relies almost entirely on fossil fuels. Without rapid adoption of low-carbon alternatives, its share of global emissions will continue to grow as other sectors decarbonize (Ritchie, 2024). Aviation emissions have risen more rapidly than any other transport mode, more than doubling since 1990. Without effective mitigation, they are projected to more than double again by 2050, potentially consuming and large chunk of the remaining global carbon budget required to limit warming to 1.5°C.

Between 1940 and 2018, non-CO_2 emissions accounted for over half of aviation's total warming impact, though their uncertainty remains about eight times greater than that of CO_2. Recent reports by the IPCC, WMO, and Copernicus Climate Change Service warn of accelerating climate change and record-breaking weather extremes, with Europe now warming at twice the global rate, the fastest of any continent.

To better understand and manage these impacts, a non-CO_2 Monitoring, Reporting, and Verification (MRV) framework was introduced on 1 January 2025 to collect data on aviation's non-CO_2 emissions. This initiative aims to strengthen scientific research and inform effective mitigation strategies. Additionally, a European Parliament pilot project launched in 2024 is assessing ways to optimize jet fuel composition - such as lowering aromatic and sulfur content - to reduce environmental impacts without compromising safety. Aircraft engine emissions, particularly nitrogen oxides (NOx) and particulate matter, also degrade air quality near airports, with potentially significant exposure to NO_2 and ultrafine particles in nearby residential areas (European Union Aviation Safety Agency, 2025).

Global air traffic is growing by about 5% annually, consuming over 5 million barrels of oil each day. Aviation emissions, particularly in fast-growing markets like China, are projected to more than triple by 2050 if unmitigated. Besides CO_2, airports and aircraft contribute to local air pollution through nitrogen oxides and fine particulate matter. Major airlines such as American Airlines, Emirates, and Lufthansa emit tens of megatonnes of CO_2 yearly. To address this challenge, the EU Emissions Trading System (EU ETS) employs market-based carbon pricing and efficiency-driven incentives with the objective of reducing emissions by 43% by 2030. Technological and operational improvements have reduced CO_2 emissions per seat by 80% since the 1950s, supported by ICAO's aircraft emission standards. Further reductions depend on sustainable aviation fuels made from waste or biomass and the gradual introduction of electric aircraft for short routes. Optimizing flight paths and promoting non-stop routes can also lower emissions, reducing CO_2 by roughly 100 kg per passenger compared with connecting flights (Sher, et al, 2021).

India's aviation sector, though contributing under 1% of national emissions, is growing rapidly and could become the world's third largest by 2030. To curb its rising carbon footprint, the government's 2019 Green Aviation Policy promotes Sustainable Aviation Fuel (SAF) from agricultural residues like sugarcane waste and rice husk. Indian Oil and Praj Industries achieved the country's first SAF-powered commercial flight in 2023. Green airport initiatives, electric ground operations, and Taxi-Bots further enhance efficiency. However, limited feedstock, high SAF costs, and weak infrastructure hinder large-scale adoption. With a 1% SAF blending target by 2025, India's progress exceeds China's but trails Brazil's. Linking clean aviation with rural bioeconomy could cut emissions while supporting farmers and sustainable growth (Saroha, 2025).

In India, substantial inter-state and inter-regional differences in vehicle ownership and emission levels necessitate the development of decentralized emission inventories for the road transport sector to inform targeted greenhouse gas (GHG) mitigation strategies. During 2003–04, total carbon dioxide emissions from the transport sector amounted to 258.10 teragrams (Tg), with road transport and aviation emerging as the dominant sources. Road transport alone contributed 94.5% of transport-related CO_2 emissions and 53.3% of carbon monoxide (CO) emissions. Maharashtra recorded the highest road transport CO_2 emissions at 28.85 Tg (11.8%), followed by Tamil Nadu (10.8%), Gujarat (9.6%), Uttar Pradesh (7.1%), Rajasthan (6.2%), and Karnataka (6.2%). Together, these states accounted for 51.8% of national road transport CO_2 emissions. Aviation was responsible for 2.9% of CO_2 emissions but accounted for a disproportionately high 45.1% of Carbon oxide (CO) emissions, while rail transport contributed 2.0% of CO_2 and 1.2% of CO emissions. Maritime transport accounted for only 0.6% of CO_2 emissions, making it the least carbon-intensive transport mode. Over the period from 2003–04 to 2005–06, aggregate CO_2 emissions from aviation, railways, and shipping increased by 24.2%, accompanied by rises of 32.3% in CO emissions and 31.8% in methane (CH_4) emissions (Ramachandra and Shwetmala, 2009).

India's transport sector is rapidly expanding, driven by rising incomes and urbanisation, and is a key contributor to energy demand and CO_2 emissions. While accounting for under 20% of final energy use, transport

consumes roughly 50% of India's oil, highlighting the need for decarbonisation, particularly in aviation and long-distance freight. Passenger mobility is dominated by two- and four-wheelers, with four-wheelers projected to grow from 9% of motorised travel in 2020 to 45% by 2050, reducing public transport shares and increasing energy demand, congestion, and emissions. Trucks handle 65% of freight, with natural gas expected to supply 35% of their fuel by 2050. Railways remain the most energy-efficient mode, and electrification will further enhance efficiency. Policy measures and electric vehicle infrastructure will be crucial to manage the sector's future energy and climate impact (Kamboj, et al, 2022).

India, the ninth-largest aviation market, operates over 120 airports, including 34 international ones. Aviation is highly carbon-intensive, projected to contribute 15–25% of global aviation emissions by 2050, with a three- to seven-fold increase since 2000. India joined CORSIA in 2016, mandatory from 2026, highlighting the urgency of mitigation. Tourism, closely linked to aviation, drives economic growth but raises emissions. Low-carbon destination management - through sustainable transport, longer stays, and targeted market strategies - is essential to align tourism growth with net-zero goals. Bio-jet fuels offer a cleaner alternative but remain costly, 60–70% above conventional fuels, posing challenges for operational efficiency (Thummala and Hiremath, 2022).

Existing literature underscores that environmental sustainability has become a central concern as economic growth intensifies environmental pressures, particularly through rising greenhouse gas emissions. While developed economies have led green transitions, shifting global economic activity toward Asia - especially China and India - has heightened the region's significance in global environmental management. The transport sector emerges as a major contributor to emissions, with road transport and aviation playing dominant roles. In India, transport accounts for a substantial share of air pollution and energy-related CO_2 emissions, driven largely by two- and three-wheelers, heavy-duty vehicles, and rapidly expanding aviation activity. Despite global climate pledges, including the Paris Agreement, and national commitments such as India's Panchamrit framework, emissions from the transport sector - covering road, rail, maritime, and aviation - continue to rise, driven by the growing demand for mobility. Aviation, in India though contributing a relatively smaller share of CO_2, has a disproportionately high climate impact owing to non-CO_2 effects and is projected to consume a significant portion of the remaining carbon budget without effective mitigation. Policy responses increasingly emphasize electric mobility, sustainable aviation fuels, market-based mechanisms, and decentralized emission inventories. However, high costs, infrastructure constraints, and uneven regional development remain key challenges, highlighting the need for integrated, sector-specific mitigation strategies to align economic growth, transport expansion, and climate goals.

While extensive research has examined transport-sector emissions in absolute terms and explored policy responses such as electric mobility and sustainable aviation fuels, there remains a lack of long-run comparative benchmarking that evaluates whether a country's transport emissions are disproportionately concentrated relative to global patterns. In particular, the application of the Revealed Comparative Advantage framework to sector-specific environmental intensity remains largely unexplored. This study addresses this gap by adapting the Balassa index to assess India's transport-sector GHG emissions relative to global averages over the period 1970–2023, thereby providing a normalized and comparative perspective on green growth performance.

2. Research Methodology

This study is based on secondary data on greenhouse gas (GHG) emissions from the transport sector at the global level, with a comparative focus on emissions from India, using EDGAR (2024) for the study period spanning 1971 to 2023 (time period *t*). The analysis employs the Revealed Comparative Advantage (RCA) framework as the primary research tool to examine cross-country patterns in general and India's relative position in particular. The RCA index is computed as follows:

RCA =(Xih/Xit)/(Xwh/Xwt),

Xih denotes country *i*'s contribution to GHG/CO_2 emissions in year *h* (2023);
Xit represents the total GHG/CO_2 emissions of country *i* over the study period *t* (1971–2023);
Xwh refers to the world's contribution to GHG/CO_2 emissions in year *h* (2023); and
Xwt indicates total global GHG/CO_2 emissions over the period *t* (1971–2023).

The transport sector data encompass mobile combustion across road, rail, maritime, and aviation modes, while greenhouse gas emissions include fossil-based CO_2, CH_4, N_2O, and fluorinated gases. These emissions are aggregated using Global Warming Potential (GWP) coefficients and reported as total GHG emissions in million tonnes of CO_2 equivalent per year (Mt CO_2e/yr).

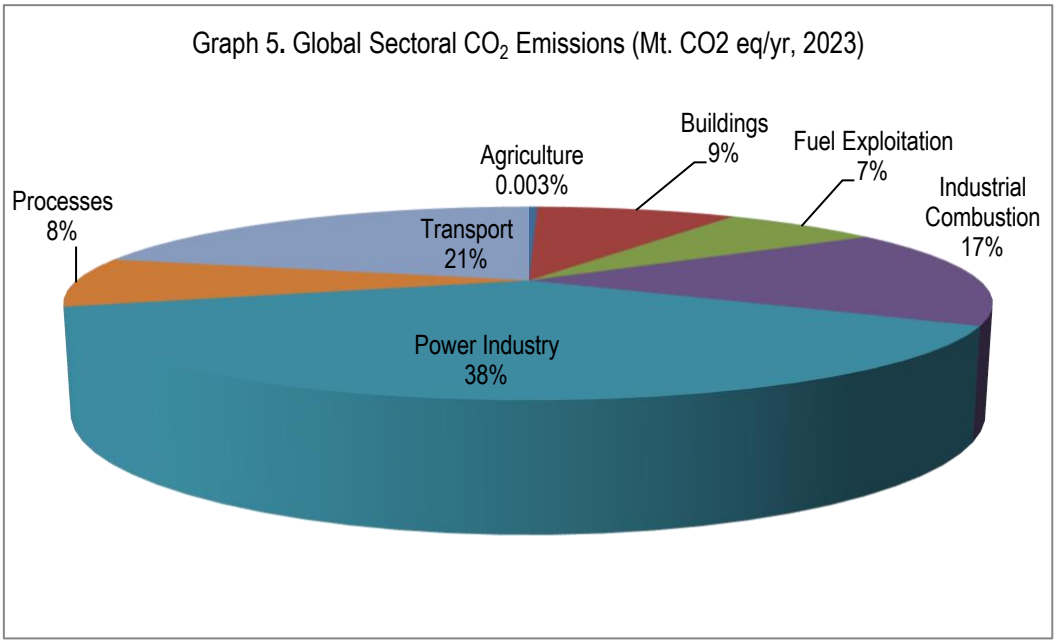
An RCA value greater than 1 indicates that a country's share of transport-related GHG/CO_2 emissions in the reference year / study period is relatively higher than the corresponding global share, implying a revealed comparative "intensity" (or disadvantage) in emissions for that sector. Conversely, an RCA value less than 1 suggests that the country's relative contribution is lower than the world average, indicating comparatively lower emission intensity in the transport sector.

By focusing on shares rather than absolute volumes, RCA highlights whether a country exhibits a disproportionate concentration of GHG/CO_2 emissions in the transport sector compared to the world average. This makes it particularly useful for identifying sectors where mitigation efforts are relatively more urgent for a given country, even when its absolute emissions may be lower or higher due to scale effects. The simplicity, transparency, and interpretability of the Balassa index further support its application as a diagnostic indicator for comparative assessment of emission intensity across countries and over time.

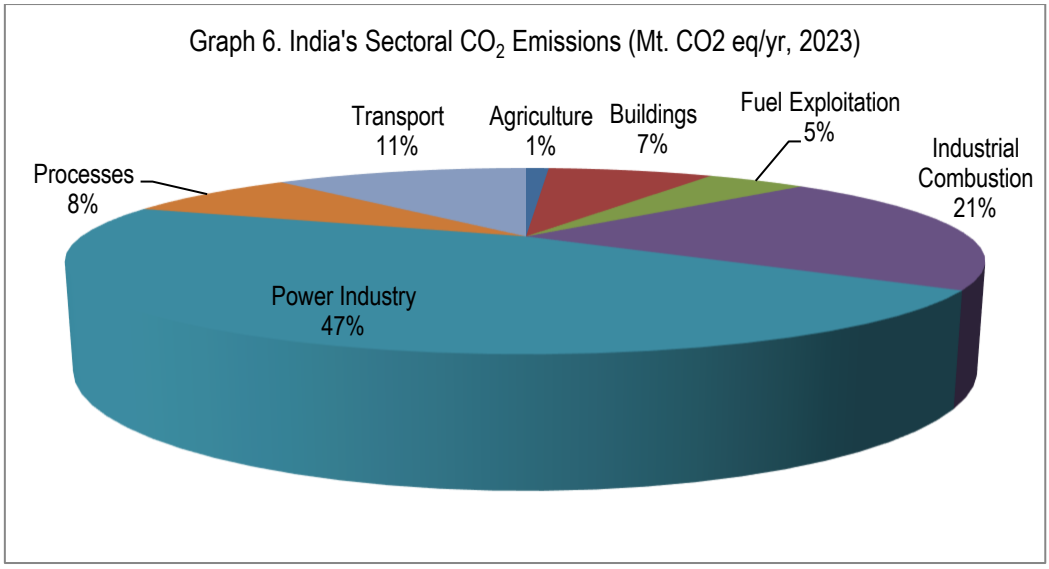
3. The Transport Sector – Revealed Comparative Advantage Analysis

The transport sector is a major contributor to global greenhouse gas (GHG) emissions and also represents a significant source of emissions in India. In terms of gas-wise contributions, carbon dioxide (CO_2) accounts for the largest share of total emissions, comprising 73.68% globally and 71.49% in India, followed by methane (CH_4) at 18.88% worldwide and 20.31% in India, and nitrous oxide (N_2O) at 4.70% globally and 6.53% in India. Methane and nitrous oxide emissions are predominantly associated with agricultural activities (EDGAR, 2024). Consequently, for sectors other than agriculture, CO_2 emissions remain the principal area of concern. The transport sector ranks as the second-largest source of CO_2 emissions globally after the power industry as illustrated in Graph 5, while in India it is the third-largest contributor, following the power sector and industrial combustion (Graph 6).

Graph 5. Global Sectoral CO_2 Emissions (Mt. CO2 eq/yr, 2023)



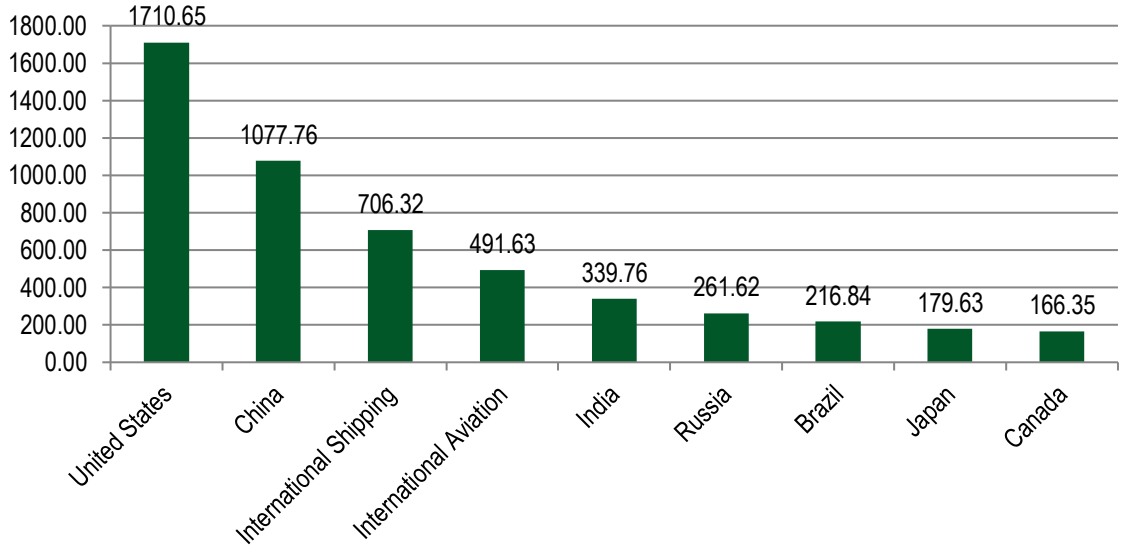
Source: EDGAR, 2024



Source: EDGAR, 2024

The Transport Sectoral Greenhouse Gas (GHG) Emissions follows the same trends as that of the overall global GHG emissions where China leads the charts, followed by United States of America and India following at the third place. However, in case of Transport sectoral emissions, two more areas exceed India, following the top two contributor countries, namely, International Shipping and International Aviation, as per the Graph 7 below (CO_2 is the major cause of emissions to transport sector, hence the data ignores the other emissions, which also follow the similar trends). The two areas need consolidated efforts to control through renewed international understanding for drastic policy formulation and implementation.

Graph 7. Transport Sector GHG Emissions in Mt. CO_2 eq/yr. (2023)



Source: EDGAR, 2024

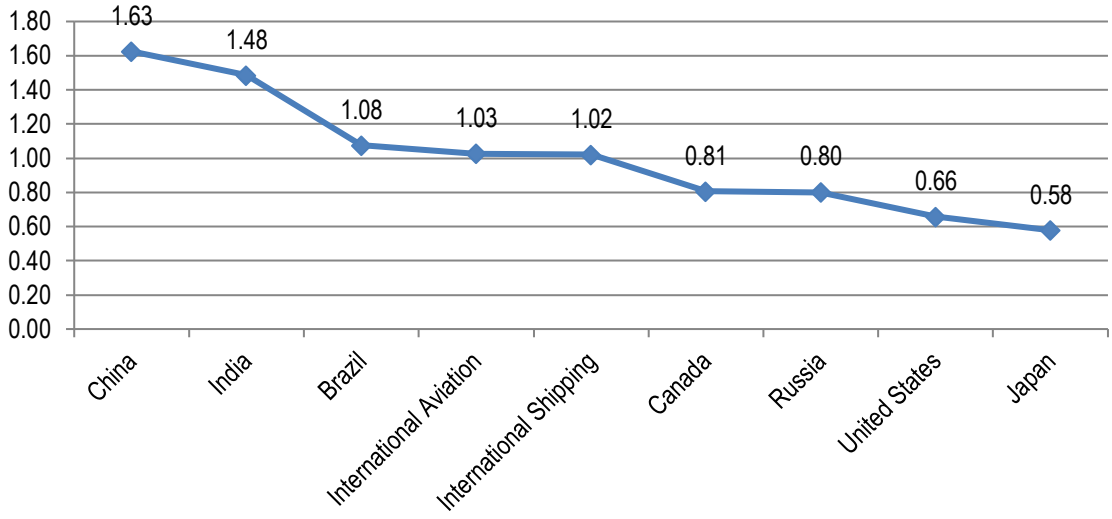
4. Comparative Advantage Analysis of GHG Emissions

The study attempts to establish the revealed comparative advantages for environmental impact related to Transport Sectoral Greenhouse Gas (GHG) emissions with respect to the World to arrive at revealed advantage or disadvantage for India with respect to other countries over the period from 1970 to 2023.

The revealed comparative advantage for total Greenhouse Gas (GHG) Emissions of all countries was calculated for the year 2023 over the previous all years from 1970 to 2023 with respect to the GHG Emissions of the World in the year 2023 over the previous years from 1970 to 2023. The revealed comparative advantage for the GHG emission impact of any country with respect to world in 2023 over the study period will be lower if the

value is less than unity and impact will be higher if the value is more than unity. The revealed comparative calculated for 210 countries and regions showed that 121 were more than unity than the World average and only 89 countries and regions were less than unity.

Graph 8. Country's RCA on GHG Emissions (2023)

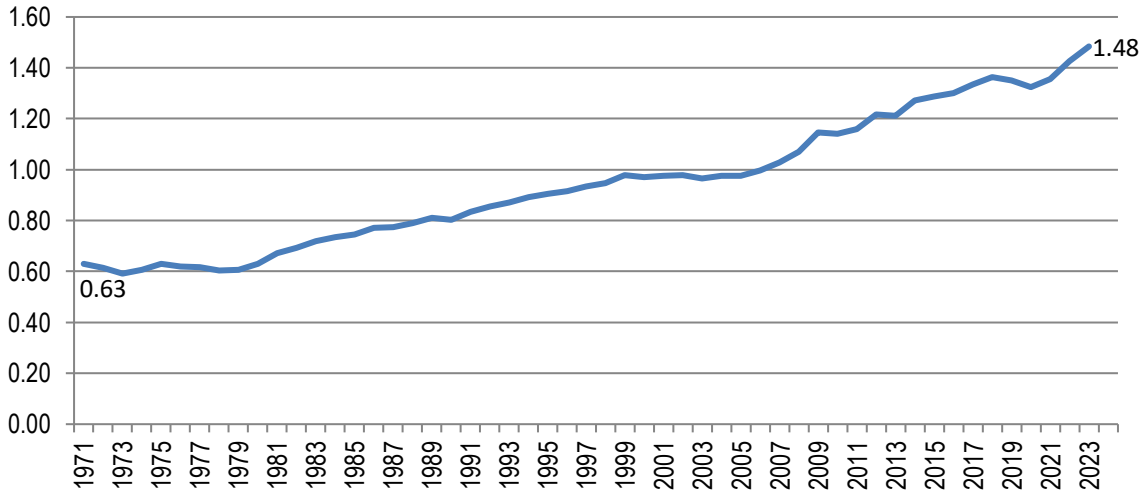


Authors' calculation based on EDGAR, 2024

The Graph above shows while Japan, United States, Russia and Canada have improved to less than unity in the revealed comparative advantage with respect to the World in 2023 when analysed over the period from 1970 to 2023; India and China are witnessing lesser revealed comparative advantage and are still having more than unity or greater GHG Emissions impact in 2023 with respect to the World. International Shipping, International Aviation and Brazil are near to the unity and are causing the almost the same environmental impact as that of the World impact. India and China to the greater extent need to bring their GHG emissions down with better policies and implementation while their economy grows further.

Studying India's rising GHG emissions over the years as shown in Graph 4 does not give the fair idea, if seen in isolation. The Graph 9 below shows India's Annual Revealed Comparative Advantage (RCA) on GHG Emissions with respect to the World over the study period.

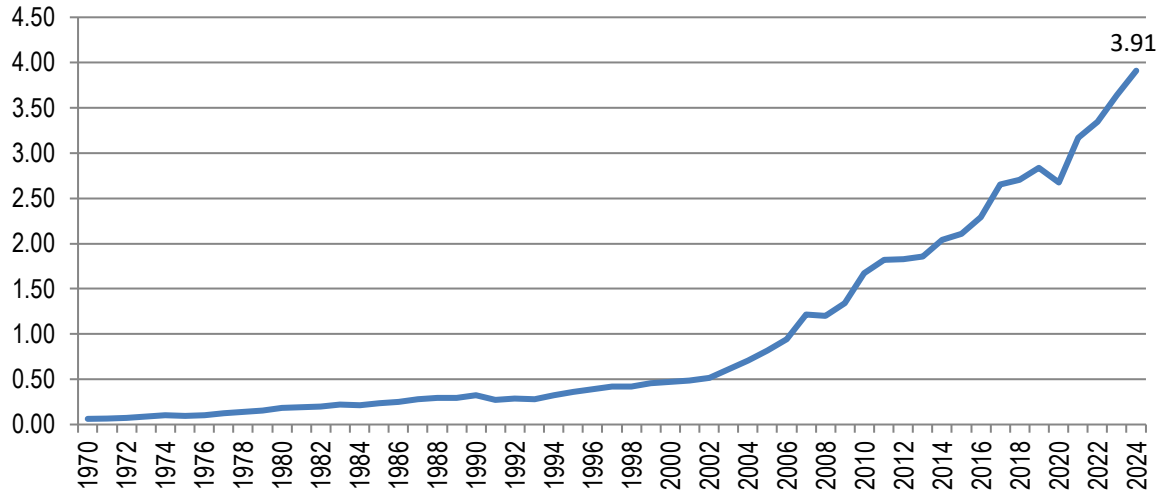
Graph 9. India's Annual RCA on GHG Emissions



Authors' calculation based on EDGAR, 2024

The graph above shows that India's environmental impact with respect to World was lesser till 2006 when it achieved unity with the World; and thereafter environmental impact with respect to World started rising; this almost coincides with the time when India started witnessing its higher GDP growth as shown in Graph 10.

Graph 10. India's GDP (current Trillion US$)

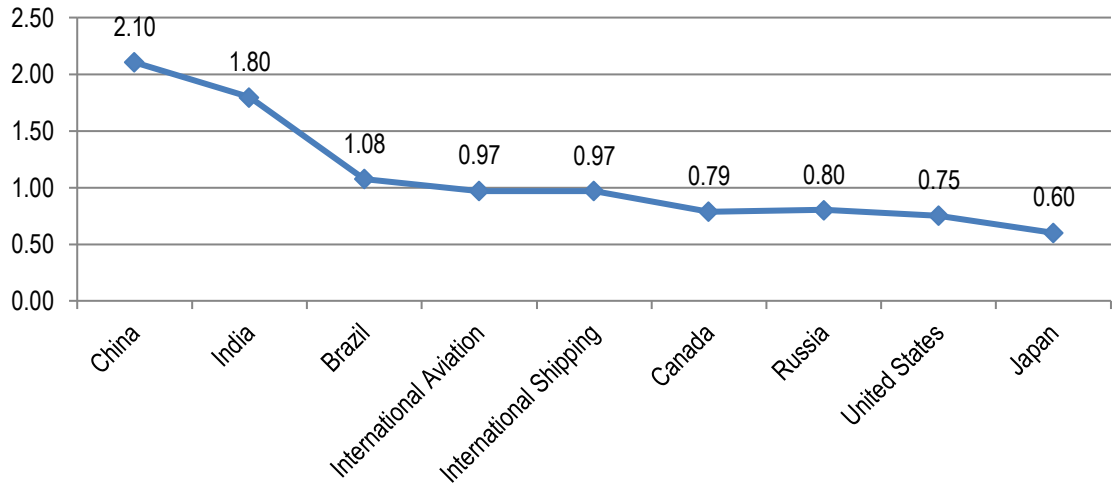


Source: The World Bank Data, 2024
https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2023&locations=IN&start=1970&view=chart

5. Comparative Advantage Analysis of Transport Sector Emissions

India and China to the greater extent need to bring their Transport sector contribute lesser emissions with better policies and implementation while their Travel and Tourism sector grows as the select countries RCA analysis on Transport Sector CO_2 emissions as shown in Graph 11 presents that India and China alone are greater than World unity. It follows the same trend as the RCA for overall GHG Emissions (Graphs 8). The Brazil though just above the World Unity in Transport CO_2 as well as overall GHG emissions, International Shipping & International Aviation are around the World Unity, whereas Canada, Russia, US and Japan are much below World Unity.

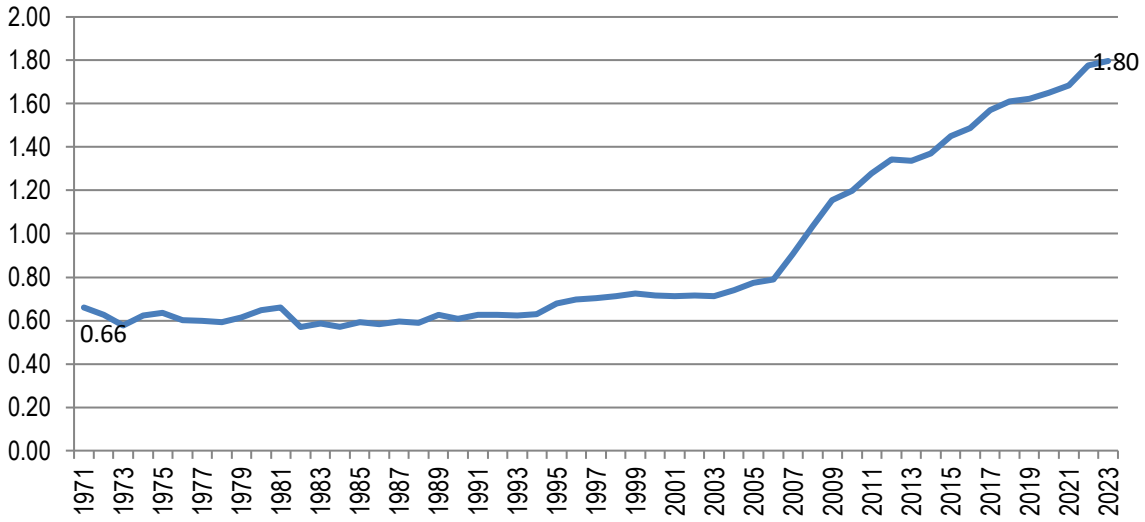
Graph 11. Country's Transport Sectoral GHG Emissions RCA (2023)



Authors' calculation based on EDGAR (Emissions Database for Global Atmospheric Research), 2024

India and China are emerging economic leaders as well as the biggest two economies in the Asia Pacific region, which is slated to be the upcoming region for travel and tourism growth. However, the economies have to re-shape their overall Emissions control in general and Transport sectoral emissions in particular. Talking about India, India's transport sectoral emissions has been lower than World unity till 2007 and sharply rose afterwards.

Graph 12. India's Annual RCA on Transport Sector Emissions



Authors' calculation based on EDGAR (Emissions Database for Global Atmospheric Research), 2024

In the advance stages of development, knowledge economy bring more cleaner technologies because wealthy nations can afford to spend more on research and development (Komen et al., 1997). Further, demand for environment quality is more than unity at higher stages of development (McConnell, 1997) (Shafik, 1994). This being the reason why the developed economies like USA, Russia, Canada and Japan have effectively controlled their overall GHG emissions as well as the Transport sector emissions as showed in this study. India needs to strengthen its knowledge economy more than its Gross income economy.

India, despite introducing notable policy initiatives to promote greener mobility, the transition of the transportation sector remains constrained by multiple structural and behavioural challenges. The high initial costs associated with clean and low-emission technologies continue to deter large-scale adoption, particularly in price-sensitive markets. Inadequate charging and alternative-fuel refuelling infrastructure further limits the operational feasibility of electric and low-carbon vehicles, especially beyond major urban centres. In addition, fragmented institutional responsibilities across multiple transport and urban authorities weaken coordination and slow the implementation of integrated sustainability strategies. Persistent behavioural preferences for private vehicle ownership and use also undermine efforts to promote public and shared transport systems. Overcoming these barriers requires coherent and coordinated policy frameworks, predictable and sustained financing mechanisms, and sustained public awareness and engagement initiatives.

To strengthen green growth outcomes in the transportation sector, a comprehensive set of policy interventions is required. Priority should be given to the rapid electrification of public and shared mobility systems to achieve large-scale emissions reductions. Greater investment in railways and water-based freight corridors can help shift freight movement towards lower-carbon modes. Transport planning should be systematically aligned with urban development to reduce travel demand and promote compact, transit-oriented cities. At the same time, research, innovation, and domestic manufacturing capabilities in clean transport technologies need to be strengthened to lower costs and build long-term competitiveness. Finally, demand-side management tools such as congestion pricing, parking regulation, and other travel-demand management measures should be deployed to discourage excessive private vehicle use and promote more sustainable mobility choices.

Conclusion

This study examined the transport sector's role in India's green growth pathway through a Revealed Comparative Advantage (RCA) analysis of transport-related greenhouse gas (GHG) emissions in relation to global trends over the period 1970–2023. The findings indicate that while India's relative environmental burden remained below the world benchmark until the mid-2000s, its transport-sector emissions intensity has since surpassed the global average. This shift coincides with accelerated economic growth, rapid motorisation, urban expansion, and rising aviation demand, highlighting the growing tension between mobility-led development and environmental sustainability. Road transport and aviation emerge as the principal contributors to this revealed comparative disadvantage, whereas advanced economies have begun to decouple transport emissions from economic growth.

The results underscore that continued reliance on fossil-fuel-intensive mobility pathways risks locking India into a high-emissions trajectory at a time when international shipping and aviation already pose additional global challenges. Achieving green growth in the transport and tourism ecosystem therefore requires a coordinated policy mix that combines rapid electrification of road transport, expansion and integration of low-carbon public transport and rail, demand management in urban mobility, and accelerated deployment of sustainable aviation fuels alongside operational efficiency improvements in aviation. Complementary measures - such as strengthened emission standards, pricing of carbon externalities, investment in clean infrastructure, and region-specific mitigation strategies informed by decentralised emission inventories - are essential to enable decoupling of transport emissions from economic growth. Overall, the study demonstrates that India's development and tourism-led mobility expansion need not be environmentally regressive if supported by timely technological transitions, robust regulatory frameworks, and behavioural shifts towards sustainable travel. Aligning transport decarbonisation with national climate commitments and long-term development goals is crucial for ensuring that future growth is both economically inclusive and environmentally resilient.

The findings that India's transport-sector emissions have exceeded the global benchmark (RCA > 1) since the mid-2000s underscore the need for the structural decarbonisation measures. Rapid electrification of public and commercial fleets, expansion of rail and low-carbon freight corridors, and integrated urban transit planning are essential to reduce fossil-fuel dependence. Regulatory standards should be complemented by market-based instruments such as carbon pricing, congestion charges, and parking reforms to address demand-side externalities. Institutional coordination across transport, energy, tourism, and urban governance bodies is critical to avoid fragmented implementation. Strengthening decentralized emission monitoring systems can support targeted mitigation strategies. Long-term progress also depends on investing in research and innovation in battery storage, sustainable aviation fuels, and smart mobility systems, alongside embedding sustainable transport education in higher learning. Finally, behavioural change is vital. Promoting public transport, shared mobility, and responsible travel practices will help align mobility expansion with climate commitments and prevent long-term carbon lock-in in India's growth trajectory.

Acknowledgments:

We acknowledge Emissions Database for Global Atmospheric Research - EDGAR as base of this study.

Credit Authorship Contribution Statement:

Syeeda Khatoon has been instrumental in conceptualization, laying down the Methodology, Writing – original draft and Supervision.
Syed Asghar Mehdi has been instrumental in Co-conceptualizing, Investigation, Project administration, Formal analysis, results and conclusions for the study.

Declaration of Competing Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Use of Generative AI and AI-Assisted Technologies

The authors declare that they have not used generative AI and AI-assisted technologies during the preparation of this work.

References

[1] Council for International Economic Understanding (2025), Aironomics 2025, Unlocking India's Blue Skies Economy, Bharat Climate Forum, New Delhi, Retrieved from: https://cieu.in/assetair/frontend/22052025%20Aironomics%202025%20Transport%20RT%20Issue%20Note.pdf

[2] Emissions Database for Global Atmospheric Research, EDGAR (2024). Community GHG Database (a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA). https://edgar.jrc.ec.europa.eu/report_2024

[3] European Union Aviation Safety Agency, EASA (2025). Aviation Environmental Impacts, Retrieved from: https://www.easa.europa.eu/en/domains/environment/eaer/aviation-environmental-impacts

[4] Irfan, U. (2018), Countries have forged a climate deal in Poland - despite Trump, Vox, Dec 16, 2018. Retrieved from: https://www.vox.com/energy-and-environment/2018/12/14/18139402/cop24-climate-change-katowice-poland

[5] Kamboj, Puneet, Ankur Malyan, Harsimran Kaur, Himani Jain and Vaibhav Chaturvedi. (2022). India Transport Energy Outlook. New Delhi: Council on Energy, Environment and Water (CEEW), Retrieved from: https://www.ceew.in/publications/india-transport-energy-use-carbon-emissions-and-decarbonisation

[6] Komen, R., Gerking, S., Folmer, H. (1997). Income and environmental R&D: empirical evidence from OECD countries. *Environment and Development Economics*, 2, 505–515, Cambridge University Press. Retrieved from: http://www.jstor.org/stable/44379191

[7] McConnell, K.E. (1997). Income and the demand for environmental quality, *Environment and Development Economics* 2, 383– 399, Cambridge University Press. Retrieved from: https://www.jstor.org/stable/44379184

[8] Pierre-Louis, K (2018). Greenhouse Gas Emissions Accelerate Like a 'Speeding Freight Train' in 2018, The New York Times, Dec. 5, 2018. Retrieved from: https://www.nytimes.com/2018/12/05/climate/greenhouse-gas-emissions-2018.html

[9] Ramachandra, T.V., Shwetmala (2009). Emissions from India's transport sector: Statewise synthesis, *Atmospheric Environment*, DOI: 10.1016/j.atmosenv.2009.07.015

[10] Ritchie, Hannah (2024). What share of global CO_2 emissions come from aviation?, Published online at OurWorldinData.org. Retrieved from: https://ourworldindata.org/global-aviation-emissions

[11] Saroha, Anshu (2025). India's Aviation Climate Agenda 2025: Status and Strategy, Impact and Policy Research Institute. Retrieved from https://www.impriindia.com/insights/indias-aviation-climate-2025-strategy/

[12] Shafik, N., (1994). Economic development and environmental quality: an econometric analysis. *Oxford Economic Papers* 46, 757– 773. DOI: https://doi.org/10.1093/oep/46.Supplement_1.757

[13] Sher F, Raore D, Klemeš JJ, Rafi-Ul-Shan PM, Khzouz M, Marintseva K, Razmkhah O, (2021). Unprecedented Impacts of Aviation Emissions on Global Environmental and Climate Change Scenario. Current Pollution Report. 2021; 7(4):549-564. DOI: https://doi.org/10.1007/s40726-021-00206-3

[14] Thummala, V. Hiremath, R.B. (2022). Green aviation in India: Airline's implementation for achieving sustainability, Cleaner and Responsible Consumption, Science Direct, Volume 7. DOI:https://doi.org/10.1016/j.clrc.2022.100082

[15] World Bank Data (2024). World Development Indicators, https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD# https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2023&locations=IN&start=1970&view=chart