NITI Aayog

SCENARIOS TOWARDS VIKSIT BHARAT AND NET ZERO

SECTORAL INSIGHTS: TRANSPORT

(VOL. 3)

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NITI Aayog

SCENARIOS TOWARDS
VIKSIT BHARAT AND NET ZERO

SECTORAL INSIGHTS: TRANSPORT

(VOL. 3)

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FOREWORD

As India aims to achieve a developed nation status by 2047, the VIKSIT BHARAT Vision needs close collaboration between all sectors of our economy. Energy is the life blood of any economy and transportation sector is a significant consumer of energy. Transportation accounts for 20% of the total energy consumed in 2025 and the absolute energy use is expected to rise to two to three times by 2047.

2. Unlike most developed nations where the subject of energy is housed in an omnibus Ministry, in India the governance of energy sector is split across multiple Ministries. The consumption of energy, of course, would necessarily be addressed across multiple Ministries. Transportation is a consumption sector which itself is the subject matter of several Ministries like Railways, Road and Highways, Civil Aviation and Shipping. The initiative taken by NITI Aayog to provide leadership in coordinating this subject which straddles across multiple Ministries, is laudable and a need of the hour.

3. The TORs of the study tasked the Committee to create scenarios for the transportation pathways leading up to 2047 with a view to assuring availability of transportation services to all citizens in an efficient manner. The study envisaged addressing the wider gamut of transportation sector, with multiple co-benefits including energy security, air quality and Make-in-India. The Committee included representatives from related Ministries, think-tanks and Industry Members, ably supported by the Energy and Climate Change vertical of NITI Aayog.

4. Indian economy is growing at a rapid rate and is also evolving into a modern, urban, technology-driven innovative economy. Past trends are of limited help in a rapidly growing sector for projecting the future. Transportation technologies are innovating at a fast rate and while we transition to electric mobility, even the hydrogen economy is now on the anvil. In light of these uncertainties, the Committee adopted a scenarios-based approach to project the pathways under two scenarios, namely Current Policy Scenario and Net-Zero Scenario. The investment plans of the automobile sector, envisaged policies of the related Ministries, transportation demands of the economy both for passengers and freight, were identified as the major drivers in the model. The India Energy Security Scenarios (IESS) 2047 which was first developed in 2012-14, by Planning Commission / NITI Aayog and has undergone various updates, has been the chosen model along with optimisation models like TIMES for generating the scenarios.

5. Finally, I take this opportunity to thank NITI Aayog for entrusting me with the responsibility of chairing this Committee. Shri Rajnath Ram, Adviser, Environment and Climate Change vertical, has been of immense help to the Committee. I must appreciate the stellar role of Shri Venugopal Mothkoor, Senior Specialist, who supported this Committee with the modelling results and Shri S.C. Gupta, former Director in PNGRB for his coordination work. The representatives of Ministries in the Committee, think-tanks and automobile sector, have all collaborated to make it possible to come to consensus, which is by all means, a very vital aspect of the present Report. I do hope the discussion contained in this Report will guide all the stakeholders in planning their actions towards attainment of the national goal of VIKSIT BHARAT.

(Dr. Anil Kumar Jain)

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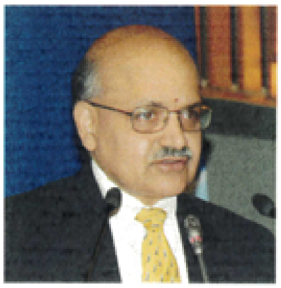

FOREWORD

The Transport sector is a crucial enabler of India's aspirations to be Viksit Bharat. Economic growth and rising incomes will lead to a significant growth in mobility, both for passengers and freight. This will also lead to growing energy demand.

Going forward, the Transport sector is at the intersection of an enormous transition in modal shift, technologies, and fuels. Several cities are strengthening public transport systems including metros and buses. The sector has seen a diversification of fuels from petrol and diesel to ethanol, Compressed Natural Gas, electricity, and hydrogen. A range of new technologies are emerging such as hybrids, plug in hybrid electric vehicles, electric vehicles, hydrogen-based vehicles. The sector is truly in a decisive transformation.

In this background, NITI Aayog undertook a detailed assessment of the Transport sector as part of the overall study on developing India's pathways to Viksit Bharat and Net Zero. The working group examined both passenger and freight segments. It assessed the importance of modal shift, clean technologies, and fuels.

The analysis suggests that there is significant potential to reduce energy demand by various strategies such as Transit-Oriented Development, adoption of public transportation enabled by last mile connectivity and greater use of clean fuels. At the same time, there is need for proper long-term planning. There is a big role for research and development by academia and industry collaborations. The report has developed pragmatic recommendations and is intended to serve as a strategic reference for policymakers, regulators, industry stakeholders, and investors.

I thank Dr. Anil Jain, Chairman, PNGRB, for providing leadership to the working group. I also thank all working group members for their guidance and support. I congratulate the NITI Aayog team led by Dr. Anshu Bharadwaj, Shri Rajnath Ram, Shri Venugopal Mothkoor, Dr. Anjali Jain, and Shri Nitin Bajpai, for their excellent efforts. This report will ensure that as India advances toward higher levels of economic prosperity, its transport system will evolve as a cornerstone of a sustainable, efficient, and self-reliant future.

Dated: 4th February, 2026

[B.V.R. Subrahmanyam]

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List of Abbreviations

AAM	Activity Analysis Module
ACC	Advanced Chemistry Cell
AMRUT	Atal Mission for Rejuvination and Urban Transformation
ASIF	Activity, Structure, Intensity, and Fuel
ATF	Aviation Turbine Fuel
ATJ	Alcohol-to-Jet
BaaS	Battery-as-a-Service
BEE	Bureau of Energy Efficiency
BPKMs	Billion Passenger-Kilometres
BRT	Bus Rapid Transit
BS	Bharat Stage
BTKMs	Billion Tonne-Kilometres
CAFE	Corporate Average Fuel Efficiency
CBG	Compressed Bio-Gas
CBO	CBG Blending Obligation
CGE	Computational General Equilibrium
CNG	Compressed Natural Gas
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPS	Current Policy Scenario
CV	Conventional Vehicle
DFC	Dedicated Freight Corridor
DPI	Digital Public Infrastructure
DRDO	Defence Research and Development Organisation
ELV	End-of-Life Vehicle
EPR	Extended Producer Responsibility
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FAR	Floor Area Ratio

FCV	Fuel Cell Vehicle
FO	Fuel Oil
FT / FT-SYN	Fischer-Tropsch (Synthesis)
GCAM	Global Change Analysis Model
GHG	Greenhouse Gas
GQ	Golden Quadrilateral
HCV	Heavy Commercial Vehicle
HDV	Heavy-Duty Vehicle
HEFA	Hydroprocessed Esters and Fatty Acids
HSD	High Speed Diesel
HSR	High-Speed Rail
ICAO	International Civil Aviation Organization
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
ICM	India Carbon Market
IEM	India Emission Model
IESS	Indian Energy Security Scenarios
INR	Indian Rupee
IR	Indian Railways
ITS	Intelligent Transport System
IUDX	India Urban Data Exchange
IWT	Inland Water Transport
LEAP	Low Emissions Analysis Platform
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MIDC	Modified Indian Driving Cycle
MMLP	Multi-Modal Logistics Park
MMT	Megatonne / Million Metric Tonnes
MTPA	Million Tonnes Per Annum
MoCA	Ministry of Civil Aviation
MoEFCC	Ministry of Environment, Forest & Climate Change
MoPNG	Ministry of Petroleum & Natural Gas
MoPSW	Ministry of Ports, Shipping & Waterways
MoRTH	Ministry of Road, Transport and Highways
MRO	Maintenance, Repair & Overhaul

MS	Motor Spirit (petrol)
$MtCO_2e$	Million tonnes of CO_2 equivalent
Mtoe	Million tonnes of oil equivalent
NDC	Nationally Determined Contribution
NITI	National Institution for Transforming India
NMT	Non-Motorised Transport
NUTP	National Urban Transport Policy
NZS	Net Zero Scenario
OMCs	Oil Marketing Companies
PASTA	Policy Ambition and Sustainable Transport Assessment
PLI	Production-Linked Incentive
PM E-DRIVE	PM Electric Drive Revolution in Innovative Vehicle Enhancement
PPP	Public-Private Partnership
PtL	Power-to-Liquid
PtX	Power-to-X
RE	Renewable Energy
RMI	Rocky Mountain Institute
RRTS	Regional Rapid Transit System
SAF	Sustainable Aviation Fuel
SATAT	Sustainable Alternative Towards Affordable Transportation
SEZ	Special Economic Zone
SIAM	Society of Indian Automobile Manufacturers
STUs	State Transport Undertakings
TOD	Transit-Oriented Development
TCO	Total Cost of Ownership
TIMES	The Integrated MARKAL EFOM System
UEI	Unified Energy Interface
UPI	Unified Payments Interface
VGF	Viability Gap Funding
WEF	World Economic Forum
WLTP	Worldwide Harmonised Light Vehicles Test Procedure
xEV	Electrified vehicles (generic term for all types of electric vehicles i.e., Battery EV, Strong Hybrid EV, Range Extender EV, Plug-in Hybrid EV)

Executive Summary

The transport sector is one of the key drivers of India's economy. It also contributes significantly to the country's energy use and emissions, accounting for 20% of final energy demand and around 10% of greenhouse gas (GHG) emissions in year 2020. As India urbanises rapidly and travel demand surges, the sector risks being locked into higher fuel imports, poorer air quality, and rising logistics costs. Decarbonising transport through modal shift, zero-emission vehicles (ZEVs), and clean fuels & technologies is therefore critical to meet India's Net Zero 2070 goal.

Modelling Approach

For this study on Net Zero pathways for the transport sector, NITI Aayog's Inter-Ministerial Working Group developed two robust modelling pathways to 2070. The modelling applies the Activity Structure Intensity Fuel (ASIF) framework through the tools including India Energy Security Scenarios (IESS) and The Integrated MARKAL-EFOM System (TIMES) to estimate transport demand and technology transition upto 2070. The models integrate data on modal share, vehicle stock, technology stack and fuel efficiency, while reflecting the impact of ongoing national programmes such as Dedicated Freight Corridors (DFCs), metro expansion, and rail modernisation. The analysis of energy demand to 2070 is based on two scenarios: a Current Policy Scenario (CPS) reflecting business-as-usual, and a Net Zero Scenario (NZS) aligned with India's 2070 target.

Deep decarbonisation is feasible, front-loaded, and visible in the comparative outcomes

By 2070, transport energy demand falls to about 200 million tonnes of oil equivalent (Mtoe) under Net Zero Scenario (NZS), around 40% lower than the 336 Mtoe projected under Current Policy Scenario (CPS). This decline stems from near-universal adoption of Zero-Emission Vehicles (ZEVs) in road transport, a structural shift towards public and shared transport, increased rail and waterways freight, and more compact, efficient urban development.

Fuel mix is decisively rebalanced from oil-heavy to clean fuels

Under Current Policy Scenario (CPS), petroleum accounts for majority of the 2070 transport energy mix. Under Net Zero Scenario (NZS), its share falls to around 21%, with demand met majorly through electricity, biofuels, and green hydrogen. Electricity's share more than doubles between 2050 and 2070, biofuels expand to about one-fourth, and hydrogen emerges as a major carrier for long-haul freight, shipping, and aviation. Natural gas plays a key role under CPS but the share is taken by Bio-CNG by 2070 in NZS.

Mobility structure shifts toward mass, shared, and rail transport

By 2070, public and shared modes account for around 60% of passenger trips under Net Zero Scenario (NZS), (vs 50% in (CPS). Passenger rail's share rises to 25% under NZS (from 20% in CPS), while freight rail expands to 30% (from 25% in CPS). Private car ownership stabilises around 200 vehicles per 1,000 people under NZS, compared to 250 under Current Policy Scenario (CPS).

Macro dividends are large and enduring

Net Zero Scenario (NZS) lowers oil imports and price-shock vulnerability, improves air quality and health gains, and seeds new clean-transport industries (batteries, chargers, electrolyzers and recycling), creating jobs and industrial capacity across manufacturing and services.

Indicator snapshot - Current Policy Scenario vs Net Zero Scenario

Table E1: Current Policy Scenario vs Net Zero Scenario – 2050 & 2070

Indicator		Current	Current Policy Scenario		Net Zero Scenario	
			2050	2070	2050	2070
Passenger Kilometres per Capita		3950	12200	14000	11000	12000
Tonne Kilometres per Capita		2920	8200	10000	6500	8000
Modal Share						
Passenger	Road	78%	73%	70%	69%	64%
	Metro	<1%	2%	2%	2%	3%
	Rail	17%	19%	20%	22%	25%
	Air	4%	7%	8%	7%	8%
Freight	Road	66%	67%	65%	63%	60%
	Rail	22%	24%	25%	27%	30%
	Air	<1%	<1%	<1%	<1%	<1%
	Waterways	8%	7%	7%	8%	8%
	Pipelines	3.60%	2%	2%	2%	2%
Road Transport	Public Share (Taxi, 3-Wheelers)	47%	49%	50%	54%	60%
Energy and Fuel Usage						
Overall Energy Demand (Mtoe)		137	335	307	250	192
Passenger Transport Energy Demand (Mtoe)		74	168	152	125	110
Freight Transport Energy Demand (Mtoe)		63	167	155	125	82

Petroleum use	86%	61%	46%	49%	21%
Electricity use	2%	14%	24%	19%	45%
Biofuels use (Ethanol, Biodiesel, Sustainable Aviation Fuel (SAF))	4%	7%	8%	13%	20%
Gas use (Natural gas/ CBG(Compressed Bio-Gas)/ GH2)	8%	18%	22%	17%	10%[i]
GH2 based ammonia & e-methanol for shipping	-	-	-	1%	4%
Vehicle Ownership (Cars per 1,000 Population)	32	170	250	130	200
Investment Requirement (2026–2070)*		USD 3.44 trillion		USD 4.3 trillion	

** Refer Report on Financing Needs (Vol. 9)*

Conclusion

Net Zero Scenario delivers a systemic transformation with lower total energy use, a predominantly clean fuel mix, and mobility patterns that ensure equal or better access with fewer private vehicles.

Key Challenges

While technically feasible, India's Net Zero transport pathway faces several systemic barriers that could raise transition costs, prolong petroleum dependence, and delay socio-economic gains. Public charging infrastructure remains sparse, around 17 chargers per million people, particularly for buses and trucks. High upfront EV costs and reliance on imported cells, critical minerals, and electronic components expose mobility to supply-chain risks. Road transport continues to dominate (78% of passengers, 66% of freight), while rail and waterways are underutilised due to connectivity and governance gaps. Fragmented institutional policies, and slow coordination on Zero-Emission Vehicles (ZEVs), Transit-Oriented Development (TOD), freight corridors, and clean-fuel policies, limits scalability and systemwide impact. Vehicle and battery recycling systems remain nascent, risking material losses and environmental harm as electrification scales.

Policy Suggestions / Levers

A. Accelerate ZEVs & Supporting Infrastructure

i. Adoption of Zero-Emission Vehicles (ZEVs) including Battery Electric Vehicles (BEVs), hydrogen based vehicles, Biofuels (Ethanol based Flex Fuel Vehicles (FFVs) and Compressed Bio-Gas (CBG) based vehicles) should be kept as key priority for the long term vision and accordingly fomalise segment-wise ZEV acceleration

i consists only clean fuels

through 2035 for two-/three-wheelers, passenger cars, buses, and trucks.

ii. Expand public and corridor-based charging and swapping infrastructure with safety and interoperability standards. Enforce EV-ready building codes, enable smart charging via metering, time-of-day pricing, and vehicle-to-grid (V2G) integration through the Unified Energy Interface (UEI).

iii. Prioritise high-utilisation fleets- buses, taxis, and logistics vehicles through aggregated procurement, Renewable Energy Services Company (RESCO) models, and corridor electrification. Strengthen domestic manufacturing of batteries, cells, and power electronics with Production Linked Incentive (PLI) backed supply chains to secure competitiveness and local value creation.

The transition strategy should begin with the phased elimination of polluting diesel vehicles and the adoption of lower-emission technologies such as CNG, hybrids, and electric vehicles. The subsequent phase should advance with the use of biofuels through FFVs, high Bio-CNG blends, and hybrid FFV models, alongside continued growth in EV adoption. The final phase should ensure full deployment of Zero-Emission Vehicles (ZEVs) such as EVs, hydrogen based vehicles, FFVs, and CBG-based models. To drive this transition, set segment-specific targets with clear timelines and compliance mechanisms across all vehicle segments.

B. Promote Modal Rebalancing and Freight Efficiency

i. Expand metro, Regional Rapid Transit System (RRTS), and bus networks with strong last-mile connectivity, and formalised paratransit integration.

ii. Encourage Transit-Oriented Development (TOD) and premium bus services.

iii. Shift freight to cleaner modes by achieving rail targets unit clarity-MMT, expanding inland waterways, coastal shipping and multimodal logistic parks (MMLPs), supported by Dedicated Freight Corridors (DFCs) and seamless trans-shipment.

iv. Use congestion and parking pricing, alongside safe walking and cycling networks, to reduce dependence on private vehicles and road freight.

C. Advancing Clean-Fuel Diversity and Decarbonising Aviation and Shipping

i. Scale sustainable biofuels and Sustainable Aviation Fuel (SAF) production with blending infrastructure for ethanol, biodiesel, and Compressed Bio-Gas (CBG) under clear sustainability standards.

ii. Develop a national roadmap for green hydrogen and e-fuels, focusing on heavy-duty transport, shipping, and aviation.

iii. Promote methanol, ammonia, and synthetic fuels for hard-to-electrify segments.

iv. Future-proof gas and petroleum pipeline networks to be hydrogen- and biofuel-compatible, integrate CBG into city gas distribution and explore slurry pipelines for bulk materials transportation.

D. Strengthening Governance, Circularity, and Financing

i. Establish Unified Metropolitan Transport Authorities (UMTAs) in major cities with Digital Public Infrastructure (DPI) and open-data systems like Unified Energy Interface (UEI) and IUDX (India Urban Data Exchange) for coordination and transparency.
ii. Leverage the India Carbon Market (ICM) to finance low-carbon mobility.
iii. Promote vehicle and battery circularity through state-level End-of-Life Vehicles (ELV) policies, PPP-based scrappage facilities, and traceable recycling systems (e.g. 'Battery Aadhaar').
iv. Raise efficiency and performance through Corporate Average Fuel Efficiency (CAFE) norms, Bharat Stage standards, lightweight design, and strict maintenance enforcement to ensure technology-neutral competition.

Investment Needs and Co-benefits

Implementing the Net Zero pathway requires about USD 4.3 trillion in cumulative investment till 2070, around 25% higher than the USD 3.44 trillion under Current Policy pathway. This additional investment, however, is a strategic opportunity than a cost burden. It yields enduring benefits through lower fuel imports, improved air quality and health outcomes, greater energy security, and robust industrial and employment growth in batteries, charging, hydrogen, and recycling. Early investment in electrification, biofuels, and hydrogen insulates India from global fuel volatility and positions the country as a global leader in clean transport technology.

Way Forward / Strategic Priorities

The next decade will determine whether India's transport transition achieves its full potential. Turning the Net Zero pathway into a delivery plan requires coordinated action across government, industry, and finance. Clear targets on Zero-Emission Vehicles (ZEVs) and clean-fuel penetration for 2025–2035, backed by funded central and state plans, can create investment certainty. Rapid deployment of charging and swapping networks, hydrogen pilots for buses and freight, and the expansion of DFCs, MMLPs, and waterways will be pivotal. Further, supportive policies should be adopted to create an enabling ecosystem, including charging infrastructure and CNG–CBG synchronisation through pipeline infrastructure. Domestic supply chains for EVs, fuel cells, and hydrogen systems underpinned by Extended Producer Responsibility (EPR) and recycling frameworks will build resilience and circularity. Finally, unified governance through UMTAs, DPI, and UEI/IUDX, combined with milestone reviews in 2030, 2035, and 2047, will ensure accountability and adaptive course correction.

1

INTRODUCTION AND CONTEXT

1

Introduction and Context

Introduction: A Strategic Imperative

India stands at a critical juncture in its development, marked by rapid urbanization, economic expansion, and rising aspirations for mobility and logistics services. The transport sector plays a foundational role in enabling this transformation, serving as a catalyst for regional integration, industrial competitiveness, and social inclusion. Given India's vast geography, spanning 3.28 million square kilometres and a population of over 1.4 billion, mobility is not merely a logistical requirement but a strategic necessity.

Mobility is both a barometer and a driver of economic development. The relationship between per capita passenger kilometres (PKMs) and prosperity is evident across global economies: advanced nations such as Germany, Japan, and the United Kingdom consistently register per capita PKM levels exceeding 11,000, reflecting the strong correlation between mobility demand and GDP per capita (Figure 1.1). This pattern illustrates how higher incomes enable greater travel capacity and vice versa. In contrast, India in 2023 recorded an average annual travel of 4,273 km per capita annually (up from 3,483 km in 2000). While this figure is modest in global terms, it represents a significant cumulative national footprint due to the scale of India's population, already surpassing many developed countries in aggregate mobility.

Efficient mobility systems expand access to education, employment, and markets. High PKM levels also correlate with productivity, urban efficiency, and reduced regional disparities.

Mobility, thus, is not just an economic service, it is the circulatory system of national growth. As of 2022–23, the transport sector accounts for about 4.5% of India's Gross Value Added.[1]

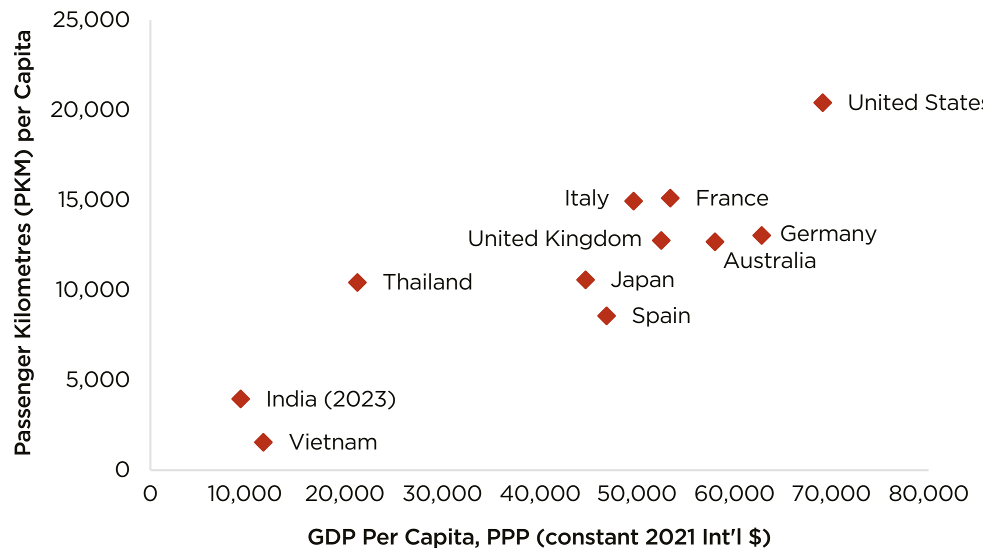


Figure 1.1: Global comparison of GDP/capita vs Passenger Kilometres (PKM) per capita

Source: World Bank, OECD[2]

1.1 A Decade of Growth (2014–2024)

India's transport sector witnessed significant progress in the last 10 years:

- **Railways:** Over 31,000 km of new tracks and 45,000 route km were electrified. The Dedicated Freight Corridors (DFCs) are 90% operational and have cut transit times by up to 40%. Passenger services were boosted with 68 Vande Bharat trains and modernisation of 1,000 Amrit stations. In addition, 77 Gati Shakti cargo terminals enhanced freight operations.[3]

- **Roadways**: The road network expanded to 6.7 million km. National Highways grew by 60% from 91,287 km in 2014 to 146,145 km in 2023. The pace of highway construction also increased by 143% to 28.3 km/day.[4] Supported by the Bharatmala Pariyojana, the road freight market crossed USD 150 billion.

- **Rural Access**: PM Gram Sadak Yojana connected 1,63,000 habitations, improving last-mile connectivity and boosting non-farm incomes.[5]

- **Ports and Shipping**: Under Sagarmala, cargo capacity rose from 581 million metric tonnes (MMT) to 855 MMT and container traffic went from 7.9 million twenty-foot equivalent unit (TEUs) to 13.5 million TEUs.[6] Major port revenues doubled to INR 24,203 crore in FY 2024-25.

- **Aviation**: Passenger volumes rose from 10.4 crore to 22 crore.[7] UDAN (Ude Desh ka Aam Nagrik) operationalised 619 routes and 88 airports.[8] Air cargo reached

8 MMT with 80 airports run on 100% renewable energy. In November 2024, India recorded a daily peak of five lakh domestic passengers.[9]

- **Pipelines**: The operational natural gas pipeline network has expanded from about 15,340 km in 2014 to roughly 25,000 km by 2024, with a further 10,000 km under construction. Over the same period, crude oil and petroleum product pipelines have also grown to around 10,500 km and 24,000 km respectively, making pipelines the dominant mode for long-distance liquid fuel transport.[10] Further, India undertook various policy interventions such as "One Nation, One Grid", unified transportation tariff, etc, to improve logistics efficiency of the network

1.2 Modal Composition of Mobility

Despite efforts toward multimodality, as of 2025, India's transport mix currently remains significantly skewed in favour of road transport. However, with continued focus on enhancing multimodality, a growing shift from road to other efficient modes is envisaged.

- **Passenger traffic**: Roads account for ~78%, rail ~17%, air 4%, and metro accounts for 1% of all traffic.
- **Freight traffic**: Roadways carry 66%, railways 22%, waterways 8%, pipelines 4%, and air only 0.06% of all freight traffic in the country.

This imbalance results in higher energy use, logistical costs, and emissions, particularly compared to more efficient and sustainable modes like rail and inland waterways. For context, while waterways account for ~25% of freight movement in China, in India it is only ~8%. Meanwhile, in the EU overall, maritime freight accounts for more than two-thirds (67.4%) of freight transport tonne-kilometres.[11]

India can correct this imbalance by leveraging its underutilised natural transport assets such as its 7,517 km coastline and 14,500 km of navigable waterways. Programmes like Sagarmala seek to modernise ports and coastal infrastructure to reduce logistics costs. The upcoming Vadhvan Port in Palghar, Maharashtra, for example, is expected to cut freight costs by 25% for Northern and Western India, while decongesting the Jawaharlal Nehru Port (JNPT) in Raigad. The Eastern Waterways Grid, which links Kolkata with Myanmar, is also creating new corridors for the North-East.

Strategically linking mineral-rich states (like Chhattisgarh, Odisha, and Jharkhand) and agriculturally productive regions (such as Uttar Pradesh, Punjab, and Madhya Pradesh) by industrial corridors and ports through road, rail, pipelines, and waterways can catalyse new growth zones. These include special economic zones (SEZs), inland logistics hubs, and rural manufacturing clusters, all of which are critical to correcting regional imbalances and achieving equitable growth.

Given the evolving economic landscape and rising mobility demands, the path forward lies in leapfrogging conventional, siloed transport planning. India must craft a future-ready paradigm that is multimodal, clean, inclusive, and digitally enabled, tapping all modes efficiently while reducing overreliance on roads.

1.3 The Dual Imperative: Economic Growth and Environmental Stewardship

India's expanding mobility should sit at the intersection of two major national goals: rapid economic development and environmental sustainability. Below is a snapshot of the current scenario:

a. **Lagging Mobility Metrics Amidst Rising Aspirations**: India's passenger kilometres and tonne kilometres are rising but still lag behind global benchmarks. Heavy reliance on private vehicles due to inadequate public transport leads to congestion, increased fuel consumption, and inequality. Road freight dominates despite being costlier and more polluting.

b. **Infrastructure Modernization**: Programs like Bharatmala, Sagarmala, and Gati Shakti are modernising India's multimodal transport grid with new highways, metro systems, electric buses, and logistics corridors.

c. **Hidden Costs**: Emissions from the transport sector account for about 10% of overall GHG emissions in the country in 2020, with road transport contributing around 90% of the transport sector emissions. Rising motorisation brings with it air pollution, traffic congestion, and higher crude oil imports that are already over 87% of total supply. Electric mobility brings its own dependencies, especially on imported lithium and battery components, and India's coal-heavy power grid adds further complexity.

d. **Urbanisation and Opportunity to Rethink Travel**: With urbanisation projected to rise from the current 36% to over 65% by 2070, cities must evolve through Transit-Oriented Development (TOD) that is compact, connected urban zones that reduce the need to travel long distances. Similarly, aligning industrial hubs with rail and port hubs can cut freight distances and energy use.

e. **Coordinated Governance**: India's transport governance involves numerous specialised ministries. Enhanced coordination among roadways, railways, ports, aviation, power, and urban planning bodies is essential to create integrated, efficient, and sustainable mobility systems.

f. **Manufacturing and Mobility are Closely Interlinked:** Manufacturing drives demand for vehicles, fuels, and logistics, while requiring an efficient freight systems to stay competitive. India's logistics costs are quoted at 13–14% of GDP, versus 8–10% in China and the EU.[12] The first official assessment now estimates logistics costs at 7.97% of GDP (₹24.01 lakh crore) in 2023–24, broadly aligning India with advanced-economy benchmarks. PM Gati Shakti and National Logistics Policy (2022) aim to consolidate and deepen these gains by keeping logistics costs comparable to global benchmarks i.e., 8% of GDP while improving service quality and multimodal connectivity across road, rail, ports, and waterways[13]. Given that the automobile industry contributes about 7.1% to the national GDP and nearly half of manufacturing GDP, efficient and low-carbon logistics will be critical as e-commerce, industrial output, and urbanisation sharply increase freight demand.

India's Singularity: Challenges & Contextual Realities

- **High Population Density and Urban Congestion**: Unlike many developed nations, India must decarbonise while managing high urban density, informal transit systems, and affordability constraints.
- **Two-Wheeler Dominance**: India's mobility is uniquely two-wheeler heavy - posing both a challenge for electrification and an opportunity for rapid EV penetration in cost-sensitive segments.
- **Transition Risks**: The shift from oil to critical minerals (e.g., lithium, cobalt) introduces new dependencies. India must invest in battery recycling, alternative chemistries, and secure supply chains.
- **Regional Disparities**: The North-East, Himalayan, and tribal regions face unique connectivity and terrain challenges, requiring tailored, resilient, and inclusive mobility solutions.
- **Behavioural and Cultural Factors**: Vehicle ownership is often aspirational. Shifting mindsets toward shared, public and Non-Motorised Transport (NMT) will require sustained behavioural nudges and urban design reforms.

1.4 Addressing Disparities

Disparities in access to transport services persist across geographies and demographics, often limiting participation in the growth story. National averages on transport performance often mask deep-rooted disparities in access, affordability, and opportunity — especially in rural areas, socio-economically disadvantaged groups, and remote geographies. Bridging these mobility gaps is a prerequisite for achieving resilient and sustainable transport systems.

Beneath national averages lie sharp disparities:

- **Access to Public Transport**: Low-income households, especially in rural and peri-urban areas, lack access to affordable transport.
- **Geographic Barriers**: India's north-eastern and Himalayan regions face unique topographic and infrastructure development challenges.[14]
- **Aspirational Mobility:** With India's low car ownership of around 33 cars per 1,000 people, cars are still an aspirational commodity for most households. Bridging affordability barriers for marginal segments is therefore critical, particularly as first-time buyers look to upgrade from two-wheelers. The opportunity lies in deliberately promoting smaller, affordable cars for these first-time buyers, which can provide significant co-benefits in terms of higher fuel efficiency, lower emissions, and reduced pressure on traffic and parking.

A truly transformative mobility vision must be rooted in equity, ensuring that no region or group is left behind. For example, in Bhubaneswar, the Mo Bus and complementary Mo E-Ride electric rickshaw feeder services, designed as part of an integrated, gender-responsive transport network, significantly expanded safe and affordable mobility for women and transgender commuters.[15] An inclusive transport strategy, thus, must ensure affordability, accessibility, and coverage for all communities.

Achieving Net Zero by 2070 is a formidable task, but with strategic planning, international collaboration, affordable finance, and broad participation from government, industry, and communities, India's transport sector transition can set a benchmark for emerging economies.

1.5 Institutional Mechanism: Inter-Ministerial Working Group on Transport

The Inter-Ministerial Working Group (IMWG) on Transport is among the several Inter-Ministerial WGs constituted by NITI Aayog to chart out a development vision aligned with India's commitment to become a Net Zero Emission nation by 2070.

This effort involves multiple working groups tasked with assessing long-term transition pathways across key domains, macroeconomic aspects of transition, sectoral transformations (transport, power, industry, buildings, and agriculture), climate finance (mitigation and adaptation), critical minerals, R&D and manufacturing, and the social implications of transition.

The Inter-Ministerial Working Group on Transport has been mandated to assess the current state of India's mobility ecosystem, spanning passenger and freight demand, modal composition, technological maturity and to recommend a comprehensive transition pathway through 2070.

This vision must balance growth with environmental responsibility, while ensuring that mobility remains accessible, affordable, and equitable. The composition of the committee was as follows:

Chaired by: Dr. Anil Jain, Chairperson, Petroleum and Natural Gas Regulatory Board (PNGRB)

Composition:

- **Representatives from Ministries/Departments:** Road Transport & Highways, Railways, Civil Aviation, Power, New & Renewable Energy, Petroleum & Natural Gas, Ports Shipping & Waterways, Heavy Industry, MSME, and Bureau of Energy Efficiency (BEE)
- **Industry and knowledge partners:** Society of Indian Automobile Manufacturers (SIAM), ICCT, RMI India, and TERI

To achieve this, the Working Group has:

- Analysed transport demand driven by GDP growth across passenger and freight segments
- Examined the impact of modal shifts (private to public transport/ motorised to non-motorised, etc.) on emissions.
- Recommended pathways for accelerated adoption of clean fuels & technologies (EVs, hybrids, biofuels, hydrogen, etc.)
- Examined scope and policies for shifting to energy-efficient modes such as rail and waterways
- Examined the role of behavioural nudges in accelerating shift to sustainable mobility solutions.
- Explored financing instruments and incentive structures to scale green transport infrastructure

2

TRANSPORT SECTOR: SCALE, STRUCTURE & GROWTH DRIVERS

Transport Sector: Scale, Structure & Growth Drivers

2

Transport is the backbone of India's growth story: connecting workers to jobs, firms to markets, and regions to each other at unprecedented scale. Every additional highway lane, metro corridor, freight train and flight route has helped compress distance and time, supporting economic expansion, urbanisation and rising incomes. Yet this very success has also driven rapid growth in energy use and emissions. As India prepares for the next phase of development, understanding the scale, structure and growth drivers of its transport sector is essential: it reveals where demand is coming from, how different modes share the load, and which policy, technology and investment choices can steer this engine of growth onto a low-carbon path.

2.1 Energy, Emissions and Infrastructure Investment

Globally, emissions from the transportation sector, as well as its proportion of total energy use, have steadily increased over the past several decades. This sector accounts for almost 23% of global CO_2[16]. In India, the transport sector accounted for 10% of the total GHG emissions in 2020, while it contributed to 20% of final energy use.

2.1.1 Infrastructure Investment

As India's economy continues to grow rapidly, the demand for logistics and transportation infrastructure will rise, opening opportunities for investments in efficient and cost-effective solutions. The current high cost of logistics underscores the potential for transformative investments in the sector. Over the years, India has scaled up public investment in transport infrastructure, supporting projects like the Golden Quadrilateral, Dedicated Freight Corridors, and Mass Rapid Transport System to enhance connectivity and efficiency. Significant investments have also been directed toward railways, aviation, and waterways, reflecting the government's commitment to a multi-modal transportation approach (Figure 2.1).

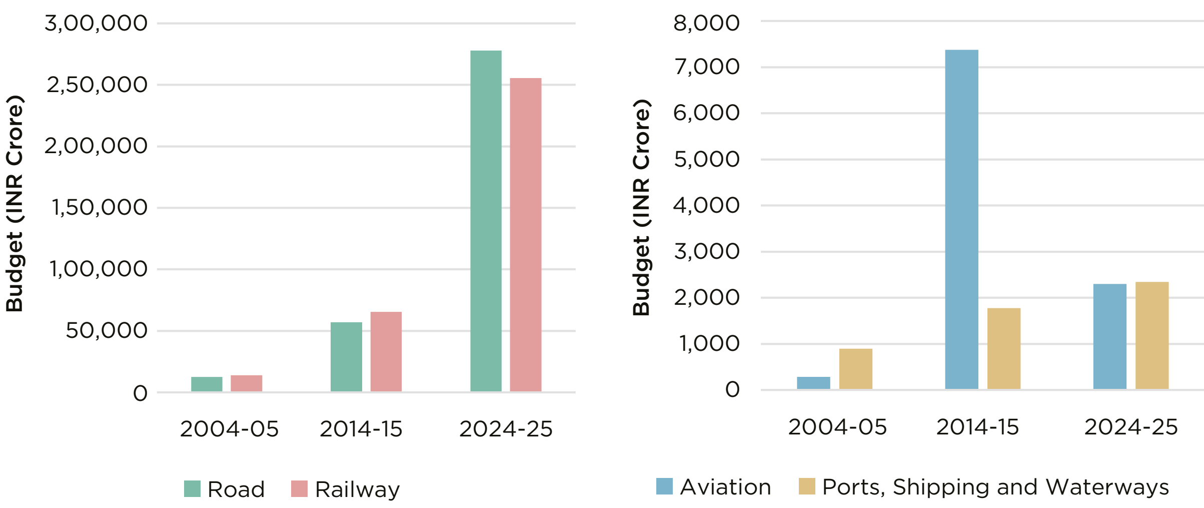


Figure 2.1: Growth in investments in public sector from 2004 to 2024 for roads, railways, waterways and aviation

Source: *Union Budget*[17]

Unlocking Scale: The Role of Public-Private Partnerships in India's Transport Transformation

Transforming India's transport through metro expansion, logistics corridors, expressways, multimodal parks, and clean mobility systems demand sustained, long-term capital flows that far exceed public budgets.

This necessitates options such as Public-Private Partnerships (PPPs) that offer a catalytic pathway to blend public intent with private investment and innovation, ensuring timely execution, cost efficiency, and lifecycle asset management. Delhi, Mumbai, Hyderabad, and Bengaluru airports are some examples of successful PPP models in the aviation sector.

PPPs enable de-risked, high-impact investments in EV infrastructure, smart urban transit, and climate-resilient logistics, which are critical components of India's Net Zero emissions and goal of a Viksit Bharat by 2047.

To successfully execute PPP models, India should continue to foster transparent regulatory regimes, bankable project pipelines, and fair risk allocation frameworks that attract institutional and private capital at scale.

Golden Quadrilateral: Transforming India's Mobility and Growth

The 2001 National Highways Development Project, particularly the Golden Quadrilateral (GQ) marked a pivotal moment in Indian mobility by slashing travel times, cutting transport costs, and unlocking economic momentum. Districts within 10 km of the GQ network saw manufacturing output surge by nearly 49% in the years following its implementation, and substantial annual savings were achieved in fuel and vehicle maintenance. These infrastructure gains spurred trade and GDP growth.[18] By 2020, vehicle ownership rose to 242 per 1,000 as GDP per capita surpassed INR 1,00,000. The 2017 Bharatmala Pariyojana continues this momentum, targeting 65,000 km of road corridors to enhance connectivity, reduce logistics costs, and support economic expansion.[19]

Transit-Oriented Development

Transit-Oriented Development (TOD) is a sustainable urban planning approach that integrates land use and public transportation to create compact, walkable communities. Centred around high-capacity transit systems such as suburban railway system, circular rail, metro, light rail, or bus rapid transit, TOD promotes mixed-use development, reducing dependency on private vehicles while enhancing accessibility and liveability.

While GDP growth drives transport infrastructure, unplanned expansion exacerbates congestion and pollution. TOD aligns growth with mobility planning, as seen in metro projects in Delhi, Bengaluru, and Mumbai. It promotes compact, walkable cities that cut emissions and boost productivity. Satellite cities like Navi Mumbai and Noida are seen to ease urban pressure with planned layouts, green infrastructure, and strong transit links, supporting balanced and sustainable regional growth.

The USA Experience

India's challenges are not unique. Countries like the United States faced similar issues during periods of rapid economic growth.

- Transit-Oriented Development (TOD) in cities like Denver and Portland successfully integrated land-use planning with transportation, promoting mixed-use development around transit hubs. This reduced reliance on private vehicles, curtailed emissions, and fostered urban growth in sustainable ways.

Japan: Efficient Urban Planning and Rail Networks

- Japan's cities, such as Tokyo and Osaka, exemplify the success of TOD. Their dense urban centres are organised around extensive rail networks such as the Tokyo Metro and Japan Railways. Mixed-use developments around stations integrate residential, commercial, and recreational spaces, significantly reducing dependence on private vehicles.

India can draw valuable lessons from such examples to devise actionable policies tailored to its unique demographic and economic contexts.

2.2 Transport Demand

In 2025, total passenger travel was estimated at 6,410 billion passenger-kilometres (BPKMs), with road transport accounting for 78%. Rail followed at 17%, while air travel and metro systems contributed 4% and 1%, respectively.

Freight transport too displayed a similar trend, with a total of 4,661 BTKMs of which roadways carried 66% of the freight, rail carried 22%, and waterways 8%. Pipelines accounted for 3.6%, while air freight remained negligible at 0.06% of the total. These figures indicate that a large share of passenger and freight movement currently takes place through road-based transport, while railways continue to play a significant and dependable role in the nation's transport ecosystem. Rail remains the largest mode of public transport and a crucial backbone for long-distance and bulk freight movement. The potential of waterways and pipelines in the transport mix is unrealised. Figure 2.2 highlights that road transport remains the dominant mode globally. Countries with stronger rail and waterways share long-term efficiency of diversified modal system. India should aspire to strengthen rail and waterways to reduce over-dependence on road transport.

Multi-Modal Transport Network Initiative

The PM Gati Shakti initiative is the cornerstone of India's efforts to advance its multimodal transportation network to enhance logistics efficiency and support economic growth. Under the initiative, 434 projects have been identified, totalling an investment of INR 11.17 lakh crore.

This initiative aims to bolster multimodal connectivity and streamline logistics operations. The development of Multimodal Logistics Parks (MMLPs) is central to this strategy. These large-scale facilities integrate transportation by road, rail, air, and sea into unified hubs, facilitating efficient cargo movement. The first MMLP is being developed in Jogighopa, Assam, to serve as a key logistics centre for India's northeastern region and neighbouring countries.

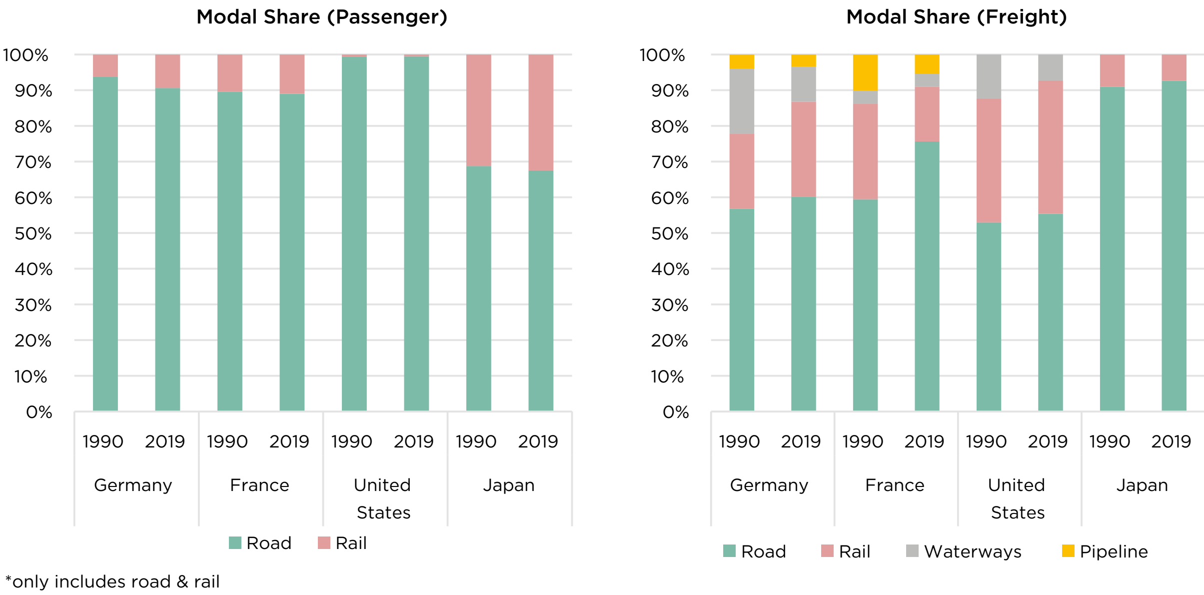


Figure 2.2: Modal share of passenger and freight transport for different countries

Source- OECD[20]

2.2.1 Modes of Transportation

Road

Road transport is India's dominant mode for passenger and freight movement, supported by over 63 lakh km of roads in 2022, including approximately 1.46 lakh kilometres of National Highways[21]. India has one of the world's largest road networks in the world.

India had 391.07 million registered vehicles as of 31 March 2025, of which 356.22 million (91.1%) were personal vehicles and 34.86 million (8.9%) were commercial vehicles. Total registrations have increased 15 times since 1990; driven by sustained economic growth, rapid urbanization, population increase, improved roads and infrastructure, expansion of the automobile industry, and easier access to vehicle finance, total registrations have risen nearly 15-fold since 1991. Two-wheelers dominate the composition, rising from 14.2 million registrations in 1991 to 286.75 million in 2025, while cars, jeeps, and taxis grew from 2.95 million to 56.3 million over the same period (Figure 2.3).[22]

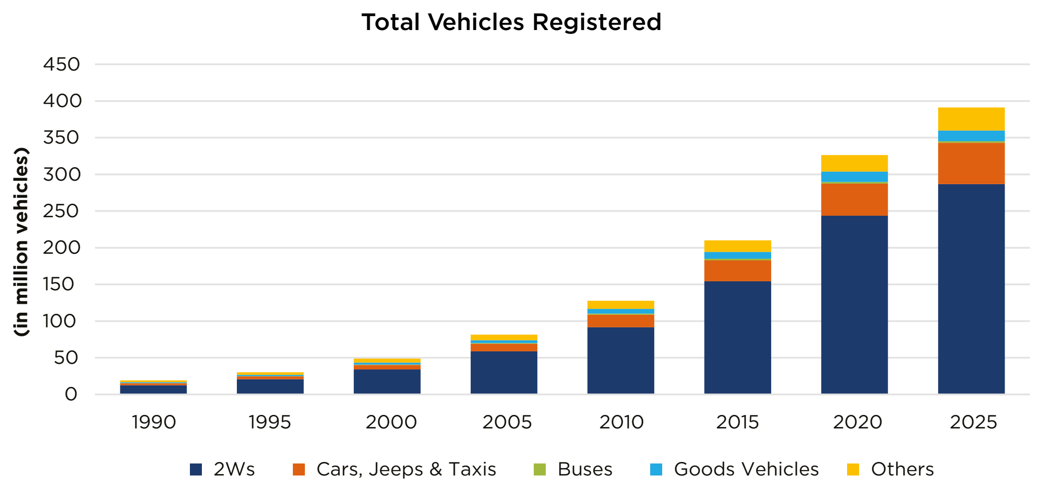


Figure 2.3: Increasing vehicle ownership since 1990

Source: *Vahan Portal 2025 & Road Statistics 2019-20*

Figure 2.4 shows that as India's GDP per capita has risen over time, the number of vehicles per 1,000 people has also increased, indicating a clear link between economic growth, higher incomes, and greater motorization.

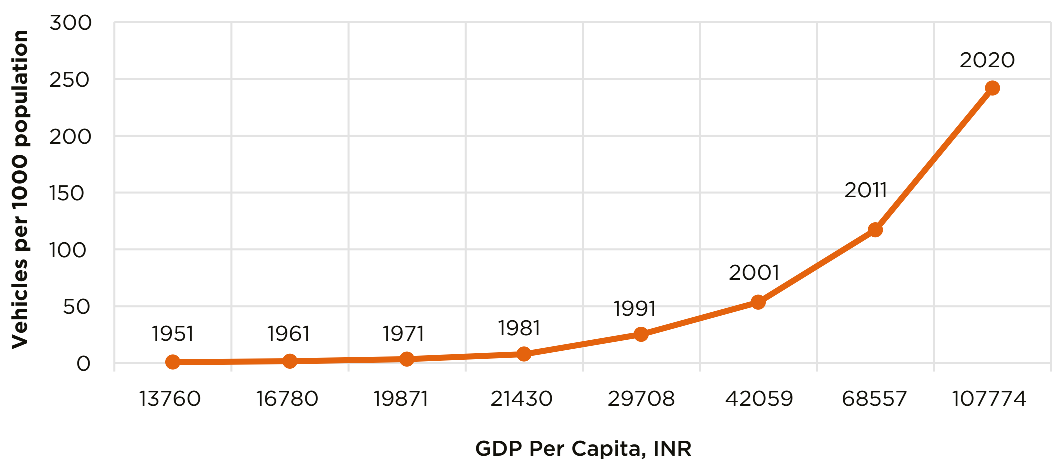


Figure 2.4: Vehicles per 1000 population vis-a-vis GDP/capita for India

Source: *Road Statistics 2019-20 and India's population projections based on MoHFW till 2036*

As shown in Figure 2.5, vehicle ownership remains the highest in advanced economies, with New Zealand and the United States exceeding 860 vehicles per 1,000 people, and countries like Germany, Japan, and Canada reporting between 600 and 700 vehicles per 1,000 people. These levels reflect high incomes, extensive road infrastructure, and decades of car-centric urban development along with rising emissions. India, therefore has an opportunity to chart a different path by prioritising public transport, e-mobility, and compact urban development, achieving its mobility goals while curbing pollution, emissions, and energy demand.

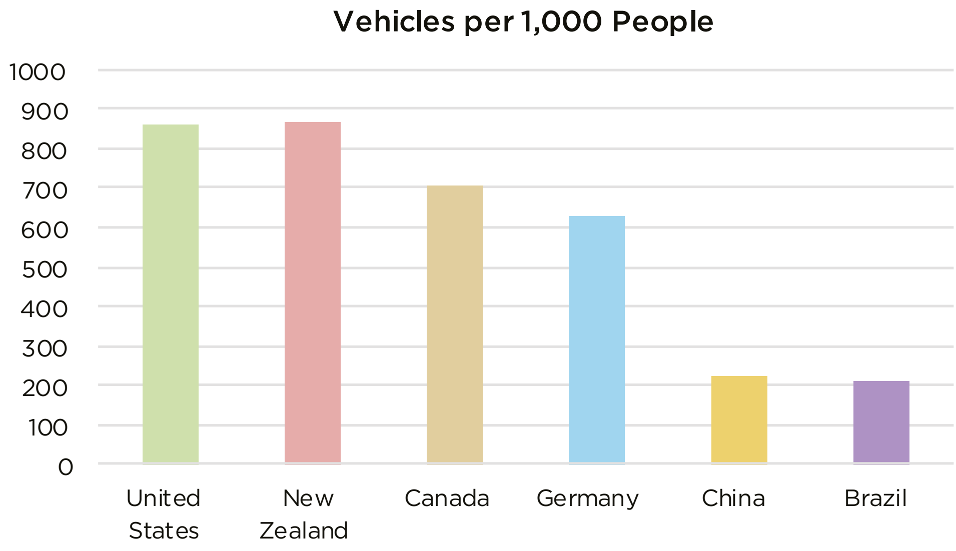


Figure 2.5: Representation of vehicles per 1000 population for developed countries

Source: *OICA – International Organisation of Motor Vehicle Manufacturers. Retrieved November 28, 2025, from https://oica.net/*[23]

Fuel mix in road transport: Road transport in India is heavily dependent on fossil fuels–primarily petrol and diesel, which accounts for more than 80% of the transport sector's energy consumption. India's focus on reducing fossil dependence has led to an increased uptake of alternative clean fuels and technologies such as, bio-CNG, ethanol, biodiesel and, hybrids and EVs. EV adoption is growing rapidly, especially in the 2W and 3W segments, with policies supporting battery swapping, incentives under Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme (now PM E-DRIVE scheme), and state EV policies. For freight, LNG and CNG along with CBG to play a key role in reducing emissions, with green hydrogen emerging as a long-term zero-emission alternative for heavy-duty vehicles.

Railways

Rail is the most energy-efficient mode for both freight and passenger transport. Between 2013-14 and 2023-24, rolling stock grew from about 3.3 lakh to 4.35 lakh units, while the share of electrified broad-gauge routes jumped from 33% to 90%, sharply reducing diesel dependence. Aiming to become a Net Zero carbon emitter by 2030 through full electrification, renewable energy integration, and energy-efficient operations, Indian Railways is also modernising via initiatives such as Vande Bharat trains and Dedicated Freight Corridors (DFCs), enhancing speed, capacity, and efficiency and encouraging a modal shift from road to rail[24]. Additionally, pilot projects on hydrogen fuel cell-based trains and battery-powered locomotives are underway as part of Indian Railways' Net Zero ambitions. While India invests across all transport sectors, rail receives the largest share of public funds due to limited private participation.

Dedicated Freight Corridors

India's High Density and Highly Utilised Networks (HDN & HUN), covering 41% of route length and carrying 81% of freight, face severe congestion as mixed traffic slows freight trains by nearly half. To address this, the Dedicated Freight Corridors (DFCs), approved in 2006, were developed to enhance freight efficiency. With 96.4% of the planned 2,843 km network now complete (1,337 km Eastern and 1,506 km Western)[25], DFCs enable uninterrupted freight movement at around 40 kmph. By December 2022, freight speeds averaged 40.7 kmph on DFCs, compared to 18.8 kmph on the conventional network. Offering higher capacity and double-stack container trains, DFCs improve port connectivity and promote a shift from road to rail, significantly enhancing logistics efficiency across India.

Metro

The 2017 Metro Rail Policy enables Central funding for viable, state-proposed metro projects, helping India build an operational metro network of over 1,000 km by January 2025[26], one of the largest globally. Metros are easing urban congestion by linking key demand centres with airports and railway stations. For instance, an IIT-Bombay study of Mumbai Metro found average time savings of 26 minutes per trip, shifting departure patterns and freeing up road space during peak hours. Moreover, the Mumbai Metropolitan Region Development Authority (MMRDA) projects that congestion in Mumbai will shrink from 137% in 2017 to 33% by 2031 as metro reach grows.[27]

High Speed Rail (HSR) Potential: Mumbai-Ahmedabad High Speed Rail (MAHSR) Project

The Mumbai-Ahmedabad High Speed Rail (MAHSR) Project (508 km) is under execution with technical and financial assistance from Government of Japan. The Project is passing through the States of Gujarat, Maharashtra and Union Territory of Dadra & Nagar Haveli with 12 stations planned at Mumbai, Thane, Virar, Boisar, Vapi, Billimora, Surat, Bharuch, Vadodara, Anand, Ahmedabad and Sabarmati. The Gujarat portion of the corridor between Vapi and Sabarmati is planned to be completed by Dec, 2027. The entire project (Maharashtra to Sabarmati section) is expected to be completed by Dec, 2029. An overall Physical progress of 54.51% has been achieved upto 30/09/2025.

In order to expand the HSR network in India beyond MAHSR corridor, Detailed Project Report (DPRs) for seven corridors have been prepared by National High Speed Rail Corporation Limited (NHSRCL) which are under examination.

Aviation

India is the world's **third-largest domestic aviation market** with rapid growth in airports (74 to 148), aircraft (448 to 674), and domestic passengers (85.2 to 136 million) between 2014-15 and 2022-23[28, 29, 30]. Domestic traffic surged 61.6% in 2022-23 after a sharp drop during the period 2020-21[31], as illustrated in Figure 2.6. In 2019, domestic aviation had a passenger load factor of 90%, a significant rise from the early 2000s, when the load factor sometimes dropped to 50%[32].

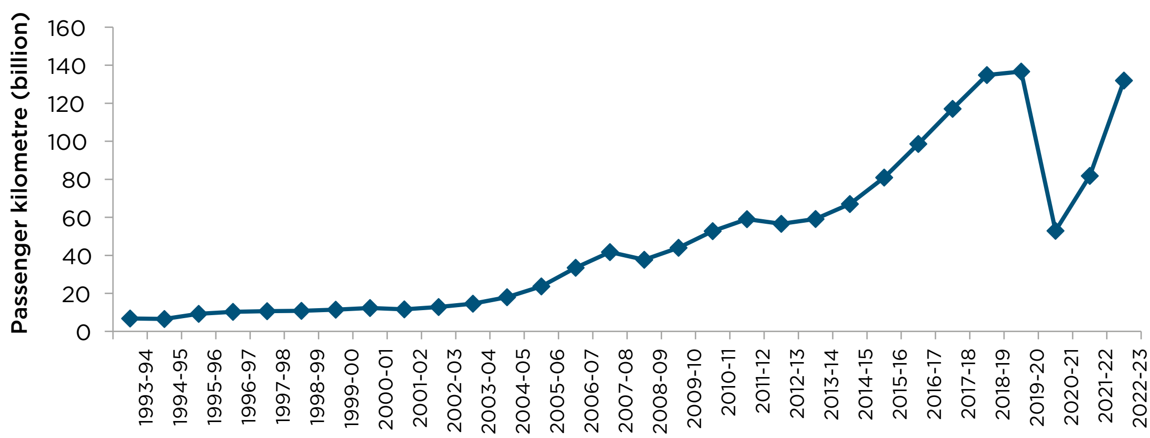


Figure 2.6: Trend of domestic air passenger traffic

Source: *Handbook of Civil Aviation Statistics*

Figure 2.7 below shows that the domestic cargo volumes have increased nearly four-fold since 2002-03. The aviation expansion will face challenge to low-carbon growth, as ATF, its primary fuel, has a high lifecycle emissions intensity of about 88.7 gCO_2e/MJ[33].

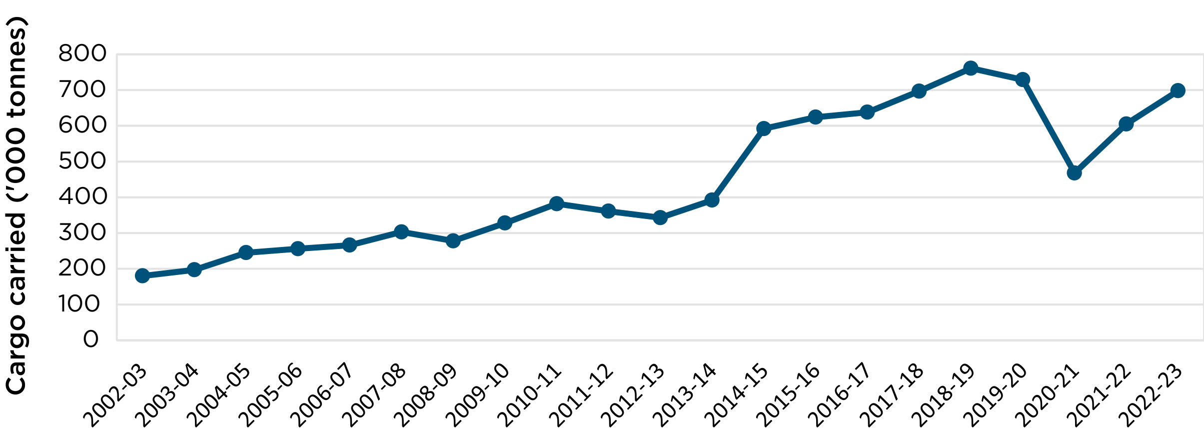


Figure 2.7: Trend of cargo carried by the domestic aviation sector

Source: Handbook of Civil Aviation Statistics, 2022-23

Waterways

India's inland waterways and coastal shipping are cost-effective and offer good potential as low-emission freight modes. Waterways' freight share reached 8% in billion tonne-kilometres (BTKMS) by 2025, with gross tonnage rising from 1.19 to 1.72 billion tonnes and the fleet from 846 to 1,039 vessels (2014–2024); Paradip Port handled the highest coastal cargo in 2022–23.

Inland and coastal vessels currently run mainly on diesel, but there is a growing push toward cleaner alternatives. This includes CNG and LNG-powered barges, biofuels, shore-to-ship power, hybrid-electric propulsion. There are also emerging options like green hydrogen and methanol for selected pilot projects and future green shipping corridors.

Pipelines

Pipelines are among India's most energy-efficient, low-cost, and low-emission modes for transporting hydrocarbons and gaseous fuels. The country now has over 25,000 km of operational natural gas pipelines, with plans to expand this to about 35,000 km under the "One Nation, One Gas Grid" initiative. In addition, more than 34,500 km of petroleum pipelines are in place, including roughly 10,447 km of crude oil pipelines, 5,231 km of LPG pipelines, and about 18,899 km of other petroleum product pipelines, with a further 4,300 km of petroleum/product pipelines under construction. They enable cleaner mobility by supporting wider use of CNG and LNG in freight and public transport. They are being future-proofed to carry fuels like ethanol blends, Compressed Bio-Gas (CBG), SAF, and green hydrogen. This will position them as a key backbone for hydrogen hubs, bio-CNG corridors, and India's Net Zero by 2070 goals.

2.3 Alternative Clean Fuels, Technologies and their Trends in Transportation

2.3.1 Electric Vehicles

Electric Vehicles are an important option in the global transformation toward sustainable transportation. As technological advances drive down battery costs and governments introduce supportive policies, EV adoption continues to increase.

In India, the shift is visible and as shown in Figure 2.8, 2Ws have grown from 0.1% of new registrations in FY 2020 to 5.38% in FY 2024, while electric 4Ws increased from 0.1% to around 5% in 2024. The 3W category has seen a remarkable jump–from 17.6% to 54.2% in the same period, even reaching 22.8% when excluding e-rickshaws and e-carts. The FAME-II scheme accelerated this transformation, and the recently launched FAME-III aims to strengthen the ecosystem with wider incentives for charging, battery swapping, and multisegment coverage. However, electrification of heavy-duty trucks remains challenging due to costs and range limitations.

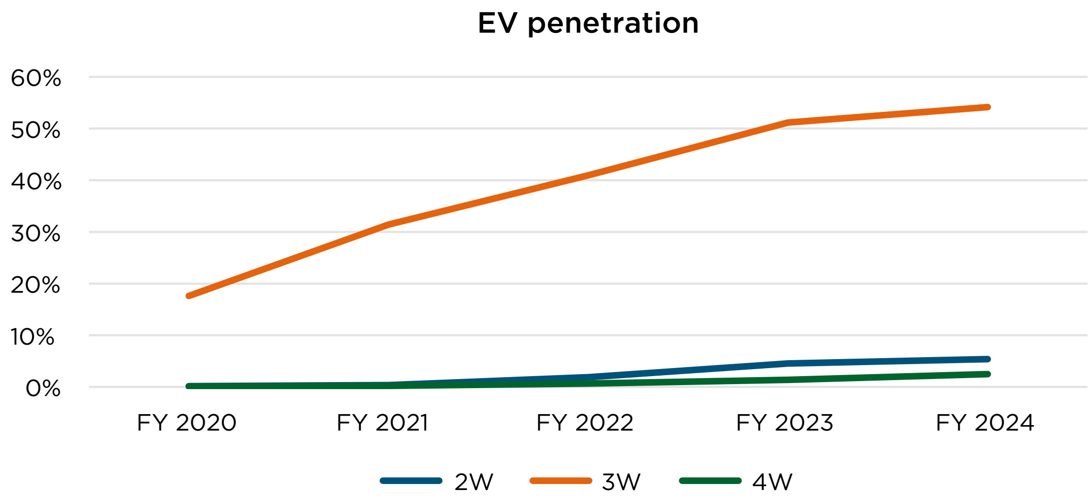


Figure 2.8: EV sales penetration (% of new registrations) in India across 2W, 3W and 4W

Source: *Vahan Portal*[34]

EV Adoption in China

China exemplifies a highly successful EV adoption story, emerging as the global leader in electric mobility. 24% of new car sales in 2024 were electric and 20% are hybrids. This growth has been driven by substantial government incentives, strategic industrial policies, and the large-scale rollout of charging infrastructure. In 2021, China accounted for nearly half of the world's electric vehicle sales; this share grew to almost two-thirds in 2024[35]. Domestic manufacturers like BYD and NIO have gained prominence, facilitating the rapid electrification of both passenger and commercial vehicles. China's EV revolution is crucial in combating urban air pollution, creating a robust industrial ecosystem, and solidifying its position as a global clean-technology powerhouse.

Not only China, but also major markets around the world are embracing both electric and partial electric i.e. hybrid technologies to decarbonise the auto sector.

xEV Technology Penetration Globally CY'24

Major Passenger Vehicles Market	Battery Electric Vehicle Penetration	Hybrid Penetration
China	24%	20%
USA	8%	12%
EU	12%	15%
Global Average	13%	14%

Source: *Nomura Research Institute*

xEV: Electrified vehicles (generic term for all types of electric vehicles i.e., Battery EV, Strong Hybrid EV, Range Extender EV, Plug-in Hybrid EV)

EV Adoption in Norway

Norway, on the other hand, has set a global benchmark for EV penetration, achieving the highest market share worldwide, with electric vehicles constituting over 80% of new car sales. Aggressive incentives, tax exemptions, and investments in a comprehensive charging network have significantly boosted consumer confidence. Norway's EV adoption is powered by a broad incentive framework-spanning exemptions on VAT and import/purchase taxes, reduced or waived road and toll charges, free municipal parking, bus-lane access, company car tax breaks, and zero-emission public procurement. This illustrates how deliberate governmental support can rapidly transform national transport systems and consumer preferences, accelerating the shift towards sustainable mobility. However, the key difference is that the market size of Norway is 1.3 lakh cars compared to 43 lakh car market in India.

Range-Extended Electric Vehicles (REEVs) as a Transitional Enabler in Electrification Strategy

Globally, mature EV markets such as China show that consumer concerns around range and charging convenience are driving diversification beyond BEVs. Range-Extended Electric Vehicles (REEVs), a BEV-derivative technology, are gaining significant traction, growing from 4% to 13% of New Energy Vehicle sales between 2021 and 2025 in China. REEVs operate as electric-first vehicles, with propulsion entirely via an electric motor and an onboard internal combustion engine functioning only as a generator when battery charge is low.

From an emissions perspective, REEVs can deliver meaningful near-term benefits. Urban usage is predominantly electric, resulting in zero tailpipe emissions comparable to BEVs. In mixed and highway usage, the engine operates intermittently at constant load and high efficiency, leading to approximately 60–70% lower CO_2 emissions per kilometre compared to conventional ICE vehicles in real-world driving. REEVs may represent a logical diversification of India's electrification strategy, and complements pure electrification until the wider ecosystem matures.

2.3.2 Biofuels in Transportation

Biofuels hold immense promise for India's dual goals of energy security and emission reduction. Through the National Biofuel Policy and Ethanol Blended Petrol (EBP) Programme, India achieved its 20% ethanol blending target ahead of schedule[36]. Ethanol derived from surplus sugarcane and grains has improved farmer incomes while promoting energy diversification.

Brazil Biofuel Program

Brazil stands out globally as a remarkable success story in biofuels, particularly ethanol derived from sugarcane. The nation's Proálcool program, initiated in 1975, has positioned the country as a global leader in sugarcane-based ethanol production. Ethanol output surged from 0.6 billion litres in 1975-76 to 3.4 billion litres in 1979-80, reaching 12.7 billion litres by 1992. Governmental support through mandates, subsidies, and infrastructure investments, alongside the widespread adoption of flex-fuel vehicles, significantly reduced reliance on imported petroleum and lowered carbon emissions. The ethanol blend in gasoline has varied over time, reaching up to 25% during certain periods. As of 2025, Brazil is considering increasing the ethanol blend to 30% (E30), with tests indicating consistent performance and environmental benefits. Effective agricultural management, favorable climatic conditions, and continuous technological innovations have reinforced Brazil's status as a biofuel powerhouse, offering a replicable model for other developing economies.

Despite these achievements, challenges persist—feedstock availability, food versus fuel competition, and fragmented logistics continue to restrict scaling. Addressing these requires investment in advanced biofuel technologies, stronger supply chains, and policy-driven research.

Harnessing Biofuels for a Circular Carbon Economy: A Pathway to Sustainable Transport

The Circular Carbon Economy (CCE) promotes sustainability by keeping carbon in a closed loop-reducing, reusing, recycling, and removing it across sectors like energy, industry, and transport.

Biofuels exemplify this principle. The CO_2 released during their combustion is not new to the atmosphere; it originates from carbon absorbed by biomass through photosynthesis. When burned, this carbon simply re-enters the atmospheric cycle, making biofuels effectively carbon-neutral under optimal conditions. However, the carbon neutrality must be tested and verified on a Life Cycle Assessment (LCA) basis for each fuel pathway.

Unlike fossil fuels, which release ancient carbon stored underground, biofuels recycle atmospheric carbon, helping to curb net emissions. When integrated with Carbon Capture and Storage (CCS), they can even achieve negative emissions, making them a key enabler of the transition toward a circular and sustainable low-carbon future.

Compressed Bio-Gas (CBG): It represents a waste-to-energy solution. Produced from agricultural residues, municipal waste, and other organic materials, CBG can seamlessly integrate with existing CNG infrastructure. Under the SATAT (Sustainable Alternative Towards Affordable Transportation) initiative, India targets 5% CBG blending by 2028-29[37]. This initiative promotes waste valorization, supports rural livelihoods, and strengthens the circular economy.

CBG: A High-Potential Fuel for India's Net Zero Mobility

Compressed Bio-gas (CBG) is produced by converting organic waste such as crop residues, cattle dung and food waste into biogas, which is then purified and compressed to make a fuel that can directly substitute CNG in vehicles. Recent lifecycle studies, indicate Bio-CNG as a vehicular fuel in India that can operate as a carbon-negative fuel over its life cycle when methane avoidance and co-product benefits are fully accounted for[38].

The International Energy Agency (IEA) estimates India's technical biomethane/CBG potential at about 87 billion cubic metres per year, giving India a advantage as a global leader in biogas and an opportunity to cut transport emissions and move towards net-zero mobility. Scaling CBG production and blending it into the existing CNG network can thus deliver deep emissions reductions while simultaneously supporting rural incomes, waste management, and energy security.

Sustainable Aviation Fuel (SAF): SAF is important for aviation industry to achieve its decarbonisation goals. Derived from second-generation ethanol and other advanced feedstocks, SAF can reduce greenhouse gas emissions by up to 80% compared to traditional jet fuel[39]. Globally, aviation contributes 3% of total CO_2 emissions and 12% of transport emissions, but its climate impact may be two to four times higher when non-CO_2 pollutants are considered. To achieve the International Civil Aviation Organization's (ICAO) aspirational goal of Carbon Neutral Growth from 2020 onward, ICAO has implemented the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a market-based measure aimed at reducing carbon emissions from international aviation. As a member state of ICAO, India is obligated to comply with CORSIA's mandatory phase starting in 2027 (Ministry of Civil Aviation (MoCA), 2023). The National Biofuels Coordination Committee has set blending targets for SAF at 1% for 2027 and 2% for 2028, applicable to international flights (MoPNG, 2023). With significant investments underway and pilot projects already operational, SAF is expected to not only help airlines comply with CORSIA but also stimulate local green fuel industries, enhancing energy security and contributing to India's overall emissions reduction goals.

2.3.3 Green Hydrogen and Its Derivatives

Green hydrogen is considered an important option for decarbonising hard-to-electrify sectors such as long-haul transport, heavy-duty trucks and shipping. Green hydrogen is produced through electrolysis powered by renewable energy[40]. The Global electrolyser capacity for green hydrogen production reached 1.4 GW by the end of 2023[41].

Germany has introduced hydrogen-powered trains, while Japan and South Korea have developed fuel-cell vehicle networks. Additionally, hydrogen internal combustion engines (H2-ICEs) are under development, achieving thermal efficiencies of approximately 40%. India's

National Green Hydrogen Mission aims to achieve 5 MTPA production capacity by 2030. Current pilots include 37 hydrogen vehicles (buses and trucks), and nine refuelling stations. Success in these initiatives will depend on proactive policymaking, targeted fiscal incentives, international technology collaborations, and robust regulatory frameworks to position India as a competitive global hub for green hydrogen.

2.3.4 Natural Gas

Compressed Natural Gas (CNG) has emerged as a key fuel option, supported by targeted government policies and sustained investments in refuelling infrastructure. Delhi has been an early mover in this transition, with early large-scale deployment of CNG in buses, taxis and auto-rickshaws. As per high-level expert committee report of PNGRB, Delhi registered around 6.5 Lakh CNG vehicles. Assuming these replaced their conventional petrol and diesel counterparts, Delhi has avoided approximately 40 Lakh tonnes of CO_2 and more than 2,500 tonnes of PM emissions. The CO_2 savings are equivalent to planting more than 70 Lakh trees across Delhi, in addition to significant positive benefit for public health[42]. Empirical studies indicate that CNG buses can emit up to 46 times less particulate matter (PM) than comparable diesel buses[43]. However, wider adoption of CNG hinges on expanding refuelling infrastructure, streamlining grid injections, and securing long-term, affordable gas supplies. Figure 2.9 shows the change in CNG vehicle penetration as percentage of new registrations across light, medium, and heavy goods vehicle (LGV, MGV, and HGV) categories.

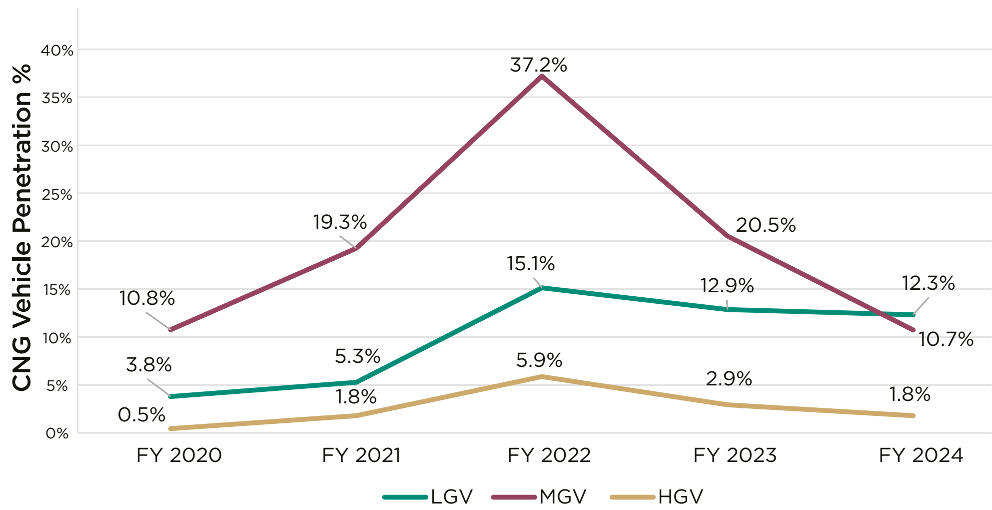


Figure 2.9: CNG vehicle sales penetration among LGVs, MGVs, and HGVs*

Source: *Vahan Portal*

* LGVs, MGVs, and HGVs: Light, Medium, and Heavy Goods Vehicles

Liquefied Natural Gas (LNG) is simultaneously gaining prominence as a lower-emission fuel option for heavy-duty vehicles (HDVs), long-haul freight and shipping, where energy density and range requirements are more demanding. Compared to conventional marine fuel oil or diesel, LNG can significantly reduce emissions, making it a technically attractive bridge solution for hard-to-abate segments. Countries such as China and the United States have already developed LNG "corridors" with dedicated refuelling infrastructure along key freight routes, enabling reliable logistics chains.

In India, LNG adoption remains at a relatively early stage despite initiatives such as the plan to develop around 50 LNG stations along the Golden Quadrilateral. Key hurdles include limited pipeline connectivity from underutilised LNG terminals, high capital costs for cryogenic storage, dispensing, and fuel tank of vehicle, a sparse refuelling network creating a demand–supply gap, and complex multi-agency approvals.

China's LNG Growth Story in HDVs: A Model for Clean Transport

Over the past decade, China has rapidly scaled the adoption of Liquefied Natural Gas (LNG) in the heavy-duty vehicle (HDV) segment, emerging as the world's largest LNG truck market. Driven by a powerful mix of policy support, economic incentives, and infrastructure development, the country's LNG journey offers valuable insights.

Key Growth Milestones

- Over 600,000 LNG HDVs on road (as of 2023) – accounting for more than 90% of the global LNG truck fleet. (Source: IEA, 2023; S&P Global)
- More than 2,000 LNG refueling stations established nationwide, strategically located on high-traffic freight corridors. (Source: NGV Global News, 2022)
- LNG trucks accounted for nearly 13% of all new HDV sales in 2021, rising from 4% in 2017. (Source: IEA, "Global EV Outlook 2022" – LNG Market Trends)
- LNG prices were consistently 20–30% cheaper than diesel during peak demand periods (2020–2022), fueling rapid adoption. (Source: China National Petroleum Corporation – CNPC reports)

China's approach—coordinated government support, scale-driven cost optimization, and clear policy signals—has made LNG HDVs not just viable, but attractive. China seeded both supply and demand in parallel. For nations seeking cleaner freight transport without waiting for full electrification, LNG can offer a scalable, near-term bridge.

3

CURRENT POLICY LANDSCAPE IN THE TRANSPORT SECTOR

Current Policy Landscape in the Transport Sector

3

Achieving Net Zero transport emissions by 2070 will require a robust, multifaceted policy framework tailored to India's needs. Key strategies include promoting Transit-Oriented Development (TOD) in cities, shifting travel to public and non-motorised modes, accelerating the adoption of clean fuels and electric vehicles (EVs), and enforcing stringent efficiency and emission norms. This chapter examines the global policy landscape driving transport decarbonisation and India's own policy initiatives, identifying how they converge and where gaps remain. Behavioural nudges and successful case studies are also examined as complementary instruments for steering India's mobility toward sustainability.

3.1 Global Trends in Transport Decarbonisation Policy

Globally, governments are enacting ambitious policies to curb transport emissions.

Vehicle electrification: The European Union (EU) has announced that all new cars sold from 2035 onward to be zero-emission, effectively phasing out new petrol and diesel vehicles. However, based on the reassessment, the target has now been relaxed slightly. Several countries and states have similar targets – for example, the UK's Zero-Emission Vehicle (ZEV) mandate requires 100% of new car and van sales to be zero-emission by 2035[44], and California in the U.S. has adopted a 2035 phase-out of new combustion car sales. In China, policymakers use a dual-credit system: automakers must meet escalating New Energy Vehicle (NEV) credit targets of 28% in 2024 and 38% in 2025, which is expected to translate to at least 20% of new car sales being electric by 2025 – aligning with China's official goal[45]. Early-adopter countries like Norway already demonstrate what's achievable: supported by incentives and charging infrastructure, 93% of new cars sold in Norway in 2023 were electric (85% fully battery-electric)[46], showing a near-total shift in the market. The United States in 2022, adopted a strong incentive-driven approach through the Inflation Reduction Act (IRA), which provided consumer tax credits (up to USD 7,500) for EV purchases and generous production credits for domestic EV battery manufacturing, spurring investment in clean vehicles. More recent actions under the Trump administration, however, have signaled a rollback of these measures, creating uncertainty for manufacturers and investors and potentially moderating the momentum of EV adoption.

Fuel decarbonisation policy. The EU's Renewable Energy Directive (RED) has set binding targets for renewable fuel use in transport. Under the latest RED III update, EU countries must achieve roughly 29% renewable energy in transport by 2030 (or equivalently a 14.5% reduction in fuel carbon intensity)[47]. This includes a dedicated sub-target of at least 5.5% coming from advanced biofuels and renewable hydrogen[48]. (RED II had previously mandated 14% renewable transport energy by 2030 with a 3.5% advanced biofuel sub-share.) Many European nations also enforce blending mandates for biofuels to meet these goals. For example, Germany, France, and others require increasing shares of ethanol and biodiesel blends in road fuels, while the EU's new ReFuelEU Aviation rules mandate blending of sustainable aviation fuels reaching 6% by 2030 and 20% by 2035[49]. These measures are pushing fuel suppliers to scale up low-carbon fuels and reduce reliance on fossil oil.

Fuel economy and emission standards. The EU has the tightest CO_2 emission rules, requiring a 55% cut in new-car emissions by 2030 compared to 2021 levels and a 100% cut (0 g/km) by 2035. China's latest light-duty rules push average fuel consumption for new passenger vehicles to 4 L/100 km on New European Driving Cycle (NEDC) test by 2025. This is backed by New Energy Vehicle (NEV) credit mandate which requires automakers to meet annual credit targets. Eligible technologies include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell vehicles (FCVs), and range-extended electric vehicles (REEVs).

Beyond regulations, many countries are supporting infrastructure and modal shift initiatives. For instance, Japan and South Korea are investing heavily in hydrogen fuel cell vehicle deployment (especially for trucks and buses) alongside EV rollouts, as part of goals to reach carbon-neutral transport by 2050. Cities around the world are also integrating transport networks and experimenting with innovative measures: Singapore has combined its mass rapid transit, buses, and ride-sharing under a unified payment system with real-time information, alongside policies like congestion pricing, to make car-light living practical. London and several European cities have introduced "ultra-low emission zones" and high parking fees to nudge commuters toward public transit and active travel. These international examples provide valuable comparisons and cautionary tales as India charts its own path.

3.2 India's Transport Sector Policy Interventions

Over the past decade, India has launched a comprehensive set of policies to promote cleaner mobility. These can be grouped into three broad categories: (a) Emission & efficiency standards, (b) Fuel and technology transition policies, and (c) Infrastructure & modal shift initiatives. Together, these measures aim to improve vehicle performance, accelerate the uptake of alternative fuels and EVs, and enhance the overall efficiency of the transport system.

3.2.1 Emission & Efficiency Standards

India's framework for cleaning up road transport rests on three complementary levers:

a. **Bharat Stage (BS) emission norms and fuel quality** standards sets limits for local air pollutants from new vehicles.

b. **Corporate Average Fuel Efficiency (CAFE) norms** cap fleet-average grams CO_2/km and push efficiency.

c. **National Vehicle Scrappage Policy (2021)** retires old, high-emitting vehicles and refreshes the fleet.

Together, these instruments tighten standards for new vehicles, fuels, and the existing fleet, steadily reducing both air pollution and CO_2 intensity.

Table 3.1: Key policies and standards on vehicle emissions and fuel efficiency

Pillar	Instrument	Scope & Mechanism	Key Milestones	Role in Emissions / Efficiency
Tailpipe emission limits & fuel quality	**Bharat Stage (BS) norms**	Euro-aligned standards for new vehicles, caps NOx, PM, CO, HC. Applied at type-approval for all new ICE vehicles.	India 2000 (≈ Euro 1) – first national norms. BS-II (2001–05), BS-III (to 2010), BS-IV nationwide by 2017. BS-VI from Apr 2020 (skipping Euro 5), BS-VI Stage 2 (BS6.2) with Real Driving Emissions and advanced On-Board Diagnostics (OBD) from Apr 2023[50].	Sharp cuts in local pollutants, especially from diesel vehicles; The leap from BS-IV to BS-VI norms in India for diesel cars cut NO_X emission limits by about two-thirds (≈68%) and PM limits by over 80%[51].
	Fuel quality standards	Align petrol/diesel quality with BS norms, where key parameter is sulfur content.	Coordinated with BS rollouts. BS-VI fuels at 10 ppm Sulfur nationwide from 2020.	Low-sulfur fuels enable advanced after-treatment, lower soot and sulfate formation, and directly improve urban air quality from new fleets.

Pillar	Instrument	Scope & Mechanism	Key Milestones	Role in Emissions / Efficiency
CO_2 & fuel-efficiency standards	**CAFE norms (fleet-average CO_2/km)**	Applies to manufacturers' new passenger-vehicle fleets capping average CO_2/km, incentivise efficient engines, light-weighting, hybrids/EVs.	Phase 1 (2017–2022): 130 g CO_2/km. Phase 2 (2022–2027): 113 g CO_2/km. Future phases under discussion to align with global best practice.[52]	Reduces fuel consumption per km; push technology upgrades and higher share of hybrid/EV models. Current rules give limited explicit credit for biofuels, flagged as an area for refinement.
Fleet renewal / end-of-life management	**National Vehicle Scrappage Policy (2021)[53]**	Systematic retirement of old and unfit vehicles via mandatory fitness tests and authorised scrappage centres.	Commercial vehicles >8 yrs and private vehicles >15 yrs must undergo automated fitness tests; failing/unfit vehicles are deregistered and scrapped. Owners receive road-tax rebates, waived registration fees on new vehicles, and scrap value.	Expected to cut emissions from replaced vehicles by 25–30%, improve average fleet fuel economy and safety, and create a formal recycling industry (recovered metals, jobs, and new-vehicle demand). Public fleets and STUs are early adopters, scrappage centres are being rolled out across states.

3.2.2 Fuel and Technology Transition Policies

India's transport-fuel strategy extends well beyond fossil-fuel efficiency. It follows a multi-track pathway including biofuels, biogas, natural gas, green hydrogen, and gaseous fuels (CNG/LNG) to cut both tailpipe and lifecycle CO_2. These measures complement vehicle-efficiency norms by lowering the carbon intensity of fuels, while also building new domestic energy industries that reduce crude-oil dependence.

Table 3.2: Key policies and programs enabling fuel transition in transport sector

	Key Instrument / Programme	Mechanism & Scope	Key Milestones & Targets	Progress & Highlights
Ethanol (E20)	**National Policy on Biofuels (2018, rev. 2022) & Ethanol Blended Petrol (EBP)**	Mandates ethanol blending in petrol, diversifies feedstock (sugarcane, maize, damaged grain) with assured pricing and OMC procurement.	E20 Target advanced from 2030 to 2025-26. E20 achieved by mid-2025 (20% blend vs 2% in 2013).[54]	E20 reduces tank-to-wheel CO_2 by 10-13%[55], improves octane and rural income linkages.

	Key Instrument / Programme	Mechanism & Scope	Key Milestones & Targets	Progress & Highlights
Biodiesel (B5)	**National Policy on Biofuels**[56]	Encourages blending biodiesel from Used Cooking Oil (UCO) and non-edible oilseeds in diesel; supports collection and supply chains.	National target: 5% biodiesel blending by 2030.[57]	Installed capacity ≈ 0.8 billion L (2025) vs demand of 5.5 billion L for B5. OMCs issued tenders for 3.7 billion L procurement[58]. UCO repurposing initiative launched in 100+ cities.
Compressed Bio-Gas (CBG)	**SATAT (Sustainable Alternative Towards Affordable Transportation)**	Produces CBG from agri-residues & municipal waste and injects into CNG grids; assures offtake by Oil Marketing Companies (OMCs) and City Gas Distributions (CGDs).	Launched in 2018, target: 5,000 plants by 2030 with CBG blending obligation of 5% in CNG/PNG from FY 2029.	As on November 2025, 173 CBG plants have been commissioned and 285 CBG plants are at various stages of construction.[59]
Natural Gas (CNG/LNG)	**National Gas Grid & Transport Corridor Programme**	Expands CNG for urban vehicles and LNG for long-haul trucks; acts as a key fuel before bio- and H_2-integration.	> Already more than 9000 CNG stations are existing as on Nov'25 and 50 LNG corridor stations planned by 2028.	CNG fleet > 9 million vehicles with 25–30% lower CO_2 and 50–80% lower PM vs diesel[60]. Pilot LNG freight corridors operational on the Golden Quadrilateral.[61]
Green Hydrogen	**National Green Hydrogen Mission (2023)**[62]	Promotes renewable-powered electrolysis to produce green H_2 for transport and industry; includes Production Linked Incentives (PLIs) and Viability gap Funding (VGF) for electrolyser manufacture and fuel-cell pilots.	Goal: 5 million tpa green H_2 by 2030 (i) Phase I (2023-26) pilots and manufacturing (ii) Phase II (2026-30) commercial scale-up.	Phase I allocates ₹19,744 crore support. Five pilot projects involving 37 hydrogen-fuelled buses and trucks (15 fuel-cell, 22 H_2-ICE). Green H_2 costs expected to drop to <USD 2/kg by 2030.[63]
Sustainable Aviation Fuel (SAF)	**National SAF Initiative aligned with ICAO CORSIA**	Develops bio-based jet fuel using Hydroprocessed Esters and Fatty Acids (HEFA), Alcohol-to-Jet (ATJ) and Fischer-Tropsch (FT) routes; promotes domestic production and blending mandates.	Target: 1% SAF blending by 2027, 2% by 2028, 10% by 2035.	India's first SAF plant produces ≈ 3,200 t/y; public-sector refineries preparing to scale to ≈ 32,000 t by 2027. Lifecycle CO_2 cuts 60–80% vs conventional jet fuel[64].

Parallel to fuel decarbonization, India's electrification drive will eliminate direct emissions from vehicles through widespread adoption of electric mobility. Policy measures spanning the FAME and PM E-DRIVE schemes, battery manufacturing PLIs, battery swapping, charging networks, and railway electrification collectively anchor this transition.

Table 3.3: Key policies and programs to promote electrification in transport sector

Pillar	Key Instrument / Programme	Mechanism & Focus	Key Milestones & Targets	Progress & Highlights
National EV Mission	FAME-I (2015–19), FAME-II (2019–24), and PM E-DRIVE (2024–26)	National-level demand incentives for EVs, and supports vehicle subsidies, charging infrastructure, and manufacturing ecosystem	FAME-I (₹895 cr), FAME-II (₹10,000 cr), PM E-DRIVE (₹10,900 cr). Targets: 8–10 million EVs and 50,000 public chargers under PM E-DRIVE[65]	>1.2 million EVs deployed under FAME-II. GST at 5%, road-tax waivers in 20+ states
Domestic Manufactur-ing	PLI – Advanced Chemistry Cell (ACC) Batteries (₹18,100 cr) and PLI – Automotive Sector (₹25,938 cr)	Incentivises domestic battery cell gigafactories and EV/FCV model production; linked to localisation and export potential	50 GWh battery capacity by 2030[66].	India is supporting 50 GWh of ACC manufacturing capacity, of which around 40 GWh has been awarded so far, with the balance under re-tendering.
Battery Swapping Policy	Battery Swapping Policy (2022): Battery-as-a-Service (BaaS) for two- and three-wheelers	Enables battery standardisation and pay-per-use energy model; reduces upfront cost by separating vehicle and battery ownership	Interoperability standards by BIS, 1,000 swap stations target by 2025[67]	India now has roughly 2,500–2,600 operational battery-swapping kiosks, with a large share located in major metropolitan regions such as Delhi NCR, Mumbai, and Bengaluru.
Charging Infrastructure	PM E-Drive	Public and private charging network expansion; grid integration and tariff rationalization	75,000 chargers (2025), 700,000 chargers by 2030 including 10,000 depot chargers	Unified Bharat EV App launched for nationwide station access[68]
Public and Shared Transport Electrification	E-Bus and Fleet Electrification Schemes	Urban transport electrification via concessional financing, PPP, and leasing models	50,000 e-buses by 2030 (PM-E Bus Sewa) and full electrification of public fleets in 20 metros by 2030	6,862 electric buses were sanctioned to various cities/STUs/ State Govt. entities for intra-city operations under the FAME-II Scheme[69].

Pillar	Key Instrument / Programme	Mechanism & Focus	Key Milestones & Targets	Progress & Highlights
Rail Transport Electrification	Mission Electrification (MoR)	Electrifies Indian Railways network; renewable integration for traction	100% broad-gauge electrification by 2027; Net Zero Carbon by 2030	More than 90% routes electrified (62,263 km). Full network and a Net Zero 2030 vision are in place

Greening the Wheels: Integrating India's Transport Sector into the Carbon Market Framework

The Bureau of Energy Efficiency (BEE) under the Ministry of Power is working towards integrating the transport sector into the India Carbon Market (ICM) to align the sector's growth trajectory with India's climate commitments.

This initiative carries far-reaching implications: it places transport squarely within the purview of emissions accountability, incentivises decarbonization, and mobilises capital toward sustainable mobility solutions.

The India Carbon Market (ICM): A Quick Primer

Launched in 2023, the India Carbon Market is a compliance and offset mechanism based trading scheme designed to promote cost-effective emissions reductions. Entities exceeding defined emissions thresholds must purchase credits from those who emit less, thereby creating an incentive structure that rewards low-carbon performance.

Led by BEE and the Ministry of Power, the ICM is being built on strong monitoring, reporting, and verification (MRV) protocols, with digital registries ensuring transparency, credibility, and trade efficiency.

India v/s global approach: The EU Emission Trading Scheme (ETS) now covers aviation, maritime, and through the new ETS II—road transport fuels, creating direct price signals that encourage fleet electrification and cleaner fuels. California's Cap-and-Trade includes transport by regulating fuel distributors upstream, complemented by its Low Carbon Fuel Standard that rewards low-carbon alternatives. China's national ETS, while still focused on power, is piloting transport inclusion through credit trading for new-energy vehicles and fuel-efficiency benchmarks.

3.2.3 Infrastructure & Modal Shift Initiatives

Decarbonisation in transport depends not only on cleaner fuels and vehicles but also on how people and goods move. India's strategy therefore integrates infrastructure, planning, and behavioural interventions that make public, shared, and non-motorised transport the preferred choice. Policies such as Transit-Oriented Development (TOD), the Smart Cities Mission, metro expansion, and Dedicated Freight Corridors (DFCs) together reduce congestion, travel distances, and fuel consumption—delivering both climate and quality-of-life dividends.

Table 3.4: Key policies and initiatives for transport infrastructure planning

Focus Area	Key Policy / Programme	Objective & Mechanism	Key Milestones & Targets	Progress & Highlights
Urban Integration & Planning	National Transit-Oriented Development Policy (2017)[70]	Promote compact, mixed-use, walkable urban growth around metro/ Bus Rapid Transit (BRT) corridors; densify and align land-use with transport.	All 100 Smart Cities to adopt Transit-Oriented Development (TOD) principles in Master Plans by 2030.	States including Delhi & Maharashtra have adopted TOD zoning, higher Floor Area Ratio (FAR) near stations. Delhi TOD corridor (Delhi–Meerut Regional Rapid Transit System) integrates housing + transit.
	Smart Cities Mission (2015–present)	Fund intelligent transport, public space upgrades, and digital mobility management.	₹ 2 lakh crore investment across 100 cities.	50+ cities introduced pedestrian zones, ITS, and cycle tracks. Pune & Chennai implemented continuous Non-Motorised Transport (NMT) corridors with > 120 km cycle lanes.
Mass Transit Expansion	Metro Rail Policy (2017) & State Metro Projects	Expand urban rail to reduce congestion & emissions.	50:50 Centre-State funding; > 1,000 km network target by 2030.	15+ cities operate metros. Delhi Metro (4.6 M daily riders, 2023) keeps over 500,000 vehicles off Delhi's roads and saves around 255,000 tonnes of fuel annually, and was the world's first metro system to earn carbon credits.[71]
	Urban Bus Modernisation & e-Bus Initiatives	Upgrade city buses (air-conditioned, digital ticketing, women drivers, e-buses via FAME).	50,000 e-buses by 2030 (PM-eBus Sewa).	Bhubaneswar "Mo Bus" fleet raised ridership 200% (2018–22); 57% shifted from private vehicles. Linked "Mo e-Ride" e-rickshaw feeders.[72, 73]

Focus Area	Key Policy / Programme	Objective & Mechanism	Key Milestones & Targets	Progress & Highlights
Freight & Logistics Shift	Dedicated Freight Corridors (Eastern & Western) + National Rail Plan 2030[74]	Shift freight from road to rail; upgrade speeds & efficiency.	3,300 km DFC network, rail freight share to rise from 27% → 45% by 2030.	95% track completion (2025); electrified corridors cut diesel use and truck traffic; rail CO_2 intensity –40%.
	Maritime India Vision 2030 & Coastal Shipping Bill 2025	Promote coastal shipping, inland waterways & green port operations.	Coastal freight share to reach 10% by 2030; all major ports to use RE power by 2030.	Green Port Guidelines (*Harit Sagar*) adopted; 80% major ports running on renewables; pilot ships using green ammonia & methanol.[75]
Aviation Greening	National Civil Aviation Policy (2016) & Green Airports Programme[76]	Improve aviation efficiency & enable bio-jet fuel use.	100% RE power for airports by 2030; SAF blending roadmap aligned to CORSIA.	> 80 airports powered by renewables; bio-jet trials underway with Indian Airlines; green-airport certifications rising.
Non-Motorised Transport (NMT)	Cycle4Change & Streets4People Challenges under Smart Cities Mission	Prioritise cycling and walking through incentives and infrastructure.	100 cities to create safe NMT corridors by 2027.	Pune, Bengaluru, New Town Kolkata launched bike-share systems and protected cycle tracks; pedestrian redesigns reduce accidents & emissions.

3.3 Behavioural Nudges for Sustainable Mobility

Technological and infrastructural advances can only go so far. To achieve sustained decarbonization, human behaviour must shift toward cleaner transport choices. Behavioural nudges use subtle psychological cues, social norms, and design principles to make low-carbon mobility the "default" or more appealing option, without restricting freedom or imposing costs. These interventions, rooted in behavioural economics and the EAST (Easy, Attractive, Social, Timely) framework, complement hard policies by addressing the cognitive and social barriers that keep people dependent on private vehicles.

Table 3.5: Behavioural nudges and interventions for promoting sustainable mobility choices

Type of Nudge	Mechanism / Intervention	Objective & Approach	Key Examples & Global/ Indian Applications
Urban Design Nudges	Modify physical environment to prompt sustainable behaviour subconsciously.	Influence travel choices and safety through visual or experiential cues.	• *Piano Stairs* (Stockholm): turned stairs into playable keys, increasing stair use by 66%. • *3D Crosswalks* (India): optical illusion to slow drivers, enhancing pedestrian safety. • *Color-coded cycle lanes* in Pune and Bengaluru improve visibility and cycling rates.[77]
Information & Social Nudges	Use real-time data, peer comparisons, or social proof to encourage modal shift.	Reduce uncertainty and leverage norms for public/ active travel.	• *Bus arrival displays & journey apps* (London, Singapore, Indian cities) reduce perceived wait time and improve reliability. • *"If you took public transport this month, you'd save ₹X & Y kg* CO_2*"* stickers on parking meters. *Neighborhood cycling norm campaigns* – highlight "30% of your peers already bike to work."
Soft Incentive Nudges (Gamification)	Reward systems, recognition, or gamified challenges.	Make sustainable behaviour rewarding and fun.	• *Singapore's off-peak travel reward app*: commuters earn points redeemable for vouchers.[78] • *"Walk/Bike to Work" challenges* (India, EU). • *"Green Wave" cycling lights* (Copenhagen): continuous greens for cyclists maintaining 20 km/h.
Default & Choice Architecture	Design defaults that favor sustainable options while preserving choice.	Overcome inertia by making eco-friendly options the "path of least resistance."	• *Corporate travel defaults*: "Train first, flight by exception." • *Opt-out carpool programs*: employees automatically enrolled unless they decline. • *Automatic bus pass renewal* systems in city metros (e.g., Bengaluru).

Type of Nudge	Mechanism / Intervention	Objective & Approach	Key Examples & Global/ Indian Applications
Social Identity & Visibility Nudges	Promote pro-environmental identity through public cues.	Create pride, visibility, and peer recognition for sustainable choices.	◆ *Green number plates for EVs (India)* – enhance social visibility, spark curiosity ("green plate effect"). ◆ *Thank-you billboards* ("You helped reduce Delhi's pollution by taking the metro").
Public Campaigns & Experience Nudges	Temporary experiential shifts to expose citizens to alternatives.	Allow people to "try" car-free mobility and experience benefits.	◆ *Raahgiri Day (Gurgaon)* – weekly car-free day encouraging walking and cycling. ◆ *Car-Free Sundays* (Pune, Hyderabad) supported by NGOs and city authorities.

While these behavioural initiatives demonstrate that India is beginning to integrate soft power approaches into its transport strategy, they remain limited in scale and reach. To realise their full potential, behavioural insights must be mainstreamed across programmes such as Smart Cities, AMRUT 2.0 (Atal Mission for Rejuvination and Urban Transformation), and future mobility campaigns.

As India advances towards Net Zero Transport, the next frontier is not just cleaner vehicles or fuels, but smarter, human-centred mobility behaviour where everyday choices collectively drive a major emissions shift.

4

PATHWAYS TO 2070: MODELLING TRANSPORT DEMAND & ENERGY USE

Pathways to 2070: Modelling Transport Demand & Energy Use

4

This chapter presents the modelling outcomes that explore how India's transport sector may evolve under two scenarios: the Current Policy Scenario (CPS) and a Net Zero Scenario (NZS) aligned with India's 2070 climate commitment. The results trace changes in passenger and freight demand, modal shares, energy use, and fuel mix trajectories through 2070, while also examining the investment requirements needed to enable this transition.

4.1 Modelling Approaches and Methodology

The analytical models used to project transport sector demand and evaluate energy consumption, emissions, and potential mitigation strategies in this study broadly fall into three categories: Top-Down, Bottom-Up, and Integrated Models.

Top-down models rely on aggregate data, macroeconomic indicators, and historical trends to estimate transport sector demand and emissions. Bottom-up models build projections based on detailed, disaggregated data, including vehicle stock, travel behaviour, trip distances, technology adoption, fuel efficiency, and vehicle lifetime. The study uses ASIF Framework (Activity, Structure, Intensity, and Fuel) which falls under the category of bottom-up models. Integrated Models, as the name suggests, aim to combine the strengths of top-down and bottom-up approaches to provide a more holistic view.

i. **Top-Down Models:** Top-down models rely on aggregate data, macroeconomic indicators, and historical trends to estimate transport sector demand and emissions. These models such as Computational General Equilibrium (CGE) Models and System Dynamics Models are valuable for capturing economy-wide interactions and policy feedback loops. However, they often lack the granularity needed to assess sector-specific policies or detailed technological transitions within the transport sector.

ii. **Bottom-Up Models:** Bottom-up models build projections based on detailed, disaggregated data, including vehicle stock, travel behaviour, trip distances, technology adoption, fuel efficiency, and vehicle lifetime. Models in this category such as the ASIF Framework (Activity, Structure, Intensity, and Fuel), Vehicle Stock Models, and Fleet-Based Energy Models are particularly useful for evaluating technology shifts, efficiency improvements, and the impact of transport-specific policies. However, they tend to overlook broader economic interactions and feedback mechanisms.

iii. **Integrated Models:** Integrated models aim to combine the strengths of both top-down and bottom-up approaches to provide a more holistic view of the transport sector. Examples include TIMES-MARKAL (a family of Energy System Optimisation Models), MESSAGE-ix, and LEAP (Low Emissions Analysis Platform). These models enable comprehensive assessments of technology pathways, policy impacts, and cross-sectoral linkages. Additionally, Network-Based Demand Models represent another important category that estimates travel demand at a high spatial and temporal resolution, effectively capturing regional variations in travel behaviour. See below boxes for description of global transport sector models and Indian transport sector models.

Various global transport sector models/methodologies

- **Global Change Analysis Model (GCAM)** is a global, multi-sectoral model that integrates energy, economy, land use, and climate systems. It includes a detailed transport module that models energy demand, fuel mix, and emissions trajectories (Developed by PNNL).
- **Low Emissions Analysis Platform (LEAP)** is a hybrid tool, integrating both top-down and bottom-up approaches, and is used for modelling fuel consumption, emissions trajectories, and the impact of different transport policies on national decarbonisation goals (Developed by Stockholm Environment Institute).
- **IEA Mobility Model (MoMo)** is a stock-based scenario planning model leverages ASIF framework to analyze global transport trends, vehicle fleets, fuel consumption, and emissions (Developed by IEA).
- **PRIMES-TREMOVE** is a detailed transport simulation model under the broader suite of energy system optimisation tools used in the EU for policy impact assessments on emissions, fuel use, and mobility trends (Developed by E3Mlab).
- **Roadmap model** is a bottom-up model based on ASIF framework with inputs derived from IEA MoMo and is used for understanding the impact of various policies and technological advancements on the future of transportation (Developed by International Council on Clean Transportation).
- **Policy Ambition and Sustainable Transport Assessment (PASTA)** is a bottom-up model integrating spatial factor and considers analyses how transport demand is met, considering mode choices and emissions (Developed by International Transport Forum).

Various Indian transport sector models/methodologies

- **Indian Energy Security Scenarios (IESS) 2047** is a scenario building bottom-up based tool with capability to understand the impact of adoption of various technology choices, fuel consumption, emissions and transport policies (Developed by NITI Aayog).
- **GCAM-India model** is a customised Indian version of global GCAM with transport demand driven by GDP, Population, modal choices and fuel prices (Customised by CEEW)
- **TptM** is a bottom-up based tool leverages ASIF framework to project transport demand, fuel use and GHG emissions (Developed by TERI)
- **India Multi-Region Times (IMRT) Model** is a hybrid model which combines ASIF framework and TIMES optimisation and uses inputs such as population, investment trends, and urbanisation rates to project transport demand (Developed by CSTEP)
- **Activity Analysis Module (AAM)** is a multi-sectoral and top-down dynamic optimisation based model leverages Social Accounting Matrix (SAM) based on National Sample Survey (NSS) data to project transport demand, fuel demand and emissions (Developed by IRADe)
- **India Emission Model (IEM)** is a bottom-up fleet stock assessment based model estimates annual emissions of pollutants from India's on-road vehicles and costs of cleaner technologies (Developed by ICCT)

4.1.1 Methodology for Final Energy Demand Estimation of Transport Sector

For this study, NITI Aayog adopted a modified bottom-up ASIF structure to project the transport demand and emissions (Figure 4.1). Emissions are product of:

i. Transport sector activity measured in passenger-km or tonne-km

ii. Modal structure of the overall transport

iii. Vehicle categorisation (2W, 3W, 4W etc) further categorised into fuel technology such as EVs, Petrol, Diesel, etc. and corresponding fuel intensity of each vehicular category

iv. Mileage for each fuel technology and vehicle category for estimating final energy demand

v. Emission factor for each fuel

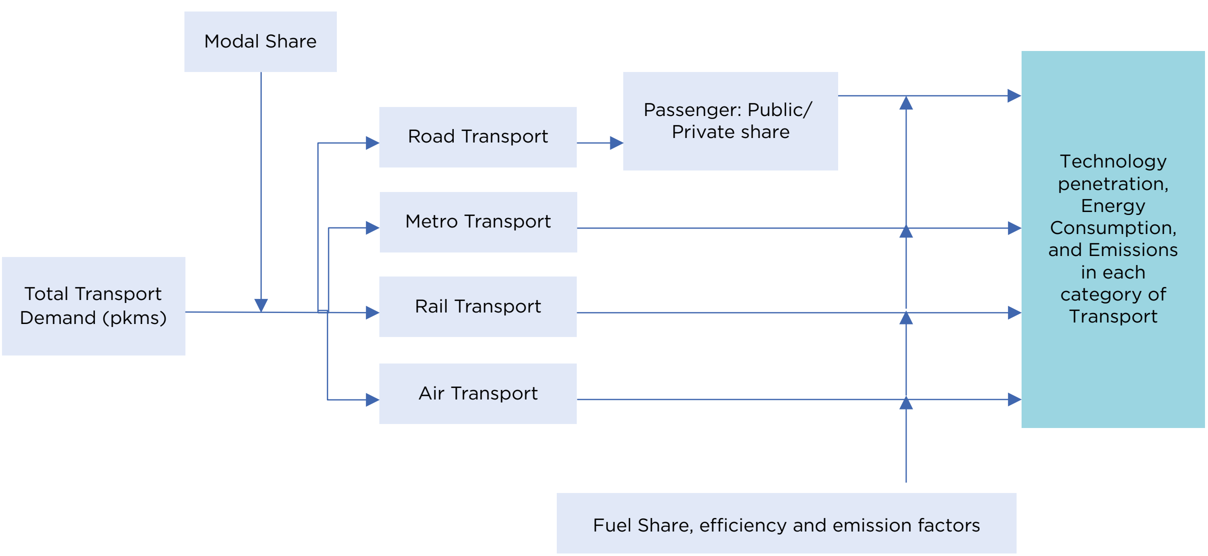
This modified ASIF structure was first adopted in the India Energy Security Scenarios (IESS), a scenario building bottom-up based tool developed by NITI Aayog. The model is capable of understanding the impact of modal shift, fuel technology choices, emissions, and transport policies.

4.1.2 Passenger and Freight Transport Modelling Approaches

The modelling of India's transport sector adopts a structured approach that differentiates between passenger and freight demand across major modes. Passenger transport is analysed under four categories, road, rail, air and metro, while water-based passenger mobility is excluded due to its negligible share and limited data. Road passenger travel is further divided into public and private modes, with detailed classifications by vehicle type (buses, cars, two- and three-wheelers, taxis, omni-buses) and fuel type (diesel, petrol, CNG/LNG, EVs, fuel-cell vehicles, and flex-fuel options). Rail accounts for both diesel and electric locomotives, with urban metro and rapid rail systems modelled separately, and aviation focuses on the transition from conventional turbine fuel to sustainable aviation fuels (SAF).

Freight transport is modelled across five segments, road, rail, air, pipeline, and water. Road freight is further divided by payload capacity (below 3.5 tonnes, 3.5-12 tonnes, and above 12 tonnes) and by fuel choice (diesel, LNG, CNG, electricity, hydrogen fuel cells). Rail freight evaluates diesel and electric traction, while water transport considers emerging alternatives such as green ammonia and green methanol alongside conventional fuels. Aviation freight explores the potential shift from ATF to SAF.

This comprehensive modelling framework adopted in TIMES (The Integrated Markal EFOM System) and IESS enables the development of transport sector pathways through 2070



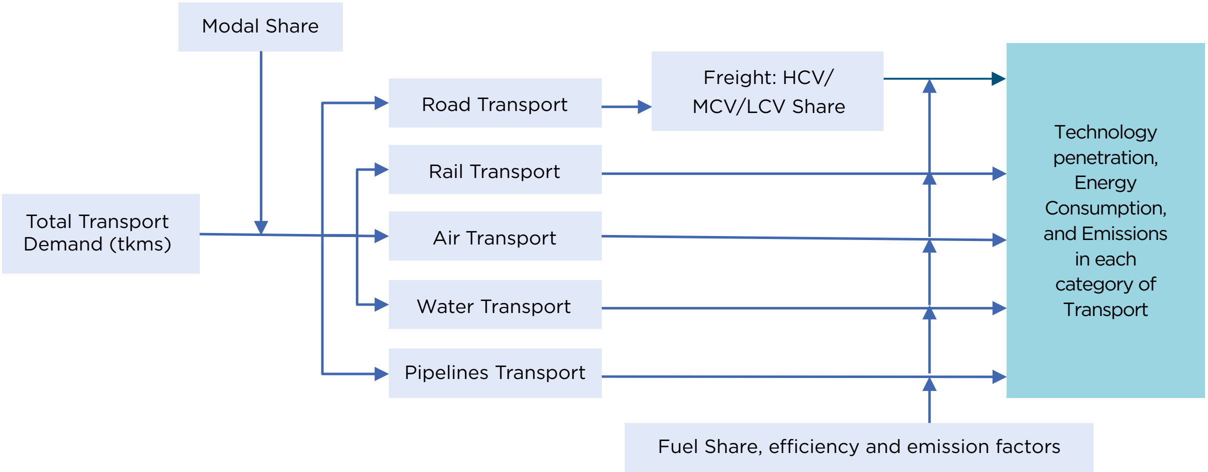


Figure 4.1: Methodology representation for transport energy and emission estimation (a) passenger and (b) freight

4.1.3 Scenarios Compared

The analyses of transport sector demand, fuel consumption, and emissions is undertaken through two scenarios: Current Policy Scenario (CPS) and Net Zero Scenario (NZS). CPS primarily reflects the historical growth rate of various inputs in the model such as modal choice, fuel efficiency improvement, technology penetration (EVs, CNGs, hybrids, hydrogen fuel vehicles, etc.). This scenario reflects the policies being implemented as of 2023. NZS reflects the ambitious choices and efforts needed to the same inputs (such as modal choice, technology penetration, fuel efficiency, etc.) so that the net emissions at economy level reach zero by 2070. The scenario also incorporated the policies already announced. Various assumptions across input parameters are discussed below, and summary is provided in Table 4.1 below:

Table 4.1: Summary of key indicators in Current Policy Scenario and Net Zero Scenario till 2050 and 2070

Indicator		2023	Current Policy Scenario		Net Zero Scenario	
			2050	2070	2050	2070
Passenger Kilometres per capita		3950	12200	14000	11000	12000
Tonne Kilometres per capita		2920	8200	10000	6500	8000
Urbanisation		37%	51%	65%	51%	65%
Modal Share						
Passenger	Road	78%	73%	70%	69%	64%
	Metro	<1%	2%	2%	2%	3%
	Rail	17%	19%	20%	22%	25%
	Air	4%	7%	8%	7%	8%

Indicator		2023	Current Policy Scenario		Net Zero Scenario	
			2050	2070	2050	2070
Freight	Road	66%	67%	65%	63%	60%
	Rail	22%	24%	25%	27%	30%
	Air	<1%	<1%	<1%	<1%	<1%
	Waterways	8%	7%	7%	8%	8%
	Pipelines	3.6%	2%	2%	2%	2%
Road Transport	Public Share (Taxi, 3-W)	47%	49%	50%	54%	60%

Transport Demand (BPKMS/ BTKMS)

The saturation value for Passenger Kilometres (PKMs) per capita is selected to lie between the levels observed in European economies (around 12,000–15,000 PKM per capita) and the United States (~20,000 PKM per capita). The higher saturation in the US is attributable to greater private vehicle ownership and longer average travel distances due to the vast geographical spread of the country.

In case of passenger, the per-capita saturation level is chosen to be 12,000 km in Net Zero Scenario (NZS) lower than the Current Policy Scenario (CPS) at 14,000 km. Similarly, in case of freight, the per-capita saturation level is chosen to be 8,000 Tonnes Kilometres (TKMs) in NZS lower than the CPS pathway of 10,000 TKMs. This reflects the anticipated adoption of active planning strategies such as Transit-Oriented Development (TOD), which would reduce overall transport demand and limit per capita mobility needs despite higher GDP per capita.

Modal Choices

Passenger

Rail: The historical trend registers a declining share of rail in passenger mobility. However, the rail share is expected to improve due to significant infrastructural investments by Indian Railways, with rail track length projected to double by 2047.

Rail transport is not only more economical but also easier to decarbonise, making it an important mode of transport to be promoted for sustainable mobility. According to the National Rail Plan, passenger demand is expected to rise from 6.9 billion passengers in 2024 to 19.2 billion passengers by 2051. With average lead distance improving from 150 km in 2024 to 300 km by 2050s, the proposed rail plan target is assumed to be achieved in Net Zero Scenario (NZS) which envisages high rail share. The share of rail in passenger transport is assumed to increase from 17% in 2025 to 20% in Current Policy Scenario (CPS) and 25% in Net Zero Scenario (NZS) by 2070, reflecting a stronger policy and investment focus on rail as a cost-effective and low-carbon mode of transport.

Metro: India's metro length grew at a rate of 80 km per year from 600 km in 2020 to 1,000 km by 2025. In-line to this, Current Policy Scenario (CPS) assumes growth of metro length as 120 km per year. The Net Zero Scenario (NZS) assumes a higher growth rate of 180 km[i] per year, reaching almost 5,000 km by 2047.

Air: According to data by the Directorate General of Civil Aviation (DGCA), passenger kms have grown at an average annual rate of 9.6% on domestic routes, and at 6.7% on international routes between 2014 and 2024. In terms of passenger numbers, domestic travel has increased at 9.7% annually, and international travel at 6.5%.

Looking ahead, it is assumed that aviation passenger traffic can sustain a 8% growth rate in passenger kms, driven by India's aspirations to become a developed economy and the consequent rise in per-capita incomes. As a result, the modal share of air travel is projected to increase from 4% in 2025 to around 8% by 2070 in both scenarios.

Freight

Rail: Key initiatives by the Government of India in this area, such as the development of Dedicated Freight Corridors (DFCs), improvements in average freight train speeds, modernisation of terminals, and reductions in rail tariffs are expected to make rail a more competitive and reliable freight option.

Driven by these improvements, the share of rail in freight transport is projected to go from 22% in 2025 to 25% by 2070 under Current Policy Scenario (CPS). Under Net Zero Scenario (NZS), rail's share is expected to reach 30% by 2070, reflecting deeper policy support, higher efficiency gains, and the inherent energy and carbon advantages of rail for long-haul freight.

In terms of absolute freight tonnage, Current Policy Scenario (CPS) and Net Zero Scenario (NZS) projections estimate 4.7- 5.2 billion tonnes (BT) being carried by rail by 2051. This aligns more closely with Scenario 4 of the National Rail Plan, which envisages around 4.8 BT of rail freight movement under a modified Business-As-Usual scenario with reduced tariffs. However, these projections are slightly below the optimistic scenarios of the National Rail Plan, which estimates 6.1-6.8 BT by 2051, achievable only with more aggressive interventions such as faster rail speeds, further tariff rationalization, and extensive DFC integration with multimodal logistics networks.

Thus, while Current Policy Scenario (CPS) and Net Zero Scenario (NZS) reflect a moderate but realistic growth trajectory, there remains potential for higher rail freight volumes if India adopts the most ambitious measures outlined in the National Rail Plan, positioning rail as the low-carbon backbone of the freight sector.

i This is not an improbable assumption of growth given that China added 748 km in 2024.

Water: The Maritime Amrit Kaal Vision 2047, set by the Ministry of Ports, Shipping & Waterways, explicitly targets quadrupling of port capacity from about 2,700 Million Metric Tonnes Per Annum (MMTPA) in 2024 to over 10,000 MMTPA by 2047, and expansion of cargo handling capacity from approximately 109 MMTPA to 500 MMTPA by the same year.

Aligned with these capacity goals, the overall movement of goods via water transport, measured in billion tonne-kilometres (BTKM), is expected to mirror this trajectory, effectively quadrupling by 2047 alongside port and cargo growth. In both Current Policy Scenario (CPS) Net Zero Scenario (NZS), the share achieved in 2047 is expected to stabilise by 2070.

Pipelines: The projections are based on volume and average distance travelled by various commodities i.e. gas, LPG, crude oil, and other petroleum products. Due to higher share of fossil commodities in Current Policy Scenario (CPS) , pipeline movement (in terms of ton-km) is expected to double by 2070. In the Net Zero Scenario (NZS), overall pipeline throughput is roughly at today's level, as sector progressively shifts from fossil fuels toward electricity and low-carbon fuels.

Share of public & private transport within road mode

Current Policy Scenario (CPS) assumes that the share of public private transport in BPKMs will continue to be tilted towards private vehicles, with the share declining only marginally from 53% to 50%. The Net Zero Scenario (NZS), though, envisages this share to drop to 40%.

Technology penetration

Within passenger/freight road segment, EV emerges as dominant choice for decarbonisation across various vehicle segments. Reflecting the historical growth and upfront cost of EVs, Current Policy Scenario (CPS) assumes delayed electrification. The Net Zero Scenario (NZS), however, assumes early electrification with supportive policies and finance. As the study projects long into future (2070), it has to account for difference in pace of electrification.

These two scenarios also assume greater adoption of CNG in passenger segment and LNG in freight segment till 2047. However, under Net Zero Scenario (NZS), share of CNG declines and is replaced by Compressed Bio-Gas (CBG) after 2047, driven by need to reduce total emissions. The NZS also assumes a greater share for hydrogen fuel cell vehicles among Heavy Commercial Vehicles (HCVs), with important role of flex-vehicles, strong-hybrids, CBG vehicles with a greater thrust on biofuels by the government.

In the aviation sector, under Net Zero Scenario (NZS), the international operations are set to achieve 1% Sustainable Aviation Fuel (SAF) blending by 2027, 2% by 2028, and 5% by 2030, with a continued increase to 50% by 2050 and 70% by 2070. Domestically, the blend is expected to rise from 2% in 2030 to 50% by 2070.

In the shipping sector, under Net Zero Scenario (NZS), low-carbon or green methanol blending in the existing fleet is targeted to start at 1.5% in 2030 and reach 50% by 2070, while low-carbon or green ammonia is set to begin at 1% in 2035 and reach 50% by 2070.

Base year

The analysis adopts 2023 as the base year, with all available empirical data calibrated and validated against this reference year. Forward-looking projections are undertaken for the period post-2023 through 2070, with the modelling horizon commencing in 2025 and results captured at five-year intervals. 2020 is used as a reference year for presenting historical data to ensure consistency of results and alignment with reported emissions.

The first projection year is 2025, and accordingly, model outputs are presented from 2025 onward. Results for 2050 are included to assess progress toward development goals and 2070 results represent the long-term Net Zero outcome.

Modelling Limitations

The findings presented in this report have emerged from a scenario-driven, economy-wide energy climate modelling framework that develops pathways across sectors towards India's Net Zero ambitions. Like all long-term models, these findings rest on key assumptions and methodological limitations, outlined below for proper interpretation:

i. **Deterministic Approach for Key Drivers:** The model adopts a deterministic framework, relying on specific projections for GDP growth, population trends, fuel prices and technology costs. This limits its flexibility to alternative scenarios, such as economic shocks or rapid cost declines in EVs.

ii. **Simplified Demand Methodology:** Demand projections link transport activity directly to GDP and overlook behavioural nudges such as policy incentives or cultural shifts, which can drive disproportionate growth in sectors such as Electric 2Ws or shared mobility. This may lead to under- or overestimation of modal shifts.

iii. **Exclusion of Inland Water Passenger Travel**: Inland water transport, though, offers efficient, low-carbon potential for future passenger mobility, limited granular data on ridership, infrastructure, and emissions limit its inclusion in the model.

iv. **Limited Technology Options for Aviation:** Beyond SAF blending, the model does not account for potential technological breakthroughs in aviation, such as hydrogen propulsion or advanced battery-electric short-haul flights.

v. **Biofuel Feedstock and Supply Chain Gaps:** While biofuel blending is incorporated in the form of ethanol, biodiesel, SAF, and CBG, the detailed assessment of feedstock availability, land-use competition, and supply chain logistics is out of the scope of this study. This may introduce uncertainty in scalable biofuel deployment for the road and aviation sector.

vi. **Overlooking Regional Demand Variations:** The model develops national-level projections, disregarding regional disparities in population density, income levels, urbanisation rates, and rural-urban divides, which could skew infrastructure needs and policy recommendations.

vii. **Exclusion of Infrastructure investment costs:** The estimated investment cost includes vehicle costs in-terms of cost to the automobile industry, and cost of batteries and EV charging infrastructures. The cost of infrastructure for road/rail expansion, aviation, metros, LNG facilities, and hydrogen filling stations is not included in the model, understating total sectoral capital needs.

Future Enhancements

Future enhancements to this study would be the integration of multiple scenarios of GDP, fuel prices and technology costs. Inclusion of behavioural nudges in the transport sector would enable realistic modal shift analysis. Further, there will be linking this model with the supply chain and land use availability for biofuel potential to resolve the scalability gaps. Inland water passenger mobility can also be integrated via detailed ridership assessment.

4.2 Activity Projections and Baseline Estimation

4.2.1 Activity Demand (BPKM/BTKM) Methodology Projections

The study adopts the widely accepted methodology of projecting transport demand through Billion Passenger Kilometres (BPKMs) and Billion Tonne Kilometres (BTKMs). Globally, the relationship between GDP per capita and per capita mobility (passenger-km per capita) has been widely observed and analysed by various think tanks, international agencies, and academic studies. It generally find that as per capita income rises, personal and public mobility also increases, and that it saturates after a certain level. This is corroborated by global evidence, seen in Figure 4.2. The projection of transport demand (passenger and freight) is based on saturation curve model. The model is specified as:

$$LN\left(\frac{S}{(S_o - S)}\right) = LN\left(\frac{GDP}{Capita}\right) * a + b$$

Where, *S* is the per capita transport demand and So is the saturation limit considered, and "*a*" and "*b*" are coefficients derived based on historical data.

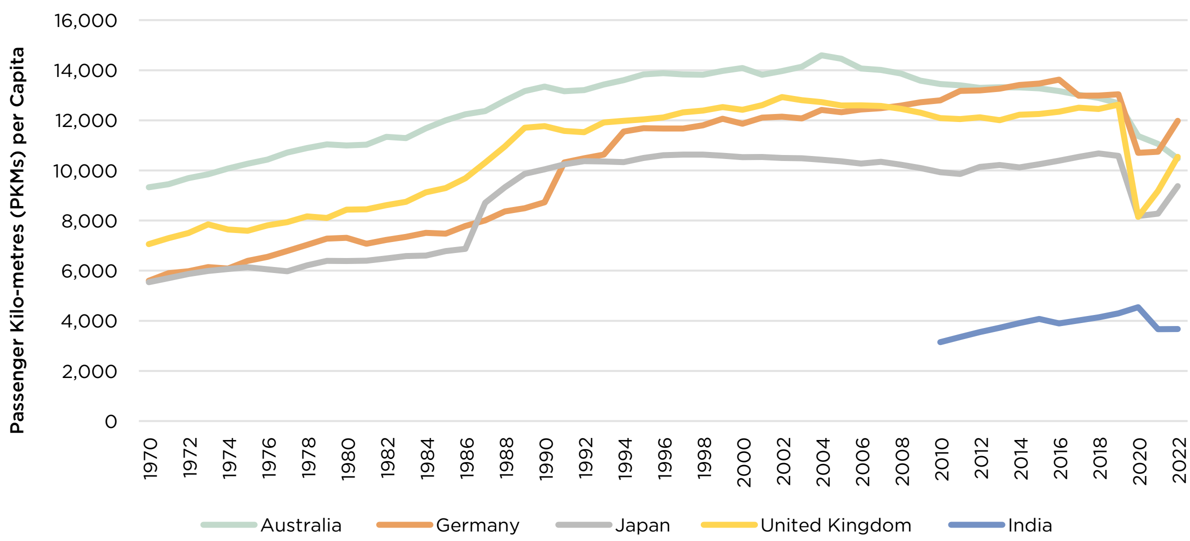


Figure 4.2: Historical growth in per capita passenger transport demand (road + rail) in various countries showing growth followed by saturation

Source: *World Bank, ITF*

4.2.2 Estimation of Baseline Transport Demand

The Billion Passenger Kilometres (BPKMs) and Billion Tonne Kilometres (BTKMs) data for rail and air transport is taken from Indian Railways and DGCA. In case of the remaining categories of roads, metro, pipeline and water transport, the working group deliberated using the data available across various ministries/departments/agencies before finally using the available data with assumptions to estimate BPKMs/BTKMs.

The *detailed assumptions* for estimation are:

- **Road transport**: MoRTH publishes the data on registered vehicles in its annual reports. The number of registered passenger vehicles is converted into BPKMs using assumptions of average occupancy of each vehicle (no. of passengers) and annual utilisation (no. of kms travelled by each vehicle). For freight, the number of registered vehicles is converted into BTKMs using assumptions of average payload of each vehicle (quantity of tonnage carried) and annual utilisation (no. of kms travelled of each vehicle. The detailed assumptions are tabulated in Annexure A.

- **Metro transport**: Daily ridership data is available for operational Metros from respective metros reports or through literature review. This data, along with average km travelled, is used to estimate Metro BPKMs.

- **Water transport**: BTKM is calculated for historical years based on fuel consumption data published by the Directorate General of Shipping.

- **Pipelines**: BTKM is estimated based on the discussions with PNGRB, fuel transported, and average energy consumption.

Using the above assessment, passenger demand is estimated at 6,410 BPKM and freight demand at 4,661 in BTKM in 2025. As such estimates are not readily available in the public domain in a consolidated form, this study contributes by establishing a baseline for passenger and freight transport demand and modal distribution in India. The likely modal split across various categories is shown in the Figure 4.3 below.

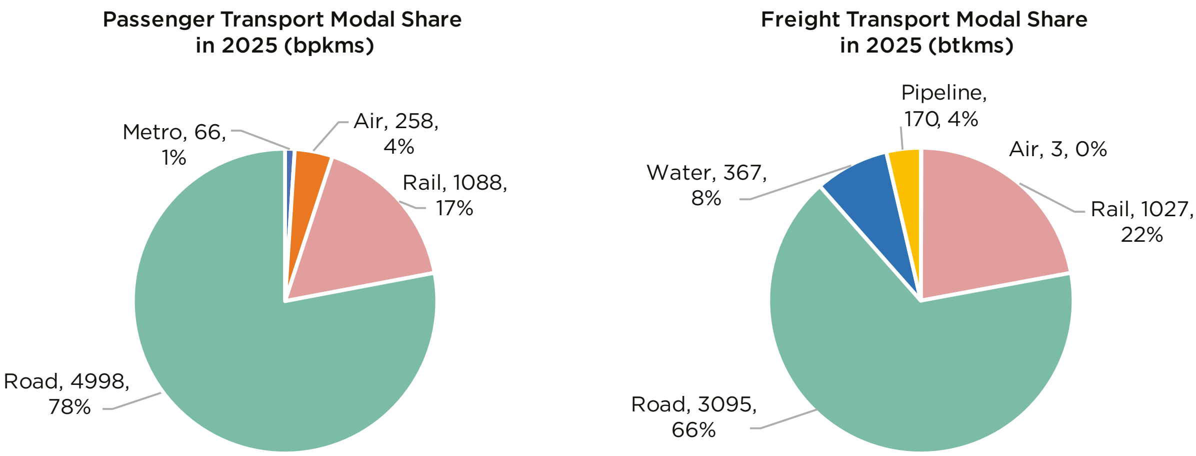


Figure 4.3: Baseline passenger transport (BPKM) and freight transport (BTKM) demand estimation (2025).

4.3 Results and Discussion

The following results section provides projections for transport energy demand and fuel mix. The projections are derived using a saturation growth curve model with GDP as a key input parameter. The analysis is structured into passenger transport and freight transport, providing insights into mode-wise demand, technology adoption, and associated energy and emission implications.

4.3.1 Passenger Transport: Demand and Modal Shift

BPKMs projections

This study projects India's passenger transport demand for both Current Policy and Net Zero scenarios. A global comparison of GDP per capita and PKM per capita (as discussed in figure 4.4) shows that as economies develop, travel demand rises significantly before it eventually saturates.

In India's Current Policy Scenario (CPS), the per capita Passenger Kilometres (PKM) is projected to grow from 4,542 in 2025 to about 14,000 PKM/capita by 2070, reflecting rising incomes, enhanced mobility infrastructure, and continued urbanization. However, the Net Zero Scenario (NZS) expects PKM/capita to saturate at around 12,000 by 2070. This reduction is attributed to active planning strategies, including Transit-Oriented Development (TOD), promotion of shared mobility, and a stronger emphasis on Non-Motorised Transport (NMT), which collectively reduce dependency on private Motorised travel even as GDP per capita rises.

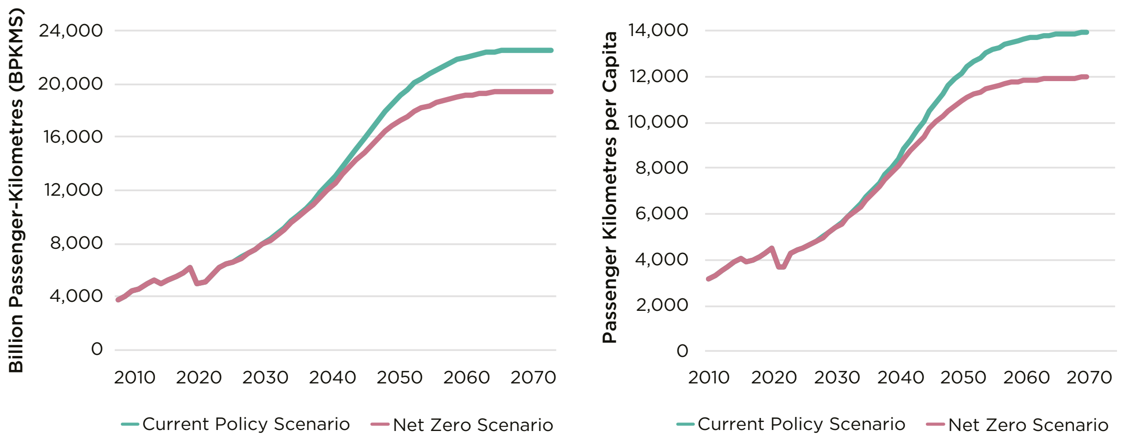


Figure 4.4: Projected growth in billion passenger-kilometres (BPKMS) and per- capita passenger kilometres (PKMS)

Figure 4.5 provides a useful reference to assess how India's mobility demand compares globally. In 2023, India is at the lower end of both GDP per capita and PKM per capita, reflecting limited personal mobility compared to developed nations. International trends clearly show a positive correlation between income and mobility, with PKM per capita rising as economies grow, before gradually saturating.

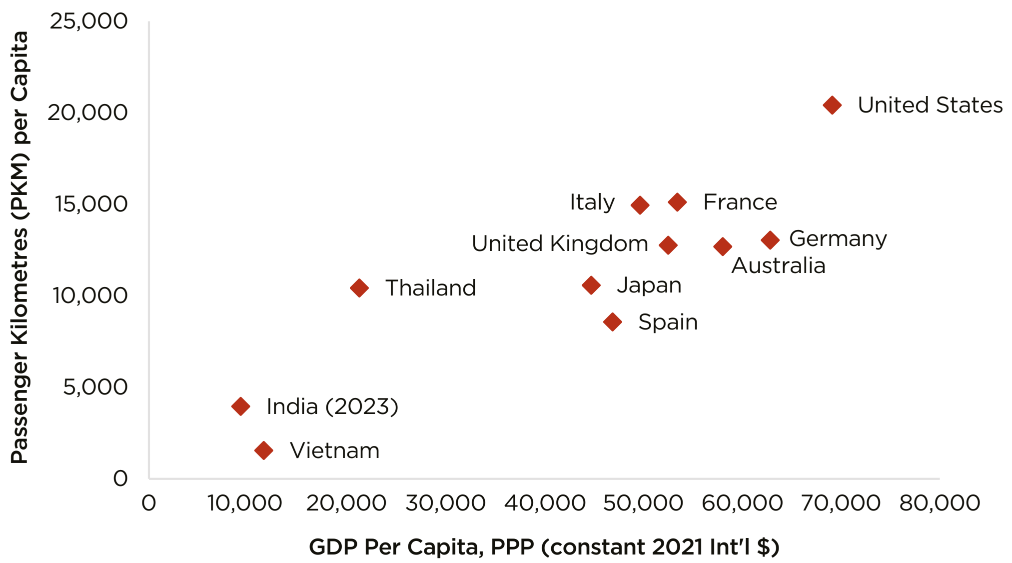


Figure 4.5: Global comparison of GDP/capita vs PKM/capita highlighting that mobility increases with rising income levels

Both the Current Policy Scenario (CPS) and Net Zero Scenario (NZS) project India to transition to a high-income quadrant by 2070. The CPS trajectory aligns with higher-mobility European country such as France and Italy, while the NZS projects similar income levels, but with lower transport intensity, indicating a deliberate shift toward more efficient and sustainable mobility choices. This is consistent with the saturation value for PKM per capita assumed for India, which lies in the range of 12,000 to 15,000 PKM/capita levels observed in European economies and the ~20,000 PKM/capita level observed in United States. The latter has a higher saturation level primarily due to greater private vehicle ownership and longer average travel distances, driven by its vast geographical spread and car-dependent transport.

India's future trajectories under Current Policy Scenario (CPS) and Net Zero Scenario (NZS) illustrate how policy and planning can shape mobility outcomes, ensuring that economic prosperity does not necessarily translate into excessive transport intensity. Instead, strategic measures such as Transit-Oriented Development (TOD), shared mobility, and Non-Motorised Transport can enable equivalent or better accessibility with lower per-capita travel demand, supporting sustainability without constraining economic growth.

Modal shift

India's passenger transport landscape is projected to undergo a gradual modal shift away from road-based travel. Road transport, which had with a 78% share in 2025, is expected to decline to 70% under the Current Policy Scenario (CPS) and to 64% under Net Zero Scenario (NZS) pathway as other modes of transport gain ground (Figure 4.6).

Rail: After decades of declining modal share, rail is projected to recover slightly, supported by doubling of India's rail track length by 2047 and service efficiency improvements.

- Under the CPS, rail's share increases modestly from 17% in 2025 to 20% by 2070
- In the NZS pathway, greater policy push and investment take the share of rail transport to 25% by 2070, offering a cost-effective and lower-emission backbone for medium- and long-distance travel. This is also in line with National Rail Plan projections where passenger demand rises from 6.9 billion in 2024 to 19.2 billion by 2051.
- This shift also assumes an increase in average passenger lead distance from 150 km in 2024 to ~300 km by 2070, supporting higher utilization.

Urban Metro & Rapid Transit: Urban rail networks expand substantially alongside intercity rail:

- Metro systems grow from ~1,000 km in 2025 to ~3,600 km under Current Policy Scenario (CPS) and ~5,000 km under and Net Zero Scenario (NZS) by 2047, assuming ~120 km/year (CPS) and ~180 km/year (NZ) of new network additions.

Aviation: Under both Current Policy and Net Zero Scenarios, air travel's modal share increases from 4% in 2025 to ~7% by 2047 before stabilizing. However, absolute demand continues to grow rapidly with rising incomes, mirroring patterns in upper-middle-income countries like China and Brazil. Managing emissions will require parallel decarbonisation measures, including SAF adoption and airport electrification.

What this means:

- Current Policy Scenario (CPS) sees incremental modal rebalancing, while Net Zero Scenario (NZS) accelerates structural change by strengthening rail and metro systems.
- International precedents (Japan, Europe) support the feasibility of maintaining higher rail and metro shares, reinforcing this pathway for India.

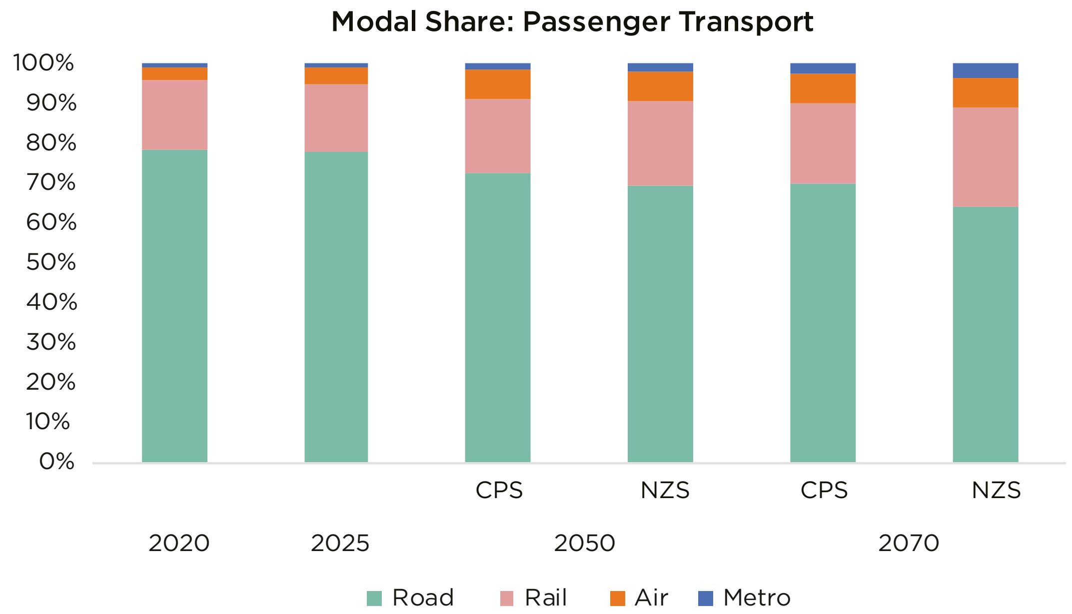


Figure 4.6: Modal shift projections of passenger transport under Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

Passenger Transport: Public vs Private and Vehicle Ownership

Public- Private Mix within Road Transport

India's road transport mix is also expected to markedly shift toward public modes. Private vehicles, comprising two-wheelers and cars, accounted for 53% of road-based passenger movement in 2025. The share of public transport is projected to rise to 50% (CPS) and 60% (NZS) (see Table 4.2), enabled by sustained expansion of public transport such as buses, taxis, and three-wheelers. Key enablers include the continued rollout of schemes such as the PM-eBus Sewa, which aims to deploy 10,000 e-buses across 100 cities, and state-led programmes promoting integrated urban mobility. Investments in digital ticketing, feeder connectivity, and shared mobility services are also expected to improve convenience and affordability, encouraging a shift away from private ownership. Globally, similar transitions are seen in cities like Bogotá and Seoul, where dedicated bus rapid transit (BRT) systems and multimodal integration have played a catalytic role in reversing private vehicle dependence.

Table 4.2: Modal share–road transport projections under CPS & NZS, 2070

	Current (2025)	Current Policy Scenario (2070)	Net Zero Scenario (2070)
Private Vehicles	53%	50%	40%
Public	47%	50%	60%

Personal Vehicular Ownership

India's vehicle ownership is set to rise sharply by 2070, driven by income growth, urbanisation and rising aspirations. This trend presents challenges for urban transport systems, particularly with respect to congestion, energy use, and emissions, highlighting the need to better align mobility growth with sustainable transport modes.

As of 2022, India had 322 million registered vehicles (MoRTH), dominated by two-wheelers (81.6%), followed by cars (14%). While there is significant growth in passenger vehicle sales from 16.9 million (2022) to 22.89 million (2024), the share of two-wheeler sales fell from 84% of the total in 2019 to 78.5% in 2024 (SIAM), indicating a slow shift toward four-wheelers and shared mobility.

Private vehicle ownership reached 197 (167 two-wheelers and 30 cars) per 1000 person in 2023. By 2070, cars per 1000 are expected to grow from 30 per 1000 person to 250 per 1000 in Current Policy Scenario (CPS) (Table 4.3). In Net Zero Scenario (NZS), the growth is lower, 200 per 1000, because of the focus on public transport. These trajectories are conservatively specified and remain below levels observed in developed economies (e.g., ~850 per 1,000 in the US and ~400 in Brazil). This reflects India's urban density, infrastructure capacity, income distribution, and a policy orientation toward public transport, shared mobility, and compact urban development, rather than convergence toward high private car dependence. The effects of rising vehicle ownership can already be observed in major metropolitan areas. For example, Bengaluru, with 2.31 million cars and 188 cars per 1,000 people in 2023, experiences persistent congestion, illustrating the importance of strengthening public transport systems and managing demand to support more sustainable urban mobility.

Table 4.3: Vehicle ownership projections

Personal Vehicle Ownership Projections (per 1000 Population)						
	2023	NITI Aayog (2050/70)		TERI (2050)	IEA (2050)	
		Current Policy Scenario	Net Zerio Scenario		STEPS[ii]	APS[iii]
2-Wheeler	167	290 (2050) 270 (2070)	290 (2050) 220 (2070)	300	275	250
4-Wheeler	30	170 (2050) 250 (2070)	130 (2050) 200 (2070)	200	140	100

4.3.2 Freight Transport: Demand and Modal Shift

BTKMs projections

India's freight transport growth is closely tied to its economic development, with rising incomes and industrial expansion driving increased demand for movement of goods. In 2025, Tonne Kilometres (TKM)/Capita stood at 3,300, with total freight transport reaching 4,661 BTKMs. Under Current Policy Scenario (CPS) , TKM/Capita is projected to increase nearly 3 times to 10,000 by 2070. In contrast, Net Zero Scenario (NZS) anticipates a slightly lower growth to 8,000 TKM/Capita, influenced by sustainability-driven policies that promote efficient logistics, rail freight expansion, electrification, and multimodal transport solutions (See Figure 4.7).

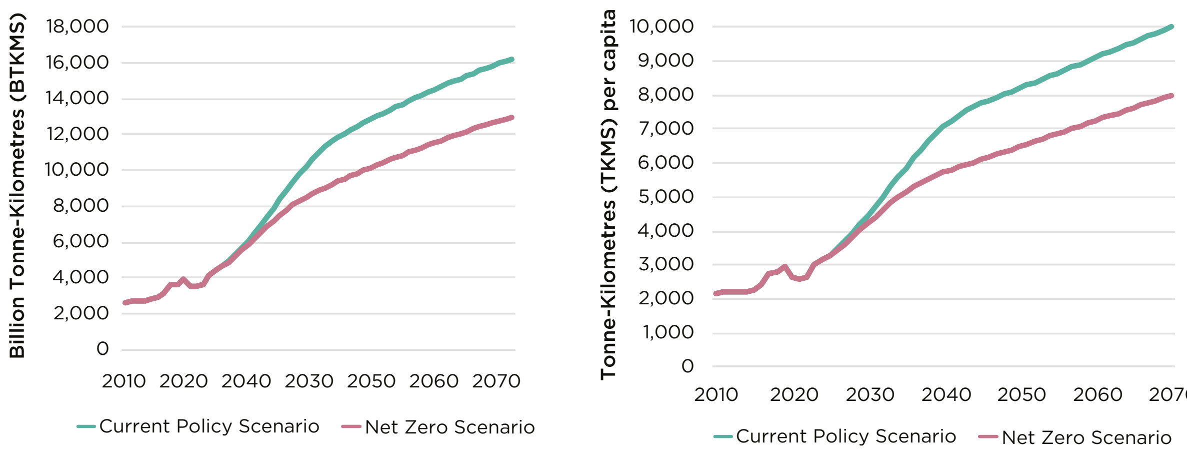


Figure 4.7: Projected growth in freight transport demand under Current Policy Scenario and Net Zero Scenario till 20270

ii STEPS (Stated Policies Scenario): Reflects the trajectory of the energy system under governments' existing and explicitly announced policies and measures.

iii APS (Announced Pledges Scenario): Assumes all announced climate and energy pledges, including long-term net-zero targets, are achieved in full and on time.

Global trends show that freight movement generally rises with GDP per capita (Agriculture+ Industry), but the correlation is not uniform (See Figure 4.8) and is influenced by factors such as geography, economic structure, and transport efficiency in shaping freight demand. Countries like the US and Australia have high tonne-kilometres per capita due to dispersed geographies and long-haul freight needs, while European nations have lower freight intensity despite high GDP, reflecting compact economies and efficient logistics. In Asia, China's high TKM per capita relative to its GDP highlights its freight-heavy industrial model.

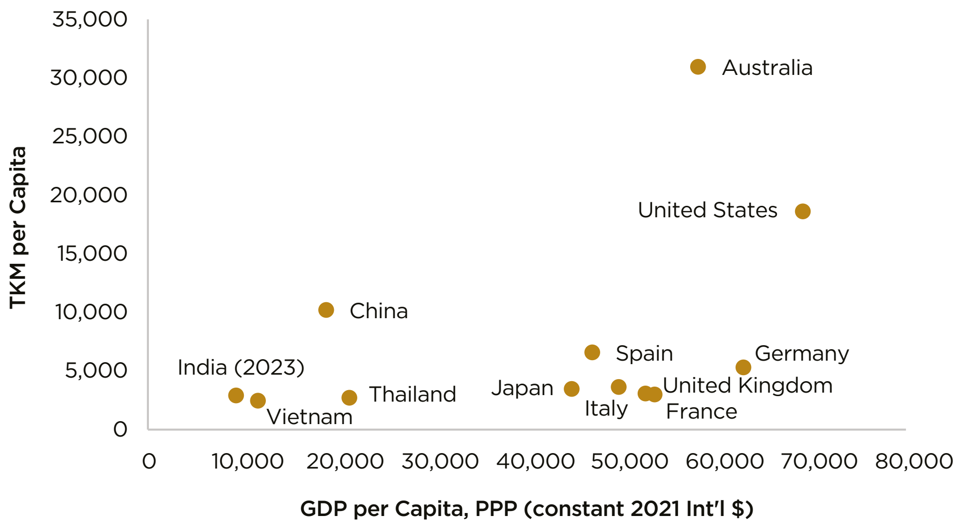


Figure 4.8: Global comparison of Freight demand per capita as a function of Income (GDP per capita)

Modal shift

India's freight mix will change differently under the Current Policy Scenario (CPS) and Net Zero Scenario (NZS) pathways, influenced by investments, policies, and decarbonisation priorities. Road freight remains the main mode in both scenarios but gradually loses share. Under CPS, road's share declines slightly from 66.4% in 2025 to 65.4% by 2070, reflecting a continued reliance on road-centric logistics typical of developing economies. In contrast, in the NZ scenario, road's share drops more substantially to 60% by 2070, as rail and waterways gain a larger share due to sustained policy support and infrastructure expansion (Figure 4.9).

Rail: Rail freight is expected to have a modest but meaningful recovery compared to its historical decline.

- Under Current Policy Scenario (CPS), rail's share rises from 22% in 2025 to 25% by 2070, driven by DFCs, higher train speeds, terminal modernization, and tariff rationalization.

- Under Net Zero Scenario (NZS), rail share goes up to 30% by 2070, supported by better efficiency and the inherent energy and carbon advantages of rail for long-haul logistics.

In absolute tonnage, Current Policy Scenario (CPS) and Net Zero Scenario (NZS) project 4.7-5.2 BT by 2050, aligning closely with Scenario 4 of the National Rail Plan, which assumes moderate tariff reductions. However, these remain below the plan's most ambitious scenarios (6.1-6.8 BT), which would require even greater interventions like faster train speeds, further tariff rationalization, and integrated multimodal logistics networks.

National Rail Plan - 2030

The **National Rail Plan (NRP) 2030** aims to create a 'future-ready' Indian Railway system, focusing on increasing the freight modal share to 45%, reducing transit times, and building capacity to meet demand through 2050.

Key strategies include 100% electrification, multi-tracking of congested routes, upgrading speeds to 160 kmph on Delhi–Howrah/Delhi–Mumbai and 130 kmph on other Golden Quadrilateral/ Golden Diagonal routes, and eliminating all level crossings on these corridors. The plan also identifies new Dedicated Freight Corridors and High-Speed Rail Corridors, assesses rolling stock and locomotive requirements, and encourages sustained private sector participation in operations, terminals, and infrastructure development

Waterways: Maritime Amrit Kaal Vision 2047 targets a fourfold increase in port capacity from 2,700 to 10,000 MMTPA and cargo handling growth from 109 MMTPA to 500 MMTPA by 2047. As a result, freight movement over waterways, is expected to quadruple by 2047 and then stabilise through 2070. Consequently, waterways' share stays around 8% in both scenarios.

Pipelines: They evolve differently across scenarios.

- Under Current Policy Scenario (CPS), higher reliance on fossil fuels leads to a doubling of PTKM by 2070, maintaining a ~2% modal share.
- Under Net Zero Scenario (NZS), pipeline volumes remain broadly stable but shift toward low-carbon fuels, while the modal share declines slightly to ~1.5% by 2070 as fossil fuel-based transport reduces.

This means that CPS delivers only incremental modal shifts, leaving road as the dominant mode and limiting efficiency gains while NZS achieves a more transformative rebalancing, with rail and waterways playing a much larger role, aligning India's freight decarbonisation with global best practices in the EU, China, and Switzerland. Greater alignment with the most ambitious National Rail Plan scenarios could unlock even higher freight rail potential, positioning it as the low-carbon backbone of India's logistics network.

Air: Air transport currently plays a limited role in India's freight movement, accounting for about 1.82 BTKMs in 2023, or approximately 0.04% of total freight activity. Air freight is projected to remain a niche mode, accordingly, its share in overall freight transport is expected to stay well below 1% under both the CPS and NZS through 2070, with growth in absolute volumes largely constrained to specific cargo segments such as express delivery, pharmaceuticals, and electronics.

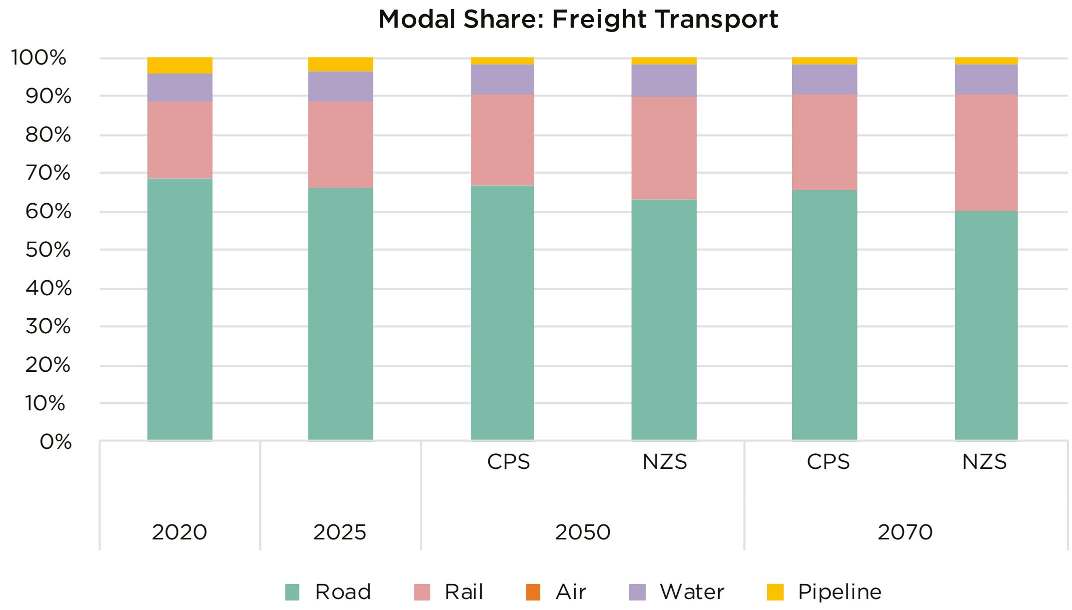


Figure 4.9: Modal shift projections of freight transport till 2070 under Current Policy Scenario (CPS) and Net Zero Scenario (NZS) highlighting increase in rail share

Freight Transport: Vehicle Ownership

India had approximately 1.5 crore registered freight vehicles in 2022. Of these 59% had payload capacity up to 3.5 tonnes, 6% had 3.5-12 tonnes, and 35% above 12 tonnes. According to SIAM data, about one million new freight vehicles were sold domestically in 2024.[79]

Freight vehicles up to 3.5 tonnes, which currently dominate the market, experience the fastest growth in both scenarios due to rising demand for last-mile delivery and urban logistics. Under Current Policy Scenario (CPS), they are expected to increase from 7 per 1000 people in 2025 to 30 per 1000 by 2050 and 36 per 1000 by 2070. In the Net Zero Scenario (NZS) pathway, their growth is expected to reach 40 per 1000 by 2070. Medium freight vehicles (3.5-12 tonnes) grow more moderately, from 0.7 in 2025 to 6.8 (CPS) and 7.5 (NZS) per 1000 people by 2070, supporting regional and mid-distance logistics. Heavy-duty freight vehicles (above 12 tonnes) grow from 2.4 to 6.4 per 1,000 people (CPS) and 4 per 1000 people (NZS), reflecting a strategic shift towards rail and low-carbon alternatives for long-haul freight movement in a sustainable transport future (Table 4.4).

Table 4.4: Freight vehicle ownership projections 2070 (per 1000 population)

Freight Vehicle Ownership Projections 2070 (Per 1000 Population)			
	Current (2025)	Current Policy Scenario (2070)	Net Zero Scenario (2070)
< 3.5 Tonnage	7	36	40
3.5–12 Tonnage	0.7	6.8	7.5
> 12 Tonnage	2.4	6.4	4
Total	**10.1**	**49.2**	**51.5**

When compared to global benchmarks**,** India's projected freight vehicle density by 2070 remains below today's U.S. and EU levels. The EU has about 80 commercial vehicles per 1,000 people, while the US has a higher density of ~89 commercial trucks per 1,000 population (excluding SUVs and pickups).

By contrast, India currently has ~10 commercial vehicles per 1,000 people at last count (2025), which is among the lowest ownership rates globally. India's projected 2070 levels of 49 per 1000 under Current Policy Scenario (CPS) and 52 per 1000 under Net Zero Scenario (NZS), with the marginally higher level under NZS reflecting a greater presence of light commercial vehicles and service-oriented fleets enabled by improved infrastructure, stronger inter-city connectivity, and more integrated urban systems.

The Net Zero Scenario emphasises a balanced logistics model, where light and medium-duty vehicles grow strongly to support urban and regional deliveries, while heavy-duty trucks remain constrained due to a deliberate modal shift toward rail and waterways for long-haul freight. This approach mirrors European multimodal logistics systems, which rely less on heavy trucks despite high overall freight volumes.

4.3.3 Technology Transitions: Electrification, Gas, and Alternative Fuels

Electrification of passenger and freight transport

Global & Domestic EV Landscape: Global EV adoption is uneven, shaped by national priorities and infrastructure. China leads with 64% of global electric car sales in 2024, supported by strong mandates and battery manufacturing. The US and Europe are expanding, with nations like Norway achieving nearly 80% EV sales. India's EV ecosystem is at a turning point, enabled by FAME incentives, reduced GST, and cost competitiveness, though future adoption hinges on sustained policy, infrastructure, and technological push. However, large-scale adoption still faces challenges such as high upfront cost, sparse charging infrastructure, limited technological readiness, high import dependency and lacks consumer awareness.

In this background, projections from NITI Aayog's scenario analysis illustrate the divergent Current Policy and Net Zero pathways. While adoption of electric mobility technologies including its derivatives accelerates across all passenger vehicle categories under NZS, particularly after 2030, the CPS exhibits a more gradual transition. Even with higher electrification, there remains a significant role for biofuel compatible vehicles, reflecting the scale of sectoral growth and the diversity of use-cases, alongside and in combination with the electric options. This contrast underscores the critical role of policy ambition, infrastructure rollout, and technology investment in shaping India's transport decarbonisation trajectory.

Table 4.5: xEV Penetration projections on annual sales for passenger & freight vehicles till 2070 for Current Policy Scenario (CPS) and Net Zero Scenario (NZS)

	Current Policy Scenario		Net Zero Scenario	
	2050	2070	2050	2070
2W	100%	100%	100%	100%
3W	90%	90%	100%	100%
4W-Cars	60%	80%	70%	85%
4W-Taxi	60%	80%	95%	95%
Bus	80%	80%	90%	90%
Vehicles payload upto 3.5 tonnes	60%	80%	90%	95%
Vehicles payload from 3.5-12 tonnes	15%	60%	50%	95%
Vehicles payload above 12 tonnes	4%	50%	25%	80%

xEV: Electrified vehicles (generic term for all types of electric vehicles i.e., Battery EV, Strong Hybrid EV, Range Extender EV, Plug-in Hybrid EV). Within the xEV portfolio, Battery EVs represent the dominant technology in terms of market penetration and deployment in the study, while other technologies are assumed to be of limited penetration.

Key Enablers & Challenges: Scenarios from analysis by think-tanks suggest early dominance of two- and three-wheeler EVs due to favourable economics. However, hurdles remain in the form of high upfront cost, urban charging gaps, reliance on coal-based electricity, and critical mineral supply risks. To ensure a secure and sustainable transition to EVs, investment in public charging, diversification of battery supply chains, and R&D in alternative chemistries must be scaled. Energy security is another major concern as a dependence on critical minerals, especially lithium, cobalt, etc. poses strategic risks. India will need to secure diversified supply chains, invest in recycling ecosystems, and promote research in alternative chemistries like sodium-ion or Lithium Iron Phosphate (LFP) batteries to address these risks.

Role of natural gas

The share of CNG/ LNG in India's transport sector particularly in cars, buses, taxis and trucks is expected to rise steadily until around 2047, after which it is expected to plateau. In the medium term, CNG/LNG is being leveraged as it offers lower emissions compared to traditional petrol and diesel, especially in urban public transport systems and high-mileage commercial fleets. For India, natural gas plays a vital role in reducing local air pollution and enhancing energy affordability while providing an immediate decarbonisation pathway during the ramp-up of electric and hydrogen-based mobility ecosystems. However, post 2047, the strategic emphasis is expected to shift decisively toward zero-emission technologies, in line with India's Net Zero vision. Natural gas share in transport is projected to decline as EVs reach cost parity, green hydrogen becomes more accessible, and ethanol-powered flex hybrids and battery-electric models expand across all vehicle classes. It is also important to decarbonise the grid from the present ~76.8% share coming from fossil origin.

This trajectory mirrors global energy strategies, where natural gas, including Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG), is increasingly seen as a clean alternative. Countries like the United States, Italy, and China have scaled CNG deployment primarily in urban public transport and freight fleets to reduce particulate emissions and meet interim climate targets. However, beyond 2040, as battery electric vehicles (BEVs) and fuel cell technologies mature and infrastructure scales up, the role of natural gas is expected to taper with scale-up of Compressed Bio-Gas (CBG) re-purposing the existing infrastructure.

Role of Alternate Fuels

Hydrogen fuel cell technology is being considered as an option for heavy-duty mobility and longer-range applications. Japan and South Korea have spearheaded national hydrogen strategies, with OEMs like Toyota (Mirai) and Hyundai (Nexo) commercialising fuel cell passenger vehicles, while also pushing fuel cell buses and trucks for logistics and transit sectors. Germany is investing in hydrogen corridors and refuelling infrastructure to support fuel cell deployment in commercial fleets. However, challenges around hydrogen production costs, infrastructure rollout, and vehicle affordability remain key bottlenecks for mass adoption.

Similarly, flex-fuel hybrid vehicles have been integral to Brazil's transport decarbonisation story. With over 85% of light-duty vehicles being flex-fuel compatible, Brazil has successfully leveraged domestic ethanol production to reduce oil imports and transport-sector emissions. These hybrids are now being adapted with electrified powertrains, creating a powerful synergy between biofuels and electrification.

In India, the push toward fuel cell and ethanol-based technologies is gradually strengthening, driven by a dual imperative, reducing oil imports and ensuring energy diversification, in the mobility sector. The government has initiated pilot projects on green hydrogen-powered buses, notably in cities like Delhi and Pune, and is incentivising R&D on fuel cell stacks under the National Hydrogen Mission. Concurrently, major OEMs, including Toyota and Maruti Suzuki, are exploring flex-fuel hybrid models tailored to Indian conditions. The Ministry of Road Transport and Highways (MoRTH) has mandated that vehicles sold in India be compatible with E20 fuel (20% ethanol blend), while promoting the transition toward E100-ready flex-fuel engines, which can achieve near-zero lifecycle emissions.

India's Net Zero Scenario (NZS) envisions the emergence of hydrogen fuel cell vehicles (HFCVs) and flex-fuel hybrids as complementary solutions to BEVs, especially in segments where electrification faces technological or infrastructural constraints. By 2070, hydrogen based buses and heavy commercial trucks are expected to account for up to 5% and 20% respectively of the overall sales respectively in NZS, offering a low-emission alternative particularly suitable for long-range and high-utilisation applications, versus limited penetration in Current Policy Scenario (CPS). Likewise, flex-fuel cars, designed to run on 100% ethanol, are projected to constitute around 10% of car sales share by 2050 under the NZS and saturate thereafter[iv]. These vehicles combine internal combustion engines (ICE) optimised for ethanol, providing both energy flexibility and near-zero lifecycle emissions when powered by sustainable biofuels.

As battery electrification accelerates, fuel cell and flex-fuel hybrid technologies will serve as critical enablers of a diversified, resilient, and inclusive clean mobility transition. Together, they form part of a broader technological portfolio that can deliver on India's long-term goals of energy security, industrial competitiveness, and deep decarbonisation in transport. It is also expected that India's renewable energy capacity will have enhanced substantially to be able to decarbonise the grid and offer green power for green hydrogen manufacture in both NZS and CPS.

4.3.4 Transport Energy Demand

India's passenger and freight transport sectors consumed total of 137 Mtoe energy in 2025. It is noteworthy that the average intensity of passenger transport (11.5 toe per million PKM) and freight transport (14.0 toe per million TKM), aligns with global averages at 12–14 toe per million PKM and 14–17 toe per million TKM respectively.

As mobility expands, overall transport energy use increases in the medium term and subsequently moderates toward 2070 as the transport system evolves. In the Current Policy and Net Zero scenario total final transport energy reaches 335 Mtoe and 250 Mtoe respectively by 2050, and further declines to 307 Mtoe and 192 Mtoe by 2070. The evolving fuel break-up underlying these trajectories is also illustrated in Figure 4.10/ Table 4.6 and discussed in the subsequent section.

Against an almost fourfold increase in passenger and freight demand (BPKMs and BTKMs) by 2070, transport energy use increases by only about 2.2 times under Current Policy Scenario (CPS). While under Net Zero Scenario (NZS), even as BPKMs and BTKMs grow by more than three times, total energy use is moderated to only about 1.4 times in 2070 compared to 2025 level. These trends reflect the efficiency dividend from electrification, modal shift toward public and rail-based transport, and improved vehicle technologies, as shown in Figure 4.11.[80]

iv Beyond 2055, FFVs are assumed to operate on pure ethanol (near 100% ethanol), and CBG vehicles are assumed to operate on pure Compressed Bio-Gas.

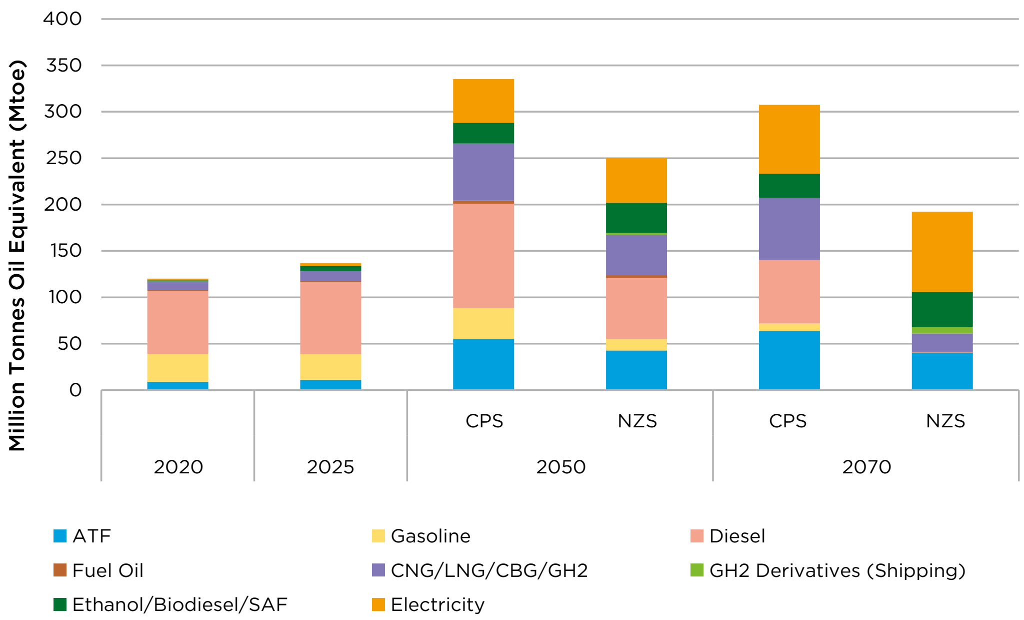


Figure 4.10: Transport energy demand under Current Policy Scenario (CPS) and Net Zero Scenario (NZS) until 2070 in Million Tonnes of Oil Equivalent (Mtoe)

The lower transport energy use in Net Zero Scenario (NZS) is a result of multiple factors; Transport Demand driven by Transit-Oriented Development (TOD), Modal Shift, share of public and private vehicles in road transport, fuel efficiency and technology shift. Under TOD, reductions also come from promoting shared mobility and prioritising Non-Motorised Transport (NMT), supported by proactive planning strategies that collectively reduce reliance on private Motorised travel and, consequently, reduction in energy consumption as compared to Current Policy Scenario.

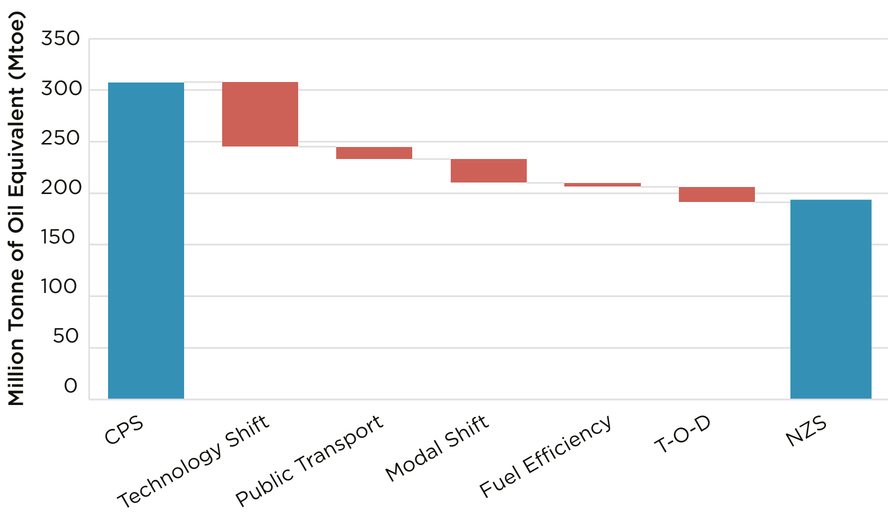


Figure 4.11: Drivers for lower energy use in Net Zero Scenario (NZS) by 2070 compared to Current Policy Scenario (CPS)

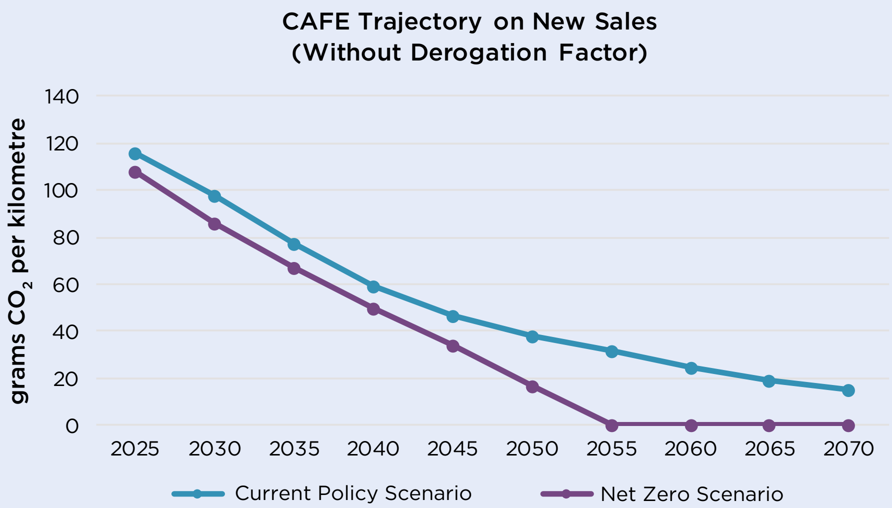
This transition hinges on the successful implementation of India's CAFE norms (see Box below). The progressive extension of fleet-wide CO_2 standards under CAFE III (91.7 g/km) and IV (70 g/km) provides the regulatory foundation for the efficiency gains. Additional wedges come from modal shift (20%) as passenger trips and freight tonnes move toward buses/metro/rail and waterways, while demand moderation (13%), through compact urban form, telework, pricing, and better land-use, caps vehicle-kilometre growth. Technology shift leads to 53% reduction, majorly due to electrification, while operational improvements (3%) deliver additional reductions through eco-driving, higher load factors, and logistics optimisation.

CAFE Norms – Driving Efficiency in the Road to Net Zero

India's Corporate Average Fuel Efficiency (CAFE) norms represent a critical regulatory tool for reducing fuel consumption and tailpipe CO_2 emissions in the passenger vehicle segment. Notified under the Energy Conservation Act and administered by the Bureau of Energy Efficiency (BEE), CAFE norms set manufacturer-level, sales-weighted average CO_2 emission limits for new passenger cars sold in India, indexed to the vehicle's unladen weight. India's framework includes super-credits (e.g., counting each EV as multiple vehicles for compliance), and derogation factors for off-cycle technologies like start-stop systems, regenerative braking, and efficient transmissions. However, these should be progressively phased out to maintain the integrity of actual emission reductions.

Introduced in 2015, the first cycle (CAFE 1, 2017-22) targeted an average CO_2 emission level of approximately 130 g/km for average weight of 1037 kg (based on MIDC cycle), which was tightened to 113 g/km under CAFE II by 2022–23. CAFE norms use a mass-based linear equation for calculating the corporate average CO_2 target:

$$\textit{Corporate Average Target } CO_2 = a + b \times (M - Mo)$$



As per the Net Zero pathways modelling, India's CAFE trajectories are illustrated in the adjacent chart, which shows a linear reduction of fleet CO_2 emissions. This pathway implicitly assumes a sharp increase in the market share of zero-emission vehicles (ZEVs)— reaching 100% ZEV sales by around 2055 to allow fleet-level emissions to taper to zero by 2070. Beyond 2055, FFVs are assumed to operate on pure ethanol (near 100% ethanol), and CBG vehicles are assumed to operate on pure Compressed Bio-Gas. Further, CAFE should incentivise the adoption of light weight, fuel-efficient, smaller entry-level cars as is increasingly the case in leading global markets, while also accounting for the lifecycle emissions benefits and carbon sequestration potential associated with sustainable biofuels.

To ensure that CAFE norms remain credible and future-ready, India must adopt a time-bound plan to sunset the relaxations and shift toward true lifecycle-zero vehicles. Doing so will not only align with the modelled Net Zero pathway but also prepare the domestic auto industry for global low-emission export standards.

a = baseline CO_2 coefficient (g/km), b = slope coefficient (g/km/kg), M = sales-weighted average kerb mass of the OEM fleet (kg), Mo = reference mass (e.g., 1170 kg in the draft CAFE III)

Transport Energy Demand and Fuel Mix

Currently, nearly 93% of energy used in India's transport sector is from petroleum products and gas. Under the Current Policy Scenario (CPS), the system remains fossil-heavy: by 2050, over three-fourth of supply is still fossil, and even by 2070 fossil fuels remain at 64% of the transport energy mix.

Table 4.6: Projections of fuel demand under Current Policy Scenario and Net Zero Scenario by 2050 & 2070

Fuel Type	2025	2050		2070	
		Current Policy Scenario	Net Zero Scenario	Current Policy Scenario	Net Zero Scenario
Aviation Turbine Fuel (ATF)	8%	16%	17%	21%	21%
Petrol	20%	10%	5%	3%	0%
Diesel	56%	34%	26%	22%	0%
Fuel Oil	1%	1%	1%	0%	0%
CNG/LNG/CBG/GH2	8%	18%	17%	22%	10%[v]
GH2 Derivatives (Shipping)	0%	0%	1%	0%	4%
Ethanol/Biodiesel/SAF	4%	7%	13%	8%	20%
Electricity	2%	14%	19%	24%	45%
Total Energy (Mtoe)	**137**	**335**	**250**	**307**	**192**

Under Net Zero Scenario (NZS), however, the mix pivots decisively toward low-carbon carriers after 2050. By mid-century, electricity, biofuels, and hydrogen collectively account for almost half of transport energy use, rising to nearly 80% by 2070. Petroleum products

v consists only clean fuels

phase out almost entirely from road transport, leaving Aviation Turbine Fuel (ATF) as the main residual fossil fuel – highlighting the difficulty of decarbonising aviation (Refer Figure 4.10 and Table 4.6).

With a decisive shift away from import dependent oil and gas, Net Zero signals reduced exposure to oil-price shocks and improves macro stability – an effect emphasised in the World Economic Outlook (WEO 2023)[81] and broader literature linking clean energy uptake with reduced price volatility risks.

Gas as an alternative fuel: India's transport sector is expected to see CNG and LNG grow steadily until around 2050, serving as an effective bridge fuel for urban buses, taxis, and high-mileage freight fleets. This growth helps cut local air pollution and reduce costs while the ecosystems for electric and hydrogen-based mobility scale up.

The long-term trajectory of natural gas in transport diverges depending on policy choices. In Current Policy Scenario (CPS), gas demand is expected to rise, potentially reaching 65 Mtoe by 2070, which risks locking in fossil assets and slowing the transition.

By contrast, in Net Zero Scenario (NZS), natural gas consumption in transport is projected to peak at about 32 Mtoe around 2045, plateaus briefly, and then transitions to clean fuels i.e., CBG as battery-electric, fuel-cell vehicles, and ethanol-ready flex hybrids reach cost parity and their infrastructure expands. In this scenario, only Bio-CNG/CBG continues beyond 2055, serving hard-to-electrify heavy-duty vehicles and passenger vehicles.

India's strategic emphasis must therefore shift decisively toward zero-emission technologies, with gas infrastructure designed for flexible repurposing into EV fast-charging or hydrogen refuelling hubs, and biomethane.

Natural gas has a valuable but time-limited role in India's transport transition. It can cut near-term pollution and costs, while the country builds out EVs, hydrogen, and a cleaner grid. Greater emphasis can be placed on improving the uptake of CBG which is sustainable and carbon-neutral/negative fuel.[82]

EV Systems Planning: The electricity demand is projected to rise to 48 Mtoe in Net Zero Scenario (NZS) and 47 Mtoe in Current Policy Scenario (CPS) by 2050. Even with higher electrification under NZS, the demand is nearly similar to CPS due to lower travel demand in NZS. Both CPS and NZS implies a substantial increase in electricity demand from transport sector, underscoring the need for robust distribution upgrades and widespread depots/fast-charging for trucks and buses, managed charging and time-of-use signals to flatten peaks. Moreover, share of renewable energy should also increase in primary energy mix. Since RE does not have the conversion losses typically seen in thermal power, this would mean that electrification of mobility sector shall have relatively lower impact on overall primary energy demand going into the future.

Hydrogen's targeted role after 2040: Hydrogen use under Net Zero Scenario (NZS) increases to about 3 million tonnes by 2050 and about 8 million tonnes by 2070. This includes green hydrogen derivatives consumed in shipping sector (E-methanol and Green Ammonia) of 0.9 million tonnes by 2050 and 2.9 million tonnes by 2070. This aligns with Global views that long-haul trucking, shipping (via ammonia), and synthetic fuels are prime early demand sectors in transport. This will require a high capacity of electrolysers and renewables.

Aviation as last challenging frontier: Aviation dominates the remaining liquid fuel component in Net Zero Scenario (NZS). ATF demand is projected at 43 Mtoe in 2050 and slightly decreases to 40 Mtoe in 2070. This is consistent with global literature identifying aviation as among the hardest modes to decarbonise rapidly and therefore reliant on liquid fuels and SAF.

Biofuels: India's experience over the past few years shows how quickly policy, supply-chain readiness, and demand alignment can scale a clean energy solution such as biofuel. India's rapid ethanol scale-up provides the launchpad. From a negligible base a decade ago, nationwide blending rose to 20% in mid-2025, five years ahead of the original 2030 target. The next step is to extend this experience beyond gasoline blending into the wider family of sustainable fuels.

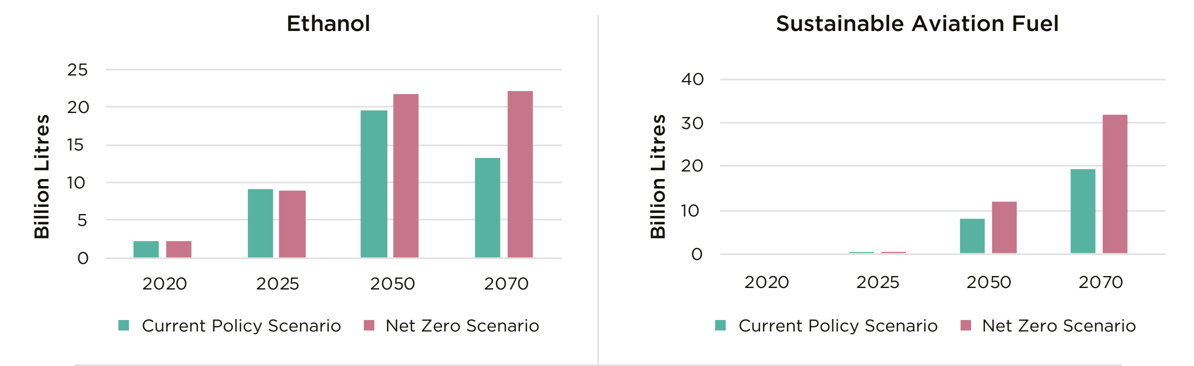


Figure 4.12: Biofuel demand under Current Policy Scenario and Net Zero Scenario by 2050 and 2070

Under Current Policy Scenario (CPS), biofuel is primarily used for road transport. Ethanol peaks at about 20 billion litres in 2050 and drops to 13 billion litres in 2070. This decline after 2050 is due to increased electrification in transport sector. In contrast, under Net Zero Scenario (NZS), ethanol plateaus at around 22 billion litres after mid-century. Flex-fuel vehicles act as a demand-side accelerator here by enabling operation on higher ethanol blends (E20–E85/E100) without range anxiety (Figure 4.12).

Under Current Policy Scenario (CPS), SAF adoption increases from about 8 billion litres in 2050 to 19 billion litres in 2070. While under Net Zero Scenario (NZS), SAF rises from about 13 billion litres in 2050 to 32 billion litres by 2070.

By 2050s, flex-fuel cars designed to run entirely on ethanol are projected to constitute around 10% of car sales under the Net Zero Scenario (NZS). These vehicles combine internal combustion engines optimised for ethanol, offering both energy flexibility and near-zero lifecycle emissions when powered by sustainable biofuels.

Biofuel supply potential in India:

India's ethanol production currently relies mainly on maize (~50%) and sugarcane (~30%), with the remainder coming from damaged food grains and other sources. According to the NITI Aayog Crop Husbandry Report on Demand and Supply (2024), by 2047–48, India's food grain production is expected to exceed domestic demand, creating a surplus of over 40 million tonnes. This potential surplus could support ethanol production of more than 16 billion litres, which would cover a substantial portion of the expected ethanol requirement of around 22 billion litres, indicating feedstock availability for higher blending goals without compromising food security.

Beyond ethanol, there is also notable potential for other biofuel pathways. For CBG, The International Energy Agency (IEA) estimates India's biogas potential at around 87 billion cubic metres (BCM), suggesting significant scope for gaseous biofuels in transport sector. For SAF, the Feasibility Study on the Use of Sustainable Aviation Fuels in India (conducted under the ICAO ACT-SAF Programme) indicates significant potential for developing a domestic SAF industry, with production estimates cited around 41.5 billion litres.

At the same time, competing biomass uses will persist, requiring careful assessment of trade-offs related to cost, energy balance, water use, and emissions.

Life Cycle Assessment of Mobility Technologies – Looking Beyond Tailpipe Emissions

As India accelerates toward its Net Zero goals, it is essential to evaluate transport technologies not just through the lens of tailpipe emissions, but across their entire life cycle. A Life Cycle Assessment (LCA) approach provides a comprehensive view of environmental impacts, spanning vehicle production, fuel or electricity generation, use-phase emissions, and end-of-life treatment. This is particularly relevant for emerging technologies like battery electric vehicles (BEVs) and hydrogen based vehicles, whose environmental benefits vary significantly depending on energy sources and materials used.

BEVs are often labelled as zero-emission vehicles due to their lack of tailpipe (tank-to-wheel) emissions. However, this is only one component of their environmental footprint. BEVs typically incur significantly higher emissions during the production phase, particularly from battery manufacturing, which relies on energy-intensive extraction and processing of critical minerals like lithium, cobalt, and nickel. When these emissions are added to those from electricity generation (well-to-tank), especially from a coal-dominated power mix like India's, the total life cycle emissions can be substantial. In fact, recent studies from IIT Kanpur and TERI suggest that under current conditions, BEVs may need to be driven for around 1.5 lakh kilometres to offset their initial emissions and become environmentally advantageous compared to internal combustion engine vehicles.

Hybrid vehicles, due to their balanced efficiency and lower reliance on high-impact battery systems, often outperform BEVs under current Indian grid conditions. However, there exists studies which indicate otherwise. ICCT and IIT Madras studies point that BEVs have lower emissions even at current grid emission factor on lifecycle basis. Further, a TERI study suggests that Bio-CNG can be carbon-negative, and that blending it up to 20% with fossil CNG can make the overall fuel close to carbon neutral on a life-cycle basis[vi]. Considering these mixed and non-conclusive evidence, NITI Aayog has launched a study on developing lifecycle assessment for EVs Vs ICEs based on transparent set of assumptions.

It is complex to compare two vehicle models based on their functionality which could differ based on Power Output, Occupancy, Affordability, Weight, etc. Various literatures that tailpipe-zero options like BEVs and hydrogen based vehicles only deliver full climate benefits when powered by clean energy sources. These results could widely differ for different segment of vehicles (small, compact, and heavy), also based on biofuel belnding scenarios. The above findings highlight a critical insight: the decarbonisation potential of new mobility technologies is not inherent, but highly contingent on upstream energy and materials.

A life cycle perspective is essential for designing robust and future-ready mobility policies. It shows that electrification alone does not guarantee decarbonisation, especially when deployed in isolation from grid and supply chain reforms. India's Net Zero strategy should prioritise not just tailpipe emissions reductions, but system-wide sustainability. This includes diversifying vehicle technologies based on application, such as BEVs for urban logistics, hybrids for personal and mid-range mobility, and hydrogen based vehicles for long-haul freight, while strengthening domestic manufacturing, ensuring circularity through battery reuse and recycling, and rapidly decarbonising the power and hydrogen supply chains.

vi *Indian Institute of Technology Kanpur (IIT Kanpur). Life Cycle Assessment (LCA) and Total Cost of Ownership (TCO) Analyses of Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), and Internal Combustion Engine Vehicles (ICEVs). Engine Research Laboratory, IIT Kanpur.*

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5

CHALLENGES IN THE TRANSPORT SECTOR TRANSITION

5

Challenges in the Transport Sector Transition

The preceding chapter outlined India's transport transition trajectory across the Current Policy Scenario (CPS) and Net Zero Scenario (NZS) pathways, highlighting the scale of transformation required through electrification, fuel diversification, modal shift, and efficiency improvements. While these results demonstrate the technical feasibility of a low-carbon transition, they also underscore that achieving such outcomes will require addressing a set of persistent and emerging constraints across the transport system.

In this context, this chapter maps the key challenges in India's transport landscape, structured into five thematic clusters aligned with the core policy response pillars: (i) Clean Mobility Transition, (ii) Infrastructure Utilization, (iii) Fuel Diversification, (iv) Systemic Gaps, and (v) Public Transport & Modal Integration. These challenges are closely aligned with, and intended to inform, the suggestions proposed for enabling the sector's Net Zero transition.

5.1 Accelerating the Clean Mobility Transition

I. Insufficient EV Charging Infrastructure

India has only 52 public charging points per million people, compared with 2,540 in China and 580 in the US[83]. This shortage drives up costs, increases range anxiety, and slows EV adoption, particularly for high-utilisation fleets that need fast-charging options. Large variation is observed in electricity price depending on the charging point location. For example, home charging electricity price varies from 6-10 INR per unit (depending on the time of the day), while public alternating current (AC) charging varies from 10-14 INR per unit and public direct current (DC) charging cost varies from 18-22 INR per unit[84]. AC chargers are slow, and fast DC chargers are expensive and limited.

II. Different Total Cost of Ownership (TCO) Parity Across Segments

While two-wheeler EVs have achieved Total Cost of Ownership (TCO) parity, heavier vehicles are yet to do so. Batteries still make ~40% of the total cost of EV[85], replacement batteries have 18% GST, and outdated Modified Indian Driving Cycle (MIDC) test overstates performance. This keeps freight and heavier segments unviable.

III. Import-Heavy EV Supply Chain

EVs need six times more minerals than internal combustion engines (IEA, 2021)[86] and India is dependent on Chinese imports for critical minerals, cells, chips, and power electronics. This makes India's EV transition vulnerable to international price shocks and geopolitical risks, limiting resilience and self-reliance.

IV. Limited Flex-Fuel Vehicle (FFV) Ecosystem

Flex fuels can play a complementary role in the clean mobility transition, particularly in hard-to-electrify vehicle segments. India's ethanol blending (19.9% in 2024-25[87]) saved significant foreign exchange and avoided petroleum imports. However, sparse retail infrastructure for dispensing E85/E100, pricing challenges, cautious OEMs, low consumer awareness and food vs. fuel trade-offs in first generation ethanol hinder growth.

V. Zero-Emission Vehicles[vii] (ZEVs) Acceleration

ZEV pathways can together enable diversified, low-emission vehicle options suited to Indian driving patterns and fuel availability. ZEVs which include Battery Electric Vehicles (BEVs), Hydrogen, Biofuels (FFVs and CBG) have no mandates in India. Without segment-wise targets and incentives, penetration remains low.

5.2 Underutilised Infrastructure and Modal Gaps

I. Underutilised Rail Infrastructure and Freight Modal Share

Despite contributing more than two-thirds of the railway revenue, freight uses only ~40% of network capacity with passenger trains getting precedence[88]. Average freight speeds remain at ~23.6 kmph due to shared tracks with passenger trains. While Dedicated Freight Corridors (DFCs) have raised speeds to ~40–45 kmph, their full potential remains unrealised[89].

II. Weak Private Participation in Rail Infrastructure

vii For the purpose of this study, Zero Emissions Vehicles mean vehicular fleet in which there are Net Zero greenhouse gas emissions after accounting of emissions throughout the value chain from production, operation, energy supply to end-of-life.

Private investment in terminals and wagons is low due to high capex, unclear revenue-sharing, and regulatory opacity. Without predictable returns, PPP-based modernisation will remain limited[90].

III. High-Cost, Low-Ridership Metro Systems

Metro expansion faces significant cost (up to INR 390 Crore/km[91]) and inadequate fare recovery. Poor last-mile access and land-use integration also supress ridership.

IV. Underutilised Liquefied Natural Gas (LNG) and Gas Infrastructure

Many LNG terminals operate below 50% capacity due to unaffordable prices[92]. Right of Way (RoW) delays, and low penetration in transport-sector stall growth and prevent a scale-up.

V. Weak Water Transport Infrastructure

Inland waterways and coastal shipping carry 8% of freight despite offering lower costs per tonne-km than road[93]. Shallow drafts, underdeveloped terminals, and poor multimodal integration hinder growth.

5.3 Fuel Diversification

I. LNG Trucking Potential for Medium and Heavy Commercial Vehicles (MHCVs)

LNG is a promising fuel for long-haul freight, releasing lower emissions than diesel. However, it faces high upfront cost[94] and limited refuelling stations. There are only around 29 refuelling stations nationwide (13 state owned and 16 private)[95].

II. Barriers to Sustainable Aviation Fuel (SAF) Adoption

India has sufficient biomass potential for SAF[96] but lacks feedstock collection and refining infrastructure. SAF is 1.5 times costlier than jet fuel and could promote unsustainable land use if dependent on first-generation feedstocks[97]. Achieving the 2% blend target by 2030 will require regulatory streamlining, capital incentives, and decentralised production capacity.

In addition, obtaining regulatory clearances for commercial SAF production can take a year or longer, creating a significant bottleneck.

III. Barriers to Decarbonising Air Travel

Electric and hydrogen aircraft offer near zero emissions but face technical and commercial barriers, especially for long-haul flights due to energy density and battery weight. R&D must continue, but short-term gains will come from SAF and improved fuel efficiency.

5.4 Strengthening Regulatory Architecture and Circularity

I. Gaps in Circularity and End of Life Vehicles (ELV) Management

India lacks formal End of Life Vehicles (ELV) recycling infrastructure. Informal scrappage dominates the sector, resulting in the loss of valuable materials and environmental risks[98].

II. Semi-High-Speed and High-Speed Rail (HSR) Potential

Indian Railways struggles to meet rising demand for air-conditioned services, pushing passengers to air travel and luxury buses. HSR can provide a high-comfort, low-alternative option but faces financing, land acquisition, and coordination hurdles[99].

5.5 Public Transport and Modal Integration

I. Declining Public and Shared Transport Use

Poor service quality and inadequate integration is reducing public transport usage in urban areas in the face of rising aspirations leading to greater adoption of private vehicles. Metro, Regional Rapid Transit System (RRTS), and bus systems should expand based on demand mapping. Last-mile electric feeders, mini-buses, and shared Intermediate Public Transport (IPT) (e-rickshaws, autos) should be integrated via Unified Metropolitan Transport Authorities (UMTAs).

II. Paratransit and Intermediate Public Transport (IPT) Regulation Gaps

Intermediate Public Transport (IPT) modes remain critical in many cities but lack regulation on safety, fares, and permits. Organising IPT under service and safety standards will improve reliability and complement formal transit.

III. Neglected Non-Motorised Transport (NMT)

According to a 2011 census, walking and cycling are used by 36% of commuters[100]. However, these modes still face a lack of investment and infrastructure that hinder more uptake.

6

TOWARDS NET ZERO TRANSPORT: KEY POLICY SUGGESTIONS

Towards Net Zero Transport: Key Policy Suggestions

6

In 2020, transport sector accounted for about 10% of India's GHG emissions and 20% of the country's total energy consumption. India's transport sector will require a fundamental transformation to reach Net Zero Emissions by 2070.

This chapter provides detailed key policy suggestions to achieve this goal, covering various segments such as urban transport, future-ready freight, pipeline infrastructure, EV ecosystem, biofuel economy, and more.

The section below provides a snapshot before going into more details for each suggestion.

Table 6.1: At a glance: Pathways for an efficient transport transition

Actions	Targets
Reimagining Urban Transport: Sustainability, Integration, and Equity	Shape urban transport systems around sustainability, integration, and equity
Future-Ready Freight: Infrastructure, Modal Integration, and Domestic Manufacturing	Modernise how India moves goods with cleaner fuels, domestic innovation, and modal integration
Strengthening Pipeline Infrastructure for Clean Fuel Transition	Position pipelines as efficient, low-carbon energy backbones for fuel transportation
Accelerating EV Adoption	Scale electrification with infrastructure, clean energy access, and circularity
Enhancing Energy Efficiency in India's Transport Sector	Raise fuel standards, modernise fleets, and keep market fair
Driving the Biofuel Economy: Innovation, Security, and Sustainability	Advance biofuels and Sustainable Aviation Fuel (SAF) to balance climate, energy security, and rural growth
Strengthening Vehicle Retirement and Recycling	Phase out old vehicles and fleets through scrappage ecosystems and incentives to deliver quick air quality wins
Promoting Non-Motorised and Active Transport	Expand safe, climate-resilient walking and cycling infrastructure
Enabling Systemic Transformation: Unified Governance, Digital Infrastructure, and Policy Innovation	Align governance, data, regulation, and innovation for long-term transformation

6.1 Reimagining Urban Transport: Sustainability, Integration, and Equity

As Indian cities grow in scale and complexity, urban mobility systems must evolve to become more inclusive, integrated, and environmentally sustainable. The following Suggestions outline a strategic approach to align infrastructure, governance, and planning with the diverse mobility needs of a rapidly urbanising population:

i. **Strengthen data-driven planning** through regular urban household travel surveys to assess current and latent travel requirements (e.g., last-mile connectivity) that would guide low-emission transport investments in urban and peri-urban areas.

ii. **Expand and integrate mass transit systems** such as sub-urban railway system, circular rail, metro rail, Regional Rapid Transit System (RRTS), and formal bus networks, ensuring alignment with demand patterns and user preferences.

iii. **Ensure seamless last-mile connectivity** by linking major transit systems with electric feeder buses, mini-buses, and shared mobility services, while formalising and regulating paratransit modes for safety and accessibility.

iv. **Transition State Transport Undertakings (STUs)** from operators to regulators by adopting models such as gross contracting, where private operators run services under public oversight.

v. **Introduce premium bus services** in urban areas with differentiated pricing and service quality, to move car users to public transport.

vi. **Enable shared mobility** by promoting/facilitating carpooling and ride-sharing services.

vii. **Promote compact, Transit-Oriented Development (TOD)** by embedding its principles in city master plans and revising land-use regulations to support high-density, mixed-use development near transit hubs.

viii. **Institutionalise coordinated governance** by empowering/establishing Unified Metropolitan Transport Authorities (UMTAs) in all major cities and mandating equity impact assessments for new urban transport projects.

6.2 Future-Ready Freight: Infrastructure, Modal Integration, and Domestic Manufacturing

The transition to sustainable freight transport in India demands simultaneous investment in clean energy adoption, enhanced modal efficiency, and domestic technological capability. The following steps outline a roadmap to decarbonise logistics while strengthening national energy security and create industrial self-reliance:

i. **Promote freight modal shift to rail** by setting clear freight rail targets, supported by dedicated funding including exploring PPPs (double tracking, increased axle loads & train lengths, scaling Dedicated Freight Corridors (DFCs)), reform freight pricing system to make it more competitive, and provide assured and timely delivery of goods, through an independent regulator.

ii. **Scale up inland water transport and coastal shipping** by using public cargo for transportation of goods such as fertilizers and coal to seed demand on strategic routes, especially along major perennial rivers in North-East India, and in coastal regions.

iii. **Optimise siting opportunities to multimodal logistics infrastructure** such as logistics parks, integrated freight corridors, and seamless trans-shipment facilities enabled by end-to-end digital platform to enhance the competitiveness of rail and water-based freight systems.

iv. **Accelerate clean fuel infrastructure** by expanding sub-urban railway system, circular rail, Compressed Bio-Gas (CBG), and flex fuel refuelling stations along highways, logistics hubs, and industrial corridors, with mandated station density to ensure accessibility and commercial viability.

v. **Enable fleet transition to cleaner fuels** through targeted fiscal incentives such as purchase subsidies, toll and tax exemptions.

vi. **Advance hydrogen mobility pilots** by scaling demonstration projects for hydrogen trains, hydrogen fuel based trucks and buses in high-payload sectors, using pilot results to guide broader deployment strategies.

vii. **Strengthen domestic manufacturing ecosystems** for clean freight technologies by supporting R&D and local production of components for cleaner vehicles including battery systems.

6.3 Strengthening Pipeline Infrastructure for Clean Fuel Transition

Pipelines are most energy efficient mode of oil and gas transportation. Transporting petroleum products via pipelines reduces the load on road and rail transport, thus easing congestion. Therefore, it is important to develop pipeline networks to ensure primary movement of petroleum products such as Petrol, Diesel, Aviation Turbine Fuel (ATF), and Liquefied Petroleum Gas (LPG) to distribution location/LPG installations be only through pipelines. In addition, beyond increasing near-term scale-up of Compressed Natural Gas (CNG) and

Liquefied Natural Gas (LNG) as transitional fuels, these pipelines must be envisioned as *future-ready assets* that are capable of facilitating the distribution of emerging low-emission fuels such as CBG, green hydrogen, hydrogen blend natural gas, synthetic methane, ethanol blends, Sustainable Aviation Fue (SAF), etc. The following steps are recommended to achieve the above scenario:

i. **Accelerate the build out of the national gas pipeline grid** by prioritising connectivity across industrial clusters, high-density freight corridors, urban transport zones, and into the hinterland to support increased adoption of cleaner fuels like CNG, LNG, and CBG.

ii. **Promote the use of existing and new pipelines for CBG integration** by enabling rural and agro-waste-based gas producers to access urban transport and industrial demand centres through the City Gas Distribution(CGD) network.

iii. **Support pilot integration of hydrogen blends** in natural gas pipelines, especially in industrial hubs and areas with high renewable energy potential, to build technical readiness and inform broader hydrogen infrastructure planning.

iv. **Maximise pipeline utilisation to decongest road and rail networks through petroleum product pipeline grid** by connecting all LPG and major petroleum distribution installations through pipelines. This strategic shift will free up critical capacity on rail and road networks, enabling them to better serve expanding passenger mobility and high-value freight segments.

v. **Design all new pipeline infrastructure with future compatibility in mind** by incorporating technical specifications that can accommodate the eventual transport of green hydrogen, biofuels, and SAF. This includes material compatibility, pressure ratings, and safety systems aligned with the specific properties of low-carbon fuels.

vi. **Promote slurry pipelines for bulk freight** to move iron ore and similar materials through pipelines instead of road/rail by undertaking feasibility studies for connecting major mines with ports and manufacturing plants. This can reduce both congestion as well as emissions.

6.4 Accelerating EV Adoption

Electrification of road transport must be aggressively pursued, with an enabling policy environment for infrastructure and market development. The key interventions that can help in accelerating electric mobility focus on systemic changes across vehicle electrification, charging infrastructure, finance, and policy frameworks to accelerate the adoption of electric vehicles in the country.

6.4.1 Strengthen the EV Charging Network

i. **Expand EV charging and battery swapping infrastructure** with density targets (1 charger per 30 EVs- like US, Norway, and 1 station per 50-100 km on highways). Develop shared charging hubs in urban clusters and along highway corridors, anchored by fleet operators. To address range anxiety for EVs, establish a nationwide network of Battery Charging cum Swapping Stations (BCSS) along National Highways, with priority to high-density freight and passenger corridors. The Government may consider allotment of land on long-term lease at concessional or promotional rates near highways to encourage the setup of BCSS. Prioritise the rollout of battery swapping networks for taxis, delivery fleets, and other high-utilisation vehicles, and set national and sub-national targets for charger and swapping station density, supported by clear standards for interoperability, safety, and accessibility.

ii. **Strengthen regulatory and financial enablers** by mandating EV-ready infrastructure in all new public buildings and 10-20% of private buildings, retrofitting existing public spaces, and providing capital and operational subsidies for charging infrastructure until it reaches commercial viability.

iii. **Enable intelligent and consumer-centric charging systems** through smart metering, time-of-day pricing, and rollout of vehicle-to-grid (V2G) integration standards. Institutionalise the right to demand an EV charger under consumer protection laws and operationalise digital visibility through a Unified Energy Interface (UEI) to support transparent and efficient energy use.

6.4.2 Accelerate EV Deployment and Availability of Clean Power

i. **Promote fleet electrification at scale** through aggregated procurement of e-buses and e-taxis, supported by risk-sharing guarantees and RESCO (Renewable Energy Service Company) models to reduce upfront capital costs. Prioritise electrification along the top 20 freight corridors by deploying charging and battery swapping infrastructure, offering time-bound toll waivers, and enabling demand aggregation.

ii. **Streamline clean energy access for EV charging** by unlocking virtual and group net metering pathways across all consumer classes, and simplifying adoption processes in states with existing regulations.

iii. **Introduce green tariff options** for EV users lacking access to on-site or direct renewable energy procurement.

iv. **Set domestic manufacturing targets** for EVs and components as a share of total production, with a focus on high-volume segments such as two- and three-wheelers, buses, and trucks.

6.4.3 Develop a Circular Economy for EV Batteries

i. **Strengthen battery end-of-life management** by ramping up collection, establishing deposit-refund or alternative recovery schemes, and adopting national guidelines for safe handling, transport and storage of retired lithium-ion batteries.

ii. **Promote battery circularity and reuse** through standards for refurbished and second-life applications, circularity-friendly battery design, and safety certifications to support safe dismantling, reuse, and resale of EV batteries.

iii. **Invest in battery innovation and traceability** by providing dedicated R&D funding for environmentally sustainable recycling technologies and developing a "Battery Aadhaar" system for traceability, data management and lifecycle monitoring.

6.5 Enhancing Energy Efficiency in India's Transport Sector

Improving energy efficiency in transport is essential to achieving a low-emission, high-performance mobility system. By embedding efficiency into the core of transport planning and operations, India can significantly reduce its energy footprint from mobility while supporting sustainable economic growth.

i. **Strengthen regulatory ambition** by advancing Corporate Average Fuel Efficiency (CAFE) norms, ensuring India remains competitive in adopting advanced automotive technologies covering all categories of vehicles and enhancing fuel efficiency. Further, Bharat Stage (BS) emission standards need to be aligned with global benchmarks like Euro 7.

ii. **Accelerate electrification of high-utilisation transport modes** by prioritising electrification of commercial vehicles–buses, taxis, and urban freight vehicles. This ensures that maximum *"passenger-kilometres"* and *"tonne-kilometres"* are converted to low-emission modes.

iii. **Modernise vehicle design and fleet composition** by mandating aerodynamic and lightweight designs for trucks and buses to improve fuel efficiency. Introduce incentives for fleet renewal and enforce stringent maintenance standards to phase out inefficient, polluting vehicles.

iv. **Introduce pricing, taxation, and incentives** as the evolving nature of technologies makes it prudent to ensure a level playing field by not having a tax structure that tilts the scales in favour of one technology or fuel or the other, and let the market determine consumer preference.

6.6 Driving the Biofuel Economy: Innovation, Security, and Sustainability

As India scales up its efforts to decarbonise the transport sector, biofuels offer a strategic pathway to reduce emissions, enhance energy security, and create rural economic value. The following suggestions outline a roadmap to accelerate adoption of biofuels, while fostering domestic innovation and minimising ecological trade-offs:

i. **Promote and incentivise flex-fuel vehicles** by enforcing regulations that require new vehicles to support multiple ethanol-petrol blends and bio-diesel blends. Offering tax benefits or fuel price rebates will also encourage consumer adoption.

ii. **Accelerate development of second- and third-generation biofuels** using non-food feedstocks such as agricultural waste, algae, and municipal solid waste to address food security and land-use concerns.

iii. **Boost domestic Sustainable Aviation Fuel (SAF) production** through capital subsidies, viability gap funding (VGF), and green tax incentives, with a focus on second-generation feedstocks such as used cooking oil and agricultural residues.

iv. **Scale Compressed Bio-Gas (CBG) production** via dedicated funding through blended finance mechanisms, feed-in tariffs, streamlined grid injection, binding state targets, blended finance, guaranteed offtake pricing, and reliable feedstock aggregation networks for consistent plant operations.

v. **Position India as a Global Biofuel hub** by leveraging its feedstock availability, refining capacity, and domestic market scale to lead in biofuel innovation and exports.

6.7 Strengthening Vehicle Retirement and Recycling

Phasing out older commercial vehicles can significantly reduce harmful emissions and improve air quality in India. A study found that a 15-year-old diesel car emits 7.6 times higher PM and 3.4 times higher NOx than a BS-IV car. It is estimated that scrapping trucks and buses older than 15 years can lead to a 17% reduction in CO_2 emissions, 18% in Hydrocarbon (HC) and NOx emissions, and 24% in PM emissions. Given the sheer volume of aging, high-emission vehicles in India, accelerating their scrapping will be crucial to the country's decarbonisation strategy. A scrappage programme would not only improve urban air quality but also directly contribute to lowering the transport sector's emissions footprint. Following are the key initiatives to promote scrapping of older vehicles in India:

i. **Mandate state-level scrappage policies to strengthen ELV recycling ecosystems** with a focus on phasing out older, high-emission Internal Combustion Engine (ICE) vehicles to reduce pollution and improve fleet efficiency. All states and union territories should formulate and notify their own vehicle scrappage policies aligned with the national framework.

ii. **Establish scrappage facilities through PPPs** by offering concessional land from state governments and enabling private sector participation in infrastructure development.

iii. **Provide targeted financial incentives** such as scrappage subsidies, road tax waivers, reduced registration charges, and lower parking fees to encourage voluntary scrapping and adoption of low emission vehicles.

iv. **Simplify and rationalise registration and Regional Transport Office (RTO) fee structures** on a periodic basis to ease the financial burden of transitioning to low emission vehicle.

v. **Launch public awareness campaigns** to inform citizens about the environmental benefits and available incentives under the scrappage policy, fostering greater participation.

6.8 Promoting Non-Motorised and Active Transport

Improving non-motorised transport (NMT) infrastructure is essential for achieving India's Net Zero goals, especially considering that 36% of Indians walked or cycled to work according to Census 2011. Walking and cycling are zero-emission modes of transport and present a major opportunity to lock in low-carbon travel behaviour if cities invest in safe, accessible and well-connected pedestrian and cycling networks. Following are some key steps to create a safe NMT infrastructure and promote higher NMT use:

i. **Scale-up well-designed pedestrian pathways and cycling networks** across cities and towns to support a safe and inclusive infrastructure for everyday mobility.

ii. **Conduct targeted awareness campaigns** and use behavioural nudges to promote walking and cycling for short trips, and public or shared transport for longer journeys.

iii. **Embed NMT in urban mobility planning** to ensure it is integrated into broader transport strategies and accessible to all socio-economic groups.

iv. **Design for climate resilience** by ensuring that NMT infrastructure is built to withstand extreme weather events and climate-related disruptions, particularly in vulnerable regions.

6.9 Enabling Systemic Transformation: Unified Governance, Digital Infrastructure, and Policy Innovation

Achieving inclusive, scalable, and sustainable mobility requires a forward-thinking, open approach to technology and data sharing. An Open Data Policy will ensure efficient and integrated transportation system. There is a critical need to design systems that can support innovation, growth, and evolving mobility needs from the outset. A Digital Public Infrastructure (DPI) for mobility offers immense potential in this field and should be prioritised. DPI in mobility can help to enable the following measures:

i. **Establish an executive body (i.e., Low-Carbon Development Cell / Secretariat) under the Prime Minister's Climate Change Council (PMCCC)** to coordinate among the various line ministries/ departments, provide continuous analytical support, coordinate cross-cutting bottlenecks, and issue implementation guidance that aligns missions and schemes across all energy sectors.

ii. **Leverage instruments such as the India Carbon Market (ICM)** to accelerate decarbonisation by enabling credit generation from low-carbon transport initiatives like fleet electrification, modal shifts, and clean fuel transitions.

iii. **Build open and interoperable digital infrastructure** by scaling up shared platforms, registries, and protocols such as the Unified Energy Interface (UEI) to enable seamless integration and innovation across mobility services, drawing inspiration from successful models such as the Unified Payments Interface (UPI).

iv. **Mandate a periodic review cycle** for transport-related laws, including the Motor Vehicles Act and National Urban Transport Policy to promote shift to cleaner fuels.

v. **Transition from fragmented systems to unified data ecosystems** by expanding initiatives like the India Urban Data Exchange (IUDX), fostering collaboration between public and private actors, and reducing duplication in service delivery.

vi. **Phased approach towards Zero-Emission Vehicles:** The transition strategy should begin with the phased elimination of polluting diesel vehicles and the adoption of lower-emission technologies such as CNG, hybrids, and electric vehicles. The subsequent phase should advance the use of biofuels through flex-fuel vehicles (FFVs), high Compressed Bio-Gas (CBG) blends, and hybrid FFV models, alongside continued growth in EV adoption. The final phase should ensure full deployment of zero-emission vehicles (ZEVs) such as EVs, FFVs, hydrogen based vehicles, and CBG-based models. To drive this transition, set segment-specific targets with clear timelines and compliance mechanisms across all vehicle segments.

vii. **Reforming costs and taxation** by reducing GST on replacement batteries, and providing incentives for lighter, energy-dense technologies till total cost of ownership (TCO) parity is achieved.

viii. **Discourage personal vehicle ownership** by implementing congestion pricing, high parking fees, and ownership taxes in urban centres.

ix. **Align the transport strategy with India's Long-Term Low Emission Development Strategy (LT-LEDS)** by incorporating traffic management as a mitigation lever, including congestion management, Intelligent Transportation Systems (ITS), demand-side management, and integrated urban transport planning.

x. **Embed road safety as a national priority** within unified governance structures. Coordinated action across vehicle manufacturers, road design standards, and enforcement agencies should be institutionalised to reduce traffic fatalities. This goal should be integrated explicitly into national mobility policy through enforceable targets, transparent monitoring, and responsive intervention mechanisms.

xi. **Institutionalise long-term innovation** by funding dedicated transport research centres and supporting startups and communities in co-creating scalable mobility solutions.

xii. **Promote Mobility as a Service (MaaS) platforms** through tax incentives and digital infrastructure support.

xiii. **Build professional capacity** by expanding programmes in transport planning, policy and economics.

7

CONCLUSION: CHARTING A COHESIVE PATH TOWARDS NET ZERO MOBILITY

7

Conclusion: Charting a Cohesive Path Towards Net Zero Mobility

India's transport sector has a pivotal role to play in acheiving two defining national priorities: Viksit Bharat by 2047 and Net Zero Emissions by 2070.

The modelling results in this report make clear that a business-as-usual path in the transport sector will lead to rising costs, congestion, and emissions. In contrast, a Net Zero pathway offers cleaner air, lower oil imports, improved competitiveness, and safer, more inclusive mobility.

7.1 A Systemic Shift Rather than Incremental Change: Technology as a Driver

Transport sector in 2020 contributed around 10% of India's GHG emissions which could double by mid-century without intervention. The Net Zero Scenario shows that only deep structural change can reverse this. Electrification of road and rail, alongside innovation in batteries, hydrogen, and Sustainable Aviation Fuel (SAF), is central. Innovation must be both high-tech and high-context - attuned to India's economic diversity, regional infrastructure, and energy resource availability.

7.2 Strategic Policy & Governance Levers

India already has strong policies such as FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles), CAFE (Corporate Average Fuel Efficiency) norms, National Logistics Policy and PM Gati Shakti. But to achieve Net Zero, they must be expanded and harmonised with climate objectives. Investments in electrification infrastructure, rail and waterways capacity, and urban mobility reforms (e.g., Transit-Oriented Development, Non-Motorised Transport infrastructure) are not just desirable, they are indispensable.

7.3 Modelling Insights

The modelling also confirms technical feasibility of India's decarbonisation - if backed by enabling policies, robust institutions, and adequate financing. Under the Net Zero Scenario (NZS):

i. **Rail's share** in passenger transport increases to 25% and freight goes to 30% by 2070.

ii. **Private car ownership** is reduced by 20% relative to Current Policy Scenario (CPS) due to enhanced public and shared mobility.

iii. **Electrification** remains the dominant strategy for decarbonising passenger and freight road transport, while partial electrification i.e. hybridisation acts as an impetus to full electrification in the initial phases.

iv. **Clean fuels** like ethanol, green-hydrogen, Compressed Bio-Gas (CBG), Sustainable Aviation Fuel (SAF), ammonia and e-methanol, emerge to complement electrification, supporting rural, industrial and long-distance mobility needs.

7.4 An Inclusive and Pragmatic Transition

India's transition must balance climate ambition with socio-economic realities. The shift to green mobility must ensure affordable access for all, supporting workers and industries in transition, and avoiding premature stranding of fossil-based infrastructure. Hybrid solutions, retrofitting legacy fleets, and skill development for a green workforce will be essential to manage the transition without economic dislocation.

7.5 Enabling the Future: Institutions, Investments & Innovation

India's ability to achieve Net Zero emissions in transport by 2070 hinges on a coherent policy ecosystem:

i. Infrastructure investments (Bharatmala, Dedicated Freight Corridors (DFCs), Sagarmala, Semi-high and High Speed Rail)

ii. Technology-specific programs (Production Linked Incentive for batteries, National Hydrogen Mission)

iii. Integrated planning frameworks (PM Gati Shakti, National Rail Plan)

These initiatives not only shape the technical assumptions of the Net Zero Scenario (NZS) but also ground its feasibility in current institutional progress.

Conclusion

India has the opportunity to lead by example globally by decarbonising one of the most challenging sectors by making mobility cleaner, safer, and more accessible. Achieving this will require sustained political will, public-private collaboration, innovative financing, and a whole-of-government and whole-of-society approach.

By advancing these elements together, India will not only meet its climate commitments but will also set a global benchmark for clean, inclusive and future-ready mobility systems. The Net Zero pathway in transport is not just an environmental necessity, but a national development opportunity.

ANNEXURES

Annexure A: Assumptions for Calculation of BPKMS/ BTKMS*

1. Macroeconomic Assumptions: Population projections and urbanisation rate based on MoHFW (till 2036) and UN population projections after 2036 (Latest update published in 2024)

Table A.1: Population and Urbanisation Assumptions

Category	2020	2025	2050	2070
Population (Million)	1347	1411	1596	1621
Urbanisation (%)	34.9%	37%	51%	64.7%

2. Table below summarises the key operational parameters assumed for different on-road vehicle segments, including typical occupancy for passenger modes, payload for freight vehicles, annual vehicle kilometres (VKM) travelled, and utilisation factors. These stylised values reflect typical Indian operating conditions drawn from national communications, transport studies, and freight assessments, and are used to convert vehicle activity into pkm and tkm for energy and emissions modelling.

Table A.2: Input Parameters for Passenger and Freight Vehicle Segments

Input Parameters	2W	3W	4W-Cars	4W-Taxis	Buses	Omnibuses	LCV<=3.5 Ton	MCV> 3.5 Ton and <= 12 Ton	HCV > 12 Ton
Occupancy	1.2	3.3	2.6	2.8	38	10	-	-	-
Payload	-	-	-	-	-	-	1.5	5.7	19.5
VKM	7500	25915	11500	70000	75000	36500	25,000	30,000	75,000
Utilisation	70%	70%	75%	90%	75%	25%	60%	70%	70%

* Billion passenger-kilometres (BPKMs), Billion tonne-kilometres (BTKMs)

3. Table below presents the assumed mileage values for major on-road vehicle segments in India (2Ws, 3Ws, 4Ws, buses, omnibuses, and freight vehicles from LCV to HCV) across conventional and alternative powertrains. These values are drawn from available literature and based on expert consultations, and are intended for use in scenario modelling and comparative analysis of energy demand and emissions across modes.

Table A.3: Vehicle Mileage by Segment and Powertrain for India

Mileage	2W	3W	4W	Buses	Omnibuses	LCV	MCV	HCV
Petrol (km/L)	52	25	15	-	-	14	3	-
Diesel (km/L)	-	27	16	4.5	7	15	5	4
CNG/LNG (km/kg)	-	25	23	7.5	10	19	6.7	3.3
Electric (km/kWh)	33	18	6.25	1	1	5.8	3.5	0.9
Hydrogen (km/kWh)	-	-	2.22	0.36	-	3.6	2	0.55
Hybrid (km/L)	-	-	27	-	-	-	-	-


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