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Assessment of national information repository and database(s) for modelling health impacts of urban transport in India

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Abstract

Adverse impacts of transport sector on human health are increasing in terms of increasing exposure to air pollution and road traffic crashes. The existing infrastructure and built environment is resulting in reduced involvement in physical activity thereby having increasingly negative impact on health. It is imperative to assess the health impacts of transport sector at city level to design appropriate strategies that can help in reducing these impacts on human health. However, assessment of health impact is very constrained in developing countries due to limited data availability. In this study, we assess the quality and level of data available in various studies and repositories to model health impacts due to transport sector in Indian cities. This analysis includes assessment of national datasets such as National Census, National Sample Surveys (NSS), Indian Human Development Survey (IHDS), Knowledge Management Center (KMC) and Comprehensive mobility Plans (CMP) for various cities. Results indicate that we cannot rely solely upon any one of these datasets for modelling health impacts of urban transport. Though each one of these data sources can provide useful information on relevant indicators in its respective domain.

Keywords: Transport and Health; Air Pollution; Phisical Activity; Road Safety

1. Introduction

Global health burden due to the transport sector has increased over the years, specifically a significant increase has been observed in the developing countries. Transport sector affects human health in four different ways i.e. exposure to air pollution, noise pollution and traffic related crashes and involvement in physical activity. Globally, ambient air quality contributed to one in every nine deaths in 2012 (World Health Organization, 2016) and road-related injuries have contributed to one in every 21 deaths in 2013 (World Health Organization, 2015). The existing per capita CO2 emissions in India are well below than that of the world's average, however, it has increased at an annual rate of 3.8% between 2005 and 2015 (IEA, 2007; IEA, 2017). Deaths due to road-related crashes have also increased at an annual growth rate of 3.75% between 2005 and 2013 in India (World Health Organization, 2015). With degrading infrastructure and increasing exposure of people to the severe air pollution levels and risk to road-related crashes, non-motorized transport (NMT) shares in Indian cities are declining (Tiwari and Jain, 2013). This is negatively affecting the involvement of people in physical activity incurred while commuting.

The majority of the studies have accounted for the health impacts due to air pollution, physical activity and traffic crashes (Gotschi and Hadden Loh, 2017; Rojas-Rueda et al., 2012; Sa et al., 2017; Stevenson et al., 2016; Tainio et al., 2016). Few studies have accounted for the impact on human health due to the exposure to noise pollution as well (Apparicio et al., 2016; Tainio, 2015). Majority of the studies due to the transport activity has been published from developed countries (Apparicio et al., 2016; Gotschi & Hadden Loh, 2017; Rojas-Rueda et al., 2012; Stevenson et al., 2016; Tainio, 2015). There are limited studies that have estimated the impacts of transport sector on health in the low and low-middle income countries except for Delhi and Sao Paulo (Guttikunda and Goel, 2013; Sa et al., 2017; Woodcock et al., 2009). This is related to the limited data availability required to model the health impacts.

In this study, we aim to discuss the minimum and maximum data required for assessing health impacts due to exposure to air pollution, risk to road related crashes and involvement in physical activity (section 2). Based on this, we assess the data availability in various Indian cities and quality of data available for the health impact assessment through national level repositories such as census and city specific transport studies (Section 3 and 4). In the last section, we discuss the need for more data collection to supplement the existing dataset and development of methods to fuse the data available from multiple sources.

2. What data is required for health impact modelling?

Models for assessing health impacts can be classified into two categories – the models that measure consequences and the models that contribute towards measuring exposure. Consequences are defined as the measurement of externalities resulting because of development activities like air quality level and noise levels. Exposure of people to different types of consequences therefore has impact on their personal health that is likely to vary by gender, income and activity schedule (Rojas-Rueda et al., 2012; Sa et al., 2017).

Transport is one of the major sectors contributing to the degrading air quality levels in cities. Exposure of users to the degraded air quality differs with the level of time spent in indoors, outdoors and types of mode used for travelling. Second, traffic crashes resulting in minor, major and severe injury and fatalities imposes significant health burden. Probability and severity of crash varies with regard to the conflicting modes of transport, level of exposure, infrastructure typology, vehicle design and other factors like demography and law enforcement (Bhalla et al., 2007). Third, transport contributes to physical activity of people in space that is likely to negate the first and second negative impact of transport sector on human health. Fourth is related to the noise generation and level of exposure of the people to noise levels beyond a defined level for a certain duration of time and time of day (Tainio, 2015).

Studies show that the travel patterns vary by ethnicity, gender, socio-economic profile and geographical location resulting in differences between exposure levels. Also, the impacts of transport sector both on air quality and safety varies by both geographical location and infrastructure typology. To quantify the impact of transport sector on human health we need to quantify first the three consequences i.e. air quality, transport safety and physical activity and understand exposure levels of people to the three impacts. A detailed understanding of health impacts across different sections of society would require disaggregation by socio-economic and demography profile of people including geographical location. Table 1 provides brief description on health impact models.

Table 1. Literature review of health impact models.

Citation	**Context**	**Impacts considered**	**Variables - consequences**	**Variables - exposure**	**Type of model**
(Johansson et al., 2017)	Stockholm	Air pollution	Volume of car Travel distance by bicycle Spatially disaggregate emissions	Travel time by bicycle Population weighted exposure	Spatial disaggregation
(Smith et al., 2013)	UK	Air pollution	Average annual air pollution level by types Share of primary emissions by car	Exposure response coefficient (literature) Mortality data - national repository Hospital admissions	Macro model

(San Jose et al., 2018)	London	Air pollution	Local development factors - air circulation and shading	Relative risks rate - mortality/morbidity based on literature	Spatial disaggregation
		Temperature	Spatially disaggregate air quality estimated using population, land use and traffic data		
			Global climate scenarios		
(Rojas-Rueda et al., 2012)	Barcelona	Air pollution	Modal split of trips per day	Average trip duration	socio-economic disaggregate and spatial disaggregation
		Road safety	Average distance travelled	Expected mortality per age group	
		Physical activity	Speed by mode	Time spent walking	
			Road traffic fatalities	Related risk functions (literature)	
			Air dispersion models		
(Gotschi & Hadden Loh, 2017)	USA	Physical activity	information of level of physical activity on trails	dose response functions disease and mortality rates	
(Sa et al., 2017)	Sao Paulo	Air pollution	Non-travel related physical activity by age and gender	travel time distribution by mode	socio-economic disaggregation
		Road safety	Air quality levels - PM 2.5	disease specific relative risks	
		Physical activity	Road traffic injury data by victim	mortality data	
(Tainio, 2015)	Poland	Air pollution	Air dispersion models	Annual average exposure of population to air pollution	Macro model
		Road safety	emission data	People exposed to noise by time	
		Physical activity	Number of fatalities by mode	Average travel time	
		Noise	Noise levels	Population data	
			Number of walking and bicycling trips		

Based on the literature review, we have classified health impact models in three levels – basic, intermediate and detailed Table 2 and Table 3. Basic level models help in estimating the overall burden of transport sector on human health. It quantifies the overall exposure level of the citizens to the three aspects of air quality, safety and physical activity without considering the effects of locational aspects and socio-economic characteristics. Intermediate-level models can be used to identify the geographical locations within the study area where people are exposed to various consequences. This therefore helps in identifying the priority locations where interventions are needed like designing built environment and provisioning infrastructure. The detailed models account for socio-economic and demography variation to understand the exposure of people belonging to different groups of society. These models help in identifying vulnerable groups of society that therefore helps in identifying policy and design interventions to reduce respective vulnerabilities.

Level of data required for measuring both consequences and exposure levels is shown in Table 2 and Table 3. For moving from one level to other level mode, data from previous level is also required. Therefore, detailed model will require all the data used for modelling basic-level and intermediate level along with the data specified for detailed-level modelling.

Table 2. Data required to measure consequences.

Consequences		**Air quality levels**	**Safety**	**Physical activity**	
Basic-level		Air quality levels (PM 2.5, 10)	Number of victims by mode (Fatal/Non-fatal)	Walking distance, bicycle distance*	Walking time, Bicycling time*
Intermediate-level	Location	Air quality levels by location	Number of victims by mode, injury level and road type	Not required	
			Number of victims by mode, injury level and built-form		
	Temporal	Air quality levels by	Number of victims by mode,		

		time of day and day of year	injury level and time of day		
Detailed level model	Gender	Not required	Number of victims by mode, injury level and gender	Walking and bicycle distance by gender	Walking and bicycling time by gender
	Age		Number of victims by mode, injury level and age group	Walking and bicycle distance by age groups	Walking and bicycling time by age groups
	Income			Walking and bicycle distance by income	Walking and bicycling time by income

*Includes distance and time for access/egress trip to PT and IPT by walk and bicycle

Table 3. Data required to measure exposure.

Exposure	Air quality level	Safety	Physical activity
Basic-level model	Travel time by modes	Travel distance by modes	Same as consequences data
		Modal share and frequency of trips	
Intermediate-level model	Travel time by mode and geographical location		
	Travel time by mode and time of day	Travel distance by mode and time of day	
	Travel time by mode and road type	Travel distance by mode and road type	
	Travel time by mode and built-form	Travel distance by mode and urban form	
Detailed level model	Travel time by mode and gender	Travel distance by mode and gender	
	Travel time by mode and age group	Travel distance by mode and age-group	
	Travel time by mode and income	Travel distance by mode and income	

Data availability is a constraint in the developing countries for estimating impact on human health. Reliable data spanning over years that measure various aspects of both consequences and exposure levels are rarely available. In India, data on travel activity pattern is available from Census of India for only other worker trips. Various Indian cities have prepared mobility plans and conducted transport and traffic studies to define strategies for improving mobility of people in the cities. These studies are based on infrastructure and household survey of sample locations and people/households, based on which travel patterns are estimated for the city for “a typical workday”. This can then be used to estimate level of exposure of people to different consequences. The data has been collated by Knowledge Management Centre, Institute of Urban Transport India and is available for various purpose. Information can also be directly extracted from the various studies available in public domain. In the next sections we have reviewed the data availability from these multiple sources.

3. Data availability from national level household surveys

Household travel surveys can provide in-depth information on travel behavior. Apart from recording the demographic and socioeconomic profile of a household and its members, household travel surveys may also help getting insight on exposure to health risks. However, there is no institutional arrangement to conduct national-level household travel surveys in India. Therefore, there is a need to identify alternative data sources that can be used to extract information required for modeling health impact of transport sector.

We consider three national surveys- Census of India, National Sample Survey (NSS) and India Human Development Survey (IHDS). Census of India (2011), the latest decennial census, recorded mode and distance of work travel for all the workers except cultivators, agricultural laborers and workers in Household Industry. Travel distance is recorded in following categories (in kilometers): 0-1, 2-5, 6-10, 11-20, 21-30, 31-50 and more than 50. Modal share is recorded in terms of 9 mode categories including walk, bicycle, motorized two-wheeler (scooter, moped, motor cycle etc.), four-wheeler automobile (car, jeep, van etc.), intermediate public transport (tempo, auto rickshaw, taxi etc.), bus, train, water transport, and any other mode. 'No-travel' is a separate category but no definition has been provided. This generates some amount of uncertainty. For example, does 'no-travel' include only those who work from home, or also those who have no fixed place of work? If former is the case, how is the work travel information of the likes of vendors and delivery personnel recorded? Apart from the lack of clarity about 'no-travel', census data has some other serious limitations. Census data is available at the district-level only disaggregated by gender.

National Sample Survey (NSS) is a representative sample survey which collects information on diverse socioeconomic subjects such as employment, consumer expenditure, health and education on all-India basis. NSS dataset makes information available at individual-level disaggregation for the sample households differentiated by sector i.e. rural/urban. NSS data can provide some useful inputs for the purpose of modeling health impact of transport. First is the quinquennial series of surveys on consumption expenditure that records household expenditure on various modes of transport (not necessarily restricted to intra-urban trips) which can be used to estimate average travel distance and mode usage at household level. Latest available consumption expenditure data is from 68th round of NSS which was conducted in 2011-12. However, this cannot be used to estimate the distance travelled by walk and bicycle. Apart from these quinquennial surveys, 71st round of NSS, which was conducted in 2014, collected information on health. It is the latest all-India data on morbidity and medical care available at the household level. Medical care, hospitalization and monthly expense for spells of ailments is reported for every individual against a very detailed list of diseases. However, this does not include road-crash related injuries. There is a need to assess the utility of the data to estimate health impacts of transport sector.

India Human Development Survey (IHDS) provides data on indicators like socioeconomic conditions, employment, education and health for 41,552 sample households. Most of the variables (relevant for our purpose) recorded by IHDS are quite similar to that recorded by NSS. Since transport expense recorded in IHDS is only gross value, it is not possible to estimate mode usage or travel distance using IHDS data. However, IHDS records the travel time to work and travel distance to education. Travel to work and education are the two most regular and dominant trip purposes. Table 4 summarizes the different level of information provided by different national level surveys. However, due to limited information available through each of the given dataset, there is a need to integrate information from these multiple sources.

Table 4. Availability of travel data in the national household surveys

Required Input	**Census**	**NSS**	**IHDS**
Demographic disaggregation	Yes	Yes	Yes
Modal usage	Yes, but aggregated	Yes	No
Travel distance	Yes, Categorical	No, but vehicle-km can be estimated grossly for each household	Yes, but only for education.
Travel time	No	No	Yes, for work
Frequency	No	No	No
Purpose	Only work	No	Yes, but only for education
Safety (incidences of road injury in a household)	No	Yes, but includes non-road accidental injuries	No
Vehicle ownership	Yes	Yes	Yes

4. Data availability reliability in CMPs or CTTS or DPR

Since the year 2006, many cities in India have prepared comprehensive mobility plans (CMPs). Prior to this, cities were preparing city traffic and transportation studies (CTTS) as per the requirement of master planning approach. The two planning documents differ in the objectives, visions and data collection methods. The objective of CTTS was to evaluate the existing infrastructure with regard to the existing and future demand for vehicular transport in the city. Based on the supply-demand gap analysis, infrastructure provision strategies like road widening and building flyovers were proposed in the CTTS. As compared to this, the objective of CMP is to achieve the vision laid in National Urban Transport Policy (NUTP) i.e. to improve mobility of people rather than of vehicles. The approach draw focus on availability of non-motorized, public and para-transit transport infrastructure, challenges faced by transport users and estimate demand for different modes of transport in alternate scenarios. As per the CMP toolkits issued in 2008 and 2014, alternate development and infrastructure development scenarios are required to be assessed with regard to the identified indicators. This approach required estimating demand for non-motorized transport, public and para-transit systems and vehicular transport. Accordingly, the strategies for infrastructure provision were identified in CMPs.

CMPs or CTTS are available through Municipal Corporation or Urban Development Authority websites. However, not all the CMPs have been uploaded on the respective websites. Therefore, researchers have access to the limited number of CMPs/CTTS. Knowledge Management Centre has been established by Institute of Urban Transport, India to create repository of information, data base, news and updates that can be effectively utilized by all the stakeholders such as Government, Business, Consultants, Academia, Citizens, Policy makers, Industry, Consultancy and Research community working in the domain of Urban Transport. As per the KMC – IUT India, 19 cities have prepared CMPs.

4.1 Data availability in Knowledge Management Centre (KMC)

Knowledge Management Centre (KMC) portal is expected to facilitate systematic collection, assimilation, transformation, loading, interpretation and analysis of data in evolving future policies, programs and strategies besides enhancing the level of awareness of citizens on urban transport matters (IUT, 2018). The project is funded under Sustainable Urban Transport Project initiated in the year 2010 under the aegis of the Ministry of Urban Development, Government of India. Currently, information on 48 cities is compiled under KMC. These cities are located across the length and breadth of India's geographical extent (Figure 1a). Out of these 48 cities, 16 are million plus cities, 10 cities have population less than a million but more than 500,000, while 22 are smaller cities with populations less than 500,000 (Figure 1b).

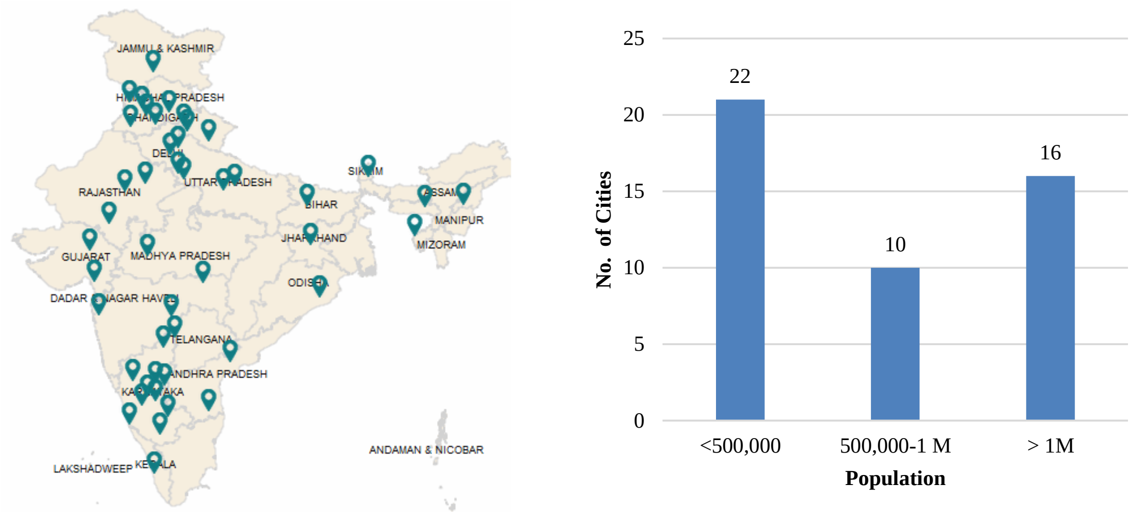

Fig. 1. (a) Location of cities covered under KMC (source: IUT, 2018); (b) KMC cities by population sizes.

4.2 KMC data structure and indicator categories

KMC dataset is divided into four primary categories of indicators as shown in figure 2. These categories are namely, demand, supply, performance and impact. Demand indicators are further divided into four subcategories of demographics, land use, socio-economic and traffic & travel characteristics. Supply indicators are subdivided into road inventory, bus system/Bus rapid transit (BRT), rail based/metro, and also air travel indicators. These are further subdivided into indicators related to bus fleet, pedestrian infrastructure, urban/sub-urban rail system, and depots/terminals/airport availability and also parking availability. Performance indicators primarily include indicators on bus operations, freight movement, fare structure in public transport and average occupancy for different modes of transport. Target indicators are currently limited to air pollution, noise pollution and road accidents.

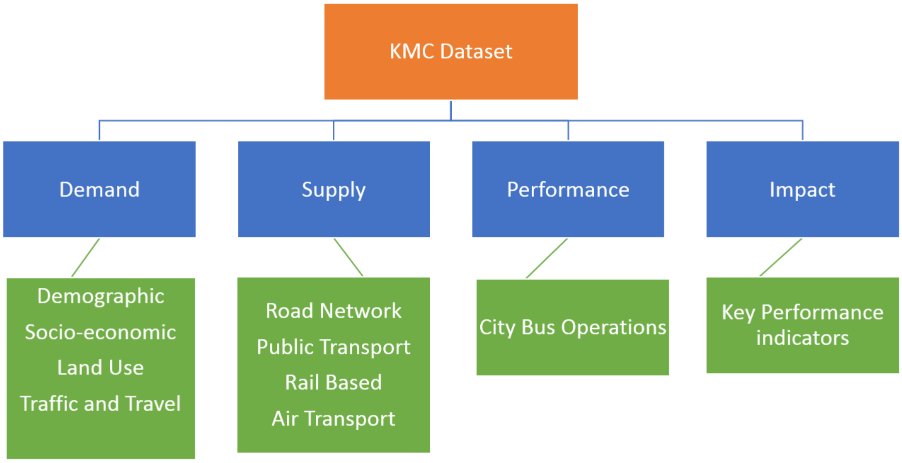

Fig. 2. KMC Data structure and Indicator categories.

A total of 221 indicators are targeted in KMC to provide comprehensive database on urban transport in the city. Out of 221 indicators, Demand, supply, performance and impact indicators account for 121, 56, 29 and 15 indicators respectively. Currently KMC is still under development and offers information only for 70 of these 221 indicators. Incidentally, information for 48, 5, 9 and 8 indicators in the categories of demand, supply, performance and impact respectively is available at present. Although, the datasets and indicators are not uniformly available for all the cities. CMPs of 19 cities are the most common source of information compiled under KMC (see Table 5). Detailed project reports (DPRs) prepared under Jawaharlal Nehru National Urban Renewal Mission (JnNURM) forms 2nd most common source of information.

Table 5: Sources of information/datasets compiled under KMC

Abbreviation	**Source**	**No. of cities**
CMP	Comprehensive Mobility Plan	19
DPR BRTS	DPR for Bus Rapid Transit System	14
TP GNCTD	Transport Department GNCTD	1
ITTP	Integrated Traffic and Transportation Plan	2
CTTPS	Comprehensive Traffic and Transportation Study	2
LCMP	Low Carbon Mobility Plan	2
BRTS Rpt	Bus Rapid Transit System Report	1
CDP	City Development Plan	6

Though KMC provides an efficient platform for transport related dataset for different cities, however, it is not updated regularly. As shown in Figure 3, there is no data available beyond the year2015, and data reported for 11 of the 48 cities is over a decade old. For a robust health impact model a mechanism for constant updating of datasets need to be put in place.

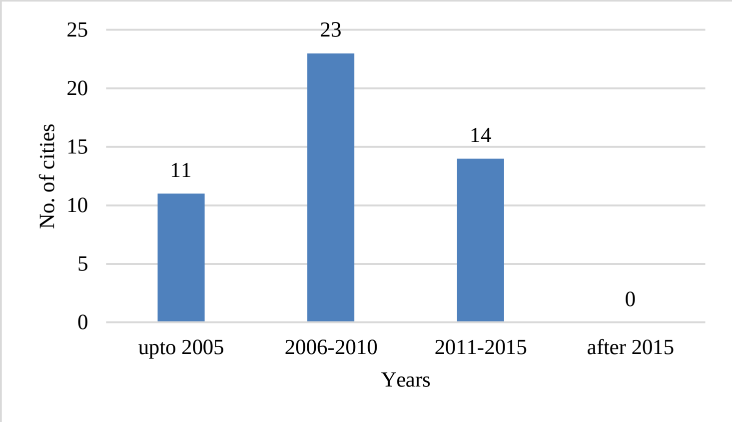

Fig. 3. Time slabs and data availability in KMC

4.3 Availability of KMC datasets for modelling health impacts of urban transport

Datasets available in KMC and required for health impact modelling of urban transport are divided into three broad categories of Demographics & travel characteristics, Fleet/Fuel information and Road accidents and fatality information. Table 6 provides availability and non-availability of datasets for different indicators under these subheads.

Table 6: availability of relevant indicator datasets for health impact modelling.

Sr.	**Dataset**	**Dataset available (No. of Cities)**	**Not Available (No. of Cities)**
Demographics & Travel characteristics			
1.	Demographics	47	1
	(Population, HHs, Males/Females, Literacy)		
2.	Monthly Income, Expenditure on transport	30	18
3.	Modal Share	39	9
4.	Per Capita Trip Rate	37	11
5.	Avg. Trip Length	17	31
6.	Mode wise trip length	32	16
7.	Purpose wise Trip Distribution	31	17
Fleet/Fuel Information			
1.	Registered Vehicles (Types)	46	2
2.	Bus Fleet	32	16
3.	Avg. km/Bus/Day	13	35
4.	Total fuel cost	11	37

Accidents/ Fatality Info			
1.	Fatalities*/100,00 Population	24	24
2.	% of Total Persons Killed in Accidents to Total Accidents	20	28

* Only aggregate data is available. Fatality data by victim is not available

As per KMC list of indicators, air quality information needs to be reported for all the cities. However, no information related to existing air quality levels are reported for any of the cities. For road related crash fatalities, data is available at aggregate level only. KMC reports number of fatalities per 100,000 population, however disaggregation by victim and impacting vehicles and data related to non-fatal crashes required to measure exposure is not available. As indicated in Table 6, data on travel patterns is limited to aggregate trip rates (including and excluding walk), modal shares and mode wise trip length distribution. Disaggregation by location and socio-economic characteristics is not provided in the existing database. Such information along with sampling size and sampling methodology can be retrieved from the available city specific reports. We have assessed the data quality and reliability available from these studies in the next section.

4.4 Data Availability in city level mobility studies

From different websites of municipal corporations, development authorities and funding agencies we had access to CMPs, CTTP and Detailed Project Report (DPR) of 16, 2 and 3 cities, respectively. DPRs are developed with an objective to assess demand for projects like provision of bus rapid transit systems (BRTS) and Metro-rail transit systems (MRTS). The DPR lead to identification of corridors and stations and defining design parameters for the respective projects. Therefore, it is likely that the data collected for preparing DPR is limited in scope to capture entire city. Though KMC compiles datasets from these different sources, the official reports are not generally accessible online. We were able to access only 3 DPRs, 2 CTTPs and 1 other such complete report. The cities for which the various studies have been taken up varies from population size of 0.1 million to 14 million. Of these majority of the cities for which the CMP or CTTP have been prepared are of population size between 0.1 million to 1 million (see Figure 4).

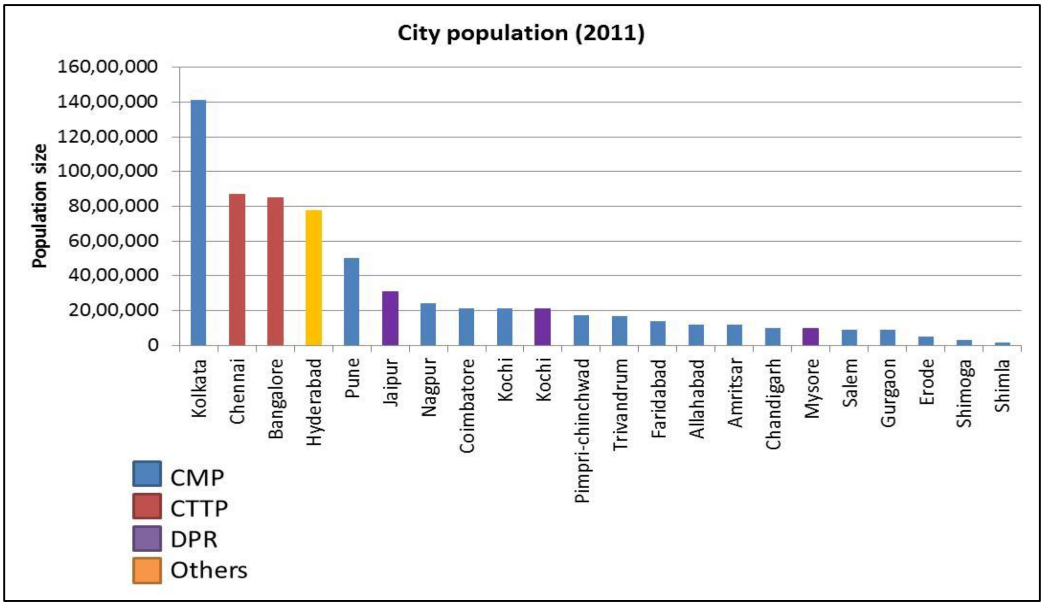

Fig. 4. Mobility reports prepared by different city population size.

Both CMPs and CTTS provide details for the travel activity pattern that includes – trip rate, trip length and modal share. The studies also report vehicular traffic flow patterns and traffic constitution within the study area. Table 7 and Table8 shows the level of data available from different city specific studies to measure consequences and exposure levels. Data is available at basic level only from the existing studies. Demography and location related variables have not been accounted while measuring travel patterns. Of the total 21 studies assessed, only four cities report air quality levels in the cities. Air quality data can also be assessed from the website of Center for Pollution Control Board. Number of fatalities by victims is not available in any of the referred studies. This therefore limits researchers to understand impacts of transport sector on exposure to road-related crashes by modes. Of the total studies assessed, 11 studies have data on walking and bicycling distance. However, these studies do not account for walking and bicycling distance to access/egress the public transport system, except for Coimbatore.

Table 7: Data available to measure consequences from city specific studies

Consequences		**Air quality levels**	**Safety**	**Physical activity**	
Basic-level		Air quality levels = 4 Hyderabad, Kolkata, Jaipur and Coimbatore	Number of fatalities = **12** Number of victims by mode = **None** Number of non-fatal crashes = **5**	Walking distance = **11*** Bicycle distance = **12**	Walking time = None Bicycling time = **None***
Intermediate-level	Location	Air quality levels by location = 4	Number of victims by mode, injury level and road type = **None** Number of victims by mode, injury level and built-form = **None**		
	Temporal	Air quality levels by time of day and day of year **= 1 (Hyderabad)**	Number of victims by mode, injury level and time of day = **None**		
Demography	Gender	Not required	Number of victims by mode, injury level and gender = **None**	Walking and bicycle distance by gender **= None**	Walking and bicycling time by gender = **None**
	Age		Number of victims by mode, injury level and age group = **None**	Walking and bicycle distance by age groups **= None**	Walking and bicycling time by age groups = **None**
	Income			Walking and bicycle distance by income = **None**	Walking and bicycling time by income = **None**

*Does not includes distance and time for access/egress trip to PT and IPT by walk and bicycle

Table 8: Data available to measure exposure from city specific studies

Exposure	**Air quality level**	**Safety**	**Physical activity**
Basic-level model	Travel time by modes = **None**	Travel distance by modes = **12**	Same as consequences data
		Modal share and = **18** frequency of trips= **12**	
Intermediate-level model	Travel time by mode and geographical location= = **None**		
	Travel time by mode and time of day= **None**	Travel distance by mode and time of day= **None**	
	Travel time by mode and road type= **None**	Travel distance by mode and road type= **None**	
	Travel time by mode and built-form= **None**	Travel distance by mode and urban form = **None**	
Detail model	Travel time by mode and gender= **None**	Travel distance by mode and gender= **None**	
	Travel time by mode and age group = **None**	Travel distance by mode and age-group= **None**	
	Travel time by mode and income= **None**	Travel distance by mode and income= **None**	

4.5 Data reliability

Data reliability can be assessed using two criteria – spatial disaggregation used for analysis also termed as the area of traffic analysis zone (TAZ) and representativeness of sample to population. Appropriate disaggregation of study scale is necessary to account for majority of the non-motorized trips in travel behavior studies and minimize the errors due to ecological fallacy (Jain and Tiwari, 2017). . Only 13 of the total studies provides detail related to the study area and number of TAZ used for the analysis. The average TAZ size range between 1.3 sq.km and 14.5 sq.km in these studies. The average TAZ in these studies is 5.9 sq.km with std. dev. of 4.1 sq.km.

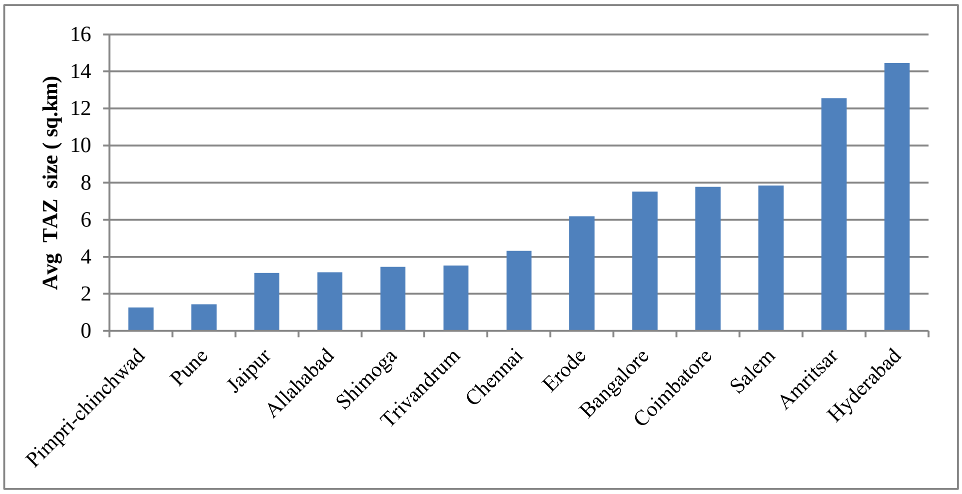

Fig. 5. Average TAZ sizes in different cities

Of the total studies assessed 15 studies have reported the sample size used to capture travel behaviour data at household level. The sample size used for conducting these studies range from 1325 households in Kochi for preparing DPR and 37,730 households for preparing CTTP for Chennai (See figure 6).

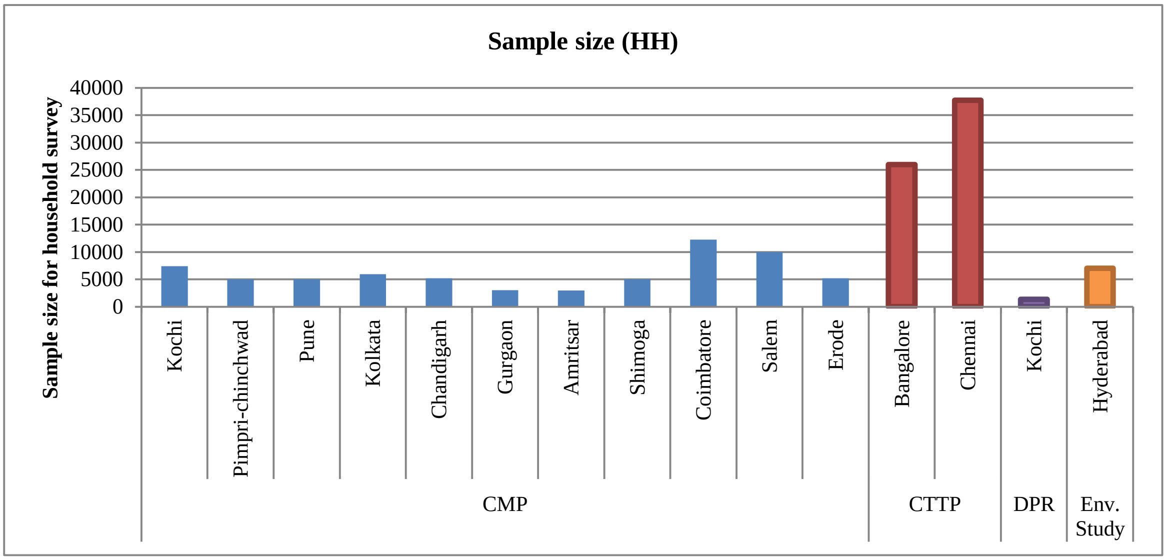

Fig. 6. Survey sample sizes in different cities

It is also required to assess the quality of survey as the large sample size alone does not guarantee the reliability of the survey for extrapolating the studied behaviour from sample to population. For the purpose we have compared the socio-economic description of the sampled households in the reported studies with the socio-economic data provided by census 2011 (Table 9).

Table: Sample sizes and distribution of households by types for various cities

City	Household size	No vehicle ownership	Own car	Own MTW	Own Bicycle	Percentage female	Sample size
Bangalore	3.88						26000
Kochi		52.22%					7400
Pimpri-chinchwad				72%		45%	4869
Pune							5000
Kolkata		49.20%					5955
Chandigarh	4.46	3%					5175
Chennai	4.09						37730
Gurgaon	3.81						3000
Amritsar							2944
Shimoga	4.5		10%		52%		5000
Coimbatore		14%					12240
Salem			4%				10000
Erode			3%				5200

The t-test analysis is conducted to assess the representativeness of the sample data collected for conducting the studies to the total population of the city. The analysis shows that except for Pimpri-Chinchwad, Shimoga and Coimbatore the t-test values are greater than 1.96 (see Figure 8). Therefore, for all the other cities the reliability score of the analysis conducted using the sample household surveys is less than the desirable limits.

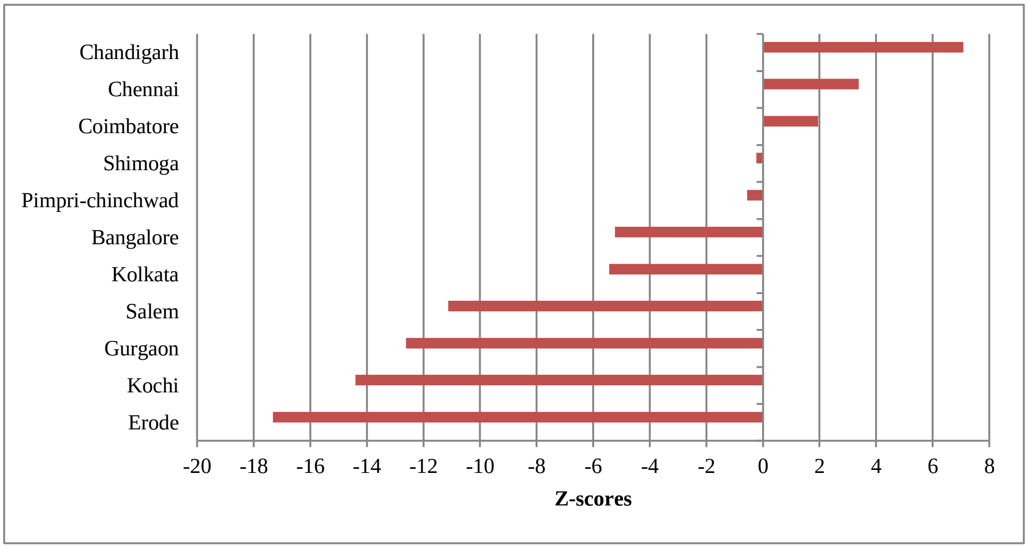

Fig 7: Reliability scores for different cities

5. Discussion and conclusions

Limited data is available to estimate the impacts of transport activity on human health in Indian cities. Most of the mobility studies conducted in Indian cities do not collect data on air quality levels. Centre for Pollution Control Board (CPCB), India has already installed continuous air quality monitors in 82 cities. These monitors continuously provide an estimate of PM 10 and PM 2.5 levels aggregated at city level. Urban Emissions also provide hourly average concentration levels of PM 2.5 and PM 10 at 25 km X 25 km grid level for India (http://www.urbanemissions.info/). The data can be used to estimate consequences with regard to the ambient air quality levels in different cities. City level mobility studies should incorporate information on air pollution and transport sectors contribution to it.

Road safety is classified in terms of fatal and non-fatal injuries. The data for non-fatal is highly unreliable and under-reported in India. Therefore, health impact studies for Indian cities need to consider years of life lost due to road-crash related fatality only. However, to estimate the impact, disaggregation of fatality data by victim and impacting modes is required. None of the studies referred in this analysis gives due weightage to road safety assessment.

Transport related involvement in physical activity can be determined based on the travel behaviour studies. These should include walking, bicycling and use of non-motorized transport for accessing/egressing public transport systems. Census of India provides mode-wise distances for ‘other worker’ trips at district level. Such data is also disaggregated by gender. City specific transport studies also provide information on travel behaviour for all the on a typical workday. However, of the total 21 referred studies, only 11 studies report walking and bicycling distance for all the trips. This does not include the walking and bicycling distance or time for accessing/egressing public transport system. There is a need to identify methods to enable the usage of travel characteristics data from Census for other worker trips to estimate travel behaviour for all trips. This information can be can be used to measure exposure level to both air pollution and road safety as well.

In conclusion, limited data is available to measure consequences in Indian cities. Second, disaggregation of travel activity by spatial location and socio-economic characteristics is not available. This therefore restricts the estimation of actual number of population exposed to different consequences. Third, only three of the total 21 city specific studies are shown to have reliable representation of sample to the total population. The existing dataset therefore restricts estimation of health impact due to transport sector to limited number of Indian cities and draw estimates only at basic level. Multiple sources of data are recognized through this study varying from national repositories to city specific studies. The type and quantum of data collected therefore varies between the different sources. There is also variation in the timeline in which the data was collected and method employed for collecting the data. Further work is required to establish methods to fill the missing data gap and utilize multiple sources of data to estimate health impacts due to transport sector in India.

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References

Apparicio, P., Carrier, M., Gelb, J.+., Seguin, A.M., & Kingham, S. 2016. Cyclists' exposure to air pollution and road traffic noise in central city neighbourhoods of Montreal. Journal of Transport Geography, 57, 63-69

Bhalla, K., Ezzati Majid, J.M., Salomon, J., & Reich, M. 2007. A Risk-Based Method for Modeling Traffic Fatalities. Risk Analysis, 27, (1) 125-136

Gotschi, T. & Hadden Loh, T. 2017. Advancing project-scale health impact modeling for active transportation: A user survey and health impact calculation of 14 US trails. Journal of Transport & Health, 4, 334-347

Guttikunda, S.K. & Goel, R. 2013. Health impacts of particulate pollution in a megacity-Delhi, India. Environmental Development, 6, 8-20

IEA 2007, Key World Energy Statistics, OECD/ International Energy Agency.

IEA 2017, Key World Energy Statistics, OECD/ International Energy Agency.

IUT 2018, Web portal of Knowledge Management centre, Institute of Urban Transport India available at http://www.iutindia.org/services/KMCentre.aspx. Accessed on 12th Sept. 2018.

Jain, D. & Tiwari, G. 2017. Population disaggregation to capture short trips - Vishakhapatnam, India-. Computers, Environment and Urban Systems, 62, 7-18

Johansson, C., L+¦venheim, B., Schantz, P., Wahlgren, L., Almstr+¦m, P., Markstedt, A., Str+¦mgren, M., Forsberg, B., & Sommar, J.N. 2017. Impacts on air pollution and health by changing commuting from car to bicycle. Science of The Total Environment, 584-585, 55-63

Rojas-Rueda, D., de Nazelle, A., Teixid+¦, O., & Nieuwenhuijsen, M.J. 2012. Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study. Environment International, 49, 100-109

Sa, T.H.d., Tainio, M., Goodman, A., Edwards, P., Haines, A., Gouveia, N., Monteiro, C., & Woodcock, J. 2017. Health impact modelling of different travel patterns on physical activity, air pollution and road injuries for Sao Paulo, Brazil. Environment International, 108, 22-31

San Jose, R., Perez, J.L., Perez, L., & Gonzalez Barras, R.M. 2018. Effects of climate change on the health of citizens modelling urban weather and air pollution. Energy, 165, 53-62

Smith, T.W., Axon, C.J., & Darton, R.C. 2013. The impact on human health of car-related air pollution in the UK, 1995GÇô2005. Atmospheric Environment, 77, 260-266

Stevenson, M., Thompson, J., de Sa, T.H., Ewing, R., Mohan, D., McClure, R., Roberts, I., Tiwari, G., Giles-Corti, B., Sun, X., Wallace, M., & Woodcock, J. 2016. Land use, transport, and population health: estimating the health benefits of compact cities. The Lancet, 388, (10062) 2925-2935

Tainio, M. 2015. Burden of disease caused by local transport in Warsaw, Poland. Journal of Transport & Health, 2, (3) 423-433

Tainio, M., de Nazelle, A.J., G+¦tschi, T., Kahlmeier, S., Rojas-Rueda, D., Nieuwenhuijsen, M.J., de S+í, T.H.r., Kelly, P., & Woodcock, J. 2016. Can air pollution negate the health benefits of cycling and walking? Preventive Medicine, 87, 233-236

Tiwari, G. & Jain, D. 2013. NMT infrastructure in India: Investment, Policy and Design Technical University of Denmark, UNEP Risø Centre on Energy, Climate and Sustainable Development.

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A., Franco, O.H., Haines, A., Hickman, R., Lindsay, G., Mittal, I., Mohan, D., Tiwari, G., Woodward, A., & Roberts, I. 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. The Lancet, 374, (9705)

World Health Organization 2015. Global status report on road safety 2015 World Health Organization.

World Health Organization 2016. Ambient air pollution: A global assessment of exposure and burden of disease.