User Guide for India's 2047 Energy Calculator

Transport Sector

Contents

1. Overview and key trends of the transport sector

The transport sector in India plays an integral part in the country's economic growth and development while consuming a large volume of the total commercial energy of the country. It is the second highest energy consuming sector after industry in India. Not only that, it is also responsible for consuming the largest share of the nation's petroleum products. Given the sector's rapid growth and the near exponential increase in vehicle ownership in India, it has also become one of the fastest growing energy demand sectors in the country (MoSPI, 2013).

Most of the motorized passenger transport in the country moves on roads, rail and air. In addition, some passenger traffic also moves on inland-waterways[1]. Freight traffic on the other hand moves largely on road and rail. A small but increasing share of freight movement also happens via pipelines, coastal shipping and on inland-water ways. However, it is road transport that is responsible for meeting the major share of both passenger and freight transport in India.

Driven by a rapidly growing economy and the economic liberalization of the early 90's there has been a particularly high growth in transport movement on roads and a large increase in the number of passenger vehicles in the country. For instance, both passenger cars and two-wheelers have seen about 10 per cent CAGR between 1991 and 2011. From a mere 2.95 million registered cars and jeeps in 1991, the number of cars and jeeps has soared to over 19.23 million by 2011 (9.82% CAGR) and registered two-wheelers have grown from about 14.2 million in 1991, to about 101.86 million by 2011.

In the wake of the rapid urbanization accompanied with the lack of adequate urban bus and national railway services, this has resulted in a large volume of the passenger and freight traffic moving to the generally more energy intensive private modes of road transport. This is a critical cause of concern given that India imports

[1] The transport sector sheets for motorized domestic passenger and freight traffic for the current version of the Energy Calculator do not capture the traffic driven and energy consumed by inland-waterways, coastal shipping and pipelines.

about 84% (in 2011-12) of the crude oil processed in the country (TERI, 2013) and an increasing reliance on petroleum products could quite easily become a concern from the point of view of the national energy security. Any resulting bottlenecks in meeting the demands of energy for transport could be detrimental for the nation's growth.

In the aims of providing connectivity to large sections of the country, of all the modes of transport, the road based transport has seen much higher shares of investments over the 9th, 10th and 11th Five Year Plans. This has resulted among others, in the large scale roll-out of the National Highways Development Program, increased focus on rural roads through the Pradhan Mantri Gram Sadak Yojna and urban transport reforms through the JNNURM (Planning Commission, 2013).

Even in the Railways, there has been a clear focus towards increasing capacities of the national network. While passenger train loads have increased due to increased engine capacities, increasing investments have seen much faster doubling of tracks over the last decade. While the total running kilometres of the railways increased from only 78,607 km to 81,865 km in the decade between 1990-91 and 2000-01, it increased to 87,114 km over the next decade (by 2010-11). The railways have also focused on electrification of the major trunk routes. Of the total 20,275 electrified rail route kilometres, over 6,000 kilometres (total 64,460 km), were electrified in the decade between 2000-01 and 2010-11 alone (MoR, 2013). The last few years have also seen the start of work for the Western Dedicated Freight Corridor (WDFC) a project that will connect the northern and western industrial hubs to the western ports of the country. Another Eastern Dedicated Freight Corridor (EDFC) is planned connecting the northern industrial hubs to the eastern ports. However, due to the much faster growth in road and air transport, the Indian Railways has been consistently losing its share in both passenger and freight mobility across the country.

With the emergence of the low-cost airlines in India, which completely redefined air traffic, the passenger traffic on air has grown over four times between 2000-01 and 2010-11. The domestic passenger traffic on commercial airlines grew from 12 billion passenger kilometres in 2000-01 to 53 billion passenger kilometres in 2010-11 (DGCA, 2013).

In terms of types of fuel use, the transport sector in India is driven largely by petroleum products such as high-speed diesel (HSD) and petrol (i.e. motor spirit/gasoline). While HSD is used to drive varying types of road transport vehicles, railways and ships, the use of motor-spirit or petrol is limited mostly to the road transport passenger sector. Other fuels used to drive transport are electricity used for railway traction and pipelines, and airline turbine fuel (ATF) used exclusively for aviation. The use of alternate fuels such as compressed natural gas (CNG) and liquefied petroleum gas (LPG) remain very limited to road transport in a handful of urban centres across the country.

Although electric traction has several merits such as much higher motor efficiencies than fossil fuel engines, the penetration of electric vehicles have been very limited in India largely due to the prohibitively high costs of these vehicles.

Given the vital role that the transport sector plays for the economy it is critical for the country to ensure that it is able to meet this rapidly growing energy demands. It is for this reason that the 12th Five Year Plan suggests that not only should transport policies and related technologies be made far more efficient but also that adequate public transport services be introduced across the country. To cut down the energy demand for freight transport it also suggests that necessary planning should be undertaken for the creation of transport hubs around manufacturing centres and ports. The plan has also emphasized on increasing the traffic movement of both passenger and freight on railways given its relative energy efficiencies over road (Planning Commission, 2013).

Taking such measures is imminent to not only ensure national energy security, but also for reducing the nation's overall carbon footprint. It is for that purpose that through a set of 'what-if' analysis of the transport sector, the 2047 Energy Calculator for India tries to identify the potential energy savings benefits by simulating the impacts of various alternative energy savings scenarios for the sector.

2. Key issues with energy use information for the transport sector

It must be mentioned that while the use of both HSD and electricity for traction purposes of the railways are well documented by the Indian Railways, the fuel use information for other domestic transport modes such as road transport are not very accurately understood. This is a result of a complete lack of regular and reliable data on national freight and passenger movement (Planning Commission, 2007).

Although it is clear that the road transport sector consumes the largest share of the energy used by the transport sector, detailed breakup of energy use by the various vehicle classes within the sector are not accurately available and are at best, estimates. Without a clear understanding and assessment of intra-sector energy use it is difficult to plan and prioritize the energy conservation efforts. Even for aviation, while the total national ATF sales information is available, the information about the actual domestic consumption of the fuel is not reported in any particular published source.

It is for that reason that a bottom-up rather that a top-down approach is used to arrive at the estimates of energy demand from the transport sector for the present exercise.

3. Categories of transport demand

This section deals with description of the categories considered for determining estimates of present and future energy demands from transport in India and identifies ways to reduce its energy dependence. The transport sector in the current version of the Calculator is simplified into two basic components, namely passenger and freight sectors (as shown in Figure 1). As part of this exercise, both passenger and freight motorized mobility in the country (only domestic transport) is assumed to be met by either road, rail or air based transport[2].

However, given that the choices available in terms of vehicle types and technologies for domestic motorized passenger transport are much more varied than that in the case of freight transport, the exercise assumes a larger number of levers for making potential differences in the energy consumption for passenger transport as compared to that of freight.

Using the TERI Transport Model to arrive at the estimates for the passenger transport demand in terms of billion passenger km (BPKM), and freight transport demand in billion tonnes km (BTKM) the exercise looks at six determinants of transport energy demand within the framework of present and future trends in the transport sector. These determinants are – (i) Passenger Transport Demand, (ii) Passenger Transport Mode, (iii) Ratio of Public Private mode share in Road, (iv) Share of EVs, (v) Freight Transport Demand, and (vi) Freight Transport Mode, of which (i) – (iv) are used to estimate energy demand for passenger traffic, while the last two determines the same for the freight traffic.

The Level One for each of these categories is the 'Least effort scenario', giving in most cases the most pessimistic outlooks. Level Two is the planned outlook, called the 'Determined effort scenario' and takes into account some technological

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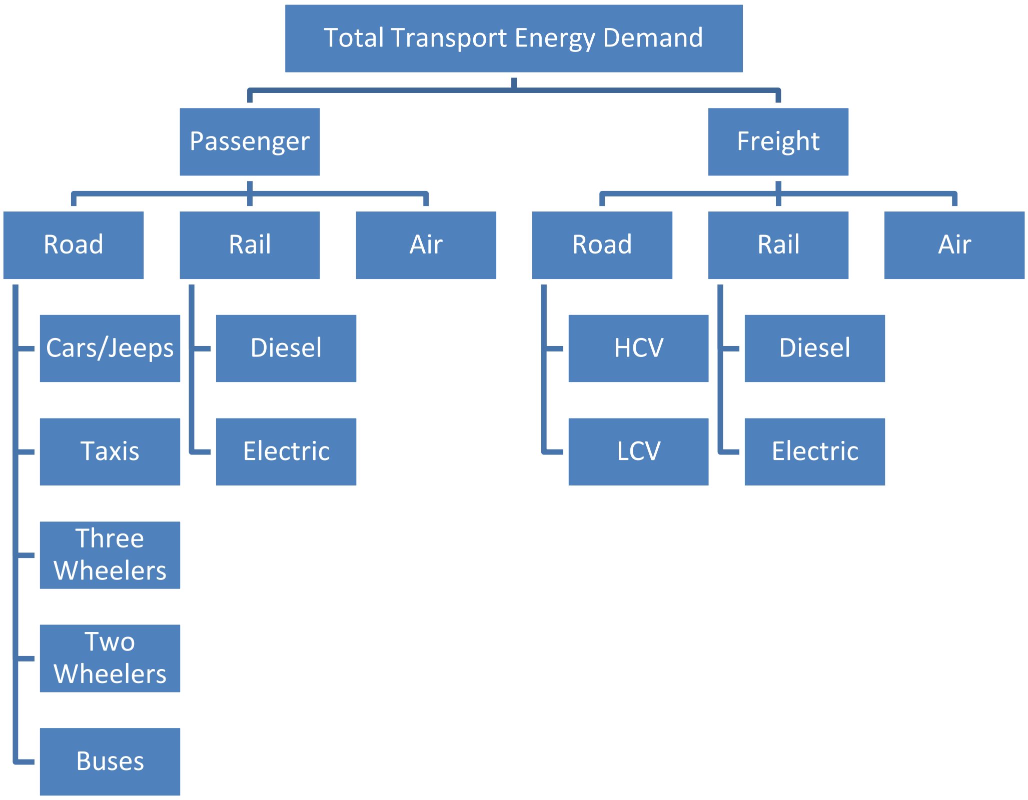
[2] And although it is understood that a minor share of passenger and an increasingly significant share of freight traffic moves on inland-waterways, coastal shipping and pipelines these modes are kept out of the present version of the Calculator due to inadequate information regarding the traffic on these modes.

improvements over and above the unplanned case. Level Three is more optimistic, and considers aggressive government policy interventions towards a better future, called the 'Aggressive effort scenario'. Finally, Level Four for any of the categories is the picture of an optimistic world as a result of 'Heroic effort'; an ideal hypothetical situation that is drawn from available technologies today.

Figure 1 Building blocks of energy demand from the transport sector



The 6 levers mentioned above have been separately developed in the Excel model under two excel sheets, and both Excel sheets having been identified by the number given in parentheses below. The following basic categories, as they appear in the Tool, are considered for generating the energy demand from the transport sector:

A. Domestic passenger transport category (sheet XII.a)

Motorized passenger transport[3] demands have been consistently growing in India over the last several decades. With increasing growth in economic activities, increased urbanization and increasing access to mobility choices under the business as usual scenario, the trend is expected to continue going into the future.

This increasing motorized passenger transport demand volumes will have to be met on road, rail or air[4], forming the three primary modes of transport of travel in the country. This category outlines the passenger traffic demand and the methods of meeting the demands on domestic road, rail and air modes. It further breaks down the passenger transport demand by the various road vehicle and technology types after classifying them into public and private. The breakdown of the passenger kilometres into the various mode and technology types are shown in Figure 3.

The detailed calculations relating to the passenger transport sector appear in sheet XII.a of the MS Excel version of the Tool. There are four levers considered under the category of passenger transport that appear as line items for users to choose from under the energy demand categories of the Tool. Each of these levers have four different levels – with Level 1 representing the worst case scenario (more energy demand due to unbridled growth in passenger transport demand), and Level 4 representing a hypothetical, highly ambitious, energy efficient scenario, wherein the demand for transport growth and energy demands moderated through planning and technology induction. Level 2 and 3, are assumed to be scenarios in between these two extremes. Following are the four levers appearing under the category of passenger transport.

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[3] Passenger transport in the entirety of this wiki-note on the transport sector is used to refer to motorized passenger transport. It is acknowledged that a large share of the mobility in India happens on non-motorized modes of transport – however, since it does not lead to energy use, it is not reflected in the present version of the calculator.

[4] Water based motorized passenger transport has not been considered for this version of the Calculator since there was inadequate data to substantiate any numbers for water based passenger transport.

a. *Passenger traffic demand*– An increasing motorized passenger transport demand with the same mix of technology as today would lead to an increasing energy demand for passenger transport. This lever allows the user of the Calculator to reduce the passenger transport demands under various assumptions across four different levels.

b. *Modal shares of passenger traffic*– The passenger transport demand in the country as selected under the previous lever is assumed to be met on roads, railways or aviation. This lever, which appears as a line item under the demand categories, allows the user to choose mode shares of road, rail and air. Given that railways is far more energy efficient than either road or air, the user is given choices to improve the share of railways under four different levels.

c. *Public and private road vehicle shares*– Road transport users have a choice set of either public or private vehicles to choose from for making their journeys. Given that public transport offers a more energy efficient solution than private modes, this lever offers the user four different levels to choose from, each with an increasingly improved share of public road transport mix.

d. *Efficient road vehicle shares*– Private road vehicles which are not wholly driven by internal combustion engines (ICE), such as hybrid, plug-in hybrid, electric and plug-in electric offer a significantly more energy efficient solution to ICE based private vehicles. This lever appearing under the passenger transport category of transport energy demand, allows the user to select from four different levels of efficient vehicle (EV) penetrations in the future, improving from Level 1 through 4.

B. Domestic freight transport category (sheet XII.b)

This category of energy demand from transport, as it appears in sheet XII.b of the Tool, outlines the current and future domestic freight traffic demand along with the modal shares of meeting that demand on road, rail and air. The following are the levers that are chosen for varying the energy demand for freight transport in the country.

a. *Freight traffic demand*– Like in the case of passenger transport demand, any increase in motorized fright traffic with an unchanged level of technology and transport mode mix will result in increased energy demands. This lever allows the user to choose from four different levels under which freight transport demands are assumed to reduce from base levels thereby reducing the energy demands.

b. *Modal shares of freight traffic*– Inter modal shares of freight traffic are given as choices for the user under this lever. Given that rail based freight transport is much more energy efficient than road, the four levels under this lever gives the user four improved rail share trajectories to choose from.

The energy from the transport sector is calculated based on the user choices from among the six levers appearing under the two categories of the transport sector. In addition to energy demand, this Tool also indicatively estimates the costs that could be incurred under these various scenarios in lieu of provision of additional infrastructure and rolling stock necessary for meeting the varying volumes and modes of travel.

4. Fixed assumptions

The energy and cost calculations from the transport sector as described in the worksheets XII.a and XII.b in the Tool are built on a set of fixed assumptions as outlined here:

1. *Population*: The estimates of population of India as it appears in row 143 of worksheet XII.a are taken from the Scenario B estimates of the Indian population as estimated by the Population Foundation of India (PFI). These population estimates are available for the century till 2100 (PFI, 2007).

Table 1 Decadal population projections for India

Population projections (in millions) from 1981 to 2031

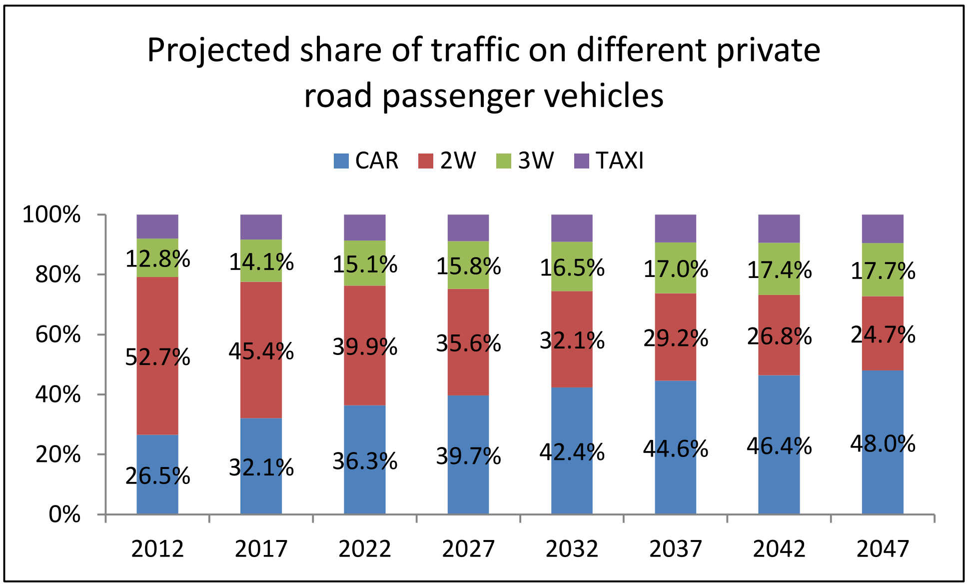
	1981	1991	2001	2011	2021	2031
Total population	6,851	8,463	10,287	11,925	13,397	14,533
Rural population	5,254	6,286	7,426	8,345	9,071	9,516
Urban population	1,597	2,176	2,861	3,579	4,326	5,017
Share of rural population	76.7%	74.3%	72.2%	70.0%	67.7%	65.5%
Share of urban population	23.3%	25.7%	27.8%	30.0%	32.3%	34.5%

Source: (PFI, 2007)

2. *Shares of traffic on public and private road vehicles*: For the purpose of this exercise, buses and omni-buses are classified as public road vehicles, while other private and intermediate modes of road vehicles such as cars, two-wheelers, three-wheelers and taxis are classified as private vehicles. The projected intra-public and intra-private shares of traffic on these vehicles are assumed to grow as per the present trends of growth of these vehicle categories, and these numbers are assumed to remain unchanged across all levels of all the different levers.

   For instance, within the category of private vehicles, the share of traffic on cars and jeeps which is 27 per cent as of 2011-12 gradually increases to about 48 per cent by 2046-47, while the share of two-wheelers drop from 53 per cent to 23 in the same duration. This intra-private vehicle share is assumed to remain constant across all levels. Similarly, the share of traffic on buses and omni-buses, the two modes within public transport are assumed to remain unchanged across the various chosen levels.

Figure 2 Projected share of traffic on different intra-private transport modes assumed unchanged across different levels



3. *Mode shares by technology*: The share of traffic projected on the various technology/fuel choices available for a particular vehicle category is assumed to remain fixed across all different levels of the various levers. For instance the share of traffic on electric and diesel traction of the railways is assumed the same as per the current projections for all the various levels. However, the shares of efficient vehicles are assumed to vary under the different levels of the EV lever. These EV shares (Table 1) are added to the fixed projected shares of conventional vehicles for cars and jeeps, two wheelers and buses as per the user choices.

Table 2 Penetration of EVs assumed under the various levels of the EV lever

		Penetration of EVs by 2051-52 under different EV lever trajectories			
Vehicle type	**2011-12**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Cars and Jeeps	0%	0%	20%	40%	50%
Two-wheelers	1%	20%	30%	45%	80%
Buses	0%	0%	5%	10%	15%

4. *Efficiency*:

   Road transport: Based on varying assumptions on the occupancy, utilization and vehicle fuel efficiency of the various road vehicles a set of efficiency numbers in terms of the fuel units per passenger and tonne kilometre are estimated. The units used are in terms of units of fuel used per passenger kilometre (or tonne kilometre) for different vehicle categories. These estimated efficiency numbers of each vehicle type by technology and fuel type is assumed to improve gradually by 0.1% annually through the entire horizon period but remains unchanged across the different trajectories.

   For instance, based on the assumed average numbers from the top ten State Road Transport Undertakings from a mix of long distance and urban bus services, the efficiency of buses are calculated as follows:

   a. Bus occupancy: 45
   b. Mileage of a diesel bus: 5.28 kmpl (CIRT IJTM, April-June11)
   c. Therefore a bus can do 237.76 (=45*5.28) passenger kilometres per litre of fuel
   d. This number is inverted to arrive at the litres of diesel consumption per passenger kilometre (i.e. 0.004 litres per passenger km) – this efficiency is assumed to improve at an annual rate of 0.1% every year.

   For freight transport, the efficiency numbers are estimated for both Heavy and Light Commercial Vehicles across the country based on appropriate assumptions and kept fixed across the various levels.

Railways: The efficiency numbers in terms of litres of diesel consumed or kilowatt hour per passenger kilometre or tonne-kilometre for railways is arrived at from the actual national averages of the Indian Railways as published in its Annual Statistical Statements (MoR, 2013). While the efficiency in the railways for passenger movement is assumed to improve as per the trends of the previous two decades, the efficiencies in moving freight on electric traction is expected to marginally improve with the introduction of the DFCs (Pangotra & Shukla). This is based on the assumption that about 12 per cent of the national freight traffic is expected to move on the WDFC after its introduction. According adjustments are made in efficiency estimates.

Aviation: The passenger efficiency numbers for aviation are arrived at by dividing the total fuel capacity of a typical Airbus 320 (approx. 23,859 litres) (Airbus, 2013), with an occupancy of about 160 and a load factor of 77.30% (DGCA, 2013). I.e. Aircraft efficiency = Total fuel capacity divided by the effective seat kilometres done on full tank. The litres consumed per air tonne kilometres are calculated similarly. The aircraft fleet is assumed to become about 0.25 per cent efficient annually during the duration of the horizon period.

5. Methodology

Starting from the estimates of total transport demand of both passenger and freight on the various modes of transport such as road, rail and air, and sheets allocate various transport demands to the various transport vehicle and technology types to arrive at the energy demand and incremental costs incurred by the sector under various scenarios. The next two sections give a detailed explanation of the techniques involved in arriving at the figures for both the kinds of traffic.

A. Passenger Transport Energy Demand

To ascertain the energy demand estimates from the perspective of passenger traffic, the following four levers are assumed to affect energy demand:

(i) **Passenger Transport Demand (PTD):** The PTD per capita is equal to the total distance covered by a passenger in a year, and is calculated as the total passenger km (in BPKM) divided by the total population. This is a determining factor of energy consumption in the transport sector as increased usage of motorized modes for transport increases energy demand, and hence, this has been chosen to forecast energy demand trajectories.

(ii) **Passenger Transport Mode (PTM):** The PTM is the medium of transport used by passengers. The total motorized transport demand is assumed to be driven by road, rail and air transport, which is further classified under different technology based on the type of fuel used. The complete classification of the mode of transport is represented in fig. 1.1 and fig. 1.2.

(iii) **Ratio of Public Private modal share in Road:** Another lever used in determining the energy demand scenarios is the share of public and private vehicles on road for passenger transport. Public transport is assumed to be more efficient catering to a larger population at a lesser cost of energy than private modes of transport. Hence, with an increasing share of public transport, the energy demand in the sector is assumed to decrease than that in a BAU scenario.

(iv) **Share of EVs:** Introduction of energy efficient vehicles, for instance, electric and hybrid cars/buses, can also affect transport energy demand significantly in the future if their share in passenger transport increases at a considerable scale.

Based on the BAU estimates from 2011-12 to 2052 with time intervals of five years, three more scenarios/levels are created which shows a change in trajectory of each lever by 2052 as compared to the BAU levels. In the case of total PTD (in BPKM), the three scenarios considered are assumed to exhibit a decline progressively in each level. The total PTD is further broken down into shares (in percentage) of modes of transport – road, railway, airways. The trajectories with respect to the share of PTD, with choices of the three modes of transport, are estimated for all the levels. Based on BAU levels, the modal share in each level is dominated by road transport, followed by rail and airway. However, railways being more energy efficient, the modal share trajectories change in favour of it with its share assumed to increase with each level by 2052, while that of roads diminish.

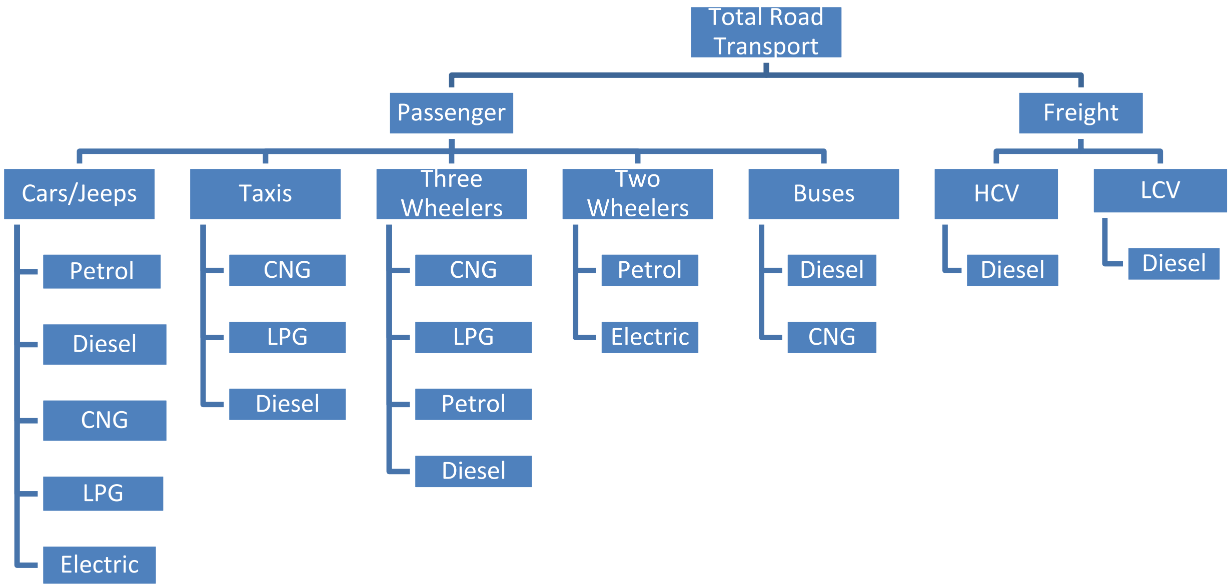
Another determinant of the passenger transport energy demand, as mentioned earlier, is the Public Private share of road transport. Public mode of road transport includes buses and omnibuses, while private vehicles include cars, three wheelers, two wheelers and taxi. The percentage share of these is determined by the passenger km in each mode. Here, the share of public transport is assumed to grow with respect to private vehicle in every successive level, starting with BAU scenario. The fourth influential factor for estimating passenger transport energy demand is the share of Energy Efficient Vehicles in passenger road transport which is classified into electric cars, electric two wheelers and electric buses. The two wheelers are expected to have an increasing share across the different scenario set-up, followed by the electric cars.

In addition, the various modes of transport have been categorized according to technology used in terms of types of fuel, as seen in the case of buses, the efficiency number as estimated in the efficiency table is multiplied with the volume of passenger kilometres on buses

The energy demand for a particular mode of transport is obtained as a product of the following:

Energy Consumption per vehicle = Passenger Kilometres performed on buses X Efficiency of buses in terms of energy consumption per passenger kilometre

Figure 3 Road Transport Technology



B. Freight Transport Energy Demand

Like in the case of passenger transport, the energy demand for domestic freight transport is captured in the worksheet on the freight transport XII.b. The worksheet gives the overall volumes of freight transport in the country along with the mode wise distribution of traffic and the average efficiency levels.

The following two levers are assumed to affect the total energy demand for freight transportation in the country.

i. Freight transport demand (FTD): The four different trajectories of freight transport demand result in four different trajectories of fuel use. These are arrived at by multiplying the vehicle efficiency numbers by the freight transport demands for that vehicle type and technology. These fuel requirement numbers are further multiplied with the calorific values of the various fuels to arrive at the energy demands for the various freight transport modes and vehicles.
ii. Freight transport mode (FTM): The FTM is the medium of transport used to move freight. The total motorized transport demand is assumed to be driven by road, rail and air transport, which is further classified under different technology based on the type of fuel used. Based on the freight transport demand chosen by the user in the previous lever, the freight transport mode allows the user to make a choice of the mode share percentages. This mode share percentage is multiplied with the total freight transport demand to arrive at the mode wise demand for freight transport. This is in turn multiplied with the efficiency factors to arrive at the total fuel consumed by road, rail and air freight transport in the country.

C. Estimates of incremental costs under different scenarios

The total traffic volumes and shares of traffic of both passenger and freight transport is segregated by mode and technology types. The costs are calculated under two heads, rolling stock costs and infrastructure costs. The incremental cost estimation under both heads is based on life-time apportionment of costs.

i. Rolling stock costs: Each technology type has an assumed life, occupancy and use cycle based on which the expected utilization of each vehicle technology is calculated over its life-time. The fixed assumptions related to the current capital and maintenance costs are used to determine the aggregate costs to be incurred on each mode specific technology over its entire lifetime. These mode-technology specific costs are apportioned by the vehicle's utilization in terms of total units of traffic (pkm/tkm) over its lifetime to estimate the cost incurred per unit of traffic. This estimate of cost of rolling stock per unit of traffic is multiplied into the total volume of traffic for a particular scenario to determine that particular scenario's rolling stock costs.

ii. Infrastructure costs: Infrastructure costs are complicated to apportion as compared to rolling stock costs because the same base infrastructure, such as a road, is used by various different modes and technologies which have varying utilization levels and lifetimes. More importantly, the exact link between the volume of infrastructure and the amount of traffic on that infrastructure is not well documented.

    To circumvent this challenge the approach followed was determining the vehicle kilometers traveled for all different modes of transport on different types of infrastructure and apportioning the costs of infrastructure to each of these mode-technologies based on their average gross laden weights. The cost of the infrastructure being used by each of these modes is thereby apportioned to each transport mode-technology in the ratio of the vehicle-weight-kilometers, which is a product of the vehicle-kilometers and the gross laden vehicle weights. This method is used to determine the volume and related infrastructure costs which would be incurred under each of the different levels and scenarios discussed in previous sections.

The sum total of the rolling stock and infrastructure costs under each of the scenarios for the different years are helpful in giving an indicative directional idea about the nature of costs to be incurred under different scenarios.

The costs incurred under the Level 2 scenario has been considered as the baseline cost for the Tool, and all incremental (or decremented) costs estimated within this Tool is calculated against this baseline.

6. Driving factors and level assumptions

The following section describes the assumptions considered for the various levels of passenger and freight transport sheets in the Calculator.

i. Passenger transport demand

The average distance travelled annually per person in India in 2011-12 is estimated to be only 5,967 km. The same statistic in the EU in 2009 was 11,700 km (Enerdata, 2012); in the UK in 2010 was 14,247 km (UK Energy Calculator, 2012); while in the US it was about 28,000 km per year in 2010-11 (BoTS, 2012). With increased economic development, there is expected to be an increase in mobility and demand for both inter-city and intra-city passenger transport in India over the next few decades.

Level 1

Level One assumes a steady increase in the per capita demand for transport over the next four decades. From current levels, distance travelled annually per person is expected to increase to 18,978 km by 2046-47. Improved access to transport infrastructure, accompanied by increasing demand for mobility due to increased economic activity would lead to an increase in total passenger transport demand. Distance travelled per capita will rise steadily for both intercity and intra city travel.

Level 2

Level Two envisions a rise in the number of activity centres across the country, thereby reducing the demand for inter-city travel of people migrating for employment opportunities. Better planning and improved urban designs would also lessen intra-city travel distances. This Level would see a drop in the overall annual demand for mobility per capita by about 9 per cent from the mobility demands envisioned by 2046-47 in level one, reaching 17,312 km by 2046-47.

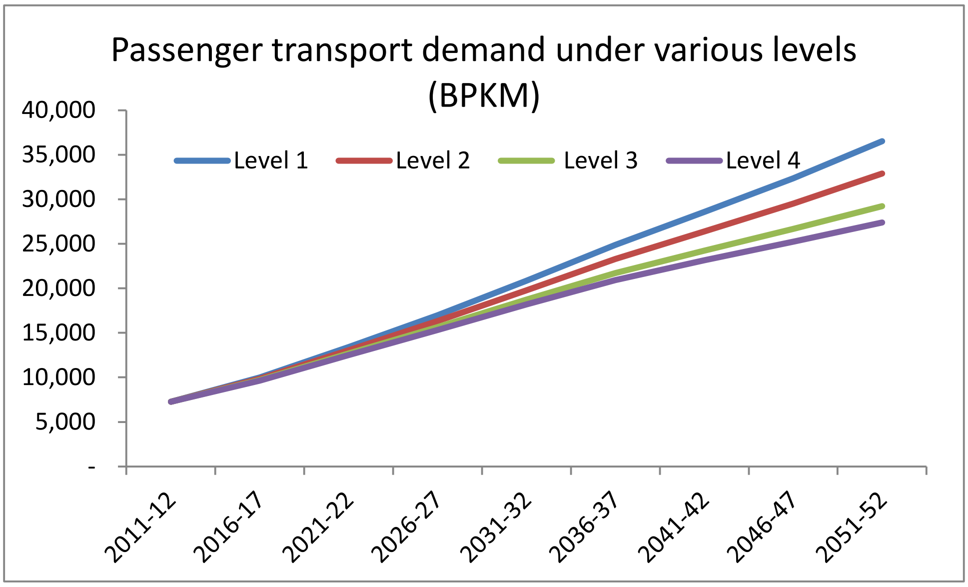
Level 3

Level Three visualizes a world where all new cities that come up in the country in the next four decades plan for Transit Oriented Development, and there is a conscious effort to incorporate similar best practices in pre-existing urban centres. Smart, IT enabled transport infrastructure enabling better route optimization for commute trips further helps in reducing the transport demand per person. Annual per capita passenger transport demands would thereby be moderated by about 18 per cent over the present mobility demands envisioned by 2046-47 under level one, reaching 15,646 km by 2046-47.

Level 4

Level Four is a world where the growth of passenger transport demand would be moderated by conscious policy initiatives on urbanization patterns and transport demand management. Realization of targeted economic development in the rural sector will significantly reduce demand for transport of migrant workers seeking

Figure 4 Passenger transport demand under various level assumptions



employment in urban centres. The measures for Transit Oriented Development would get strengthened further, with focus on minimizing the need for commute trips and other trips for daily needs. Further improvement in IT and IT enabled services would markedly reduce demands for both intra and inter-city passenger travel. All these initiatives would reduce the annual per capita passenger transport demand by about 26 per cent over the passenger transport demands envisioned by 2046-47 under level one, reaching 13,979 km by 2046-47.

ii. Passenger transport mode

In 2011-12, estimated travel by road accounted for 85% and rail accounted for 14% of total passenger traffic. The remaining 1% traffic was on air. The share of public modes of transport (Buses and Omnibuses) on roads was estimated to about 74%. Electric vehicles witnessed a limited penetration in the market, the prominent share of which, around 1%, was mainly in the two wheeler segment. With improved road transport infrastructure and increased penetration of private modes of road transport, railways have been consistently losing share in the overall passenger traffic volumes in India. The decade between 2000-01 and 2010-11 also saw a rapid growth in air transport in India. Given the present trends, Railways is expected to further lose share in the overall transport mix in the country over the next few decades.

Level:1

This level assumes that the present trends in mobility shares will continue till 2046-47. The intermodal share of passenger transport demand is expected to tilt further towards road based modes. There would be a surge in the total number of cars and jeeps by 2046-47 thereby decreasing the share of public road based transport to 46%.The penetration of electric two-wheelers is still assumed to be limited because of the absence of any incentive mechanism and thereby increases as per past trends to 18% in 2046-47. Although there will be a growth in rail based transport systems, the growth will be marginal compared to road and air transport. As a result, by 2046-47, the share of road in passenger transport will become about 86% while the share of rail will be about 12%. In addition, as more planned airports in smaller cities become operational and money value of time increases, it is expected that the share of aviation in the overall passenger transport demand will increase to 2%.

Level:2

Level Two envisages a focus on rail based mass transport systems. Metro and suburban rail systems would be extended to a number of urban centers across the country. Faster train sets will operate for inter-city rail passenger services. This would positively affect the trend of falling shares of rail based passenger transport and the intermodal share of rail would rise to 15% by 2046-47. Demand for faster intercity travel would maintain civil aviation shares at about 2% While road based passenger transport would still dominate, with an increase in the share of public road based transport to about 57%, its share would marginally reduce to about 83% of the total passenger transport demand by 2046-47.This level also assumes policy decisions on the side of the government to subsidize electric vehicles, thereby increasing the penetration of electric four-wheelers to 18%,electric two-wheelers to 26% and electric buses to 4% of the road based transport in 2046-47.

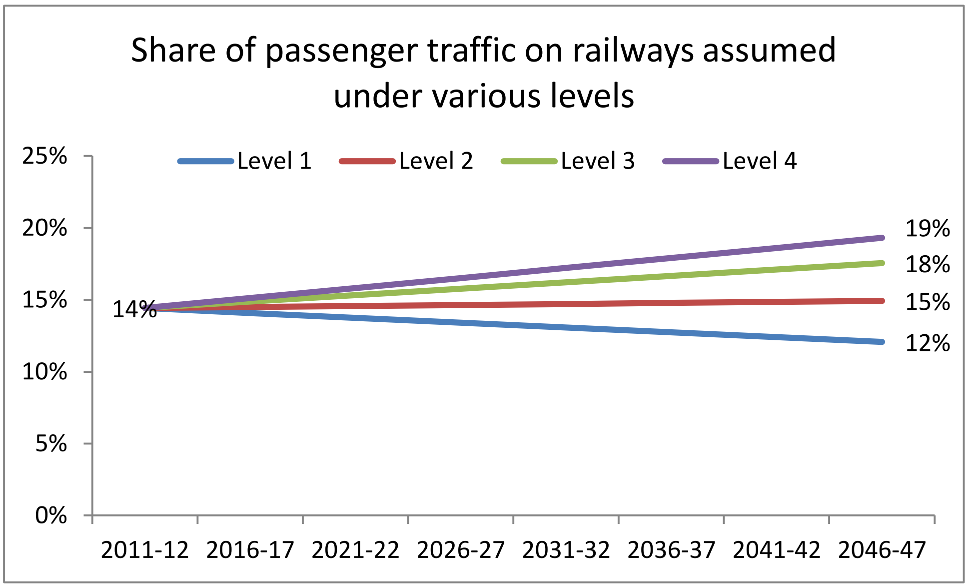
Level:3

Level Three assumes conscious and increased government policies towards incentivizing metro and suburban rail services, introduction of high-speed rail corridors and projects like Regional Rapid Transit System (RRTS) across various urban centers. This will aid in shifting larger volumes of passenger mobility from road and air to rail based transport systems. The share of road is assumed to decrease to less than 81% by 2046-47 in this level while rail and aviation will occupy about 17% and less than 2% shares respectively. Incentivizing metro services would increase the share of public transportation in road based transport to about 66% in 2046-47.Additionally, this level assumes that the National Electric Mobility Mission Plan kicks in and thereby the penetration of electric two-wheelers increases to 40%, electric four-wheelers increases to 35% and electric buses increase to 9% of the road based transport in 2046-47.

Level:4

In level four, the focus of government policies is expected to further enhance investments in rail based public transport like metros in all urban cities and Rapid Rail Transit Systems for all urban conglomerates. For inter-city travel, priority in investment will be to shrink travel time between all state capitals and major metros to 12 hours or less through faster train services. High Speed Rail at 300 km/hour for high demand passenger corridors will help reduce the incidence of air travel. Based on this, Level Four envisages that the intermodal share for rail would increase to almost 20% of the total passenger movement. The share of road will decrease to around 79%; with 79% of the same comprising of public road based modes of transport and the share of air would be about 1%. The share of electric vehicles in road based transport is assumed to increase to about 44% electric four-wheelers, 70% of electric two-wheelers and 13% of electric buses in 2046-47.

Figure 5 Share of passenger traffic on railways assumed under various levels



iii. Freight transport demand

Freight transport demand is dependent on the nature of economic activity in the country and is linked to the growth in the agricultural, industrial, mining, manufacturing, and service sectors. Measured in terms of ton-kilometers moved, the demand for freight transport has grown at a very fast rate in the first decade of the twenty first century. Given India's economic growth potential, the demand for freight movement is set to significantly increase in the future from 1,604 billion ton-kilometers in 2011-12.

Level:1

With an increasing growth in industrial activity, Level One sees a continuous rise in freight demand. Sectors such as power, cement and minerals are expected to continue to see an increasing demand for transport. Additionally with increasing economic wealth, the demand for white goods is also expected to grow, adding to the overall freight demand. All this would lead to an increase in the freight transport requirement from present levels to about 16,653 BTKMs by 2046-47.

Level:2

Level Two assumes that as the demand for freight transportation grows, there is a slight moderation in the distances of cargo transportation, as economic activities get more organized through formation of logistics hubs and industrial clusters. Further, with better planned markets and points of consumption, the freight traffic volumes are expected to reduce by 9% of Level One 2046-47 levels to reach 15,190 BTKM's by 2046-47.

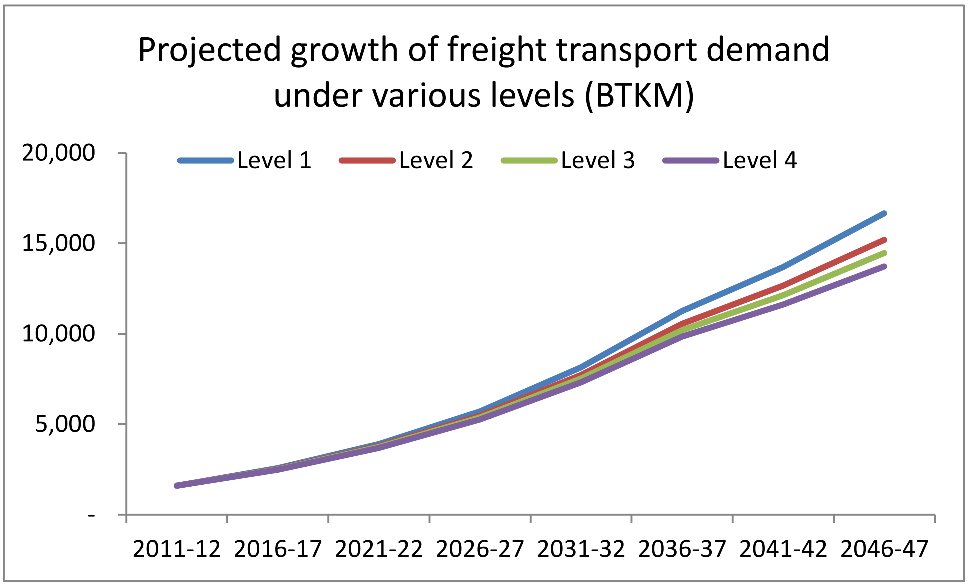
Level:3

Level Three envisages an improved scenario with organized logistics assisted by better information technology solutions to optimize route planning and more efficient movement of goods across the country. Planned industrial clusters along with optimized transport logistics serving commercial and industrial needs would help in reducing the total volume of freight traffic by about 13 % from the Level One levels, to reach 14,459 BTKM's by 2046-47.

Level:4

Level Four envisions India with significantly improved logistic planning along with a movement towards local production and local consumption. Concentrated economic activity in the form of logistics parks, industrial clusters, and industrial centers would result in reduction in the average leads for freight transport on both rail and road. This would imply a reduction in volume of freight traffic by about 18 % over Level One by 2046-47 to reach 13,728 BTKM's by 2046-47.

Figure 6 Projected volumes of freight transport under various levels of freight demand



iv. Freight transport mode

Railways is estimated to have accounted for about 42% and roadways for about 58% of India's total freight traffic in 2011-12. The trend in the last few decades has seen an increase in the share of traffic on roads in the total share of surface freight transportation. This is partly linked to an increase in the share of manufactured goods like white goods, fast moving consumer (FMC) goods etc. These cargos move over shorter distances and are time sensitive. The share of road has also increased due to the highly competitive nature of road transport, convenience and flexibility in tariffs, and the capability of road to handle smaller loads. The share of inland water ways and pipelines, which are both energy efficient modes of transport are relatively low and hence not being projected in this exercise.

Level 1

Level one assumes that the observed trend of the past three decades continues till 2046-47, with the modal share rising significantly in favor of roadways. Large-scale investments in highways and expressways are expected to encourage the use of road over railways even for travel distances beyond 700 km. However, it would also lead to congestion due to the increase in road freight traffic which could decrease transport efficiencies after a certain point of time. The share of road in India's total freight traffic by 2046-47 will show a marked increase to 71%, and the share of rail will decline to 29%.

Level 2

Level Two sees the introduction of two Dedicated Freight Corridors –Eastern and Western by 2020. Wagons with higher payload (25 ton per axle) will further improve rail efficiency and capacity. Railway freight transport will see a manifold increase in average speeds from 25 kmph to 50-60 kmph on the freight corridors. This would also be accompanied with tariff rationalization, both of which would work towards attracting more rail based transport. Thus the trend of falling share of rail based transport is expected to get arrested at about 36% by 2046-47.

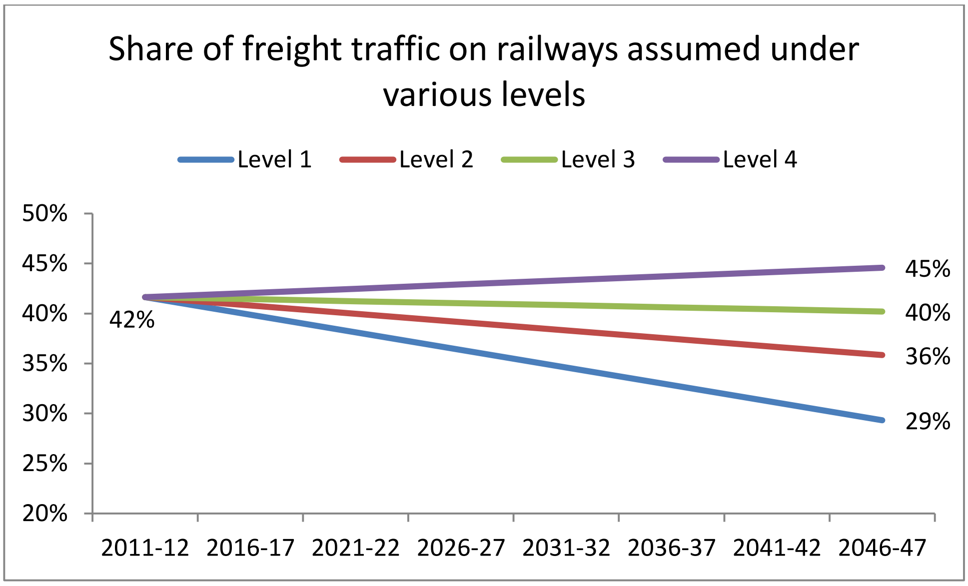
Level 3

Level Three sees higher investments in rail based freight transport. This level sees an improvement in infrastructure for freight transport via the introduction of DFCs on all four legs of the Golden Quadrilateral (connecting Delhi, Kolkata, Chennai and Mumbai). Rationalization in the tariff regime of railway freight transport, coupled with increased speeds and a shift towards containerization would increase the share of the freight traffic on railways to 40% by 2046-47, with roads accounting for 60%.

Level 4

Level Four sees the introduction of Dedicated Freight Corridors throughout the four legs of the Golden Quadrilateral as well as the diagonals connecting Delhi to Chennai, and Kolkata to Mumbai. The policy changes to encourage a modal shift towards rail freight would continue, along with tariff rationalization, increased privatization etc. New technologies, such as RoadRailers (highway trailers that are specially equipped for intermodal movement on railway tracks and highways) would further help increase the inter-modal share of Railways to 45% by 2046-47.

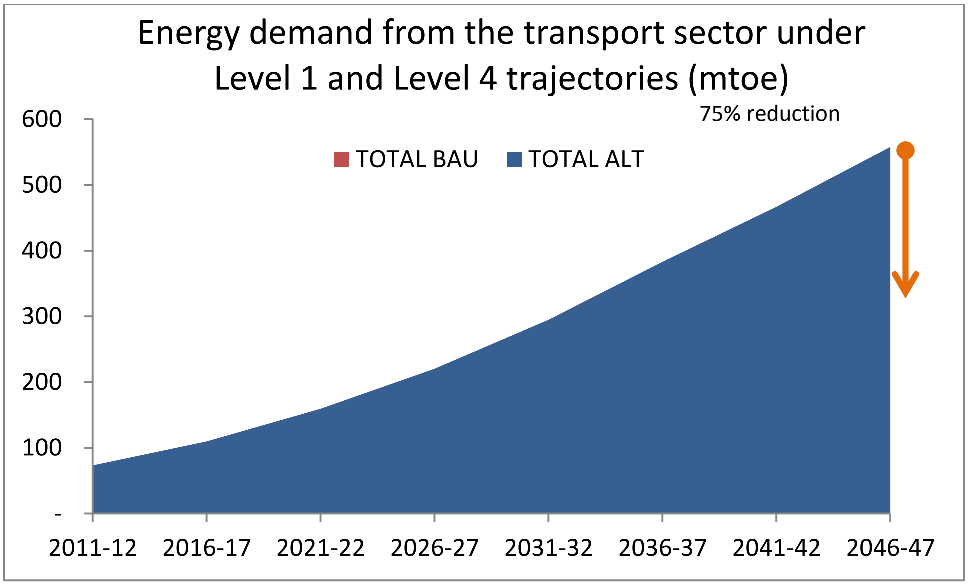
Figure 7 Share of freight traffic on railways assumed under various levels



7. Results

Based on the various levels as has been described in the previous section, there is a large potential for reducing the total demand of energy from the transport sector. When the total energy consumed under the business as usual Level 1 scenario is compared with the Level 4 scenario of all the various levers, it is seen that there is a potential to reduce the energy demand from transport by almost 75 per cent by 2046-47.

Figure 8 Comparison of total energy demand from transport under the various Level 1 and Level 4 scenarios



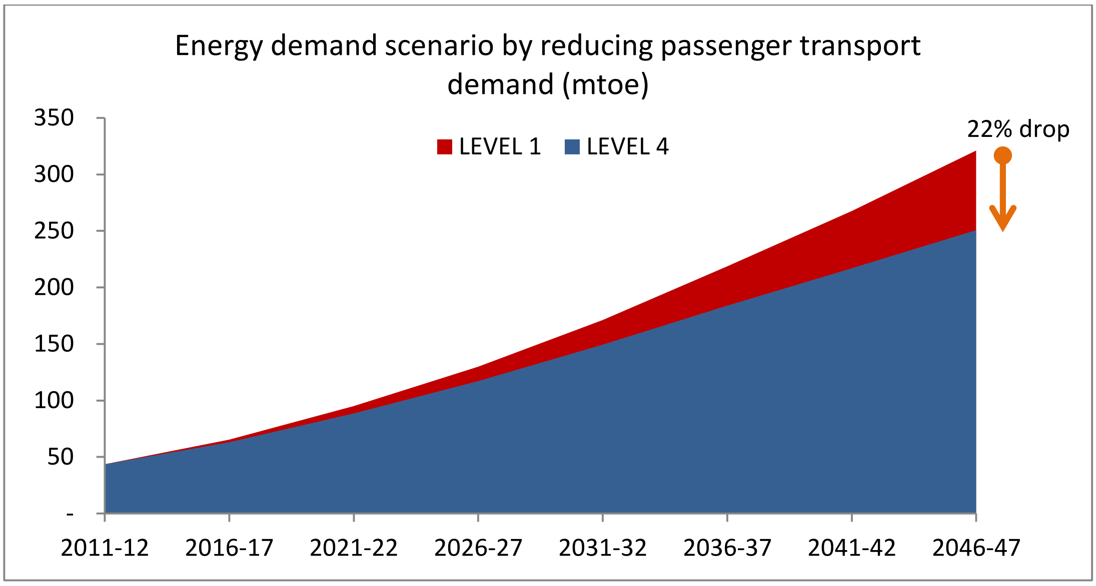
This aggregated energy savings as a result of energy reduction measures assumed under the various passenger and freight levels are shown in Figure 8.

i. Reducing the passenger transport demand

The reduction the passenger transport demands result in an almost equivalent reduction in the energy demands from passenger transport.

The savings potential is shown in Figure 9.

Figure 9 Potential energy demand reductions possible by reducing the passenger transport demand

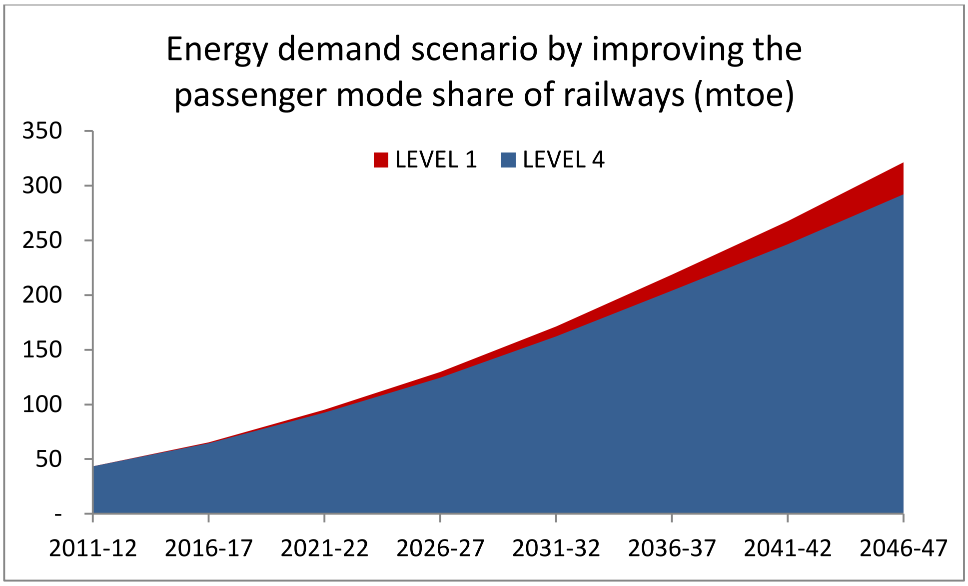


ii. Improving the share of railways in passenger transport mode

The shift of passenger traffic from road and air to rail based transport could also lead to a large savings in the energy demand from passenger transport. By moving from the present 14 per cent share of traffic on railways as of 2011-12 to the assumed 19 per cent by 2046-47 under the level 4 of the passenger transport mode about 9 per cent reduction in energy is possible.

The comparison of energy demand under the Level 1 and 4 of the passenger transport mode lever is shown in figure 10.

Figure 10 Comparison of potential energy consumption by passenger transport under the different levels of the passenger transport mode lever

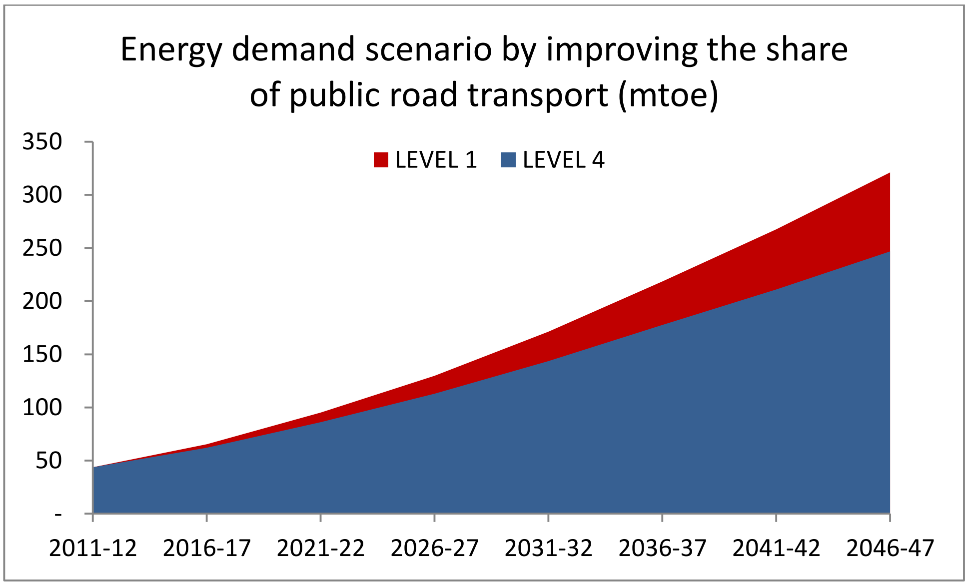


iii. Improvement in the public and private share of passenger road transport

Given the present trends of growth of private transport, the share of public transport is expected to drop to about 46 per cent by 2946-47. This forms the level 1 of this lever. By retaining the share of traffic on public road transport modes to 66 per cent by 2046-47 it is possible to reduce that year's energy demand by 23 per cent.

The energy demand comparison across these two levels is shown in Figure 11.

Figure 11 Comparison of potential energy demands by increasing the share of public road transport

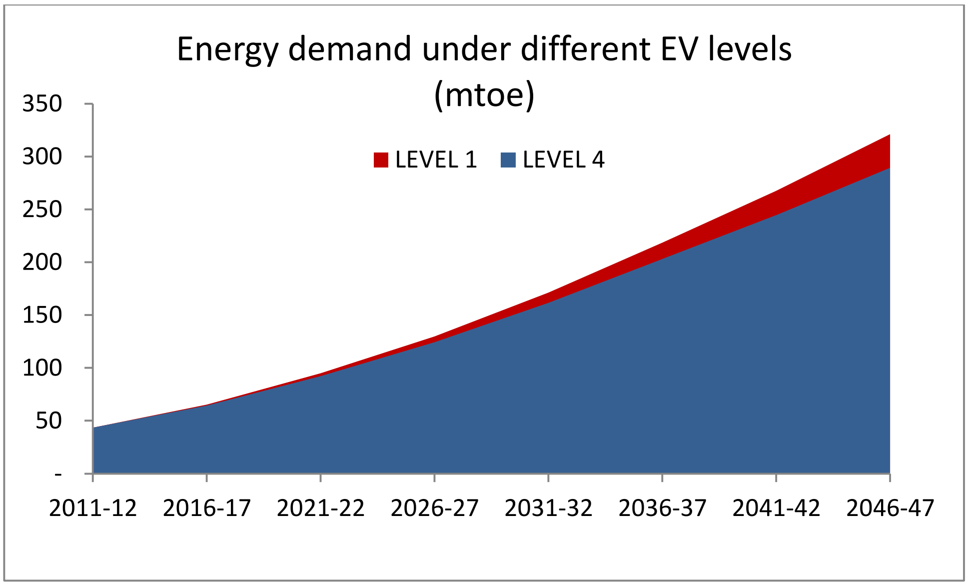


iv. Increasing the penetration of efficient vehicles

By increasing the share of efficient vehicles in passenger cars, two-wheelers and buses, it is possible to reduce the total energy demand from passenger transport by about 10 per cent of 2046-47 levels.

The energy demand comparison between the two extreme levels of the EV lever is shown in Figure 12.

Figure 12 Comparison of potential energy demand by passenger transport under the different EV levels

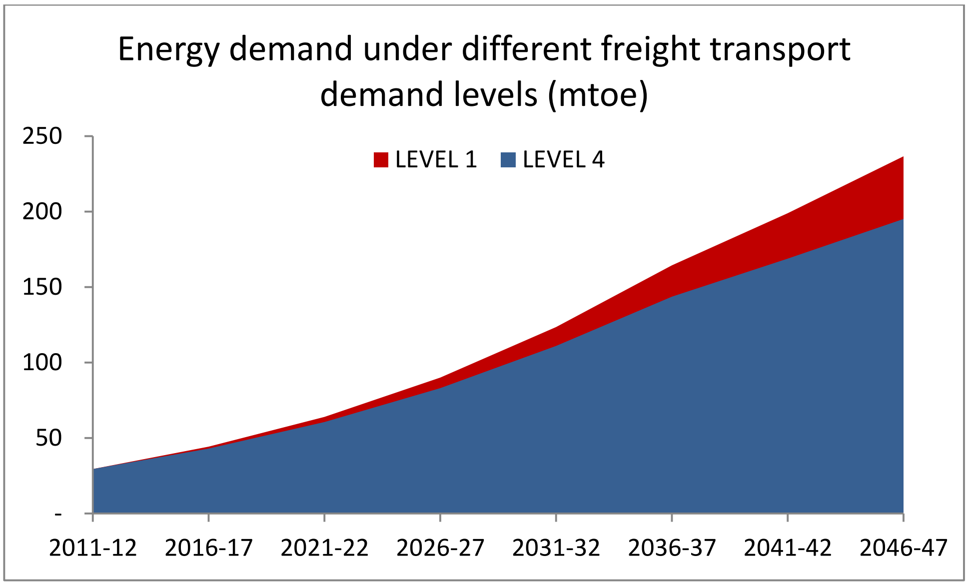


v. Reduction in the freight transport demand levels

As in the case of passenger transport demand, a reduction in the levels of freight transport demand has the potentials to reduce the total energy demand from freight transport. From a demand of 237 mtoe it is possible to reduce the energy demand for freight transport to 195 mtoe in 2046-47 – an 18 per cent drop.

The energy demand comparison between the level 1 and level 4 of the freight transport demand lever is shown in figure 13.

Figure 13 Comparison of energy demand by freight transport under level 1 and 4 of freight transport demand

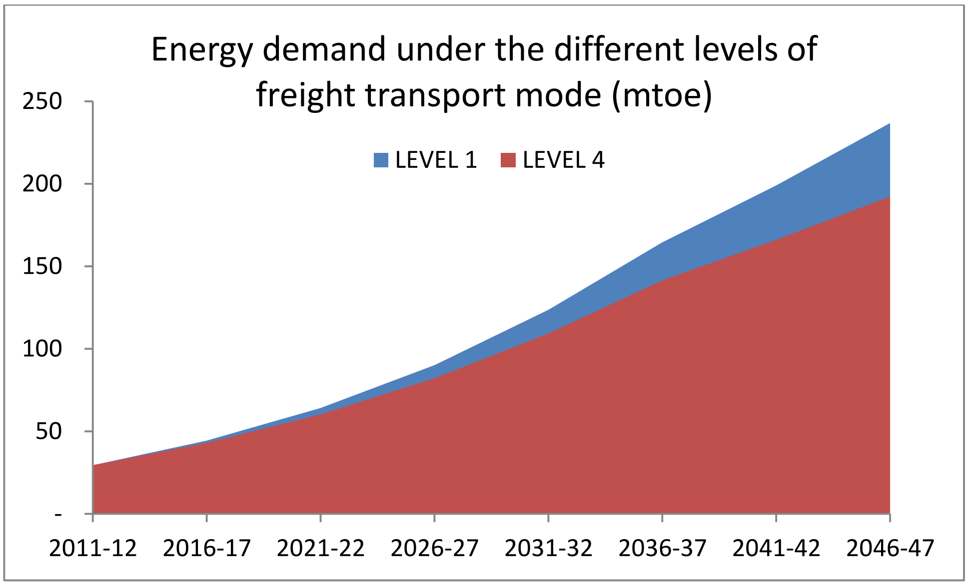


vi. Increasing the share of railways in total freight transport

Railways being the relatively more energy efficiency mode as compared to either road or air for freight transport, an increase in the share of rail based transport has the potentials to reduce the energy demand from freight transport in the country.

As shown in Figure 14, there is a potential of reducing the energy demands of 2046-47 by about 19 per cent between levels 1 and 4 of this lever.

Figure 14 Comparison of energy demand by freight transport under level 1 and 4 of freight transport mode



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