RESEARCH PAPER

Implemented by

Estimating Vehicular Emissions from autorickshaws plying in Bengaluru city

CONTENTS

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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 autorickshaws, 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, autorickshaw 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 autorickshaw is indispensable (Box 1), however varying from city to city. As illustrated in Box 1, 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, autorickshaws act as main haul public transport. In other cities where formal public transport services are present(about 40-

BOX 1 ROLE OF AUTORICKSHAWS IN INDIAN CITIES

Autorickshaws serve as an integral mode for meeting the mobility needs of Indian cities. They serve as an intermediate public transport for the cities with limited public transport and as a main haul public transport for cities with no formal public transport. Autorickshaws also provide first and last mile connectivity to the commuters by acting as a feeder to public transport. The table illustrates the modal share of autorickshaws in a few Indian cities.

Table 1 Vehicle share and mode share of autorickshaw's in few Indian cities

City	Share of AR's in registered vehicles	Mode share of AR's
Amritsar	2%	22%
Jaipur	2%	25%
Delhi	1%	5%
Pune	2%	7.2%

Source: Compiled data by TERI, 2017

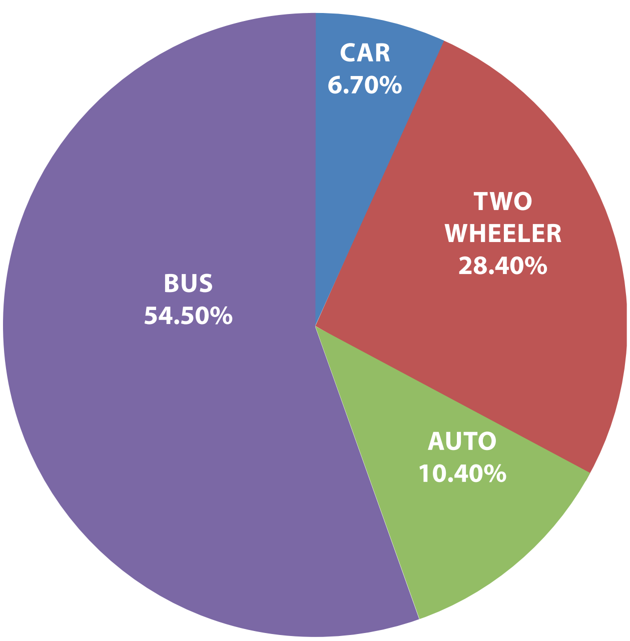

Figure 1 Mode share of Bengaluru

50 Indian cities), autorickshaws serve as both feeder to the formal public transport and as an intermediate public transport (Kumar, 2016). It emerges as the preferred choice mode (Box 1) 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 autorickshaws is about 10.4 % (DULT, 2014). More than 1, 00,000 autorickshaws in the city emerges as the key mode choice for the commuters for reasons such as easy/frequent availability and affordability. The autorickshaws largely serve as an intermediate public transport for trip distances of 8-10 kms (DULT, 2014) 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 autorickshaws with the current fleet of 1.2 lacs (MoRTH, 2015) are an indispensable mode of intermediate public transport in the city. The number of registered autorickshaws in the city have increased from 0.8 lacs in 2008 (MoRTH, 2008) to 1.2 lacs in 2015 (MoRTH, 2015) indicating an increasing demand. As per the analysis done by TERI, autorickshaws comprise only about 2% of the total registered vehicles in the city (MoRTH, 2015), however, their modal share amounts to 10.4% (DULT, 2010)(Refer Figure 1). Clearly, autorickshaws are shouldering a significant share of the mobility needs of inhabitants of Bengaluru along with the other means of public transport.

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 autorickshaws based on the engine technology autorickshaws powered by 2 stroke and 4 stroke engine. The dominant fuel type in almost autorickshaws is LPG. Out of the two engine variants, the 2 stroke engine emits relatively more CO_2 and contributes to higher pollution than the 4 stroke engine (GTZ, 2012). Autorickshaws, 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 autorickshaws such as subsidising the conversion of 2 stroke autorickshaws to 4 stroke and imposing ban on issue of permit for 2 stroke autorickshaws. However, 24,000 two stroke powered auto-rickshaws[1] 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.

[1] The number of two stroke autorickshaws was given by the Transport Department of Bengaluru

The European Union's Switch Asia project is funding a study on "Switching to a sustainable auto-rickshaw system" in an endeavour to reduce CO_2 emissions and air pollution (caused primarily by PM 10 and NOx) from autorickshaws 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 autorickshaws to clean technology based autorickshaws. The project is being implemented by consortium of Fondoziane ACRA, ENVIU Foundation, Women Health and Development (WHAD) and The Energy and Resources Institute (TERI). This paper developed by TERI aims to estimate the vehicular emissions (CO_2, NOx, PM_{10}) emitted by autorickshaws plying in Bengaluru.

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 (Figure 2). The vehicle types considered for the analysis are 2 stroke and 4 stroke autorickshaws plying in Bengaluru city.

Objective

The objective of the research paper is to estimate the vehicular emissions in form of carbon dioxide (CO_2), particulate matter 10 (PM_{10}) and nitrogen oxide (NO_X) emitted by the autorickshaws plying in Bengaluru city.

Methodology to estimate vehicular emissions

The proposed methodology has three steps as explained

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

(For detailed methodology refer Annexure II)

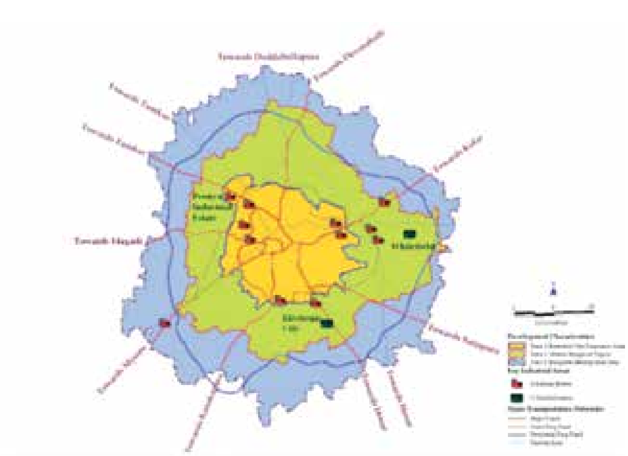

Figure 2 Bengaluru metropolitan Area

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) (see Table 2).

TABLE 2 DATA REQUIRED FOR ESTIMATION OF VEHICULAR EMISSIONS

S.no	Data required	Sources/Method
1	Total autorickshaws-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

Total autorickshaws: The data for total registered autorickshaws was extracted from the annual road transport year book and was further validated from regional transport office. The data regarding the age wise classification of autorickshaws was derived from the data set of pollution under control (PUC) vehicles. The number of 2 stroke and 4 stroke engine based autorickshaws plying in Bengaluru were not officially recorded, but based upon the interview with the Transport commissioner and PUC data set, the numbers were derived.

Average Fuel Efficiency and Average Daily km: The average fuel efficiency and average daily km were estimated through the fuel diary survey of 542 autorickshaws. (refer Table 3). These auto drivers work very closely with the Namma Auto team and were trained specifically for the surveys. The driver training was done explaining them how to fill the fuel diary format for the estimation of vehicular pollution.

TABLE 3 VEHICLE SAMPLE SIZE BASED ON ENGINE TECHNOLOGY

Fuel type	2 Stroke	4 Stroke
LPG	203	339
Total	542 autorickshaws	

In the fuel diary survey, a fuel diary format was given to auto drivers to maintain the readings of their fuel consumption and odometer (distance travelled) to calculate the average fuel efficiency and average daily km travelled. The format of the fuel diary is attached in Annex. Drivers were trained to fill the survey forms. 540 responses were received and recorded.

Survey to validate fuel consumption estimated from the fuel diary method is explained as under:

Through additional surveys, results from the fuel diaries were validated. These additional surveys involved hiring 2 stroke and 4 stroke autorickshaws (2 each) on a normal week day in Bengaluru. The odometer reading of autorickshaw when on reserve was taken after which a specified quantity of fuel was filled. The autorickshaw was then plied by the driver in typical weekday traffic conditions. The next odometer reading, when the autorickshaw again went on reserve, was then noted.

Data Collected

Total Vehicle fleet

A summary of the registered autorickshaws from 2007 to 2015 is presented in Figure 3. The total registered autorickshaws were obtained from Road transport year book issued by Ministry of Road Transport and Highways, Government of India.

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 similar trend is anticipated in the future. A dip in the autorickshaw 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 autorickshaws 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.

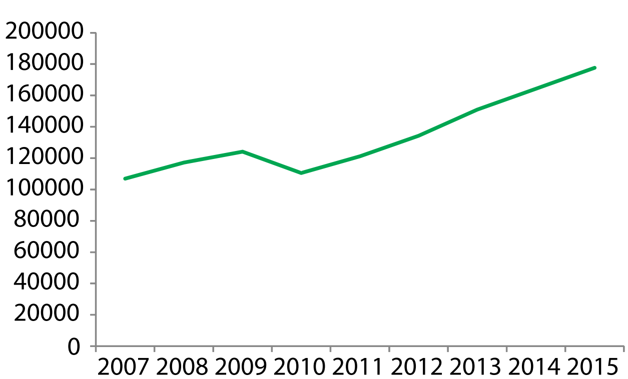

Figure 3 Trend of autorickshaws
Source: Road transport year book

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 6. Prior to 2005, 4 stroke autorickshaws were not manufactured in India; therefore percentage of two stroke autorickshaws 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 4 AGE PROFILE OF 2S & 4S AUTORICKSHAWS IN BENGALURU

Year	2s	4s
2011-2015	0.80%	75.4%
2006-2010	21.60%	24.6%
2000-2005	77.60%	—

Source: Transport department, Karnataka

Emission Factor

The following emission factors (Table 5) were considered to calculate emissions and air pollution:

TABLE 5 EMISSION FACTORS FOR 3 WHEELER LPG VEHICLES

Type of vehicle	Age	Fuel	Nox	PM
3w (2s)	1996-2000	LPG	0.05	0.171
3w (2s)	2000-2005	LPG	0.04	0.13
3w (2s)	2006-2010	LPG	0.2	0.045
3w (2s)	2011-2015	LPG	0.125	0.036
3w (4s)	2006-2010	LPG	0.5	0.015
3w (4s)	2011-2015	LPG	0.3125	0.012
One lpg equivalent CO_2 emission(t/tj) = 63.10				

Source: CPCB 2011

Average Daily KM and Average fuel efficiency

According to equation (1) in order to estimate the emissions we require average daily km, average fuel efficiency and number of autorickshaws. Table 6 summarizes the data collated from the primary survey/ Fuel diary survey by TERI.

TABLE 6 DAILY AVERAGE KMS AND AVERAGE OCCUPANCY OF AUTORICKSHAWS

	2 Stroke	4 Stroke	Total
Numbers	24000	96018	120018
Daily average km	118	112	
Average fuel efficiency	16.44 kmpl	18.44 kmpl	

Source: TERI survey,2017

According to the travel data, the daily average kilometres for 2 and 4 stroke autorickshaws are 118 and 112 respectively (Table 6). It is observed that 2 stroke autorickshaws 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 autorickshaws are more fuel efficient than their two stroke counterparts.

TABLE 7 VEHICLE KM

(Figures in mn)	2 Stroke	4 Stroke	Total
Annual Vehicle kilometers travel (VKT)	2.8	10.74	13.56
Fuel Consumed	0.17	0.57	0.74

Source: TERI survey,2017

The total vehicle kilometres travel served by autorickshaws 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.

Results

The vehicular emissions (carbon emission, NOx and PM 10) are estimated for the two stroke and four stroke autorickshaws in Bengaluru for the year 2017 and are summarised in Table 8.

TABLE 8 VEHICULAR EMISSIONS EMITTED BY THE AUTORICKSHAWS

	CO_2 (tonne/ day)	NO_x (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
	CO_2 (tonne/ year)	**NO_x (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
	CO_2 (mn tonne/ year)	**NO_x (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 CO_2 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 PM_{10} are emitted from the autorickshaws in Bengaluru. In which two stroke autorickshaws contribute 282 tonne, 0.1tonne and 0.3 tonne of carbon emission, NOx and PM 10, respectively. On an average an LPG autorickshaw emits 3.72 tonne of carbon emission, 16 kg of NOx and 5 kg of PM_{10} per year.

Annual vehicular emission of a 2 stroke autorickshaw is 4.3 tonne, 1.5 kg and 4kg of CO_2, NOx and PM 10 respectively. Thus, total annual emissions from one lakh twenty thousand autorickshaws in Bengaluru amount to 0.45 million tonne, 1445 tonne, and 164 tonne of CO_2, NOx and PM_{10} respectively. In which two stroke autorickshaws contribute 0.11 million tonne, 37.5 tonne and 114.5 tonne of CO_2, NOx, and PM_{10}, respectively.

Alternative Scenarios

The autorickshaw 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 Goel & Guttikunda, 2015 vehicle exhaust emissions are responsible for up to 21% of the ambient PM_{10} 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 autorickshaw sector is 0.44 million tonne. In the business-as-usual scenario, with addition of 1.5 lakh autorickshaws 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 PM_{10} and 1587 million tonnes of Nox annually. In the business-as-usual scenario with addition of every 1.5 lakh autorickshaws in five years (as reported by RTO), there will be an addition of 212 million tonne of PM_{10} and 1983 million tonne of NOx annually.

According to equation (1), 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 autorickshaws.

The results from the above described scenarios are explained in Table 9:

TABLE 9 VEHICULAR EMISSIONS ALTERNATIVE SCENARIOS

S.no.	Scenarios	Annual CO_2 emissions (million tonne/year)	Annual PM_{10} emissions (tonne/ year)	Annual NO_x emissions (tonne/year)
1	Baseline	0.45	164.6	1445.3
2	Scenario I	0.34	50.0	1407.7
3	Scenario II	0.43	62.5	1759.5
4	Scenario III	0.34	50.0	1407.7
5	Scenario IV	0.24	35.0	985.4
6	Scenario V	0.14	20.0	563.1
7	Scenario VI	0	0	0

As explained in Table 9, the potential for reducing vehicular emissions and contribution of transport sector to ambient pollution lies in switching to cleaner electric autorickshaws which offer zero emissions. Currently, the Transport Department of Karnataka has notified a ban on 2 stroke autorickshaws 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 autorickshaws with 4 stroke autorickshaws, PM_{10} will reduce by 62%, but there would be minimal reduction of 0.02 million tonne in the carbon emissions and. composition of NO_x 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 NO_x 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 autorickshaws with electric ones, the observed carbon emissions are 0.24 million tonne per year, while those of NO_x and PM_{10} 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.

Recommendations

Existing Policy Landscape

The existing policy landscape is driven towards promotion of electric autorickshaws. The policies, as highlighted in Table 10, are in place at the national and state levels for promoting electric autorickshaws.

Policy Interventions

As per the results, adoption of electric autorickshaws will substantially reduce the tail pipe carbon emissions. Thus, policy interventions should promote faster adoption of electric vehicles. The current policy landscape supports penetration of electric autorickshaws to the system and encourages elimination of 2 stroke engine-based autorickshaws. However, to push demand and for faster adoption of electric autorickshaws, some specific demand and supply-based initiatives are required which are listed in Table 11.

In order to promote faster adoption of electric autorickshaws, both the demand and supply-based effective strategies, such as subsidies, tax incentives, rebates for auto drivers and manufacturers should be adopted. The market prerequisites for establishment of ecosystem involves the provision of direct consumer financial incentives in the form of subsidies and non-financial benefits, such as permit waiver, phase-wise removal of ICE technology-based autorickshaws through scrapping and incentives in retrofitting mechanisms. Additionally, privileges can be offered in the form of dedicated parking, zero toll charges, electric auto zones within the city, feeder service to metro stations with electric autos, and free access to public charging facilities.

To promote faster adoption of electric autorickshaws, the supply-side initiatives are equally important. The electric vehicle policy at the state level and the FAME scheme at the

TABLE 10 EXISTING POLICY LANDSCAPE

National Level		
1	FAME Scheme	The central government with FAME scheme offers subsidy from a minimum of ₹ 3,300 to a maximum of ₹ 61,000.
2	PIB- 27 Dec 2017- Government push for Electric Vehicles :10 Cities selected for pilot project of Multi-Modal Electric Public Transport under FAME India	Amongst the 10 cities, Bengaluru is selected for pilot of Multi Modal Electric Public transport under the FAME. Bengaluru will get subsidy for 500 three wheelers.
State level		
3	Government of Karnataka in 2005-06	Converted all autorickshaws to LPG.
4	Present Initiatives by Transport Department of Karnataka	Ban on 2 stroke engine based autorickshaws.
5	Scrapping Notification	A subsidy of ₹ 30,000 will be given to old 2 stroke auto for the scrapping. The scrapping will be done for 10,000 autorickshaws by 31st March 2018.
6	Karnataka Electric Vehicle and Energy Storage Policy 2017	The policy stated encouragement to existing autorickshaws for retrofitting and shift towards electric. The policy aims at 100% electric autorickshaws by 2030. The policy mandates prerequisite charging infrastructure. It provides tax incentives to the manufacturers.

TABLE 11: POLICY INTERVENTIONS

Policy initiatives inducing demand		
1	Transport Permits	• Phase-wise removal of ICE-powered autorickshaws from the system by restricting the renewal of permit. • Setting up ecosystem for electric autorickshaws, initiating with removal of permit requirement or open permit system for electric autorickshaws. • Waiver on permit fees for electric autos and increasing the permit renewal period for e-autos. • Issuance of free permit of electric autos to women drivers to support women employment. • Providing flexibility in carriage system to electric autos with both contract and shared services.
2	Driving License	• Creating distinct licence category for electric auto drivers with reduced time interval for obtaining the badge and general license. • Lowering of/creating differential in driving licence application and renewal fee between ICE auto and e-auto drivers. • Increasing renewal period of driving licence for e-auto drivers.
3	Costs	• Upfront subsidies for purchasing new vehicles and retrofitting old vehicles. • Additional subsidy by local governments, in addition to FAME incentive. • Low interest rates on loans for e-autos • Tax waivers such as road tax exemption • Lowering the GST on batteries (when bought separately for replacement)
Planning-based interventions		
1	Planning-based interventions	• Availability of charging stations • Dedicated parking space for electric autos with charging facility. • Zero toll charges. • Electric auto zones within the city. • Dedicated electric auto feeder service to metro stations. • Free access to public charging facilities.
Supply-side Policy Interventions		
1	Manufacturers	• Offering tax benefits and tariff exemptions.
2	Scarping of ICE technology-based three wheelers	• Adopting phase-wise scrapping policy to encourage retrofitting or replacement with electric autos.
Public Awareness		
1	Public Awareness	• Sensitizing consumers on benefits of switching to electric rickshaws. • Conducting awareness programme for the consumers and auto unions regarding the benefits of the electric autos. • Involving various NGOs for propagating awareness about the subsidies on electric autos.

central level are offering various financial incentives to the manufacturers. Additionally, differential tax mechanisms and tariff exemptions have also been recommended.

The prerequisite ecosystem with availability of charging infrastructure should be provided. A phase-wise approach should be adopted to eliminate or replace the existing ICE technology-based three wheelers with electric autos to be updated in the scrapping notification.

Finally, increasing consumer awareness and sensitizing consumers on the benefits of switching to electric autos should be propagated through awareness programmes. These initiatives will catalyse faster adoption of electric autorickshaws in Bengaluru.

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Annexure I

Format

Instructions		
■ Enter your name and vehicle registration number in the fuel dairy. ■ As you stop at the fuel station the tank should be at reserve ■ The fuel purchase number starting with 01 for first fuel purchase, 02 for second fuel purchase ■ Record the date of the fuel purchase ■ Record the number showing on the odometer when the first fuel purchase is made as the start odometer reading and end odometer reading before the second fuel purchase. ■ Indicate the fuel purchased by checking the appropriate circle. ■ Record the number of litres/kilograms showing on the fuel pump and then indicate whether you purchased in litres or kilograms. ■ Record the price per l/kg in INR. ■ Record the average daily kms travelled.		
1. Driver Name	2. Vehicle Number	3. Fuel Purchase no. 0 1
4. Date day mm 2016	5. Odometer Start Reading	6. Odometer End Reading
7. Type of Fuel Petrol Diesel LPG	8. Amount of fuel purchased Litres Kilo Grams	9. Fuel Price per l/kg Litres Kilo Grams
10. Average Daily Km travelled		
11. Average Occupancy:		
12. Color of Auto- Black/ Green	13. Age of auto:	

Annexure II

Methodology for estimation of carbon footprint

1. Estimating mode-wise vehicle kilometers (VKM)

For year 'x',

VKMA2 = V A2 X D A2

where,

VKM A2 = Annual vehicle kms for 2 stroke autorickshaw 'A2' in year 'x'

V A2= Total number of on-road 2-Stroke autorickshaw 'A2' in year 'x'

D A2 = Annual mileage per vehicle for 2-Stroke autorickshaw 'A2' (in kms) in year 'x'

A2 = 2- stroke autorickshaw, A4 = 4 stroke autorickshaw

Similarly, vehicle km for four stroke autorickshaws are estimated

2. Estimating total fuel consumption from autorickshaws (TOE)

For year 'x',

Fuel *A2* = VKM A2 X FE A2

Where,

Fuel *A2* = Total annual fuel consumption of 2-Stroke autorickshaw 'A2' in year 'x' (TOE)

FE M1 = Fuel economy of 2-Stroke autorickshaw 'A2' (TOE/km)

Note: The fuel economy numbers in grams were converted to TOE units using the fuel specific calorific values.

Similarly fuel consumption for four stroke autorickshaws were estimated.

3. Estimating CO_2 emissions

Emissions from 2- stroke autorickshaws (tonne)

For year 'x',

EA2 = Fuel A2 X Energy conversion factor (g to tj)

CO_2 *A2 = E A2 X EF A2*

where,

CO_2 *A2* = Total CO_2 emissions for 2-Stroke autorickshaw 'A2' in year 'x' (tonne)

EF M1 = CO_2 emission factor for 2-Stroke autorickshaw 'A2' (t/tj)

Source of emissions factor: (MoEF, 2007)

Similarly, carbon emissions for four stroke autorickshaws have been estimated

4. Total CO_2 emissions

Emissions for year 'x' (in tonne) = CO_2 A2 + CO_2 A4

5. Estimating PM_{10}

Particulate matter from 2- stroke autorickshaws (tonne)

For year 'x',

PM_{10} *A2* = VKM A2 X 365 X EF (PM_{10})A2/ 10 ^ 6

Where,

PM_{10} *A2* = Total PM_{10} emitted from 2-Stroke autorickshaw 'A2' in year 'x' (tonne)

EF (PM_{10})*A2* = PM_{10} emission factor for 2-Stroke autorickshaw 'A2' (g/km)

Source: (CPCB, 2015)

Similarly, particulate matter 10 for four stroke autorickshaws has been estimated

6. Total PM 10

Particulate matter for year 'x' (in tonne) = PM_{10} *A2* + PM_{10} *A4*

7. Estimating Nitrogen oxides (NOx)

Annual NOx emission from 2- stroke autorickshaws (in tonne) for year 'x',

NOx A2 = VKM A2 X 365 X EF A2 /10 ^ 6

Where,

NOx A2 = Total NOx emitted from 2-Stroke autorickshaw 'A2' in year 'x' (tonnes)

EF (NOx) A2 = NOx emission factor for 2-Stroke autorickshaw 'A2' (g/km)

Source: (CPCB, 2015)

Similarly, NOx for four stroke autorickshaws has been estimated

8. Total NOx

NOx emissions for year 'x' (in tonne) = *NOx A2* + *NOx A4*

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