

# Energy Security Insights



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## Editorial

In the decade of 1990–2000, the growth of energy consumption was the fastest in the transport sector, among all end-use sectors on a global scale. The World Energy Outlook 2007 predicts that this trend will continue. It also expects that India, with its rapidly growing economy, will experience the fastest growth in energy use in the transportation sector in the world. The current transport scenario in India and the trends confirm this. Emerging Asian countries led by India and China are expected to account for 45% of the total world oil use increase through 2025. Transport contributes close to 24% of CO<sub>2</sub> globally and this number, again led by China and India, is projected to grow significantly if transport activities in developing countries grow on a business as usual trajectory.

In India, the transport sector is the second largest consumer of commercial energy, currently some 18%; the sector also consumes the lion's share of petroleum products, about 50%, and its contribution to CO<sub>2</sub> is close to 14%. According to TERI's projections, the sector's share in the consumption of commercial energy will grow to some 65% and CO<sub>2</sub> emissions from the sector will grow 14 times by 2050 unless transport is put on a low carbon path. Clearly, if our Prime Minister's commitment to keep India's per capita CO<sub>2</sub> emissions at or below the global average is to be honoured, CO<sub>2</sub> emissions from the transport sector need to be contained. Besides, India is currently importing about 79% of its oil requirements of about 106 million metric tonnes (MMT); this could grow to about 93% of about 700 MMT by 2031 if energy consumption in all the sectors, and in particular the transport sector, grows unabated. This will have major implications for India's energy security.

Recognizing the need to reduce the growth of energy consumption in the transport sector, the Government of India came up with the National Urban Transport Policy (NUTP) in 2006 to encourage states and cities to invest in public transport and adopt measures to increase the share of public transport and non-motorized transport. The Government of India also agreed to fund urban transport through the Jawaharlal Nehru Urban Renewal Mission (JNNURM) in cities provided they drew up comprehensive mobility plans, which were consistent with the NUTP, a decision that sent out a strong signal to Indian cities on the need to adopt sustainable low carbon transport policies. The National Action Plan on Climate Change (NAPCC), through its Sustainable Habitat Mission, also lays emphasis on public transport and non-motorized transport in urban India.

The share of the railways in the inter-city movement of freight and passengers and the share of public transport and motorized transport in urban India are steadily declining. It is imperative that we arrest this decline and increase the shares of the more energy efficient modes as otherwise we would be severely undermining India's energy security and impairing our environment. We need to adopt, with a sense of urgency, the approach of 'AVOID', which implies the integration of land use with transport planning and other measures to reduce travel demand; 'SHIFT', which requires an inter-modal shift from road transport to other energy efficient modes like the railways, water transport, and public transport in cities; and 'IMPROVE', which calls for improvement in vehicle technology and fuels in the planning and management of transport in India. These measures are within our reach. What we need is a recognition of the need, at all levels of government and among all stakeholders, to adopt this approach, the necessary political will, and integrated institutional arrangements to address 'transport' as one activity and one sector and not in fragmented segments. To adapt an old English adage 'let us close the garage doors before our cars speed on our roads.'

S Sundar  
Distinguished Fellow, TERI

# Transport and energy linkages: a modelling approach

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Energy security of an economy has close inter-linkages with its transport sector—an energy-intensive sector. The transport sector accounts for 26% of the world's energy use and is the second largest consumer of energy. Most economies are dependent on petroleum products to meet a lion's share of their transport energy demand. Dependence on a single fuel is the major energy security concern faced by the sector, and the Indian transport sector is no different.

The Indian transport sector is the second largest energy consuming sector, after the industrial sector. It accounts for nearly 18% of the total energy consumption (TERI 2007). Moreover, nearly 98% of this energy demand is met by petroleum products, highlighting the high dependence of the sector on a single fuel (TERI 2007).<sup>1</sup>

Dependence on imported crude oil is one of the biggest energy security concerns for India. Though the country is a net exporter of petroleum products, with increasing domestic energy demand—triggered by the transport sector—our dependence on imported crude oil has been rising steadily. Currently, India imports nearly 79%<sup>2</sup> of its total petroleum product consumption (PPAC 2010). According to TERI's estimates, under the Business as Usual (BaU) scenario, India's crude oil imports could rise to as high as 93% (TERI 2006) by 2031/32. It is worth highlighting here that at 79% crude oil import dependence, the country is importing close to 128 million metric tonnes (MMT) of oil and by 2031, the amount of crude to be imported would increase to about 688 MMT. With a majority of this crude being sourced from politically sensitive regions such as the Middle East and Nigeria, the concern regarding the security of energy supply is fully justified. The increased dependence on fossil energy also has climate change implications, which is apparent from the fact that the transport sector is the second biggest contributor to greenhouse gas (GHG) emissions. This makes the case stronger for initiating a change in the

current energy consumption patterns for the sector.

This article discusses the various drivers behind the current high dependence of the transport sector on oil, as well as the long-term energy security implications if the current energy consumption patterns continue. The article concludes by suggesting strategies that can be adopted to decrease the dependence on oil.

## The Indian transport sector

While road and rail account for a major share in the modal mix of transport in the country, roadways dominate the sector in terms of both passenger and freight traffic. Share of other modes such as coastal shipping and aviation is minuscule. A concern in the inter-modal share has been the steady decline in the share of railways. Currently, 55% of freight traffic moves on roads, whereas only 34% depends on railways. The situation is worse in case of passenger traffic, where about 87% of the traffic moves on road and only about 13% uses rail. In the last seven years, automobile sales in the country have risen by a compounded average growth rate (CAGR) of 10%. Amongst the various categories, passenger vehicles have increased by a sharp 14% (SIAM 2010). The drivers for this increase in passenger vehicles are the rising incomes of the Indian population and the lack of public transport in most cities. Undoubtedly, using roads has its advantages such as convenience, door-to-door transportation facility, ease of tracking, and others, over other means of transportation including railways; however, rail transportation has a number of characteristics that makes it preferable to road transportation. For example, it is six times more energy-efficient than road and four times more economical. The social costs in terms of environmental damage or degradation are also significantly lower in case of rail. It is the only major transport mode capable of using any form of primary energy source (TERI 2007). Development

<sup>1</sup>Figures for 2004/05

<sup>2</sup>Figures for 2008/09

of other modes such as coastal transportation and in-land waterways has been by and large neglected. One of the key reasons that have stifled the growth of coastal transport is that there is no supporting coastal shipping. A number of committees have been formed over time, which have identified several issues stifling the growth of the sector. These issues relate to cabotage, high import duties, ship acquisition, and manning (Sundar 2010).

### The expected future trajectory

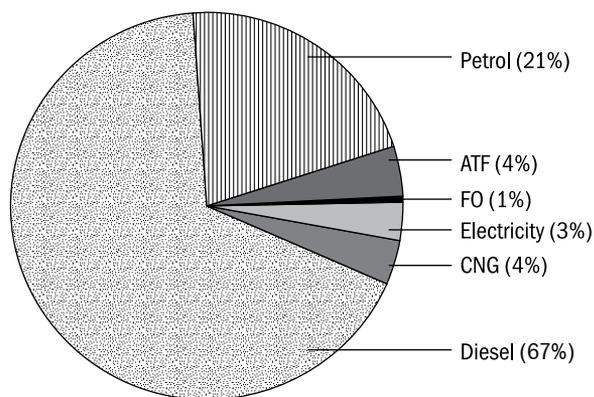
Recognizing the importance of the transport sector and the deep-seated linkages it has with the energy sector, TERI undertook an exercise to project energy requirements of the sector within a 2000 to 2050 time-frame.<sup>3</sup> The energy and the associated carbon emissions were projected under a BaU scenario and an alternate policy scenario.

### Key results

As expected, under the BaU scenario, the energy consumption in the transport sector is expected to increase from 57 million tonnes of oil equivalent (MTOE) in 2000, to 550 MTOE in 2050. The rate of growth for total energy consumed in the sector is about 5%, which is approximately equal to 14 times increase in energy from the base year to 2050. The increase in energy consumption is primarily fuelled by the road sector, which accounts for nearly 91% of the total energy demand. An inter-modal comparison shows that the growth in energy demand has been the highest in the road sector (freight) and the aviation sector (passenger)—at about 6%. Thus, the current trend of dominance of energy-inefficient private vehicles vis-à-vis modes of public transport is expected to continue in the BaU scenario. The modal mix will also continue to be dominated by the road sector.

A key concern associated with the transport sector is the lack of substitute for petroleum products. This situation is expected to continue in the long run. The dominance of petroleum products and diesel in the fuel basket for the transport sector is apparent. By 2050, diesel will account for 67% of the total energy consumed by the transport sector (Figure 1).

Interesting trends emerge in the alternate policy scenario. First, the total energy requirement in the transport sector decreases to nearly half—from 550

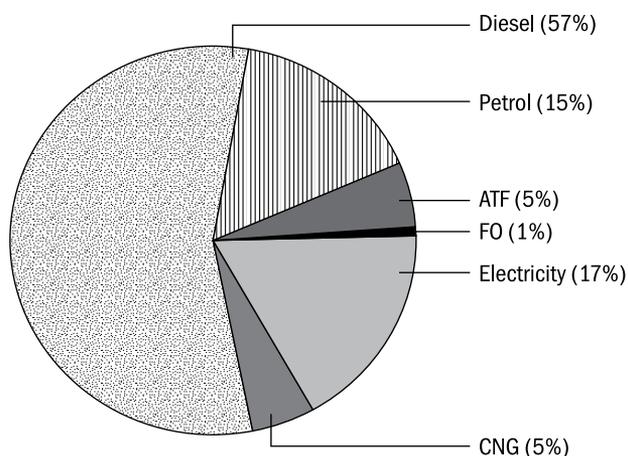


**Figure 1** Fuel mix for the transport sector under the Business as Usual (2050)

Source TERI

MTOE in the BaU to 321 MTOE in the alternate policy scenario—implying a less energy-intensive transport sector. Second, the energy consumption growth rate for the sector is about 4%, which means that there is an eightfold increase in the energy demand, as compared to the base year. Third, an inter-modal mix comparison reveals that in the alternate scenario, the growth has been the maximum in the public modes of transport such as rail (passenger and freight), air (passenger), and shipping (freight). The fuel mix is more diversified vis-à-vis the BaU, and the share of diesel in the fuel basket is expected to decline to 57% (Figure 2).

Another change in the fuel usage pattern is the increased use of electricity in the transport sector. Its



**Figure 2** Fuel mix for the transport sector under alternate policy scenario (2050)

Source TERI

<sup>3</sup>The model results presented in this paper are TERI model results. The exercise was conducted for the Institute of Transport Policy Studies, Japan.

share rises from a mere 3% in the BaU scenario to a substantial 17% in the alternate scenario. In fact, it is the biggest energy source after diesel in the alternate scenario. Keeping in mind the climate prerogative, it is assumed that a major portion of electricity will be generated using renewable energy resources.

The modal shift has been a major contributor to the decline in energy requirements of the sector in the alternate scenario. Though in both the scenarios, the share of railways has been steadily increasing, in the BaU, the share peaks at 32% by 2050, whereas in the alternate scenario, the share is expected to increase to 50% during the same time period. In case of freight transport, this difference is even steeper. Under the BaU, there is a steady decline in the share of rail freight, which is only about 23% by 2050. However, in the alternate scenario, rail (freight) share steadily increases to 60% by 2050.

The energy security implication of the transport sector is highlighted by the quantity of diesel required to meet the transport demand. In the BaU, it is expected that nearly 370 MTOE will be required to cater to the demand. In the alternate scenario, though the diesel requirements decline substantially to only 181 MTOE, the questions still remain regarding the increase in India's dependence on imports of the crude and petroleum products.

The trajectory of CO<sub>2</sub> emissions in the two scenarios is similar to energy transitions. The aggregate emissions in the BaU are expected to be about 1732 million tonnes of CO<sub>2</sub> in 2050, which is nearly a 14-fold increase, as compared to the year 2000. Passenger transport and freight transport are expected to contribute equally to emissions, and this trend is expected to continue in the alternate scenario. Among the various modes, the freight road sector is expected to account for a lion's share.

The aggregate emissions level in the alternate scenario is expected to be about 1061 million tonnes in 2050—an eight-times increase compared to the base year. Among the various modes, the road (passenger) sector is anticipated to account for a major share of emissions. Though, in most of the modes, a dip is seen between the BaU and the alternate scenario, with an overall reduction of 38%; for the railways sector (freight and passenger), there has been an increase in the emissions because of its increased usage consequent to the substantial shift from road to rail.

## **Moving towards a less energy intensive transport sector**

The results in the previous section highlight the necessity of shifting the transport sector to an alternate energy pathway at the earliest. The transport sector has a number of inefficiencies, which need to be addressed in order to decrease its dependence on oil. Following are some of the strategies that the sector needs to adopt on priority basis.

### ***Rebalancing the modal share inefficiencies***

As highlighted in the model results, a suitable change in modal mix can lead to a move away from private transport towards public transport. Such a shift has multiple benefits, including decrease in energy consumption, carbon emissions, and congestion on roads. Despite these advantages, modal mix in India is still skewed towards private transport. To initiate the desired change, a number of interventions are required to address barriers such as lack of infrastructure, perception issues, and lack of incentives to shift to public transport.

There is a pressing need to develop a comprehensive and integrated policy to address all these concerns, albeit the interventions would need to be prioritized based on the area under consideration. First, there is a need to develop a reliable public transport system. This is the cornerstone to successfully shift travel load from private to public transport. Being an investment-intensive exercise, substantial investments would be required to develop the infrastructure. Second, intermediate transport options would also have to be planned to ensure the actual modal shift, which has been one of the stumbling blocks. Private transport provides door-to-door facility, which public transport cannot provide, and hence arises the need for robust intermediate transport system.

Third, interventions are required to move traffic away from road towards rail transport. As mentioned earlier, and also highlighted in the model, rail is a more efficient mode than road, especially in case of freight transport. Thus, in the long-term in the alternate scenario, the share of rail is higher vis-à-vis road. It is suggested that existing distortions in the rail freight and passenger pricing need to be corrected to incentivize the shift of traffic from road to rail.

### ***Reduction in need to travel***

Interventions are required to reduce the very need to travel. This requires a multi-pronged approach and multi-level efforts. Given that a large chunk of the transport demand will emerge from urban sectors, urban planning needs to be looked at in an integrated manner. While cities are being planned, routes would need to be laid out in such a manner that bottlenecks are taken care of. Here again, emphasis needs to be placed on streamlining public transport in urban planning. For instance, while planning roads in the city, they should be considered as a means of intermediate transport, feeding into the public transport system of the city. Technology can be used to effectively manage traffic. Policies and regulatory interventions would need to be interlinked with the urban planning process so as to bring out the desired outcomes. Along with planning, technology, and policy and regulatory interventions, lifestyle changes would also be required to reduce the need for transportation.

### ***Electrification of the transport sector***

At the macro level, there is a need to invest in technologies that will drive the transport sector away from petroleum to electricity. However, here it is of utmost importance to ensure that the country's electricity mix also steadily moves away from coal to cleaner sources of energy—natural gas in the short- to medium-term, and renewable energy resources in the longer term. Electricity is a more flexible option for the sector, as it can be produced from a number of fuels, both fossil and non-fossil. A number of mass transit modes run on electricity. Shifting from personal petrol/diesel vehicles to electricity-fuelled public transport would not only help in curtailing energy demand of the sector but would also address congestion problems.

Electric and hybrid vehicles are also an option for personal travel, but there are a number of factors that have to be addressed to give these vehicles a push in India. First, there is a lack of adequate infrastructure to support electric vehicles, including availability of charging stations, manufacturing capacities, and so on. Second, in a country, which is reeling under electricity shortages<sup>4</sup> and where 40% of the rural population still does not have access to electricity

(NSSO 2008), electricity for the transport sector is much lower on priority. Third, the technology for electric vehicles is still at a nascent stage, which is reflected in the high prices of these vehicles.

### ***Incentives to improve technologies for better efficiency***

Despite all efforts, as seen in the model, it would be tough to phase out vehicles that run on petroleum products. Moreover, in the short- to medium-term, their dominance in the modal mix is inevitable. Thus, there is a need to promote fuel-efficient petrol/diesel vehicles. Also, sustained efforts need to be made to continuously improve the fuel efficiency of these vehicles. Policy interventions and incentives can play an important role in promoting fuel-efficient vehicles. Tax structures should be designed such that inefficient cars and fuel guzzlers are heavily taxed so as to deter consumers from buying them. Additionally, high excise tax slabs can prove to be a disincentive to automobile manufacturers in manufacturing such cars.

While promoting fuel-efficient cars, a consistent effort is required to improve fuel quality. This would help in reducing the environmental impacts of petroleum product usage. Here, integration is required between the refineries in the country and the transport sector. India has made some progress in introducing better quality fuels by launching the Bharat Stage IV fuel in 13 of the most polluted cities in the country. However, the challenge the country faces is introducing Bharat Stage III fuels in the rest of the country because of limited capacities of the Indian refineries to produce these fuels.

### ***Promote alternative fuels***

From an energy security perspective, it is essential to bring down the dependence of the transport sector on petroleum products. Besides all the above-mentioned interventions to facilitate a decrease in demand in petroleum products, there is also a need to replace petroleum products in the transport sector. Diversification of fuel mix of the transport sector is imperative and so is the need to promote alternative fuels. Biofuels such as bio-ethanol and bio-diesel have been considered as two substitutes for petrol and diesel, respectively. However, penetration of these alternative fuels is at a nascent stage in the country.

<sup>4</sup>Electricity shortages in India were about 10% energy shortage and about 13% peak shortages in 2009/10. Source: Central Electricity Authority, Ministry of Power, Government of India.

There are concerns about adequate availability of these alternatives to replace a substantial chunk of petroleum products. In case of bio-diesel, the country still does not have adequate experience to establish a business case for investing in the fuel. Investments are required in research and development of second generation biofuels based on lignocellulosic material, which are expected to be more suitable as alternative fuels. Compressed natural gas (CNG) is also being used in the transport sector in select cities in India. Here again, investments are required in developing gas distribution networks across cities to ensure that CNG is able to cater to a portion of petroleum product demand in the transport sector.

## Conclusion

The transport sector is one of the major energy consuming sectors of the Indian economy. The current consumption patterns dominated by the road sector and personal vehicles are clearly unsustainable.

To meet its energy requirements, the sector is almost completely dependent on imported oil. If this trend continues, in the medium- to long-term, the energy requirement of the transport sector would increase manifold, thus escalating energy security concerns for the country. Continued usage of fossil fuels will have negative implications such as increased carbon emissions. These factors exacerbate the need for the sector to look for a less energy intensive growth path. There are a number of strategies, elucidated previously, that can be adopted to curtail the energy demand. However, it must be highlighted that to implement any of the aforementioned strategies, support would be required from all the

relevant stakeholders, especially the policy-makers. Currently, a number of institutions are involved in the Indian transport sector. For instance, road transport is managed by the Ministry of Roads and Highways, railways has its separate ministry, and so does the aviation and urban transport segments. Distortions exist in the price of fuels such as diesel and the end use prices such as cross subsidization of rail passenger traffic with freight traffic, which limits the use of railways for freight transport.

The need of the hour is to develop an integrated view on transport sector, taking into account all the modes and fuels. The integrated approach is a must to ensure that there is healthy competition among various modes, and that majority traffic moves to the most efficient sources of transport and subsequently to a sustainable path forward.

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# Potential and challenges of electricity-driven vehicles in India

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## Why do we need electric vehicles in India?

In India, road transport has emerged as a dominant segment of the transport sector, accounting for 4.5% of the country's gross domestic product (GDP) (as of 2006/07). Quite intriguingly, from 2000/01 till 2006/07, the annual average growth rate registered by GDP with respect to the road transport sector was 9.4%, which was considerably higher than the overall growth rate of GDP during the same period (RBI 2010). An important feature of the road-based mobility in India is the phenomenal growth registered by the motor vehicle population over the years.<sup>1</sup>

Road-based mobility in India has two major concerns. First, the lion's share of its energy requirements comes from non-renewable fossil fuels, namely, petroleum products. India imports more than 75% of crude oil for meeting its energy requirements.<sup>2</sup> However, the price of imported crude has become volatile due to changing fundamentals (spare capacity and stockpiles), fluctuating dollar rate, lack of consistency in the pace of economic recovery, unsettling geopolitics, and influx of speculative elements. Second, although India has an overall low vehicle density, present personalized modes—two-wheelers and cars—account for more than four-fifths of the motor vehicle population in the country, as compared to their share of little over three-fifths in 1951 (GoI 2009). Moreover, the ownership of these personalized modes, especially cars, is asymmetrically skewed in favour of the urban metropolis. It is quite obvious that as India shifts to a higher growth

trajectory, ownership of personal vehicles, especially cars, will grow at a rapid pace, with increase in per capita incomes and increased urbanization, coupled with growing aspiration of the middle class. The issue might get even more compounded with rising consumer preferences for energy guzzler vehicles, thereby leading to higher energy consumption and concomitantly higher greenhouse gas (GHG) emissions from road transport.<sup>3</sup>

Thus, the biggest challenge faced by India's road sector lies in decoupling the inherent growth in personalized modes from the oil consumption and associated GHG emissions (especially CO<sub>2</sub>). Ideally, as a solution, one would like to look out for measures that could stunt the growth of personalized modes itself. But, given the existing imperfections in government policies and the absence of a sound, reliable, adequate, and efficient public transport, one would rather look for befitting viable alternatives that could kill two birds (oil consumption and GHG emissions) with one stone.

Vehicles running on electricity (fully or partly) do provide one such alternative and could act as a double-edged sword towards decarbonizing the future trajectory of road transport in India. These vehicles not only provide an avenue for lowering the fossil fuel consumption and GHG emissions up to zero level,<sup>4</sup> but also provide the co-benefits of lower air pollutants, lesser noise, and very high fuel efficiency as compared to conventional gasoline or diesel-powered vehicles.

<sup>1</sup> Between 1951 and 2006, vehicle population grew at a compound annual growth rate (CAGR) of nearly 11% (GoI 2009).

<sup>2</sup> Total commercial energy consumption in the transport sector in 2007 was estimated to be 1766.6 peta joules (PJ). Diesel accounted for 65% of the total energy used in the road transport sector, followed by petrol (24%), and aviation turbine fuel (ATF) (7%). The rest (4%) constitute coal, low diesel oil (LDO), fuel oil (FO), compressed natural gas (CNG), and liquefied LPG (GoI 2010).

<sup>3</sup> As per the latest available figures for 2007, the road transport sector emitted 123.55 million tonnes of CO<sub>2</sub> equivalent, which is 87% of the total emissions from the transport sector. In terms of specific gases, the road transport sector emitted 121.21 million tonnes of CO<sub>2</sub>, 0.023 million tonnes of methane (CH<sub>4</sub>), and 0.006 million tonnes of nitrous oxide (N<sub>2</sub>O) (GoI 2010).

<sup>4</sup> The lowering of GHG emissions up to zero level would be contingent upon the source of electricity. Although fully electric-driven vehicles do not emit any GHGs from the tail pipe, the source of power generation needs to be taken into account in order to make a life-cycle assessment of GHGs that finally get emitted in the process. In India, however, lion's share of electricity is generated from inferior quality coal. Hence, it would not be correct to designate these modes as completely green.

## Understanding the electric and hybrid electric vehicle technology<sup>5</sup>

Electric vehicles (EVs) use an electric motor for propulsion and rechargeable batteries for storing electricity. Unlike the conventional gasoline or diesel-powered vehicles, battery-powered vehicles do not have an internal combustion engine (ICE), drive train, and a fuel tank. Energy in the batteries provides the motive and auxiliary power<sup>6</sup> on board the vehicle. The motive power is provided to the electric motor through an electronic motor controller, based on inputs to the accelerator. Batteries are recharged from the grid-electricity and brake-energy regeneration, and also potentially from non-grid sources such as photovoltaic panels at recharging centres. Since the EVs do not burn fossil fuels to generate power for propulsion, they have zero emission and do not cause pollution. In terms of fuel efficiency, an electric motor converts 75% of the chemical energy from batteries to turn the wheels, as compared to ICEs, which convert only 20% of the energy stored in gasoline.<sup>7</sup> Thus, electric vehicles are nearly three times more fuel efficient than conventional gasoline-powered vehicles. Furthermore, as electricity costs substantially less than oil, the operating cost per kilometre for an EV is far less than that of a gasoline-driven car.

Hybrid electric vehicles (HEV) use both ICE and electric propulsion systems, with adequate battery capacity to store the electricity generated by the engine or by the brake-energy regeneration system. The batteries power the motor when necessary, provide auxiliary motive power to the engine or even allow the engine to be turned off at low speeds. In these vehicles, the electric motor usually provides a boost when the vehicle is started, and is recharged during vehicle operation. The process results in considerable improvement in fuel economy and thus significantly reduces fossil fuel consumption and CO<sub>2</sub> emissions.

A plug-in hybrid electric vehicle (PHEV) is essentially an HEV with additional batteries and a plug. This lends the vehicle an ability to use electricity from the grid to move. As the charge of larger battery pack of PHEV gets slowly depleted, some

types of PHEVs may operate all-electrically, while others may use both electric power from the battery and mechanical power from the ICE. PHEVs do have variegated design options, but all of these use electricity from the grid to replace liquid fuels used by ICE in vehicles.

Table 1 provides a general comparative evaluation of EVs, HEVs, and PHEVs in terms of necessary infrastructure, scale benefits, vehicle range, and battery efficiency,

## Electricity-driven vehicles in India: pluses and minuses

In India, although EVs have reached the stage of mass production in the form of two-wheeled bikes and scooters, the four-wheeled vehicles (especially low-duty vehicles [LDVs]) are yet to catch up.

In the two-wheel segment, YObykes (from Electrotherm, a Gujarat-based company) offers two scooterette and four bike models with motor powers ranging from 200 W–250 W. These light vehicles can move at a top speed of 25 km per hour, up to 75 km on a full charge of six to eight hours. YObykes manufacturing facility has an installed capacity of 250 000 units per year. The company has also launched high-speed and high-powered electric two-wheelers, in order to compete with the mainstream scooter category, and is planning to roll out the first electric motorcycle operating on battery power. Other notable manufacturers of electric two-wheelers include EKO Vehicles based in Bengaluru, and ACE motors based in Pune. EKO Vehicles have also recently launched the first hybrid bike with two variants, namely Strike and ET. The new bikes, developed in collaboration with companies based in the US and UK, run on battery and gasoline, enabling them to deliver twice the mileage for every litre of petrol. Other major regional players in e-bikes include Scooters India, Atlas Cycles, and Avon Cycles, among others.

In India, the pioneer of electric cars is the Reva Electric Car Company, which is a joint venture between the Maini Group of India and AEV, California. The company began its operations in 1994 from Bengaluru and soon after launched the first

<sup>5</sup> This section largely draws on IEA (2009a,b).

<sup>6</sup> Motive power is the energy used to propel a vehicle, while auxiliary power is usually defined as the energy used to perform functions other than propulsion. However, motive power can also be auxiliary, rather than primary, as in the case of hybrid electric vehicles.

<sup>7</sup> See <<http://www.fueleconomy.gov/feg/evtech.shtml>>

**Table 1** Comparative evaluation of some key features of HEVs, PHEVs, and EVs

HEVs/ PHEVs	EVs
<p><b>Charging infrastructure</b> HEVs do not require new refuelling infrastructure. For PHEVs, however, charging at home is essential in order to gain adequate driving range. Although, public recharging infrastructure is not a prerequisite, some consumers might prefer the availability of day-time charging opportunities.</p>	<p>The installation of public charging infrastructure is a must in order to increase the daily driving range. Fast recharging would be all the more essential for longer trips, with minimum halts in between.</p>
<p><b>Scale factor</b> The mass production of vehicles that may be necessary to derive the economies of scale (in terms of reduced production costs) may be lower than those needed for EVs. However, large-scale battery production at cheaper rate is a prerequisite in order to derive reasonable scale benefits.</p>	<p>Mass annual production level of 50 000 to 100 000 vehicles pertaining to each model may be necessary in order to derive adequate scale economies. However, deriving the scale benefits would be conditional upon mass scale battery production at reasonable cost (as in the case of HEVs).</p>
<p><b>Vehicle driving range</b> Optimal battery capacity and the range that could be obtained from the grid-based electricity could vary by markets, and also depend on the segment of the consumer that the vehicle is catering to and their willingness to pay for additional batteries in order to gain additional driving range.</p>	<p>Minimum range varies by regions and is contingent upon the daily driving level. The range obtained from EVs in one complete charging is currently significantly low, and often acts as a deterrent in consumer choice, especially in developing countries where the refuelling infrastructure is a serious constraint.</p>
<p><b>Battery efficiency</b></p> <ul style="list-style-type: none"> <li>• <b>Storage capacity</b> Batteries for PHEVs usually need to have higher power densities.<sup>8</sup></li> <li>• <b>Battery duty (discharge) cycles</b> PHEV batteries are subject to deep discharge cycles (in all-electric mode), besides frequent shallow cycles when the engine is in hybrid mode. The batteries used in case of non-PHEVs (that is, normal HEVs), however, experience shallow discharge/recharge cycles.</li> <li>• <b>Life expectancy/durability/other aspects</b> Currently, research and development is being carried out in battery technology in order to improve durability, life-expectancy, power density, energy density, temperature sensitivity, reductions in recharge time, with an overall emphasis on lowering of costs. However, since all these elements are interrelated, the biggest challenge is to simultaneously improve upon all these features in a battery by avoiding a trade-off between features.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Storage capacity</b> Batteries for EVs are required to be designed to optimize their energy storage capacities.</li> <li>• <b>Battery duty (discharge) cycles</b> Batteries for EVs are usually subjected to repeated deep discharge cycles without many intermediate or shallow cycles.</li> <li>• <b>Life expectancy/durability/other aspects</b> Same as in HEVs/PHEVs.</li> </ul>

HEV-hybrid electric vehicle; PHEV-plug-in hybrid electric vehicle; EV-electric vehicle

**Source** Based on information obtained from IEA (2009b)

two-seater electric car in India, which we all know as Reva-i. The green car revolution that Reva started is now being carried forward by the country's other major carmakers like Tata Motors. At the Delhi Auto Expo-2010, the company showcased a Tata Indica Vista electric model. The same year, Tata Motors also showcased the electric version of the Nano at

the Geneva Motor Show. General Motors India, in collaboration with Reva Electric Car Company, is also expected to launch Chevrolet E-Spark during the latter part of 2010.

Most Indian cities are characterized by congested roads, leading to low vehicular speeds, and limited driving distances. These characteristics make India

<sup>8</sup> The power density of a battery is related to its energy density, as well as its ability to discharge quickly. Energy density is usually the parameter used to compare one type of battery system with another. Energy density of a battery is its capacity divided by either the weight of the battery or its volume. A battery with a higher energy density will be lighter than a similar capacity battery with a lower energy density.

a leading contender for the current fleet of EVs, the features of which are ideally suited for Indian driving conditions. India is also uniquely and favourably positioned for these vehicles because of the availability of mechanical hardware and low manufacturing cost. Other notable advantages include low labour cost, low production start-up cost, availability of R&D facilities in electrical, electronics, and auto component industries, and a very large potential domestic city markets (Maini 2003). Another advantage of EVs is that these require low maintenance because they do not have oil filters, air filters, spark plugs or radiators. Moreover, low-speed EVs with power less than 250 W and speed less than 25 km per hour are exempt from registration, and hence, do not come under the purview of the Central Motor Vehicle Acts and Rules. Despite these advantages, and environmental benefits (such as reduced fossil fuel consumption, reduced GHG—as well as non-GHG—emissions, augmented fuel economy, and reduced noise pollution), EVs have remained a non-starter and sales in this segment are yet to pick up the Indian driving conditions.<sup>9</sup> The key constraints—some technical and others functional—that have been singled out by a number of recent studies on EVs include high price; limited driving range; lack of charging infrastructure; slow pace of improvement in technology, especially related to motors and performance, durability, and cost of batteries; dearth of holistic government support; and regulatory challenges.

The cost of battery accounts for a substantial share of the cost of the EV, and it is one of the key factors that limits the driving range. If a driver demands, for instance, a 500 km driving range, then even with the most efficient motor and battery systems, the battery capacity should be about 75 kWh. According to the International Energy Agency (IEA 2009b), with the more efficient (high-volume) battery priced at about \$500 per kWh in the near future, the battery alone would cost \$35 000–\$40 000 per vehicle. This is why, in order to make EVs more affordable, the models that are plying at present, or have been recently announced, have less driving

ranges (50–200 km), which necessitates significantly lower battery capacities. Although Indian driving conditions or driving requirements are suited to such low ranges, it does curtail the driving freedom, thus acting as a major deterrent to consumer adoption. Furthermore, as pointed out in Table 1, the primary challenge in developing battery technologies comes from avoiding a trade-off in one feature, while ensuring improvement in another. For instance, with a view to improve the journey range of a battery or charge quickly or increase in the storage capacity, compromise should not be made on the durability or life expectancy of the battery.

Furthermore, the battery also needs to be replaced every two or three years, which adds to the cost burden. For an e-bike or e-scooter user in Indian cities, replacing the battery makes a lot of difference, as the running cost of two-wheelers gets multiplied many times on account of battery replacement. According to Chetan Maini of Reva Electric Car Company, however, the running cost of an electric car, even after accounting for battery replacement costs, would still be significantly lower than the average running cost of a conventional gasoline car. This advantage, however, is due to cheaper cost of electricity at present, and the benefit would largely disappear once the electricity prices go up (Chattopadhyay 2010). Since at present, it is not be easy to decouple the vehicle purchase costs from the battery cost (initial and replacement cost), in order to increase the consumer base, battery technology needs to be developed to such an extent that the vehicle price as a whole becomes competitive and does not pinch the consumer's pocket. There are a number of battery technologies that exist at present,<sup>10</sup> which differ in terms of power density or energy density<sup>11</sup>. However, lithium-ion batteries have a clear edge over other battery technologies, when optimized for power and energy densities, but are exorbitantly priced. These batteries need to be developed by incorporating new technologies in order to make them lighter and cheaper, with better storage capacities and without compromising on other features.

<sup>9</sup> As per the September 2009 figures quoted by the Society of Manufacturers of Electric Vehicles, two-wheeler manufacturers and importers sold nearly 100 000 units in 2008/09, of which a majority were imported. Reva sold around 600 vehicles during 2008/09 (Srivastava S. 2009. Electric vehicle makers seek 25% government subsidy. Details available at <[www.livemint.com/2009/05/04004524/Electric-vehicle-makers-seek-2.html](http://www.livemint.com/2009/05/04004524/Electric-vehicle-makers-seek-2.html)>)

<sup>10</sup> The battery technologies when considered chronologically in terms of their evolution are: lead-acid batteries, nickel-cadmium batteries, sodium nickel-chloride batteries, nickel metal hydride batteries, and lithium-ion batteries.

<sup>11</sup> See Footnote 8 for definitions of energy density and power density.

Another important issue is the disposal and recycling of batteries. As far as India is concerned, the batteries that are currently being used are lead-acid batteries. Although these batteries are relatively cheaper, lead is a hazardous element with serious health implications. Thus, due care needs to be taken while disposing or recycling these batteries. The Battery Management and Handling Rules, 2001,<sup>12</sup> require lead battery manufacturers to re-collect 90% of their used batteries. However, there are no policy safeguards to ensure that the batteries are returned at the end of their life to the mandated recyclers. In reality, these are disposed of through environment-unfriendly methods, thereby leading to contamination.

Outdoor charging facilities are almost absent in Indian cities. What exist are handful of voluntary initiatives at local level, which are grossly inadequate for EVs plying on roads. The government at the centre, state or local levels have not displayed much interest in installing charging facilities at public places or along the roadside. Their disinterest is bound to persist unless the number of electricity-driven vehicles plying on Indian roads reaches a critical mass. Furthermore, adequate and reliable supply of power to charge the vehicles and the fuel used for power generation (at present coal accounts for the largest share of power generation in India, while renewable energy has an insignificant share) are also matters of serious concern.

Additionally, in case of EVs, effective regulations pertaining to road-worthiness and safety features are lacking. Bigger and more established automobile companies are self-regulated and stick to their own standards. However, due to the absence of stringent testing procedures or certification processes<sup>13</sup>, the smaller and more unorganized players are mostly importing e-bikes and selling them in India. They lack the post-purchase service back-up, have little regard for quality, and usually lack adequate spare parts that are crucial for these vehicles. This, in a way, invokes a negative perception in consumers and acts

as a deterrent to the growth of the e-bikes industry (Basu 2009).

Although India has been globally recognized as a growing hub of electricity-driven vehicle production, and the government did help in kick-starting the industry, most of the Indian manufacturers are still of the view that low numbers and the existing duty structure make manufacturing unviable. Although India does not have any national policy targets for EV manufacturing, in 2008, the centre waived the excise duty on battery-operated vehicles. This was followed by some states/cities such as Chandigarh (offered a subsidy of 15% on battery-operated vehicles), Bengaluru (4% VAT waiver for the initial five years after the launch and registration cost), West Bengal, Madhya Pradesh, Kerala, and Gujarat (VAT rates for EVs brought down to 4%) announcing incentives to promote EVs. Delhi also announced a 29.5% discount on all EVs.

A buyer in Delhi would get 15% subsidy on the base price, a VAT refund of 12.5%, and 2% concession on road tax and registration expenses. Other cities refund road tax and registration charges (Chattopadhyay 2010; EPA 2009). Furthermore, the Union Budget 2010 has been hailed as a green budget, which has elicited a lot of hope for EVs by removing customs duties levied on imports of critical components used in these vehicles.

### The way ahead

A more recent study carried out by Frost & Sullivan (F&S 2010) among Indian vehicle owners reveals that the concept of electricity-driven vehicles is slowly catching up in the country. The study, released in February 2010, reveals that due to post-purchase concerns such as battery life, distance travelled, maintenance cost, acceleration, and top speed, only 7% of Indian vehicle-owners are “very likely” to purchase an EV in future. Another finding of the study was that buyers are also willing to pay a premium over the base price for purchasing those vehicles, although the premium is fairly low, thus

<sup>12</sup> <<http://envfor.nic.in/legis/hsm/leadbat.html>>

<sup>13</sup>The testing and certification processes are mandated for conventional vehicles by the Automobile Research Association of India (ARAI), which is the apex body for vehicle certification. In India, for every vehicle, irrespective of it being a two, three or four-wheeler, ARAI testing is mandatory. Hence, the automotive manufacturers need to test and get their vehicles approved by ARAI before getting them on the road. ARAI testing can be carried out with the following objectives: (1) for getting the vehicle approved or (2) for getting vehicle exemption. ARAI regulations for low-speed electric bikes are as follows: maximum speed of the vehicle with a single person load (75 kg) should not be more than 25 kmph; maximum power delivered at the wheel with a single person riding should not exceed 250 W. At maximum power condition, the vehicle will be tested for 30 minutes. Once the vehicle passes the above tests, it will be certified for exemption from licence and registration (<<http://www.evhub.biz/electric-vehicle-technology/arai-testing-and-regulations-for-electric-bikes-in-india>>).

<sup>13</sup>For more details on the notion of loss-aversion and payback periods, see JTRC 2010.

highlighting an increased acceptance of the technology.

Given the concerns expressed by the existing EV owners, chances of Indians buying new cars (who usually tend to be loss-averse and want shorter payback periods<sup>14</sup>) opting for an electricity-driven vehicle will be all the more unlikely. In view of these concerns and the aforementioned roadblocks, the coming decade would be crucial in terms of garnering policy support in two primary areas: (1) ensuring the cost-competitiveness of vehicles, and (2) providing for adequate recharging infrastructure.

Research, development, and demonstration should thus essentially emphasize on reduction in battery costs and ensure adequate material supply, while focusing on smart-grid and vehicle-grid interface. The government, besides providing fiscal support, should also provide non-fiscal and non-monetary support by creating a conducive environment by making available adequate charging facility in public places like parking lots, malls, office complexes, and so on. Parking fees can be exempted for these vehicles, and the cars can be allowed to enter car-free zones in order to generate or increase awareness about these greener modes. Besides addressing the current constraints pertaining to technology, infrastructure, and regulation, the government, in collaboration with the industry, also needs to develop performance metrics for some key attributes like driving range and battery requirement in order to ensure that these vehicles achieve their true potential. Above all, the government needs to use a judicious mix of policies grounded in broad societal goals (for instance, energy security and low CO<sub>2</sub> emissions) in order to provide a clear framework and strike a balance in the interests of the stakeholders. For example, the government

should continue to promote renewable energy (such as solar and wind) more aggressively so that in future the EV become green in the true sense.

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<sup>14</sup> For more details on the notion of loss-aversion and payback periods, see JTRC 2010.

# Taking the urban transport sector on a less energy intensive route

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Efficient, effective, and environment-friendly transport system is vital for the socio-economic development of urban areas that are witnessing an enormous increase in passenger and freight movements. In an attempt to bridge the demand-supply gap in the urban transport sector, the current focus has been only on the provision of additional infrastructure, rather than meeting the demand in a more efficient manner. The failure of existing urban transport practices to deliver effective and environment-friendly solutions has reinforced the case for sustainable provision of transport services, rather than infinite expansion of the current disorganized system. This paper aims to raise the key issues related to the urban transport sector in India, and also suggests measures to reduce the energy-intensive pattern of sector's growth.

## Key issues in transport sector in Indian cities

With the substantial increase in transport demand in Indian cities over the past few years, intra-city transport provision has become a topic of concern. Increasing population, spatial footprints, personal motorized vehicles, rising household incomes, and economic development in cities have all added to the demand for urban transport. This demand is larger than the available capacity of public and intermediate public transport (IPT) systems and has pushed up the share of personal transport, which has led to problems such as congestion, pollution, increased use of fossil energy, road injuries, and fatalities. It can be observed that as on March 2006, the bus fleet in most large Indian cities constituted only about 1% of the entire passenger vehicular fleet indicating the public transport handicap faced by Indian cities (MoRTH 2009).

Figure 1 shows the large share of personal transport fleet (cars and two-wheelers), as compared to public transport (buses) and IPT modes (taxis, three-wheelers, and omni buses) in a few large Indian cities.

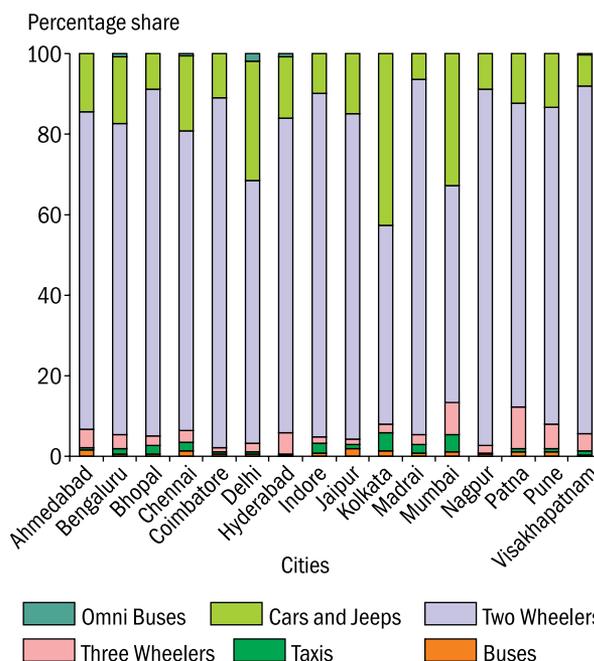


Figure 1 Share of different modes of transport comprising the registered vehicular fleet in a few large Indian cities (As of March 2006)

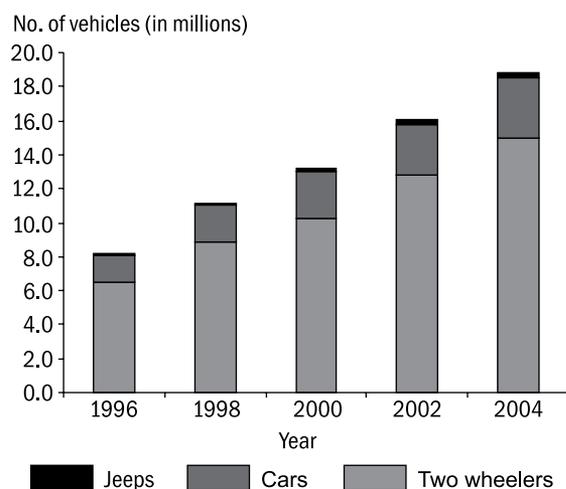
Source MoRTH (2009)

India has more than 5000 cities and towns. Of these, about 440 have a population of 1 million, while 35 have a population above 1 million (GoI 2001). However, in 2006, only 20 cities in the country had organized bus services. Very few cities have rail-based public transport system in addition to bus services. Organized urban rail service exists in four cities only, namely, Mumbai, Delhi, Kolkata, and Chennai. Intermediate public transport that serves as an intermediary service between public and private transport caters to the travel demand in many cities. However, the sector is highly unorganized and is witnessing uncontrolled growth, especially in large cities.

The state of non-motorized transport (NMT) in cities is no better. Although in 2007, walking and cycling constituted a significant share (approximately 40%) of modal distribution in cities, inadequate provision and poor quality of NMT infrastructure have led to continuous decline in the same (WSA and

MoUD 2008). The share of cyclists and pedestrians affected in road accidents is still significant in many Indian cities.

Inadequate public transport and NMT infrastructure are among the key drivers behind increasing share of personal vehicles in Indian cities. According to a study of 30 select cities<sup>1</sup> undertaken by Wilbur Smith Associates Pvt. Ltd (WSA) and Ministry of Urban Development (MoUD) in 2008, while there has occurred a steady decline in the share of public transport over the past two decades, the share of personalized modes, especially two wheelers, has increased at the rate of 12% per annum. The share of NMT has also been on the decline in many large cities. Figure 2 shows that personal vehicles, that is, cars, jeeps, and two-wheelers in metropolitan cities have more than doubled within a period of just



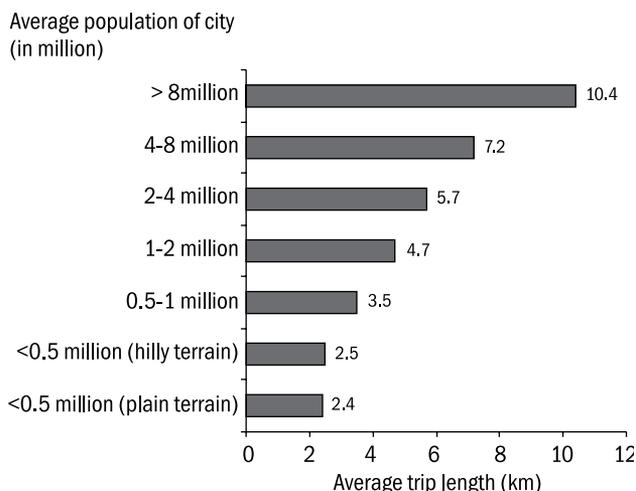
eight years (from 1996 to 2004).

**Figure 2** Number of registered cars, jeeps, and two-wheelers in metropolitan cities in India (1996-2004)

**Source** MoRTH (various years)

The rapid rise in personal vehicles can also be attributed to the horizontal sprawling of cities, which has resulted in increasing the need to travel longer distances. This phenomenon is quite evident in large cities, where the average trip length is much longer as compared to smaller cities (WSA and MoUD 2008). Figure 3 gives a comparison of average trip lengths of various cities with different population sizes. Urban sprawl, the need to travel longer distances, and increasing dependence on personal modes indicate

poor integration of land uses and transport networks/systems in our cities. Acknowledging this fact, the government, through its National Urban Transport Policy (NUTP), has begun encouraging cities to draw up integrated land use and transport plans. Even though cities have complied and have come up with comprehensive mobility plans, the quality and effectiveness of these plans in terms of achieving the goals of integration are yet to be evaluated, considering the fact that the capacity to develop and implement such plans is limited.



**Figure 3** Comparison of average trip lengths (km) in cities with different population sizes

**Source** WSA and MoUD 2008

The current state of affairs in cities, specifically the growing number of low-occupancy personal vehicles, has resulted in increased consumption of energy in the urban transport sector. It is estimated that with the current occupancy loads of cars and buses in Indian cities, per passenger kilometre fuel consumption of buses that run on diesel and compressed natural gas (CNG) is lower by 80%–85%, as compared to cars that use diesel and CNG. Hence, the rise in the number of cars in cities is leading to increased pressure on the fuel demand by the transport sector, which is already the second largest consumer of energy in the country. There is an urgent need to arrest the current pattern of urban transport growth and make it more energy efficient. Various interventions to achieve this desired path of

<sup>1</sup> Agra, Ahmedabad, Amritsar, Bengaluru, Bhopal, Bhubaneswar, Bikaner, Chandigarh, Chennai, Delhi, Hubli-Dharwad, Gangtok, Guwahati, Hyderabad, Jaipur, Kanpur, Kochi, Kolkata, Madurai, Mumbai, Nagpur, Panaji, Patna, Puducherry, Pune, Raipur, Shimla, Surat, Trivandrum, and Varanasi.

growth of the transport sector in Indian cities are discussed in the next section.

## Measures to alter the energy intensive growth pattern in transport sector in Indian cities

### *Urban planning interventions*

The design of new developments and retrofitting of existing cities need to follow the principles of integrated development. Planners need to formulate future plans for city development by adopting integrated land use and transportation planning. Integrated development concepts can be implemented by designing self-sufficient neighbourhoods, along with transit and NMT-oriented designs, mixed land uses, zoning and density regulations, carefully designed building bylaws, and correct locational and scale decisions, which can be instrumental in:

- reducing the need to travel,
- reducing the length of journeys,
- encouraging use of public transport and NMT, and
- reducing reliance on motorized personal transport.

The objective should be to provide enough low-energy-intensive modal choices such as cycling, walking, and public transport to the city's population through integrated planning concepts. Stockholm and Portland, Oregon (USA), are a couple of good examples of integrated land use and transport planning, wherein mixed-use and compact development concepts have become successful with able support from quality public transport. Within India also, developments like Old Delhi, Jaipur, and so on offer lessons in integrated development concepts for city planners. There is a need to integrate all these concepts into the city plans, while ensuring their implementation. Capacity-building of agencies dealing with city and transport planning is required to execute sustainable planning practices.

### *Infrastructure interventions*

Public transport and NMT have been universally acknowledged as the mainstay of any sustainable transport system. This is because, to a large extent, they are able to mitigate the social, economic, and environmental negative externalities of travelling (TERI 2009). In addition to being less energy intensive as compared to personal modes of travel, the advantages of a sound public transport system are as follows (TERI 2009).

- They are more “surface efficient”, and hence, reduce congestion.
- They result in fuel savings and emission reductions and provide safer means of travel.
- They serve the travel needs of the “disadvantaged” sections of the society, namely, the urban poor, women, children, and the elderly, as well as those households that do not own a vehicle.
- They restore cohesion in the society by providing access to jobs and education, thereby creating greater economic opportunities, leading to a better standard of living.

Integration of public transport services and NMT is necessary in cities to encourage convenient multi-modal trips for commuters and discourage the use of personal modes. The integration has to be in terms of both physical infrastructure provision and ticketing. Indore has successfully demonstrated integration of its public transport system; Delhi is also aiming to promote an integrated multi-modal system comprising metro rail, buses, and feeder services.

### *Policy interventions*

Augmentation in public transport and NMT infrastructure needs to be complemented by policy measures and demand management tools that discourage the use of personal modes of travel. Several instruments can be used to achieve this objective, including the following:

- Vehicle taxation
- Road taxes
- Parking fees
- Congestion pricing
- Building bylaws
- Zoning regulations
- Rewards and incentives from employers/ government

In addition to the above, government policies need to ensure that owners of personal vehicles abide by the standards of fuel efficiency, emissions, and in-use vehicle maintenance; and at the same time, phase out old vehicles in order to encourage less energy consumption. Towards this, the government needs to create adequate policy framework, consisting of mandatory vehicle fuel efficiency standards, emission norms, and inspection and maintenance system, supported by a strong institutional set-up for implementation and enforcement of these policies.

### **Technology interventions**

Improved and advanced technologies can be instrumental in bringing down energy consumption levels in urban areas. Advanced technologies like hybrid, electric, and solar vehicles need to be encouraged along with alternative clean fuels. Large urban areas where congestion levels are high need to deploy intelligent traffic management systems to ensure optimum traffic speeds and reduce idling and traffic congestion.

Technology can also be useful in terms of reducing the need to travel. Information and telecommunication technologies can be used to promote e-work, e-education, e-shopping, e-medicine, e-governance, and so on, all of which will reduce the need to travel, thereby resulting in energy savings.

### **Conclusion**

The current urban transportation situation in Indian cities is following an energy-intensive pathway, with the rapidly increasing share of personal modes, and public transport and NMT shares declining at the same time. The cities are facing numerous challenges such as increasing population, vehicle ownership levels, sprawls, and travel demands that

need to be addressed in the most energy-efficient manner. Response to these challenges should be in the form of a judicious combination of urban planning, infrastructure, and policy and technological interventions, which can effectively alter the current path of transport development and make transport less energy intensive and more sustainable.

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# Transport policies in select developed countries: lessons for India

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## Introduction

Although the Indian transport sector has progressed manifold during the 50 years of planned development, both in terms of spread and capacity, the rapid shift in favour of road vis-à-vis rail and increasing personalized modes of transport have become a cause for concern. The Indian transport sector is one of the largest in the world. It serves a land area of 3.3 million km<sup>2</sup> and is the biggest consumer of petroleum products in the country. According to the International Energy Outlook (2007), India is expected to experience the maximum increase in energy consumption in the transport sector among the non-Organization for Economic Cooperation and Development (OECD) countries, thus making for a strong case to look at options to make the sector less energy intensive. Analysing policy interventions in select countries like the United Kingdom (London), Singapore, Sweden, and Norway highlights that integrated planning and effective policy implementation can achieve actual improvements in transport network performance, thereby leading to reduced dependence on personalized modes and resultant energy savings.

This paper discusses transport policies of these countries to bring to light how they have developed an effective and efficient public transport system through an integrated policy approach.

## London, United Kingdom

Currently, London supports 27 million trips per day, which contributes to approximately 22% of the city's total emissions (London CO<sub>2</sub> 2007). Road transport accounts for about 80% of the emissions, of which private vehicles and road freight result in 50% and 25%, respectively, of the total emissions (Transport for London 2006). However, unlike other sectors, transport emissions in London have remained at a static level since 1990, despite the rapid growth in the city's population and economy. This is due to high levels of public transport use and unprecedented investment in the public transport network since 2000, alongside implementation of policies like

congestion pricing to combat congestion and traffic to manage.

Transport activities in London are managed by the Transport for London (TfL), which is a local government body responsible for most of the transport system throughout Greater London. TfL introduced the groundbreaking Central London Congestion Charge in February 2003, which has proved to be immensely successful in reducing personalized travel demand. Vehicles entering the charging zone between 7 a.m. and 6.30 p.m. on weekdays are charged £8 as a congestion charge. Other policies that have encouraged public transport include substantial investment in the public transport network, including a significant increase in bus capacity, and the ongoing programme of underground renewal. Approximately £4 billion have already been spent since the start of TfL's investment initiative. Additional investments have been made towards safer road layouts for walking, including expansion of London's cycle network, increased cycle parking, and cycle training. Fare incentives such as free travel for those under 18 and protecting the freedom pass for older and disabled Londoners have also been effective. All such measures have led to a greater number of walking trips, and a 72% rise in cycling on the major road network in 2005/06, as compared to 2000. Availing of buses has also increased by 40% over the same period. The Mayor of London has plans to make London the first major city in the world to charge cars entering its central business area on the basis of their carbon emission levels. Under this initiative, vehicles with maximum pollution will be charged £25 a day, while zero-emission vehicles will travel for free.

Besides TfL, other relevant endeavours include developing low-carbon engine technologies, developing the biofuel industry (which requires fuel suppliers to ensure by 2010 that 5% of their sales are from renewable sources), preparing government policies to promote low CO<sub>2</sub> lifestyles (such as an increase in vehicle excise duty [VED] on the most CO<sub>2</sub> polluting cars), levying of differential resident

permit charges on the basis of a car's CO<sub>2</sub> emissions, providing free parking to electric vehicles, and so on. Over the past few years, London has also witnessed the commercial launch of energy-saving propulsion systems such as hybrid and electric vehicles. Besides these interventions, other policies include continued support in terms of investments in public transport, walking, and cycling<sup>1</sup>; travel demand management, incentivization of the most fuel-efficient cars through a 100% discount, and dissuading from purchasing vehicles that lead to maximum pollution by imposing a higher-than-usual standard charge<sup>2</sup>; all new buses to be diesel-electric hybrids as soon as there is volume production available<sup>3</sup>; and adoption of low CO<sub>2</sub> vehicles and infrastructure via a range of investment decisions and policies.<sup>4</sup>

Thus, it is evident that the radical scheme on congestion pricing, coupled with focused investments in public transport, walking and cycling, new and efficient car technologies, along with effective travel demand management policies demonstrate that integrated planning can lead to visible improvements in transport network performance, in terms of reduced dependence on personalized modes and resultant energy savings.

## Singapore

The success of Singapore in developing an efficient land transportation infrastructure must be viewed from the perspective of integrated land use and transportation planning. The Government of Singapore established the Land Transport Authority (LTA) in 1995, to spearhead improvements in the land transport system. The 1996 white paper on "A World Class Land Transport System" provided the guidelines for the city's land transport development.

Singapore was the first country to implement Area Licensing Scheme (ALS) for traffic management. ALS was introduced in 1975 to reduce congestion and discourage personal vehicle use. A vehicle entering the restricted zone (of 620 hectares) during peak hours (7:30–10:15 a.m. and 4:30–6:30 p.m.)

is required to procure a licensing ticket on a daily/monthly basis. Subsequently, the first phase of the Electronic Road Pricing (ERP) was implemented in September 1998 to replace the ALS. The purpose of ERP is to moderate and spread out vehicle usage for a more optimal and congestion-free road network. The Vehicle Quota System (VQS) was implemented in May 1990 to control growth of the vehicle population at a sustainable rate. The implementation of this system enabled the LTA to manage the vehicle population growth at 3% per annum. Singapore has successfully applied advanced technologies to improve the efficiency and sustainability of its land transportation system. Apart from the ERP system, the global positioning system (GPS)-enabled taxi dispatching system was implemented in 1996. Taxis are a convenient form of public transport, yet because of their low passenger carrying capacity as compared to buses and mass rapid transit (MRT), they contribute more to traffic congestion and consume higher fuel on a per passenger basis. It is for this reason that the total number of taxis in Singapore is controlled.

To encourage energy efficiency, the key strategy has been to promote public transport and curb the use of private vehicles. Since 1 October 2006, all new diesel vehicles are required to comply with the Euro-IV emission standard. This directive alone will ensure that all taxis in Singapore will be of Euro-IV standard by 2014. However, all public buses will be able to comply with the same standard only by 2023. LTA is working with bus operators to advance the conversion of their buses to Euro-IV standard by 2020.

In order to promote green vehicles, LTA and the National Environment Agency (NEA) jointly introduced the Green Vehicle Rebate (GVR) in January 2001. GVR aims to bring about a change in consumer behaviour to support clean emerging technologies, by narrowing the cost-differential between a green vehicle and the conventional equivalent model. Further, the Fuel Economy Labelling Scheme (FELS) for passenger vehicles

<sup>1</sup> By 2025, London has targetted an increase in cycling trips by 400%. Also a 10% rise in walking is targetted by 2015, with a longer-term aim of more than one million additional walking trips by 2025.

<sup>2</sup> It is also proposed that the tax levied on the most polluting categories must be increased further if car purchasers are to be influenced to select low carbon cars, and similarly rewarded for choosing cleaner options.

<sup>3</sup> These buses emit 30%–40% less CO<sub>2</sub> than diesel buses of similar size.

<sup>4</sup> TfL will continue its support to hydrogen-powered buses on specific routes to accelerate development and eventual commercialization of this technology. It will introduce 10 hydrogen-fuelled buses as part of the London Hydrogen Partnership Transport Action Plan by 2010. TfL will also encourage train operating companies to increasingly source the energy used on electrified sections from renewable sources.

is administered by the Singapore Environment Council and supported by NEA. The main objective of this scheme is to raise consumer awareness on fuel economy in passenger vehicles. As part of the programme, LTA is targeting to achieve a per capita 7% improvement in energy consumption for the land transport sector by 2020.

Singapore has recently initiated the Singapore Green Plan 2012, which aims at reducing CO<sub>2</sub> emissions by at least 25% of the 1990 level by 2012. One of the targets under this plan is the introduction of “green vehicles” (such as hybrid and CNG). Singapore is already incentivizing green vehicles and encouraging public fleet operators to switch from diesel to CNG. At present, the public transport mode share stands at 63% during morning peak hours. With the aforementioned measures, LTA is targeting to increase this proportion to 70% by 2020.

## Sweden

The overall transport policy objective in Sweden can be categorized under six sub-goals.

- Accessible transport system
- High transport quality standards
- Safe transport
- Good environment
- Favourable regional development
- Transport system managed by, and equally serves the interests of, women and men

The Swedish Parliament passed the Congestion Tax Act on 16 June 2004. Congestion tax is imposed on registered Swedish vehicles driving into and out of the Stockholm inner city zone on weekdays between 6.30 a.m. and 6.29 p.m. The accumulated passages made by any vehicle during a month are aggregated into what is called a “tax decision”. The Swedish Road Administration (SRA) sends out the tax notification to the vehicle owner at the end of each month when passages occurred, and the total amount of congestion tax payable for the previous month is calculated.

Sweden is an environment-friendly country, which believes in integrated planning as a measure to put in place an efficient and sustainable transport policy. The SRA has the overall responsibility of the environmental impact of the road transport system. The goal is that road traffic should be energy

efficient, environmentally sustainable, and eco-cycle adapted. To achieve this end, the government emphasizes on clean, economical, and safe vehicles. Recently, the government has introduced the eco-car<sup>5</sup> subsidy. Its purpose is to encourage more people to buy fuel-efficient cars and vehicles operating on renewable fuels. For a car to be able to qualify for the eco-car subsidy, it must meet certain technical specifications along with additional requirements in case of conventional cars (for cars running on petrol, CO<sub>2</sub> emissions should not exceed 120 grs/km. during driving); alternative fuel cars (cars that run on fuels other than petrol, diesel or liquefied petroleum gas [LPG]); electric cars (where the consumption of electric energy per 100 km. may not exceed 37 kilowatt hours); and to brand new cars as well. The eco-car subsidy is applicable to only those private individuals who buy a new green car, and not to a corporate or any other legal entity. During 2007–09, the government had allocated SEK 250 million for the subsidy.

Sweden also has national-level incentives for biofuels, including tax exemption schemes, under which vehicles running on biofuels are exempt from congestion charges and pay a lower registration tax. Buses, taxis, a number of private cars, and garbage collection trucks run on biogas (Franks 2005). Presently, about 15% of all new cars sold in Sweden are environment-friendly, which run on ethanol or biogas. Sweden is also working actively in the EU to permit a higher blend of ethanol in petrol. In addition, a legal framework is being developed to make it mandatory to have at least one fuel pump for renewable transport fuel (E85, biogas) at every gasoline and diesel-oil filling station.<sup>6</sup>

Swedish regulations also include clauses to undertake regular compulsory inspection of vehicles so that the necessary maintenance of the vehicle is undertaken to ensure that the emission control system is functioning properly.

## Norway

The national transport planning processes in Norway and Sweden have several common features in matters related to content, planning process, and planning methods. In Norway, the Directorate of Public Roads, an independent body under the Ministry of Transport and Communications, is the headquarters of the

<sup>5</sup>An eco-car has low CO<sub>2</sub> and other harmful emissions and low noise levels.

<sup>6</sup>Blended petrol, with up to 85% concentration bio-ethanol and 15% petrol

Norwegian Public Roads Administration.

For over 50 years in Norway, tolls have been successfully used as financial instruments for road construction (Jeromonachou, Potter, and Warren 2004). Funds from these projects form the main financial source of road, and to a certain extent, public transport investment programmes. Norway has also introduced congestion pricing, revenue from which is used for wider purposes such as building public transport projects and subsidizing tickets. In 2004, the government introduced an incentive-based state funding scheme for public transport in larger urban areas. The system rewards local authorities in larger cities, which implement measures that encourage increased use of public transport and dissuade private car traffic.

Norway has also introduced various environmental policy measures in the road transport sector, using the pricing mechanism. For instance, the tax system is designed to encourage the use of alternative, low-emission fuels. Norway already has a strong history of tax incentives for cars running on alternative energy sources such as electricity. In 1990, registration taxes for electric cars were abolished. Thereafter, in 1996, annual vehicle taxation and road tolls were scrapped for these vehicles. In 2001, their value added tax (VAT) was also removed. All these measures have made the use of electric cars in Norway an attractive proposition. Norway has also introduced hydrogen cars, which, too, enjoy tax incentives. However, the availability of renewable energy for hydrogen production is scarce. At the end of March 2007, the Oslo Municipal Council discussed a suggestion that the buses in Oslo should run on environment-friendly fuel.

### **Comparative assessment with India and lessons to be learnt**

In India, public transportation is not as well developed as Sweden, Singapore, London or Norway. Even though there has been a swift increase in demand for urban transport, the Indian cities have not been able to meet the challenge. Table 1 gives a comparative account of the transportation policies in other countries vis-à-vis India.

As is evident from the Table, the integrated transport system (ITS) is fairly well-developed in other countries. India needs an ITS system that is cost-effective, efficient, and at the same time,

compatible with the present level of development in related areas in the country.

As far as emphasis on fuel-efficient vehicles or green vehicles is concerned, several countries have implemented useful measures. These include the green vehicle rebate in Singapore, subsidies on green cars in Sweden, cars that run on electricity, and hydrogen cars in London and Norway. However, in India, limited progress has been made in the introduction of alternative fuels.

In some of these countries, for instance, in Sweden, we also find national-level initiatives to use biofuels. In London, the RTFO has been introduced, which requires fuel suppliers to ensure that by 2010, 5% of their sales are from renewable sources. In India, biofuel as a future source of energy, has the potential to change the urban transportation scenario. India is the world's fourth largest producer of ethanol. Unlike Brazil, where ethanol is produced directly from sugarcane juice, and the US, which uses corn for production, India produces ethanol from bagasse.<sup>7</sup>

In India, the Central Pollution Control Board (CPCB) under the Ministry of Environment and Forests (MoEF) has been executing a nationwide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP). However, most of the cities have violated the prescribed air quality standards, and in most of these cases, the major cause of deteriorating air quality has been growth in vehicle population. Unlike many developed countries, in India, there is a marked absence of proper enforcement regulations.

In comparison to the other countries discussed in this paper, parking charges in India are minimal. It is important to formulate regulations in terms of strict parking charges, considering the tremendous growth of private vehicles in the country. If revenues from increased parking charges are utilized to develop alternatives to personalized modes (as is the case with most other countries), this instrument can be a progressive one. With more than 90% of public transport passengers in Indian cities relying on buses, it is especially important to upgrade bus services by making available modern, convenient, comfortable, and safe vehicles. The ideal source of such funding would be some sort of dedicated gasoline or private motor vehicle tax, revenues from which could be used in the improvement of urban transport conditions,

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<sup>7</sup> Bagasse, or molasses, is the waste product obtained after the extraction and refining of sugar from sugar cane.

**Table 1** Transportation policies in select countries vis-à-vis India

Policies	India	London	Singapore	Sweden	Norway
Intelligent Transport System (ITS)	Absent	Developing	GLIDE, EMAS, J-Eyes	Developed	Developed
Emphasis on green vehicles/fuel-efficient vehicles	Some of the cities have shifted to compressed natural gas (CNG) in public transport	Cars with hybrid engines and electric vehicles	Green Vehicle Rebate; Fuel Economy Labelling Scheme; Incentivizing green vehicles by switching from diesel to CNG	Eco-car subsidies	Electric cars and hydrogen cars
Incentives on biofuels/biogas	Absent	The Renewable Transport Fuels Obligation has come into effect on 15 April 2008		Tax exemption schemes on biofuels	At planning stage
Regulation on vehicle emissions	Poor enforcement of existing regulations	Vehicle excise duty on the most CO <sub>2</sub> polluting cars; emissions-influenced charging into the congestion charging scheme has been proposed	Introduction of Euro-IV emissions standard	Strict regulations are enforced. Vehicles have to undergo compulsory inspection	
Financial instrument	Minimal parking charges	Congestion charge	Electronic road pricing, Parking charges based on market demand	Congestion tax	Congestion tax and tolls; progressive parking taxes
Control of private vehicles and emphasis on non-motorized modes	Absent	Continued investments in public transport; expanding cycle networks	Vehicle quota system	Investment in efficient and high quality public transport and making it accessible for all	Emphasis on public transport by providing discounts (for example, bicycles and public transport tickets given to employees free of tax)

**Source** Based on information obtained from IEA 2009b

including better roadways, better bicycling and walking facilities, and above all, better bus and rail services. Most of the countries discussed in this article have either used congestion charges or parking charges, or even both, to fund alternative and efficient public transport modes. Congestion pricing is an important source through which such investments could be funded. The charges should be initiated for private vehicles in metro cities. This would, slowly but surely, increase the demand for public transport. Such instruments have proved to be implementable and useful in other countries, and therefore, are surely an option for India. However, it all depends on the awareness levels of people and public support that can be garnered while undertaking such measures.

The National Urban Transport Policy (NUTP), if implemented effectively, provides a way forward. The document states that the key objective is to

move people, and not vehicles. Thus, it emphasizes promotion of cost-effective public transport as well as prioritizes non-motorized modes such as cycling and walking. Effective implementation of the NUTP, however, requires concerted effort at the city level.

Some of the initiatives that have been made in the past few years in an attempt to improve transport include construction of flyovers in a number of cities, widening of roads, and construction of the Mass Rapid Transit System (MRTS) in Delhi, among others.

### Conclusion

For India, therefore, public transport is the priority area for policy measures in order to avoid further deterioration of air quality, traffic safety, and congestion. The need for mass transit and the scope for its adoption in the major cities of the country are

being discussed for more than three decades now. However, not many concrete actions have been undertaken. While some improvements can take place even with the existing funding levels, the rest would require massive infusion of new funding for expanded and modernized bus and rail systems. At the same time, state and local governments must give traffic priority to buses—through special bus lanes and signal priority over private transport. With more than 90% of public transport passengers in Indian cities relying on buses, it is especially important to upgrade bus services through modern, convenient, comfortable, and safe vehicles. The ideal source of such funding would be some sort of dedicated gasoline or private motor vehicle tax. Congestion pricing and parking taxes are other sources through which such investments could be funded. Also, there should be stricter emissions norms to be followed in the cities and heavy penalty mechanism should be in place for non-conformance.

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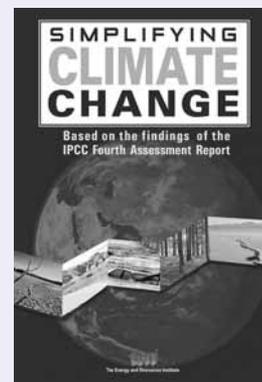
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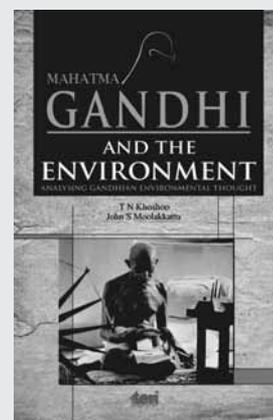
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