How Reliable are the Official Estimates of India's Road Transport Energy Consumption and Carbon Emissions?

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Abstract

Official statistics on road transport energy consumption in India claims possible decouple between road transport energy consumption and transport demand between 1995 to 2005. Transport sector fuel consumption over 1995 to 2005 ***does not show any increase in fuel consumption*** *while over the same period, number of vehicles increased three fold, freight activity (tonkm) increased by more than 2 times while the GDP per capita increased by more than 5% annually.*

But is this really good news?

The main objective of this research is to correlate official fuel consumption data (i.e. top-down) with bottom up quantifications and identify potential conflicts. Using bottom-up studies conducted by different researchers and by developing a baseline with different scenarios, various issues are identified for improvement. It was found that official statistics on road transport fuel consumption do not provide enough justification and insights on the implication of the growing travel demand. Diesel consumption data was found to be the main source of variation between top-down and bottom-up estimates. The trends and scenarios in this research explain and establish the need to prioritize diesel vehicle data collection to improve bottom-up modelling in India.

Keywords: Transport Emissions, India, Diesel, ASIF

I. INTRODUCTION

In India, over the past decade, transport demand has exceeded (GDP) Gross Domestic Product growth rates[1]. This growth in travel demand has a huge implication on energy use and transport emissions. India's transport sector is powered by diesel and it accounts for 60-90% of transport fuel consumption [2,3]. Latest research from UNEP projects six times increase in transport fuel consumption from 2010 to 2050 under business as usual growth in India [4], while International Energy Outlook 2013 estimates that the India's transportation energy use would grow at fastest rate in the world, averaging 5.1 percent per year, compared with the world average of 1.1 percent per year[5].

In order to improve efficiency of transport sector, India has now taken a voluntary pledge to reduce its emissions intensity by 20–25% by 2020, from the 2005 levels. However, in order to plan for future energy efficiency improvements or low carbon transport, it is essential to understand the past performance of road transport sector in terms of fuel consumption and carbon emissions.

Review of official statistics from India on road transport CO_2 emissions over the last two decades provides the following facts

1. India's first national communication report to United Nations Framework Convention on Climate Change (UNFCCC) had estimated **72 million tons** of CO_2 in 1994 with only **29 million vehicles** [6]
2. India's premier institute which supports Green House Gas inventories in transport sector had estimated **105 million tons** of CO_2 with **48 million vehicles** in 2000 [2]
3. India's second national communication report to UNFCCC has estimated 121 million tons of CO_2 in 2007 with 91 million registered vehicles [3]
4. Energy statistics 2011 suggest that transport emissions as established by official fuel sales in 2010 was 145 million tons while vehicle ownership was 128 million [7,8]
5. Transport sector fuel consumption over 1995 to 2005 **does not show any increase in fuel consumption** (33 MT in 1995 to 31 MT in 2005) while over the same period, number of vehicles increased three fold, freight activity (tonkm) increased by more than 2 times while the GDP per capita increased by more than 5% annually based on planning commission estimates. [7,8,9,10]

The above statements point towards one important conclusion i.e. road transport CO_2 emissions are starting to decouple from vehicle ownership and activity levels in India over the last decade. The Indian Planning Commission estimate lowered fuel consumption growth rates due to i) improved efficiency of vehicles, ii) increased fuel price and iii) better road conditions [10].

But is this really good news?

This paper investigates if the road transport sector in India is showing signs of decouple between energy consumption and travel demand or if there are inconsistencies in the official estimates and therefore not reflect the ground realities. First a top down assessment is discussed which is followed by a discussion on bottom-up approach, drivers relevant for bottom-up assessment, bottom-up quantifications followed by a discussion on ways and means to improve bottom-up estimates in India are also discussed.

II. TOP DOWN ESTIMATES

Collecting fuel sales from data suppliers of fuels provides valuable insights on fuel consumption in the sector. Since fuel is taxed, this data is considered to be accurate. The Ministry of Petroleum and Natural gas (MoPNG) is mandated to collect and report fuel production, import and consumption statistics which it does though the Petroleum Planning and Analysis Cell (PPAC) Statistics from India's MoPNG [7,11,12] and International Energy Agency (IEA) [9] establish that from 1995 to 2005, transport sector fuel consumption has not shown any growth i.e. stagnant consumption from 33 MT in 1995 to 31 MT in 2005.

In the same period, gasoline and diesel consumption show contrasting consumption patterns. While, gasoline consumption has nearly doubled at an annual growth rate of 6% i.e. (from 4.68 to 8.65 MT), diesel consumption in transport has decreased at an annual rate of 2.5%. Since, transport sector is mainly powered by diesel (60-90%), analyzing diesel consumption over the past two decades therefore, holds the key to understand if road transport sector in India is showing signs of decouple between energy consumption and travel demand.

The main point of interest is year 1995-1996 (below figure) where we see a drop of 28% in diesel consumption. It took nearly 13 years to recover this drop as the diesel consumption growth increased marginally. During the same period, nearly 25,000 new commercial heavy duty diesel vehicles were added to fleet annually [13].

Researchers who have analyzed this drop have come to following conclusions.

Figure 1 - Official Estimates of Diesel Consumption (MTOE) in Road Transport [7,11,12]

1. Timilsina et al [14] reported that the change in diesel consumption maybe a statistical adjustment in the reporting of diesel consumption and further suggests that *"It is thus likely that both CO_2 emission growth and transportation energy intensity for India ought to be revised downwards from 1980 to 1995 to reflect this adjustment".* They found that the transport energy intensity (energy consumption per GDP output) in India was steadily improving from 1980 to 2005. If there was no improvement in energy intensity, emissions could have increased by additional 143% between 1980 to 2005. In addition to this improvement in energy intensity, model mix positive impact has resulted in restriction of emission growth by 14.3%.

2. The IEA in its 2004 energy outlook projections reflected moderation of transport growth and subsequent fuel consumption and scaled down the earlier estimates and projections of oil consumption (WEO 2000). The 2000 Outlook reported 1997 transport CO_2 emissions as 124 MT while the 2004 Outlook reported 2002 transport CO_2 emissions as 94 MT. The 2020 projections of Outlook 2000 were reduced by half in outlook 2004. Though IEA did not disclose the reason behind reducing the projection by 50% , the main cause can be attributed to revised diesel consumption levels being considered as a statistical adjustment(below table). [15,16]

	2020 Road Transport CO_2 (MT)
IEA World Energy Outlook 2000	**407**
IEA World Energy Outlook 2004	238
IEA World Energy Outlook 2012	239

Table 1 - World Energy Outlook 2020 Projections for Road Transport CO_2 Emissions

3. US EIA in its international energy outlook (IEO) 2005 revised the 2020 energy consumption projections by 45% (reduction) when compared with IEO 2002 [17,18].

4. Stephane et al. reports that in 1996 a serious break in diesel consumption trend was observed. It suggests - *"In reality, no major activity disturbance or technology breakthrough can explain such a decline over a one year period. It is believed that a major restructuring in statistics accounting explains this trend, however, no official document or note was found to justify this argument. Hence we*

assumed that more recent statistics on diesel consumption for the transport sector reflect the real consumption, we back calculated with the vehicle stock the historical diesel consumption" [19]

Majority of researchers and institutions have considered the significant drop in diesel consumption as a statistical correction and reduced their future projections due to stagnant diesel consumption growth. The government also has considered the low growth in transport fuel consumption as a reality based on the submissions to UNFCCC.

This modest growth is a contrast to the rapid increase in vehicle numbers, economic activity and absence and poor implementation of comprehensive sustainable transport policies and options. In terms of transport CO_2 intensity with respect to economy (i.e.kg CO_2 per GDP USD constant 2005), the intensity increases between 1980 to 1995 (0.16 to 0.22) and decreases from 1995 to 2005 (0.22 to 0.11). This decrease is at a rate of -6.6% annually. From 2005 to 2010, transport CO_2 intensity has stabilized around 0.12. No other country has shown such a dramatic improvement in intensity [1,20]. In the subsequent section, with bottom-up analysis this aspect is dissected in more detail.

III. BOTTOM-UP APPROACH

In 1998, Lee Schipper et al.[21] developed an ASIF framework which is an acronym for “activity” , “mode share”, “intensity”, “fuel mix”. This framework shifted the entire discussion from black box modelling to a transparent system of calculating emissions thus establishing the business case for low carbon transport in Asia. In this framework, Emissions (G) in the transport sector are dependent on the level of travel activity (A) in passenger kilometers (or ton-km for freight), across all modes; the mode structure (S); the fuel intensity of each mode (I), in litres per passenger-km (or ton-km for freight),; and the carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per litre of fuel consumed.

$$\mathbf{G = A * S * I * F}$$

Thus, the main factors influencing carbon emissions in transport are,

Activity and Mode Share – It describes how much and how people or freight travel and is measured in terms of passenger –km or ton-km and disaggregated by mode type including Non Motorized Transport. Passenger kms (or freight kilometre) are calculated using number of vehicles, number of trips, the distances travelled and the occupancy (or loading) on the vehicles.

The fuel intensity of mode is generally measured in energy units per passenger-km i.e. liters of fuel per passenger-km or in megajoules (MJ) per pass-km. It depends on the vehicle fuel intensity, occupancy driving behaviour, engine technology, weight, aerodynamic design and congestion on the road.

Carbon content of fuel i.e. F is amount of carbon released per unit of energy consumed.

The relative importance of each of the connected components to total changes in emissions varies with demand and policy interventions. Not all parameters would respond similarly to a given stimulus and each component may directly or indirectly influence other components. For example, increased fuel efficiency may lead to more travel demand or increased occupancy of vehicles may reduce total vehicle kilometres. In India, "A" and "S" factors have undergone significant transformation when compared with "I" and "F". Of all the ASIF components in India,” F” the carbon content of fuels has not changed in the road transport sector and thus neglected in the subsequent discussions. The main requirement of bottom-up modelling is to get number of vehicles, fuel efficiency per kilometer per year and kilometer driven per vehicle per year all distinguished by fuel. This is a major challenge in a country like India where limited resources are spent on collecting periodic data.

IV. DRIVERS FOR BOTTOM-UP EMISSION GROWTH

Transport sector demand is growing rapidly with economic growth, urbanization, increased investment in infrastructure, industrialization etc. High income growth over the past decade has translated in increased vehicle ownership and use. The vehicle registrations have increased from 5 million in 1981 to 142 million in 2011 [8]. While the total number of vehicles are high, ownership levels (measured as motorization levels) are low (114 vehicles for 1,000 people). Some experts expect an acceleration in the increase in vehicle ownership levels in the coming decades with the growth nearly twice as fast as per-capita income in India [22] or almost four times faster the growth of population [23].

Currently, 72% of the vehicle fleet consists of only two wheelers. cars constitute the fastest growing vehicle segment on road with 10.6% annual growth from 2001 to 2011. It is interesting to note that passenger and freight transport demand exceeds the vehicle growth levels. The Eleventh five year plan estimates that between 2000 and 2010, passenger kilometer travel (pkm) increased at an annual rate of 15% i.e. from 2076 to 5578 billion PKM and freight travel increased 8% annually from 494 to 1115 billion tkm [10]. Ministry of Urban Development (MoUD) estimates that the urban transport demand (passenger kilometer travel) has been increasing at 7% from 1994 to 2007 [24].

This increase has been facilitated with the massive expansion of national highways which links different cities in India, high economic growth and comparatively smaller growth in Indian railways. India has around 3.3 million kilometers of road network which is the second largest in the world and over the past two decades, road infrastructure has expanded at an annual rate of 3.4%. This rapid expansion of highways has attracted the traffic from railways. In 1980, road network used to carry 38% of freight and 72% of passenger traffic, it now carries nearly 60% of freight and 87% of passenger traffic [25]. Clearly, not only the transport demand has increased, modal-mix has also shifted towards more carbon intensive road transport sector.

V. FINDINGS

Bottom-up investigations by different studies however, reveals a completely different story. estimates (below figure) indicate that during 2000 to 2010, annual growth rate of emissions ranged from 6-14% while, top down estimates from fuel sales indicate 3.4% annual growth rate. There is a significant gap between what government statistics suggest and what bottom-up estimates reveal.

Study	Time Period	% Growth rates in Road Transport CO_2 emissions
Clean Air Asia [1]	2000-2010	8
Baidiya [26]	2000-2005	6.6
A T Kearney [27]	2000-2010	6.1
ICCT Roadmap [20]	2000-2010	6.7
IEA Momo [28]	2000-2010	6.6
TERI [29]	2001-2006	14.5
ITPS [30]	2000-2010	8
ADB [31]	2005-2008	8

Table 2 - Road Transport CO_2 Emissions Annual Growth Rate

In past, Zhou et al.[32] had built several scenarios to discover the drop in diesel consumption between 1995 to 2000 and the main conclusion was that such drop is unrealistic and further research is required to investigate diesel consumption trends in India.

There is a wide variation among the bottom-up emission estimates and the predominant cause of variation is the error in computing diesel consumption. It is interesting to note that gasoline consumption explains only 20% of the variation as seen from the below table.

Year	Top down CO_2 Emissions from Fuel sales	Bottom-up Road Transport CO2(MT) estimates range		Bottom-up Road Transport Gasoline CO2 (MT) estimates range	
		Low	High	Low	High
2000	86	81	138	18	37
2005	90	120	219	24	43
2010	145	161	315	40	82

Table 3 - Road Transport CO_2 Emissions Comparison of Top-down and Bottom-up Estimates

Lack of data on fuel type segregated vehicles is also causing serious distortions in the estimates. For example, IEA World Energy Outlook 1998 [33] suggest that 80% of road vehicles in India run on diesel fuel while Clean Air Asia [1] suggests nearly 11%of road vehicles run on diesel fuel in 2000.

Below figure provides diesel consumption estimates based on various top down and bottom-up studies. All the bottom-up studies show high increase in diesel consumption. It is very interesting to note that while official diesel consumption annual growth rates decreases from 8% to -2% from 1985 -1995 to 1995-2005, the diesel vehicle ownership rates increases from 7 to 11% from 1985 - 1995 and 1995 -2005. Clearly, increase in vehicle ownership cannot lead to reduction in fuel consumption values until and unless, the vehicle activity reduction and fuel efficiency values have shown radical improvements as established by below scenarios.

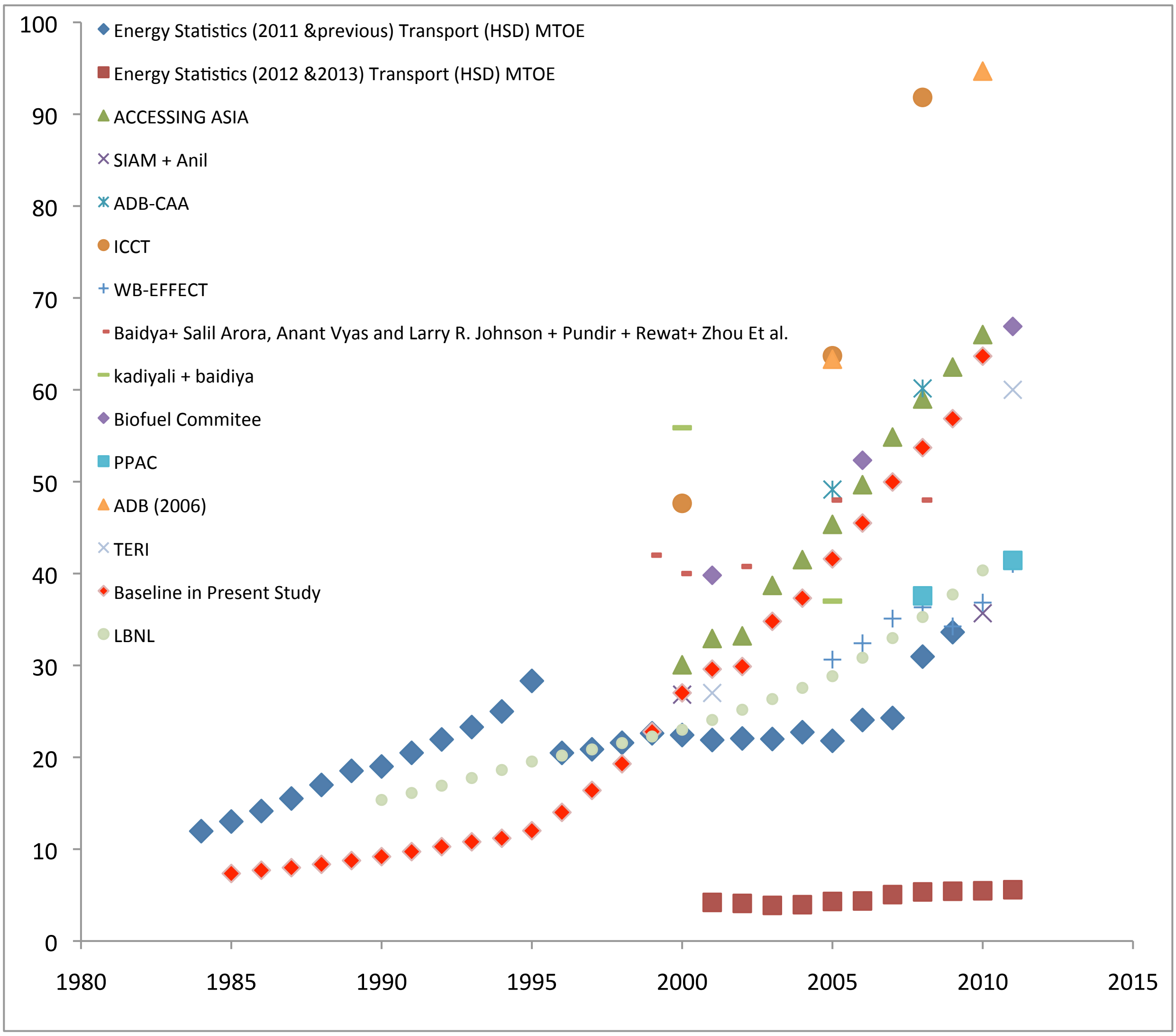

Figure 2 : Diesel Consumption in Road Transport [1,2,7,11,12,26,29,30,31,32,34,35,36,37,38,39]

In order to understand the road transport diesel consumption, a baseline from 1985 to 2010 is established using vehicle statistics from Ministry of Road Transport and Highways' annual reports , literature review and assumptions as detailed out in below table

Modes	Average Vehicle Travel/Year				Average Fuel Efficiency (kmpl)			
	Max	Min	Average	**This study**	Max	Min	Average	**This study**
3 Wheeler	44000	14850	31425	**30000**	43	20	35	**35**
Car	35000	7500	13306	**12000**	18	8	13	**16**
Bus	126700	30000	74302	**50000**	6	3	4	**4.5**
LCV	60000	19400	31859	**25000**	13	7	10	**10**
Truck	108000	30000	56299	**50000**	5	2	3	**4**

Table 4 - Variation of Average Vehicle Travel and Average Fuel Efficiency

The baseline established (above figure) considers constant vehicle activity and fuel efficiency values over the years. The constructed baseline falls below the official fuel consumption values till 1999 and after this it gains sufficient lead when compared to official consumption values by 2010. There is a significant variation with official values both pre 1999 and post 1999. The diesel consumption growth rates for 1985-1995 and 1995-2005 are 5% and 13% respectively. This finding contradicts official diesel consumption annual growth rates of 8% and -2% from 1985 -1995 to 1995-2005.

An alternate scenario was also considered where it is assumed that only 70% of vehicles registered are available on roads. This assumption stems from the research by Baidiya et al. and others [35,38,31,32] where it was established that only two thirds or maximum three quarters of the vehicles registered are actually circulating on the road. Based on the revised calculations, the variation still exists predominantly before 2002 and after 2002 till 2007. The diesel consumption growth rates for 1985-1995, 1995-2005 and 2005-2010 are 5%, 13% and 9%. Since majority of diesel vehicles (LCV, HCV and bus) are commercial vehicles, they are registered annually and thus, there should not be a great anomaly in vehicle on roads and registered vehicles.

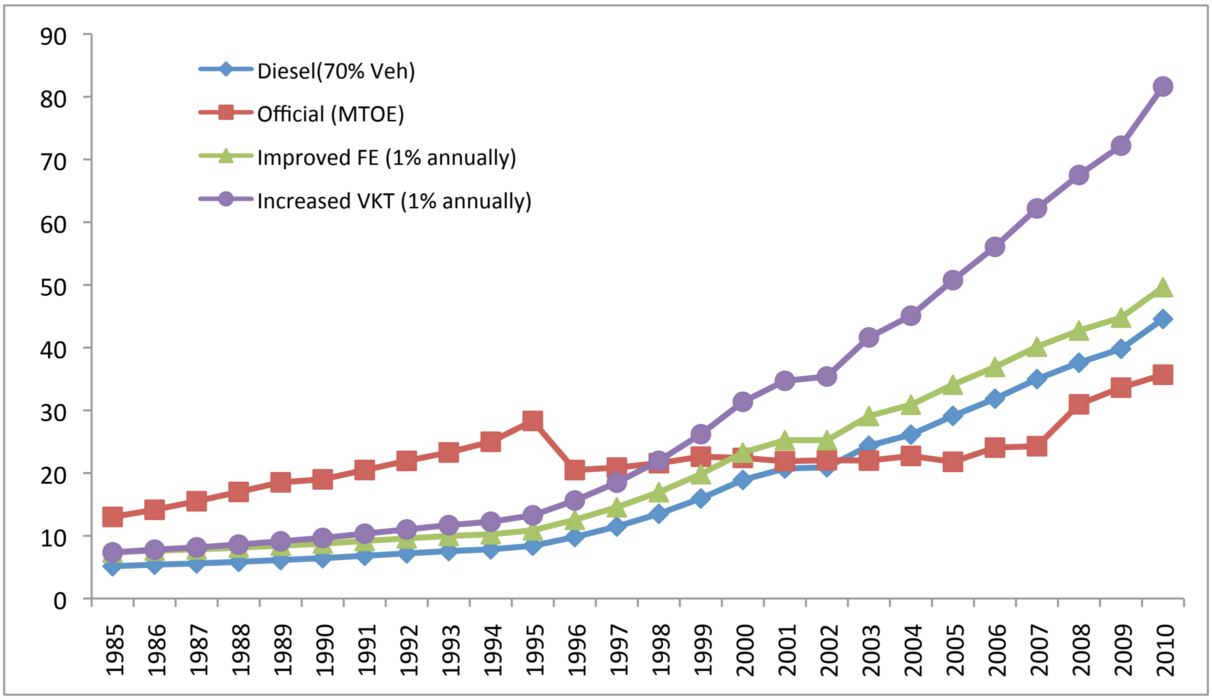

Figure 3 : Diesel Consumption Scenario Variations in Road Transport

Many researchers and studies have concluded that vehicle activity levels have increased over the years due to infrastructure improvements and low vehicle ownership. If the vehicle activity levels would increase annually (by say 1%), the variation post 1999 levels would increase further (above figure). Considering a scenario where the vehicle activity levels do not increase, but fuel efficiency of vehicles improves by 1% annually from 1985, the variation in pre 1999 levels increases further. different studies over the years have not suggested any drastic improvement in fuel efficiency of vehicles due to absence of fuel economy standards. Clearly, it is very difficult to replicate official diesel consumption values with bottom-up measurements and official consumption values seem to be unreliable.

Stephane et al. [19] has considered the official statistics to be reflective of fuel consumption and have tried to correlate official fuel consumption data with bottom-up diesel consumption values from 1990 to 2005. In order to match the official consumption values, the energy efficiency of vehicles need to increase by 1-4% annually while the travel distance for each mode needs to reduce by 1-2% annually from 1990 onwards. This is impossible to achieve without the implementation of aggressive Avoid-shift-Improve [40] policies and strategies.

Based on the scenarios, official fuel consumption data does seems to overestimate diesel consumption before 1995 and underestimates fuel consumption after 1995 and both these variations are very high in magnitude.

Interestingly, among diesel vehicles there is no consistency in consumption patterns in different bottom-up studies as shown in below table. Clearly, with annual diesel fuel subsidies amounting to 10 billion USD [41], lack of clear insight on diesel consumption among various modes may delay policy implementation.

Modes	Diesel Consumption (% in road transport)						
	CAA[1]	SIAM[38]	PPAC[38]	ICCT[20]	Author-Baseline	LBNL[19]	PPAC-M/s Nielsen [48]
Car	2	10	23	4	3	8	19
Bus	24	11	18	19	22	25	14
Trucks	74	72	58	76	74	68	40

Table 5 - Variation in Diesel Consumption Share of Different Modes of Road Transport

Combining top-down CO_2 estimates with travel demand i.e. official road transport CO_2 emissions and official travel activity in 2010 (8572 billion pkm & 1115 billion ton-km), efficiency of passenger and freight travel can be derived. For passenger and freight transport, an efficiency of **4 grams of CO_2/pkm** and **87 grams of CO_2/ton-km** respectively is obtained. A value of 4 grams of CO_2 per passenger kilometer is impossible to achieve on road even if all the people travel in only buses. India's freight industry is plagued with high empty trips, low capacity of trucks, poor road geometrics and fragmented industry and thus efficiency cannot be high (87 g/tkm). Further, review of international literature on grams of CO_2/tonkm of road freight provides a range between 130 to 350 grams per tonkm [1,20]. Clearly, Indian freight cannot have the best efficiency.

Considering the issues involved, India's transport sector efficiency cannot be so low and thus transport CO_2 emissions or fuel consumption as suggested by official statistics does not correlate with ground realities.

All the above discussion on official fuel consumption values have been carried out using data from energy statistics of the Indian government [7,11,12] and IEA [9]. However, latest updates from energy statistics 2012 and 2013 [42,43] have readjusted 2001 to 2011 diesel consumption values which are lower by 5 to 6 times than pre-2011 values. Majority of transport sector diesel consumption has been reallocated to 'miscellaneous category' without enough clarification. This change of statistics in 2012 and 2013 have been carried out only for road transport sector and not for railways and waterways. The 2011 road transport diesel consumption value has been readjusted around 5 million tons from earlier 33 million tons. In terms of CO_2 emissions from diesel consumption, it is a drop from around 100 million tons to around 15 million tons. Since Indian transport industry is mainly powered by diesel, drastic modification in diesel consumption values would mean drastic reduction in India's transport emissions.

In top down approach, there are always possibilities of misallocation of deliveries between main source categories, to neglect impact of fuel adulteration and smuggling and due to tax evasion, fuel consumption not getting reflected on fuel tax receipts. In India, fuel adulteration is significant. Since, gasoline is taxed most heavily, followed by diesel, kerosene, industrial solvents and recycled lubricants, there are financial benefits of adulteration at the expense of air pollution and deterioration of vehicle [44]. Many estimates have indicated loss to an extent of 10% of fuel sales.

Thus, official diesel consumption values need to be revised and the Indian Government needs to consider using bottom-up approach with better data for estimating fuel consumption and for planning policies. Ideally, top down approach is more accurate than bottom-up approach as the number of assumptions and data requirements are less. However, Indian top-down estimates really do not reflect the travel demand increase. Also, the total fuel consumption does not provide any insights on the transport problems i.e. the fuel sold can be consumed by any kind of motorized mode of transport and isolating the impact of each mode is impossible. With top-down approach, authorities cannot really differentiate between good news from bad. Thus, bottom-up measurements provide the answers for decision making. It allows measurement of policies, strategies, projects, contribution of modes etc

VI. IMPROVING BOTTOM-UP ESTIMATES

If detailed vehicle activity data is available, it is considered as a "best practice" to perform a validation of total fuel sales against fuel used based on passenger and vehicle kilometres travelled. This often leads to adjustment of travel activity as fuel sales are considered as accurate while travel activity most unreliable in ASIF framework. For example, in Global Change Assessment model [45], the travel demand is reduced by 41% and 29% for passenger and freight travel activity in India to match official fuel consumption data. Clearly, if the official fuel consumption data is misreported or misallocated, reduction in travel demand may lead to unrealistic estimates and may not provide valuable insights for planning and investments.

In order to improve bottom-up quantifications, availability of national household travel surveys, origin-destination surveys, commodity flow surveys is a must. These surveys provide valuable insights on travel activity patterns. Further, on-road measurements of fuel efficiency of vehicles and occupancy or load-factor observations or surveys are also required for proper estimation of fuel consumption and emissions. Presently, all the above information is absent and there is complete lack of regular and reliable data on passenger and freight movement.

It is interesting to note that the data on different components of “ASIF”, belongs to different ministries or authorities i.e. transport, energy (MoPNG), finance, Home affairs, Urban Development and environmental ministries provide the necessary data for crunching numbers for ASIF in India. MoPNG provides fuel consumption statistics while MoEF has the mandate to estimate and report emissions from transport sector.

The Ministry of Road Transport & Highways (MORTH) maintains the National Database on road transport sector and provides basic information on transport activity, taxation and infrastructure. The mandate to improve urban transport data is on the Ministry of Urban Development and the Institute of Urban Transport which manages the affairs of the National Urban Transport Information Centre. This center has been established in 2006 to compile data on urban transport in scientifically designed formats and maintain it methodically. Further, for urban transport, under the Jawaharlal Nehru Urban Renewal Mission, there was a provision of grant assistance to state governments of about 40% of the cost of studies on issues related to traffic and transportation in urban areas. This led to manifold increase in city level transport data collection.

In terms of vehicle on road, private vehicles have fifteen years registration validity in India and thus exact vehicles on road can be different from number of vehicles registered. In 2005, the difference in vehicle ownership (vehicles on road) considered in different studies was as high as 33 million vehicles (below figure). Since, the vehicle taxation is also not levied annually for private vehicles, there is almost no clear way to distinguish between vehicles registered and actually in-use. However, commercial vehicles registration data (especially registered buses and trucks) is relatively more accurate as the registration renewal process is carried out annually. But researchers often consider trucks and bus data to be highly unreliable [31,35,38] which needs more investigation.

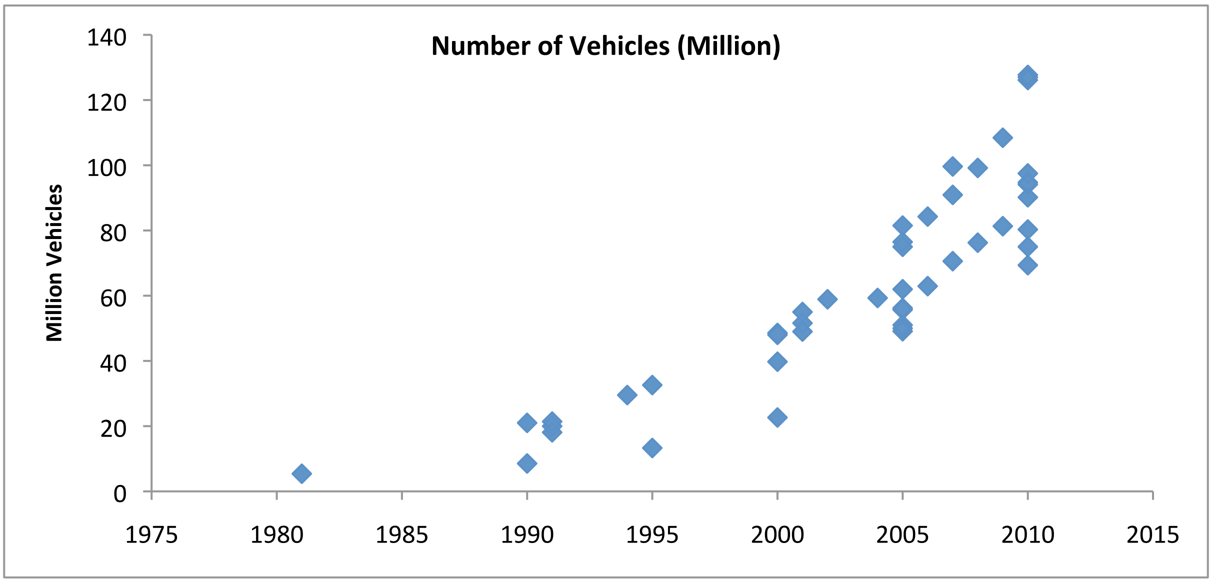

Figure 4 : Variation in Total Vehicles on Road in Different Studies [1,2,8,19,20,26,27,30,31,32,36 and 37]

In terms of vehicle activity, trucks and buses have maximum variation among different studies. Average vehicle travel per year for truck and bus can vary from 30,000 to 120,000 (as shown in table). Since, data is not available, researchers have to resort to expert judgment in estimating average travel of vehicle and this sometimes can contribute to substantial variations. For example, the Indian Planning Commission in its twelfth five year plan [46] estimates that a bus on an average conducts 7.7 million passenger kilometer travel per year. Assuming a normal occupancy of 40 would establish that a bus needs to annually travel 192,000km to cater for 7.7 million annual PKM which is practically not possible.

For accurate bottom-up quantifications, the transport data needs to be disaggregated. For example, many researchers consider 'cars' as a single variable and allocate travel activity to it. Cars can mean - mini cars, taxis, SUV's and can be powered by gasoline, diesel, CNG etc. Different types of cars can have different travel patterns and different fuel efficiencies. For example, Society of Indian Automobile Manufacturers(SIAM) considers commercial LDV's (jeeps, LCV's modified for passengers) to travel annually to about 43,000 km and personal utility vehicles to travel around 20,000 km, Diesel personal cars to travel around 11,000 km while a Diesel taxi about 24,000 km annually. For, all these classifications, if a single variable is proposed and activity allocated based on single use, errors would magnify. Aggregating different modes into a single mode reduces the accuracy of bottom-up estimates.

Planning commission estimates of travel demand [10] do not consider non motorized transport (NMT) modes such as walking and cycling while quantifying passenger kilometer travel (PKM). PKM is considered as "the sum of the length of journeys travelled by all passengers carried by a vehicle". This is a significant barrier in understanding NMT usage and to establish its role in reducing carbon emissions.

Type of data collected and generated is often influenced by its need (driver). Currently, Indian authorities have not conducted adequate surveys and investigations exclusively for bottom-up modeling. With increasing focus on low carbon transport, India will increasingly need to take informed decisions on various transport-related policies and investments required to reduce carbon emissions.

For improving bottom-up modelling, exclusive focus on diesel vehicles provides a great opportunity to improve estimates in the short term. Diesel vehicles currently constitute less than 10% of total fleet but contribute around 30% of total vehicle travel and consume around 70% of total fuel as per government statistics. Since majority of diesel vehicles are commercial in nature, there is a huge opportunity to introduce a systematic collection of data of vehicle on road, activity and fuel efficiency.

The problem is not only with the data or assumptions but sometimes even with the approach adopted. Recently India appointed an expert committee to evaluate options to reduce India's emission intensity over 2005-2020. This study published a report called as "Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth" [47]. In transport sector, the methodology adopted is to calculate individual impact of policy measure such as mode shift, fuel efficiency of vehicles etc. and adding up the individual savings to determine the total impact under different scenarios such as "determined effort" and "aggressive effort" etc depicting different implementation and economic growth scenarios. For example, the report recommends that under 8% GDP growth and under scenarios such as "determined effort" and "aggressive effort", the total reductions due to various strategies is 42 and 63 million tons of CO_2.

The problem with this approach is that it simply adds up the impact of each policy and calculates total savings which is a violation of ASIF principle. In transport CO_2 computations, implementation of one policy would impact the other policies (for example improving fuel efficiency of vehicles would reduce the impact of mode shift) when calculated individually. Calculating the impact of each policy individually and summing up the individual impact to calculate the net savings is not scientifically correct. With this approach the quantum of error would be very large. The total reductions with the available policy packages would be definitely less than what has been projected thus reducing the impact of the plan.

VII. CONCLUSION

Use of official data on fuel consumption in road transport sector may lead to serious errors. Correlating official fuel consumption with official travel demand estimates conclude that that Indian transport sector maybe the most efficient sector in the world. With increasing travel distance, it is very difficult to reduce fuel consumption even with the implementation of aggressive fuel economy standards. Currently, India has not yet implemented fuel economy standards nor has it implemented very aggressive 'avoid' and 'shift' strategies. Clearly, the official statistics on road transport fuel consumption do not provide enough justification and insights on the implication of the growing travel demand on fuel consumption and carbon emissions.

The total number of motor vehicles and the total distance traveled are the key variables in determining total fuel consumption and carbon emissions. Unfortunately, till both this information is collected and updated the quality of the bottom-up measurements cannot be improved. The trends and scenarios in this research explain and establish the need to **prioritize diesel vehicle data collection** to improve bottom-up modeling. In India, annual diesel fuel subsidies cost society around 10 billion USD and lack of clear insight on diesel consumption among various modes may delay policy implementation. Improving diesel consumption data will provide quick wins in reducing variation among bottom-up modeling estimates and provide better insights on energy efficiency in transport sector. In the long term, the establishment of national transport household surveys as a supplement to national census should be prioritized. Clearly, mobility of 1.2 billion people cannot be planned without adequate resources allocated to data generation and analysis.

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