Issue Brief

INTEGRATING HEALTH BENEFITS
INTO TRANSPORTATION PLANNING AND POLICY IN INDIA

March 2014
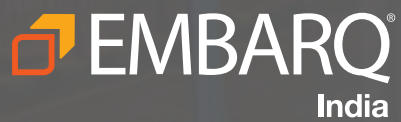
EMBARQ
India

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HEALTH IMPACTS AND TRANSPORTATION

Typical transportation investment or policy proposals in India may consider evaluation factors such as connectivity with surrounding areas, land use and socioeconomic impacts, funding availability and commitment, and stakeholder support constraints. However they overlook one important factor: health impacts of transportation.

Rapid motorization of Indian cities has led to a public health crisis in the form of increased traffic injuries and fatalities, exposure to air and noise pollution, and decreased physical activity among many other adverse health and environmental impacts. There is thus an urgent need to assess health impacts of transportation prior to project implementation to better inform decision-makers how to maximize the benefits and minimize the negative impacts on health. This also requires increased engagement and discussion between public health professionals and urban transport professionals, an objective that this Issue Brief aims to accomplish.

Health Impact Assessment (HIA) methodologies and tools have been used extensively in the developed world primarily to support broader environmental impact assessments of projects, programs, and policies, but only recently in the transportation sector. The concept of conducting an HIA has now started to gain traction in the developing world. Unfortunately, much of the methodology and indicators are specific to a developed world context.

This issue brief aims to develop an appropriate methodology for assessing the health impacts from urban transportation projects, plans, and policies in the Indian context. Through a review of the literature and expert input from transportation planners and public health professionals, we first identified the HIA typologies and health impacts relevant to the transportation sector in India. We then developed a methodology to conduct HIAs focusing on modal shift and vehicle kilometers traveled for Indian cities, where measurement of health outcomes can be difficult and resource-intensive. We applied the methodology and evidence gathered through the review to the City of Indore, Madhya Pradesh to evaluate the health impacts of the recently implemented BRT corridor in the city. We estimate that about 19 lives can be saved per year after 2014, accounting for the reduction fatalities from reduction in private motorized VKT, reduction in air pollution exposure, and health benefits from increased physical activity. Finally, we present recommendations and conclusions on the importance of integrating health benefits into urban transportation planning and policy in India.

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SECTION 1
URBAN TRANSPORT
IN INDIA

Rapid population growth, urbanization, suburban sprawl, rising incomes, and sharply climbing motor vehicle ownership, especially two-wheelers has led to a transport crisis in Indian cities (Pucher et al. 2007). In India, two- wheelers account for the largest proportion of all registered vehicles in India, equal to 71 percent (World Health Organization 2009b). With limited funding, most transport facilities are used far beyond their design capacity leading to deteriorated levels of service for all users. Unabated motorization has resulted in increasing congestion and overcrowded public transport (Singh 2005). Walking and bicycling still provides mobility to a large percentage of people in many cities, especially the poor who often do not have other alternatives (Leather et al. 2011). Unfortunately the needs of pedestrians and cyclists have been virtually ignored in most cities. This has resulted in alarming levels of congestion, air pollution, noise, traffic and decreased physical activity. All these factors have a negative impact on population health.

A 2013 WHO report on Road Safety found that vulnerable road users (pedestrians and motorized two- or three-wheeler users) accounted for more than half of the road traffic deaths in India, with pedestrians comprising 21 percent and motorized two- or three-wheeler users comprising 32 percent or road deaths (World Health Organization - SEARO 2013). While India's national policy encourages walking and cycling as an alternative to using cars, there are no infrastructure measures such as designated lanes or other policies to protect vulnerable road users from other vehicle users (World Health Organization 2013) (World Health Organization 2013, Wegman 2013). The overcrowding of pedestrians and cyclists on road shoulders increases the risks to them (Wegman 2013). An incompatible mix of both motorized and non-motorized vehicles traveling at widely different speeds also makes conditions unsafe for pedestrians and cyclists (Pucher et al. 2005).

As illustrated in Figure 1, India has the world's highest chronic respiratory and asthma-related deaths (World Health Report 2004) and asthma alone caused 5.18 percent of all deaths in 2002, an average of 54 deaths per million people per year (Global Health Observatory Data Repository 2008).

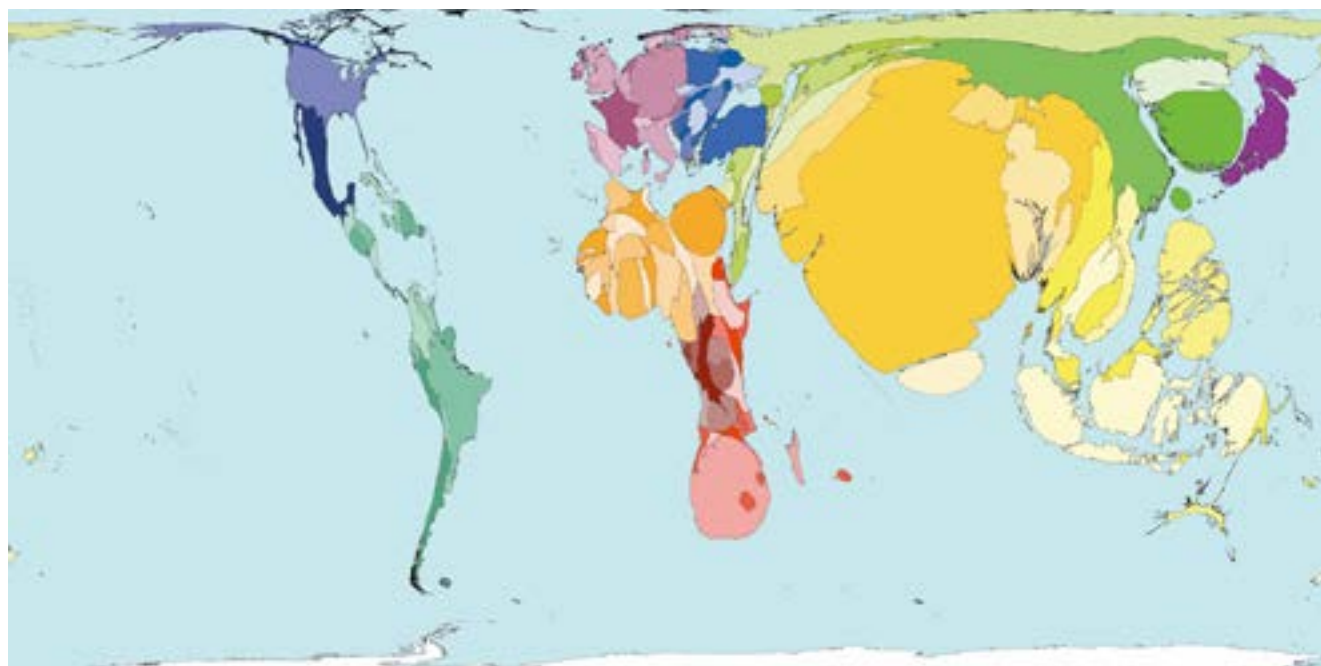Table 1 lists the Air Quality Index (AQI) values for Ozone and Particulate Matter (PM) and the associated health concerns.

Both PM10 and PM2.5 can cause respiratory health problems such as coughing, wheezing, reduced lung function, asthma attacks and in some cases, early death (Air Info Now 2014, AIRNow 2014)

*PM has two sets of cautionary statements, which correspond to the two sizes of PM that are measured:

A Cartogram (Rate-Adjusted Map) of Asthma-related Death Rates

Source: www.worldmapper.org (World Health Report 2004)

Table 1: Particulate Matter - Air Quality Index (AQI) and Health Concerns

AQI Values	Air Quality Descriptor	Health Concerns*	
		PM2.5	PM10
0-50	*Good*	None	None
51-100**	*Moderate*	None	None
101-150	*Unhealthy for sensitive groups*	People with respiratory or heart diseases, the elderly, and children should limit prolonged exertion.	People with respiratory disease such as asthma, should limit outdoor exertion.
151-200	*Unhealty*	People with respiratory or heart diseases, the elderly, and children should avoid prolonged exertion, everyone else should limit prolonged exertion.	People with respiratory disease such as asthma, should limit outdoor exertion, everyone else, especially the elderly nd children should limit prolonged outdoor exertion
201-300	*Very Unhealthy*	People with respiratory or heart diseases, the elderly, and children should any outdoor activiy, everyone else should avoid prolonged exertion	People with respiratory disease such as asthma should avoid any outdoor activiy, everlyone else, especially the elderly and children should limit outdoor exertion.
301-500	*Hazardous*	Everyone should avoid any outdoor exertion, people with respiratory or heart disease, the elderly and children should remain indoors.	Everyone should avoid any outdoor exertion, people with respiratory disease such as asthma should remain indoors.

• Particles up to 2.5 micrometers in diameter (PM2.5)
• Particles up to 10 micrometers in diameter (PM10)
** • An AQI of 100 for PM2.5 corresponds to a PM2.5 level of 40 micrograms per cubic meter (averaged over 24 hours).
• An AQI of 100 for PM10 corresponds to a PM10 level of 150 micrograms per cubic meter (averaged over 24 hours).
Source: (Air Info Now 2014, AIRNow 2014

As illustrated in Figure 2, in 2011, 9 out of 15 cities in India had an unhealthy PM10 AQI value, with some smaller cities like Ludhiana and Kanpur having very unhealthy air quality (Global Health Observatory Data Repository 2011).

A study conducted by Tel Aviv University researchers also found that air pollution levels in Indian cities have increased rapidly between 2002 and 2010 (Alpert, Shvainshtein, and Kishcha 2012). Calcutta had an average increase of 7.6 percent in air pollution and Bangalore had the highest increase of 34 percent.

According to a recent article in The New York Times (Harris 2014), the average daily peak PM2.5 values in India's capital city Delhi, were closer to 500 with the air quality described as hazardous. The article also highlighted that India was one of the seven countries in South Asia with the worst air quality as a result of which, Indians had the weakest lung capacity in the world. A Moderate Resolution Imaging Spectroradiometer (MODIS) image (Figure 3) captured on NASA Aqua Satellite (Earth Observatory 2013) showed a thick haze over the Indian subcontinent.

The haze was likely due to several reasons, urban pollution being one of the key factors.

The alarming statistics on road traffic death and increase in the burden of disease rates in India clarify the urgent need to assess the health impacts of transportation to better inform decision-makers on the negative health impacts of transportation.

Health Impact Assessment (HIA) methodologies have been used extensively in the developed world (Human Impact Partners 2013). Nevertheless, their use in the transportation sector has been limited. In developing countries, the methodologies and indicators typically used for HIA are sometimes not applicable as they are specific to the context of developed countries (Vohra 2007). For example, the Health and Economic Assessment Tool (HEAT) developed by the WHO is based on detailed pedestrian and cyclist survey data from Copenhagen and only includes assumptions for European countries (World Health Organization 2011b).

Figure 2: Annual Mean PM10 in Indian Cities
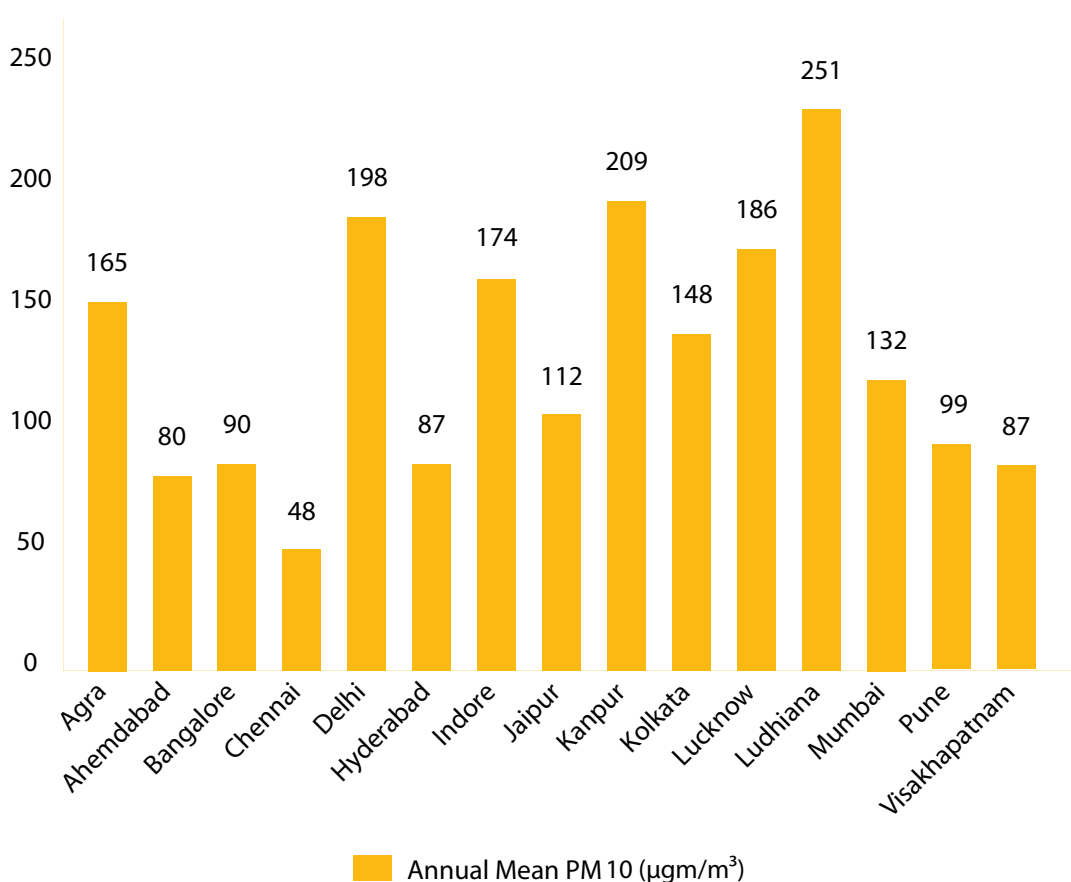
Source: From WHO Database: outdoor air pollution in cities (Global Health Observatory Data Repository 2011)

This makes the tool less relevant for Indian cities where dedicated pedestrian and cyclist infrastructure is either non-existent or significantly lower in quality and quantity than those found in many European cities.

> **HIAs inform decision-makers about potential public health impacts of proposed transportation investments and proposals.**

Through a review of the literature and expert input from transportation planners and public health professionals in India, this Issue Brief details a methodology to assess the key health impacts from transportation projects, plans, or policies within the Indian context. As a pilot application, we apply the HIA methodology described in Section 4 to Indore, India's 11th most populous city.

Indore has been identified as one of the cities with very high vehicular pollution (MOEF 2014). Due to the rapid growth in motorization, the city faces tremendous negative externalities including unsafe traffic patterns, congestion, physical inactivity among the population, air pollution and other issues, not within the scope of this research.

A 2010 study on the urban transportation sector in Indore identified that the major contributors of CO_2 equivalent GHG emissions in the city were motorized two-wheelers (65%) and unorganized public transport vehicles (20%) (ACCRN 2010).

The specific case analyzed is of the Indore Bus Rapid Transit (BRT) corridor (called iBus), a project implemented in 2013. The Issue Brief uses evidence from the HIA literature to estimate the health impacts of the Indore BRT project in terms of total human lives saved.

Ultimately, the research presented here aims to enhance discourse between the public health and urban transport professional communities and identify and minimize the negative impacts of transport projects on health outcomes in a city.

SECTION 2
HEALTH IMPACT
ASSESSMENTS

> **HIAs inform decision-makers about potential public health impacts of proposed transportation investments and proposals.**

HIAs have become a useful tool for integrating health considerations into the decision-making process. It is a systematic process that uses an array of data sources, analytical methods, and stakeholder inputs to determine the potential public health effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects (National Research Council 2011). Characteristics of HIA typically include a broad definition of health; consideration of economic, social, or environmental health determinants; application to a broad set of policy sectors; involvement of affected stakeholders; explicit concerns about social justice; and a commitment to transparency (Quigley et al. 2006). An HIA may investigate how a proposal may impact air quality, water quality, noise level, physical activity rates, injury and death rates, access to healthy foods and other potential health factors. The main reason for conducting an HIA is to inform decision-makers about the potential public health impacts that may result from implementation of proposed projects, programs, or policies and recommend appropriate actions to manage those effects. HIAs also increase stakeholder participation and improves health equity across different socioeconomic groups (Braveman 2014) (Quigley et al. 2006) (Human Impact Partners 2011)

Figure 3: NASA Aqua Satellite Image showing a Thick Haze over India
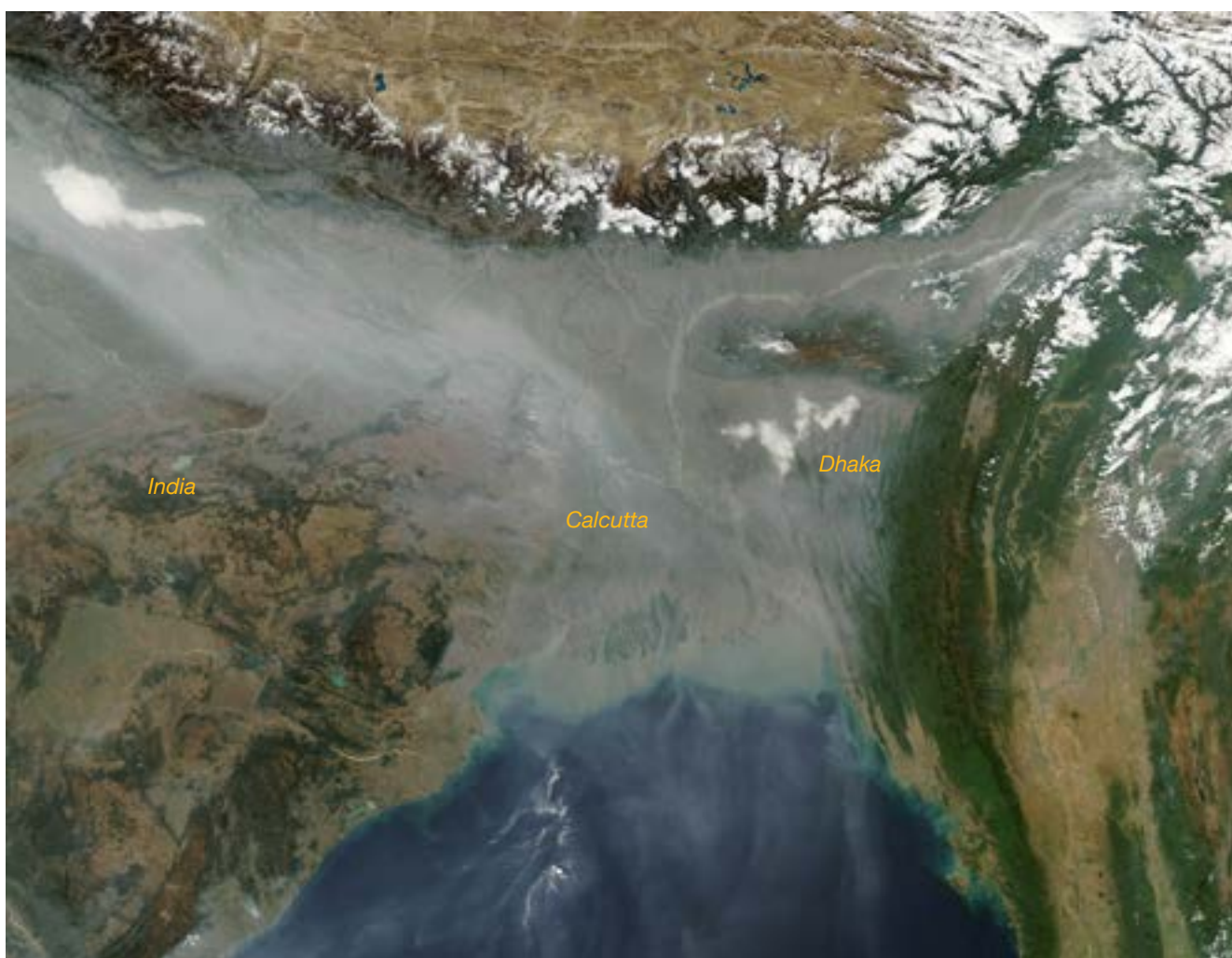
Source: www.earthobservatory.nasa.gov (Earth Observatory 2013)

General HIA Process

HIA has become routine in Europe and is becoming more common in the United States (Dannenberg et al. 2006). Although HIAs differ widely in scope, depth, and level of public engagement, they usually follow the steps mentioned below:

• **Screening** determines the need, value and feasibility of a HIA in the decision-making process.

• **Scoping** identifies which health impacts are to be evaluated, the populations that might be affected, and the research questions that must be examined.

• **Assessment** characterizes the potential health effects of alternative decisions based on available evidence.

• **Recommendations** provide strategies to manage identified adverse health impacts and to maximize health benefits.

• **Reporting** communicates the findings and recommendations to decision-makers, the public, and other stakeholders (Human Impact Partners 2013) (National Research Council Committee on Health Impact Assessment 2011).

• **Monitoring** and Evaluation tracks the implementation of the decision and its impacts on health determinants and outcomes, along with impacts on decision-making processes (Dannenberg et al. 2006).

HIA Typologies Relevant to the Transportation Sector

Transportation HIAs can take place at any level, from site to corridor, city, regional, and national. HIAs could be led by the private, public, or voluntary sector. At the moment, most HIAs are led by the public sector (health or local government). HIAs can either be rapid or comprehensive. Rapid appraisals, also called mini HIAs use existing information and evidence that is already available or easily accessible with limited community participation. Comprehensive HIAs involve the collection of new data and may include a comprehensive literature review, greater participation of local residents through a survey, and/or a primary study of health effects of the same proposal elsewhere (Dannenberg et al. 2006).

Table 2: Health Impact Assessments in Transportation

| Type | Studies Conducted | |
	Key Purpose with Number of	Examples
Transportation Plan or Project such as new trails, public transit stations, roadway expansions, rail lines, and bus service improvements	Road/Highway Corridor: 13 Transportation, Public Transit or Pedestrian or Bicycle Plan: 12 Bicycle or Pedestrian Facilities: 8 Transit Corridor: 6 Transit Station: 2 Reduce Emissions: 3	New Zealand: Pika Pika Expressway (2012) USA: Clark County Washington Pedestrian and Bicycle Plan (2010) USA: Nebraska South 24th Street Road Diet (2012) UK: London to West Midlands Rail (2004) UK: Victoria Station Upgrade (2007)
Transportation Policy or Program	Reduce Vehicle Miles Traveled/Mode Shift: 2 Reduce Congestion: 1 Other: 2	India: New Delhi Transport Policy (2003) Spain: Shift Car Use to Non-Motorized Policies (2012) USA: Policies to Reduce Vehicles Miles Traveled in Oregon (2010)
Comprehensive or specific area plans that consider the future development of transportation facilities	Specific Area Plan: 5 Comprehensive Plan: 2	UK: Clarendon Square Rapid HIA (2009) USA: Atlanta Regional Plan 2040 (2011)

Source: EMBARQ India, based on literature review

International Health Impact Assessments In Transportation

In a developing world context, major development agencies have focused on reducing the impact of communicable diseases and there are few concrete examples of HIA in transportation (Vohra 2007). Two HIAs have been conducted in India. Both were based on current or hypothetical policies and one was strictly descriptive (Woodcock J. 2009, Teewari 2003). On the other hand, Europe and Australasia have been conducting HIAs for the past decade while the practice is also slowly gathering momentum in the United States (Dora 2003), where so far only a few states have conducted HIAs for transportation projects and/or attempted to integrate the HIA into the Environmental Impact Review process for these projects (Caltrans 2011)

HIAs have been conducted in transportation at the national, regional, city, and local scale within a breadth of topic areas including transportation plans, projects, policies and programs (Human Impact Partners 2013). Elements of these have been taken to adapt a methodology for similar work in India. Table 2 lists the type and range of potential transportation projects, policies and plans for which HIAs have been conducted around the world.

Gaps And Challenges With Health Impact Assessments Relevant To India

There are a number of limitations to the HIA process that are especially pertinent to a relatively lower income country such as India. These include the lack of experience in HIA and the need for tools, documentation, training, and resources.

A recent review of completed HIAs concluded that very few HIA's are conducted in developing country settings such as India (Winkler et al. 2010). This is due to weak or non-existent policies and procedures for institutionalizing HIA, shortage of human and institutional capacity to conduct HIAs, non-availability of baseline data, and a lack of standardized methodology, multi-sector collaboration, and political will (Erlanger 2008). HIAs undertaken in resource-poor settings are also challenged by limited baseline population health and transportation trends data, and lack of historical community engagement. This can result in HIAs that are rushed, with limited scope for collecting new data upon which to base an assessment (Winkler M.S. 2010). Subjectivity enters the process and over-simplifying assumptions might be made to compensate for this lack of data, which can affect the validity of the outcome (Lock 2000). Finally, the resource intensive process of meaningful community engagement would be more difficult in resource-strapped India (Parry 2003). Despite the difficulties identified in this section, it is important that we develop an appropriate HIA methodology for transportation projects in the Indian context due to the rapid increase in road traffic deaths and disease rates in India. The following section describes how to overcome these challenges.

Literature Review On Health Impacts Of Transportation

The following sections provide a summary of available literature on the health impacts of transportation investment or policy proposals, including peer-reviewed and grey literature across the urban and transportation planning, engineering, policy, and public health disciplines.

Most HIA literature is non-standard and grey literature. This includes studies by government agencies and by private and non-government organizations with unknown review status, and various online reports created primarily in response to the emerging practice. Relevant research examining the possible health impacts of transportation, HIAs of transportation projects and policies, and HIAs in the developing world context were identified by searching Google Scholar, Social Sciences Index, PUBMED, and Google databases for primary and secondary research material. These databases were chosen for the breadth of fields they covered, including health, land planning, civil engineering, and transportation research. The methodological framework provided in Section 4 was also formulated based on previous research conducted in India and with professional input.

SECTION 3
HEALTH IMPACTS OF TRANSPORTATION

Transportation plays a key role in facilitating the movement of people and goods and provides easy access to key community and social destinations. It is one of the 10 key determinants of health (World Health Organization 2010) and can have positive outcomes when mobility helps in areas like physical activity, or negative outcomes, when mobility generates pollutants that cause respiratory disease or results in traffic-related injuries and deaths. The frequency and destination of travel and travel modes have major repercussions on individual health (Dora 1999).

This section presents evidence regarding the possible health impacts of transportation and transportation related issues such as air pollution, traffic injuries and fatalities, physical activity and noise pollution.

Air Pollution Exposure From Transportation

Outdoor air pollution, which caused an estimated 620,000 deaths in India in 2010 (Lim 2013) is a serious environmental risk to health. Outdoor air pollution has become the fifth leading cause of disease in India. It caused 6.2 lakh deaths in 2010, a six-fold increase from 2000 (Hindustan Times 2013). Air pollution is also the seventh leading cause of loss of healthy years of life due to illness with 18 million healthy years lost (Health Effects Institute 2013) (Lim 2013). A recent study that compared air pollution by ranked India only behind China, Pakistan, Nepal and Bangladesh (Emerson 2012).

Negative Health Impacts Of Air Pollutants From Transportation

Transportation-related air pollutants are one of the largest contributors to unhealthy air quality (Pucher et al. 2005). The ones that most affect health include small particulate matter (PM10 and PM2.5) in addition to carbon monoxide

Transportation related air pollutants are one of the largest contributors to unhealthy outdoor air quality.

(CO), oxides of nitrogen (NOx), ground-level ozone and benzene (Krzyanowski 2005). Most Indian cities exceed national guidelines for particulate matter (PM10) and are three times above the levels recommended by the World Health Organization (World Health Organization 2012). Concentrations of other pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter 2.5 (PM2.5) are also above the recommended limits (EMBARQ India 2010). Small particulate matter (PM2.5) is of particular concern because the small size allows these particles to penetrate deep into the respiratory system, bypassing usual defenses against dust (Hosking 2011).

For instance, vehicles contributed 41 percent of particulate matter emissions and 67 percent of all NOx emissions released in Bangalore, in the southern state of Karnataka in India (Centre for Science and Environment 2013). This can be attributed to the large and mostly old fleet of motorized two-wheelers (motorcycles and scooters) and three-wheelers (auto rickshaws) with highly inefficient, poorly maintained, very polluting two-stroke engines (Pucher et al.

2005). Two-stroke engines emit particularly high levels of CO, NOx and PM10 (Hosking 2011).

In Bangalore, vehicles contributed to 41% of particulate matter emissions.

Exposure to traffic emissions has been linked to many adverse health effects including: pre-mature mortality, cardiac symptoms, exacerbation of asthma symptoms, diminished lung function, increased hospitalization and others (EPA-US 2013, EPA-US). Particulate matter is one of the leading causes of acute lower respiratory infections and cancer. The World Health Organization found that acute respiratory infections were one of the most common causes of deaths in children under 5 in India, and contributed to 13 percent of in-patient deaths in pediatric wards in India (Bhat and Manjunath 2013). A recent study by Patankar et al (2011) investigated the link between air pollution and health. It found the total monetary burden of exposure, including personal burden, government expenditure and societal cost to be an estimated 4522.96 million Indian Rupees (INR) or US$ 113.08 million for a 50-µg/m³ increase in PM10 (Patankar and Trivedi. 2011).

Positive Health Impacts Of Reduced Emissions From Transportation

Successful policies and programs to reduce urban traffic levels and speeds, and to improve vehicle technologies and fuels, have shown to lower ambient pollution levels and improve health.

In the European Economic Area (EEA), the switch to catalytic converters and other technological improvements in vehicles led to substantial reductions in pollutant emissions, with PM emissions decreasing by 30 percent from 1990 to 2007 (European Environment Agency 2010). Implementation of the Metrobus in Mexico City was estimated to reduce an average of 144 tons of total hydrocarbons, 690 tons of oxides of nitrogen, 2.8 tons of fine particulate matter, and 1.3 tons of sulfur dioxide annually. This roughly translated to an average of $3 million (U.S. dollars) in health benefits each year (Instituto Nacional de Ecología 2006).

Drastic reductions in traffic at both the 1996 Olympics at Atlanta and the 2008 Olympics in China also led to improved air quality. Beijing imposed stringent restrictions on motor vehicle use that resulted in a 50 percent reduction in asthma outpatient visits, a 31 percent reduction in PM2.5, and a 35 percent reduction in PM10 concentrations (Li et al. 2010) (Wang, Primbs, et al. 2009). Atlanta saw similar results when motorized travel was reduced during the 1996 Olympics. When peak morning traffic decreased by 23 percent and peak ozone levels decreased by 28 percent, emergency visits for asthma incidents in children decreased by 42 percent (Friedman et al. 2001). Without similar measures to reduce emissions, the projected increase in motorization in India will only exacerbate the burden of disease from air pollution (Pucher et al. 2005).

Traffic And Transport-Related Injury And Fatalities

Traffic crashes in Indian cities are among the primary causes of accidental deaths and hospitalizations (10 - 30%) in the country (Gururaj 2008) (Singh 2005) (Pucher et al. 2005). According to the National Crime Records Bureau (NCRB), road accidents account for 37.4 percent of the total accidental deaths in India. In 2012, about 1.6 millionIndians died and 4.6 million were seriously injured (National Crime Records Bureau 2014).

Even controlling for population growth in India, the traffic fatality rate per million inhabitants has tripled over the past three decades, so that the average Indian is now over three times as likely to be killed in a traffic accident when compared to thirty years ago (Mohan et al. 2009). A 2008 study on road traffic deaths and injuries estimated an economic loss of 3 percent of India's gross domestic product (GDP) and more than 3.5 million hospitalizations by 2015 (Gururaj 2008).

In the city of Bangalore alone, more than 10,000 are hospitalized annually due to injuries caused by traffic accidents (Leather et al. 2011).

Mode Share Of Traffic Injuries And Fatalities In Indian Cities

Compared to other developing countries, two-wheeler riders, pedestrians and bicyclists constitute the largest proportion of road crash victims in India (Singh 2005) (Gururaj 2008). Two-wheelers accounted for 23.2 percent and pedestrians and cyclists accounted for 10.5 percent of annual road traffic injuries (National Crime Records Bureau 2014). The lower pedestrian and cyclist death rates may be explained by the fact that crashes involving pedestrians or cyclists in official road traffic injury statistics, are usually underreported by the enforcing agency (Elvik and Myse 1999). Data from the WHO shows that traffic fatalities in India are significantly under-reported by about 78 percent nationwide (World Health Organization 2013).

Pedestrians, cyclists, two- and three-wheeler users, also known as 'vulnerable road users ' are at a higher risk due to the absence of a protective shell around them when compared to other vehicles (World Health Organization 2009b). Those traveling by auto-rickshaws represent 6 percent of fatalities and the risk of injury for transit and public transport users is generally lower (World Health Organization 2009b), (Litman 2011).

Two-wheelers account for 71% of all registered vehicles in India.

A study by Bhattacharya et.al (2007) highlighted the economic burden due to traffic fatalities and estimated the cost of a fatality to be 1.3 million rupees. The study also found that vulnerable road users were willing to pay up to 0.5 million rupees to reduce their risk of dying in roadtraffic accidents (Bhattacharya, Alberini, and Cropper 2007).

Causes Of Traffic Injuries And Fatalities In Indian Cities

Increasing motorization in countries has long been known to have a correlation with rising road fatalities (Duduta, Adriazola-Steil, and Hidalgo 2014) (Scurfield et al. 2004). Between 1971 and 2001, India has had a 20-fold increase in the combined number of vehicles (including cars, taxis, trucks and motorcycles) (Pucher et al. 2005). The rapid increase in vehicles combined with the inadequate provision of transport facilities to separate the motor vehicle traffic from slow moving cycle rickshaws, bicycles, and pedestrians can be attributed to the rise in traffic crashes in India. Mixing a wide diversity of roadway

> *From 1971 to 2001, India has had a 20-fold increase in the combined number of vehicles.*

users usually causes a range of safety problems, since the modes have very different sizes, maneuverability, capacities, speeds, and other operating characteristics. Most roads in Indian cities are narrow and there is a general lack and/or compliance of modern traffic signals and signage and inadequate enforcement by the police (Pucher et al. 2005). The urban poor, who are more likely to travel either on foot or by non-motorized transport modes than the more affluent, are especially vulnerable (Singh 2005). Children and the elderly are also more likely to be victims of traffic collisions (J, Mudu, and Dora 2011).

Physical Activity And Transportation

Lack of physical activity is responsible for over three million deaths per year globally (Lee et al. 2012). It is a leading risk factor for a number of diseases, many of them chronic, including obesity, type 2 diabetes, heart disease, and cancer (World Health Organization 2009a).

> *In Bangalore over 20% of trips shorter than 2 km (1.3 miles) are made by motorcycles or other two-wheelers.*

It can also affect mental health and well-being (Douglas et al. 2007). Traditionally an issue in developed countries, these diseases are increasingly occurring in low- and middle-income countries as well (World Health Organization 2004). Multiple studies have found that obesity and a lack of physical activity is on the rise in India, especially for those living in urban areas, probably due to higher car usage (Wang, Chen, et al. 2009), (Yadav and Krishnan 2008), (Ebrahim 2010) (Bauman et al. 2009). South Asia now has the world's highest population with diabetes (Shaw, Sicree, and Zimmett Baker 2010).

Increasing Physical Activity through Active Transportation

One of the most effective methods of encouraging physical activity is through transport and urban planning policies that encourage walking and bicycling (Heath et al. 2006). While the walking mode share is still high, it is declining across Asian cities including India (Leather et al. 2011). As the average trip is only between 1 to 7 kilometers (i.e., between 0.6 and 4.3 miles), most Indian cities can be easily accessed by walking and cycling. Unfortunately many pedestrians have shifted to motorized transport due to degradation of pedestrian infrastructure.

In Bangalore, for example, over 20 percent of trips shorter than 2 km (1.3 miles) are made by motorcycle and nearly 26 percent of total trips are shorter than 5 km (3.1 miles) (Leather et al. 2011).

Positive Health Impacts Of Increased Physical Activity From Transportation

A number of comprehensive assessments have shown that the health benefits of physical activity achieved while walking or bicycling greatly outweigh the risks due to poor air quality and road traffic casualties (Rojas-Rueda et al. 2011) (Roberts-Hughes 2013) (de Nazelle et al. 2011). Life years gained among individuals who shift from car to bicycle is estimated to be three to 14 months compared to 0.8 to 40 days lost through increased inhaled air pollution, and five to nine days lost due to an increase in traffic accidents (De Hartog 2010).

Using public transit promotes physical activity, as it involves walking to and from transit stops (Besser and Dannenberg. 2005). More recently, researchers comparing the risks and benefits of bicycling concluded that the greatest health benefit of bicycling is the physical activity (Rojas-Rueda et al. 2011) (Rabl and Nazelle 2012).

In the developing city of Shanghai, a study of women commuters showed that cycle commuters have approximately a 20–30 percent lower chance of dying in a year than commuters using other means of transport – even after injury risks and other risk factors were considered (Matthews et al. 2007). Mode shift to walking and cycling reduces emissions and improves health through physical activity. In developing cities with heavy mixed traffic volumes, mitigating air pollution and traffic injury are important to minimize the risks, and maximize the benefits, of active travel (Andersen et al. 2000) (Hosking 2011).

Noise Pollution from Transportation

Rapid urbanization along with road network and infrastructure expansions contribute to the increase in noise pollution (Douglas et al. 2007). In India, the increase in the volume of vehicles and traffic on the road and activities related to urbanization and industrialization have been identified as the key sources of noise pollution (Singh and Kaur 2014) (Marathe 2012). While not as serious as air pollution, regular exposure to sound levels of 55-65 decibels can affect human beings in both psychological and physiological ways such as sleep interferences, speech problems, raised blood pleasure, fatigue, auditory damages (Stansfeld and Matheson 2003) and in some instances, cardiovascular disease (Selander et al. 2014) (TOI 2013).

Indian cities such as Delhi and Mumbai are among the noisiest cities in the world (Singh and Davar 2004) (Hindustan Times 2014, Singh and Davar 2004) with alarmingly high noise levels during festivals, private

> *Indian cities such as Delhi and Mumbai are among the noisiest cities in the world.*

functions, religious events etc. (Singh and Shinde 2013) (Awaaz 2013).

A study done by CE Delft in 2007 estimates the social cost of road traffic noise in European cities to be € 40 billion per year and that people are willing to pay more to avoid traffic noise (Boer and Schroten 2007).

The WHO night noise guidelines for European Cities (World Health Organization 2014) and Guidelines for Community Noise (World Health Organization 1999) provides guidelines and recommendations to prevent the adverse impacts of

noise pollution. Similarly, the US EPA (EPA-US 2012) along with several states in the US also publish (WSDOT 2014) permissible noise levels and enforce them.

In India, permissible noise emission levels and rules are published as part of the Environment Protection (EP) Act in 1999 (Awaaz 2013) but due to lack of enforcement, noise levels continue to exacerbate. Given the increasing growth in vehicle ownership rates and traffic, noise levels are projected to worsen in Indian cities (Pucher et al. 2005).

The methodological framework provided in Section 4 does not consider health impacts due to noise, but can be expanded in future research to include noise pollution induced health impacts like stress and sleep disturbances.

SECTION 4
DEVELOPING A HIA METHODOLOGY FOR THE TRANSPORTATION SECTOR IN INDIA

The methodology outlined in this section aims to define a framework to measure the health impacts of investment in sustainable transportation projects in the urban Indian context. Due to the range of potential transportation projects, policies, and plans as outlined in Table 2, this report will focus on projects which would induce a modal shift at the city level towards the more sustainable mode in question. Some examples could be an increase in quantity or quality of city bus services or other public transit options, implementation of a city-wide bicycle rental program, or a city-wide education and encouragement campaign on walking.

The process begins with ascertaining baseline indicators and projecting how a project will affect health outcomes based on alternative scenarios. The conceptual framework in Figure 4 demonstrates this relationship.
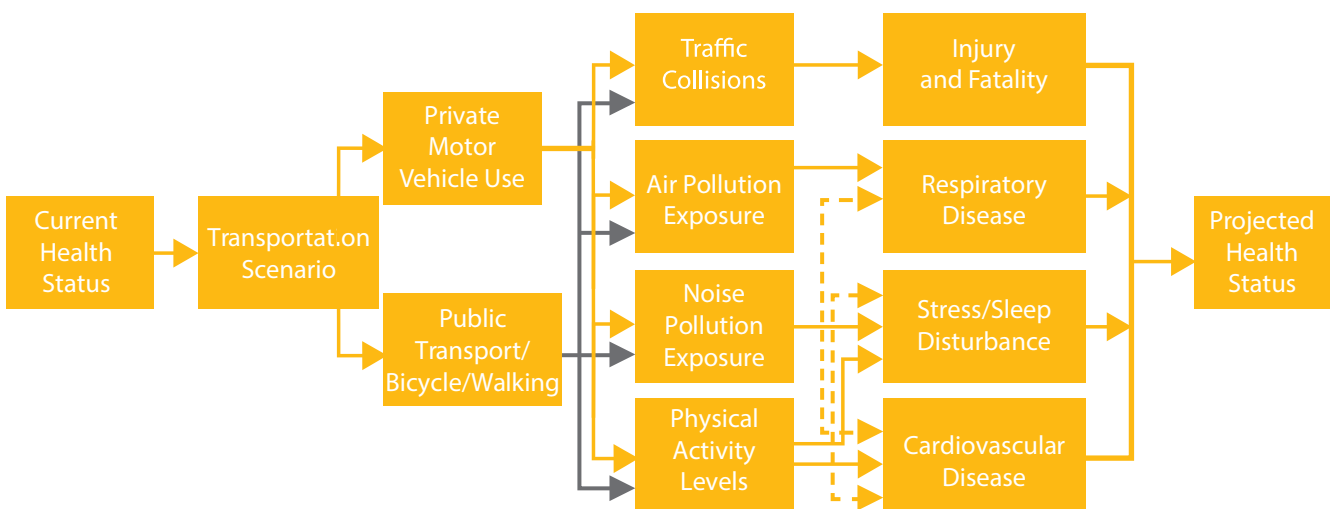
Identifying Baseline Data Needs

While considering the health impacts of alternative transportation scenarios, it is important to understand the characteristics of the urban population, their current health status, and the existing conditions of the transportation system that will be affected.

HIAs typically use a range of structured and evaluated sources of qualitative and quantitative evidence that includes public and stakeholder perceptions and experiences as well as public health, epidemiological, toxicological and medical knowledge (Vohra 2007). Table 3 outlines the data needed to establish a baseline and lists potential data sources for conducting transportation HIAs in India, taking the example of the city of Indore in the state of Madhya Pradesh in India.

Where cause and effect are well established, a proxy measure can be used instead of the eventual health outcomes; for example, monitoring air pollution rather than emissions for mortality from cardiorespiratory diseases. The health impacts can then be modeled by considering future scenarios. While more research is needed to improve quantitative forecasting, decision-makers must recognize that not all health impacts can be precisely measured. When data is missing, a literature review or qualitative

Figure 4: Basic Conceptual Framework of Health Impact Assessment of Transportation

Source: EMBARQ India, based on literature review, (Han et al. 2007) (Bellocchia et al. 2013)

Table 3: Baseline Data Needs for a Transportation HIA in India

Data Needs	Potential Data Sources
• Population Demographics • Current population and growth rate • Age • Ethnicity • Sex • Income and Employment • Education	• Census of India • Survey Data • Literature Review
• Community Health • Life Expectancy • Asthma • Diabetes • Coronary Heart Disease • Obesity • Traffic Injury Data and Fatalities by Vehicle Type • Physical Activity Levels • Mental health/stress/road rage incidence	• Health Services or Department at Indore Muncipal Corporation, Indore, Madhya Pradesh. • National Institute of Mental Health and Neurosciences (NIMHANS) based in Bangalore • National Crime Records Bureau of India • Survey Data • Literature Review
• Transportation Behaviour, Infrastructure, and other Environmental Factors • Urban Area and Mode share • Trip Length and Vehicle Occupancy • Air quality	• Comprehensive Mobility Plan • Travel demand modeling for specific projects/policies (potential sources: Indore Municipal Corporation, Indore Development Authority, Atal Indore City Transport Services Limited) • Direct Measurement of Air Quality • Literature Review

research can reveal the direction, but not necessarily the magnitude, of an effect on a health indicator (Dannenberg, 2008). Figure 5 provides a more detailed framework for modeling the health impacts of a transportation project or policy.

Quantifying The Health Impact Of Air Pollution

Frameworks for quantifying the health impacts of transport related to air pollution require a series of steps and involve additional analysis beyond transport model outputs (Watkiss et al. 2000). The Activity Structure Intensity Fuel (ASIF) framework developed by Schipper et al (Schipper, Marie-Lilliu, and Gorham 2000) has been applied in a previous Indian study of the impacts of a transportation policy on emissions (Prabhu and Pai 2012).
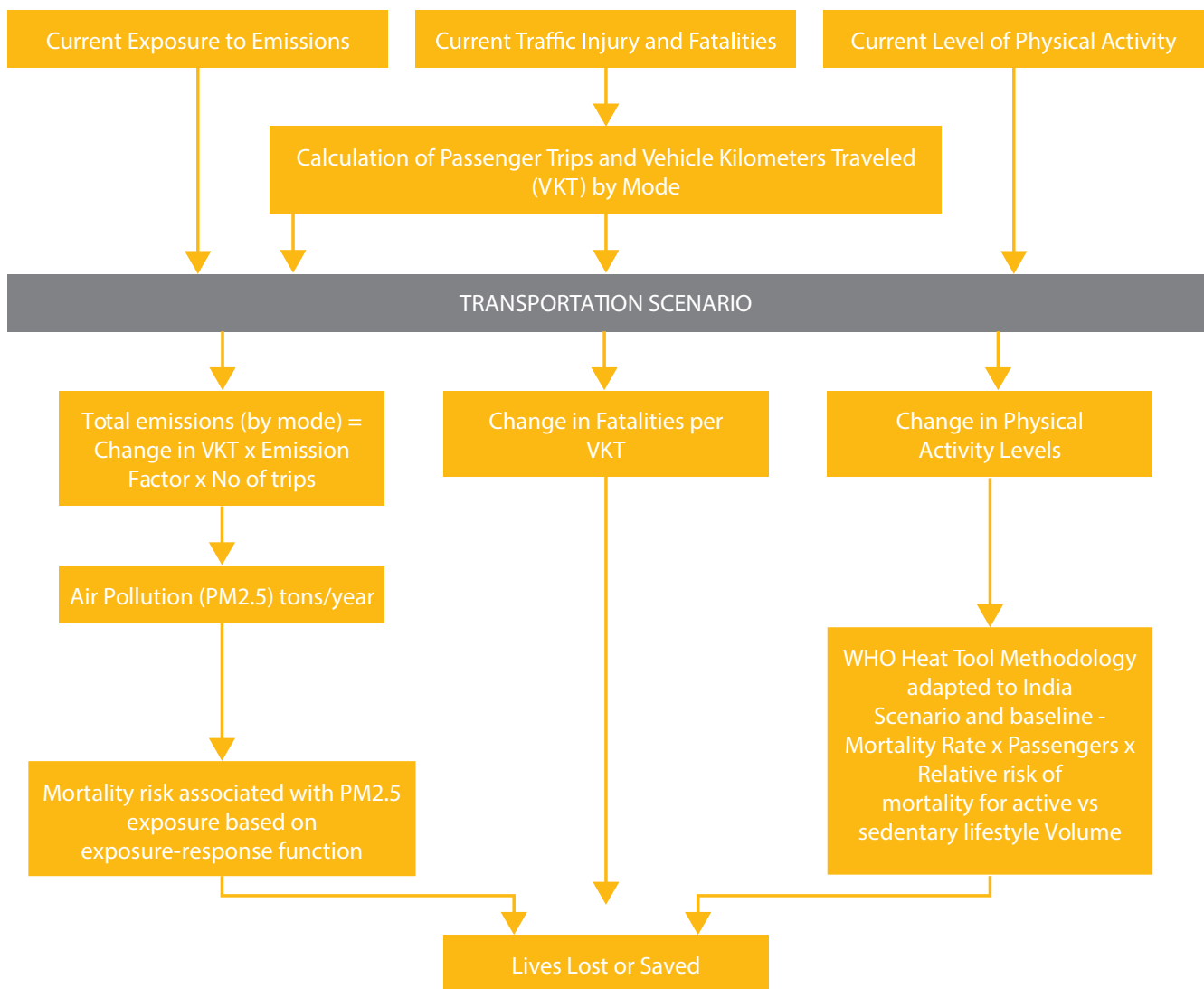
This framework could be used to assess total transport emissions from mode share and transport activity as seen in Figure 6 (Schipper, Marie-Lilliu, and Gorham 2000).

While there are many different pollutants related to emissions from transport, Particulate Matter 2.5 (PM2.5) is considered the most dangerous (Hosking 2011). This methodology therefore concentrates on the risks of increased mortality resulting from PM2.5 concentrations. The pollution data is then combined with population data to estimate the increase in population weighted air pollution. The final step is to quantify health impacts with the use of exposure-response functions from epidemiological studies, which link ambient air quality to health endpoints per the following equation (Watkiss et al. 2000):

> *Mortality Risk = (Total Transport Emissions*Exposure-Response Function)*

n the absence of an exposure-response function from India, this study recommends using the WHO guidelines specifying the mortality risk from PM2.5 concentrations above its recommended guideline values (World Health

Figure 5: Detailed Methodology for Estimating Health Impacts of Different Transportation Scenarios

Current Exposure to Emissions	Current Traffic Injury and Fatalities	Current Level of Physical Activity

Calculation of Passenger Trips and Vehicle Kilometers Traveled (VKT) by Mode

TRANSPORTATION SCENARIO

Total emissions (by mode) = Change in VKT x Emission Factor x No of trips	Change in Fatalities per VKT	Change in Physical Activity Levels

Air Pollution (PM2.5) tons/year

WHO Heat Tool Methodology adapted to India Scenario and baseline - Mortality Rate x Passengers x Relative risk of mortality for active vs sedentary lifestyle Volume

Mortality risk associated with PM2.5 exposure based on exposure-response function

Lives Lost or Saved

Organization 2006) or a recent meta-analysis from China which has a similar transportation system and faces similar transportation data challenges as India (Aunan and Pan 2004).

The main limitations with this method are that historical data for travel information is often limited in Indian cities (Prabhu and Pai 2012). It would be more accurate to directly measure transport emissions. Some of the larger cities in India, like Bangalore or Mumbai might have greater technical capacity and may have the resources and technology required for this, but it may be beyond the capacity of a smaller Indian city.

Quantifying The Health Impact Of Traffic Injuries And Fatalities

There are some well-established quantification methodologies for predicting transport accidents and casualties. Studies done to establish linkages between increases in vehicle kilometers travelled (VKT) and road accidents and fatalities have shown that per capita fatality rates tend to increase with per capita annual vehicle distance (Litman 2012). However, some researchers have also found that fatality rates may decrease with increasing VKT (Bhalla 2007). Other aspects such as infrastructure improvements, better policy, driver awareness,

and enforcement also tend to decrease fatality rates but it is at a slower pace (Hidalgo and Duduta 2014). In the case study discussed later in this Issue Brief, we quantify the traffic safety impact based on reduction in VKT alone and do not quantify additional risk reduction possible from infrastructure improvements.
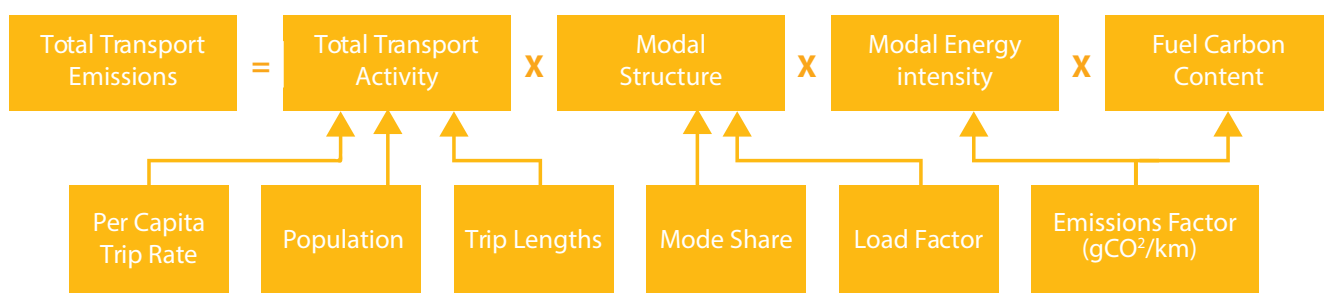
Higher congestion, which is correlated with higher VKT, may reduce speeds to an extent that accidents are less severe and do not lead to fatalities. People may also adjust their driving behavior with increasing traffic and may alter speeds or take more care, which may lower fatality rates. Historical accident data can be used as a means of predicting future accident rates from new schemes or policies, but the particular trends seen in the historical and local data in Indian cities being studied must be taken into account. Local data can be obtained from the local traffic police or the Incidence of Road Accidental Deaths by Vehicle Type in the report on Accidental Deaths and Suicides in India by the National Crime Records Bureau (National Crime Records Bureau 2014) . Records should ideally cover at least the last three years prior to the assessment so that a reliable trend can be established. The change in the risk factor over time can then be used to project the risk factor in future years. If there are drastic changes in risk factors over consecutive years for which reasons are not apparent (as in the case of the Indore case study we discuss later), the average of known recent fatality rates may be used. The local accident rate is predicted by fatalities per million vehicle kilometer from population projections as in the following equation (Watkiss et al. 2000):

The methods described provide a simplified approach to the assessment of transport accidents. In practice, however many issues remain ambiguous.

The relationships between motorized traffic volume, traffic speeds, accident rates and accident severity are complex and evidence is uncertain. Non-motorized transport users present different challenges. While pedestrians and cyclists face higher levels of fatality and serious injury from collisions than other road users, providing pedestrian and cyclist friendly infrastructure provisions actually improves safety (Duduta, Adriazola-Steil, and Hidalgo 2014). Our literature review also shows that fatality rates decrease with increase in the numbers of cyclists and pedestrians, an effect known as "safety in numbers" (Jacobsen 2003). In addition, people usually walk or cycle to access public transportation (Besser and Dannenberg. 2005). These additional components of the transport trip have to be taken into account, especially in light of the different accident rates and severity classes associated with walking and cycling (Watkiss et al. 2000).

> **Predicted Fatalities = [Average Fatality Rate (deaths/VKT) of past X years] or [Projected fatalities/VKT based on historic data] x Projected VKT**

Figure 6: The ASIF Equation for Measuring Total Transport Emissions

Quantifying The Health Impacts Of Physical Activity

In order to quantify physical activity, information is needed on the existing activity patterns of the relevant population which can be obtained via population surveys (Watkiss et al. 2000). In the absence of other alternatives, the WHO HEAT tool has been used by practitioners and researchers to determine the health impacts and reduced mortality rates from physical activity. This tool is based on relative risk data from published studies that controlled for leisure-time physical activity as well as the usual socioeconomic variables (age, sex, smoking, etc.) (World Health Organization 2011b). As per the HEAT tool, the relative risk of all-cause mortality among regular bicycle users is 0.72 compared to non-users, and 0.78 for regular walkers. The cumulative health benefits and lives saved are then estimated based on the population that stands to benefit, and the current mortality rate via the following equation (World Health Organization 2011b):

> *Reduction in Mortality Rate = 1-Relative Risk (volume of walking or cycling/ reference volume of walking or cycling)*

Quantifying physical activity is perhaps the greatest challenge within the Indian context. Unlike other more developed countries, India does not assess population physical activity on a regular basis and jobs requiring physical labor may be misperceived as benefits due to active transportation.

Acquiring baseline data requires primary data collection, which can be expensive and time-consuming. Therefore, despite the fact that the WHO HEAT tool (World Health Organization 2011b) is based on factors obtained from the European context that are not necessarily applicable in India, it provides a good approximation. The relative risk factors in the tool are derived from very different cycling and walking environments in Europe. The tool is also designed for adult populations aged 20-64 and cannot capture health benefits of physical activity for children or the elderly (World Health Organization 2011b). Additionally, the tool does not capture the effects of physical activity on morbidity. Further research is needed to assess the reduced mortality and morbidity risk from increased physical activity in the Indian context. Currently, since the WHO HEAT tool is the most widely used means to determine the health benefits of change in physical activity, we use the relative risk assumptions from the tool in the analysis that follows.

SECTION 5
APPLYING THE EVIDENCE TO A LOCAL PROJECT: INDORE, MADHYA PRADESH, INDIA

This section estimates the health benefits from a Bus Rapid Transit System (BRTS) for residents of a corridor within the city of Indore, Madhya Pradesh, India using the HIA methodology developed in Section 4.

This case study covers three aspects related to health and transport – emissions from air pollution, impact of increased physical activity, and reduction in traffic fatalities.

Background On Indore

Indore is the largest city in the state of Madhya Pradesh and the 11th most populous city in India (India 2011). It is a major economic center in Central and Western India, and serves as an education, medical, industrial and trade hub. Population growth, rising incomes, economic growth and migration have all led to increased vehicle numbers and traffic within the city (SUTP 2014). Indore is a city with very high vehicular pollution (MOEF 2014), and the major contributors to emissions have been found to be motorized two-wheelers and unorganized public transport (ACCRN 2010).
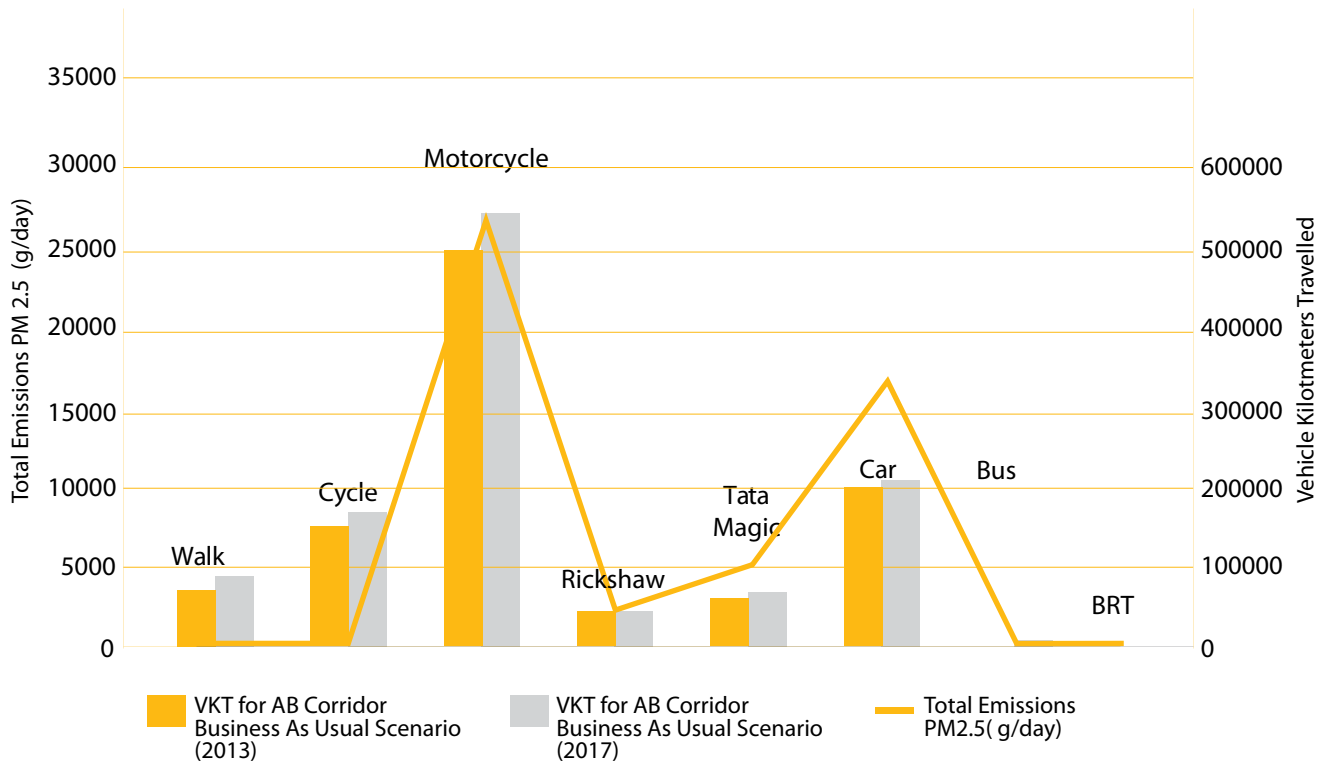
BRTS In Indore

To combat some of these issues, Indore recently implemented a Bus Rapid Transit System (BRTS) that began operations in May 2013. According to Hidalgo and Carrigan (2010), "Bus rapid transit (BRT), is a rubber-tired mode of public transport that enables efficient travel and flexibly combines stations, vehicles, services, running ways, and intelligent transportation system (ITS) elements into an integrated system with a strong brand that evokes a unique identity" (Hidalgo and Carrigan 2010).

A Bus Rapid Transit System has been successfully implemented in the city of Ahmedabad in India, and many other smaller cities are planning to introduce similar systems. It is seen as a viable solution to the growing demand for public transport in India. The BRTS is also known to have significant public health benefits, as seen in Colombia and Mexico (Carrigan et al. 2013). In Mexico City, the PM2.5 exposure levels of passengers commuting by BRT reduced by 25 – 35 percent compared to those travelling by non-BRT buses (Zuk 2007).

Figure 7: : VKT by Mode and PM2.5 Emissions in a BAU Scenario, Current (2013) and Projected (2017)

Source: EMBARQ India Analysis, based on data provided by TARU survey for Public Health and Road Safety Study for BRTS Indore, 2010

In Indore, the first phase of the BRTS was implemented along Agra Bombay Road or AB Road (MPPCB 2010) which cuts across the city. The length of the road is around 12 kilometers with 19 bus stops along the corridor (TARU 2012). Traffic is generally slow at peak hours due to bottle-necks, junctions and on-going construction activity at various sections along the road. It has been identified as one of the most polluted areas in Indore with the highest amount of Suspended Particulate Matter (SPM) (TARU 2012).

In 2012, the research organization TARU and EMBARQ India conducted a study on public health and road safety in Indore (TARU 2012). This study measured the public safety and health impacts of the BRT corridor through a combination of primary and secondary data collected through air quality observations, surveys measuring travel behavior and physical activity levels, traffic volume counts, and historical road accident and mortality data for the City of Indore. According to this 2012 survey of 2214 residents who live within 1 kilometer on either side of the AB Road corridor, 137 people (6.19 %) mentioned being diagnosed with hypertension, 92 people (1.85 %) with diabetes, and 41 people (4.16 %) with asthma (TARU 2012). Air quality exposure and the baseline 24-hour mean PM2.5

concentrations along AB corridor were measured using DustTrak monitors (TARU 2012). Figure 7 provides the current (2013) and projected (business as usual scenario projected out to 2017) vehicle kilometers travelled (VKT) by transport mode and the associated PM2.5 concentrations in Indore.

> *Exposure to air pollutants while commuting could be effectively reduced by introducing a BRTS.*

Methods

In 2014, the bus operating agency in Indore plans to triple the number of buses on the BRTS corridor from the current 15 buses to 45, while discontinuing the use of the TATA Magic minivans and the regular city buses in the corridor. Based on the latest BRTS ridership data available, this information was used to estimate the mode shift likely to occur when these changes are implemented. The results were then projected to 2017, using a conservative population growth rate of 2 percent per annum since the BRTS corridor passes through a mature area of Indore

Figure 8: Indore Mode Share in 2017 with and without BRT
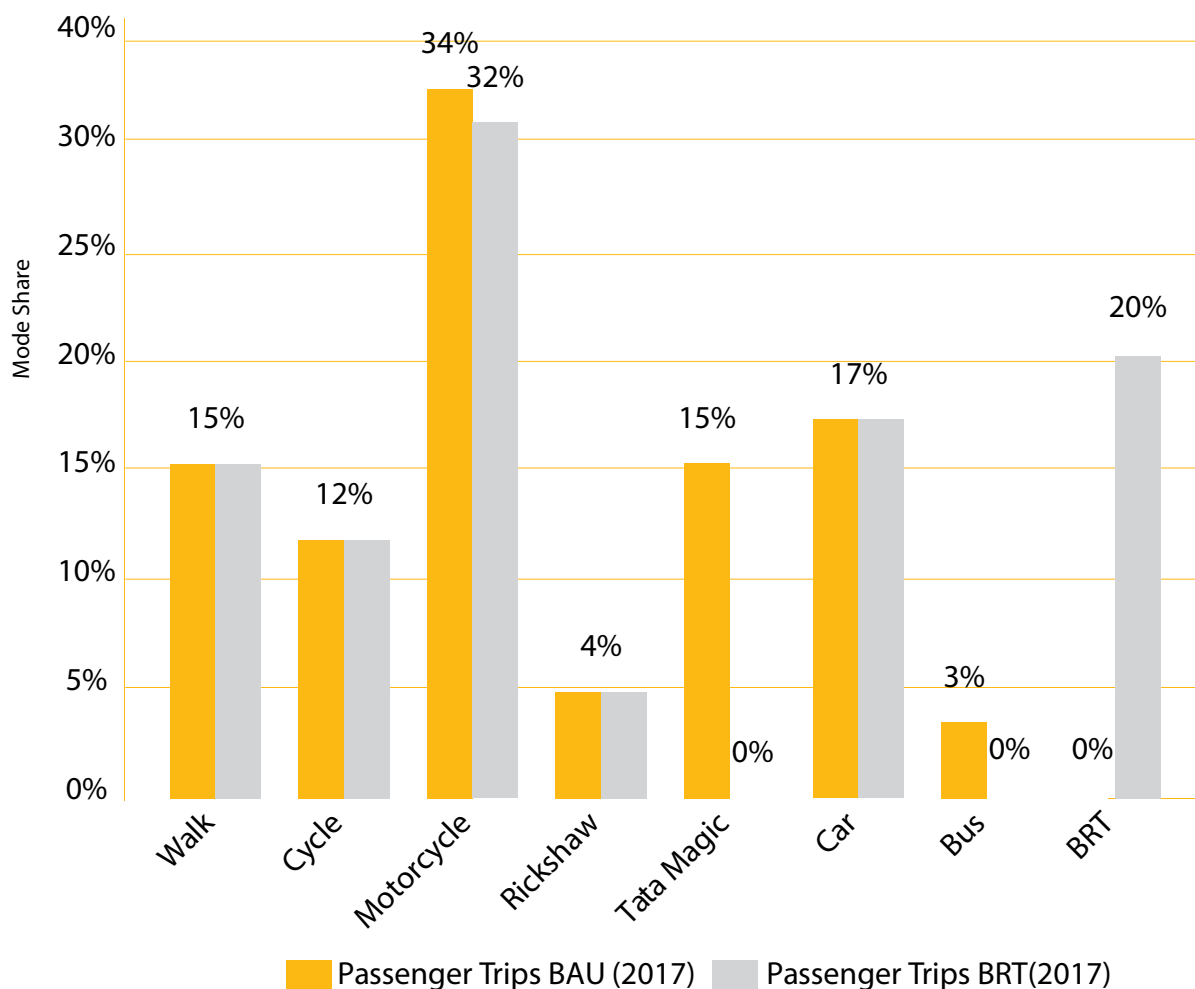
Source: EMBARQ India Analysis, based on data provided by TARU survey for Public Health and Road Safety Study for BRTS Indore, 2010
* Tata Magic is a passenger microvan

city (the historical population growth rate from the India Census 2011 is 3.2 percent per annum). This growth rate was applied to both future scenarios (BAU and BRT) as the Indore Comprehensive Mobility Plan is yet to be published.

The difference in Vehicle Kilometers Travelled (VKT) of this BRTS scenario five years into the future was compared to a Business-as-Usual (BAU) scenario in which mode shares were assumed to remain constant. Although future year mode shares for private motorized modes in Indore in the BAU scenario may likely have been higher, this assumption allows a conservative analysis.

Health impacts from this difference in motorized VKT included lives saved from increased physical activity, reduced traffic fatalities, and reduced mortality risk from decreased exposure to PM2.5 air pollution. Based on the analysis, Figure 8 shows the transport mode shares in

Indore in a BAU scenario and after BRT implementation in the year 2017.

(Note: Refer to the Appendix: Mode Shift Analysis for detailed analyses.)

Estimating The Health Impacts Of Air Pollution

Exposure to air pollutants during commuting could be effectively reduced by introducing BRT systems, mainly by reducing the penetration of emissions from surrounding traffic (Wohrnschimmel et al. 2008).

This case study concentrates on the risks of increased mortality resulting from PM2.5 concentrations as they are considered most dangerous and connected to a broad

Figure 9: VKT by Mode and PM2.5 Emissions after BRT Implementation for 2017 - Compared with BAU Scenario for 2017
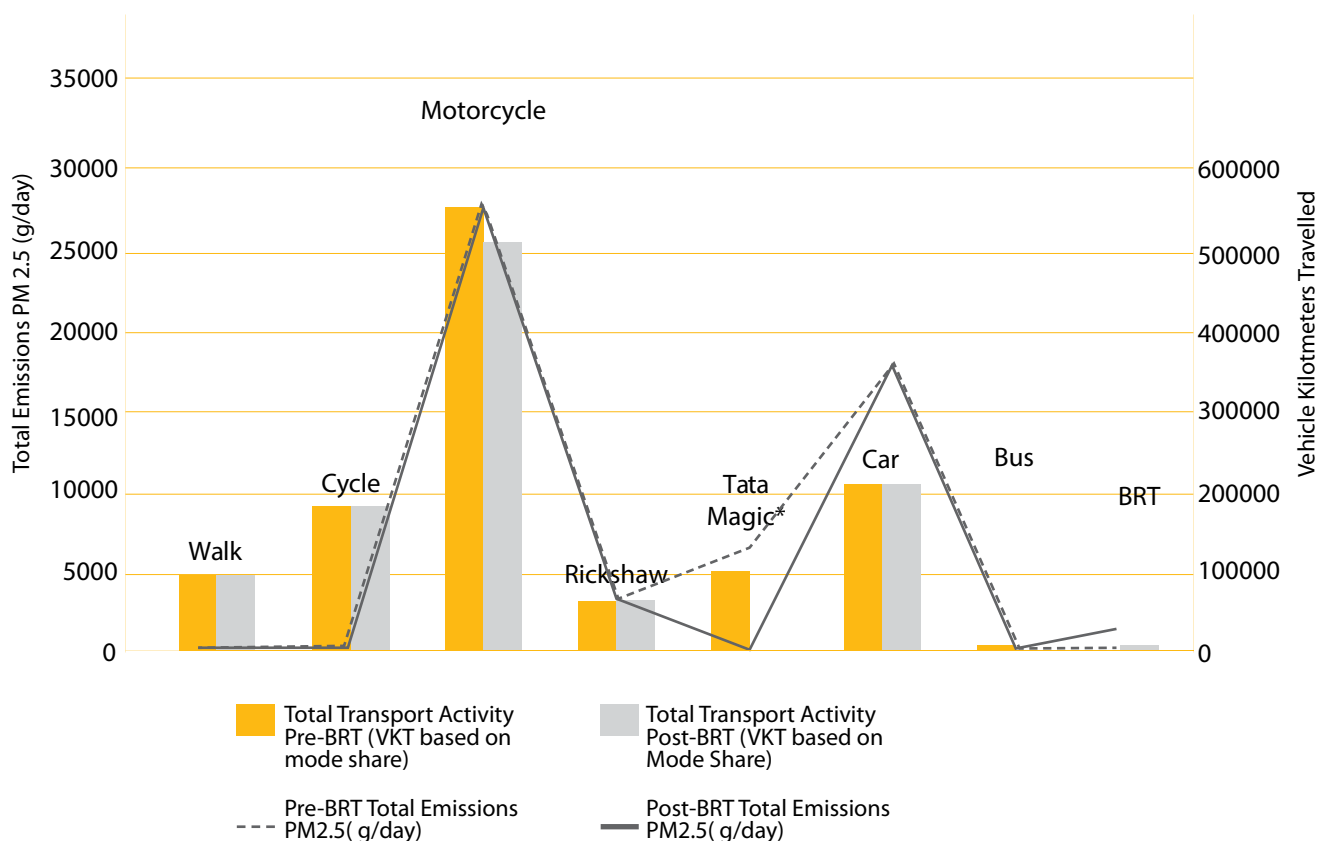
Source: EMBARQ India Analysis, based on data provided TARU survey for Public Health and Road Safety Study for BRTS Indore, 2010

* Tata Magic is a passenger microvan

range of respiratory and cardiovascular complications (World Health Organization 2011a) (World Health Organization 2005).

In order to determine the personal exposure level of commuters and baseline 24-hour mean concentrations of PM2.5, pollution levels were measured along all the bus stops on AB Road and inside the buses. The difference in emissions observed between BAU 2017 and BRTS 2017 scenarios was assumed to be the reason for the decline in PM2.5 concentration, by the same proportion of which transport emissions make up overall emissions in Indore (Pai 2010, Guttikunda and Jawahar 2012). In other words, if transportation contributes about 47 percent of PM2.5 emissions in Indore (Guttikunda and Jawahar 2012), it was assumed that the PM2.5 concentration reduced by 47 percent of the emissions reduction attributable to the BRT project.

(Note: Refer to the Appendix: Air Pollution Analysis for detailed analyses.)

In addition, WHO guidelines specifying the mortality risk from exposure to PM2.5 concentrations above its recommended guideline values were also applied to estimated 2017 levels (World Health Organization 2005). Figure 9 provides the vehicle kilometers travelled (VKT) by transport mode share and the associated PM2.5 concentrations with BRT systems in Indore.

Estimating Health Impacts of Traffic Safety

Evidence from around the world establishes linkages between the reduction in vehicle kilometers travelled (VKT) and road accidents and fatalities, showing that per capita fatality rates tend to increase with per capita annual vehicle mileage but they tend to decline significantly with increase in public transport ridership (Litman 2012). Hidalgo

and Duduta also show that relative risk per kilometer driven in emerging regions of the world decreases over time. The study also found that fatality rates tend to decrease through reduced exposure to automobile travel, infrastructure improvements, better policy and enforcement (Hidalgo and Duduta 2014).Data for the total road accidents and fatalities on AB Road for the years between 2008 and 2010 were collected from police stations with jurisdiction over various segments of AB Road. The data showed a significant drop from 2008 to 2009 for unknown reasons and hence was not considered reliable for the analysis. In addition, only two estimates of change (2008-2009 and 2009-2010) were available. Therefore, to estimate the reduction in fatalities, the fatality rate (fatalities per million VKT per capita) for the future scenarios was assumed to be the average of the 2008 - 2010 values for the corridor in this case. This average value was then used to estimate the number of fatalities given the difference in motorized VKT between the two scenarios.

(Note: Refer to the Appendix: Traffic Fatalities for detailed analyses.)

Estimating Health Impacts of Physical Activity

The current status of physical activity of residents along AB Road was determined through a primary survey. The number of persons walking and cycling for work, as well as the average duration of each activity was recorded. The estimation of lives saved in the BRTS scenario due to increased physical activity from taking transit was based on assumptions used in the HEAT Tool (World Health Organization 2011b). The WHO HEAT tool is designed to estimate the reduced mortality risk from increased physical activity in an adult population.

(Note: Refer to the Appendix: Physical Activity for detailed analyses.)

> *Per capita fatality rates tend to increase with per capita annual vehicle mileage but they tend to decline significantly with increase in public transport ridership.*

Results

It was found that over the course of five years (2013-2017), about 96 deaths could be prevented along the BRTS corridor of AB Road compared to current trends in motorization with no BRTS investment. With the introduction of BRTS, about 14 lives can be saved from increasing walking or bicycling and 5 lives can be saved from reduced traffic fatalities per year in the corridor after 2014. The reduction in emissions between a BAU scenario and post BRT scenario was 11 percent and mortality risk from PM2.5 exposure could be reduced by 1.1percent. Further limitations and assumptions of the analysis are outlined in the following sections.

Assumptions and Limitations in Estimating Mode Shift and Travel Activity

The analysis of mode share and travel activity consisted of the following three parts:

> • Traffic safety impact is quantified based on reduction in VKT alone. Additional risk reduction possible from infrastructure improvements has not been quantified;
> • Estimate the mode shift in the Indore BRTS corridor from survey data on previous modes used by BRTS users and information on projected changes to service levels for other modes (Tata Magic and city bus);
> • Apply the change in mode shares to 2017 VKT projections for the AB corridor in Indore with BRTS; and
> • Compare these changes in motorized VKT to a 2017 BAU scenario.

Estimating Mode Shift

Mode shares and ridership data were available for 2013, the first year that the BRTS was in place in. Average daily passenger trips were estimated by multiplying the per capita trip rate (PCTR) by the population in the corridor. The number of trips that switched to BRTS from each mode was then calculated using 2013 BRTS user survey data. This was used to determine the proportion of each mode that switched to the BRTS with redistribution of the TATA Magic and city bus trips equally across other modes to avoid bias. Constant trip rates were assumed.

For purposes of simplification, a number of variables that existed at the city level were assumed to be true for the corridor level. In the absence of more detailed information, some of these variables were also assumed to remain constant from implementation of the BRT in 2013 to 2017 including trip lengths, per capita trip rate (PCTR) and BAU mode shares. With increasing economic growth and travel these would most likely marginally increase. Using average total daily trips from 2013, total daily trips for 2014-2017 were calculated from the assumed PCTR and future population.

Trips by each mode for the first year were then determined based on user survey data showing that of the new BRTS trips, about 35 percent shifted from the TATA Magic, 16 percent from cars, and 49 percent from two-wheelers.

Of the new BRTS trips, about 35 % shifted from The TATA Magic, 16 % from cars, and 49 % from two-wheelers.

Assumptions In Estimating Health Impacts

Air Pollution

While the present mortality risk due to PM2.5 was determined based on primary data, future mortality risk could only be a rough estimate. This is mainly because translating future emissions from change in VKT could only give the change in annual tons of emissions, but not concentrations, which are expressed as micrograms per meter cube ($\mu g/m^3$). This would have required the use of advanced models that are beyond the scope of this study. Instead, the proportion of emissions derived from transport was estimated to change the overall concentration with decreased VKT between BRTS and BAU scenarios. Only emissions from reduced VKT were considered while other emissions were assumed to be constant.

The following assumptions were made in estimating air pollution health impacts:

- BRTS service replaced equivalent bus services and TATA Magic trips in 2014.
- Trip rates and trip lengths remain constant
- Mode shift is based on ridership and user survey data in 2013 and ridership increases based on increase in buses after that, from 2014-2017.
- Dedicated BRTS bus-only lanes did not significantly worsen congestion in the other lanes.
- The analysis assumes that 45 BRT buses will be plying on the corridor by 2015 as per current plans. If more buses are added the mode shares for BRT could increase beyond the figures estimated in this analysis.

Traffic Fatalities

In the case of fatalities, there has been a clear relationship established around the world between road accidents and vehicle kilometers (or miles) travelled.

The Ministry of Road Transport and Highways under the Government of India reports the Road Accidents in India annually (Highways 2012), but quantifies the number of road accidents per lakh (100,000) population, per ten thousand vehicles and per ten thousand kilometers of road length. Road accidents and injuries per ten thousand or million vehicle kilometers travelled would be very useful to quantify the impacts of sustainable transport interventions. In addition, studying impacts of specific projects, such as

BRT, cycling or pedestrian infrastructure on road safety, as has been done in the case of BRT Systems in Colombia and Mexico would help to establish a similar database in the Indian context that can help cities plan transportation infrastructure projects from the perspective of road safety. This analysis only considers the impacts of reduced private motorized VKT on road safety.

Assuming that traffic accidents increase with increasing private motorized VKT in the absence of supporting infrastructure, the primary assumption in the analysis is that the rate of traffic accidents per capita remains constant. AB Road is a National Highway and is one of the busiest and main commute routes in the city. Bad traffic conditions due to construction activity and bottle-necks are seen to cause the maximum number of fatalities. While the final number may be considered conservative and the introduction of BRTS with segregated traffic lanes and medians could save even more lives. In addition this analysis may not reflect actual numbers as the data collection had limitations such as non-reporting of all accidents to the police, especially hit-and-run, change in jurisdiction of the police stations over the last few years and different methods of reporting by the different stations (TARU 2012).

Physical Activity

In the case of physical activity of residents along AB Road, data collected on walking and cycling to work in a household survey was applied to the entire corridor population to determine total physical activity. While the BAU scenario assumed that the percentage of people walking and cycling and the time spent in these activities to remain the same, the BRTS scenario assumed that the number of people using transit would increase and thus walking levels would increase. The reference volume of physical activity for transit was assumed to be half of that of walking as transit trips tend to include 15 minutes of walking compared to the assumed 30 minutes of walking trips (Freeland et al. 2013). To translate this into lives saved, the Mortality Rate for Indore from the Annual Health Survey (Census of India 2012) was used in the HEAT tool. The main issue with the WHO HEAT tool is that the relative risks for walking and bicycling were derived from the European context and may not be as accurate in the Indian context. The health benefits can be expected to be much greater when the BRTS is introduced for the entire city.

Recommendations

Despite the limitations of data and assumptions made in the analysis, the analysis shows significant positive health impacts from the BRTS in Indore. These benefits may justify the expansion of the Indore BRTS from the public health perspective. . Specific recommendations in tracking public health progress are outlined in the following section.

Exposure To Particulate Matter

The lack of monitoring of PM2.5 in Indian cities is an area of immediate concern, as most health problems are related to exposure to PM2.5. Even with the lack of monitoring data and only the results of the primary survey to go by, the levels of PM2.5 are extremely high for both the city core and periphery. The WHO Air Quality Guidelines (World Health Organization 2005) specify a value of $10\mu g/m^3$ as the annual mean, and $25\mu g/m^3$ for the 24-hour mean. By both these standards, the existing values in Indore city are very high at $137 \mu g/m^3$. Further research in this area is needed with regard to source apportionment in order to determine which sectors to focus on for emissions reduction strategies, and also mortality and

disease studies for population exposure to PM2.5. Further research in this area is needed with regard to

> *WHO Air Quality Guidelines specify a value of $10\mu g/m^3$ as the annual mean, and $25\mu g/m^3$ for the 24-hour mean and the existing values in Indore city are very high at $137 \mu g/m^3$*

source apportionment in order to determine which sectors to focus on for emissions reduction strategies, and also mortality and disease studies for population exposure to PM2.5.

Physical Activity

Data regarding the status of physical activity needs to be collected at a city level, as many of the diseases related to sedentary lifestyles feature among the top 10 causes of mortality in India.

Results from the household survey along AB Road revealed that only 8 percent of the respondents bicycle regularly although 20 percent owned a bicycle, and only 10 percent walk regularly. Bicycling was also seen to be more common among low and middle income groups, while walking was popular among women. These low figures could be due to the poor walking and cycling infrastructure, and also because AB Road is a very wide road with heavy traffic, no central median, and lack of facilities for pedestrians and cyclists.

> *Diseases related to sedentary lifestyles feature among the top 10 causes of mortality in India.*

In addition, respondents were unhappy with the safety, shade and parking facilities for cyclists. Pollution and cleanliness of footpaths were also some of the main areas of concern for walkers. Even taking these reasons into account, the figures are very low and this reflects a serious concern related to transportation decision making in India, where non-motorized modes are not given enough emphasis. Most respondents expressed their willingness to walk if the infrastructure is improved, and this clearly stresses the need for improving infrastructure and safety of pedestrians and cyclists as these activities not only increase health benefits but also reduce emissions and improve the environment.

Traffic Fatalities

One of the main areas of concern for cities such as Indore is the growth in the numbers of motorized two-wheelers, which contribute to increased vehicles on the road and also increased vehicle kilometers, congestion, and air pollution. They are even seen to be involved in a large number of accidents. Increasing the share of public transportation through improved facilities and efficiency, and also investing in infrastructure encouraging non–motorized transport modes becomes essential in such a case. Research on the impacts of public transport and non-motorized transport infrastructure on reducing risk factors in the Indian context should also be considered. As in other countries, road accident data should be presented in terms of VKT in India as well so as to help establish a definite connection between road safety and VKT and thus help to quantify the impacts from sustainable transport solutions.

INTEGRATING HEALTH BENEFITS INTO TRANSPORTATION PLANNING AND POLICY

Public health objectives are among the top priorities for any country, and the impacts of transport investments on public health are many. Integrating these two concerns would lead to benefits in terms of reduced pollution and emissions, increasing physical activity and reducing traffic fatalities. Even conservative estimates reveal that the impact in terms of reducing mortality and saving lives from sustainable transport investments are substantial. In the pilot application of the methodology to the Indore BRTS, we estimated 10.8 percent reduction in fatalities as compared with the Business-As-Usual (BAU) scenario. If transportation planners were to consider this aspect in policy making, it would lead to improved decision making and much greater health benefits and savings in health-related costs for the country and its citizens. However, in order to more accurately estimate these impacts, more research is needed to develop measurement tools that more accurately reflect the environmental context of India and other developing countries. This is especially true of measuring physical activity for which there is the least research available.

The lack of empirical evidence can make hypothesizing the health impacts of a proposed transport investment difficult. However by identifying the health impacts, such as air pollution, traffic related injuries and physical health, to name a few, the health impact of a transportation investment or policy proposal can be identified. While preparing an HIA, researchers should consider the following:

> • Nature and kind of transportation investment/ intervention
> • Previous research and evidence about possible health impacts
> • Description of the area where the investment is planned and decision on study area for analysis
> • Demographics around the planning area
> • Economic impacts such as increase or decrease in travel costs
> • Changes to travel and traffic patterns

As a first step, this issue brief has outlined a framework and methodology for assessing the health impacts of transportation projects and policies in Indian cities, based on an in-depth multidisciplinary literature review and inputs from local transportation and health experts. To assess the impact on health by a transportation proposal, the methodological framework presented in Section 4 needs to be applied and tested by transportation professionals in India, to understand further practical and capacity challenges.

Future studies should look to further build the evidence based on health impacts and India- specific measurement tools, especially for physical activity. As discussed earlier, the poor in India are most vulnerable to air pollution exposure and road accidents because they are the largest proportion of pedestrians and cyclists. The equity issues related to the health impacts of transportation decisions also require careful study. The pace and scale of environmental, social, and economic change occurring across India contribute to the urgency of applying health impact assessment models to growing travel demand of an increasingly affluent populace with ever widening inequality. HIA methodologies are helpful in estimating the complete economic benefits of transportation projects, complementing the usual metrics like time savings and reduction in operational costs.

APPENDICES

INDORE MODE SHIFT AND HEALTH DATA ANALYSIS
MODE SHIFT ANALYSIS

We have used a conservative BAU scenario and the following assumptions were made in estimating mode shifts:

- All mode shares are constant in BAU, although it is highly likely that motorization may increase.
- Trip rates and trip lengths remain constant

- Regular bus service and TATA Magic service is eliminated in favor of BRT and emissions on the two modes are similar.
- Lost lane for BRT does not result in increased congestion in the corridor leading to more idle emission.

Passenger Trips Pre BRT/BAU

Indore Mode Share	Passenger Trips Pre- BRT/BAU				
	2013	2014	2015	2016	2017
Walk	67,113	68,455	69,824	71,221	72,645
Cycle	53,690	54,764	55,859	56,977	58,116
Motorcycle	1,49,917	1,52,915	1,55,973	1,59,093	1,62,275
Rickshaw	18,290	18,656	19,029	19,410	19,798
Tata Magic*	67,113	68,455	69,824	71,221	72,645
Car	76,101	77,624	79,176	80,759	82,375
Bus	15,212	15,516	15,827	16,143	16,466
BRT	0	0	0	0	0
TOTAL	4,47,437	4,56,386	4,65,513	4,74,823	4,84,320

Passenger Trips Post BRT

Indore Mode Share	Passenger Trips with BRT				
	2013	2014	2015	2016	2017
Walk	67,113	68,455	69,824	71,221	72,645
Cycle	53,690	54,764	55,859	56,977	58,116
Motorcycle	1,42,518	1,45,368	1,48,275	1,51,241	1,54,266
Rickshaw	18,290	18,656	19,029	19,410	19,798
Tata Magic*	61,828	0	0	0	0
Car	73,685	75,159	76,662	78,196	79,760
Bus	0	0	0	0	0
BRT	30,700	92,528	94,378	96,266	98,191
TOTAL	4,47,825	4,54,930	4,64,029	4,73,310	4,82,776

Air Pollution Analysis

Risk was calculated based on WHO's standard guideline of 25 µg/m³ 24-hour concentration and increased mortality risk of 1% for every 10 µg/m³ increase.

Air Pollution	2010	BAU 2017	BRT 2017
PM2.5 (µg/m³)	137	171	161
AQG	25	25	25
C24-AQG	112	145	135.8
Increased risk of short term mortality (percentage) from PM2.5	11.20%	14.59%	13.51%
Decrease in risk with BRT (%)			1.09%

Risk = (C24 – AQG)/ 0.01 µg/m³

where C24 is the 24 hour mean exposure to PM2.5

AQG is the Air Quality Guideline of the WHO

Emission Levels	
2010 Emissions	34109
BAU Emissions	52085
BRT Emissions	46333
Difference in Emissions 2010 vs BAU	12426
% Difference in Emissions 2010 vs BAU	52.70%
Difference in Emissions 2010 vs BRT	12224
% Difference in Emissions 2010 vs BRT	35.84%
Difference in Emissions BAU vs BRT	5752
% Difference in Emissions BAU vs BRT	11.04%

Traffic Fatalities

The following assumption was made to calculate lives saved:

- Average annual fatalities per year remains constant.

Year	Fatalities with BAU	Fatalities with BRT	Lives Saved
2013	46.00	43.94	2.06
2014	46.92	41.84	5.08
2015	47.86	42.68	5.18
2016	48.82	43.53	5.29
2017	49.79	44.40	5.39
Total Lives Saved			22.99

Lives saved due to increased physical activity was calculated using the following formula:

$$LS_{PA} = \left(M * PA_b * \left(1 - RM_a^{\left(\frac{Vb_m}{V_m}\right)}\right)\right) - \left(M * PA_s * \left(1 - RM_a^{\left(\frac{Vs_m}{V_m}\right)}\right)\right)$$

Where:

LS_{PA}:   Lives saved due to increased physical activity

PA_s: Annual Passengers/Population in effected area, scenario

PA_b: Annual Passengers/Population in effected area, baseline

M: Mortality rate (deaths per 100,000)

RM_m: Relative risk of mortality for active versus sedentary lifestyle, by mode

Vb_m: Average annual volume of activity per person (hours) in baseline, by mode m

Vs_m: Average annual volume of activity per person (hours) in scenario, by mode m

V_m: Reference volume of activity, by mode m

Physical Activity

Lives Saved due to Increased Physical Activity	2010	BAU	BRT
Lives saved walking	13.80	13.81	13.85
Lives saved from cycling	26.63	26.63	26.71
Lives saved from transit	2.97	2.97	17.46
Total Lives Saved	43.40	43.40	58.03
Lives Saved per year with BRT			**14.63**
Lives Saved in 5 years with BRT			**73.15**

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END NOTES

1. Air Quality Index (AQI) – An index to report air quality values. AQI is calculated for five major air pollutants: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur-dioxide, and nitrogen dioxide. Raw measurements from several locations are converted into AQI values for each pollutant and the highest AQI value is reported as the AQI value for the day.

2. Particulate Matter (PM) – Particles in the air, causing a kind of air pollution. They are categorized based on their size and where they come from. The bigger and coarser particles (between 2.5 and 10 micrometers in diameter) are called PM10 and come from road dust, crushing, grinding and agricultural operations. The finer particles (2.5 micrometers in diameter and smaller) are called PM2.5 and come from burning plants, wildfires, power plants, industrial processes and vehicle emissions. Because of its size and sources, PM2.5 ¬is considered to be toxic and has worse health effects than PM10

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