Emission Saving Made by a Passenger by Choosing to Travel by Delhi Metro

Approach and Methodology

TERI's estimation considers Delhi Metro and five motorized modes of road transport, namely: bus, private car, cab/taxi, three-wheeler (auto-rickshaw), and two-wheeler. Of these six modes; metro (run by Delhi Metro Rail Corporation, DMRC) and bus [run by Delhi Transport Corporation (DTC) and Delhi Integrated Multi-modal Transport System Ltd. (DIMTS)] are considered the only two mass transportation (public transport) modes available in Delhi. This estimation uses data pertaining to 2019-20 for the two public transport systems, as the two subsequent years were disrupted by COVID-19 pandemic. **Table 1** lists the input data used in the estimation of emission (grams of CO_2) per passenger-kilometre (PKM) from the different modes of transport in Delhi.

Table 1: Input Data for Emission Estimation

Modes	Parameters		Values
Metro	Electricity consumed for the year (MWh)- Traction (including renewables)		6,99,000
	Electricity (renewable) consumed for the year (MWh)- Traction		2,56,860
	Passenger kilometre (PKM) for the year (billion)		16.998
	Grid emission factor including renewables (tonne CO_2/MWh) [**assumption**][1]		0.71
	Grid emission factor (tonne CO_2/MWh) [**assumption**][1]		0.80
Bus	Total km driven (crores) (in year)	DTC-AC	7.76
		DTC- non AC	14.96
		Cluster[#]	20.71
	Total number of passengers (crores) (in year)	DTC-AC	36.16
		DTC- non AC	85.66
		Cluster[##]	64.64
	Average lead per passenger (km)[2]		8.60
	Average mileage (km/kg of CNG) [**assumption**][3]	DTC-AC	2
		DTC- non AC	2.50
		Cluster	3
	Emission factor [**assumption**][4]	CNG (kg CO_2/kg)	2.69
Private car	Number of registered cars in Delhi[5] (till June 12, 2023)	Petrol (includes Petrol/hybrid, petrol/LPG)	27,07,140
		Diesel (includes Diesel/hybrid)	6,95,495
		CNG (includes Petrol/CNG)	6,26,893
	Average mileage [**assumption**][6]	Petrol (km/l)	15.79
		Diesel (km/l)	17.61
		CNG (km/kg)	23.54
	Emission factor [**assumption**][4]	Petrol (kg CO_2/l)	2.27
		Diesel (kg CO_2/l)	2.64

Modes	Parameters		Values
		CNG (kg CO_2/kg)	2.69
	Average occupancy [**assumption**][6]		1.6
Cab/taxi	Average occupancy [**assumption**][6]		1.16
	Emission factor [**assumption**][4]	CNG (kg CO_2/kg)	2.69
	Average mileage [**assumption**][6]	CNG (km/kg)	23.54
Three-wheeler	Emission factor [**assumption**][4]	CNG (kg CO_2/kg)	2.69
	Average occupancy [**assumption**][6]		1.4
	Average mileage [**assumption**]	CNG (km/kg)	30
Two-wheeler	Average mileage (km/l) [**assumption**][6]	Petrol Motorcycle	57.85
		Scooter	48
	Emission factor [**assumption**][4]	Petrol (kg CO_2/l)	2.27
	Motorcycle : Scooter (distribution) [**assumption**]		75 : 25
	Average occupancy [**assumption**]		1

Note: [#]Calculated using statistics on fleet size, fleet utilization (%), daily vehicle utilization (km/bus/day); [##]Estimated based on the daily average number of passengers; fuel specific emission factors are measured for well-to-wheel.
Source: Metro- DMRC; Bus- GNCTD (2023) (chapter 12); [1]- CEA (2022) (emission factor excluding imports); [2]- STU Profile and Performance 2019-20 (p. 118- DTC urban); [3]- Ravichandran (2017); [4]- India GHG Program; [5]- Vahan database (accessed on June 12, 2023); [6]- TERI.

Delhi Metro

Method 1:

In the first approach the entire electricity consumed by Delhi Metro for traction operation is considered. Since DMRC sourced a part (37%) of its energy from Rewa (solar energy), the grid emission factor including renewable energy sources is considered for considering the emission impact of Delhi Metro. Emission intensity (gms of CO_2/PKM) from Delhi Metro is calculated as:

$$\frac{Electricity\ consumed\ \times Grid\ emission\ factor\ (inclusive\ of\ renewables)}{PKM\ for\ the\ year}$$

Step 1: Calculating Total Emission (EM)

EM= Electricity consumed × Grid emission factor (including renewables) = 699000 (MWh) × 0.7121 (tonnes of CO_2 / MWh) = 497787.55 tonnes of CO_2

Step 2: Calculating Emission Intensity (EI) of Delhi Metro

EI= Dividing total emission by annual PKM = EM/PKM = 497787.55 (tonnes of CO_2)/16998 (million) = **29.29 gms of CO_2/PKM**

Method 2:

Delhi Metro sources a significant portion of its energy requirement from solar energy. Since the generation and operation of electricity at solar power plants produce zero greenhouse gases, this approach only considers the electricity consumed from non-renewables for the traction operation of Delhi Metro and the corresponding grid emission factor (excluding renewables). In 2019-20, DMRC consumed 4,42,140 MWh electricity from non-renewable sources. First, the total emission (EM) from Delhi Metro operation is calculated using the grid emission factor (excluding renewables) as follows:

$$EM = Electricity\ from\ non-renewable\ sources\ \times Grid\ emission\ factor$$

As a second step, emission intensity (EI) of Delhi Metro is calculated as:

$$EI = \frac{EM}{PKM}$$

Step 1: Calculating Total Emission (EM)

EM= Electricity consumed (non-renewables) × Grid emission factor (excluding renewables) = 442140 (MWh) × 0.7969 (tonnes of CO_2 / MWh) = 352341.37 tonnes of CO_2

Step 2: Calculating Emission Intensity (EI) of Delhi Metro

EI= Dividing total emission by annual PKM = EM/PKM = 352341.37 (tonnes of CO_2)/16998 (million) = **20.73 gms of CO_2/PKM**

Bus

Three types of buses are considered, DTC AC; DTC non-AC; and Cluster Bus (all use CNG as fuel). First, the amount of CNG consumption for each bus type is estimated as:

$$FC = \frac{Total\ kilometres\ driven}{Average\ mileage}$$

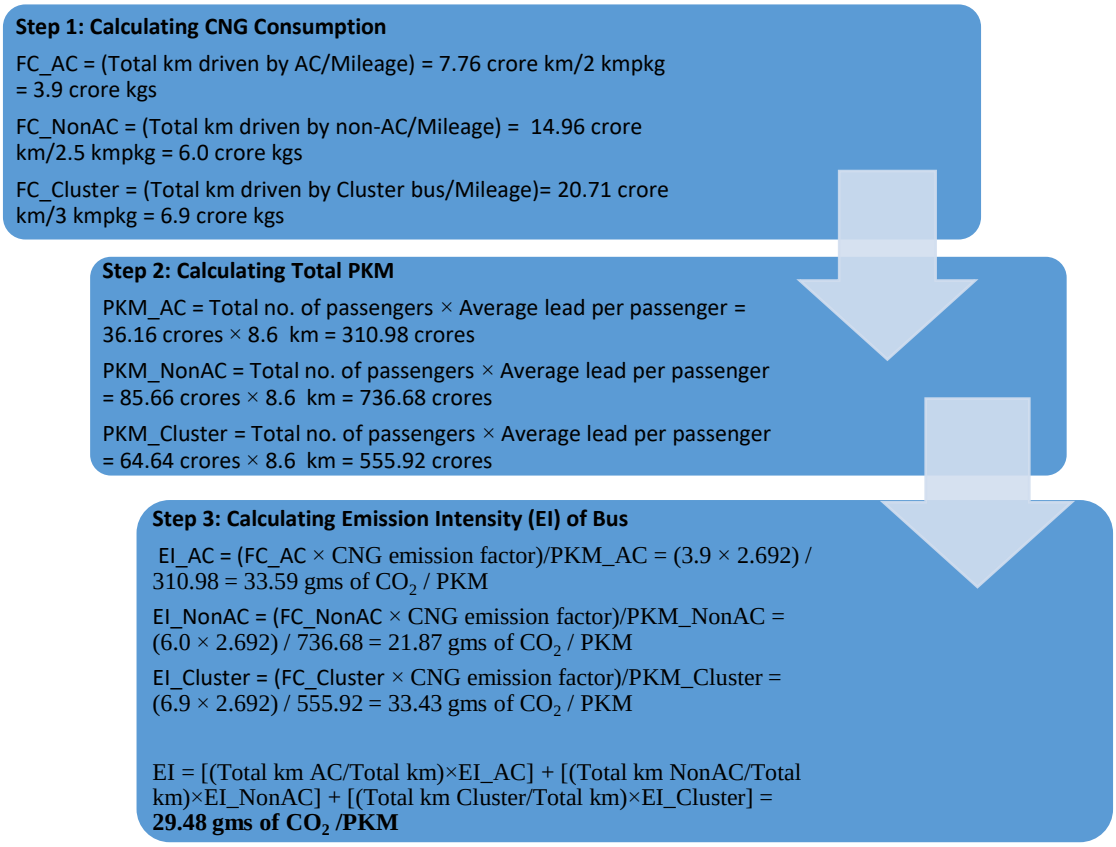
Second, the PKM for each bus type is estimated as:

$$PKM = Total\ number\ of\ passengers\ \times Average\ lead\ per\ passenger$$

Third, the average emission intensity (gms of CO_2/PKM) for each bus type is arrived at as:

$$EI = \frac{FC \times CNG\ emission\ factor}{PKM}$$

Finally, the overall emission intensity of a bus is estimated as the weighted average (weights based on total passengers carried by each bus type) of the average emission intensity for each bus type.



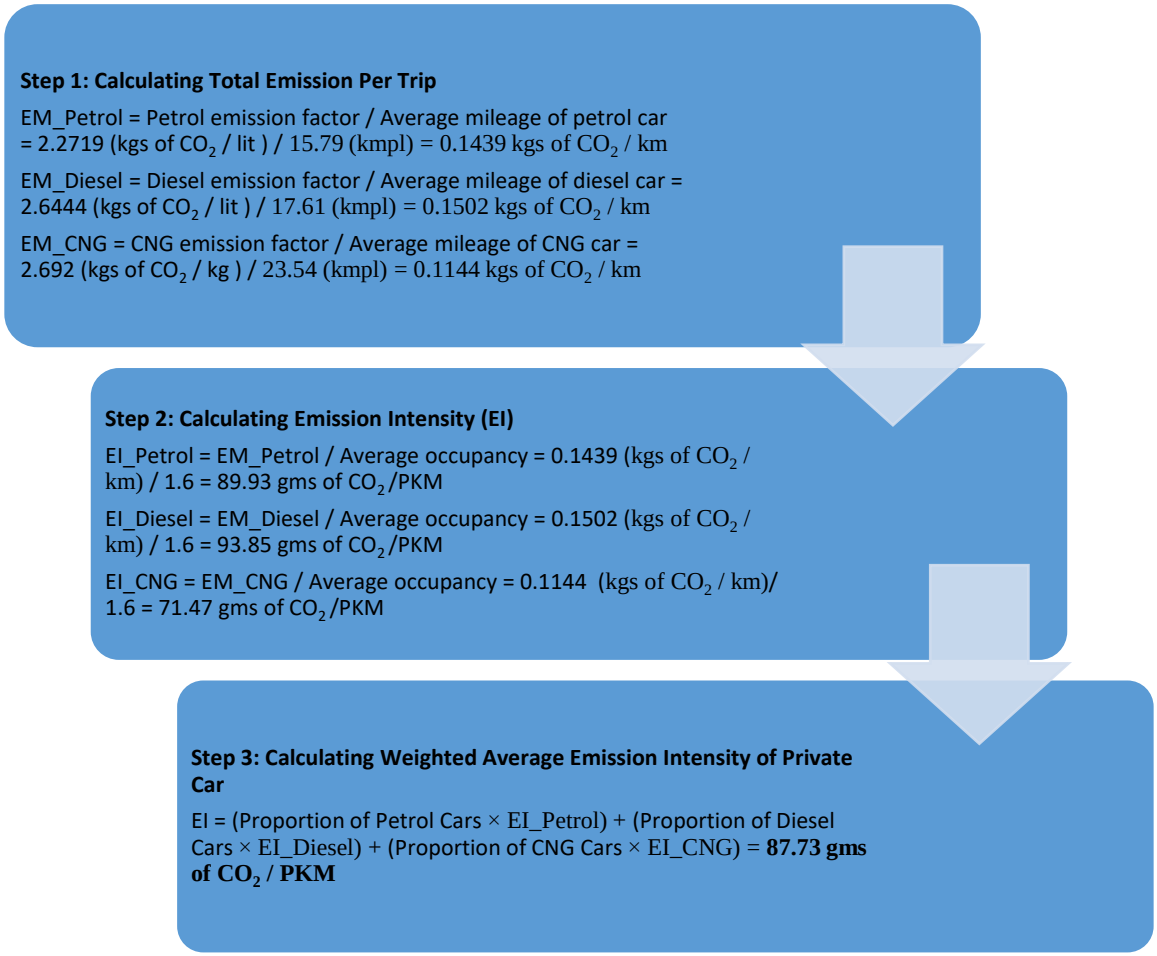
Private car

Three fuel types are considered for estimating the emission intensity of private car: petrol, diesel, and CNG. Average occupancy of 1.6 is assumed in estimation. Average emission intensity of a car for each fuel type is estimated as:

$$\frac{\left(\frac{Fuel\ type\ emission\ factor}{Average\ mileage\ of\ car\ of\ the\ fuel\ type}\right)}{Average\ occupancy}$$

The overall emission intensity of private car is then estimated as the weighted average (weights based on the distribution of four-wheelers by fuel types, accessed from Vahan database) of the

fuel specific average emission intensities. It is assumed that the proportion of fuel types for on-road private cars is identically distributed as for the number of cars registered in Delhi.



Cab/taxi

Average occupancy of 1.16 is assumed for estimation, along with the assumption that all the cabs/taxis on Delhi road are CNG vehicles. Average emission intensity of cab/taxi is estimated as:

$$\frac{\left(\frac{CNG\ emission\ factor}{Average\ mileage\ of\ CNG}\right)}{Average\ occupancy}$$

Step 1: Calculating Emission per Trip

EM = CNG emission factor / Average mileage = 2.692 (kgs of CO_2 /kg) / 23.54 (kmpkg)= 114.36 gms of CO_2 / km

Step 2: Calculating Emission Intensity (EI) of Cab/Taxi

EI = EM / Average occupancy = 114.36 (gms of CO_2 / km)/ 1.16 = **98.58 gms of CO_2 /PKM**

Three-wheeler

Only CNG auto-rickshaws are considered in the estimation process. It is assumed that average occupancy per three-wheeler is 1.4. Average emission intensity of three-wheeler is estimated as:

$$\frac{\left(\frac{CNG\ emission\ factor}{Average\ mileage\ of\ CNG}\right)}{Average\ occupancy}$$

Step 1: Calculating Emission per Trip

EM = CNG emission factor / Average mileage of three-wheeler= 2.692 (kgs of CO_2 /kg) / 30 (kmpkg) = 89.73 gms of CO_2 / km

Step 2: Calculating Emission Intensity (EI) of Three-wheeler

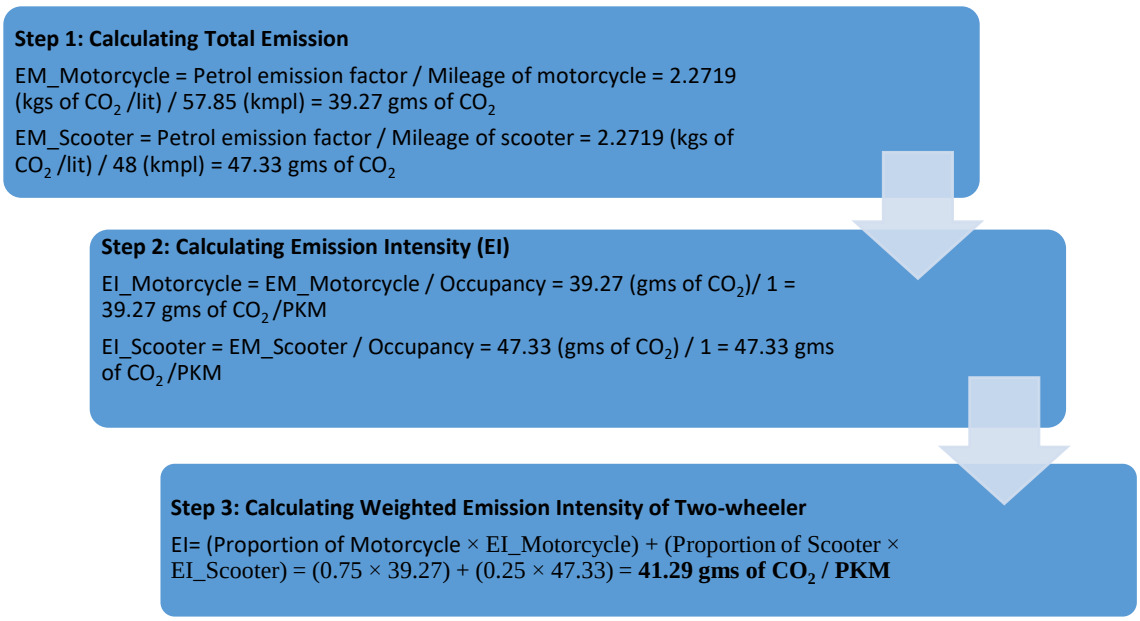
EI = EM / Average occupancy = 89.73 (gms of CO_2 / km) / 1.4 = **64.10 gms of CO_2 /PKM**

Two-wheeler

Two categories of two-wheelers are considered, motorcycle and scooter. It is assumed that average occupancy of two-wheeler is 1. First, average emission intensity of each type of two-wheeler is estimated as:

$$\frac{\left(\frac{Petrol\ emission\ factor}{Average\ mileage\ of\ vehicle\ type}\right)}{Average\ occupancy}$$

Then, the overall emission intensity of two-wheeler is estimated as a weighted average (assuming the motorcycle-to-scooter ratio to be 75:25) of the average emission intensities of motorcycles and scooters.



Findings

Based on the methodologies mentioned in section 1, **Table 2** lists the emission intensities of different mode types.

Table 2: Emission Intensities of Different Modes of Transport in Delhi

Modes	Emission intensity (gms of CO_2/PKM)
Delhi Metro- Method 1	29.29
Delhi Metro- Method 2	20.73
Bus (DTC, DIMTS Cluster)	29.48
Private car	87.73
Cab/taxi	98.58
Three-wheeler (auto-rickshaw)	64.10
Two-wheeler	41.29

Note: With the assumption of average 1.4 passengers per two-wheeler, the emission intensity of a two-wheeler is 29.49 gms of CO_2/PKM.
Source: TERI's estimate.

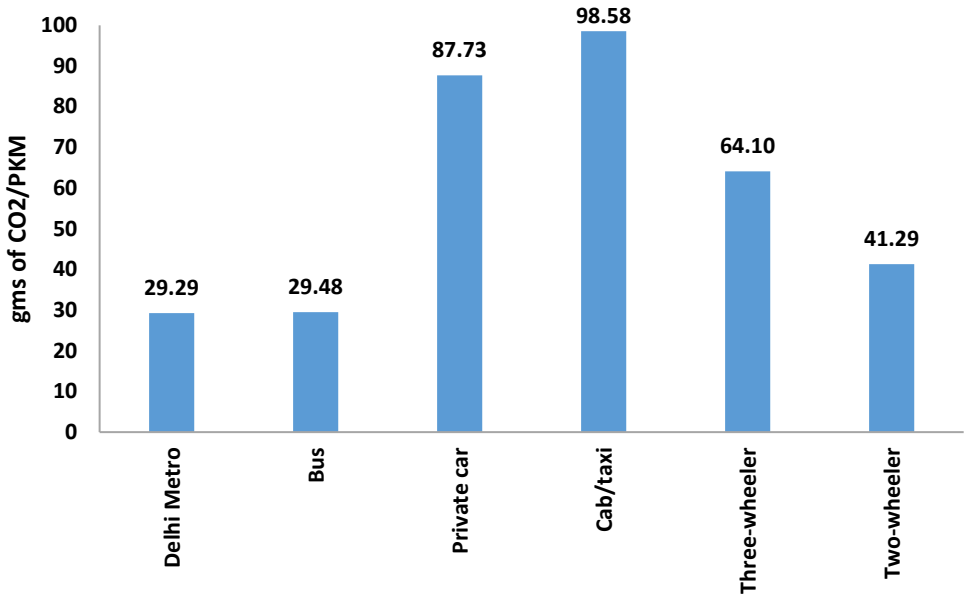


Figure 1: Emission Intensity of Different Modes of Transport- Delhi

Note: Emission intensity of Delhi Metro is based on Method 1.

Source: TERI's estimate.

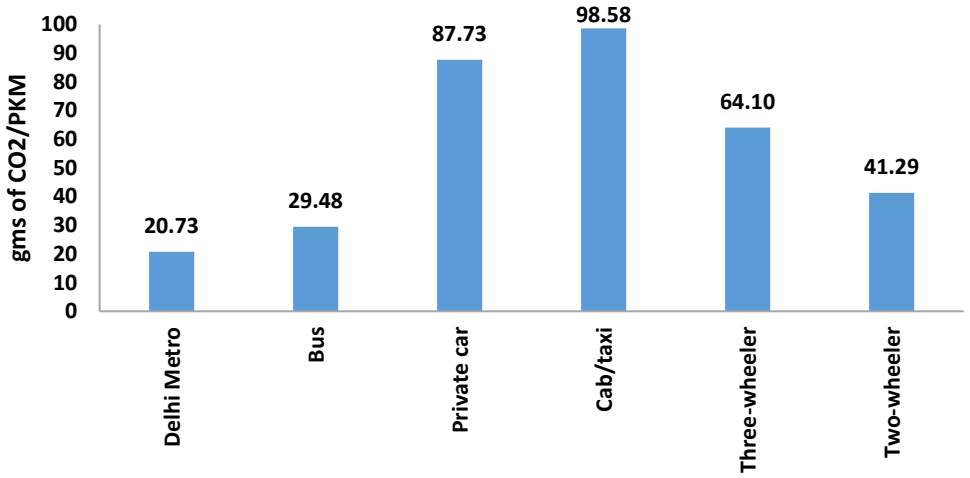


Figure 2: Emission Intensity of Different Modes of Transport- Delhi

Note: Emission intensity of Delhi Metro is based on the Method 2.

Source: TERI's estimate.

The actual emission intensity of Delhi Metro will fall within the range given by Methods 1 and 2. DMRC sources around 35% of its total energy needs from renewables (higher than the national average)[1], so the *emission intensity is likely to be lower than the currently used grid emission intensity* of 0.71 tonnes of CO_2/MWh in Method 1. While Method 1 provides the upper-bound,

[1]As per CEA, power generation from renewable energy sources has increased gradually since 2015 and in 2021-22 its share in power generation was 11.5% (see CEA, 2022).

Method 2 provides the lower bound based on the emission from usage of electricity only sourced from non-renewable sources.

Emission savings per passenger

A study by DIMTS in 2018 found that the modal-split of an average motorized trip (excluding Delhi Metro) in Delhi is distributed as follows: 34% by two-wheeler, 14% by auto-rickshaws, 8% by cabs/taxis, 16% by personal cars, and 28% by bus. Using the proportions of each mode of transport as weight, the weighted emission intensity from road transport in Delhi is estimated to be **53.11** gms of CO_2/PKM, whereas the emission intensities for Delhi Metro are estimated to be **29.29** gms of CO_2/PKM (from Method 1) and **20.73** gms of CO_2/PKM (from Method 2). This translates to an estimated emission saving to the extent of **23.82** gms of CO_2/km (for Method 1) and **32.38** gms of CO_2/km (for Method 2) by a passenger if he/she chooses Delhi Metro as a mode of transport.

It is to be noted that the road distance between an origin-destination (OD) pair is generally higher than the distance between the same OD pair by metro. So, the effect of emission saving per passenger will have a multiplier impact as the gap between the road and metro distance for the same OD pair increases. In addition to indicating the exact emission saved based on the origin-destination distance, the following statements can indicate the same. The first statement corresponds to calculation based on Method 1, while the second statement is for calculation based on Method 2.

"Congratulations! You saved XXXX $kgCO_2$."

"Your Carbon Footprint is 45% lower than other modes of transport"

Thank you for choosing Delhi Metro!

"Congratulations! You saved XXXX $kgCO_2$."

"Your Carbon Footprint is 61% lower than other modes of transport"

Thank you for choosing Delhi Metro!

References

CEA. (2022). *CO_2 baseline database for the Indian power sector: User guide version 18.0*. New Delhi: Ministry of Power, Government of India.

GNCTD. (2023). *Economic survey of Delhi 2022-23*. New Delhi: Government of NCT of Delhi.

NIUA. (2020). *Baseline report: Transport*. New Delhi: National Institute of Urban Affairs.

Ravichandran, D. (August 30, 2017). Delhi Transport Corporation operations decoded. *MotorIndia*. https://www.motorindiaonline.in/delhi-transport-corporation-operations-decoded/#:~:text=On%20an%20average%2C%20the%20low,floor%20bus%2C%20according%20to%20DTC