Estimating vehicular emissions from auto rickshaws plying in Bengaluru

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Abstract— The growing vehicular pollution has caused serious health hazard in Indian metropolitan cities, Bengaluru being one of the major victims. The vehicular emissions are primarily dependent on the fuel type and vehicle technology. The objective of this research paper is to estimate the vehicular emissions in form of carbon dioxide (CO2), particulate matter 10 (PM10) and nitrogen oxide (NOX) emitted by the auto rickshaws plying in Bengaluru city and recommend policy based solution based upon the estimated alternative scenarios.

Index Terms— 2- stroke, auto rickshaws, Bengaluru, electric auto rickshaws, policy recommendations, scenarios, vehicular emissions

1 INTRODUCTION

DURING the past few decades, cities in developing countries have exhibited a radical boom in urbanisation, leading to increased mobility. To meet these needs, there is an urgent requirement of availability of regular and affordable mobility opportunities. In most of the South Asian cities, the public transport systems do not render services in commensurate with the growing transport demand. Thus, mobility needs are mostly met through informally provided modes of transport, usually referred to as Intermediate Public Transport (IPT) or para transit systems such as auto rickshaws, taxi's, mini buses etc. Intermediate public transport fills up the void left by inadequate public transport availability in most developing cities. Among the wide array of intermediate public transport modes, auto rickshaw is the most popular one. It is an affordable and convenient mode of travel and hence is a popular choice in South Asian countries such as India, Bangladesh, Indonesia, Pakistan and Thailand. In Indian cities, the role of auto rickshaw is indispensable, however varying from city to city. Despite low vehicle share the three wheelers serve as mode choice for mobility in Indian cities. Cities, that have no government-provided public transport services such as bus- or rail-based transport, auto rickshaws act as main haul public transport. In other cities where formal public transport services are present (about 40-50 Indian cities), auto rickshaws serve as both feeder to the formal public transport and as an intermediate public transport [1]. It emerges as the preferred choice mode for commuting in most of the Indian cities and holds an average mode share above 10% (Teri estimates, 2017) in all the mega cities in India.

In Bengaluru, which is one of the five mega cities, despite the presence of formal public transport systems such as Bangalore Metropolitan Transport Corporation (BMTC) buses, the sub urban rail system and the Namma metro system, the mode share of auto rickshaws is about 10.4 % [2]. More than 1, 00,000 auto rickshaws in the city emerges as the key mode choice for the commuters for reasons such as easy/frequent availability and affordability. The auto rickshaws largely serve as an intermediate public transport for trip distances of 8-10 kms [3] and provide feeder services to the existing city public transport system. Even though the city has recently witnessed a surge in aggregator-based taxi services such as ola and uber, the auto rickshaws with the current fleet of 1.2 lacs [4] are an indispensable mode of intermediate public transport in the city. The number of registered auto rickshaws in the city have increased from 0.8 lacs in 2008 [5] to 1.2 lacs in 2015 [6] indicating an increasing demand. As per the analysis done by TERI, auto rickshaws comprise only about 2% of the total registered vehicles in the city [7], however, their modal share amounts to 10.4% [8] (Refer Table 1). Clearly, auto rickshaws are shouldering a significant share of the mobility needs of inhabitants of Bengaluru along with the other means of public transport.

Table 1: Mode share of communters in Bengaluru city

	Type of Mode	% share
1.	Bus	54.5
2.	Car	6.7
3.	Two-Wheeler	28.4
4.	Auto	10.4

Even though the auto-rickshaws form an essential fabric of the intermediate public transit system, they like other motorized modes, operate with externalities for the environment and public health, essentially on account of emissions arising from their operations. At present, Bengaluru has two categories of auto rickshaws based on the engine technology auto rickshaws powered by 2-stroke and 4-stroke engine. The dominant fuel type in almost auto rickshaws is LPG. Out of the two engine variants, the 2-stroke engine emits relatively more CO2 and contributes to higher pollution than the 4-stroke engine [9]. Auto rickshaws, which are powered by 2-stroke engines, pose a serious threat to air quality. Hence, the Transport department of Bengaluru has been strategizing various interventions to phase out 2-stroke powered auto rickshaws such as subsidising the conversion of 2-stroke auto rickshaws to 4-stroke and imposing ban on issue of permit for 2-stroke auto rickshaws. However, 24,000 two stroke powered auto-rickshaws continue to ply in the city due to lack of enforcement and absence of awareness among the drivers about the subsidies offered by the Government.

The European Union's Switch Asia project is funding a study on "Switching to a sustainable auto-rickshaw system" in an endeavour to reduce CO2 emissions and air pollution (caused

primarily by PM 10 and NOx) from auto rickshaws in Bengaluru. Additionally, the project also looks at promoting sustainable lifestyles and reducing poverty. The activities of the Switch Asia Project, under the Namma auto intervention, aim to accelerate the transition of two-stroke auto rickshaws to clean technology-based auto rickshaws. The project is being implemented by consortium of Fondoziane ACRA, ENVIU Foundation, Women Health and Development (WHAD) and The Energy and Resource Institute (TERI). This paper aims to estimate the vehicular emissions (CO2, NOx, PM10) emitted by auto rickshaws plying in Bengaluru.

2 Scope

The scope of this study is the Bengaluru Metropolitan region, which includes Bengaluru city and outer growth, all within the geographical area of 709 sq km. The vehicle types considered for the analysis are 2-stroke and 4-stroke auto rickshaws plying in Bengaluru city.

3 Objective

The objective of the research paper is to estimate the vehicular emissions in form of carbon dioxide (CO2), particulate matter 10 (PM10) and nitrogen oxide (NOX) emitted by the auto rickshaws plying in Bengaluru city.

4 Methodology

Methodology to estimate the vehicular emissions**,** the proposed methodology has three steps as explained

1. Estimating travel demand for different technology based three wheelers.
2. Assessing fleet composition of on-road vehicles.
3. Using identified emission model to estimate accurate emissions.

5 Data required

Primary surveys and data analysis were conducted to benchmark the vehicle and passenger travel characteristics in Bengaluru. With the means of primary and secondary survey, following data was collated: (1) average daily km (2) average daily fuel efficiency (km/litre) (refer Table 2).

Table 2: Data required for estimation of vehicular emissions

S.no	Data required	Sources/Method
1	Total auto rickshaws-classification by age and engine technology	Secondary data collected from Regional transport offices, Pollution under control centres
2	Fuel efficiency	Primary survey – Fuel diary survey
3	Average Daily Km travelled	Primary survey – Fuel diary survey

6 Data collection

6.1 Total Vehicle fleet

The total registered auto rickshaws were obtained from Road transport year book issued by Ministry of Roads Transport and Highways. Except for a minor decline in numbers during 2009-10, the registered fleet has depicted a steady growth and by analysing the growing demand. A dip in the auto rickshaw numbers between 2009 and 2010 was observed due to the mandated cap on number of allowed registrations. The steady growth thereafter was due to constant rate of annual permits issued. There was no official record of no. of two stroke and four stroke auto rickshaws with the regional transport offices. Based on the discussions and interviews with the authorities it was found that about 24,000 LPG fuelled 2-stroke autos and 96,018 LPG fuelled 4-stroke autos were plying in Bengaluru.

6.2 Vehicle age mix

In order to model the fleet retirements, TERI collected the dataset consisting of registration date of vehicles tested from Pollution under Control (PUC) in Bengaluru for the year 2015-16 from the Transport department of Karnataka. In total, information of around 69,651 three wheeler vehicles was recorded in that data set. The age profile of 4-stroke and 2-stroke autos as derived from this dataset is provided in table 3. Prior to 2005, 4-stroke auto rickshaws were not manufactured in India; therefore percentage of two stroke auto rickshaws was very high. After the ban on manufacturing of 2-stroke vehicles in Bengaluru in 2010, the percentage of 4-stroke vehicles rocketed to a much higher side.

Table 3: Age profile of 2s & 4s autorickshaws in Bengaluru

Year	2- Stroke	4-stroke
2011-2012	0.80%	75.4 %
2006-2010	21.60	24.6%
2006-2005	77.60%	-

6.3 Average Daily KM and Average fuel efficiency

In order to estimate the emissions we require average daily km, average fuel efficiency and number of auto rickshaws. The table below summarizes the data collated from the primary survey/ Fuel diary survey by TERI.

Table 4: Daily average kms and average occupancy of autorickshaws

	2- Stroke	4-stroke	Total
Numbers	24000	96018	120018
Daily Average Km	118 km	112km	
Average Fuel Effeciency	16.4 kmpl	18.4 kmpl	

According to the travel data, the daily average kilometres for 2 and 4-stroke auto rickshaws are 118 and 112 respectively (ta-

ble 4). It is observed that 2-stroke auto rickshaws have higher trip length as compared to 4-stroke autos. This is because 2-stroke autos primarily serve in the peripheral areas of the city. It is also observed that the four stroke auto rickshaws are more fuel efficient than their two stroke counterparts. The total vehicle kilometres travel served by auto rickshaws is around 13.5 million in Bengaluru city in which 2.8 million and 10 .74 million is served by 2-stroke and four stroke autos respectively. The total fuel consumed by autos plying in the city is 0.74 million grams of LPG.

7. RESULTS

The vehicular emissions (carbon emission, NOx and PM 10) are estimated for the two stroke and four stroke auto rickshaws in Bengaluru for the year 2017 and are summarised in the below Table 5.

Table 5: Vehicular emissions emitted by the autorickshaws

	CO2 (tonne/ day)	**NOx (tonne/ day)**	**PM 10 (tonne/ day)**
Emissions from autorickshaws (Both 2-stroke an 4-stroke)	1223.89	3.96	0.45
Emissions from 2 stroke auto's	282.63	0.10	0.31
Emissions from 4-stroke auto's	941.26	3.85	0.13
	CO2 (tonne/ year)	NOx (tonne/ year)	PM 10 (tonne/year)
Annual Average Emissions from an autorickshaw	3.72	0.016	0.005
Annual Emissions from 2 stroke autos	4.3	0.0015	0.004
Annual Emissions from 4-stroke autos	3.57	0.014	0.0005
	CO2 (mn tonne/ year)	NOx (tonne/ year)	PM 10 (tonne/ year)
Annual emissions from autorickshaws (Both 2-stroke and 4-stroke)	0.45	1445.27	164.62
Annual Emissions from 2 stroke autos	0.11	37.58	114.62
Annual Emissions from 4-stroke autos	0.34	1407.68	50

The emissions are directly related to the amount of fuel burnt. With a gradual increase in the total number of in-use vehicles, the total fuel burnt and the CO2 emissions and vehicular emissions also increased; in spite of switching to LPG . In a day approx. 1200 tonnes of carbon dioxide and 4 tonne of NOx and 0.5 tonne of PM10 are emitted from the auto rickshaws in Bengaluru. In which two stroke auto rickshaws contribute 282 tonne, 0.1tonne and 0.3 tonne of carbon emission, NOx and PM 10, respectively. On an average an LPG auto rickshaw emits 3.72 tonne of carbon emission, 16 kg of NOx and 5 kg of PM10 per year. Annual vehicular emission of a 2-stroke auto rickshaw is 4.3 tonne, 1.5 kg and 4kg of CO2, NOx and PM 10 respectively. Thus, total annual emissions from one lakh twenty thousand auto rickshaws in Bengaluru amount to 0.45 million tonne, 1445 tonne, and 164 tonne of CO2, NOx and PM10 respectively. In which two stroke auto rickshaws contribute 0.11 million tonne, 37.5 tonne and 114.5 tonne of CO2, NOx, and PM10, respectively.

8. ALTERNATIVE SCENARIOS

The auto rickshaw sector plays an integral role in the movement of passengers within the city. However, the sector contribution of vehicle exhaust emissions to ambient pollution is substantial and needs more positive interventions for future emission control. According to [10] vehicle exhaust emissions are responsible for up to 21% of the ambient PM10 pollution in the city, with the residential and commercial sections of the city experiencing up to 50% of particulate matter from transport sector, on a daily basis.

In case of Bengaluru, the total annual carbon emissions caused by the auto rickshaw sector is 0.44 million tonne. In the business-as-usual scenario, with addition of 1.5 lakh auto rickshaws in five years (as reported by RTO) there will be an addition of 0.5 million tonne of carbon emissions. Similarly, in case of vehicular emissions like PM 10 and NOx, the city is currently experiencing 170.14 million tonnes of PM10 and 1587 million tonnes of Nox annually. In the business-as-usual scenario with addition of every 1.5 lakh auto rickshaws in five years (as reported by RTO), there will be an addition of 212 million tonne of PM10 and 1983 million tonne of NOx annually.

According to methodolgy, the overall emissions can be reduced only if we reduce the number of on-road vehicles or the annual mileage of the in-use vehicles or the fleet average emission factors. However, the transport department has added a cap on issuing a permit for new vehicles; but the annual mileage has only increased as of now. Thus the decreasing emission trends for various pollutants are primarily due to changes in the emission factors and change in the fuel type (Diesel to LPG). While the benefits of the latter are nullified due to a rapid increase in the overall vehicle fleet, the former is still the main proponent for controlling the emissions in the city.

Based on discussions with Transport Department, the following scenarios have been worked out:

- The Transport Department has issued a ban on plying of 2-stroke autos in the city. Scenario I discusses the outcome of the ban.

- Scenario II discusses the outcome of replacement of banned autos in the city with 4-stroke autos.
- Scenario III discusses the outcome of replacement of banned autos in the city with electric autos.
- Scenario IV discusses phase-wise replacement with electric autos. In the first phase, in addition to replacing all 2-stroke autos with electric autos, 30% of 4-stroke autos will also be replaced by electric ones.
- Scenario V discusses the second phase in which in addition to replacing 2-stroke autos with electric autos, 60% of 4-stroke autos will also be replaced by electric ones.
- Scenario VI discusses the complete shift to electric auto rickshaws.

The results from the above described scenarios are explained in Table 6:

Table 6: Vehicular emissions alternative scenarios

S.no	Scenarios	Annual CO2 emissions (million tonne/year)	Annual PM10 emissions (tonne/ year)	Annual NOx emissions (tonne/year
1	**Baseline**	0.45	164.6	1445.3
2	**Scenario I**	0.34	50	1407.7
3	**Scenario II**	0.43	62.5	1759.5
4	**Scenario III**	0.34	50	1407.7
5	**Scenario IV**	0.24	35	985.4
6	**Scenario V**	0.14	20	563.1
7	**Scenario VI**	0	0	0

As explained in Table 6, the potential for reducing vehicular emissions and contribution of transport sector to ambient pollution lies in switching to cleaner electric auto rickshaws which offer zero emissions. Currently, the Transport Department of Karnataka has notified a ban on 2-stroke auto rickshaws which will reduce the carbon emissions by 0.11 million tonne per year, PM 10 by 114.5 million tonne per year, and NOx by 37.6 million tonnes per year. But, if the demand–supply gap is covered through replacement of 24,000 two stroke auto rickshaws with 4-stroke auto rickshaws, PM10 will reduce by 62%, but there would be minimal reduction of 0.02 million tonne in the carbon emissions and. composition of NOx will increase by 21%. Thus, in order to reduce vehicular emissions, electric autos should be promoted. By switching to electric autos in Scenario III, the carbon emissions will reduce by 0.11 million tonne per year, PM 10 will reduce by 114.5 million tonne per year, and NOx by 37.6 million tonne per year. Additionally, 0.17 million gram of LPG will also be saved which could be used as subsidy for the poor. With the current policy landscape, the Bengaluru transport department is promoting electric autos. However, adoption of a phase-wise approach is recommended to introduce penetration of electric vehicles in the Bengaluru city. As per Scenario IV, with 30% replacement of 4-stroke auto rickshaws with electric ones, the observed carbon emissions are 0.24 million tonne per year, while those of NOx and PM10 are 985 and 35 tonne per year, respectively. With 60% fleet replacement with electric, the observed carbon emissions are 0.14 million tonne per year, NOx and PM 10 are 563 and 20 tonne per year, respectively. The complete replacement with electric will lead to zero tail pipe emissions and save 0.74 million gram of LPG.

9. Conclusion

The paper estimates the vehicular emissions in the form of CO2, PM 10 and NOx caused by the 2-stroke auto rickshaws plying in Bengaluru. The data required for the estimating the vehicular emission is the total number of fleet, average daily km and the average fuel consumed. As the Government of Karnataka is planning banned the 2-stroke autos, the paper estimates the reduction in vehicular emissions caused ban as the business- as- usual scenario. To meet the demand- supply alternative scenarios are developed in alignment of the Government policies and it has been recommended a rather than replacing the 2-stroke auto rickshaw fleet with the 4 – stroke auto rickshaws which will increase the NOx emitted and nullify the objective of ban. A phase wise shift to electric auto rickshaws should be implemented which will help in achieving the objective of reducing vehicular emissions and would smoothen the implementation process.

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