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The Energy and Resources Institute

Benefits of Cycling in India

An Economic, Environmental, and Social Assessment

Supported by
ALL INDIA CYCLE MANUFACTURERS' ASSOCIATION

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Table of Contents

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Foreword

Cycling is, and has been, a major mode of mobility in India. Traffic surveys show that cycle trips account for more than 15% of trips in most towns, and even in a large city such as Delhi, cycling accounts for over 10% of trips in the city. This is largely because bicycles play a major role in enabling livelihoods of the urban poor by providing a cost-effective transport option. In recent years, health and environmental quality have emerged as the new drivers of supporting cycling activity, but growth due to these drivers has been constrained by the cycle-unfriendly environment and infrastructure in our cities.

This constraint to the growth of the cycling share is unfortunate because Indian cities, with mixed land-use patterns, have relatively short commuting distances—60% of trip lengths in Indian cities are of less than 5 km, and 80% of less than 10 km. These are the ideal trip lengths for bicycling, and provide an extremely effective option for India to move to a mobility mode with zero greenhouse gas emissions.

Consequently, in order to enhance the share of cycling, policy measures to create and provide large-scale safe cycling infrastructure, accompanied by regulations on the use of private motorized vehicles, have to be implemented. Additionally, subsidies/tax remittances and microfinancing options need to be prioritized for low-income households. To this end, an economic appraisal and quantification of the various benefits of cycling can motivate these interventions.

I am pleased that TERI, in its endeavour to promote sustainable and inclusive mobility, has undertaken this study to estimate the economic benefits of cycling in India. Through a comprehensive review of internally accepted methodologies, this study quantifies the fuel, energy, emissions, and health savings that could be realized from a modal shift towards cycling. I hope that these assessments would be useful at multiple levels of governance to upscale and promote bicycle use in the country.

Ajay Mathur
Director-General, TERI

Motivation behind the Study

Ever since its introduction as a form of mobility, the bicycle has remained an integral part of the transport system. In recent decades, its acknowledgement as a sustainable mode of transport (Annex) has brought it to the forefront of the mobility landscape. Cycling provides inherent, incredible, and indefinite benefits in the form of zero dependence on energy sources, zero pollution, and improved health. Additionally, bicycles can provide critical support to the urban and rural poor who do not have access to the basic mobility for seeking livelihood, education, and so on. Despite these merits, unlike many developed and developing countries bicycle penetration in India remains low. Although India's National Urban Transport Policy (2006) emphasizes the need for safe cycling infrastructure for pan-India promotion of cycling, the same is yet to be realized in urban and rural areas.

In this context, it was repeatedly felt by the various cycling stakeholders at different forums that one of the major knowledge gaps is the absence of empirical evidence of the economic benefits of cycling in India. Economic appraisal is an established practice in transport planning. However, the techniques for assessing the economic value of cycling benefits have historically been applied less systematically than the approaches used for assessing the other costs and benefits of new infrastructure. Moreover, such studies in many developed countries are becoming increasingly common for judicious appraisal, informed decision-making, and cycling promotion at the individual, society, and institutional/governmental levels. They have also resulted in the creation of national cycling plans/strategies/laws and separate funds. Therefore, this study in the Indian context is a step forward in that direction.

Executive Summary

Cycling is one of the most sustainable modes of transportation. It has numerous benefits in the form of zero dependence on fossil fuels, zero emissions and pollution, health benefits from increased physical activity, besides being an affordable means of mobility for low-income households. For these individuals, especially in rural areas, it improves access to jobs, education, and health facilities. Additionally, by addressing low female school enrolment, it has shown immense potential to promote gender empowerment. However, despite its many benefits, bicycles in India are increasingly being used by only captive users, who do not have access to any other form of mobility. Resultantly, India is witnessing a very slow growth in bicycle ownership and a decline in the use of bicycles as a form of mobility (TERI, 2014). In the period between 2001 and 2011, the share of bicycle-owning households has only increased by 1%. The corresponding share in rural areas has increased by 3.4%, whereas in urban areas it has declined by 4.1%.

Rising income levels, absence of safe cycling infrastructure, and increased affordability of motorized vehicles (especially two-wheelers) are the major factors that have led to a decline in the share of bicycles. Specifically, in cities short-distance trips which can be undertaken by bicycles are now being made by cars and two-wheelers instead.

This increasing motorization in urban and rural areas has given rise to many negative externalities such as dependence on fossil fuels, GHG emissions, congestion, pollution and the associated health impacts. In order to minimize the costs associated with these externalities, the current and future projected travel demand needs to be served by sustainable modes of transportation like cycling.

To promote the widespread use of bicycles, dedicated initiatives such as tax concessions for low-income individuals, construction of adequate and safe cycling infrastructure, and measures to reduce the use of private vehicles such as congestion and parking pricing and awareness campaigns to highlight the benefits of cycling need to be undertaken. These measures should be implemented to retain the existing high share of cyclists and to motivate a shift among those who currently rely on private motor vehicles even for short distances.

In order to encourage such measures the benefits of cycling for the economy, the environment, and society have to be estimated. To this end, the study undertakes a comprehensive review of the internationally accepted methodologies used to quantify the benefits associated with cycling. Further, by employing these methodologies the study quantifies the benefits of cycling in India.

Review of International Studies

Most of the evaluation exercises to evaluate the long-term benefits of investment in cycling have been undertaken in developed countries in the form of cost-benefit analysis. The purpose of these studies has been to establish that the long-term benefits of cycling to health, the economy, and the environment far exceed the short -term costs of investment in cycling.

The study undertaken by the European Cyclists' Federation (Neun & Haubold, 2016) estimates that substituting 32% of the car trips in the European Union (EU-28) by bicycles could result in the annual fuel savings of €28 billion. Using WHO HEAT, E. Fishman and others (2015) quantified the health benefits of cycling due to increased physical activity for the entire population of the Netherlands during 2010–13. The study estimates that 74 minutes of cycling per week prevents 6,500 premature deaths and results in savings of €19 billion every year. The Cycle to Work Alliance carried out a behavioural impact analysis to evaluate the health and emission reduction impact of the cycle-to-work scheme in the UK for an average work trip of 7 km. Launched in 1999, the scheme has attracted over 1 million workers till 2018. By providing tax-exemption benefits, the scheme encourages employers to loan bicycles and cycling safety equipment to employees. It has resulted in an annual emission reduction of 0.13 million tonnes of CO_2, equivalent to the average annual CO_2 emissions of 24,000 households in the UK (Cycle to Work Alliance, 2011).

From the review of international studies, it emerges that the benefits of cycling can be demarcated into direct benefits, which accrue to individuals, and indirect benefits, which are realized by society on account of increased cycling and reduced use of motorized transport. The scope of this study is limited to the valuation of certain direct benefits like improved health, personal fuel savings and travel time savings and indirect benefits like emission reduction, energy security and reduced inequality. Large-scale substitution of motorized private transport by cycling can also reduce noise pollution, improve road safety, and provide recreational value to users.

Analysing Work Trips in India

A detailed analysis of the 'other workers' data from Census of India, 2011 provides insights into the travel characteristics of India's workforce. In order to obtain workforce numbers for 2015-16, an average annual growth rate of 3.27% is estimated using the census data on other workers from 1981 till 2011 and employment statistics given by the International Labour Organization. In order to better understand the spatial variation in mode choice and travel distances, the data is analysed at the national, urban, rural, and city levels. It is observed that more than 50% of the people in India use non-motorized forms of transport, such as walking and cycling, to travel to work followed by two-wheelers (18%) and buses (16%). In urban and rural India, on-foot trips account for the highest share of work trips with the share being 12% higher in rural areas. In rural areas, for meeting the daily travel requirements, workers are most dependent on cycling after walking. However, in urban areas, after walking workers are most dependent on two-wheelers.

As the data provides information on two key variables of 'distance from residence to place of work' and 'mode of travel to place of work', the study makes an attempt to quantify the benefits associated with large-scale uptake of cycling. A brief overview of the key results is given in the following section.

Estimation of Direct Benefits

The benefits that directly accrue to individuals due to the uptake of cycling are defined as direct benefits. In the study, personal fuel savings, health benefits due to increased physical activity, reduced air pollution, and travel-time savings by marginal unskilled workers are quantified.

Table 0.1 Estimated Direct Benefits of Increased Cycling

Benefits	Trips Substituted by Bicycle	Methodology	Value of the Benefits (INR Billion)
Personal fuel savings	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	27
Health benefits due to:			
2a) Increased physical activity (net present value of the accumulated benefits over 15 years)	50% substitution of two-wheeler and four-wheeler trips under the average distance of 5 km	WHO HEAT	1435
2b) Reduced air pollution	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI's Air Quality Modelling Framework	241
Travel-time savings	50% substitution of walking trips above the average distance of 3.5 km	Wage Rate Model	112
Total direct benefits			**1815**

Source: TERI Analysis

Estimation of Indirect Benefits

The benefits that accrue to society due to a modal shift towards cycling are defined as indirect benefits. In the study, energy savings (toe) and reduced CO_2 emissions have been estimated.

Table 0.2 Estimated Indirect Benefits of Increased Cycling

Benefits	Trips Substituted by Bicycle	Methodology	Quantum of Savings (Million Tonnes)
Energy savings (oil equivalent)	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	0.35
CO_2 emission reduction	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	1

Source: TERI Analysis

In this study, it is estimated that if bicycles were to substitute the two- and four-wheelers used for short-distance trips, it can result in an annual benefit of INR 1.8 trillion, which is equivalent to 1.6% of India's annual GDP for 2015–16.

These benefits can be realized by providing safe cycling infrastructure and conducting awareness campaigns to highlight the various benefits of cycling and by dispelling the notion of bicycles as the poor person's mode of transport. Additionally, cities should plan city-wide bicycle-sharing schemes instead of only focusing on specific locations. In order to increase the share of cycling among choice users, the aforementioned measures have to be supplemented by regulations on the use of private motorized vehicles, such as congestion and parking pricing and pollution tax.

To increase bicycle access among low-income households, the provision of microfinancing options and implementation of cycle-distribution schemes should be undertaken. Given that at present the expenditure on bicycles accounts for a large share of household income, it is important to make bicycles more affordable for low-income households. This could be achieved by reducing the GST rate on bicycles costing less than INR 5,000 from the existing 12% to the lowest rate of 5%. It is also recomended that a 'Bicycle Development Council' should be established for growth and development of the sector in India.

Passenger Transport in India

In the last decade, the number of total registered motor vehicles in India has grown at a CAGR of 9.9%, from 89 million vehicles in 2006 to 230 million in 2016. This trend has been spearheaded by the unprecedented rate of urbanization and population growth in India.

A large share of this growth has come in the form of increasing two-wheeler and car ownership, with the CAGR of these two vehicle segments (10.1%) exceeding that of the entire motorized vehicle fleet in India (MoRTH, 2016). Two-wheelers have specially played a significant role in the increasing ownership of private vehicles and presently account for 73.5% of the total registered vehicle fleet in the country (MoRTH 2016). Rising income levels, increased affordability and convenience of motorized transport, lack of non-motorized transport infrastructure, and inadequacy of public transport have contributed to this proliferation of private motorized vehicles.

The aforementioned trend is a cause of concern as motorized transport has huge negative externalities in terms of vehicular emissions, increased fuel dependence, congestion, air pollution, and road accidents, which have far-reaching implications for the economy and society.

In the last decade itself, fuel use in the transport sector has more than doubled from 40.29 million tons of oil equivalent (Mtoe) in 2006 to 86.70 MTOE in 2016 (TERI, 2017). A large share of the sector's energy requirements has been met by conventional fossil fuels, with the sector accounting for 70% and 99% of the total diesel and petrol sales, respectively, in 2012–13 (MoPNG, 2016). A predominant share of these fuels has been consumed by the road transport sector with two-wheelers accounting for 61.42% of the total petrol sales and four-wheelers accounting for 34.33% of total the total petrol sales and 13.15% of the total diesel sales (MoPNG, 2016).[1]

Hence, increasing ownership and use of motorized vehicles not only has implications for the transport sector's energy-related CO_2 emissions, which at present account for 8–10% of the total CO_2 emissions in India (MoEFCC, 2015), but also for the country's foreign reserves and energy security as 80% of our crude oil requirements are met through imports.[2]

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[1]   Press Information Bureau, available at http://pib.nic.in/newsite/PrintRelease.aspx?relid=102799 (last accessed on September 4, 2018).

[2]   *The Economic Times*, 'India's Oil Import Bill to Jump by 25% in FY18', March 26, 2018, available at https://economictimes.indiatimes.com/industry/energy/oil-gas/indias-oil-import-bill-to-jump-by-25-in-fy18/articleshow/63464408.cms (last accessed on September 4, 2018).

The increasing share of these vehicles is also contributing to alarming levels of air pollution in cities, with 14 Indian cities featuring in the list of the world's 20 most polluted cities[3] (WHO, 2018), increasing the risk of heart disease, lung cancer, and respiratory diseases. As transport demand continues to grow with rapid urbanization, increasing per capita income, and population growth, the dependence on motorized transport could further exacerbate the incidence of these negative externalities, making it a highly unsustainable mode of transportation with heavy cost implications for the economy and society. Keeping in view this emerging trend of unsustainable transport, it is imperative that India shifts to mobility solutions that minimize these costs to society.

1.1 Cycling: A Sustainable Form of Mobility

The benefits of cycling vary from zero dependence on fossil fuels and zero emissions, to health benefits and affordable transportation for low-income households. Data from national surveys of travel behaviour and health indicators show that countries with the highest levels of cycling and walking have the lowest obesity rates. Further, the experiences of cities like Antwerp, London, and Seville exhibit how policymakers are now promoting the development of cycling as a part of their air-quality improvement plans (European Cyclists' Federation, 2014). Hence, the economic, health, and social benefits of cycling clearly indicate its potential in promoting sustainable mobility.

[3] In terms of the annual average concentration of $PM_{2.5}$ in ug/m³

In India, cycling has always been an important mode of transport, for it has catered to the mobility requirements of millions of Indians by providing efficient and affordable transportation. Specifically for low-income households, which neither have access to nor can afford other means of transport, cycling has enabled access to jobs, schools, and medical facilities.

However, despite its many benefits, cycling use in India is declining and bicycle

Annual Growth Rate (%)	Cars	Two Wheelers	Cycles
Urban (%)	15	11	3
Rural (%)	11	16	3
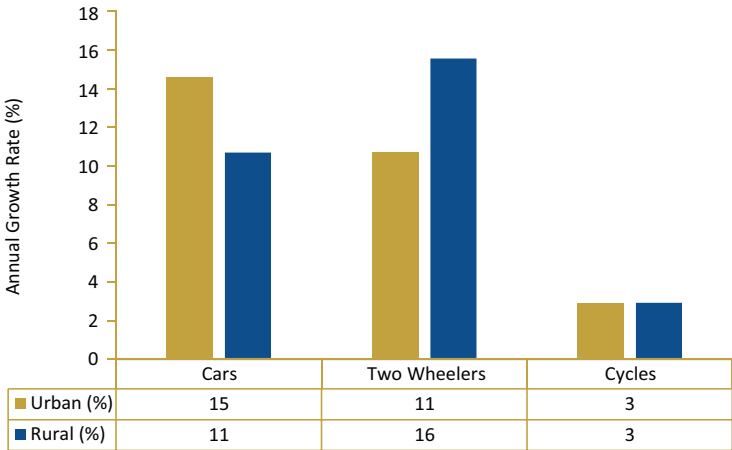
Figure 1a Household Bicycle Ownership in India (2001–11)
Source: TERI Analysis

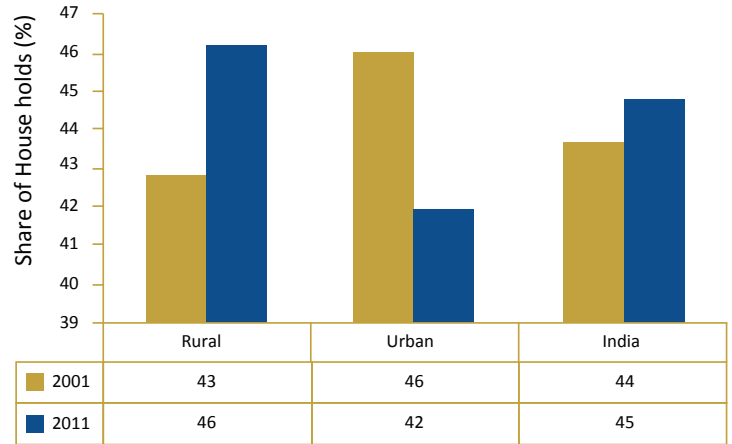| Share of House holds (%)	Rural	Urban	India
2001	43	46	44
2011	46	42	45

Figure 1b Household Bicycle Ownership in India (2001–11)
Source: TERI Analysis

ownership is not observing a high growth rate. The household bicycle ownership increased at an annual average rate of 3% between 2001 and 2011, with the number of bicycle-owning households increasing to 111 million in 2011 from 84 million in 2001 (GoI, 2011). However, during the same period much higher growth in household ownership of two-wheelers and cars was observed (Figures 1a and 1b).

Bicycle users in India are either captive or choice users. Captive users, who belong to low-income households, are dependent on cycling as their primary means of mobility. Among these individuals, bicycle ownership has remained stagnant due to the lack of the requisite financing options and the high price of bicycles.[4] For choice users, the absence of adequate safe cycling infrastructure has curtailed the use of bicycles. In addition, increasing levels of income combined with multiple financing options have increased the preference for private motorized transport (TERI, 2014).

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[4]   For low-income households, the potential expenditure on cycles account for a large share of the total household income.

Thus, in order to promote the widespread use of bicycles, a combination of hard and soft measures should be adopted. Hard measures such as the construction of safe cycling infrastructure, easy financing of basic bicycles, and support to the Indian bicycle industry for bridging the technological gap for production of premium bicycles can be implemented. In addition, soft measures such as nationwide awareness campaigns to highlight the various benefits of cycling and to change the perception of bicycles as the poor person's mode of transport can be undertaken. These measures should be implemented to retain the existing share of cyclists and to motivate a shift among those who currently rely on private motor vehicles, even for short distances.

In order to upscale such investments in cycling, the economic benefits of cycling have to be quantified. Such an exercise can favourably influence policy decisions the promote cycling.

To this end, the study explores and quantifies the various benefits associated with cycling in order to promote sustainable mobility in India. The objectives of the study are:

➢ To conduct an in-depth literature review of the accepted methodologies and approaches for estimating the economic, environmental, and social benefits of cycling.

➢ To then use the appropriate methodologies to quantify the benefits of cycling in India.

Specifically, the study quantifies personal fuel savings, health benefits, travel-time savings, energy consumption, and emission reduction as a result of substituting private motorized vehicles by bicycles.

Review of Internationally Adopted Methodologies

Conventionally, the economic benefits of cycling have been quantified to evaluate the long-term benefits of investment in the cycling ecosystem. Most of these evaluation exercises have been undertaken in developed countries and have taken the form of a cost-benefit analysis. The purpose of these studies has been to establish that the long-term benefits of cycling to health, the economy, and the environment far exceed the short-term costs of investment in cycling. This section reviews international studies to identify the accepted methodologies and approaches to estimate the economic benefits of cycling. From the review, it emerges that the benefits of cycling can be demarcated into direct benefits, which accrue to individuals, and indirect benefits, which are realized by society on account of increased cycling and reduced use of motorized transport. The scope of this study is limited to the valuation of certain direct and indirect benefits only (Figure 2).

2.1 Direct Benefits

In this study, direct benefits of cycling to individuals are estimated in the form of personal fuel savings, reduced health expenditure, and travel-time savings[1] to low-income households. The following section reviews the methodologies that are conventionally adopted to quantify the aforementioned benefits.

2.1.1 Personal Fuel Savings

Personal fuel savings from cycling are estimated on the basis of the methodologies adopted in Gotschi (2011) and Neun and Haubold (2016). Gotschi (2011) undertakes a cost-benefit analysis over the period 1991–2040 with the objective of estimating the return on past and planned cycling infrastructure

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[1] From substituting walking by cycling over average trip distances exceeding 3.5 km.
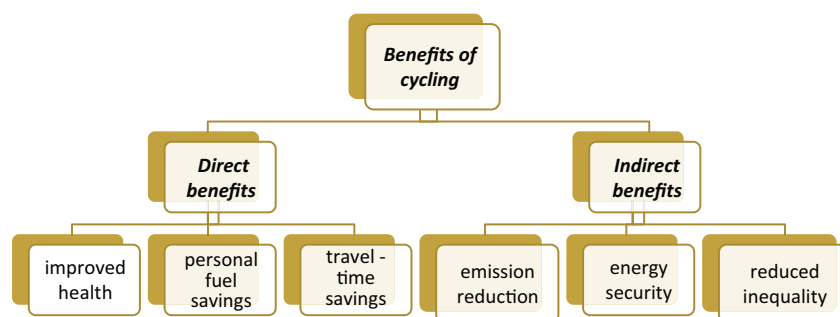

Figure 2 Estimated Direct and Indirect Benefits of Cycling

investments in Portland, Oregon, USA. Corresponding to three cycling mode share targets of 15%, 20%, and 25% by 2030, the study estimates fuel savings from the substitution of all four-wheeler trips covering a distance of less than or equal to three miles[2] by bicycle trips. The estimation is based on actual average national fuel prices ($/gallon) and assumptions regarding the fuel economy (miles/gallon) of vehicles. Fuel savings from these scenarios amount to $143, $180, and $218 million, respectively, by 2040. Similarly, the study undertaken by the European Cyclists' Federation (Neun & Haubold, 2016) estimates that substituting 32% of the car trips in the European Union (EU-28) by bicycles could result in the annual fuel savings of €28 billion.

2.1.2 Health Benefits of Increased Cycling

The health benefits of cycling can be primarily categorized into benefits due to increased physical activity and those due to reduction in air pollution from large-scale substitution of motorized vehicle trips.

The benefits of increased physical activity can be estimated using the Health Economic Assessment Tool (HEAT) developed by the World Health Organization (WHO)[3] or the cost-of-illness (CoI) approach. Using WHO HEAT, E. Fishman and others (2015) quantified the health benefits of cycling due to increased physical activity for

the entire population of the Netherlands during 2010–13. The study estimates that 74 minutes of cycling per week prevents 6,500 premature deaths[4] and results in savings of €19 billion every year. The benefits accrue as a result of annual infrastructure investments of €0.5 billion and are equivalent to 3% of country's GDP. Since the Netherlands has the highest bicycle use in the world (27% of all trips), the study is representative of the large-scale returns on the requisite investment in cycling infrastructure.

The CoI approach quantifies the direct and indirect costs associated with cardiovascular diseases, diabetes, and obesity, which are caused by a sedentary lifestyle. Foltynova and Kohlova (2002) estimate the health benefits associated with a 2% increase in the number of kilometres ridden by bicycles in Pilsen,

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[2] 1 mile = 1.609 km

[3] To facilitate evidence-based decision-making, the WHO has developed, in collaboration with experts, an online tool to estimate the value of reduced mortality that results from regular walking or cycling. See http://www.euro.who.int/en/health-topics/environment-and-health/Transport-and-health/activities/guidance-and-tools/health-economic-assessment-tool-heat-for-cycling-and-walking. (last accessed on September 6, 2018).

[4] Premature deaths are deaths that occur before a person reaches an expected age. Many of these deaths are considered to be preventable. See http://www.countyhealthrankings.org/explore-health-rankings/what-and-why-we-rank/health-outcomes/mortality/premature-death (last accessed on September 6, 2018).

Czech Republic. The study estimates a 9% reduction in mortality due to decreased incidence of cardiovascular diseases (CVDs). This reduction in mortality is translated into monetary savings by applying the value of statistical life specific to the Czech Republic. The study also estimates morbidity reduction benefits in the form of a 50% risk reduction of coronary heart disease and colon cancer using the CoI approach. Under this approach, reduced risks are translated into reduced inpatient and out-patient costs of treatment. Together mortality and morbidity reduction benefits add up to CZK 130 million.

The health benefits of improved air quality are quantified using the impact pathway approach (IPA). The EU (2014) uses the IPA to measure the impact of change in vehicular emissions on human health. This approach involves the translation of vehicular emissions into ambient pollution concentration through air-dispersion modelling, the identification of exposed population, the use of dose-response functions, and the estimation of willingness to pay for reduced human health risks. This study estimates that savings of €0.43 billion are realized on account of reduced air pollution.

Traffic congestion imposes additional travel time on other road users and further results in incremental fuel use and emissions. The substitution of motorized transport by cycling for short-distance trips in urban areas can result in travel-time savings during the peak hours. Garrad (2009) estimates that walking and cycling by 0.1 million people in Melbourne freed up road length equivalent to the length of 106,360 cars (479 km of road space) and resulted in annual savings of $19 million in 2006.

2.2 Indirect Benefits

Indirect benefits to the economy and society due to increased levels of cycling are realized in the form of CO_2 emission reduction, energy savings, infrastructure savings, job creation, and increased access to socio-economic opportunities.

The Cycle to Work Alliance carried out a behavioural impact analysis to evaluate the health and emission reduction impact of the cycle-to-work scheme in the UK for an average work trip of 7 km. Launched in 1999, the scheme has attracted over 1 million workers till 2018. By providing tax-exemption benefits, the scheme encourages employers to loan bicycles and cycling safety equipment to employees. It has resulted in an annual emission reduction of 0.13 million tonnes of CO_2,[5] equivalent to the average annual CO_2 emissions of 24,000 households in the UK (Cycle to Work Alliance, 2011).

Cycling infrastructure requires only 2% of the resources required for building infrastructure for motorized vehicles (Neun and Haubold, 2016). It has been estimated that cycling infrastructure requires less road space and has lower maintenance costs in comparison to the higher weathering costs associated with motorized transport (Litman, 2018).

Promotion of cycling can create higher economic benefits in terms of growth of the bicycle industry. Increased sales of bicycles and cycling equipment can boost the growth of other related industries such as repair, manufacturing, and tourism. In 2016, a doubling of bicycling mode share

5 For the behavioural impact analysis, 44,599 employees were surveyed, of which 30,587 indicated that they would travel to work by cars in the absence of the scheme.

from 7.6% to 15.3% increased the retail turnover in EU-27 by more than €27 billion (Blondiau, Zeebroeck, and Haubold, 2016).

This benefit is realized on account of additional job creation in the bicycle industry, which amounts to an added employment of 400,000 workers.[6] Such job creation provides employment to individuals with low qualifications and

promotes inclusive growth. Lastly, cycling can improve access to job opportunities for low-income individuals who do not have access to any other form of mobility.

Large-scale substitution of motorized private transport by cycling can also reduce noise pollution, improve road safety, and provide recreational value to users.

6   At present, the bicycle industry in EU-27 employs more than 650,000 workers.

Analysis of Work Trips in India

In order to identify the current travel patterns in India and to determine the potential of cycling in meeting travel demand, a detailed data repository of motorized and non-motorized trips is required. However, there exists no comprehensive database that monitors and records the travel behaviour of the entire population. It is only recently that the Census of India, 2011, collected and published data on work trips undertaken by the 'other workers'. 'Other workers' are defined in the census as 'workers who have been engaged in some economic activity during the last one year, but are not cultivators or agricultural labourers or in household industry'. The data collected includes two key travel variables: (i) distance from residence to place of work and (ii) mode of travel to place of work.

In 2011, the 'other workers' category included 200 million workers. In order to obtain workforce numbers for 2015–16, an average annual growth rate of 3.27% is estimated using the census data on other workers from 1981 till 2011 and employment statistics given by the International Labour Organization. The projection yields a total workforce of 235 million workers in the 'other workers' category by 2015–16.

The TERI study assumes that work trips are a reasonable representation of travel

patterns in the country, as it is often stated that they account for a predominant share of the total trips in India.

A detailed analysis of the 'other workers' data provides insights into the travel characteristics of India's workforce. In order to better understand the spatial variation in mode choice and travel distances, the data is analysed at the national, urban, rural, and city levels.

It is observed that more than 50% of the people in India use non-motorized forms of transport, such as walking and cycling, to travel to work followed by two-wheelers (18%) and buses (16%) (Figure 3).

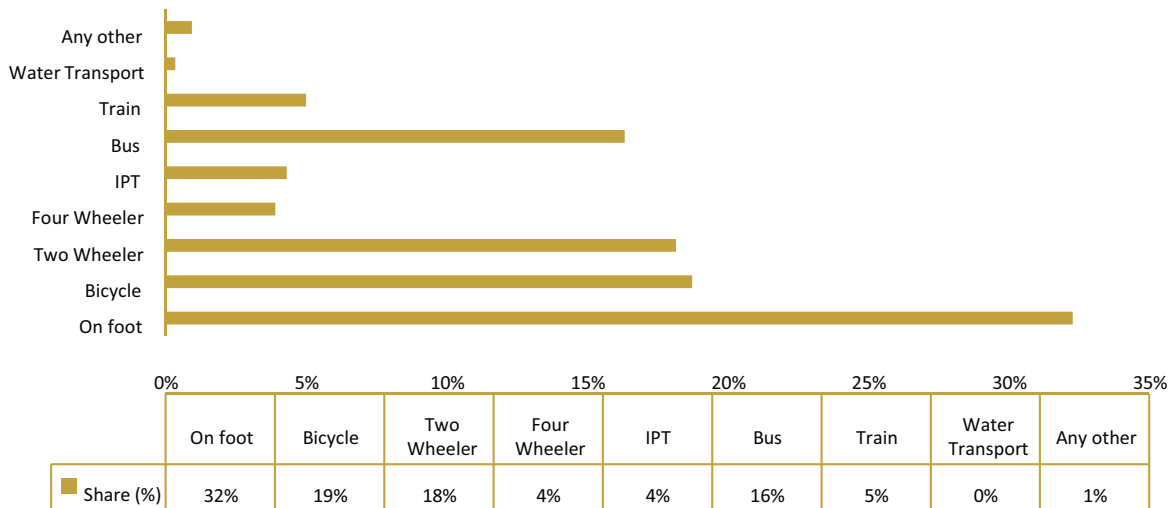|	On foot	Bicycle	Two Wheeler	Four Wheeler	IPT	Bus	Train	Water Transport	Any other
Share (%)	32%	19%	18%	4%	4%	16%	5%	0%	1%

Figure 3 Share of Work Trips by Mode in India (2016)[1]
Source: TERI Analysis

In urban and rural India, on-foot trips account for the highest share of work trips with the share being 12% higher in rural areas. In terms of bicycle use, urban and rural areas exhibit different travel patterns. In rural areas, for meeting the daily travel requirements, workers are most dependent on cycling after walking. It is estimated that 21% of the work trips in rural India are undertaken by bicycles. However, in urban areas, after walking workers are most dependent on two-wheelers. The latter accounts for 17% of the total work trips followed by cycling (13%) (Figure 4). The aforementioned trends are indicative of the increasing motorization in cities, which is a result of rising incomes and greater affordability of private vehicles.
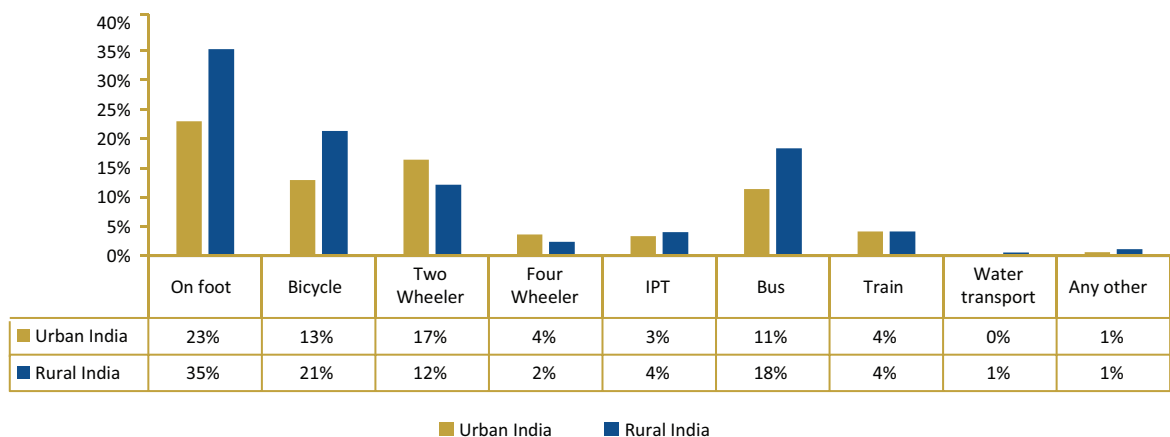

	On foot	Bicycle	Two Wheeler	Four Wheeler	IPT	Bus	Train	Water transport	Any other
Urban India	23%	13%	17%	4%	3%	11%	4%	0%	1%
Rural India	35%	21%	12%	2%	4%	18%	4%	1%	1%

■ Urban India   ■ Rural India

Figure 4 Share of Work Trips by Mode in Urban and Rural India (2016)
Source: TERI Analysis

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[1] Cars, jeeps, and vans are categorized as four-wheelers. Tempos, autos, and taxis are categorized as intermediate public transport (IPT).

A further analysis of travel patterns in urban India reveals that there is a significant variation in the distribution of work trips across different modes and distance categories. Walking is the dominant form of mobility in the distance category of 0-1 km, two-wheelers and cars are the preferred mode of transport for 24% of the trips within the distance of 5 km, while 21% of the trips are undertaken by bicycle. It is also observed that up to the distance of 10 km, 60% of the work-trips are undertaken through NMT. This trend indicates that a significant share of workforce still depends on NMT as the primary mode of transport and hence, it is important to provide adequate, safe and secure cycling infrastructure in urban areas. Additionally, a large proportion of captive users still depend on bicycle for accessing work opportunities in the distance category of 21–30 km (Figure 5). Hence, adequate financing options should be made available to captive users to make the mode more affordable.
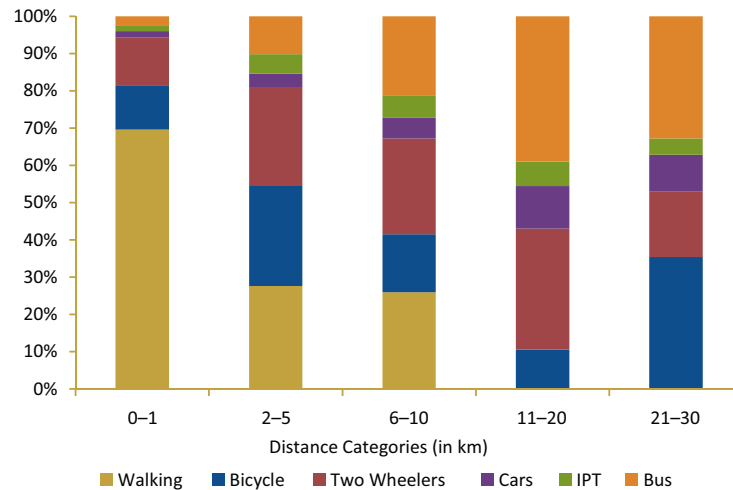

Figure 5 Share of Work Trips by Modes in Urban India (2016)
Source: TERI Analysis

Estimation of Direct Benefits

4.1   Personal Fuel Savings

Over the last few decades, the Indian transport sector has experienced large-scale motorization. The number of registered vehicles in the country has grown at a CAGR of 10.6%, from 0.3 million in 1950 to 230 million in 2016 (MoRTH, 2016). It is important to highlight that this growth has not been uniform across all vehicle segments; over time, the composition of India's vehicle fleet has transformed greatly in favour of private motorized vehicles. At present, private vehicles account for more than 80% of the registered vehicle fleet in the country, with two-wheelers alone accounting for 75%. (Figure 6).
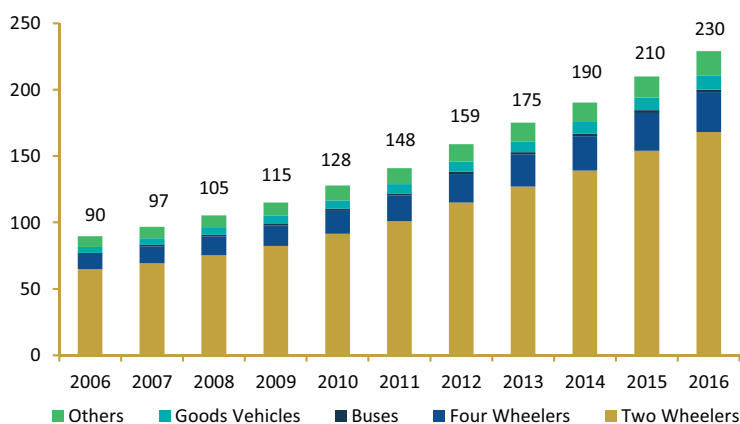

Figure 6 Number of Registered Vehicles in India by Mode (in Million)[1]
Source: TERI Analysis

Chart legend: Others · Goods Vehicles · Buses · Four Wheelers · Two Wheelers

Values above bars: 2006: 90, 2007: 97, 2008: 105, 2009: 115, 2010: 128, 2011: 148, 2012: 159, 2013: 175, 2014: 190, 2015: 210, 2016: 230

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[1]   Others include tractors, trailers, three-wheelers (passenger vehicles)/LMVs, and other miscellaneous vehicles for which category-wise breakup is not reported by states/UTs.

Although urban and rural areas have both experienced increasing levels of private vehicle use, the observed pace of motorization has been much higher in cities, with 51 million plus cities in India accounting for 31% of the total registered vehicles in the country (MoRTH, 2016). The aforementioned trends might seem surprising as Indian cities have conventionally been characterized by high population densities and mixed land-use patterns, which have resulted in close proximity of residential and commercial areas, resulting in short average trip distances of 7.5 km in large cities[2] and of 5 km in medium-to-small cities (Tiwari, 2007; Pai, 2008).[3] However, rapid urbanization, inefficient and inadequate public transportation, insufficient investment in the NMT infrastructure, and rising levels of per capita income have not allowed cities to reap the benefits of favourable land-use patterns and have instead given way to large-scale proliferation of private motorized vehicles like two- and four-wheelers (Clean Air Asia, 2013; TERI, 2015).[4] Since such vehicles are predominantly powered by fossil fuels like petrol and diesel, the volatile and

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[2]   Cities with a population exceeding 4 million
[3]   Cities with a population exceeding 1 million
[4]   See http://shaktifoundation.in/wp-content/uploads/2015/03/Promoting-NMT-in-Asian-Cities-Policymakers-Toolbox.pdf and http://www.teriin.org/projects/green/pdf/National-Transport.pdf (last accessed on September 4, 2018).

Box 1 The Case of Ho Chi Minh City, China

Over the last few decades, the built urban area of Ho Chi Minh City has increased substantially. This, combined with insufficient investment in public transport and the non-motorized transport (NMT) infrastructure, has led to a decline in the share of NMT transport from 61% in 1995 to 33% in 2002. The city now has 4.7 million registered two-wheelers, and at 1.5 motorcycles per capita, has the highest two-wheeler ownership per land area in the world.

Source: Clean Air Asia, 2013

ever-rising prices of these fuels have steadily increased the operating costs of private vehicles over time. A recent study by Bloomberg reveals that middle income households in India approximately spend 73% of their daily income to purchase a gallon (3.76 litres) of petrol.[5] Hence, by shifting to non-motorized forms of transportation like cycling, individuals can save a large proportion of their daily income.

With sufficient investment in cycling infrastructure, a large share of these trips can be undertaken by bicycles instead of four-wheelers and two-wheelers and the fuel cost can be avoided. In order to quantify the benefits that could accrue to individuals by shifting to bicycles for short-distance trips (trip distance $\leq$ 8 km), personal fuel savings that would be realized by such a modal shift have been monetized.[6]

For the same, the TERI transport model, which is a bottom-up model, has been used that first estimates the total transport demand to assess the energy consumption and CO_2 emissions by the Indian transportation sector. The model has been used extensively to evaluate

the decarbonization potential of various carbon mitigation strategies (CPCB, 2015; Planning Commission, 2014). Under the modelling framework, the transport sector is disaggregated into roadways, railways, airways, and waterways. In the model, a demand-driven approach is adopted wherein socio-economic variables such as the GDP and population are used to estimate the travel demand up to 2057. The annual transport demand is calculated on the basis of differential assumptions of fuel share by type, fleet utilization, and vehicle occupancy.

In this study, the model is used to estimate the total movement of two- and four-wheelers (in terms of annual vehicle km) for the purpose of work travel. Firstly, vehicle occupancy assumptions in this model are employed to estimate the number of two-wheelers and four-wheelers used for short-distance work trips, post which assumptions about fuel share by type and average trip distances are used to estimate the vehicle km for two-wheelers and four-wheelers, separately for urban and rural areas. Fuel efficiencies for petrol, diesel, CNG, and LPG vehicles (for 2015–16) are used to estimate the per-km fuel consumption of these vehicles. The total fuel consumption is estimated as a product of the vehicle km (VKM) and per-km fuel consumption and is monetized by

[5] See https://www.bloomberg.com/graphics/gas-prices/#20172:India:USD:g (last accessed on September 4, 2018).
[6] In this study, average trip distances $\leq$ 8 km are referred to as short-distance trips.

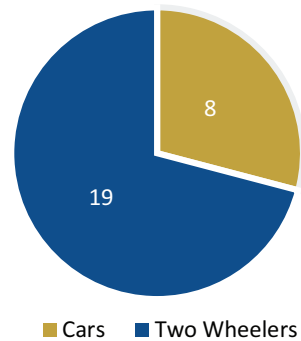using the average state-specific per-litre fuel prices in 2015–16 for petrol, diesel, LPG, and CNG.[7]

Figure 7a Estimated Personal Fuel Savings (INR Billion) on Four- and Two-Wheeler Trips (2016)
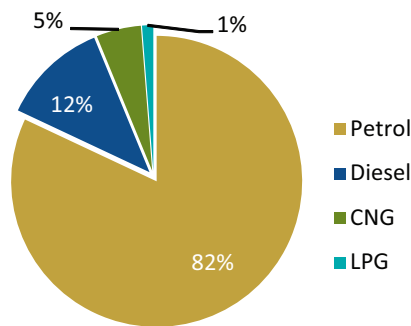

Figure 7b Personal Fuel Savings on Four-Wheeler Trips (2016)
Source: TERI Analysis

It is estimated that a 50% substitution of short-distance work trips could result in the total fuel expenditure savings of 27 billion rupees (Figure 7a), with fuel savings (petrol) on two-wheelers accounting for 70% and on cars accounting for 23%. The scenario results with 75% and 100% substitution of motorized two- and four-wheeler trips are also presented in Table 1.

Table 1 Personal Fuel Savings in Alternate Scenarios

Scenario	Personal Fuel Savings (INR Billion)		
	Two-wheelers	Four-wheelers	Total
75% substitution of two- and four-wheeler trips	29	12	41
100% substitution of two- and four-wheeler trips	39	16	55

Source: TERI Analysis

4.2 Health Benefits Due to Increased Physical Activity

Globally, sedentary lifestyles have had an adverse impact on the mental and physical health of people. Lack of physical activity due to the increased use of motorized vehicles has further exacerbated the health problems in many countries. According to the WHO, sedentary lifestyles are now the fourth leading risk factor for global mortality and are responsible for 27% of diabetes and 30% of ischemic heart disease burden.[8]

4.2.1 Economic Burden of Physical Inactivity in India

Physical inactivity is a major behavioural risk factor responsible for a significant proportion of non-communicable diseases (NCDs), which the WHO says are responsible for almost 60% of the deaths in India. Among these, CVDs and diabetes are responsible for 44% and 3% of the NCD mortality, respectively. Due to physical inactivity,

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[7] The fuel prices are obtained from https://www.mypetrolprice.com/ (last accessed on September 4, 2018).

[8] See http://www.who.int/dietphysicalactivity/pa/en/ (last accessed on September 4, 2018).

According to the WHO, in India 40% of household expenditures for treating NCDs are financed by household borrowing and sales of assets.

a 22% increase in age-standardized prevalence of obesity has been observed in India over the period 2010–14 (WHO, 2014). The increased incidence of obesity has contributed to the early onset of type 2 diabetes and CVDs with more than 63 million people in the country now suffering from the former (Bloom et al., 2014).

The treatment of non-communicable diseases is not only a financial burden for common people, but also a huge cost to the economy in terms of medical expenditure and lost productive time (TERI, 2014). Using their EPIC model, the World Economic Forum and the Harvard School of Public Health have estimated that India will incur an economic loss of $4.58 trillion (in trillions of 2010 dollars) for the period 2012–30 due to the prevalence of NCDs. This is equivalent to more than six times of India's total health expenditure over 19 years prior to 2012 (TERI, 2014). Therefore, it is critical to promote healthy lifestyles, especially in Indian cities where active transport options like cycling can play an important role in countering sedentary lifestyle diseases. This can be done by incorporating cycling into everyday life through work trips (Fishman, Böcker, and Helbich, 2015).

4.2.2 WHO HEAT Tool

HEAT developed by the WHO provides transport planners with an estimate of the societal value of reduced mortality from physical activity such as regular walking and cycling. HEAT aims to promote the integration of the economic benefits of reduced premature mortality from the use of active transport into the economic appraisal of transport and urban planning and policy interventions.

HEAT estimates the value of reduced mortality due to specified amounts of walking or cycling by developing a dose-response relationship. The tool can be used for comprehensive NMT planning assessments that have significant health impacts (Box 2).

Box 2 Possible Assessments via HEAT

The tool can be used for different assessments, for example:

• Planning for a new infrastructural investment for active transport

• Valuing the reduced mortality due to the past or current level of walking/cycling

• For more comprehensive economic appraisals or health impact assessments

If x people regularly walk or cycle an amount of y, the tool estimates the economic value of the health benefits that occur due to the reduction in mortality owing to physical activity.

The basic calculation quantifies the number of lives that can be saved, or the reduction in a population's premature mortality rate owing to regular cycling over a given period by considering factors like the distance travelled, number of days cycled, country mortality rate, value of statistical life, assessment period, and the discount factor.

The WHO HEAT has been specifically designed for European countries, but country-specific data on crude death rates (CDRs), value of statistical life (VSL), and discount rates can be fed into the tool to get more appropriate estimates based on the local situations. Hence, in order to estimate the total savings that can be realized by reduced expenditure on health treatments and reduced mortality impact, India-specific VSL has been used in the tool. The recent estimates on VSL were available for 2010 (Mani, 2014); for estimation purpose, these estimates are converted at the price level of 2016 using the consumer price index (CPI). Based on the conversions, the VSL for the working-age group (between 20 and 64 years) in India is estimated as INR 28 million. The CDR of 6.5 deaths per 1000 persons has been taken for India.[9] The tool also assumes a 5-year build-up time for realizing the total benefits of full uptake of cycling which has been incorporated in the estimation. In order to arrive at the present value of the total savings that will be achieved, a discount factor of 5% has been used.[10]

4.2.3 Estimation of Health Savings

Given the prospective amount of increase that can be achieved in the share of cycling and the subsequent health savings that can be realized by promoting an active lifestyle, the study has estimated the likely benefits and potential life savings by using the WHO HEAT. Based on the census data and forecast, in 2016, more than 20 million people were using private motor vehicles for work trips across three short-distance categories (0–1 km, 2–5 km, and 6–10 km) in urban India. If these people were to switch to cycling, leading to a subsequent substitution of 40 million daily work trips, the tool estimates the total amount of health savings that can be attained by

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[9] See http://www.censusindia.gov.in/2011-Documents/CRS_Report/crs_report%202015_23062017.pdf (last accessed on September 4, 2018).

[10] See https://www.ispor.org/consortiums/asia/PEGuidelines_India_March2016.pdf (last accessed on September 4, 2018).

Box 3 Global Health Savings from Cycling

- Cycling in the Netherlands has prevented 6,500 premature deaths annually and led to the total economic benefits of €19 billion per year as health savings.

- In Barcelona, an increase of 72.5% work trips by cycling resulted in the average economic savings of €4.7 million per year over 2009–13.

- According to a study conducted by C40 in Mexico, the substitution of car and taxi trips by a cycle-sharing initiative—EcoBici—resulted in the annual health benefits of USD 26 million.

Source: Fishman, Schepers, and Kamphuis (2015); Katherine et al. (2017); C40 Cities (2016)

2025–26 and 2030–31, that is, over a period of 10–15 years. For achieving the same, a number of scenarios have been considered, and each scenario varies on the basis of assumptions regarding:

➢ the average distance cycled per person per day

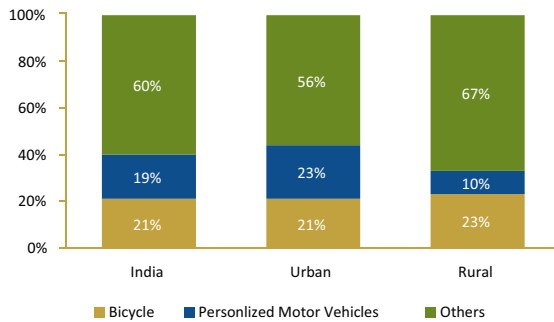➢ the number of days a person is cycling in a year

Figure 8 Share of Trips by Motorized Vehicles Within the Distance of 5 km
Source: TERI Analysis

4.2.4 Monetized Health Benefits

This section shows the present value of the monetized benefits over a period of 10 and 15 years, that is, by 2026 and 2031.[11]

Scenario 1 represents the present value of the total health savings that can be achieved between 2016 and 2026, if trips made by two-wheelers and cars within the average distance of 8 km are substituted by cycling. The savings have been estimated considering different combinations of the 'distance travelled' and the 'number of days cycled'. Similarly, Scenario 2 represents the present value of the total health savings that can be achieved over a period of 15 years, from 2016 to 2031.

Scenario 1

Number of Days Cycled	240	120	60
Distance Categories			
<8 km	4767	2384	1192
<3.5 km	2136	1068	534
<0.5 km	96	48	24

The table represents the present value of the total health savings accumulated over 10 years—that is, from 2016–26—if two trips are substituted across the distance categories and for the given number of days.

*All figures are in INR billion
- Highly ambitious
- Moderately high
- Moderate
- Low
- Very low

Scenario 2

Number of Days Cycled	240	120	60
Distance Categories			
<8 km	6408	3204	1602
<3.5 km	2871	1435	718
<0.5 km	129	65	32

The table represents the present value of the total health savings accumulated over 15 years—that is, from 2016–31—if two trips are substituted across the distance categories and for the given number of days.

*All figures are in INR billion
- Highly ambitious
- Moderately high
- Moderate
- Low
- Very low

Source: TERI Analysis

From the aforementioned results, it can be observed that in a moderate scenario with 50% substitution of work trips, 4,756 premature deaths can be avoided. The value of these reduced mortalities amount to INR 1,068 billion and INR 1,435 billion, which is equivalent to 0.9–1.3% of India's total GDP. In a highly ambitious scenario with 100% substitution of two- and four-wheeler work trips by cycling, a total accumulated savings of INR 4,767 billion and INR 6,408 billion can be achieved over 10–15 years, respectively, which is equivalent to 4–6% of India's GDP in 2016.[12]

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[11] The dose-response functions given in the WHO HEAT are used.

[12] See https://www.rbi.org.in/scripts/PublicationsView. aspx?id=17777 (real GDP at market price; last accessed on September 20, 2018).

Based on the sensitivity analysis, the present value of the accumulated benefits has also been estimated by applying a discount rate of 8%. As a result, the accumulated value of health benefits reduces from INR 1,068 billion to INR 928 billion by 2026 (equivalent to 0.8% of the GDP) in the moderate scenario. By 2031, the savings reduce from INR 1,435 billion to INR 1,184 billion (equivalent to 1% of the GDP).

Given the large-scale impact increased physical activity due to cycling can have on reducing the economic burden of unhealthy lifestyles, cycling needs to be promoted by implementing urban transport programmes like safe cycling lanes and bike-sharing schemes.

4.3 Health Benefits of Reduced Air Pollution

Ambient air pollution (AAP) is one of the major causes of ill health in India—it ranks 5th in the incidence of mortality and 7th in the incidence of disease burden. As per the global disease burden risk assessment, air pollution exposure in 2015 resulted in 1.8 million premature deaths and 49 million disability adjusted life years (DALYs) (Centre for Environmental Health, 2017). In terms of its health impacts, long-term exposure to air pollution can impede lung development in children, impact cognitive development, and increase the risk of respiratory mortality and cardiac diseases. Increased exposure to air pollution significantly impacts the economy by reducing labour productivity due to premature mortality and morbidity. According to the World Bank (2016), it cost India 8% of its GDP in 2013. Since vehicular emissions are a major source of

air pollution in urban India, the substitution of motorized transport by more sustainable forms like cycling can go a long way in reducing the burden of diseases.
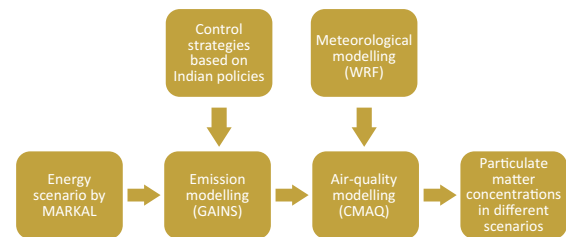
4.3.1 Methodology

Figure 9 Methodology for Air-Quality Modelling

In order to estimate the health benefits of reduced air pollution due to increased levels of cycling, TERI's air-quality modelling framework (Figure 9) is used. Firstly, energy consumption from all sectors, including transport, is estimated. For the transport sector, the energy consumption is estimated using the current mode shares in terms of passenger km (PKM) for the business-as-usual (BAU) scenario. The estimated energy consumption data is fed into the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-ASIA model along with the penetration of various control strategies[13] in different sectors to estimate $PM_{2.5}$ and PM_{10} emissions.

To estimate the changes in particulate matter (PM) concentrations at different levels of increased cycling, three alternate energy scenarios—ALT1, ALT2, and ALT3—are created by using TERI's MARKAL (Market Allocation) model. These scenarios (ALT1, ALT2, and ALT3) consider a shift of 25%, 50%, and 73% PKM,[14] respectively, from motorized vehicles to cycling. PM

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[13] Regulatory policies implemented by the government to reduce emissions.
[14] For an average trip length of 8 km or less

concentrations in alternate scenarios have been estimated using the methodology applied in the BAU scenario. $PM_{2.5}$ (PM with aerodynamic diameter $\leq 2.5\mu m$) and PM_{10} (PM with aerodynamic diameter $\leq 10\mu m$) emissions in different scenarios are shown in Figure 10.
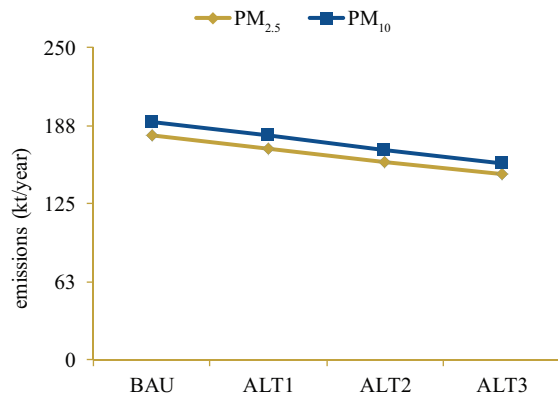

Figure 10 $PM_{2.5}$ and PM_{10} Emissions from Transport Sector in Four Different Scenarios
Source: TERI Analysis

The obtained PM concentrations are then used for estimating health impacts in terms of cardiovascular mortality based on the methodology proposed by the WHO (2004):

The first step of the assessment comprises attributable proportion (AP) calculation, which indicates the fraction of health effects that can be attributed to the exposure in a given population (Eq. 1)

$$AP = \frac{\sum[\{RR_c - 1\} \times p(c)]}{\{RR_c \times p(c)\}} \text{ (1)}$$

Where, RRc is relative risk due to specific concentration and p(c) is the proportion of the target population in category c of exposure. RRc has been calculated as change in the relative risk due to change in pollutant concentration using Eq. 2 (adopted from Cairncross et al., 2007).

$$RR_c = Exp\ (\beta \times (C - Tc))\ \text{(2)}$$

Where, β is risk coefficient given by the WHO, and in this study, 0.00893 is used, C is the resultant concentration, and Tc is the threshold concentration. The excess cases (ΔN) are calculated using Eq. 3.

$$\Delta N(c) = [(RR_c - 1) \times p(c) \times I \times (1 - AP)] \times N\ \text{(3)}$$

Where, N is the population and I is the baseline incidence for the said disease or death rate for the said diseases. As can be observed in Figure 11, the maximum reduction in mortalities is obtained in scenario ALT 3, where 73% of PKM in the BAU scenario are shifted to cycling.
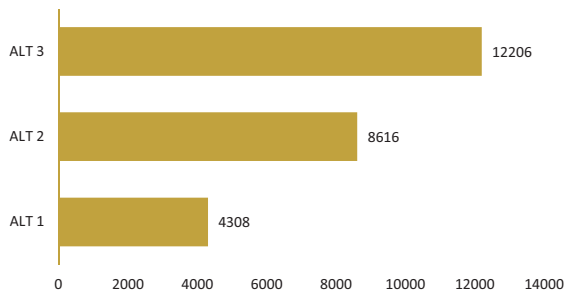

Figure 11 Reductions in Premature Mortality Due to Reduced Air Pollution
Source: TERI Analysis

To estimate the value of reduced mortality due to increased cycling, the VSL estimate mentioned in section 4.2.2 is used (Table 2). In a moderate scenario with 50% substitution of motorized PKM by cycling, 8,616 premature deaths can be prevented. The aforementioned amounts to savings of INR 241 billion.

Table 2 Cost of Mortalities Avoided Due to Modal Shift in Three Scenarios

Scenario	Health Benefits of Reduced Air Pollution (INR Million)
ALT 1	120624
ALT 2	241248
ALT 3	341768

4.4 Economic Value of Travel-Time Savings by Poor

In countries all over the world, it has been observed that the travel patterns of the poor are highly different from those of their high-income counterparts (Lucas, 2016). 'Transport poverty' refers to a condition where those who are economically or socially disadvantaged bear excessive travel-time costs to access job, education, and health opportunities and are forced to travel in unsafe and unhealthy conditions (Titheridge, 2014; Lucas, 2016). The poor often do not have access to private or public transportation and are, thus, relatively less mobile. For the poor, the lack of mobility can exacerbate the incidence of poverty by limiting access to economic opportunities, education, and health services.

In order to address this fundamental equity concern around mobility, sustainable and just transportation systems should be developed which provide accessible, safe, and affordable transport to the poor. Providing bicycles to the urban and rural poor can spearhead the process of achieving this multidimensional objective.

4.4.1 Travel Patterns of India's Poor

In poor countries, more than 50% of the total trips are undertaken on foot (World Bank, 2008). The same holds true for India, where despite the increasing ownership of private vehicles, walking remains the dominant form of mobility because there are many 'captive users' who cannot afford or access any other means of transportation. These captive users are often the urban and rural poor who are forced to spend excessive travel time to access economic and social opportunities by walking.

An analysis of the other workers' census data illustrates the dominance of walking as the primary form of mobility in India. The analysis reveals that 32% of the Indian workforce walks to work (Figure 3). In terms of distance categories, 31% of this workforce undertakes an average work trip of 3.5 km, while 26% undertakes an average work trip of 8 km on foot.

This study assumes that the afore-mentioned work trips are largely undertaken by marginal unskilled workers, namely, the urban and rural poor. In the absence of accessible and affordable transportation, these individuals spend a significant portion of their time commuting to and fro.[15] This study monetizes the benefit to the economy from travel-time savings that can be achieved by providing bicycles to these workers. In order to estimate the value of travel time, it is assumed that all the workers who walk to work for a distance greater than/equal to 3.5 km are unskilled daily-wage labourers, who do not have access to any other means of transport. Under the aforementioned assumptions, the value of travel time savings (VTTS) for unskilled manual workers is estimated, where the VTTS is defined as the cost of travel time saved by faster travel. It is estimated as a product of the total time saved and the unit cost of travel time (Litman, 2018).[16] The time saved by faster

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[15] For trip distances that are too long to be traversed on foot, unskilled workers rely on IPT forms such as shared tempos and autos. However, for unskilled workers and individuals living in slums, travelling by these modes costs them 25–30% of their daily wages (Tiwari 2007; Cervero, 2013). Hence, in the instances where the poor do not spend a significant proportion of their time, they are forced to spend a significant proportion of their income.

[16] See http://bca.transportationeconomics.org/benefits/travel-time (last accessed on September 4, 2018); https://www.its.leeds.ac.uk/projects/WBToolkit/Note10.htm (last accessed on September 4, 2018); https://www.transportation.gov/sites/dot.dev/files/docs/vot_guidance_092811c.pdf (last accessed on September 4, 2018);http://www.vtpi.org/tca/tca0502.pdf (last accessed on September 4, 2018).

Box 4 Travel-Time Costs in Other Developing Countries

- In Mexico, 20% of the workers spend up to three hours on work trips, while about 10% spend more than five hours.

- In the Latin American cities of Lima and Rio de Janeiro, the urban poor have been forced to relocate 30–40 km away from the employment centres. As a result, the travel time for the poorest section of the city exceeds three hours.

Source: World Bank, 2008

travel is estimated by assuming that all the workers who originally walked to work for a distance greater than/equal to 3.5 km now cycle to work. For all the workers in the sample, the time saving from substitution of walking by cycling is estimated on the basis of certain assumptions about the average cycling and walking speed in India (Table 3).

Table 3 Average Speeds

Mode	Average speed (km/h)
Walking	5
Cycling	12

In order to estimate the unit cost of travel time, methodologies outlined in the economic valuation notes of the World Bank are referred to.[17] The note specifies methods suitable for the valuation of travel-time savings in work trips, to evaluate transportation projects in developing countries. Essentially, there exist two models to evaluate the value of travel-time savings in work trips: the wage rate model and the Hensher model. This study uses the wage rate model, which is grounded in

the classical economic theory of marginal productivity. Under assumptions of a perfectly competitive market, the model assumes that the unit cost of travel time is equal to the wage rate of the worker.

The workforce in the sample is spatially demarcated, and hence the value of travel-time savings is estimated separately for urban and rural workers. For urban workers, the area-wise Minimum Wages for the Central Sphere for 2015–16, as listed by the Ministry of Labour and Employment, are used. For rural India, the wage rate corresponds to the State Wise Notified Wages for MGNREGA (2015–16). The total annual value of travel-time savings is obtained as a summation of the savings in urban and rural India.

It is estimated that providing bicycles to unskilled workers in India can result in an annual travel-time savings worth INR 112 billion. These savings are representative of the additional output that can be produced in the economy as a result of increase in work hours, which amount to 23 million added hours (Figure 12).

[17] See http://siteresources.worldbank.org/INTTRANSPORT/ Resources/336291-1227561426235/5611053- 1231943010251/trn-15EENote2.pdf (last accessed on September 4, 2018).
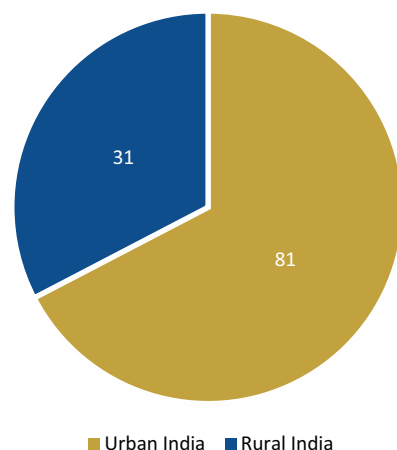
Figure 12 Value of Travel-Time Savings in India
In INR Billion (2016)

Source: TERI Analysis

The estimated benefits presented in Figure 12 correspond to a 50% substitution of walking trips greater than/equal to 3.5 km. Scenario results for 75% and 100% substitution of walking trips have also been evaluated (Table 4).

Table 4 Value of Travel-Time Savings in Alternate Scenarios

Scenario	Value of Travel Time Saved (INR Billion)			Man Hours Saved
	Urban India	Rural India	Total	Total
75% substitution of cycling trips	109	47	156	26
100% substitution of cycling trips	130	63	193	29

Source: TERI Analysis

4.4.2 Bicycles for Enhancing Social Development

In addition to travel-time savings, the provision of bicycles can also address equity concerns in developing countries. It can enhance the income-earning potential of low-income households, increase school enrolment rates, and improve the socio-economic status of women. The World Bicycle Relief (WBR)—a global bicycle charity that manufactures and distributes bicycles in the rural regions of developing countries to improve the economic, social, and health status of individuals—argues that the provision of bicycles increases student attendance and academic performance by 28% and 59%, respectively. It also increases the patient visits of healthcare workers by 45% and provides a safer mode of transport for women.[18]

Specifically, an analysis of the bicycle-distribution schemes in India reveals the immense potential of bicycles in promoting female education. The most well-known of these schemes is the Mukhyamantri Cycle Yojana introduced by the Bihar government in 2006 for addressing the poor school enrolment of girls in high schools. Under this scheme, girls enroling for Class IX were provided INR 2,000 for purchasing a bicycle. As per Muralidharan and Prakash (2013), the scheme resulted in a 5% increase in the enrolment rate of girls in secondary school and a 25% reduction in the gender gap in enrolment.

A more recent scheme is the Sabooj Sathi (Green Companion) scheme launched by West Bengal in 2015. It aims to distribute bicycles to all students of classes X and XII in government or government-aided secondary and higher secondary schools. In the first two phases of the scheme, 3,423,004 cycles have been distributed which have not only improved access to higher secondary schools but have also improved the general mobility of the

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[18] See https://worldbicyclerelief.org/en/ (last accessed on September 4, 2018).

people, especially girls (Pratichi Institute, 2017). The success of such schemes has motivated the introduction of bicycle-distribution programmes in various states such as Karnataka, Odisha, Madhya Pradesh, Punjab, Andhra Pradesh, Assam, Rajasthan, and Tamil Nadu.

Box 5 Bicycle as an Income-Generating Asset

Bicycles Against Poverty is an organization that distributes bicycles to rural African communities on a lease-to-own basis. It has distributed over 2,700 bicycles in over 40,000 rural communities in Uganda. According to the organization, bicycles have made it possible for rural farmers to carry five times the crops and travel four times the distance to access better market opportunities.

Source: Bicycles Against Poverty, 2018

Estimation of Indirect Benefits

5.1 Energy Savings and Emissions Reduction

Interlinkages between population increase, economic activity, and growth in transport are well established. Rising per capita incomes have led to increased use of private motor vehicles, which has resulted in growing reliance on fossil fuels with a subsequent increase in energy demand and emissions along with externalities of pollution and congestion.

5.1.1 Increase in Motorization and India's Fuel Dependency

Presently, the transport sector is growing at a rate that exceeds the GDP's growth rate. This growth, particularly in urban centres with a high density of vehicle population, consumes a significant amount of energy and contributes immensely to carbon emissions.

India's transport sector is highly dominated by road transport and accounts for 86% of the passenger movement with a very

As per official estimates, every day nearly 50,000 new motor vehicles (two-wheelers, autos, and cars) register in India, which explains a 10% increase in vehicle registration annually for the past decade.

high fuel consumption and CO_2 emissions. As per the all-India study conducted by Nielsen for the Petroleum Planning and Analysis Cell (PPAC), the transport sector consumed 70% of the diesel and 99.6% of the petrol in 2013. Of this, cars accounted for 34.3% of petrol consumption and 13.15% of diesel consumption, while two-wheelers accounted for the maximum share of petrol consumption (61.42%) in the transport sector.

Considering the expected level of population growth and urbanization, if the current trend of private motorization continues, it will only put more pressure on India's energy resource base, which is meagre as compared to the population it sustains. Since the bulk of the transportation energy demand is met by imported petroleum, higher import prices can have huge implications for India's current account balance with a higher public spending on importing oil. From this perspective, it is important to regulate the transport policies in favour of energy conservation by promoting smarter mobility solutions with an emphasis on mobility shift towards active transport. As a high proportion of the trips in India are within a range of 10 km, private car and two-wheeler trips can be substituted by cycling, thereby reducing the fuel dependency of the transport sector.

Box 6 India's Crude Oil Imports

- In 2015, India imported more than 80% of its oil at a cost of INR 4.2 lakh crore.

- India's crude import bill increased at a CAGR of 9% in 2006–16 from INR 1.71 lakh crore in 2006 to INR 4.16 lakh crore in 2016, as the imports grew from 99 million metric tons to 203 million metric tons.

Source: PPAC, 2013

5.1.2 Fuel Savings from Bicycles

An analysis of the work trip data suggests that in 2015–16, more than 50 million daily work trips up to the average distance of 8 km were undertaken by two-wheelers and cars. The fuel requirements of these 50 million daily trips were largely met by petrol and diesel. Of the total annual petrol consumption of around 800 million litres, 75% was consumed by two-wheelers. The high proliferation of two-wheelers is directly related to increase in per capita income levels, ease of access, and affordability, as the per-km cost of two-wheelers is very low and hence people find it more convenient even for short-distance travel. Promoting the use of cycling for such short-distance

Petrol ■ Diesel ■ CNG ■ LPG

Figure 13 Share of Fuel Consumption by Cars in India (2016)
Source: TERI Analysis

trips can become a value-added solution to reduce fuel consumption as, in terms of affordability, it is the cheapest mode of transport.

The TERI analysis reveals that by a 50% substitution of short-distance private motorized trips by cycling, India can save more than 0.35 Mtoe annually. A 75% and 100% substitution of these trips could result in the annual savings of 0.52 Mtoe and 0.7 Mtoe respectively.

Considering India's increased import dependence and low-energy efficiency in the transport sector, it is important to bring out some comprehensive programmes to promote sustainable transport systems, primarily active transport.
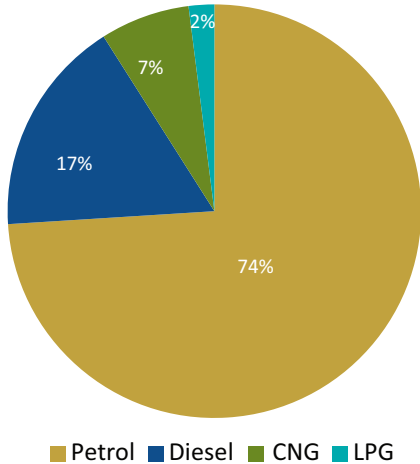
5.1.3 Emission Reduction Due to Increased Cycling

Emissions linked with the increased transport energy demand remain a key concern for India's mitigation targets, and the growth of the transport sector will play a crucial role in determining India's future emission scenario. In 2015, 87% of the total CO_2 equivalent emissions in the transport sector were emitted by road transport (TERI, 2018), and much of this increase in emission is a result of the high rate of private motorization. The transport sector contributes around 32%, 17.4%,

13.3%, 19.5%, 43.5%, 56.86%, and 25% to the total GHG footprint of Delhi, Greater Mumbai, Kolkata, Chennai, Greater Bengaluru, Hyderabad, and Ahmedabad, respectively.[1] Amongst the million plus cities, six major cities (Delhi, Bengaluru, Chennai, Ahmedabad, Greater Mumbai, and Surat) account for 41.3% of the total registered motor vehicles in 2016 (MoRTH, 2016). The major cause of growing reliance on private motor vehicles in most Indian cities can be attributed to the lack of alternative modes of transportation and absence of amenities for convenient access to active transport, such as the provision of walkways and bicycle paths.

A 50% substitution of work trips undertaken by cars and two-wheelers under the average distance of 8 km can reduce annual CO_2 emissions by 1 million tonnes. As most of these trips are made by two-wheelers, they have the highest share of 68% in the total CO_2 emissions.

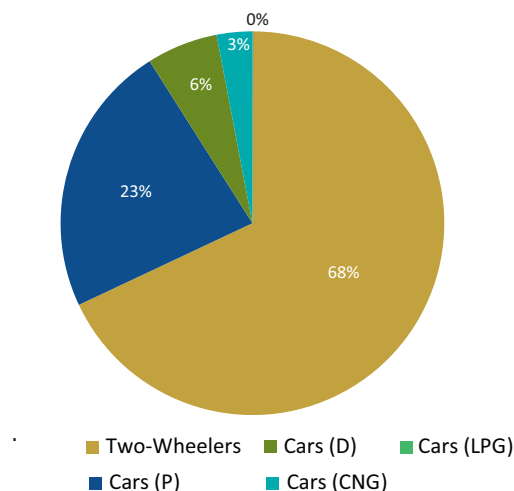**Figure 14** CO_2 Emissions by Private Motor Vehicles (2016)
Source: TERI Analysis

The carbon footprint of India's transport sector will keep on increasing if adequate measures are not taken at the earliest. As cities are becoming increasingly congested, the use of two-wheelers and cars for short-distance trips can lead to higher CO_2 emissions because of reduced average speed and idling. In such a scenario, it is important to identify the potential trips that can be easily substituted by cycling, leading to higher environmental benefits along with the ease of mobility. Concerted efforts towards the substitution of various short-distance daily trips to school, to the workplace, or to supermarkets by bicycles can not only help in reducing the fuel requirement but also enhances the development of the physical environment with limited financial resources.

Alternate scenarios with 75% and 100% shift from motorized vehicles to bicycles have also been evaluated and the results have been summarized (Table 5).

Table 5 Volume of Energy Savings and Emission Reduction in Alternate Scenarios

Scenario	Energy Savings and Emission Reduction	
	Energy Savings (Mtoe)	CO_2 Emission Reduction (Million Tonnes)
75% substitution of two- and four-wheeler trips	0.52	1.5
100% substitution of two- and four-wheeler trips	0.7	2

Source: TERI Analysis

1 See http://wgbis.ces.iisc.ernet.in/energy/paper/Mitigation-and-adaptation-strategy/A20162912344_46.pdf (last accessed on September 4, 2018).

Potential Benefits of Increased Cycling: Policy Implications

As discussed earlier, cycling is one of the most sustainable modes of transport. It has numerous benefits in terms of zero fuel consumption, zero emissions, and health benefits from increased physical activity. Additionally, it is an affordable means of transport for millions of low-income individuals. In order to quantify these benefits, the study estimates that a 50% substitution of motorized trips (cars and two-wheelers) within the distance of 8 km can yield an annual benefit of INR 1.8 trillion (Table 6). These benefits amount to 1.6% of India's annual GDP for 2015–16.

Table 6 Estimated Direct Benefits of Increased Cycling

Benefits	Trips Substituted by Bicycle	Methodology	Value of the Benefits (INR Billion)
Personal fuel savings	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	27
Health benefits due to:			
2a) Increased physical activity (net present value of the accumulated benefits over 15 years)	50% substitution of two-wheeler and four-wheeler trips under the average distance of 5 km	WHO HEAT	1435
2b) Reduced air pollution	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI's Air Quality Modelling Framework	241
Travel-time savings	50% substitution of walking trips above the average distance of 3.5 km	Wage Rate Model	112
Total direct benefits			**1815**

Table 7 Estimated Indirect Benefits of Increased Cycling

Benefits	Trips Substituted by Bicycle	Methodology	Quantum of Savings (Million Tonnes)
Energy savings (oil equivalent)	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	0.35
CO_2 emission reduction	50% substitution of two-wheeler and four-wheeler trips under the average distance of 8 km	TERI Transport Model	1

Box 7 Impact of Financial Incentives on Bicycle Ownership
- In Kenya, due to a tax cut from 80% to 20% between 1986 and 1989 (one-third reduction in price), bicycle sales increased by 1500%.
- In Lima (Peru), the provision of low-interest loans to low-income families resulted in an 8% increase in the mode share of cycles.

Source: TERI, 2014

Despite the many benefits of cycling, bicycle ownership and use in India is steadily declining. However, considering the wide-ranging benefits of cycling, it is critical to promote this form of active transport by undertaking dedicated measures. To this end, measures to improve cycling shares in cities and rural areas are proposed in the following section.

6.1 Improving Bicycle Ownership among Captive Users

As per the current trend in India, captive users (low-income individuals) are the primary users of bicycles in the country. For such individuals bicycles are an invaluable asset used for multifarious income-generating activities such as the vtransportation of farm products from villages to markets and the sale of goods like newspapers and LPG cylinders. Further,

as a cost-effective form of mobility, they enable access to key facilities such as schools and hospitals. Specifically, bicycle ownership and access positively impact the socio-economic condition of women by improving the school enrolment of girls and increasing the participation of women in income-generating activities.

Despite this, the level of bicycle ownership across this section remains low. The primary reasons for this are the high price of bicycles (as a share of household income) and the lack of financing options. At present, the cheapest bicycle available in India costs around INR 2,500–5,000, which accounts for 15% of the annual per capita income in rural areas. In comparison, the cheapest bicycle in China accounts for only 2.5% of the annual per capita income in rural areas. The greater affordability of bicycles is reflected in the ownership level in China, which is almost double than that of India (TERI, 2014).

Box 8 Impact of Investment in Cycling Infrastructure
- In the 1970s, increased auto traffic and the absence of cycling infrastructure resulted in very high casualties amongst cyclists in Netherlands. Protests over the high level of fatalities combined with the 1973 oil crisis motivated the government to promote bicycle infrastructure to quell the protests and address energy concerns (Covington 2013)[6].
- Similarly, in the Netherlands, government investment increased the cycling levels by 50% during 1980–97 (Tiwari and Jain, 2013).
- In Bogota, the integration of public transport and NMT infrastructure by the construction of a 300-km long network for bicyclists and pedestrians increased the mode share of bicycles from 0.9% to 4% (Santos et al., 2010).

Hence, making bicycles affordable can greatly benefit low-income individuals intending to purchase this mode of transport. Currently, a bicycle costing between INR 2,500 and INR 5,000 has 12% of the GST component. Lowering the GST to 5% with input tax credit would help bring the relative cost down for a highly price-sensitive consumer segment.[1] The high upfront cost of bicycle ownership can also be circumvented by the provision of microcredit loans to such individuals. This can be done by the inclusion of bicycles under the priority-lending guidelines of the Reserve Bank of India (RBI).

6.2 Promoting Cycling among Choice Users

Over the past decades, the mode share of cycling in Indian cities has declined in urban areas—household bicycle ownership has reduced from 46% in 2001 to 42% in 2011 (GoI, 2011). This can be attributed to the lack of cycling infrastructure and the risk of road accidents. Safe cycling infrastructure can play a crucial role in increasing the level of bicycle ownership among choice users.

An analysis of the municipal corporation budget allocation for Ahmedabad, Bengaluru, Chennai, Pune, and Nagpur reveals that in 2012–16, only 25% of the budget was allocated to transport. Of this, 45% was spent on infrastructure for motorized transport,[2] 30% on general expenses, 15% on public transport, and 7% on mixed-mode, while only 2% was spent on NMT infrastructure development (SUM Net India, 2017).

Increasing investment on cycling infrastructure can motivate choice users to shift and can provide safe cycling conditions for captive users who often travel in unsafe and unhealthy conditions. Further, mandating investment on NMT for projects that seek to develop motorized and public transport infrastructure can address the issues pertaining to last-mile connectivity.

Additionally, cities should plan bicycle-sharing schemes at various locations across cities and supplement the same with awareness campaigns to highlight the benefits of bike-sharing.

The aformentioned measures need to be supplemented by regulations on the use of private motorized vehicles. Measures such as the implementation of congestion and parking pricing and pollution tax can prove to be effective in motivating the use of bicycles among choice users.

Bicycle is a sustainable, eco-friendly and affordable means of transport and presently requires national level intervention for its successful promotion. Hence, it is suggested that a 'Bicycle Development Council' should be established for growth and development of the sector in India.

Lastly, the government should initiate mass awareness campaigns to highlight the various benefits of cycling. A nationwide awareness campaign should be initiated with the Ministry of Health and Family Welfare; Ministry of Human Resource Development; Ministry of Environment, Forest and Climate Change; and Ministry of Urban Development and Housing as partners. The focus of the campaign should be to highlight the economic, social, health, and environmental benefits of cycling and to change the perception of the bicycle as the poor person's mode of mobility and an unsafe mode of transport.

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[1] See https://cbec-gst.gov.in/gst-goods-services-rates.html (last accessed on September 4, 2018).
[2] Of the investment in motorized transport infrastructure, 49% was spent on new roads and 37% on road repairs.

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Annex: What Is Sustainable Transportation?

Elements of Sustainable Transport System

Efficient, effective and environment friendly transport system is vital for the socio-economic development of urban areas, which are facing an enormous increase in the demand for passenger and freight movements. In an attempt to fill this demand supply gap in urban transport sector, the service providers have focused only on the provision of additional infrastructure rather than meeting the demand in a more efficient manner. The failure of current urban transport practices to deliver socio-economic and environmental friendly solutions has reinforced the case for sustainable provision of transport services in our cities.

The Concept

A reasonable start to evolve a framework for sustainable transport provision is to define the term 'sustainable transport' at the very outset. Although there is no universally accepted definition of sustainable transport, the following elements are common to most definitions:

➢ Considering economic, social, and environmental costs and benefits of developing transport services
➢ Addressing mobility concerns of all vulnerable segments of the society and developing a transport system that provides equal development opportunities to all
➢ Minimizing environmental impacts of transport activities

Transportation has significant economic, social and environmental impacts, and is an important factor in overall sustainability of habitations[1]. Sustainability implies that the present needs of the population are met without compromising the ability of future generations to meet their own needs[2]. When applied to transportation, the word sustainable qualifies the transport system as a system that meets the present day demands of transport by ensuring that environmental, social, and economic considerations are factored into the decisions so as to ensure that the future demand for mobility can be met in a judicious manner[3].

Introduction of the concept of sustainability in transport provision has led to a paradigm shift from the existing transport planning practices. Although less, there have been a few initiatives by city planners to plan for equitable, efficient and environment-friendly transport systems. City planners have now started viewing transport beyond the traditional concept of just physical mobility to a broader concept of accessibility i.e. people's ability to obtain desired goods and services[1]. The broad areas that any sustainable transport definition needs to cover are: (i) social, (ii) economic, and (iii) environmental factors. The definition should essentially qualify transport as promoting equity, fostering clean and healthy environment, promoting economic growth and a balanced system in which walking, cycling, public transportation and private vehicles are all viable options for the society.

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1   http://www.vtpi.org/sustain/sti.pdf
2   Our Common Future: Report of the World Commission on Environment and Development (1987)
3   California Transport Plan, 2025 (published in 2006)

Source: Review of Comprehensive Mobility Plans (TERI, 2011)

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