Decarbonising India's Transport System

Charting the Way Forward

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Decarbonising Transport Initiative

The International Transport Forum

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Decarbonising Transport in Emerging Economies: The case of India

With 1.4 billion people, India's population is second only to the People's Republic of China (hereafter "China") (United Nations, 2019) and is the sixth largest economy globally, following the United States, China, the European Union, Japan and the United Kingdom (World Bank, 2021). India is also the world's fourth largest emitter of greenhouse gases (GHG) from fuel combustion after the United States, China and the European Union, even though its per capita emissions remain well below the global average (IEA, 2020a). Expectations for rapid growth in population and gross domestic product, along with growing energy needs to sustain these developments, highlight India as of paramount importance for future trends in global GHG emissions (Slater, 2020), and UN Secretary-General Antonio Guterres has singled out the central role of India in the world's efforts to mitigate climate change (United Nations, 2020).

Transport is an important part of these considerations, due to its relevance for oil demand and direct emissions, as well as its role as a key facilitator for economic development. In addition to final energy use and direct emissions of GHGs, largely due to oil combustion, transport is also responsible for increased energy demand and GHG emissions due to infrastructure construction, vehicle manufacturing and fuel production. Additional environmental and health impacts of transport also stem from emissions of local pollutants such as NO_x and particulate matter. Depending on its modal structure and which technologies are used to propel the vehicles needed to move people and goods, transport is a sector that can lock-in significant emissions into the future, due to the long lifespan of vehicles and fuel supply infrastructure. Transport technologies have a central role to play in industrial development, especially in a context where effective decarbonisation necessitates co-ordinated actions across different sectors. Transport decarbonisation policies can also help manage fuel oil demand, a priority for the government due to high import dependence, currently 82% of total consumption (Ministry of Petroleum and Natural Gas, 2018).

The objective of this scoping paper is to take a closer look at these aspects, opening with an analysis of current transport activity in India, including recent developments for passenger and freight services, related energy use and GHG emissions. Then reviewing key policy instruments designed to shape transport developments for the immediate future and beyond, focusing on measures taken at both national and urban levels. The subsequent Section investigates future transport scenarios in India, taking into account work carried out by several research institutes and outlining key aspects that should be considered in future work on transport decarbonisation. The final Section builds on these insights charting a way forward for a climate change mitigation strategy for the Indian transport sector. In particular, it underlines the importance of taking an approach that is limited not only to reducing direct GHG emissions, but takes into account a lifecycle perspective.

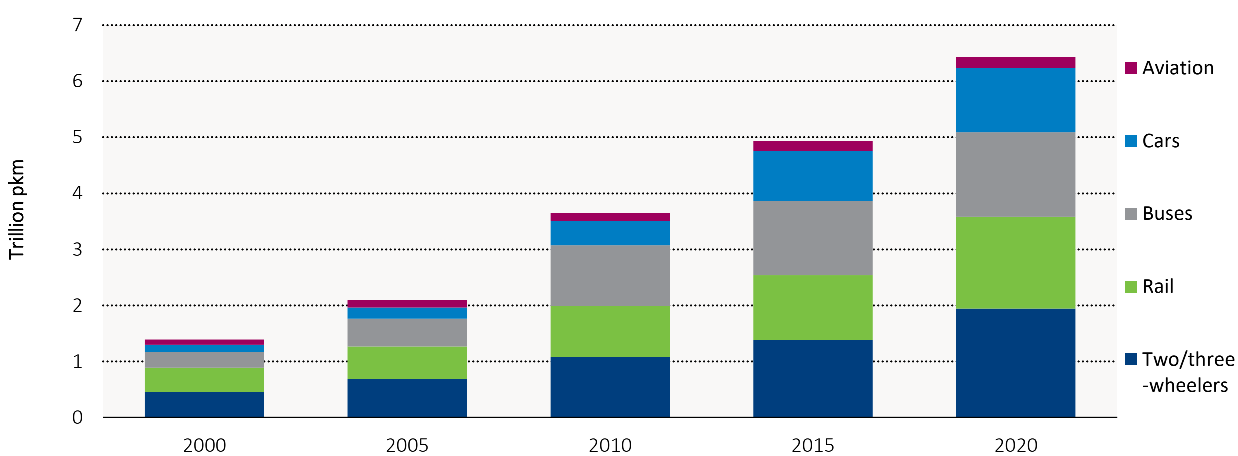
Overview of the transport sector in India

This Section reviews India's current transport landscape in terms of activity and energy use, as well as emissions of GHG and local pollutants. It opens with a review of passenger transport that considers absolute activity levels, as well as factors that determine which transport modes prevail in urban and overland mobility. The Section then takes stock of the country's freight transport sector and closes with an overview of how various transport modes contribute to India's energy use and environmental footprint.

Passenger transport activity

Estimates indicate that passenger transport activity in India more than tripled from 2000 to 2020, reaching over 6 trillion passenger kilometres (pkm), despite major impacts due to the Covid-19 pandemic in 2020 (Box 1).

Figure 1. Passenger transport activity in India by mode (trillion passenger kilometres), 2000-20



Notes and sources: ITF analysis prepared with the support of the IEA Mobility Model. Estimates of activity of road transport modes are based on assumptions data on vehicle sales and stock, combined with estimates on average mileages and load factors. Vehicle stocks are calculated for each road mode using historic vehicle sales data and calibrating against available statistics on stock. This results in an average vehicle lifespan of 14 years for two-wheelers, 16 years for three-wheelers and 19 years for cars and buses. Assumptions for average vehicle mileage per year before Covid-19 are close to 6 000 km for two-wheelers, 20 000 km for three-wheelers, 12 000 km for cars, and 30 000 km for buses. Assumptions for average load factors (in pkm per vehicle km [vkm]) are 1.1 for two-wheelers, 1.8 for three-wheelers, 2.6 for cars and 35 for buses. Mileage and loads in earlier years are not assumed to vary significantly from these magnitudes, and mileage variations for 2020 are informed by the discussion in Box 1. Aviation includes domestic and international activity.

While estimates presented in the Figure are based on these transparent assumptions, it is important to acknowledge that there is a lack of consensus within the research community, partly regarding the amount of fuel (namely diesel) used for road vehicles. Other uncertain aspects include the number of registered vehicles that are actually used and average distances travelled. Data for 2020 rely on estimations that have a higher degree of uncertainty than in earlier years.

Sales data for two- and three-wheelers and for cars are from SIAM (2021); sales data for buses are from ICRA (2020); rail transport statistics are based on UIC (2021); vehicle stock data for two-wheelers, cars and buses are from Government of India (2021); aviation estimates are based on data from ICAO (2020). Assumptions on load factors of buses are informed by UITP (2002, 2015) and IDTP (2021).

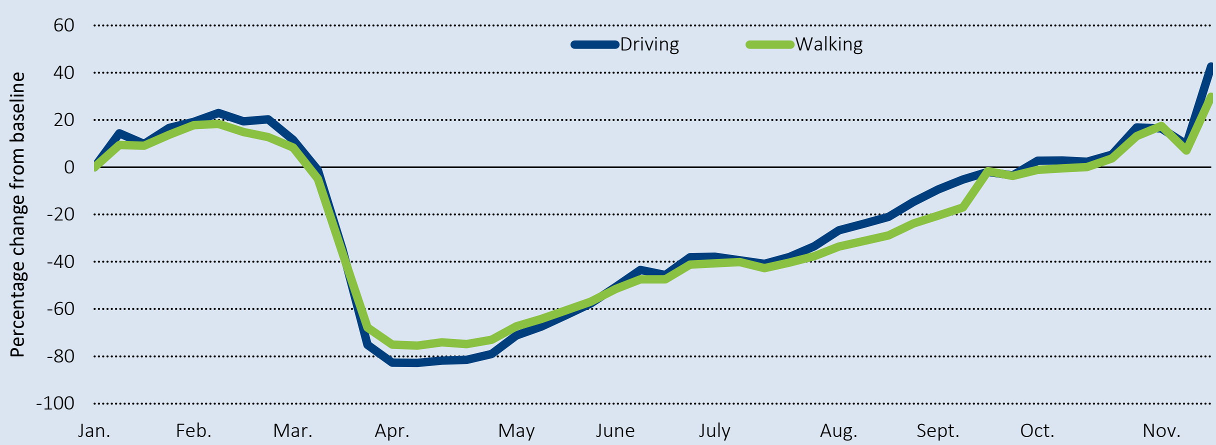
In common with other Asian emerging economies, many households in India own motorised two-wheelers, accounting for more than 70% of the total registered vehicles (MoRTH, 2019) and, along with China, is one of the world's largest markets for scooters and motorcycles, with sales in India reaching close to 20 million per year before the Covid-19 pandemic (SIAM, 2021). This makes two-wheelers a significant contributor to overall motorised transport activity (Figure 1). Their extensive use in cities also makes two- and three-wheelers responsible for a major share of urban transport activity.

Passenger mobility in India is also characterised by paratransit services, also known as intermediate public transport (IPT), contributing both to main haul and feeder services for other modes of transport (Gadepalli, 2016). IPT is largely served by motorised auto-rickshaws (three-wheelers), although may also be provided by non-motorised options, such as a cycle rickshaw. IPT services are more common in smaller cities, with short trip distances, partly due to insufficient active transport (walking and cycling) and lacking public transport facilities. In larger cities IPT services mostly provide the first and last mile connection to mass transit stations, such as metro and suburban rail or bus rapid transit (BRT) systems.

Box 1. Impacts of Covid-19 on the Indian transport sector

Covid-19 has shaped mobility patterns worldwide since early 2020. In India, the government implemented a strict national lock-down on 24 March 2020. The lockdown was first announced to last 21 days, but was later extended and mobility took a dip for the rest of the year (BBC, 2020).

Figure 2. Index for changes of routing requests on Apple Maps in India, January to November 2020



Note: Figure shows the weekly average change in routing requests for walking and driving in urban areas on the Apple Maps routing application. The baseline is the number of requests on 13 January 2020.

Source: Apple (2020).

Urban mobility came to a standstill during the lockdown and by April 2020 had decreased by 80% compared to the beginning of the year (Figure 2) and non-urban travel also plunged. In May 2020 Rail India suspended all passenger services and only operated special trains to bring home migrant workers (Ministry of Railways, 2020a). In August 2020 the government announced that scheduled passenger services on intercity and suburban trains would remain suspended until further notice (Ministry of Railways, 2020b).

By April, the number of scheduled flights at Indian airports had collapsed by 82% year-on-year and was still 44% below 2019 levels by November 2020 (OAG, 2020).

Railways make a significant contribution to passenger transport in India, especially if compared with the ASEAN region, where the modal share of intercity rail is negligible. The Indian rail system, along with those of China, the European Union and the Russian Federation (hereafter “Russia”), provides some of the largest passenger transport services (in pkm) globally. The estimated current modal share for rail in India is about a quarter of all pkm. India was also estimated to have the second-highest absolute level of passenger rail activity in 2016, close behind China (IEA, 2019a).

Metro networks currently operate in only 11 Indian cities (plus one under construction); however, the government is keen to extend metro services to 50 cities (IEA, 2019a; Deccan Chronicle, 2019). Existing metro rail and suburban rail systems in India often lack integration with the local transport network, resulting in low ridership and with fare revenues failing to cover operating costs in several cities (Venkatraman, 2020). Kolkata was the first city to implement a metro rail transport system, followed by Delhi, however cities such as Hyderabad, Chennai and Mumbai had suburban rail systems even before the introduction of metro rail systems. Part of the energy needed for metro operations in Delhi, including station lighting, is powered by solar power from photo voltaic cells on station roofs, parking locations and city depots (DMRC, 2020). Suburban rail usage in Mumbai is exceptionally high compared to other systems in the country, this can be attributed to the efficient operation by Western Railway and Central Railway and to the linear form of the city. The Integrated Transport Plan for the National Capital Region (NCR) 2032 also includes the development of a Regional Rapid Transit System (RRTS), a high-speed and high-capacity commuter service connecting the regional nodes in the NCR (NCRTC, 2020).[2]

Despite the fact that non-motorised transport infrastructure lags in many cities, shares of walking and cycling are high compared to major cities in developed regions (see Box 2 for a comparison with London).

Box 2. Non-motorised transport in India

The share of non-motorised transport in many Indian cities is high compared to similarly sized cities globally, for example, Pai (2007) reported that in Indian cities with populations of over 1 million, non-motorised transport accounted for more than 25% of passenger trips, compared with approximately 14% in London, with a population of 6.6 million. Surat is the city with the greatest share of walking and cycling (55% for a population of 2.4 million), whereas Bangalore has the lowest (25% for a population of 8.6 million) (Pai, 2007).

The census of India in 2011 reported that over 30% of the trips to work are made on foot and 17% by bicycle. Continuous, wide, unobstructed footpaths or bicycle paths are lacking in most Indian cities. Better infrastructure, together with improved road safety, would further encourage walking and cycling.

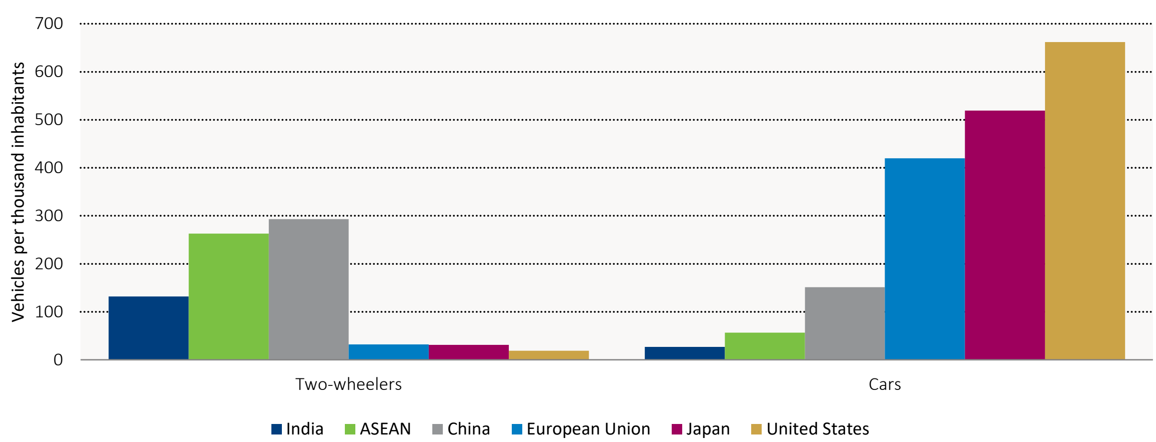
Safety for pedestrians and cyclists is a major concern, particularly as motorisation is increasing, and those who are reliant on active travel modes, such as the urban poor, are disproportionately affected. Around 12% of reported road fatalities are pedestrians and cyclists, however the WHO estimates this number to be much higher (WHO, 2018).

In 2020, buses accounted for roughly 20% of all pkm (Figure 1) and at least 25% of India’s urban residents depend on public transport (Abhishek, 2020). The importance of buses in the Indian urban modal mix is consistent with the low-income level since this is one of the factors associated with a lower reliance on private modes. Despite the high relevance of buses in the Indian modal mix for passenger transport, most Indian cities remain ill-prepared to deliver high-quality, inclusive mobility. Formal city bus systems are only available in a few larger Indian cities such as Delhi, Bangalore, and Chennai, and serve only a small portion of public transport demand. While new BRT systems introduced in several cities serve central routes, they lack feeder services and sufficient reach to extend their benefits to poorer communities. Ridership levels and trends for urban transport by bus vary between cities.[3]

Although public transport use in many cities is high, the transport providers – mainly state-run entities – incur operating losses of 6%-27% (Gadepalli and Rayaprolu, 2020; MoRTH, 2017). In many Tier II and III[4] cities, informal operators fill the void created by poor public transport services. These services are usually faster and more affordable than state run public transport as operating costs are lower and they operate on the most profitable routes.

With more than 35 million cars on Indian roads in 2019, passenger cars accounted for just below 20% of all passenger transport activity in 2020 (OICA, 2016; OICA, 2019). This relatively low share of transport by passenger car is principally due to vehicle ownership levels, which are well below those observed in other major economies (Figure 3). However, levels of car ownership are rapidly increasing, almost doubling in the past ten years, with vehicle sales close to 3 million per year (and exceeding this value in 2017 and 2018)[5] before the Covid-19 pandemic.

Figure 3. Vehicle ownership rates for cars and two-wheelers in selected countries and regions (per 1 000 inhabitants), 2018



Note: Ownership rates are estimated based on vehicle stocks calculated from historic sales data. Assumed average vehicle lifespan ranges from 9-14 years for two-wheelers and from 13-19 years for cars.

Source: Vehicle sales data are from SIAM (2021); OICA (2019); OICA (2016); ACEM (2021); JAMA (2020); ASEAN Automotive Federation (2020); Web Bike World (2016); CAAM (2021). Population data are from UN (2019).

The growing number of cars on the road results in increased urban congestion. A review of comprehensive mobility plans (CMPs) in 2010 showed that average motor vehicle speed on urban roads in India was 15-16 km/h (CSTEP and IUT, 2014). The TomTom Traffic Index ranks Bengaluru as having the worst global levels of traffic congestion, with Mumbai, Pune and New Delhi in fourth, fifth and eighth positions, respectively (TomTom, 2019). Cities in India also face a severe shortage in space and on-street parking can block up to 60% of the road width. In dense cities the area of a single parking space is larger than the area of a plot for low-income housing (ITDP, 2012). A typical response to accommodate growing motor vehicles and ease congestion is to provide additional road space, often in the form of flyovers, signal free roads and ring roads, leading to a vicious cycle of automobile dependency (Gupta, 2014).

In recent years, the increase in car travel was partly induced by app-based taxi services, which have a growing presence in the urban transport scene in India, offering a cost-effective service compared to car ownership. Ridesharing in India is governed by state governments and the two major ridesharing operators are Ola and Uber, which launched in India in 2010 and 2014, respectively. Ola holds more than 50% of the market, Uber holds around 30% and other small operators, such as Meru, Jugnoo, ixigo, hold the remaining 20% (Kaushal, 2018). The advent of ridesharing spurred technology development with cashless payments and delivery of information to consumers. Improvements in ridesharing are expected to reduce personal vehicle demand and provide employment opportunities (Ghosh, 2019), however some form of government regulation is essential to protect local businesses and create a level playing field for all service providers.

Transport by air is still low compared with other major economies with higher income levels, however aviation saw sustained growth prior to the Covid-19 pandemic. In particular, growth in Indian domestic aviation was the fastest globally in the four years leading up to 2019, continuing to grow in 2019, albeit at a lower rate, despite the Jet Airways bankruptcy (Timperley, 2019; IATA, 2019).

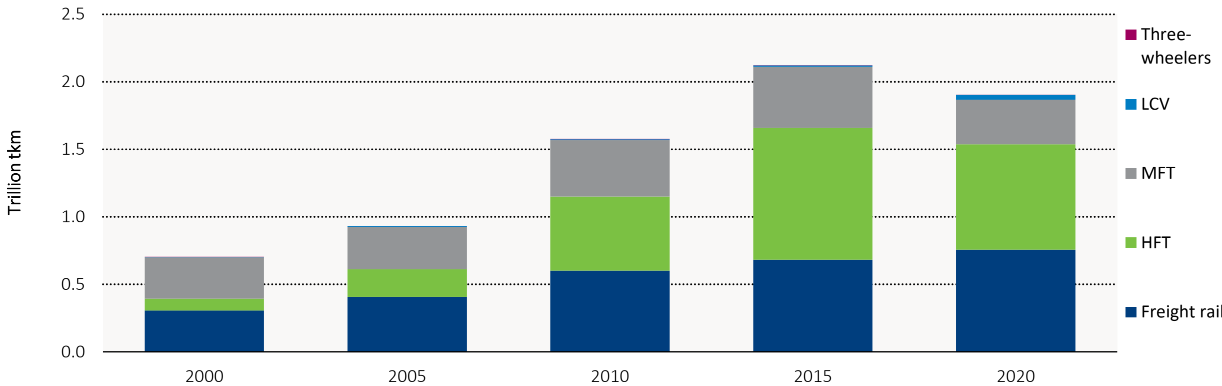
Freight transport activity

As in all economies, maritime transport has a central role as an enabler of international trade for India and, due to the long distances required for international movement of goods, accounts for substantial tonne kilometres (tkm). Based on analysis of trade data by commodity and origin/destination distances, total international maritime transport activity to and from India is estimated to be between 2.5 and 3 trillion tkm per year in the period 2015-20, exceeding the volume of inland transport activity in the country, which is estimated to be around 2 trillion tkm for the same period, up from 1.5 trillion tkm in 2010 (Figure 4).

Rail remains a key mode of freight transport in India, despite a declining share in recent years, rail freight activity is larger than for the whole of Europe, roughly 25% of the tkm of North America or China, and around 30% of the tkm of rail transport in Russia (IEA, 2019a). The coal sector and railways are strongly interdependent in India, 60% of coal is transported by rail and coal is the leading product shipped on the rail network, accounting for 40% of Indian Railways' revenue (IEA, 2020b). The stagnation of transported coal volumes and declining average distances have led to reduced rail freight activity (in tkm) in recent years. Charges for freight rail transport are significantly higher than in other countries as freight revenues are used to subsidise passenger rail transport (IEA, 2019a; IEA, 2020b).[6]

Trucks with gross vehicle weight (GVW) over 3.5 tonnes account for the largest portion of road transport activity, with a share of over 80% of total road freight traffic. This reflects the fact that these vehicles have a high load capacity and drive large distances, typically for long distance transport of large amounts of goods. Nevertheless, as is the case in other emerging economies, the modal share of medium-sized trucks (GVW above 3.5 tonnes and below 12 tonnes) out of all trucks (including trucks with a GVW above 12 tonnes) in India is higher than in developed economies. This can be at least partly explained by the quality of the road network (IEA, 2017). Light commercial vehicles (GVW below 3.5 tonnes) have a limited modal share in India. This is due to their low load capacity and ownership rates (similar to passenger cars, light commercial vehicle ownership grows with increasing income and tends to stabilise once incomes exceed USD 30 000 per capita) (IEA, 2017). Rickshaws (three-wheelers) are common in India's cities and are also partly used for freight transport.

Figure 4. Freight transport activity in India by inland mode (trillion tonne kilometres), 2000-20



Notes: Freight transport activity by inland mode, excluding domestic navigation. LCV= light commercial vehicle with gross vehicle weight (GVW) up to 3.5 tonnes; MFT= medium freight truck with GVW 3.5-12 tonnes; HFT= heavy freight truck with GVW over 12 tonnes.

Source: ITF analysis prepared with the support of the IEA Mobility Model. Estimates of activity of road transport modes are based on data on vehicle stock, combined with estimates of average mileage and load factors. Vehicle stocks are calculated for each road mode using historic vehicle sales data and calibrating against available statistics on stock. For commercial vehicles, this assumes an average vehicle lifespan of 21 years (LCVs), 20 years (MFTs) and 18 years (HFTs). Assumptions for average vehicle mileage per year before Covid-19 are close to 11 000 km (LCVs), 24 000 km (MFTs) and 37 000 km (HFTs). Average load factors (tkm per vkm) are 1 (LCVs), 9 (MFTs) and 16 (HFTs). Mileages and loads in earlier years are not assumed to vary significantly from these magnitudes. Mileage variations for 2020 are informed by the discussion in Box 1. Data for 2020 rely on estimations that have a higher degree of uncertainty than earlier years. See also the note to Figure 1 regarding other data uncertainties. Commercial vehicle sales data are from Autocar Pro (2019); commercial vehicle stock data are from Government of India (2021); load factor data for commercial vehicles are informed by IEA (2017); rail data are informed by IEA (2019a).

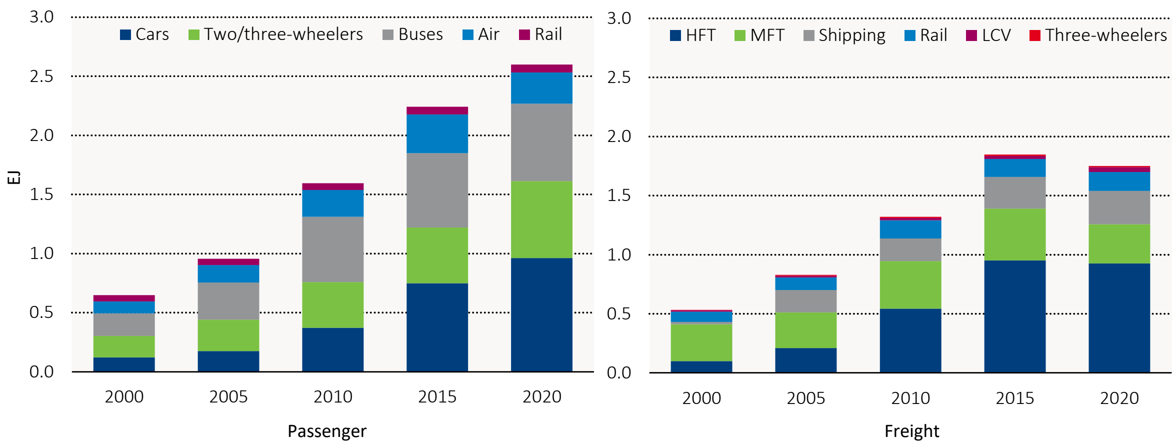
Energy use, greenhouse gas and pollutant emissions from transport

The Indian transport sector is a major contributor to national energy use, GHG emissions and air pollution levels. Establishing the most appropriate way to regulate the sector will impact on these levels nationwide.

Energy use

The transport sector's contribution to final energy demand in 2020 reached an estimated 4.3 exajoules (EJ) in 2020, almost 20% of the final energy use for India (IEA, 2020b), which is still lower than the global average of 29% (IEA, 2020c). Transport energy use has shown growth of around 50% since 2010, despite the strong impacts of Covid-19 (Figure 5). Oil products contribute 95% of final energy used in the Indian transport sector (IEA, 2020b) with natural gas (available only in major cities[7]), biofuels[8] and electricity make up the remaining 5%. Taking into account 20% of upstream energy and refining losses (in addition to the final demand of petroleum products), energy use due to fuel for transport is roughly 12% of the total primary energy demand in the country, excluding pipelines.[9] End-use and refining demand are major contributors to the total demand for oil in India (accounting for roughly 50%), which make India the world's third-largest consumer of oil and the fourth-largest oil refiner (IEA, 2020b).

Figure 5. Energy use by mode in passenger and freight transport in India (exajoules), 2000-20



Note: LCV= light commercial vehicle; MFT= medium freight truck; HFT= heavy freight truck.

Sources: ITF analysis prepared with the support of the IEA Mobility Model. Results for freight transport exclude domestic aviation. ITF analysis based on activity data outlined in earlier figures and energy use (in 2018) of 2 litres of gasoline equivalent (Lge) per 100 km for two-wheelers, 3 Lge per 100 km for three-wheelers, 6.4 Lge per 100 km for cars, 36 Lge per 100 km for buses, 7 Lge per 100 km for LCVs, 26 Lge per 100 km for MFTs and 46 Lge per 100 km for HFTs. Energy intensities are 0.04 MJ/pkm for passenger rail services, 0.2 MJ/tkm for freight rail and 1.35 MJ/pkm for passenger aviation. Energy intensities for cars in earlier years reflect variations in energy intensity. Data for 2020 rely on estimations that have a higher degree of uncertainty than earlier years. See also the note to Figures 3 and 4 regarding other data uncertainties. Data for rail are informed by IEA (2019a); for cars, by IEA (2019b); for medium and heavy road vehicles, by IEA (2017) and Delgado et al. (2016); for LCVs, estimates are consistent with data available from Deo (2021); for aviation, data are informed by IEA (2020c) and ICAO (2020).

In 2020, an estimated 60% of final energy use in the Indian transport sector related to passenger transport, compared with 40% for freight transport. Cars had the highest share in final energy demand for passenger transport (mainly petrol and diesel[10]), accounting for more than a third of the total. This share is higher than their contribution to passenger transport (Figure 1), reflecting their higher energy use per pkm compared to rail, buses or two- and three-wheelers. However, it is worth noting that passenger cars in India are comparably fuel efficient by international standards, mostly due to their small size and weight.

Rail is the most energy efficient mode of passenger transport, with only a 3% share in passenger transport energy use for a 25% share in passenger transport activity. Rail is already making an important contribution in limiting transport energy demand in India by displacing travel that would otherwise take place by more energy intensive modes. This is a key reason why promoting the use of rail, and other energy efficient means of passenger transport, can decouple growth in passenger activity from increasing energy use, and indirectly reduce GHG emissions and resulting climate impacts from transport.

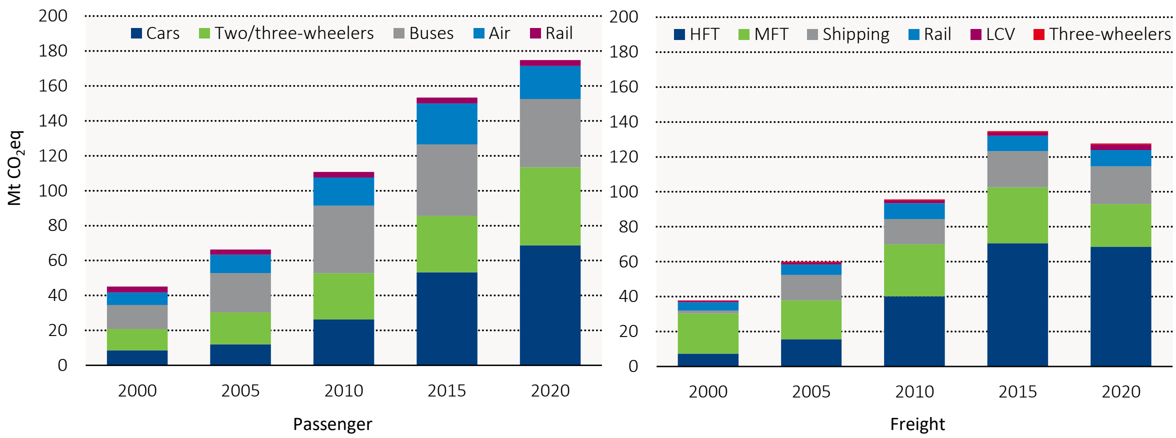
Rail is also the most energy efficient land-based transport mode for freight: inland freight rail transport activity was close to 30%, yet its share in freight transport energy use was just 9% in 2020. Rail also has a high reliance on electricity, which can be produced from renewables to eliminate GHG emissions. Of conventional passenger rail activity, 54% is powered by electricity (on a passenger kilometre basis), compared to 65% of total freight rail activity (on a tonne-kilometre basis) (IEA, 2019a; IEA, 2020b).

Trucks are the largest energy consumer in this sector, using an estimated 1.3 EJ in 2020, over 70% of all energy used to transport freight and is the fastest growing segment in freight transport energy use, doubling since 2010.

Greenhouse gas emissions

Trends in GHG emissions from the Indian transport sector generally mirror those of energy use. Tank-to-wheel GHG emissions (accounting for CO_2 emissions occurring during fuel combustion, but not for emissions taking place upstream, in particular for the conversion of primary energy into energy vectors that can be used by transport vehicles) are estimated at 300 Mt in 2020 (including maritime transport). The strong link between trends in energy use and GHG emissions from the transport sector are a result of high oil dependency.

Figure 6. Tank-to-wheel CO_2 emissions by mode for passenger and freight transport in India (million tonnes of CO_2 equivalent), 2000-20



Note: LCV= light commercial vehicle; MFT = medium freight truck; HFT = heavy freight truck.

Sources: ITF analysis prepared with the support of the IEA Mobility Model. Results are based on energy use data outlined in earlier figures. Emissions related with biofuels are informed by the analysis developed in Prussi et al. (2020) with simplified assumptions about attribution to different production pathways. Data for 2020 rely on estimations that have a higher degree of uncertainty than earlier years. See also the note to Figure 1 regarding other data uncertainties. CO_2 intensities for fossil fuels are from IPCC (2019); carbon intensities of electricity generation are from IEA (2020c).

Emissions of local pollutants

In addition to GHG emissions, the Indian transport sector is also responsible for emissions of local pollutants, with significant negative impacts on human health. This is a major issue, since over 84% of India's population (and primarily the urban poor) are exposed to high concentrations of ambient air pollution, mainly from particulate matter (PM) (Sharma, 2020). In 2019, India's capital Delhi was the worst city in the World Air Quality Report's ranking of annual fine particulate matter (PM2.5) levels, with half of the 50 most polluted cities also being in India (IQAir, 2020). In urban areas, PM2.5 emissions are caused by industry and vehicles (IQAir, 2021). To address the issue in the case of road vehicles, pollutant emission standards have been enforced since the mid-1980s (see Box 4 for an overview of recent policy developments). However, older polluting vehicles still result in a lock-in of pollution, especially evident in cities.

Current policies on climate, energy and transport

In 2009, the Government of India released the first-ever National Action Plan on Climate Change (NAPCC). The plan has eight missions that define broad policy directions for reducing India's emissions intensity: i) National Solar Mission; ii) National Mission for Enhanced Energy Efficiency; iii) National Mission on Sustainable Habitat; iv) National Water Mission; v) National Mission for Sustaining the Himalayan Ecosystem; vi) National Mission for a Green India; vii) National Mission for Sustainable Agriculture; and viii) National Mission on Strategic Knowledge for Climate Change.

The Mission on Sustainable Habitat outlines measures to reduce emissions in the transport sector. The Mission proposes modal shift and better urban planning in order to move towards low carbon transport systems. It also encourages the promotion of alternative fuels and suggests the need for research and development in biofuels. Hydrogen has also been recognised as a potential future energy source for the transport sector.

In 2015, with its first Nationally Determined Contribution (NDC), India committed to reduce the emissions intensity of its GDP by 33%-35% by 2030 compared to 2005 (Government of India, 2015). The NDC has also set the target for 40% of India's installed electricity capacity to be renewable or nuclear by 2030. In addition, India's NDC includes the creation of an additional carbon sink by increasing forest and tree cover, plus enhanced investment in vulnerable sectors to adapt to climate change.

The Indian government has long recognised the importance of tackling climate change. In 2002, India hosted the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change in New Delhi, where the Delhi Ministerial Declaration was adopted, calling for developed countries to transfer technology in an effort to minimise the impact of climate change on developing countries. This stance is consistent with the significant flows of climate funds received by the country and the ambitious goals regarding clean energy and transport technology deployment (Timperley, 2019).

Transport focus

India's policies on climate, energy and transport – including measures found in the NDC – can be broadly categorised in three groups: travel demand and modal choice management, energy efficiency, and diversification towards low-carbon energy vectors.

Travel demand and modal choice management

India's NDC includes measures that are directly related to travel demand and modal choice management, aiming to foster economic competitiveness and the relevance of energy efficient modes, such as public transport, rail and waterborne transport. These include, in particular, the pledge to construct 550 km of metro lines (under construction) plus a further 600 km (under consideration), the approval of 39 urban transport and mass rapid transport projects and the construction of two dedicated rail freight corridors: 1 520 km Mumbai-Delhi (Western Dedicated Freight Corridor) and 1 856 km Ludhiana-Dankuni (Eastern Dedicated Freight Corridor). The NDC also encourages promotion of coastal shipping and inland water transport, as well as committing to increase the share of railways in total land transport from 36% to 45% (Government of India, 2015). Speaking at the India Energy Forum CERAWeek 2019, Minister of Railways, Piyush Goyal stated: "by 2030, we are working to make the Indian railways the world's first net-zero railway" (Energyworld, 2019).

Prime Minister Narendra Modi announced that USB 1.4 trillion would be invested in economic and social infrastructure projects through the National Infrastructure Pipeline (NIP) between 2019 and 2025 (Ministry of Finance, 2019). Between 2020 and 2025, sectors such as energy (24%), roads (18%), urban (17%), ports and airports (2%) and railways (12%) amount to around 73% of the projected capital expenditure on infrastructure in India (Department of Economic Affairs, 2020). Within the transport sector, projects worth USD 831 billion have been identified, relating primarily to: roads and bridges, railway tracks, urban public transport, ports, airports and aviation infrastructure, railway terminal infrastructure, railway rolling stock, shipyards, highways (India Investment Grid, 2020).

These policy objectives can be framed in the broader context of recent policy developments on urban transport planning in India. Prior to 2005, only the large cities such as Delhi, Mumbai, Chennai, and Kolkata had developed urban transport plans (Gijre and Gupta, 2020). Urban transport functions are now devolved to state governments, and states look up to national guidelines to take action (see Box 3 for details).

Box 3. Policies affecting urban transport

Urban transport in India is managed at the national level by three ministries: Housing and Urban Affairs (MoHUA), Railways and Road Transport, and Highways. The MoHUA acts as the nodal ministry for co-ordination, appraisal and approval of urban transport issues (Gijre and Gupta, 2020). The constitution of India includes urban development and urban transport as a function of the states and, following amendment, has further devolved urban development, strengthening lower tiers of the administration. The MoHUA develops policy guidelines (and in certain cases, provides financial assistance for urban issues), however, these are not binding on state and local governments.

The **National Urban Transport Policy (NUTP)** was introduced in 2006 and focuses on the movement of people rather than vehicles on Indian roads. It acknowledges the need to reduce air pollution and underlines the need for cities to promote public transport, integrate walking and cycling and manage the use of private vehicles, by way of comprehensive mobility plans. The NUTP also recommends the establishment of a Unified Metropolitan Transport Authority (UMTA) in cities with over a million inhabitants.[11] UMTAs are a function under the state government and in some large cities, such as Hyderabad and Chennai, these exist at a city level.[12] Many of the early UMTAs were created to satisfy the mandatory requirement for a city or state to have a UMTA in order to receive certain funds under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) (Kalra, 2020). Among established UMTAs, Hyderabad's is seen as strong with a clear organisational and decision-making structure. Powers and responsibilities are given to the UMTA to approve transport projects and convene necessary stakeholders to implement local transport policy. Urban development authorities, municipal administrations and transport ministries in the states also develop committees to integrate transport planning tasks that fall under various agencies and departments. These structures might improve inter-agency information flow, but the need for technical capacity is not formally addressed. A detailed record of spatial and transport data at an urban level is also absent in many of the cities.[13]

The **Transit Oriented Development (TOD) policy** was introduced by MoHUA in 2017 to support land-use integration with metro rail and other mass transit projects. It also addresses urban development within 500-800 metres around mass transit stations, promoting high density areas (also referring to land value capture), encouraging active transport connectivity and the design of streets for universal accessibility for people with reduced mobility.

The **Green Urban Mobility Scheme 2017** also encourages public-private partnerships for mass transit projects, such as metro rail projects (India Today, 2017). Over a period of seven years, its main aim is to promote hybrid/electric vehicles and non-fossil fuels in 103 cities with more than 500 000 inhabitants. The interventions include setting up footpaths, public bike sharing schemes, bus rapid transit systems and clean fuels for public transport. Part of the funds required to implement these interventions will be contributed by central government (30%), urban local bodies (10%) and the remaining from multi-lateral agencies by way of loans.

The **Metro Rail Policy 2017** was approved by the cabinet in August 2017. The policy highlights the need for quality public transport that can meet the mobility needs of a growing urban population. The policy looks at metro rail growth in recent years and underlines the need to standardise norms and develop a procurement framework for implementing metro rail projects. The policy recommends multi-modal transport in cities, of which metro rail forms the backbone. It also advises cities to develop comprehensive mobility plans (CMP) and focus on developing a UMTA as a statutory body to develop the CMP and manage an Urban Transport Fund (UTF). It also recommends that urban local bodies are considered stakeholders in metro rail projects. The policy also underlines the need for TOD and for feeder services to the metro to reach a catchment area of at least 5 km^2 for each metro station. Land value capture is also recommended as a strategy to finance metro rail projects through a special purpose vehicle/agency implementing the metro rail project (MoHUA, 2017).

Energy efficiency in transport

India developed several energy efficiency flagship programmes in the framework of its National Mission on Enhanced Energy Efficiency, although these focus on the industry and business sectors (IEA, 2020b). However, India's NDC refers to the use of fuel-efficiency standards as instruments that allow the improvement of energy efficiency in transport and the promotion of hybrid and electric vehicles (EVs).

In January 2014, the government set CO_2 emission targets for passenger cars at the equivalent of 130 grammes of CO_2 per kilometre (g CO_2/km) in 2017 and 113 g CO_2/km in 2022 (Transportpolicy, 2021a). In August 2017, India was one of the first countries in the world to publish fuel efficiency standards for commercial heavy-duty vehicles. Phase 1 came in effect in April 2018, while Phase 2 will become effective in April 2021 (Garg and Sharpe, 2017). These standards are still based on simplified engine testing standards and will need to be upgraded to rely on more sophisticated testing tools, possibly through the adaptation of the Vehicle Energy Consumption Calculation Tool (VECTO) developed by the European Commission (Sharpe et al., 2019). Additional regulations aim to limit the emissions of local pollutants from cars and heavy road transport vehicles (Box 4).

Box 4. Recent policy developments to mitigate emissions of local pollutants from transport

In 2016, the Ministry of Road Transport and Highways issued a draft notification of Bharat Stage (BS) VI emission standards for motor vehicles, effective April 2020, on a par with EURO 6 and VI standards for light and heavy road vehicles (Transportpolicy, 2021b; Transportpolicy, 2021c; IEA, 2020b).

The same year, the Ministry of Petroleum and Natural Gas also announced a nationwide supply of BS VI fuel in conjunction with the proposed BS VI emission standard. The BS VI standard specifies 10 parts per million (ppm) sulphur for petrol and diesel fuels.

The BS VI regulation establishes an important precedent by leapfrogging regulations equivalent to Euro 4 and IV.

Energy efficiency policies will need to be updated, extended and complemented to ensure consistency with the Paris Climate Agreement (GFEI, 2020). In India, the government has already started to undertake an ambitious journey to electrify its vehicle fleet. An important milestone in this process was the 2017 declaration by Piyush Goyal, the Minister of Power at the time, who called initially for a ban on petrol and diesel car sales by 2030 (Times of India, 2017), a target that was revised down in 2018 to 30% of the new car market (Government of India, 2018) and that was later complemented by a stated ambition to electrify all three-wheelers by 2023 and two-wheelers by 2025 (Government of India, 2019).

The transition to EVs has been propelled by various factors, among which are the international commitments that India has ratified (such as the Paris Accord), growing GHG emissions from the transport sector, and the deteriorating air quality that now ranks Indian cities as amongst the most polluted cities globally. Additionally, the transition to new technologies is also expected to rejuvenate the Indian economy with innovative ventures (ILO, 2018).

EV promotion is rooted in the **National Electric Mobility Mission Plan (NEMMP) 2020** (adopted in 2013), which laid out a roadmap to accelerate the adoption and manufacture of electric and hybrid vehicles in the country, with the aim of achieving national fuel security. Under NEMMP, the **Faster Adoption and Manufacturing of Hybrid and EV (FAME)** scheme was introduced in 2015 with an initial budget of INR 8.95 billion (Indian rupees) (equivalent to USD 130 million). It aimed at reducing the upfront purchase price of hybrid and EVs to stimulate early adoption and market creation. Under Phase I of the scheme, more than 270 000 hybrid and EV sales were promoted. Between 2015 and 2017, out of the total vehicles that benefited from the scheme, mild hybrid four-wheelers accounted for 66%, strong hybrid cars 1.7% and battery-electric cars 1%.[14] From April 2017, the government stopped extending benefits to mild hybrid vehicles under the FAME scheme (Ministry of Heavy Industries and Public Enterprises, 2017), as a way to scale up strong hybrids and battery-operated EVs. However, in 2019, the Ministry of Road Transport and Highways wrote to the finance ministry asking for the goods and services tax on hybrid vehicles to be reduced and brought in line with levels for EVs (The Economic Times, 2019). Although the tax rates were not equalised, the move was seen as a departure from the government's earlier stand of moving directly from internal combustion engines to EVs.

In 2018, the Ministry of Power launched the **National E-Mobility Programme** to be implemented by Energy Efficiency Services Limited (EESL). This programme aims to incentivise vehicle manufacturers, charging infrastructure companies, fleet operators and service providers to achieve economies of scale and drive down costs, to create local manufacturing facilities and to improve technical competencies for the long-term growth of the EV industry. The programme includes a public procurement pillar with the aim to create demand for EVs through the early electrification of government-owned fleets, however EESL has faced significant implementation challenges in this regard (IEA, 2019c).

Phase II of the FAME scheme began in April 2019, with the budget significantly increased to over INR 100 billion (USD 1.4 billion). Its aim is to provide upfront incentives on public transport, such as procuring more e-buses and to support the deployment of charging infrastructure.

At national level, several ministries and departments have formulated policies that support the national EV transition strategy. At state level, transport departments have also developed EV policies aimed at providing charging infrastructure, offering subsidies for EVs and setting targets to electrify fleets for government vehicles and public transport. More than ten states in India have final or draft EV policies that support the national electric mobility policies including: Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, New Delhi, Tamil Nadu, Telangana, Uttarakhand and Uttar Pradesh. States with draft policies include: Bihar, Gujarat, Himachal Pradesh and Punjab. Most state EV policies prioritise two-and three-wheelers, public transportation, and job creation. Telangana state government targets 100% electric public transport by 2030 and Karnataka state aims to operate 100% electric three- and four-wheeled freight vehicles by 2030.

In addition to government interventions, industry demand has seen an increase in EV manufacture and sales, and the private sector is also investing in infrastructure for charging and battery swapping technologies (NITI Aayog and Rocky Mountain Institute, 2019).

The transition towards electric two- and three-wheelers is picking up significant pace (KPMG, 2020). For the financial year 2019-20, more than 0.5 million EVs were registered in India, including electric two- and three-wheelers, rickshaws, cars and e-buses (CEEW - Centre for Energy Finance, 2020). The various incentives from national government and the potential seen from the private sector has given a chance for existing and new business to seize the EV market. Shared e-mobility systems are on the rise, operators such as Ola Cabs have initiated electric mobility services and Yulu bikes, a Bangalore based start-up, has more than 2 000 e-bikes and over 200 bike stations in Bangalore and Delhi (Kumar et al., 2020). On the manufacturing side, key EV players, such as Mahindra and Maruti, have announced new manufacturing facilities solely for EVs (Gaurav et al., 2019).

Low-carbon energy vectors

Achieving effective GHG emission reduction from transport electrification requires a transition to low-carbon electricity, especially for light vehicles such as passenger cars.

The Government of India has successfully undertaken a series of actions that could allow India to meet its energy intensity and electricity sector decarbonisation pledges ahead of schedule (Slater, 2020). Nevertheless, coal currently continues to be the largest domestic source of energy in India and electricity generation and coal supply has increased rapidly since the early 2000s (IEA, 2020b).

In 2018, India's investment in solar photovoltaic was greater than in all fossil fuel sources of electricity combined, and the country installed almost as much new solar generating capacity as the United States (IEA, 2020b; Slater, 2020). Large-scale auctions have contributed to swift renewable energy development at rapidly decreasing prices, and in 2019, allowed India to deploy 84 gigawatts (GW) of grid-connected renewable electricity capacity (out of 366 GW of total electricity generation capacity, including more than 220 GW of coal plants) (IEA, 2020b). These developments are not only enabling the country to move confidently towards its target of 175 GW of renewables by 2022, with expectations of reaching 225 GW (Timperley, 2019), but also to aim for an electricity mix that could eventually include 450 GW of renewable energy capacity, as announced in September 2019 by the Indian Prime Minister (Timperley, 2019; IEA, 2020b). The cost competitiveness of renewable electricity with respect to coal was also underlined in a recent statement by Antonio Guterres, the Secretary General of the United Nations, who stated that 50% of coal for power generation will be uncompetitive in 2022, rising to 85% by 2025. In the same statement, Guterres commended India for its decision to take forward the International Solar Alliance and its plans for a World Solar Bank, which will mobilise USD 1 trillion of investments in solar projects over the coming decade (United Nations, 2020).

Low carbon fuels, including sustainably produced biofuel, are another mode of reducing the carbon intensity of transport movements. The fiscal treatment of petroleum products (petrol, diesel and kerosene) has a central role to play in this context. In India, petrol and diesel are subject to an excise duty imposed by the central government, and a value-added tax (VAT) and dealer commission, imposed by the state oil companies (IEA, 2020b). Compared with other major developing energy markets, India has significantly higher road transport fuel prices, but it does not apply any explicit tax related with the carbon content of the fuels.

A diesel subsidy ended in 2014/15 (IEA, 2020b), however, kerosene was still subsidised by the government in 2019, although its price is being gradually increased to phase out the subsidies (IEA, 2020b). India is also a signatory to the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) by the International Civil Aviation Organisation (ICAO), although it has not signed up for the voluntary pilot phase (Timperley, 2019).

In 2018, India defined an updated National Policy on Biofuels, which sets an indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030 (Ministry of Petroleum and Natural Gas, 2018).[15] This goal is to be achieved by: i) reinforcing ongoing ethanol and biodiesel supplies by increasing domestic production; ii) setting up second generation (2G) bio refineries; iii) developing new feedstock for biofuels; iv) developing new technologies for conversion to biofuels; and v) creating a suitable environment for biofuels and the integration with main fuels.

The updated biofuels policy also outlines specific measures, including additional tax incentives, an administratively set higher purchase price and investment support (IEA, 2020b). India's ethanol production comes from molasses residue feedstock, a by-product from the sugar industry, raising few sustainability concerns. Furthermore, a feedstock extension in the new biofuels policy takes account of food production, for example, only allowing damaged grains, which also has limited sustainability concerns (IEA, 2020b). Sustainable production of biofuels, however, is an issue that could gain relevance if production is to be scaled up to meet the 2030 target.

The Ministry of New and Renewable Energy (MNRE) has also been supporting the research, development and demonstration of hydrogen, acknowledging that developing hydrogen as an energy vector comes with challenges in production, storage, technology development, infrastructure, energy economy and public acceptance. In particular, the MNRE set up a National Hydrogen Energy Board, which in 2006 outlined a blueprint for hydrogen energy development in a National Hydrogen Energy Road Map (MNRE, 2006). The document indicates that hydrogen has been used as a raw material and utility over a long period in the fertilizer, chemical and petroleum refining industries. It identifies internal combustion engines and turbines, as well as fuel cells, as potential applications for transport, yet acknowledges that these technologies have not matched the performance of competing devices and systems and were not cost effective. The Road Map also highlighted hydrogen production as a key area of concern, underlining the need to urgently develop low-cost and low-carbon (preferably carbon free) hydrogen production pathways.

More recent analysis, in India and beyond, also identifies hydrogen as a possible option for use in fuel cells for trucking and as a feedstock for other transport fuels (including electrofuels). Hydrogen could additionally help balance supply and demand in the power sector (where hydrogen can provide a supplementary role to renewables and batteries) and replace fossil fuels in industry (Hall, 2020; IEA, 2019d). These analyses flag that production costs for low-carbon hydrogen are still higher than fossil-fuel based hydrogen or other fossil-fuel equivalents, but they suggest that parity could be reached in the future.

Achieving meaningful results from a climate change perspective will require production to take place not only from pathways that lead to very low CO_2 emissions, but that are also reliant on low-carbon energy, due to limitations in the thermodynamic efficiency of hydrogen production and use, compared with the case of direct electrification.

Projected developments for transport decarbonisation

A number of universities, think-tanks, companies and multinational organisations have aimed to quantify future transport demand and CO_2 emissions for the Indian transport sector, taking into account current conditions, existing policies and technologies, as well as future developments.

Modelling future transport demand is reliant on a number of assumptions and data inputs. No modelled results should be considered to be a definite indication of the future, modelling inputs are unlikely to be the same for different modelling exercises and results are dependent upon the quality of the data and assumptions made in the model. However, they provide an important quantitative basis for decision making.

A selection of results from a number of modelling exercises regarding transport, energy and GHG emissions are presented and compared in the following Section, with a view to identifying key trends and aspects that future work on transport decarbonisation in India should take into account.

Travel demand projections

The organisations in Table 1 have all undertaken modelling efforts to quantify transport activity and CO_2 emissions in India and to understand how they might change in the future, taking into account different policy frameworks. Scenarios produced by the organisations can be broadly classified into three different categories: business-as-usual (BAU), new policy and high ambition scenarios.

- BAU scenarios are intended to estimate future levels of transport demand and emissions in the absence of further government policy. Therefore, main drivers of change in BAU scenarios are macroeconomic effects such as population and economic growth. BAU scenarios account for the influence of current enacted government policy. However, policy measures that have been announced but are yet to be enacted are not considered.
- New policy scenarios aim to determine the effect of all announced policy measures, though aspirational targets that are yet to be substantiated with detailed regulation tend to be excluded.
- High ambition scenarios aim to determine the effect that new stringent government policy (that has not necessarily already been announced) can have on improving a number of outcomes for the transport sector, such as reducing CO_2 emissions.

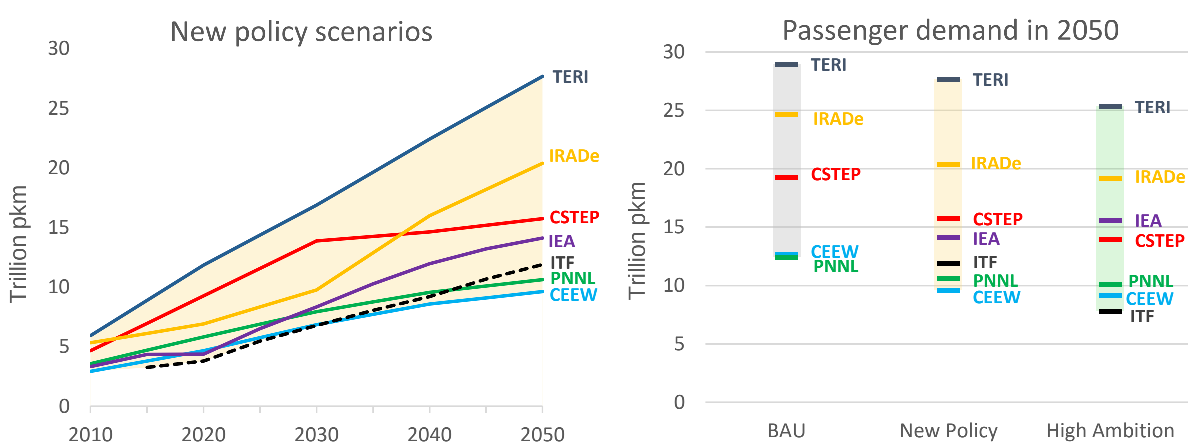
Scenarios for passenger road transport demand (expressed in pkm) in a new policy context are presented in Figure 7. According to these assessments, passenger road transport demand is set to grow 300%-500% between 2010 and 2050, driven by growth in population and GDP per capita, which are set to expand by around 27% and 360% respectively (IMF, 2020; United Nations, 2019).

A large degree of uncertainty exists in both estimates of road transport pkm in the base year, as well as the rates of growth between models. This uncertainty is driven by the limited availability and accuracy of passenger transport statistics. Uncertainty is further compounded by differences in model structure and assumptions made by each organisation and, following the Covid-19 pandemic in 2020, on the nature of the recovery that will ensue (among the scenarios shown in Figure 7, only the IEA and ITF results include the effects of the pandemic).

Table 1. Organisations publishing Indian transport sector projections

Acronym	Organisation
CEEW	Council on Energy, Environment and Water
CSTEP	Centre for Study of Science, Technology and Policy
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IRADe	Integrated Research and Action for Development
ITF	International Transport Forum
PNNL	Pacific Northwest National Laboratory
TERI	The Energy and Resources Institute

Figure 7. Future road passenger transport demand in India (trillion passenger kilometres), 2010-50



Source: ITF analysis based on ITF (forthcoming), IEA (2020d) and data shared by the ICCT from CSTEP, CEEW, IRADe, PNNL and TERI (Shakti Foundation, 2019).

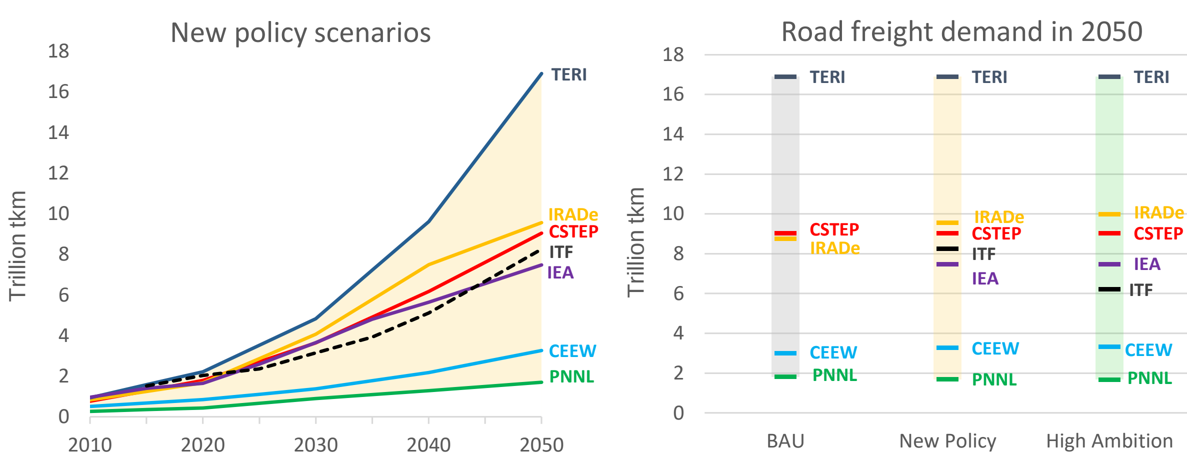
Road passenger transport demand in the year 2050 for each model and scenario is presented in Figure 7 (right). BAU scenarios for each model have the highest results. Adding in new policy announcements lowers estimates of demand, highlighting the importance of following through with existing announcements. High ambition scenarios produce the lowest estimates of road passenger transport demand in all scenarios, apart from the IEA high ambition scenario, which shows a slight increase over its new policy scenario. Policies such as better urban planning and fuel (or carbon) taxation can help reduce passenger kilometres by 0%-33% from new policy scenario levels in 2050.

Rail passenger transport is also projected to increase significantly. In an assessment compatible with the new policy scenario (but pre-dating the Covid-19 pandemic), the IEA indicated rail passenger transport could reach 3.7 trillion pkm in 2050, more than doubling compared with 2017, and broadly maintaining today's level of rail share in passenger transport (IEA, 2019a). In the same analysis, the IEA also underlined that the government of India has launched a number of initiatives aiming to enhance overall mobility across all modes of transport through improved infrastructure, including through the expansion of railways.

In 2019, India stated its aim to construct around 100 new airports in the following 10-15 years and, prior to the Covid-19 pandemic, was set to become the world's third largest aviation market by 2020 (Timperley, 2019). Passenger numbers for domestic and international flights (not included in Figure 7) doubled between 2010 and 2019 and were projected to triple by the late 2030s (Timperley, 2019), however following Covid-19, and depending on the nature of the recovery, it may take a further five years to reach this level (IATA, 2020).

Future scenarios for road freight transport developments (expressed in tkm) are presented in Figure 8. Levels of freight transport are expected to grow significantly over the next decades, despite differences in magnitude across different modelling exercises. Road freight activity is also estimated to be relatively similar between BAU and new policy scenarios across the board, with some high ambition scenarios showing slight reductions, reflecting supply chain improvements.

Figure 8. Future road freight transport demand in India (trillion tonne kilometres), 2010-50



Source: ITF analysis based on: ITF (forthcoming), IEA (2020d) and data shared by the ICCT from CSTEP, CEEW, IRADe, PNNL and TERI (Shakti Foundation, 2019).

Increases are also foreseen for freight rail and maritime freight, although growth is projected to be at a lower rate than for other modes.

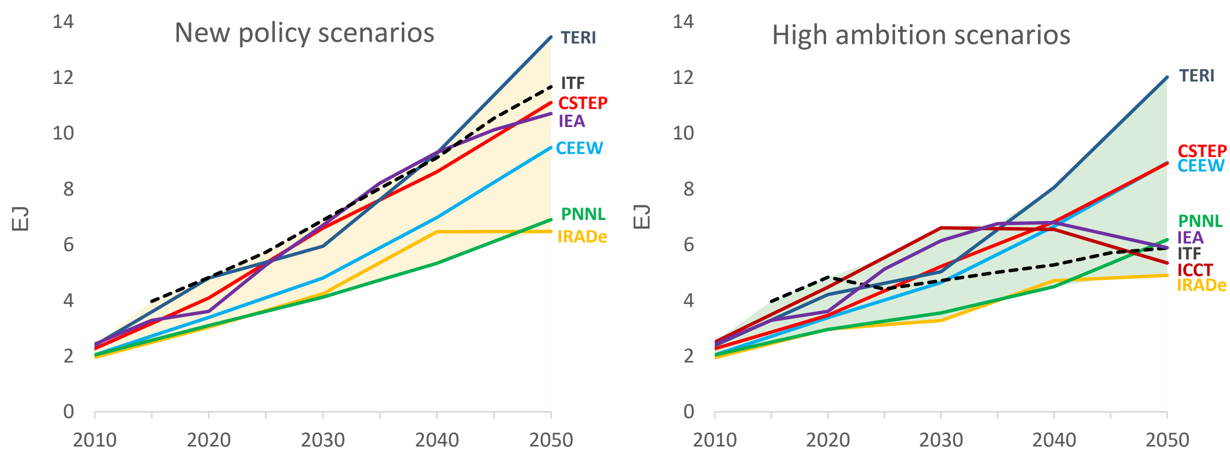
In particular, freight rail tkm in India is projected to more than triple, according to IEA new policy scenarios (IEA, 2019a), where rail retains a predominant role as a carrier of bulk materials, but also suffers from increased competition for other goods. Overall, both passenger and freight rail activity in India is projected to grow much more quickly than in other countries. Transportation of coal represents a large proportion of freight rail activity, therefore a drop in coal use for electricity generation (compatible with a high ambition decarbonisation framework) comes with lower prospects for rail activity, unless the rail sector is successful in increasing its competitiveness for the movement of other goods (namely containers). New policy scenarios for maritime freight activity show projected increases close to a factor of ten compared with 2015 (IEA, 2020d).

Notwithstanding additional uncertainties on the pace of the recovery of economic growth following the Covid-19 pandemic, all scenarios suggest a rapid expansion in levels of Indian transport activity, regardless of differences that exist across different modelling exercises.

Impacts on energy and greenhouse gas emissions

The growing demand for transportation and vehicle use is projected to lead to growing energy use and CO_2 emissions by 2050 in all modelling exercises. Figure 9 shows final energy consumption from Indian inland road transport (both passenger and freight) for new policy and high ambition scenarios.

Figure 9. Future final energy consumption (exajoules) from road transport in India, 2010-50



Source: ITF analysis based on ITF (forthcoming), IEA (2020d) and data shared by the ICCT from CSTEP, CEEW, IRADe, PNNL and TERI (Shakti Foundation, 2019).

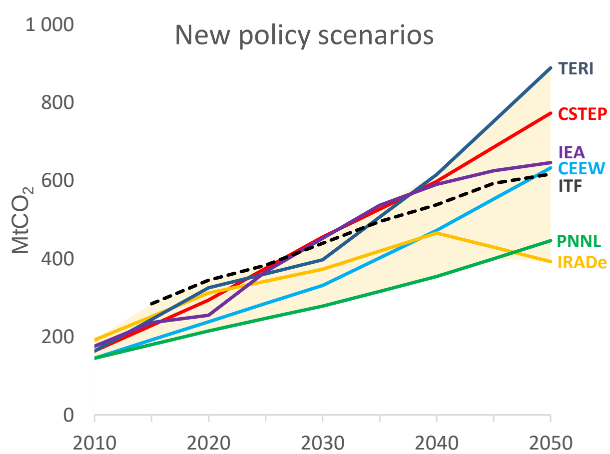
In new policy scenarios, increases in passenger and freight inland transport activity lead to energy use growing between 300%-600%, primarily due to increased vehicle use. Energy efficiency improvements are more than offset by an increased number of vehicles and a growing share of travel by more energy-intensive modes, such as passenger cars.

The rapid growth in energy use is set to cause a similarly large increase in CO_2 emissions, unless new policy measures are introduced. Figure 10 compares direct CO_2 emissions from the Indian road transport sector (the main source of direct GHG emissions for inland transport) for new policy and high ambition scenarios. The increase in CO_2 emissions in new policy scenarios are predicted to be between 200%-540% (although subject to uncertainties arising from the Covid-19 pandemic), which highlights that existing policy announcements are likely insufficient to cause a peak in CO_2 emissions for inland transport before 2050. This means that further policy action is required to mitigate GHG emissions in a way that could meet the ambition of the Paris Agreement.

The results of high ambition scenarios, Figure 10 (right), show that new policy announcements can play an important role in reducing future CO_2 emissions in road transport. Maximising opportunities to develop compact cities, avoiding urban sprawl, incentivising modal shifts away from private passenger vehicles, enhancing the extent of energy efficiency improvements, including by stimulating the adoption of EVs and low carbon fuels, are all important policy measures in this regard. In four of the eight models (two of which attempt to include the impact of Covid-19), CO_2 emissions in high ambition scenarios can peak before 2050.

Comparing the high ambition results considered here with the assessment of available emission budgets carried out by Climate Action Tracker (Climate Action Tracker, 2021), suggests that the results shown in Figure 10 (right) are likely compatible with a 2-degree mitigation pathway, especially for the four modelling exercises at the bottom of the range. This comparison, however, also suggests that for India to achieve net zero emissions shortly after 2050 (a result that could ensure compliance with a 1.5 degree scenario) would require additional policy action.

Figure 10. Future direct CO_2 emissions from road transport in India (million tonnes CO_2 equivalent), 2010-50



Source: ITF analysis based on: ITF (forthcoming), IEA (2020d) and data shared by the ICCT from CSTEP, CEEW, IRADe, PNNL and TERI (Shakti Foundation, 2019).

Despite uncertainties arising from the Covid-19 pandemic, this assessment confirms that a range of policy actions will be crucial to ensure the objectives of the Paris Agreement and other United Nations Sustainable Development Goals are met.

Domestic and international aviation and shipping (excluded from the results shown in Figure 10, but significant contributors to the total energy use and direct CO_2 emissions from transport vehicles) will also need to be subject to significant policy action to ensure that global goals are met.

The importance of taking a holistic approach to transport decarbonisation

The results summarised in the previous Chapter are limited to direct CO_2 emissions produced at the vehicle tailpipe (also known as tank-to-wheel). Nevertheless, energy and emission impacts from transport also need to consider contributions from fuel production (and electricity generation in the case of EVs). These upstream emissions, also known as well-to-tank, represent a growing share of future transport emissions as alternative energy vectors, such as electricity, hydrogen, biofuels and electrofuels displace conventional petroleum-based fuels.

The carbon intensity of electricity production, for example, is dependent on the sources of energy used and is an important component of the total emissions associated with the use of EVs over their lifetime. Minimising these emissions will be crucial to ensure that global decarbonisation goals set out in the Paris Agreement are met. Similar considerations apply for vehicles that rely on hydrogen or other energy vectors that could replace petroleum products.

Assessments focused solely on tank-to-wheel energy use and GHG emissions also omit emissions produced during vehicle manufacture and disposal. As with well-to-tank emissions, these are also set to grow in importance in the coming decades. EVs, for example, do not produce tailpipe CO_2 emissions and may use low GHG emission energy from electricity production (e.g. if electricity is from renewable energy), however they incur higher energy use and GHG emissions than combustion engine vehicles during manufacture and end-of-life disposal.[16] Similar considerations apply for fuel cell EVs. Additionally, the relative importance of emissions occurring in vehicle manufacturing depends on a range of factors including lifetime mileage.

Energy use and GHG emissions also accompany the construction, maintenance and end-of-life management of infrastructure (e.g. roads, railways, airports and ports) required for the delivery of transport services. As with vehicle manufacturing, energy use and GHG emissions associated with transport infrastructure derive from materials extraction, processing, infrastructure construction, operation, maintenance and end-of-life treatment. In particular, energy use and emissions attributable to transport infrastructure include impacts due to materials – namely steel and cement – that are currently produced from carbon-intensive industrial processes.

New mobility services, such as shared micromobility[17] and ridesourcing[18], also add energy needs and environmental effects given the need for servicing (including refuelling or charging), repositioning and parking for shared vehicles and the need for vehicle movements without passengers (ITF, 2020).

The impacts due to energy and GHG emissions throughout the entire lifecycle and supply chain of transport services, on the top of final energy use and direct GHG emissions, have a significant magnitude. For example, for a passenger car produced with current technologies, using a combustion engine, running on petroleum fuel in an urban environment with paved roads, GHG emissions per vehicle kilometre due to fuel production and vehicle manufacturing can add 30% to direct GHG emissions from the tailpipe. Road infrastructure can contribute a further 10% in cities, and more in rural areas (ITF, 2020). Results are similar for urban buses, although higher mileage roughly halves the relevance of vehicle manufacturing and infrastructure construction (ITF, 2020).

This underlines the importance of ensuring that energy efficiency and GHG emission mitigation measures in the transport sector are developed with a holistic perspective on energy and environmental impacts, based on a "cradle to grave" analysis. This same approach is necessary to establish the full environmental impacts of the transport sector, since these impacts extend beyond energy use and GHG emissions and include local air pollutants, effects on water use and habitat change.

The uptake of new types of vehicles, sources of energy and business models in the transport sector may also be accompanied by a greater integration of these systems across the economy. For example, batteries are not only an energy storage device needed on EVs, but also something that could help optimise electricity distribution systems. Similarly, hydrogen may not only be relevant as a transport energy vector, but also as a way to store electricity produced from renewables when production exceeds demand.

The cross-sectoral nature of these developments requires enhanced capacity to co-operate between different parts of the public administration (e.g. transport ministries with energy ministries), which are likely to benefit significantly from an increased capacity to evaluate different options on a holistic basis.

Major economies, such as the European Union and the United States, have already equipped themselves with tools capable of assessing transport systems by taking a lifecycle approach, key examples include:

- The Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) model developed by the Argonne National Laboratory (ANL, 2020a; ANL, 2020b), which covers both vehicle and fuel components in two different modules and has already been used to support policy developments in California (Wang, 2018), in particular its Low Carbon Fuel Standard (ARB, 2019), and at the ICAO (ICAO, 2021).
- The well-to-wheel assessment developed in a collaborative effort of the Joint Research Centre (JRC) of the European Commission, the European Council for Automotive Research and Development (EUCAR) and the European Oil Company Organisation for the Conservation of Clean Air and Water in Europe (Concawe). This effort targets primarily the evaluation of energy use and GHG emissions for different road fuel and powertrain configurations in Europe (JEC, 2020). It has been instrumental in the European Union for the development of policy instruments, such as the Fuel quality and the Renewable energy Directives (European Commission, 2021a; European Commission, 2021b).

Recent academic research has also looked at the lifecycle of transport infrastructure, with a particular focus on road and rail in North America (Transportation life-cycle assessment, 2020), building on earlier research by some of these same researchers (Chester and Horvath, 2009).

India, which is a large and rapidly growing economy, will have a key role in addressing climate change mitigation. To this end, the country should work to develop tools for the assessment of energy and GHG emission impacts from different transport services from a lifecycle perspective. Depending on the system boundaries that define them, lifecycle assessments can have a flexible scope of application and, therefore, taking this approach will also enable the project to deliver tools that could be suitable for use at different administrative levels, e.g. for country- and city-level analyses.

Annex

List of key stakeholders for the Indian transport sector

Institution	Description of relevant role(s)
NITI Aayog	The transport vertical at NITI Aayog is committed to promoting and facilitating efficient, sustainable, environmentally friendly multi-modal transport systems. Actively contributing towards the development of a roadmap for India's mobility and designated as the nodal agency for the promotion of electric vehicle (EV) solutions.
Ministry of Road Transport and Highways (MoRTH)	Responsible for Road Transport, National Highways and Transport Research policies, with a view to increasing the mobility and efficiency of the road transport system.
Ministry of Housing and Urban Affairs (MoHUA)	Has a dedicated Urban Transport Wing responsible for co-ordination, appraisal and approval of urban transport matters, including: BRT systems, urban transit infrastructure and metro rail projects.
Ministry of Railways (MoR)	Exercises all central government policy powers and administers, supervises, and directs the entities that provide most of the rail services in India.
Ministry of Civil Aviation (MoCA)	Responsible for the formulation of national policies for the development and regulation of the civil aviation sector.
Ministry of Environment, Forest and Climate Change (MoEFCC)	The nodal agency for planning, co-ordination and overseeing the implementation of India's environmental and forestry policies.
Ministry of Power (MoP): Energy Efficiency Services Limited (EESL) Bureau of Energy Efficiency (BEE)	MoP is involved in the electric mobility transformation. EESL is set up under the MoP, to create and sustain markets for energy efficiency. EESL works closely with BEE and is leading the market related activities of the National Mission for Enhanced Energy Efficiency under NAPCC.
Ministry of New and Renewable Energy	The nodal ministry for all matters relating to new and renewable energy.
Ministry of Heavy Industries and Public Enterprises	Responsible for promoting the automobile industry. A key stakeholder for this project, liaising with the auto and ancillary industry and for developing appropriate vehicle standards.
Logistics division in the Department of Commerce	Responsible for developing an action plan for the integrated development of the logistics sector, by way of policy changes, improving existing procedures, identifying bottlenecks and encouraging technological development in the sector.
Ministry of Ports, Shipping and Waterways	The apex body for formulating and administering the rules, regulations and laws relating to ports, shipping and waterways, including shipbuilding and repair, major ports, national waterways and inland water transport.
Ministry of Finance	Given the relevance of taxation and financial legislation for transport, energy and climate policies, it has a significant relevance for the work on transport decarbonisation.
Society of Indian Automobile Manufacturers (SIAM)	An important link between industry and the policy-making process, and for identifying appropriate technological interventions possible within the current Indian auto-industry framework.
Society of Manufacturers of Electric Vehicles (SMEV)	Registered association representing Indian manufacturers of EV and EV components.
Automotive Component Manufacturers Association of India (ACMA)	Representing the Indian auto component manufacturers, giving insights into the auto components industry in India, and identifying the policy enablers required to become an EV eco-space.

Federation of Indian Chambers of Commerce and Industry (FICCI)	Largest and oldest apex business organisation in India. Non-government and not-for-profit. Relevant sub sectors: Electric Mobility, Transport Infrastructure, Environment and Climate Change, Renewable Energy, Hydrocarbons, Power and Urban Infrastructure and Smart Cities.

Notes

1 For more information on the ITF Decarbonising Transport Initiative see www.itf-oecd.org/decarbonising-transport (accessed 30 January 2021).

2 The corridors being developed under Phase I include: Delhi-Meerut, Delhi-Panipat and Delhi-Alwar, plus five more for the subsequent phases of the project. RRTS aims to provide savings of travel time and cost to encourage a shift to rail and hence reduce energy use and emissions, improve access to jobs and enhance economic activity in the region. The Thiruvananthapuram-Kasaragod Semi High-Speed Rail (SilverLine) Project is another high-speed inter-urban rail project currently under construction and due to be completed by 2025. SilverLine would have an operating speed of 200 kmph, reducing the total travel time to less than four hours, compared with the present 10 to 12 hours. The project also plans for trains and stations to be 100% reliant on renewable energy sources (K-rail, 2020).

3 For example, between 2001-07 the public transport use in Bengaluru almost doubled, while the population of the city increased from 5.7 million to about 8 million and the city size increased from 195 km^2 to about 350 km^2. This is due to the expansion and improvement of the Bengaluru Metropolitan Transport Corporation's (BMTC) services (Revi et al., 2015).

4 The cities in India are categorised on the basis of a grading structure devised by the Government of India. Following the recommendations of the Sixth Central Pay Commission of 2008, the cities are categorised under sections X, Y and Z, based on population. Another term for the categories is Tier-I, Tier-II and Tier-III cities, from largest to smallest, respectively. In 2015, Ministry of Finance classified 8 cities as Tier I and 88 cities as Tier II (Ministry of Finance, 2015).

5 In 2020, absolute values of car sales declined, with reported data for the period between April and October 2020 (the first half of India's financial year) dipping by 26% year-on-year (SIAM, 2020). In 2019, sales were 2.9 million (OICA, 2019; OICA, 2019).

6 If freight rail activity is outpaced by increased demand for passenger rail services, revenues from rail freight may fall short of the amounts needed to subsidise passenger rail, requiring other revenue sources (e.g. from land value capture). Although investment in rail freight corridors should help to limit the declining share of freight rail in total inland transport activity, it is also important to have the possibility of reducing rail freight costs in order to keep prices competitive.

7 By March 2020, the Petroleum and Natural Gas Regulatory Board (PNGRB) had authorised 230 geographical areas for development of the City Gas Distribution (CGD) Network across the country, which covers around 71% of India's population and 53% of its area (Ministry of Petroleum and Natural Gas, 2020). This translates to 402 districts in 27 states or Union Territories having access to CGD Networks for supply of natural gas. The remaining areas will be covered in future bidding rounds subject to techno-commercial viability, natural gas pipeline connectivity and natural gas availability.

8 Around 2 billion litres of ethanol are used as fuel across India. By 2017/18, the ethanol blending rate exceeded 4%, however the 5% ethanol blending mandate was not met. India's biodiesel production is still at an early stage of development (IEA, 2020b)

9 The higher share of transport in final energy figures than in primary energy figures reflects the fact that there are greater losses in energy transformation in sectors other than transport (e.g. industry and buildings). This is due to higher losses in electricity generation, which is currently largely reliant on coal. A significant share of freight traffic is also for pipelines, which is not addressed here and are used entirely to transport liquid and gaseous fuels.

10 India, together with Europe, is the only major car market where diesel vehicles have a high market share.

11 In 2014, this policy was reviewed by the Institute of Urban Transport (IUT), which further elaborated on the need for an equitable allocation of road space for all users and the need to promote active transport in cities.

12 A common critique of UMTAs is that a UMTA mimics a conventional committee structure, and such committees have existed previously for specific projects. It is also reported that many state and city level authorities have requested central government to provide guidelines and procedures for the establishment, requirements and functions of UMTAs (Gijre and Gupta, 2020).

13 In addition to organisational defragmentation, there is also weak transport planning capacity at state and local levels. Cities usually develop a comprehensive mobility plan (CMP) covering their spatial jurisdictions. Many of these plans provide recommendations for urban transport projects, but the required cost-benefit analysis is often unpublished in the CMPs. CMPs are a main source for transport related data about a city as a substantial number of studies are conducted prior to developing the CMP, however in most cases CMP recommendations are not in line with regional plans and master plans developed at state level.

14 Mild hybrids are internal combustion engine (ICE) vehicles with an assisting electric engine. They do not have an electric-only propulsion mode and their battery charges, for example, through regenerative breaking. The battery of both strong hybrid cars and battery-electric cars relies on chargers connected to the power grid. Strong hybrid cars feature an electric motor and an ICE, while battery-electric cars rely exclusively on electricity for propulsion.

15 India’s National Policy on Biofuels (2009) had a target to blend 20% biofuels into the diesel and petrol mix by 2017. However, India has fallen well short of these targets, so far only reaching around 2% bioethanol and 0.1% biodiesel blend in 2018 (Timperley, 2019).

16 These processes include material extraction, processing, vehicle component fabrication (e.g. battery production), assembly, production and use of fluids (e.g. lubricants, coolants), delivery to the point of sale, and end-of-life treatment when scrapped (i.e. the re-use, recycling or disposal of vehicle parts).

17 Shared micromobility options include e-scooter and bicycle sharing services, along with a broad range of other shared light mobility devices (ITF, 2020).

18 Ridesourcing refers to on-demand ride services delivered by ride-matching platforms such as Didi, Uber, Grab, Ola, Lyft, etc. It primarily targets short passenger trips, often of less than 15 km, but can include longer journeys of up to 50 km, for example to and from airports (ITF, 2020).

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Decarbonising India's Transport System

This report presents an analysis of current transport activity in India and reviews key policy instruments set up by Indian institutions to shape transport developments in the coming years. It also investigates future scenarios of transport in India and outlines key aspects that should be considered in the upcoming work on transport decarbonisation. The final section builds on these insights, charting a way forward for a climate change mitigation strategy for the Indian transport sector. In particular, it underlines the importance of taking an approach that is not limited to direct GHG emission reductions but takes into account a lifecycle perspective.

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