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How the present would have looked like? Impact of non-motorized transport and public transport infrastructure on travel behavior, energy consumption and CO_2 emissions – Delhi, Pune and Patna

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ABSTRACT

Transport sector is one of the major consumers of energy and contributor to pollution levels. The corresponding impact on environment is determined by the travel demand i.e. the city size and the transport infrastructure. In the study, we have explored three scenarios – improving bicycle infrastructure, improving bus infrastructure and improving both bicycle and bus infrastructure for three Indian cities – Delhi, Pune and Patna on travel behavior, fuel consumption and equivalent CO_2 emissions. The impacts are studied on the existing travel patterns to understand what would have been the fuel consumption pattern and emission levels had the infrastructure improved some years back. With the help of building scenarios for existing situation we have therefore tried to reduce uncertainties and draw sole attention toward improving basic infrastructure in Indian cities. Even though same scenarios are assumed for the three cities the studied impacts vary with respect to the population size. The study therefore highlights the need to adopt different strategies according to city size. The study has shown that improving bus infrastructure along with bicycle infrastructure results in maximum decrease in equivalent CO_2 emissions.

1. Introduction

Increasing urbanization and motorization specifically in developing countries is laying burden on environment. Worldwide, energy consumption and emission levels are increasing but differing trends are observed in Organization of Economically Developed (OECD) and non-OECD countries. Between 2002 and 2012, total energy consumption has increased by 69% in non-OECD countries while the same has remained stable in OECD countries during the period. Transport sector is one of the largest consumers of energy. In non-OECD countries, the energy consumption from the transport sector is increasing at an annual growth rate of 5% and so are the CO_2 emissions where the maximum growth is driven by the road sector (International Energy Agency, 2014).

India is the world's fourth largest consumer of oil and the third largest contributor to energy related CO_2 emissions (U.S. Energy Information Administration, 2015). In 2012, transport sector in India accounted to 36% of the total energy consumption of the country (U.S. Energy Information Administration, 2014b) contributing to 12% of the total CO_2 emissions (International Energy Agency, 2014). However, per capita CO_2 emissions by transport sector of India are only one-sixth of the worlds' and one-third of China's per capita CO_2 emissions. The relatively low level of per capita CO_2 emissions from the transport sector of India is associated with the high use of low carbon modes of transport (walk, bicycle and bus) (Wilbur Smith Associates, 2008).

India is witnessing consistent growth in urbanization (2.7% annually Desa 2015) and motorization (9.3% annually as per Ministry of Road Transport and Highways (2013)). It is expected that by 2025, India will be more than 50% urbanized (U.S. Energy Information Administration, 2013) and the personal motorized vehicle ownership will be between 300 and 500 vehicles per 1000 persons by 2050 (Tiwari et al., 2010). It is evident that the growing travel demands in urban India will be increasingly met by personal

Abbreviations: ASIF, travel activity (A), modal split (S), energy intensity (I) and emission factor (F); BAU, business as usual; Equivalent CO_2 emissions, unit of measure that describes the global warming potential produced by GHGs; LEAP, long range energy alternatives planning model; MTW, motorized two-wheeler; NMT, non-motorized transport.

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motorized vehicles as compared to non-motorized transport (NMT) and public transport (Dhar & Shukla, 2015).

The increasing burden of urbanization on the environment necessitates the need to intervene to reduce the negative impacts of urban mobility. A way to achieve the underlying agenda is ensuring safety and comfort to the users of low carbon modes. Most Indian cities have been investing to ensure fast mobility of vehicles that includes road widening schemes and provision of flyovers and foot-over bridges (JNNURM, 2009). While there are minimal plans to invest in improving the basic transport infrastructure for pedestrians, bicyclists and bus users (Tiwari & Jain, 2013). This has detrimental impact on the safety and comfort of both NMT and public transport users.

In this study scenarios are developed to estimate the relative impacts of improving bicycle and bus infrastructure on travel behavior, energy consumption and equivalent CO_2 emissions[1] for the year 2011. Scenarios for the future year involve various uncertainties that are both objective and subjective (Nocera, Tonin, & Cavallaro, 2015). Estimating the impact for the year 2011 reduces uncertainties arising from projection of population and travel demand and assumptions related to the technological progress and its penetration rate. The purpose of the study is to draw sole attention towards the need for improving bicycle and bus infrastructure in Indian cities. The study explores three infrastructures improvement strategies i.e. improving only bicycle, improving only bus infrastructure and improving both bicycle and bus infrastructure.

In the study bottom up approach is used to determine the impact of improving bicycle and bus infrastructure on the energy consumption and CO_2 emissions. In the scenario modal shifts are estimated based on the trip length frequency distribution of each mode from which the shifts are expected. Modal shifts in alternate scenarios are based on the literature review of stated preference studies related to travel mode choice conducted in Indian cities in the recent past.

The three Indian cities of different population size i.e. Delhi (16.31 million), Pune (5.04 million) and Patna (2.05 million) are chosen to illustrate the impact on mode choice and to study the relative impacts on energy consumption and CO_2 emissions. The results are extrapolated at national level to estimate the likely energy consumption and equivalent CO_2 emissions had bicycle and bus infrastructure improved some years back.

2. Literature review – scenarios and assumptions

Scenario based methodologies are widely used to understand the impact of policies and strategies on the environment and the society (Hickman, Ashiru, & Banister, 2011). In 1960s, Kahn and Weiner defined scenarios as the hypothetical sequence of events that help in drawing attention on causal processes and decision points (Geurs & van Wee, 2004). Scenarios are not the statement of what will happen but of what might happen as there are many assumptions and methodologies involved in developing the same (U.S. Energy Information Administration, 2014a). Scenario based approaches can be classified as forecasting (predictive), scenario planning (explorative) and back casting (normative). These approaches can answer significant questions – "What will happen", "What can happen" and "How to achieve the set targets", respectively (Borjesson, 2012; Höjer, Gullberg, & Pettersson, 2011; Vergragt & Quist, 2011).

Numerous studies have been done to estimate the energy consumption and emission levels by transport sector under the varying policy regimes at global, national and local level. Models like Long Range Energy Alternatives Planning (LEAP) Model, ASIF approach (prepared by the International Energy Agency), MARKetAL location model and detailed sectoral and activity analysis models have been used for the purpose (Ghate & Sundar, 2010).

U.S. Energy Information Administration (EIA) has developed reference case scenario along with alternate scenarios assuming varied macroeconomic growth rates, world oil prices, and rates of technological progress; to estimate energy consumption and emissions by all sectors including transport for different regions of the world (U.S. Energy Information Administration, 2014a). Scenarios for the transport sector are based on the likely modal shifts, energy markets and technological changes. It is estimated that India's transportation sector energy use will increase at the annual rate of 5.1% in the reference case scenario. However, various uncertainties are involved in the developed scenarios attributing to the penetration factor of technology and adaptability of alternate fuel choices.

In 2004, Das and Parikh estimated energy consumption and emissions from transport sector of Delhi and Mumbai to determine the impact of varying economic growth pattern. In the analysis, econometric model is used to estimate vehicle stocks (as function of income per capita and GDP growth) and applied attrition factor to estimate the number of vehicles that actually exist in a particular year. Based on the utilization factor of vehicle types in particular city; travel demand met by different vehicle types is determined. Finally LEAP model has been used to determine the energy consumption and emission levels. The authors have estimated that in high growth rate scenario energy consumption in transport sector will be 1.7 times higher than the Business as Usual (BAU) scenario registering the increase in CO_2 emissions by 325% between 1997 and 2020. The study however does not consider the impact of improving infrastructure and the resulting change in travel patterns.

A study by Schipper, Banerjee, and Ng (2009a) estimated emissions from land transport of India under four scenarios namely BAU, energy-efficient small cars; a two-wheeler world; and sustainable urban transport. Focus of the study was to explore the impacts of different mobility and fuel use pattern on CO_2 emissions. In the study it is estimated that the sustainable urban transport scenario that involves both demand and supply management is likely to result in reducing emission levels by 30% from the BAU scenario in 2030. The authors have stated that the scenarios involve uncertainties related to the travel demand estimation and the projection of vehicle – kilometers by different vehicles.

Khanna, Jain, Sharma, & Mishra (2011) estimated energy consumption and emission levels in increased bus share and increased metro rail share scenario for Delhi. Travel demand for future years is estimated by regressing travel levels against time. In the study, travel mode shares have been assumed under each scenario, for example, bus transit scenario shows increase in existing bus trips from 38% to 75% in Delhi. At present pedestrians share is 34%, rickshaw and bicycle trips are another 10% (Rites, 2008). The given increase in public transport share implies shift from non-motorized to motorized transport. Therefore, the assumed shifts to public transport in the study are very unlikely and more carbon intensive.

Woodcock et al. (2009) assessed impact of alternate future developments in transport on health for two different settings—London, and Delhi to understand the impact on greenhouse gas (GHG) emissions and traffic mortalities. In the study, BAU scenario for 2030 has been compared with the three alternate scenarios i.e. lower-carbon-emission motor vehicles, increased active travel, and combination of the two. In the BAU scenario population, vehicle stock and travel demand are projected. As per the study, it is expected that CO_2 levels in Delhi will reduce by 12%. 9.6% and 47% in low carbon emission, increased active travel and combined scenario, respectively as compared to the BAU scenario.

[1] The concentration of CO_2 that would cause the same level of global warming as caused by the GHGs (Brander & Davis, 2012).