Monitoring report form for CDM project activity
(Version 09.0)

MONITORING REPORT			
Title of the project activity	Metro Delhi, India		
UNFCCC reference number of the project activity	4463		
Version number of the PDD applicable to this monitoring report	5.0		
Version number of this monitoring report	01		
Completion date of this monitoring report	04/04/2022		
Monitoring period number	1st Monitoring period of 2nd crediting period		
Duration of this monitoring period	30/06/2018 to 31/12/2020		
Monitoring report number for this monitoring period	Not applicable		
Project participants	Delhi Metro Rail Corporation Ltd. Grütter Consulting AG		
Host Party	India		
Applied methodologies and standardized baselines	ACM0016: Baseline Methodology for Mass Rapid Transit Projects; Version 04 Standardized baseline: not applicable		
Sectoral scopes	Transport (sectoral scope 7)		
Amount of GHG emission reductions or net anthropogenic GHG removals achieved by the project activity in this monitoring period	Amount achieved before 1 January 2013	Amount achieved from 1 January 2013 until 31 December 2020	Amount achieved from 1 January 2021
	0	390,242	0
Amount of GHG emission reductions or net anthropogenic GHG removals estimated ex ante for this monitoring period in the PDD	1,290,027		

SECTION A. Description of project activity

A.1. General description of project activity

The objective of the project is the establishment and operation of an efficient, safe, rapid, convenient, comfortable and effective modern mass transit system ensuring high ridership levels in the city of Delhi, India. The Mass Rapid Transit System (MRTS) is a partially elevated, partially underground and partially at-grade heavy duty metro.

The CDM project includes all corridors of Phase II except New Delhi – Airport and Airport – Dwarka Sector 21 of Metro Delhi managed by DMRC (Delhi Metro Rail Corporation Ltd.). Phase I is not included as CDM project.

Core aspects of Metro Delhi are:

- A new infrastructure consisting of 101.27 kilometres of state-of-the art metro with new trains, and pre-board ticketing using rechargeable electronic cards.
- Equipment and turnstiles at the entrance to each station will deduct the corresponding fare.
- Centralized coordinated train control providing monitoring and communications to schedule services and real-time response to contingencies.

For implementation and subsequent operation of Metro Delhi MRTS, a company under the name Delhi Metro Rail Corporation Ltd. (DMRC) was registered on 03/05/1995 under the Companies Act, 1956. DMRC has equal equity participation from GOI (Government of India) and GNCTD (Government of National Capital Territory of Delhi).

The baseline situation is a continuation of traditional modes of transport including buses, taxis, private cars, rickshaws, motorcycles and bikes. In absence of the project the passengers move from their trip origination to their trip destination by buses, by taxis, by motorized rickshaws, by the existing 3 lines of the metro and by NMT (Non-Motorized Transport). To a very limited degree some urban trips are also made by the existing railway lines although latter are used basically for inter-urban travel. In the baseline situation, these modes of transport would continue to operate and transport passengers from their trip origin to their trip destination.

In the project situation, the metro complements other modes of transport and replaces partially trips made by conventional or traditional means of transit by metro. The CDM project replaces trips made by conventional transport modes with metro, being a more efficient, faster, safer and more reliable transport means. The baseline scenario is comparable to the situation prior to the project. The baseline scenario however incorporates technological advancements in terms of emissions per distance driven of various modes of transport as well as eventual fuel changes of baseline modes of transport during the project activity.

Emission reductions are achieved through reducing GHG emissions per passenger-kilometre, comparing conventional modes of transport with metro. The metro has as main environmental aspect that the resource efficiency of transporting passengers in Delhi is improved i.e. emissions per passenger kilometre are reduced compared to the situation without project.

Table 1 lists the relevant dates of the project activity.

Table 1: Relevant Dates of the Project Metro Delhi, India

Corridor	Construction start date	Commissioning date
Shahadara-Dilshad Garden	April 2006	04/06/2008
Vishwavidyalaya-Jhahangirpuri	November 2005	04/02/2009
Indraprastha-New Ashok	November 2005	13/11/2009

Nagar / Yamuna Bank[1]		
New Ashok Nagar /Yamuna Bank-Noida	July 2006	13/11/2009
Inderlok – Kirtinagar – Mundka	April 2006	02/04/2010
Yamuna Bank –Anand Vihar ISBT	June 2006	07/01/2010
Anand Vihar – Vaishali	June 2008	14/07/2011
QM-Huda City Centre	November 2006	21/06/2010
Central Secretariate –QM	November 2006	03/09/2010
Central Secretariat – Badarpur	April 2007	14/01/2011
Dwarka Sector 9 – 21	March 2006	30/10/2010

Source: Verified Monitoring Report 2nd monitoring period, Table 1[2]

The project was registered as a CDM project as of 30/06/2011. For this monitoring period, all lines as described in the PDD were fully operational.

The project did not operate April to August 2020 due to COVID-19.

The total emission reductions achieved in this monitoring period are **390,242 tCO_2**

A.2. Location of project activity

Host country

India

Region/State/Province

New Delhi

City/Town/Community

Delhi

Physical/Geographical location

The spatial extent of the project is in accordance with the methodology, the metropolitan area of Delhi. The spatial area includes the trip origins and destinations of passengers using Metro Delhi. The geographical coordinates of Delhi are 28˚24' to 28˚53' North and 76˚50' to 77˚20' East.

A.3. Parties and project participants

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
India (host)	Delhi Metro Rail Corporation Ltd. (private entity)	No

[1] The Letter of Approval was issued 1.9.2005, however the contract was signed 10.11.2005 and from this date onwards real construction started. The contract is also a legally binding document with a financial commitment.

[2] CDM: Metro Delhi, India (unfccc.int)

Parties involved	Project participants	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
Switzerland	Grütter Consulting AG (private entity)	No

A.4. References to applied methodologies and standardized baselines

ACM0016: Baseline Methodology for Mass Rapid Transit Projects; Version 04.0[3]

Following tools were used:

- "Tool for the demonstration and assessment of additionality", Version 05.2[4]
- Tool 05 "Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation" Version 3.0[5]
- Tool 03 "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion" Version 3.0[6]
- Tool 18: "Baseline emissions for modal shift measures in urban passenger transport" Version 01[7]

A.5. Crediting period type and duration

Crediting period: 7 years renewable; starting date 30/06/2011

Crediting period corresponding to this monitoring period: 30/06/2018 to 29/06/2025

SECTION B. Implementation of project activity

B.1. Description of implemented project activity

The total length of metro tracks included in the project is 102.23 km. The following table lists all metro corridors part of the CDM project.

Table 2: Corridors of CDM Project Metro Delhi, India

Corridor	Length (km)	Commissioning date
Shahadara-Dilshad Garden	3.09	04/06/2008
Vishwavidyalaya-Jhahangirpuri	6.36	04/02/2009
Indraprastha-New Ashok Nagar	8.07	13/11/2009
New Ashok Nagar-Noida	7.00	13/11/2009
Inderlok – Kirtinagar –Mundka	18.46	02/04/2010
Yamuna Bank –Anand Vihar ISBT	6.17	07/01/2010
Anand Vihar – Vaishali	2.57	14/07/2011

[3] EB85_repan10_ACM0016_ver_04.0.pdf (unfccc.int)

[4] Tool for the demonstration and assessment of additionality. (Version 05.2). (unfccc.int)

[5] CDM: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation (unfccc.int)

[6] CDM: Tool to calculate project or leakage CO2 emissions from fossil fuel combustion (unfccc.int)

[7] CDM: Baseline emissions for modal shift measures in urban passenger transport (unfccc.int)

Central Secretariate –QM-Gurgaon	27.58	21/06/2010 and 03/09/2010
Central Secretariat – Badarpur	20.16	14/01/2011
Dwarka Sector 9 – 21	2.77	30/10/2010
Total	**102.23**	

Source: Approved Monitoring Report 4th monitoring period, Table 2

In relation with the planning as listed in the PDD under Table 3 the commissioning date for most corridors was delayed which is not unusual in large scale infrastructure projects. However as of start of this monitoring period all corridors had been commissioned.

The same corridors as originally planned have been implemented (see Table 3 PDD). Line distance per corridor is the same as in the PDD with marginal differences of in total for all lines of 400 meters less than projected (0.4% of total).

The following table lists all stations of Phase II.

Table 3: DMRC Stations of Phase II Corridors

Corridor	Stations	Line[8]
Shahadara-Dilshad Garden	Dilshad Garden, Jhilmil, Mansarowar Park, Shahdara	Part of Line 1 (red line)
Vishwavidyalaya-Jhahangirpuri	Jahangirpuri, Adarsh Nagar, Azadpur, Modal Town, GTB Nagar, Vishwavidyalaya	Part of Line 2 (yellow line)
Indraprastha-New Ashok Nagar	Indraprastha, Yamuna Bank (repeated station), Akshardham, Mayur Vihar 1, Mayur Viha 1 Extension, New Ashok Nagar	Part of Line 3 (blue line)
New Ashok Nagar-Noida	New Ashok Nagar, Noida Sector 15, Noida Sector 16, Noida Sector 18, Botanical Garden, Golf Course, Noida City Centre	Part of Line 3 (blue line)
Inderlok – Kirtinagar – Mundka	Inderlok[9], Ashok Park Main, Satguru Ram Singh Marg, Kirtinagar[10], Punjabi Bagh, Shivaji Park, Madi Pur, Paschim Vihar (East), Paschim Vihar (West), Peeragarhi, Udyog Nagar, Surajmal Stadium, Nangloi, Nangloi Railway Station, Rajdhani Park, Mundka	Line 5 (green line)
Yamuna Bank –Anand Vihar ISBT	Yamuna Bank, Laxmi Nagar, Nirman Vihar, Preet Vihar, Karkarduma, Anand Vihar ISBT	Part of Line 3 (blue line)
Anand Vihar – Vaishali	Anand Vihar ISBT, Kaushambi, Vaishali	Part of Line 3 (blue line)
QM-Gurgaon	Qutab Minar, Chhattarpur, Sultanpur, Ghitorni, Arjangarh, Guru Dronacharge, Sikandarpur, MG Road, IFFCO Chowk, Huda City Centre	Part of Line 2 (yellow line)
Central Secretariat – QM	Central Secretariat[11], Udyog Bhawan, Race Course, Jor Bagh, INA Market, AIIMS, Green Park, Hauz Khas, Malviya Nagar, Saket, Qutab Minar	Part of Line 2 (yellow line)
Central Secretariat – Badarpur	Central Secretariat[12], Khan Market, JLN Stadium, Jangpura, Lajpat Nagar, Moolchand, Kailash Colony, Nehru Place, Kalkaji Mandir, Govind Puri, Okhla, Jasola, Sarita Vihar, Mohan Estate,Toughlakabad, Badarpur	Line 6 (violet line)
Dwarka Sector 9 – 21	Dwarka Section 9, Dwarka Section 8, Dwarka Section 21[13]	Part of Line 3 (blue line)

Source: Approved Monitoring Report 4th monitoring period, Table 3

The corridors consist of two broad gauge lines at 4.1 m centre to centre on elevated sections. For underground corridors, track centres are governed by spacing of tunnels and box design. Track structure on the main lines is broad gauge (1,676 mm) and standard gauge (1.435 mm) with 60-kg UIC wear resistant rails. On elevated alignment, the track is of ballastless type.

Traction system is 25kV ac 50Hz single phase. The entire power supply is monitored and controlled from a centralized Operation Central Control (OCC). The OCC takes care of the ongoing monitoring of the metro service via various technical systems and keeps contact by radio and

[8] See website for colour codes used by DMRC http://www.delhimetrorail.com/

[9] Station shared with Phase I line

[10] Station shared with Phase I line

[11] Station shared with Phase I line

[12] Station shared with Phase I line

[13] Station shared with airport link

telephone with the train drivers, the mobile personnel and the metro service vehicles. The control center also monitors the metro service via the CCTV systems that exist along the train line as well as answering and dealing with calls via the emergency call system at the train stations. The OCC controller is also responsible for monitoring the other technical systems relating to the metro service such as the power supply and signal installations, in addition to lighting, as well as ticket vending machines at the metro stations.

The metro runs partially underground, partially at grade and partially elevated. Each train has between 4 and 6 cars and runs frequencies between 3 and 12 minutes depending on lines, time of the day and passenger demand. 90 broad gauge (of which 89 with 6 cars and 1 with 4 cars) and 48 standard gauge (of which 46 with 4 cars and 2 with 6 cars) trains have been acquired (total 734 cars). 694 cars (95%) are indigenous and the rest are from Germany and South Korea. The seating capacity per car is between 42 and 50 persons and the standing capacity between 272 and 330 thus achieving a capacity of around 1,500 passengers per 4-car train and 2,260 for a 6-car train.

Continuous Automatic Train Control (CATC) system with cab signalling is provided for the metro system operation transporting a high volume of passengers at tight headways to ensure strict safety enforcement monitoring. The metro has automatic signalling in the section. Automatic train supervision provides for high safety with trains running at close headway ensuring continuous safe train operations, and eliminates accidents due to drivers passing signals at danger. It includes continuous speed monitoring and automatic application of brake in case of disregard of signal, providing safety and enforcing speed limits on sections having permanent and temporary speed restrictions and improving capacity with safer and smoother operations as the driver will have continuous display of the target speed and the distance to go status in his cab enabling him to optimize the speed potential of the track section.

For efficient ticketing and passenger control an Automatic Farer Collection (AFC) is provided. The base AFC system makes use of contactless smart tokens for single and "Contact-less Smart Card Tickets" for multiple journey as well as working with multiple operators. Entry gates are computer controlled retractable flap type automatic gates at entry and at exit with disabled wide reversible gates for disabled people.

To ensure the highest degree of reliability and all time power availability for the underground Metro Corridor, 3 MRTS Power receiving stations are inter-connected for transfer of power from one to another through Fire Retardant Low Smoke (FRLS) cable feeders. These receiving stations are remote controlled from Centralized Operation Control Centre through Supervisory Control & Data Acquisition System (SCADA). In the unlikely event of total power failure due to simultaneous collapse of Northern Grid and IP Gas Turbine Power Station, emergency lighting in the tunnel and at the MRTS stations is automatically switched on and fed the stand by Generator Sets. In addition, all the trains also have modern Ni-Cd Batteries to continue to provide lighting and air conditioning even when the train is stopped in event of complete power failure. The ventilation and air conditioning arrangements in the tunnel and the underground stations are so designed that emergency ventilation arrangements for the stations and tunnel continue to be maintained from the standby Generator Sets in such exigencies[14].

No event occurred during the monitoring period, which impacts the applicability of the methodology.

[14] See PDD as well as Verified Monitoring Report 2nd monitoring period for more information and data sources

B.2. Post-registration changes

B.2.1. Temporary deviations from the registered monitoring plan, applied methodologies, standardized baselines or other methodological regulatory documents

No temporary deviations have been applied during this monitoring period.

B.2.2. Corrections

No corrections to project information or parameters fixed at validation have been approved during this monitoring period or are submitted with this monitoring report.

B.2.3. Changes to the start date of the crediting period

No changes to the start date of the crediting period have been approved during this monitoring period or are submitted with this monitoring report.

B.2.4. Inclusion of monitoring plan

No monitoring plan has been included which was not included to the registered PDD.

B.2.5. Permanent changes to the registered monitoring plan, or permanent deviation of monitoring from the applied methodologies, standardized baselines, or other methodological regulatory documents

No changes.

B.2.6. Changes to project design

No changes.

B.2.7. Changes specific to afforestation or reforestation project activity

Not applicable

SECTION C. Description of monitoring system

The monitoring methodology is based on ACM0016 Version 04.

The monitoring plan has two aims: to ensure the environmental integrity of the project activity and to ensure that the data monitoring requirements are closely aligned with the current practice of the project operator.

A monitoring manual for the project was originally developed by Grütter Consulting AG. It defines all responsibilities and procedures. Since approval of the 1st monitoring report staff of DMRC are realizing the monitoring of the parameters in accordance with the procedures applied formerly. This concerns passenger numbers and electricity traction consumption. All other parameters required are collected and managed by Grütter Consulting AG which authored the methodology ACM0016, the original PDD as well as the revised PDD and is contractually responsible for the monitoring reports.

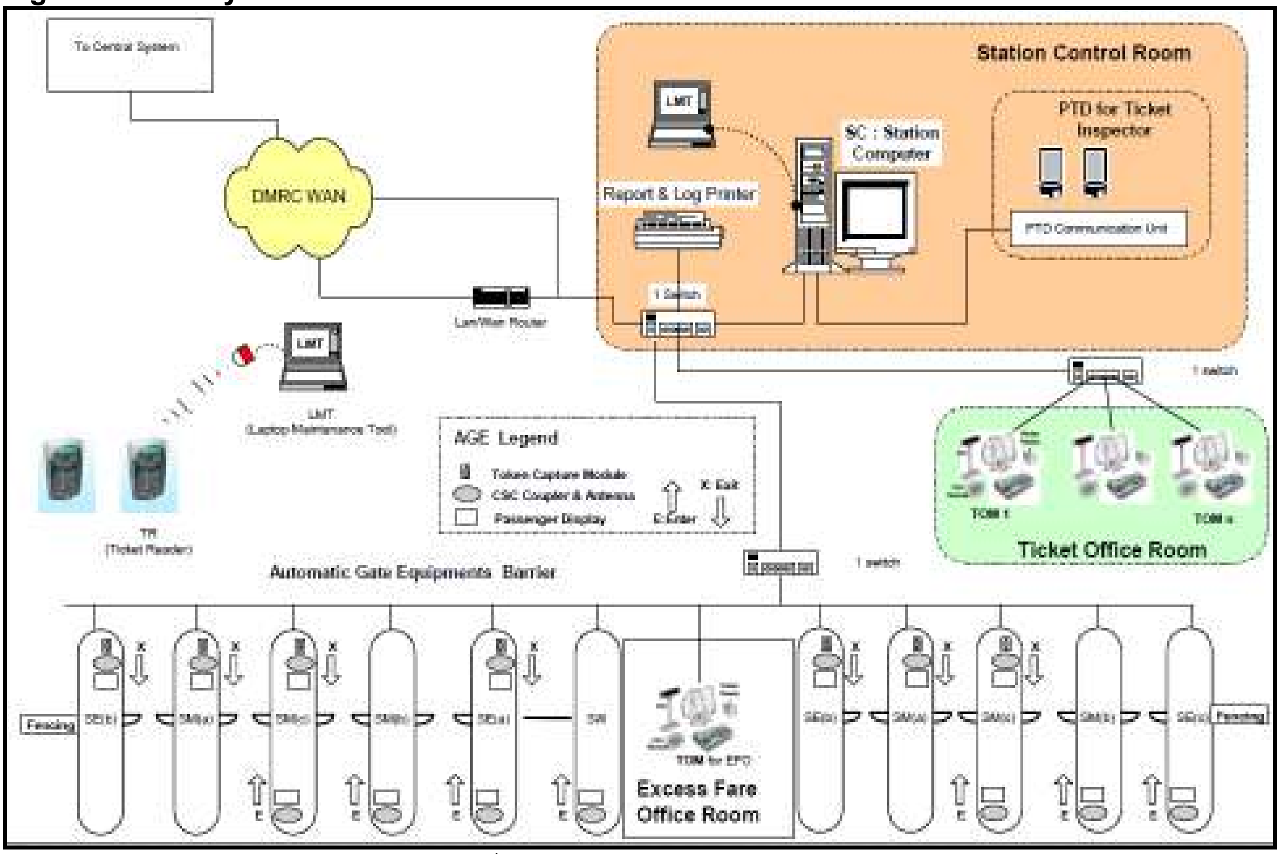
The environmental section of DMRC is responsible for CDM project monitoring. This area responds directly to the Managing Director.

The identical procedure and steps have been applied in the prior monitoring periods verified successfully and with issuance of CERs.

PARAMETER PASSENGERS[15]

Passenger flow data is based on the AFC system (Automatic Fare Collection System) which consists of semiautomatic ticket vending machines, automatic entry-exit gates, station computer and a central server. The AFC realizes access control of passengers, ticket reading/writing, transaction collection and reports, stock management and equipment supervision. Components of the system are a Data Center (DC), Middle Ware Server (MS), Archiving Server (AS), Production Server (PS), Administration Console and Certificate Authority (AC&CA), Network Management Console (NMC), Local Workstations (LW) and a Firewall (F). AFC equipment at stations are a station computer, AFC gates, ticket office, Ticket Reader (TR), Portable Data Terminals (PTD), Gate Remote Control Unit (GRCU), emergency switch, network switch and power plant. The system architecture is shown in the following figure.

Figure 1: AFC System Architecture



Source: Verified Monitoring Report 2nd monitoring period, Figure 1

PASSENGER SURVEYS

[15] See for data sources Verified Monitoring Report 2nd monitoring period

No passenger surveys were realized in this monitoring period in accordance with the registered PDD.

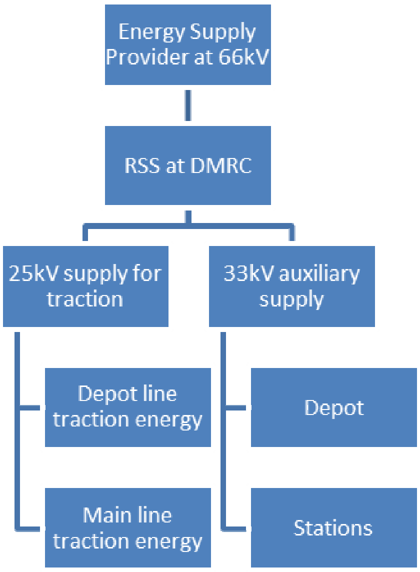
ELECTRICITY CONSUMPTION

DMRC takes power from various distribution companies of Delhi and the National Capital Region. The electricity is received at 220KV, 132 KV or 66 KV level as per availability and contract agreement with the distribution companies. The electricity is stepped down at the RSS (Receiving Sub Station) of DMRC to lower voltages in the following manner:

- 25 KV, 1 phase for traction requirement and
- 33 KV, 3 phase for auxiliary power requirements.

The following figure shows the energy path.

Figure 2: DMRC Power Distribution System



The energy at 25KV is connected to overhead traction wires for running of trains. Total energy is read from 66 KV energy meters being the sum of all energy meters of RSS in that line. Traction energy is thereafter read from traction meter. Traction energy (TE) data is recorded every month by DMRC officials under the Operations & Maintenance Wing, Traction. The recordings are done manually. Both hard and soft copies of the traction data are stored by the Operations & Maintenance Wing, Traction. The car-kilometer are determined for Phase I, Phase II and Phase III based on section wise data per train based on dispatch data plus data if the train has 4 or 6 coaches thus determining exactly total car-km per month and Phase II car-km per month. The traction energy of the project (Phase II) is thereafter the total traction energy divided by the total car-km and multiplied with the Phase II car-km i.e. the specific electricity consumption per car-km is determined to calculate thereafter the Phase II electricity used for traction. The regenerative energy is used by other trains running on the same lines. Only minor energy which is not utilized during late hours goes back to DISCOM. The recorded energy of meters which is used for billing purpose does not include this export part and is thus conservative. The TE meters are located at the Receiving Sub Station (RSS).

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante

Data/Parameter	**$SFC_{C/T, G/D}$**
Data unit	g/km
Description	Specific fuel consumed of passenger cars (C) and taxis (T) using gasoline or diesel
Source of data	UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport
Value(s) applied	Gasoline car/taxi: 44 g/km Diesel car/taxi: 42 g/km
Choice of data or measurement methods and procedures	The globally applicable default value based on the tool is taken as no updated surveys of fuel consumption of cars or taxis is available for Delhi (alternative 1) nor national/international literature with comparable surroundings (alternative 2). IPCC default values have not been updated in 2006 and are therefore outdated (alternative 3) and design data plus detailed registration data is not available per vehicle models and years (alternative 4). Therefore alternative 5 is chosen with globally applicable default values. Globally applicable default values based on tool: 1. Gasoline car/taxi 6 l/100km 2. Diesel car/taxi 5 l/100km Specific weight of fuels: a). Density of gasoline: 0.741 kg/l b). Density of diesel: 0.844 kg/l Source: IEA (2005), Energy Statistics Manual, Table A3.8 (File R1) Calculation: (default value/100) * specific weight *1000 = specific fuel consumption in g/km
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	**$SFC_{C/T, CNG}$**
Data unit	g/km
Description	Specific fuel consumed of passenger cars (C) and taxis (T) using CNG
Source of data	EEA (2018), EMEP/EEA air pollutant emission inventory guidebook 2016 – Update July 2018, Table 3-15
Value(s) applied	63 g/km
Choice of data or measurement methods and procedures	Alternative 2 taken Based on the UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport: No updated surveys of fuel consumption of cars or taxis is available for Delhi (alternative 1). International literature is taken using the lowest available value (alternative 2). IPCC default values have not been updated in 2006 and therefore outdated (alternative 3), design data plus detailed registration data is not available per vehicle models and years (alternative 4) and the UNFCCC has no globally applicable default value for CNG vehicles (alternative 5).
Purpose of data / parameter	Baseline and project emissions
Additional comments	The COPERT model of EEA is also used by IPCC

Data/Parameter	SFC_M
Data unit	g/km
Description	Specific fuel consumed of motorcycles
Source of data	UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport
Value(s) applied	15
Choice of data or measurement methods and procedures	The globally applicable default value based on the tool is taken as no updated surveys of fuel consumption of motorcycles is available for Delhi (alternative 1) nor national/international literature with comparable surroundings (alternative 2). IPCC default values have not been updated in 2006 and are therefore outdated (alternative 3) and design data plus detailed registration data is not available per vehicle models and years (alternative 4). Therefore alternative 5 is chosen with globally applicable default values. Globally applicable default values based on tool: 2 l/100km Density of gasoline: 0.741 kg/l Source: IEA (2005), Energy Statistics Manual, Table A3.8 Calculation: (default value/100) * specific weight *1000 = specific fuel consumption in g/km
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	SFC_{TR}
Data unit	g/km
Description	Specific fuel consumed of motorized auto-rickshaws
Source of data	Reynolds et.al. (2011) Determinants of PM and GHG emissions from natural gas-fuelled auto-rickshaws in Delhi; Transportation Research Part D Transport and Environment 16(2): 160-165 March 2011, table 3 lower value 4-stroke and 2-stroke (File R3)
Value(s) applied	35
Choice of data or measurement methods and procedures	Based on the UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport: No updated surveys of fuel consumption of auto-rickshaws is available for Delhi (alternative 1). National literature is taken using the lowest available value (alternative 2). IPCC default values have not been updated in 2006 and therefore outdated (alternative 3), design data plus detailed registration data is not available per vehicle models and years (alternative 4) and the UNFCCC has no globally applicable default value for CNG vehicles (alternative 5). The lower value between 4-stroke and 2-stroke vehicles is taken to be conservative.
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	SFC_B
Data unit	g/km
Description	Specific fuel consumed of buses
Source of data	Delhi Transport Corporation (DTC), Operational Statistics March 2019, Table 1-8
Value(s) applied	459
Choice of data or measurement methods and procedures	Based on the UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport: alternative 1 is chosen based on official published data of Delhi. DTC manages the urban bus fleet of Delhi. Data of all buses (not based on survey). Data for the year 2017-18. Entire urban bus fleet based on CNG. Value expressed in km per kg and transformed to g per km Value reported by DTC: 2.18 km per kg Transform from km per kg to g per km: 1/2.18*1000 = 459
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	$N_{C,G/D/CNG}$
Data unit	%
Description	Percentage of passenger cars using fuel type: gasoline, diesel or CNG
Source of data	Department of Transport, Delhi, VAHAN 4.0 Database accessed 26.09.2018
Value(s) applied	Gasoline: 62.6% Diesel: 25.8% CNG: 11.6%
Choice of data or measurement methods and procedures	official registration statistics
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	$N_{T,CNG}$
Data unit	%
Description	Percentage of taxis using CNG
Source of data	Supreme Court of India mandated that all commercial passenger vehicles including taxis be CNG powered; see https://scroll.in/article/807463/delhi-has-relied-on-cng-to-control-its-pollution-in-the-past-but-will-it-work-this-time
Value(s) applied	100%
Choice of data or measurement methods and procedures	Official regulation of Delhi asking for public transport vehicles to be CNG
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	$N_{TR,CNG}$
Data unit	%
Description	Percentage of motorized auto-rickshaws using CNG
Source of data	Department of Transport, Delhi, VAHAN 4.0 Database accessed 26.09.2018
Value(s) applied	100%
Choice of data or measurement methods and procedures	Official regulation of Delhi asking for public transport vehicles to be CNG
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	$N_{M,G}$
Data unit	%
Description	Percentage of motorcycles using gasoline
Source of data	Department of Transport, Delhi, VAHAN 4.0 Database accessed 26.09.2018
Value(s) applied	100%
Choice of data or measurement methods and procedures	Official registration statistics; less than 1% of motorcycles are electric.
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	$N_{B,CNG}$
Data unit	%
Description	Percentage of buses using CNG
Source of data	Department of Transport, Delhi, VAHAN 4.0 Database accessed 26.09.2018 (File R5) and Delhi Transport Corporation (DTC), Operational Statistics March 2019, Table 1-8
Value(s) applied	100%
Choice of data or measurement methods and procedures	Official regulation of Delhi asking for public transport vehicles to be CNG
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	EF_{Grid}
Data unit	$kgCO_2/kWh$
Description	Emission factor of the grid
Source of data	Government of India, Central Electricity Authority, CO2 Baseline Database for the Indian Power Sector, version 13.0, June 2018, Table S-1
Value(s) applied	0.92
Choice of data or measurement methods and procedures	Combined Margin; official data; follow procedures as in “Tool to calculate baseline, project and/or leakage emissions from electricity consumption”, newest version of tool
Purpose of data / parameter	Project emissions
Additional comments	none

Data/Parameter	TDL
Data unit	%
Description	Average technical transmission and distribution losses for providing electricity
Source of data	Power Systems Operation Corporation Ltd. 2019
Value(s) applied	2.6%
Choice of data or measurement methods and procedures	Highest of 12 values reported for Northern Grid; official reported value
Purpose of data / parameter	Project emissions
Additional comments	none

Data/Parameter	$OC_{C,T,M}$
Data unit	Passengers
Description	Average occupation rate of passenger cars (C), taxis (T) and motorcycles
Source of data	UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport
Value(s) applied	Car: 2 Taxi: 1.1 (excluding driver) Motorcycle: 1.5
Choice of data or measurement methods and procedures	The default value based on the tool is taken as no updated official reports or studies available for Delhi (alternative 1).
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	**OC_{TR}**
Data unit	Passengers
Description	Average occupation rate of motorized rickshaws
Source of data	Lotus, 2019
Value(s) applied	1.6
Choice of data or measurement methods and procedures	UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport; No study of municipality available (alternative 1), no default value from tool available (alternative 2); survey of occupation rate for Delhi realized by 3rd Party (alternative 3) The survey was performed July 2019 in Delhi. The statistical analysis shows: AV Average: 1.62 passengers SD Standard deviation: 1.1 CIW (Confidence interval width): 0.12 Sample size: 1,285 rickshaws Required sample size: $N = \frac{1.96^2 \times \left(\frac{SD}{AV}\right)^2}{0.1^2}$ N = 178 rickshaws Actual sample size = 1,285 units i.e. the actual sample size is much higher than the required sample size. See also UNFCCC sample size calculator (File R9b) Reliability test: $R = \frac{0.5 \times (CIW)}{AV} \times 100\,\%$ R= 4% which is far better than the minimum required of 10% (see UNFCCC Guideline “Sampling and surveys for CDM project activities and programmes of activities” Version 04.0
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data/Parameter	**OC_B**
Data unit	Passengers
Description	Average occupation rate of buses
Source of data	UNFCCC CDM Tool 18 Methodological tool: Baseline emissions for modal shift measures in urban passenger transport
Value(s) applied	42.4
Choice of data or measurement methods and procedures	The default value based on the tool is taken as no updated official reports or studies available for Delhi (alternative 1): 80% for South Asia. The average capacity of DTC buses used in Delhi is 53 passengers (33 seated and 20 standing) Calculation: 80% * 53 = 42.4
Purpose of data / parameter	Baseline and project emissions
Additional comments	none

Data / Parameter	$EC_{EL,R}$
Unit	MWh
Description	Quantity of electricity consumed by the baseline rail system per annum
Source of data	India Railways, IR Yearbook 2017-18, Northern Line suburban point 32.25, page 404
Value(s) applied	2,636
Choice of data or Measurement methods and procedures	Electric consumption for commuter rail system of Northern Railways entering Delhi
Purpose of data / parameter	Baseline and project emissions
Additional comments	Is monitored annually if survey shows that passengers use suburban rail

Data / Parameter	$P_{EL,R}$
Unit	Passengers
Description	Total passengers transported by baseline suburban rail-system per year
Source of data	India Railways, IR Yearbook 2017-18 passenger revenue statistics, Northern Line suburban, statement 12, p.75
Value(s) applied	2,557,000
Choice of data or Measurement methods and procedures	Passengers for commuter rail system of Northern Railways entering Delhi
Purpose of data / parameter	Baseline and project emissions
Additional comments	Is monitored annually if survey shows that passengers use suburban rail

Data / Parameter	$TD_{EL,R}$
Unit	Km
Description	Average trip distance of baseline urban rail passengers prior project start on rail system
Source of data	Grütter Consulting AG, 2008
Value(s) applied	29
Choice of data or Measurement methods and procedures	Same year as for data passenger on rail system and electricity consumption of rail system Upper 95% confidence interval
Purpose of data / parameter	Baseline and project emissions
Additional comments	Only rail trip distance not total trip distance

D.2. Data and parameters monitored

Data/Parameter	$NCV_{G/D/CNG}$
Unit	MJ/kg
Description	Net calorific value of gasoline, diesel and CNG
Measured/calculated/default	Default
Source of data	IPCC 2006, table 1.2, lower 95% confidence interval
Value(s) of monitored parameter	Gasoline: 42.5 Diesel: 41.4 CNG: 46.5
Monitoring equipment	None
Measuring/reading/recording frequency	Annual

Calculation method (if applicable)	Not applicable
QA/QC procedures	None
Purpose of data/parameter	Baseline and Project
Additional comments	None

Data/Parameter	**$EF_{CO2,G/D/CNG}$**
Unit	gCO_2/MJ
Description	CO_2 emission factor for gasoline, diesel and CNG
Measured/calculated/default	Default
Source of data	IPCC 2006, table 1.4, lower 95% confidence interval
Value(s) of monitored parameter	Gasoline: 67.5 Diesel: 72.6 CNG: 54.3
Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	No new values
Purpose of data/parameter	Baseline and Project
Additional comments	None

Data/Parameter	**$EF_{KM,B,CH4}$**
Unit	gCO_{2eq}/km
Description	CH_4 emission factor of CNG buses per kilometre in CO_{2eq}
Measured/calculated/default	Default
Source of data	IPCC 2006, table 3.2.4. and IPCC, 2013
Value(s) of monitored parameter	193
Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Value of 7,715 mg CH_4 of IPCC is multiplied with the GWP of 25 for CH_4 to calculate CO_{2eq}
QA/QC procedures	None
Purpose of data/parameter	Baseline and Project
Additional comments	None

Data/Parameter	**$EF_{KM,C/T/TR,CH4}$**
Unit	gCO_{2eq}/km
Description	CH_4 emission factor of CNG cars. Taxis and motorized auto-rickshaws per kilometre in CO_{2eq}
Measured/calculated/default	Default
Source of data	IPCC 2006, table 3.2.4. (average of upper and lower boundary) and IPCC, 2013
Value(s) of monitored parameter	12

Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Average of 725 mg and 215 mg CH_4 of IPCC is multiplied with the GWP of 25 for CH_4 to calculate CO_{2eq}
QA/QC procedures	None
Purpose of data/parameter	Baseline and Project
Additional comments	None

Data/Parameter	**$N_{x,C}$**
Unit	Vehicles
Description	Number of passenger cars (C) using fuel type *x*
Measured/calculated/default	Measured
Source of data	Government of National Capital Territory of Delhi, Transport Department, Vahan 4.0 Database accessed 26.09.2018 (File 6)
Value(s) of monitored parameter	Diesel: 42,277 (25.8%) Gasoline: 114,972 (62.6%) CNG: 21,330 (11.6%)
Monitoring equipment	Registration statistics
Measuring/reading/recording frequency	Latest available data not elder as 3 years
Calculation method (if applicable)	Relevant is only the percentage distribution per fuel and not the absolute figures as the relative share is used to determine the emission factor per kilometre. LPG vehicles constitute less than 0.1% of total and are thus not considered. Electric vehicles constitute less than 0.1% of total and are thus not considered.
QA/QC procedures	None
Purpose of data/parameter	Baseline, Project
Additional comments	Biofuel usage in gasoline: 2018: 3.9%, 2019: 4.5% and 2020: 5.0% (File 5, table 5); biofuel in diesel 0.1% in 2018, 0.2% in 2019 and 0.1% in 2020 (File 5 table 6).This bio-fuel share has been included to determine the new EF cars (File 1).

Data/Parameter	**$N_{x,T}$**
Unit	Vehicles
Description	Number of Taxis (T) using fuel type *x*
Measured/calculated/default	Measured
Source of data	The Supreme Court of India mandated that all commercial passenger vehicles including taxis be CNG powered (July 28, 1998 implemented by late 2002; see U. Narain et.al., The Impact of Delhi's CNG Program on Air Quality, RFF, 2007, Appendix A; File 10)
Value(s) of monitored parameter	Not required as 100% CNG due to Supreme Court Decision
Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Relevant is only the percentage distribution per fuel and not the absolute figures as the relative share is used to determine the emission factor per kilometre.
QA/QC procedures	None
Purpose of data/parameter	Baseline, Project

Additional comments	The Supreme Court Decision was already valid as of baseline determination and therefore no change relative to baseline fuel composition of taxis.

Data/Parameter	**$N_{x,TR}$**
Unit	Vehicles
Description	Number of motorized auto-rickshaws (TR) using fuel type *x*
Measured/calculated/default	Measured
Source of data	The Supreme Court of India mandated that all commercial passenger vehicles including motorized auto-rickshaws be CNG powered (July 28, 1998 implemented by late 2002; see U. Narain et.al., The Impact of Delhi's CNG Program on Air Quality, RFF, 2007, Appendix A; File 10)
Value(s) of monitored parameter	Not required as 100% CNG due to Supreme Court Decision
Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Relevant is only the percentage distribution per fuel and not the absolute figures as the relative share is used to determine the emission factor per kilometre.
QA/QC procedures	None
Purpose of data/parameter	Baseline, Project
Additional comments	The Supreme Court Decision was already valid as of baseline determination and therefore no change relative to baseline fuel composition of motorized rickshaws.

Data/Parameter	**$N_{x,M}$**
Unit	Vehicles
Description	Number of motorcycles (M) using fuel type *x*
Measured/calculated/default	Measured
Source of data	Government of National Capital Territory of Delhi, Transport Department, Vahan 4.0 Database accessed 26.09.2018 (File 6)
Value(s) of monitored parameter	480,309 100% gasoline Less than 0.1% electric
Monitoring equipment	None
Measuring/reading/recording frequency	Annual
Calculation method (if applicable)	Relevant is only the percentage distribution per fuel and not the absolute figures as the relative share is used to determine the emission factor per kilometre.
QA/QC procedures	None
Purpose of data/parameter	Baseline, project
Additional comments	ACM0016 states that the share of fuels per vehicle category must be identified and if relevant the emission factor must be re-calculated.

Data/Parameter	**P**
Unit	Passengers
Description	Total passengers transported by the project
Measured/calculated/default	Measured
Source of data	DMRC, 2021 (File 8)

Value(s) of monitored parameter	808,177,128
Monitoring equipment	Turnpike controls at stations and electronic smart cards. Only passengers are included which enter stations of the lines include in the project.
Measuring/reading/recording frequency	Daily
Calculation method (if applicable)	Not applicable
QA/QC procedures	The passenger numbers are calculated based on the entry from Phase-II stations. At the end of the day system automatically takes all the entry passengers of Phase-II stations and this value is counted as entry of that day. All data from individual equipment to central computer is encrypted using 3DES algorithm
Purpose of data/parameter	Project and Baseline
Additional comments	None

Data/Parameter	**EC_{PJ}**
Unit	kWh
Description	Electricity consumed by MRTS (trains)
Measured/calculated/default	Measured and calculated
Source of data	DMRC, 2021 (File 7)
Value(s) of monitored parameter	354,784,350
Monitoring equipment	Traction energy is recorded by DMRC per line.
Measuring/reading/recording frequency	Continuously, aggregated monthly
Calculation method (if applicable)	Traction energy is read from traction meter. The car-km for phase I, phase II and phase III are calculated for all lines. TE for Phase II is Total TE consumed for each line minus the TE consumed by Phase I and III based on car-km distances for each phase i.e. the specific electricity consumption per car-km is calculated and thereafter Phase II energy consumption is based on the specific value multiplied with car-km of Phase II. The table below shows the total traction energy consumption Phase II energy consumption based on total energy/total car-km * car-km Phase II.
QA/QC procedures	Control with electricity invoices for total energy.
Purpose of data/parameter	Project
Additional comments	None

Table 4: Traction Energy (monitoring period)

Year	Total car-km	Phase II car-km	Total traction energy in kWh	Phase II traction energy in kWh
01/07/2018 to 31/12/2018	231,733,975	148,285,020	58,135,097	**90,921,667**
2019	508,644,933	327,916,866	116,087,174	**180,029,148**
2020	240,952,850	168,797,060	58,708,460	**83,833,535**
Total	981,331,758	644,998,946	232,930,731	**354,784,350**

Source: File 3 based on File 1

Data/Parameter	**$EC_{EL,R}$**
Unit	MWh
Description	Quantity of electricity consumed by the baseline rail system per annum
Measured/calculated/default	Measured
Source of data	File 2, IR Yearbook 2019-20 EMU statistics, Northern Line suburban point 32.25 page 404, cumulative 2018-19 and 2019-20

Value(s) of monitored parameter	3,567
Monitoring equipment	None
Measuring/reading/recording frequency	Annual, last available year
Calculation method (if applicable)	Not applicable
QA/QC procedures	
Purpose of data/parameter	Baseline and Project
Additional comments	Required to establish the emission factor per PKM for suburban rail

Data/Parameter	$\mathbf{P_{EL,R}}$
Unit	Passengers
Description	Total passengers transported by baseline rail-system per year
Measured/calculated/default	Measured
Source of data	File 2, IR Yearbook 2019-20 pax revenue statistics, Northern Line suburban, statement 12 p.75, cumulative 2018-19 and 2019-2020
Value(s) of monitored parameter	3,346,000
Monitoring equipment	None
Measuring/reading/recording frequency	Annual, last available year
Calculation method (if applicable)	None
QA/QC procedures	
Purpose of data/parameter	Baseline and Project
Additional comments	Required for the emission factor suburban rail system; same year and source as $EC_{EL,R}$

Data/Parameter	$\mathbf{BTD_{p,i}}$
Unit	Kilometre
Description	Baseline trip distance of the cluster *p* of surveyed passengers using mode *i*
Measured/calculated/ default	Measured and calculated
Source of data	Absolute Market Research and Consultants Private Ltd. (File 9 and 11, 11a,11b)
Value(s) of monitored parameter	Calculated for each passenger surveyed for each mode used in the baseline trip. See for values per passenger per mode File 9
Monitoring equipment	None
Measuring/reading/recording frequency	Realized 11/2021; Due to COVID-19 the survey could not be realized in 2020 as planned
Calculation method (if applicable)	Based on distance between starting and ending point of trip using mode *i* in the baseline determined through electronic maps.
QA/QC procedures	See Section D.3. for survey details
Purpose of data/parameter	Baseline
Additional comments	See Section D.3. for survey details Distance is not required and not calculated if NMT (Non-Motorized Transit) is used as latter has an emission factor of 0 (the trip distance is only required to calculate the emissions caused).

Data/Parameter	$IPTD_{p,i}$
Unit	Kilometre
Description	Indirect project trip distance of the surveyed passenger using mode *i*
Measured/calculated/ default	Measured
Source of data	Absolute Market Research and Consultants Private Ltd. (File 9 and 11, 11a,11b)
Value(s) of monitored parameter	Calculated for each passenger surveyed for each mode used to and from the metro. See for values per passenger per mode File 9
Monitoring equipment	None
Measuring/reading/recording frequency	Realized 11/2021; Due to COVID-19 the survey could not be realized in 2020 as planned
Calculation method (if applicable)	Based on distance between starting point and entry point of metro and exit point of metro and end trip point using mode *i* in the baseline determined through electronic maps.
QA/QC procedures	See Section D.3. for survey details
Purpose of data/parameter	Project
Additional comments	See Section D.3. for survey details Distance is not required and not calculated if NMT (Non-Motorized Transit) is used as latter has an emission factor of 0 (the trip distance is only required to calculate the emissions caused).

Data/Parameter	FEX_p
Unit	None
Description	Expansion factor for each surveyed passenger *p* surveyed (each surveyed passenger has a different expansion factor)
Measured/calculated/ default	Calculated
Source of data	Grütter Consulting based on passenger data DMRC (per hour per station for the survey week and for the year) and survey results of Absolute Market Research and Consultants Private Ltd, (File 9 and 11,11a,11b)
Value(s) of monitored parameter	Calculated for each passenger surveyed; see File 9
Monitoring equipment	None
Measuring/reading/recording frequency	Realized 11/2021; Due to COVID-19 the survey could not be realized in 2020 as planned
Calculation method (if applicable)	See Section D.3. for survey details
QA/QC procedures	See Section D.3. for survey details
Purpose of data/parameter	Baseline and Project
Additional comments	See Section D.3. for survey details

Data/parameter:	P_{SPER}
Unit	Passengers
Description	Number of passengers in the period of the survey (1 week)
Measured/calculated/default	Measured
Source of data	DMRC, File 12
Value(s) of monitored parameter	Value per station per hour per day for each survey week

Monitoring equipment	Turnpike controls at stations and electronic smart cards.
Measuring/reading/recording frequency:	Realized 11/2021; Due to COVID-19 the survey could not be realized in 2020 as planned
Calculation method (if applicable):	Emissions are calculated per passenger and then expanded to the total; the number of passengers per station per hour and per day is required for FEX
QA/QC procedures:	See Section D.3. for survey details
Purpose of data/parameter	Baseline and Project
Additional comments:	See Section D.3. for survey details

D.3. Implementation of sampling plan

A passenger survey is used to determine indirect project emissions as well as baseline emissions. This includes the parameters MS_i, FEX, BTD, and IPTD.

A. SURVEY

The methodological design of the survey is presented in detail. The surveys was made by an external survey company.

Table 5: Technical Summary Data Sheet of the Survey Strategy and Sample Design Metro Delhi Passenger Survey

Parameters	Main parameters: • Baseline emissions; • Indirect project emissions. Secondary parameters and inputs: • Proportion of passengers using each mode of transport, with the project and in absence of the project; • The average distance travelled by these modes with the project and in absence of the project.
Target population	Passengers over 12 years using the Metro Delhi.
Sample frame	Passenger flow in all the stations Phase II of the Metro Delhi.
Sample design	Two staged probabilistic design: • First stage: stratified – simple random sampling (SRS); • Second stage: systematic sampling based on passengers flow per station. Stratum: Lines and Stations. Sub stratum: Days in the week and hours.
Relative error level (CV)[16]	For the survey a global desired level of precision (relative standard error or coefficient of variation – CV) between 5% and 10% for the parameters of interest is targeted, which implies at the same time having precision levels of 90/10. Results obtained are based on a 95% confidence level using the more conservative boundary.

[16] Relative error level refers to the coefficient of variation (CV), which is calculated as the ratio between the standard deviation of the average and the population average.

Coverage	Urban area where the Metro Delhi operates.
Size of Universe	Generally, in one day Metro Delhi transports around 1.4 million passengers on the Phase II lines[17].
Sample size	The sample size is around 2,000 surveys in each survey.
Pilot Test	The pilot test corresponds to a survey realized July 2008 during an entire week in a continuous manner. 804 passengers of Delhi Metro were interviewed. Since the project start 6 surveys (2 per annum) have already been carried out which allowed to adjust the survey sample size based on the calculated CV.
Sample frequency	2x annually during an entire week (compulsory based on the methodology is for year 4 only 1 survey).
Method of information collection	The information is obtained through the face-to-face application of the established questionnaire on a random base.

Survey Objective

The survey objective is to determine:

- The baseline emissions caused by passengers which use Metro Delhi Phase II and in absence of latter would have used other modes of transport to realize their trip;
- The indirect project emissions of passengers using Metro Delhi Phase II which correspond to the emissions caused from the trip origin to the metro entry station and from the metro exit station to the final destination.

Target Population

The target population are passengers over 12 years of age. Smaller children are excluded due to problems in answering the questions. Also, smaller children in general are accompanied by their parents or an adult and thus have the same trip sequence as the adult person.

Geographical Coverage

The geographical coverage is the area where metro Delhi operates (project boundary).

Sample Frequency

The surveys were realized 15-21 of November 2021. The surveys took place during an entire week. The selected weeks do not correspond to a public holiday and are representative for the average demand for transport services in the considered year.

Sample Frame

The simple frame is the passenger flow in all the stations of Phase II Metro Delhi. Data for the passenger frame is obtained from the system manager.

Survey Design

The survey was conducted among Delhi Metro commuters at DMRC phase-2 stations. The survey design is identical to previously realized surveys. To get a better representation and complete

[17] See File 1 based on numbers of passengers 2015 and 365 days per annum

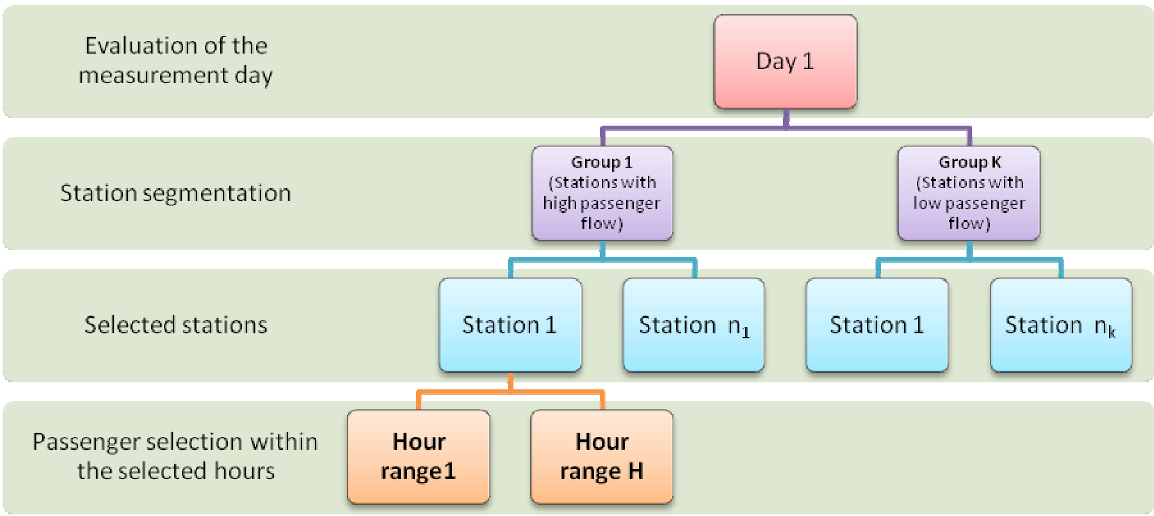
coverage of target population, this target sample was distributed among stations, days and time slots:

- **Target Population:** DMRC Commuters (Above 12 years)
- **Total Sample Size:** 2,000 per survey
- **Sampling Frame:** Passenger flow at the stations (as per the passenger flow data given)
- **Coverage:** 84 Metro stations of DMRC phase-2
- **Sampling Method: Two stage stratified sampling**
  - **Stratum:** Stations
  - **Sub-Stratum:** Days in the weeks & hours: Proportionate allocation of passenger flow among these stratum

At first the relevant stratums i.e. “station” & “timeslots” and their actual representation in the population were identified. After stratification, a probability sample was determined for each stratum. The proportionate allocation was used for determining the sample size of each stratum, i.e. the sample size for each stratum (station/timeslot) is proportionate to the population size of that stratum. Thus, each stratum has a “sampling fraction”.

The given weekly passenger was partitioned into groups i.e. stations, days and timeslots. The stratification model used is represented by the following scheme, where the process for a specific day is shown which applies routinely for the seven measurement days.

Figure 3: Survey Stratification Model



The stations were stratified into three strata i.e. heavy, medium and low traffic. This stratification was done through the 3-cluster solutions. On the basis of that distribution, the sampling fraction for each stratum was determined.

For the timeslot stratification, the average hourly traffic flow for all 7 days was calculated. The timeslots were classified based on the variations in the average traffic flow. On the average traffic flow data, a 5-cluster solution was performed and the 5 time slots (stratums) were defined. Proportionate allocation uses the sampling fraction in each of the strata that is proportional to that of the total population. The size of the sample in each stratum is taken in proportion to the size of the stratum.

The sampling fraction of the day is the ratio between the total traffic flow of that day and total traffic flow of the week. The sample of one day is allocated to the pre-defined stratum (stations and time slots). Sampling Fraction for n1 station at t1 hour = (Traffic flow at n1 station during t1 hour for total week) / (total traffic follow of the week)

Sample Selection

The selection method guarantees a random and non-biased selection process especially important in face-to-face interviews. The random distribution allows that the sample mirrors the total population in any other non-observed variables such as age, gender, religion, personal preferences etc. The selection of stations is carried out according to a SRS design, through the negative coordinated algorithm. The same happens for the defined hour ranges: within each range a specific hour is selected under this method for the sample selection. Given that there is no reference frame or list frame for the identification of DMRC users, the selection of the sample in the last stage is performed according to the systematic sampling design, replicated identically for each stratum and considering the following steps:

- A random starting point is generated according to the statistics tables of uniform distribution between 1 and the average flow of passengers in the evaluation hour;
- Systematic selection of passengers: every n passenger entering the station, starting with the random number. In this way, if the random number is 10, the first passenger selected is the 10^{th} that enters the station, the 2^{nd} n+10 and thus successively every n passenger. The number n, called selection interval is determined based on the passenger flow per hour and the sample distribution of the specific measurement day.

Method for Information Collection

The information is obtained through the face-to-face application of the established questionnaire. In a briefing session, the questionnaire was explained in the detail and mock sessions were taken by the supervisors to ensure the understanding of interviewers.

Sample Size Determination

The results of the 8 surveys since 2011 were used to determine the size of the sample. The estimated coefficient variation for the baseline and the project emissions was calculated for this purpose. The sample size of 2,000 users of Metro showed to be sufficient based on the CV and the statistical analysis of the surveys realized previously.

Criteria for Evaluating Data Consistency

Considering that in each one of the years there will be at least two measurements, the weekly measurement and the test-retest, through these the consistency on information collection is guaranteed.

The assessment of consistency can be carried out by three supplementary statistical methods:

1. A mean difference test is performed through a t – Student test, where the differences presented between both measurements are evaluated, for: 1.Proportion of users that use each type of modes of transport and 2. Average trip travel distance. To perform the mean difference test, it is necessary to determine beforehand, if the two samples come from the same population. Thereafter a F test is carried out to determine the variability difference between one and the other. To assess that data used to estimate the study parameters follow the same distribution the Mann Whitney non-parametric U test and the Wilcoxon T test can be used.

2. To evaluate the users proportion per modes of transport, the Pearson's Chi Square can be used, where categories are defined for each mode of transport.

3. Globally and internally in each survey realized, consistency of data reported in the survey may be assessed through the Cronbach alpha coefficient. In practice it is assumed that values higher

than 0.7 in the coefficient indicate an adequate consistency degree. Values over 0.9 should be rechecked to avoid redundancy of data.

For the internal consistency the Cronbach alpha coefficient is used whilst to test for consistency between different periods of measurement the first two options of testing are used.

The Cronbach alpha coefficient will be calculated for each stratum established as these a priori control the variations in the responses and therefore the control eliminates biases which could be generated due to hetereogenity and inconsistency in information.

With the goal of evaluating the possible correlation between BE and IPE a hypothesis test based on the Pearson or Spearman coefficient is made. The parameter to determine the existence of correlation is the *p* value. If the *p* value is less than 0.05 (significance value) it is concluded that the correlation is significant.

If a correlation between BE and IPE exists[18] the variance associated to the estimator (defined as the difference between the two parameters) would have a covariance different from 0. If the variables *x* and *y* are correlated then:

Var(X-Y) = Var(X) + Var(Y) – 2 Cov (X,Y), where COV (X,Y) is not 0.

If the correlation is significant complex estimators and alternative methods of variance need to be used which do not guarantee however that the estimators are unbiased and have a minimal variance. On the other hand if the correlation is non-significant the estimation of the two parameters BE and IPE separately leads to the same result as calculating them jointly.

Realizing the estimation of BE and IPE guarantees that even in the case of correlation we have no problem with the bias in the variance of the estimators i.e. even if we determine correlation the results are correct and no additional step needs to be taken. In the case of having no correlation we could also determine directly the difference between BE and IPE per passenger reaching the same result (in the case of correlation it is necessary in all cases to make the estimation of BE and IPE separately).

Therefore it is preferable, as suggested in these procedures, to calculate the two parameters separately and to determine for each one an unbiased level of error. Additionally for each parameter separate confidence levels can thus be constructed. If the two confidence intervals overlap we have an indication of non-significant differences between BE and IPE.

Estimation of Total Baseline and Indirect Project Emissions

The estimation of the total baseline and the total indirect project emissions considers the emissions per passenger according to the distance per mode and the number of passengers that represent the selected passenger over the passenger flow (expansion factor).

The emissions are calculated as follows:

$$BE = \sum_{k=1}^{n} BE_k \times FEX(year_{End})_k$$

$$IPE = \sum_{k=1}^{n} IPE_k \times FEX(year_{End})_k$$

[18] This is however not expected and empirical data from surveys realized have shown no correlation.

Where:

BE	Total baseline emissions
IPE	Total indirect project emissions
BE_k	Total baseline emissions per surveyed passenger *k*
IPE_k	Total indirect project emissions per surveyed passenger *k*
$FEX(year_{End})_k$	Expansion factor for each surveyed passenger *k*
n	total number of passengers selected
k	k^{th} individual passenger selected

Relative Error Level and Confidence Intervals

The error levels (estimated variance and variation coefficient) for the parameters of total baseline emissions and total indirect project emissions are calculated according to the methodology. Based on these results the confidence intervals are determined with a confidence level of 95%.

$$CI(BE) = BE \pm Z_{1-\alpha/2} \times \sqrt{Var(BE)}$$

$$CI(IPE) = IPE \pm Z_{1-\alpha/2} \times \sqrt{Var(IPE)}$$

Where:

CI(BE)	confidence interval of 95% for total baseline emissions
CI(IPE)	confidence interval of 95% for total indirect project emissions
$Z_{1-\alpha/2}$	percentile of normal distribution for a 95% confidence interval (α = 5%)
Var(BE)	estimated variance for total baseline emissions
Var(IPE):	estimated variance for total indirect project emissions

Finally, for total baseline emissions the lower 95% boundary is taken and for the indirect project emissions the upper 95% boundary is taken to have a conservative calculation of emission reductions.

Table 6: Survey Parameter Results

Parameter	07-12/2018		2019		2020	
	Baseline	Project	Baseline	Project	Baseline	Project
Average emissions per passenger expanded gCO_2	1,230	319	1,227	318	1,227	323
Cv (%)	1.20%	2.80%	1.20%	2.81%	1.20%	2.81%
STDEV (per passenger)	14.8	8.9	14.8	9.0	14.8	9.1
Lower 95% boundary gCO_2/passenger	1,201	301	1,198	301	1,198	305
Upper 95% boundary gCO_2/passenger	1,259	336	1,256	336	1,256	340

Source: File 9

SECTION E. Calculation of emission reductions or net anthropogenic removals

E.1. Calculation of baseline emissions or baseline net removals

$$BE_y = \frac{P_y}{P_{SPER}} \sum_p \left(BE_{p,y} \cdot FEX_{p,y} \right)$$

Where:

BE_y	Baseline emissions in the year *y* (g CO_2)
$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y* (each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)

$$\mathrm{BE_{p,y}} = \sum_{\mathrm{i}} \mathrm{BTD_{p,i,y}} \cdot \mathrm{EF_{PKM,i,y}}$$

Where:

$BE_{p,y}$	Baseline emissions per surveyed passenger *p* in the year *y* (g CO_2)
$BTD_{,p,i,y}$	Baseline trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)
$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)
i	Relevant vehicle category
p	Surveyed passenger
y	Year of the crediting period

$$\mathrm{EF_{PKM,i,y}} = \frac{\mathrm{EF_{KM,i,y}}}{\mathrm{OC_i}}$$

Where:

$EF_{PKM,i}$	Emission factor per passenger-kilometre of vehicle category *i* in the year *y* (g CO_2/PKM)
$EF_{KM,i}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
OC_i	Average occupation rate of vehicle category *i* prior project start (passengers)
i	Relevant vehicle category
y	Year of the crediting period

$$EF_{KM,i,y} = (IR_i)^{t+y} \cdot \frac{\sum_x (SFC_{i,x} \cdot NCV_{x,y} \cdot EF_{CO2,x,y} \cdot N_{x,i})}{N_i}$$

Where:

$EF_{KM,i,,y,}$	Emission factor per kilometre of vehicle category *i* in the year *y* (g CO_2/km)
$SFC_{x,i}$	Specific fuel consumption of vehicle category *i* using fuel type *x* prior project start (g/km)
$NCV_{x,y}$	Net calorific value of fuel *x* in the year *y* (J/g)
$EF_{CO2,x,y}$	Carbon emission factor for fuel type *x* in the year *y* (g CO_2/J)
$N_{x,i}$	Number of vehicles of category *i* using fuel type *x* prior to project start (units)
$N_{x,i}$	Number of vehicles of category *i* prior to project start (units)
IR_i^{t+y}	Technology improvement factor for the vehicle of category *i* per year *t+y* (ratio)
i	Relevant vehicle category
x	Fuel type
t	Years of annual improvement (dependent on age of data per vehicle category)
y	Year of the crediting period

The EF i.e. also cars, taxis, buses, motorcycles and motorized rickshaws is updated based on ACM0016:

- If the bio-fuel share changes;
- If the share of fuel types used per vehicle category changes;
- If NCV or EF data changes.

The biofuel shares are listed in the following table.

Table 7: Biofuel shares

Fuel	2018	2019	2020
Gasoline	3.9%	4.5%	5.0%
Diesel	0.1%	0.2%	0.1%

Source: File 5, table 5 and 6

The following table shows the EF for baseline modes of transport.

Table 8: EF per PKM per Mode (gCO_2/pkm)

Detail	2018	2019	2020
Emission factor per pkm car	64	64	64
Emission factor per pkm taxi	156	156	156
Emission factor per pkm motorcycle	63	63	63
Emission factor per pkm rickshaw	28	27	27
Emission factor per pkm bus	32	32	32
Suburban rail	35	35	35

Source: File 1

Baseline Results

Table 9: Baseline Emission Calculation

Parameter	07-12/2018	2019	2020
Passengers	232,433,816	449,901,385	125,841,927
Baseline emissions per passenger (lower 95% confidence interval) in gCO_{2e}	1,201	1,198	1,198
Baseline emissions tCO_2	**279,154**	**538,982**	**150,759**

Source: CER spreadsheet

The total baseline emissions of the monitoring period are **968,895 tCO_{2eq}**

E.2. Calculation of project emissions or actual net removals

Project emissions are calculated as follows:

$$\mathrm{PE_y} = \mathrm{DPE_y} + \mathrm{IPE_y}$$

Where:

$PE_{,y,}$	Project emissions in the year *y* (tCO_2)
DPE_y	Direct project emissions in the year *y* (tCO_2)
IPE_y	Indirect project emissions in the year *y* (tCO_2)

$$DPE_y = EC_{PJ,y} \times EF_{grid,CM} \times (1 + TDL)$$

Where:

DPE_y	Direct project emissions in the year *y* (tCO_2)
$EC_{PJ,y}$	Quantity of electricity consumed of project for traction energy (MWh)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (tCO_2/MWh)
TDL	Average technical transmission and distribution losses for providing electricity

$$IPE_y = \frac{P_y}{P_{SPER}} \sum_p \left(IPE_{p,y} \cdot FEX_{p,y} \right)$$

Where:

IPE_y	Indirect project emissions in the year *y* (g CO_2)
$IPE_{p,y}$	Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)
$FEX_{p,y}$	Expansion factor for each surveyed passenger *p* surveyed in the year *y* (each surveyed passenger has a different expansion factor)
P_y	Total number of passengers in the year *y*
P_{SPER}	Number of passengers in the time period of the survey (1 week)
p	Surveyed passenger
y	Year of the crediting period

$$IPE_{p,y} = \sum_i IPTD_{p,i,y} \times EF_{PKM,i,y}$$

Where:

$IPE_{p,y}$	Indirect project emissions per surveyed passenger *p* in the year *y* (g CO_2)
$BTD_{,p,i,y}$	Indirect project trip distance *p* per surveyed passenger using mode *i* in the year *y* (PKM)
$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of mode *i* in the year *y* (g CO_2/PKM)
i	Relevant vehicle category
p	Surveyed passenger
y	Year of the crediting period

The following table lists the parameters required for calculating IDPE. For IDPE the same EF_{PKM} are used as for the baseline.

Table 10: Parameters for Indirect Project Emission Calculation

Parameter	07-12/2018	2019	2020

Passengers	232,433,816	449,901,385	125,841,927
Indirect project emissions per passenger (upper 95% confidence interval) in gCO_{2e}	301	301	305
Indirect Project Emissions tCO_2	**69,963**	**135,420**	**38,382**

Source: CER spreadsheet

Table 11: Project Emissions in tCO_{2e}

Parameter	07-12/2018	2019	2020
Direct project emissions	85,823	169,933	79,132
Indirect project emissions	69,963	135,420	38,382
Total Project Emissions	**155,785**	**305,353**	**117,514**

Source: CER spreadsheet

The total project emissions of the monitoring period are **578,653 tCO_{2eq}**

For details see CER spreadsheet.

E.3. Calculation of leakage emissions

No leakage based on PDD.

E.4. Calculation of emission reductions or net anthropogenic removals

	Baseline GHG emissions or baseline net GHG removals (t CO_2e)	Project GHG emissions or actual net GHG removals (t CO_2e)	Leakage GHG emissions (t CO_2e)	GHG emission reductions or net anthropogenic GHG removals (t CO_2e)			
				Before 01/01/ 2013	From 01/01/ 2013 until 31/12/ 2020	From 01/01/ 2021	Total amount
Total	968,895	578,653	0	0	390,242	0	390,242

E.5. Comparison of emission reductions or net anthropogenic removals achieved with estimates in the registered PDD

Amount achieved during this monitoring period (t CO_2e)	Amount estimated ex ante for this monitoring period in the PDD (t CO_2e)
390,242	1,290,027

E.5.1. Explanation of calculation of "amount estimated ex ante for this monitoring period in the PDD"

The calculations were based on ex-ante projections of passenger numbers and corresponding but not exactly correlated electricity consumption plus expected travel patterns of Metro users based on past surveys and past data.

The significantly lower ERs compared to the projections are due to the huge decrease in passenger numbers due to COVID19 in comparison with projected passenger numbers. Projected passenger numbers for this monitoring period (see PDD) were 1,296 million passengers whilst actual numbers were 808 million or 40% less than expected. The ERs decreased much more as the occupation rate of trains dropped drastically i.e. project emissions did not reduce in the same amount as baseline emissions. At the same time the trip structure of people changed as can be seen in the survey of 2021 with shorter average trip distance and therefore significantly lower GHG baseline emissions per passenger trip.

E.6. Remarks on increase in achieved emission reductions

ERs are significantly lower than expected.

E.7. Remarks on scale of small-scale project activity

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Not applicable as the project is a large-scale project.

Document information

Version	Date	Description
09.0	8 October 2021	Revision to: • Ensure consistency with version 03.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN).
08.0	6 April 2021	Revision to: • Reflect the “Clarification: Regulatory requirements under temporary measures for post-2020 cases” (CDM-EB109-A01-CLAR).
07.0	31 May 2019	Revision to: • Ensure consistency with version 02.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Add a section on remarks on the observance of the scale limit of small-scale project activity during the crediting period; • Add "changes specific to afforestation or reforestation project activity" as a possible post-registration changes; • Clarify the reporting of net anthropogenic GHG removals for A/R project activities between two commitment periods; • Make editorial improvements.
06.0	7 June 2017	Revision to: • Ensure consistency with version 01.0 of the “CDM project standard for project activities” (CDM-EB93-A04-STAN); • Make editorial improvements.
05.1	4 May 2015	Editorial revision to correct version numbering.
05.0	1 April 2015	Revisions to: • Include provisions related to delayed submission of a monitoring plan; • Provisions related to the Host Party; • Remove reference to programme of activities; • Overall editorial improvement.
04.0	25 June 2014	Revisions to: • Include the Attachment: Instructions for filling out the monitoring report form (these instructions supersede the "Guideline: Completing the monitoring report form" (Version 04.0)); • Include provisions related to standardized baselines; • Add contact information on a responsible person(s)/ entity(ies) for completing the CDM-MR-FORM in A.6 and Appendix 1; • Change the reference number from *F-CDM-MR* to *CDM-MR-FORM*; • Editorial improvement.
03.2	5 November 2013	Editorial revision to correct table in page 1.
03.1	2 January 2013	Editorial revision to correct table in section E.5.

Version	Date	Description
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB 70, Annex 11).
02.0	13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01.0	28 May 2010	EB 54, Annex 34. Initial adoption.

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