Monitoring report form
(Version 04.0)

MONITORING REPORT	
Title of the project activity	Metro Delhi, India
Reference number of the project activity	4463
Version number of the monitoring report	1.0
Completion date of the monitoring report	25/10/2014
Registration date of the project activity	30/06/2011
Monitoring period number and duration of this monitoring period	2nd monitoring period 01/07/2012 to 30/06/2014
Project participant(s)	Delhi Metro Rail Corporation Ltd. Grütter Consulting AG
Host Party(ies)	India
Sectoral scope and selected methodology(ies), and where applicable, applied standardized baseline(s)	Transport, sectoral scope 7 ACM0016, Version 0.1, Baseline Methodology for Mass Rapid Transit Projects
Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD	996,408[1]
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period	1,054,071
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period up to 31 December 2012(if applicable)	187,471
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period from 1 January 2013 onwards (if applicable).	877,996

[1] 2012 according to PDD 477,389tCERs (actual ½ year and therefore 238,695tCERs), 2013 full year (497,989 tCERs) and 2015 519,448 tCERs (actual ½ year and therefore 259,724tCERs)

SECTION A. Description of project activity

A.1. Purpose and 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 (Mass Rapid Transit System), 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 Nagar[2]	November 2005	13/11/2009
New Ashok Nagar-Noida	July 2006	13/11/2009
Inderlok – Kirtinagar –Mundka	April 2006	02/04/2010
Yamuna Bank –Anand Vihar ISBT	June 2006	07/01/2010

[2] 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.

Anand Vihar – Vaishali	June 2008	14/07/2011
QM-Gurgaon	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: Construction start date: PDD table 3; Commissioning date: File 1

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 operated continuously during the entire crediting period.

The total emission reductions achieved in this monitoring period are **1,054,071 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, according to 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 participant(s)

Party involved ((host) indicates a host Party)	Private and/or public entity(ies) project participants (as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
India (host)	Delhi Metro Rail Corporation Ltd. (private entity)	No
Switzerland	Grütter Consulting AG (private entity)	No

A.4. Reference of applied methodology and standardized baseline

ACM0016: Baseline Methodology for Mass Rapid Transit Projects; Version 1.0

This methodology also refers to the latest approved version of the following tools:

- "Tool for the demonstration and assessment of additionality", Version 05.2
- "Tool to calculate baseline, project and/or leakage emissions from electricity consumption", Version 01

A.5. Crediting period of project activity

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

Crediting period corresponding to this monitoring period: 30/06/2011 to 29/06/2018

A.6. Contact information of responsible persons/ entities

Responsible for this Monitoring Report is:
Jürg Grütter
Grütter Consulting AG
Thiersteinerstr 22, 4153 Reinach, Switzerland
jgruetter@transport-ghg.com, www.transport-ghg.com

The person/entity is a project participant.

SECTION B. Implementation of project activity

B.1. Description of implemented registered project activity

The total length of metro tracks included in the project is 101.27 km. The following table lists all metro corridors part of the CDM project.

Table 2: Corridors of CDM Project Metro Delhi, India

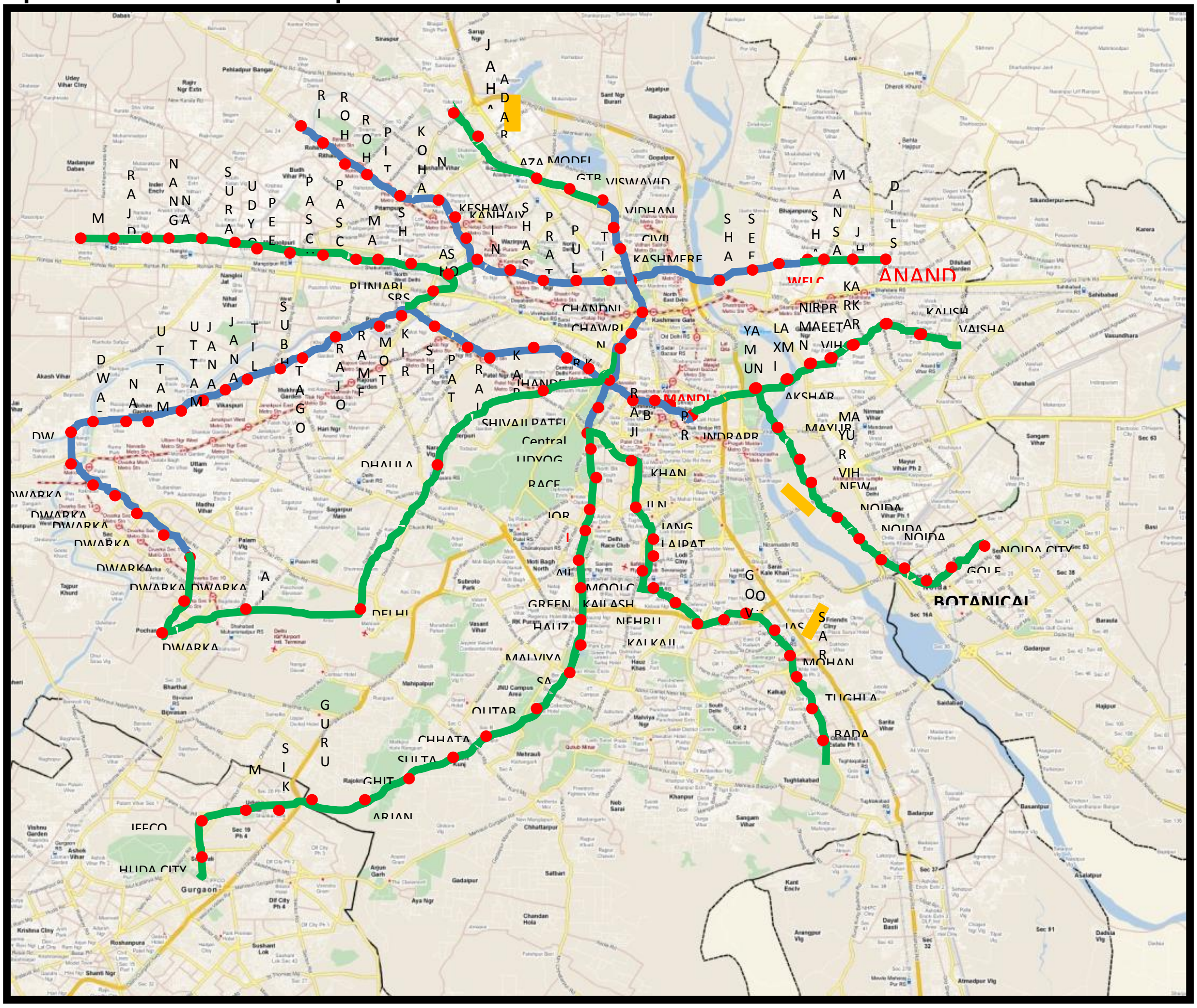
Corridor	Length (km)	Commissioning date
Shahadara-Dilshad Garden	3.09	04/06/2008
Vishwavidyalaya-Jhahangirpuri	6.36	04/02/2009
Indraprastha-New Ashok Nagar	7.72	13/11/2009
New Ashok Nagar-Noida	7.00	13/11/2009
Inderlok – Kirtinagar –Mundka	18.47	02/04/2010
Yamuna Bank –Anand Vihar ISBT	6.17	07/01/2010
Anand Vihar – Vaishali	2.54	14/07/2011
QM-Gurgaon	14.47	21/06/2010
Central Secretariate –QM	12.53	03/09/2010
Central Secretariat – Badarpur	20.16	14/01/2011
Dwarka Sector 9 – 21	2.76	30/10/2010
Total	**101.27**	

Source: File 1

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 map shows all DMRC corridors in operation including Phase I and Phase II (the project) corridors.

Map 1: DMRC Corridors in Operation



Phase I Lines
Phase II Lines

Table 3: DMRC Stations of Phase II Corridors

Corridor	Stations	Line[3]
Shahadara-Dilshad Garden	Shahdara, Dishad Garden, Jhimil, Mansarowar Park	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 (repeated station)	Part of Line 3 (blue line)
New Ashok Nagar-Noida	New Ashok Nagar (repeated station), 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 [4] , Ashok Park Main(repeated station), Satguru Ram Singh Marg, Kirtinagar[5], Ashok Park Main (repeated station), 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)

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

[4] Station shared with Phase I line

[5] Station shared with Phase I line

Yamuna Bank –Anand Vihar ISBT	Yamuna Bank (repeated station), Laxmi Nagar, Nirman Vihar, Preet Vihar, Karkarduma, Anand Vihar ISBT (repeated station)	Part of Line 3 (blue line)
Anand Vihar – Vaishali	Anand Vihar ISBT (repeated station), Kaushambi, Vaishali	Part of Line 3 (blue line)
QM-Gurgaon	Qutab Minar (repeated station), 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 (repeated station), Udyog Bhawan, Race Course, Jor Bagh, INA Market, AIIMS, Green Park, Hauz Khas, Malviya Nagar, Saket, Qutab Minar (repeated station)	Part of Line 2 (yellow line)
Central Secretariat – Badarpur	Central Secretariat (repeated station), 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	Part of Line 3 (blue line)

In total the project has 83 stations.

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 telephone with the train drivers, the mobile personnel and the metro service vehicles. The control centre 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 be 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 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 sitting 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[6].

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. 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

[6] See also File 23

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[7].

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)[8]. 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.

No special events influencing CER calculations have been registered during the monitoring period. The relevant dates have been listed in Table 1. No event occurred during the monitoring period, which impacts the applicability of the methodology.

B.2. Post registration changes

B.2.1. Temporary deviations from registered monitoring plan, applied methodology or applied standardized baseline

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. Permanent changes from registered monitoring plan, applied methodology or applied standardized baseline

No permanent changes from the registered monitoring plan, applied methodologies or applied standardized baseline have been approved during this monitoring period or are submitted with this monitoring report.

B.2.4. Changes to project design of registered project activity

No changes to the project design of the project activity have been approved during this monitoring period or are submitted with this monitoring report.

B.2.5. Changes to start date of 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.2.6. Types of changes specific to afforestation or reforestation project activity

Not applicable

SECTION C. Description of monitoring system

The monitoring methodology is based on ACM0016 Version 1.

[7] See File 4 for detailed system description

[8] See File 10 for contract

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 developed by Grütter Consulting AG[9]. It defines all responsibilities and procedures. DMRC was trained on the manual 06/2012[10]. For each data parameter the information sources, units, frequency of measurement as well as data quality assurance processes are described in detail. Grütter Consulting AG is contractually responsible for the monitoring reports for all 7 years of the 1st crediting period.

The environmental section of DMRC is responsible for CDM project monitoring. This area responds directly to the Managing Director. DMRC has ISO 14001 certifications for different parts of construction of Phase II and has realized certifications or these are under process for ISO 9001, ISO 140001 and OHSAS 18001 for the operations of Phase I and Phase II corridors[11].

PARAMETER PASSENGERS

Passenger flow data is based on the AFC system (Automatic Fare Collection System)[12] which consists of semiautomatic ticket vending machines, automatic entry-exit gates, station computer and a central server. Picture 1 shows the AFC gates, picture 2 the ticket office machine, picture 3 the ticket reader and picture 4 the smart ticket validator.

Picture 1: AFC Gates

Picture 2: Ticket Office Machine

[9] File 2

[10] File 24

[11] File 3a/b

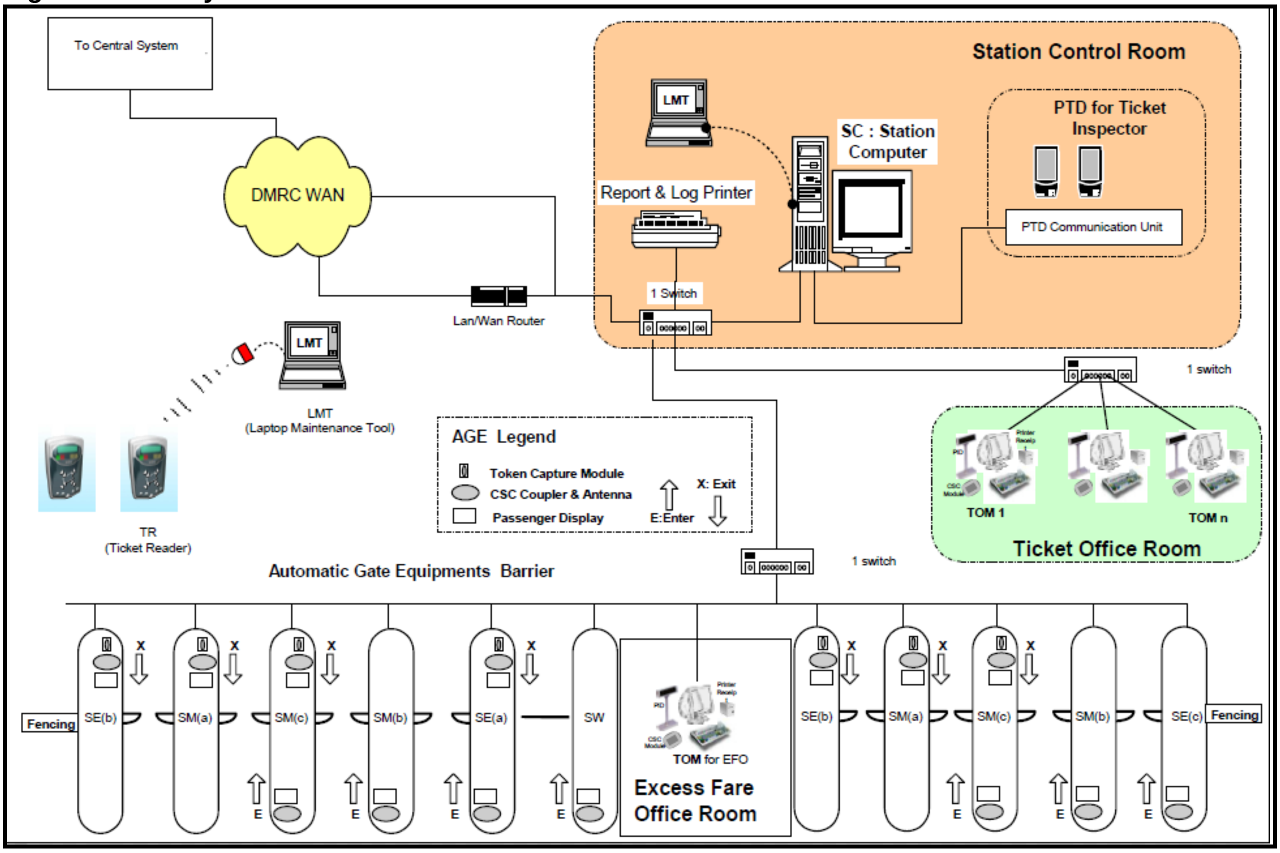
[12] See File 4

Picture 3: Ticket Reader

Picture 4: Smart Ticket Validator

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: File 4

PASSENGER SURVEYS

The passenger surveys were realized 2012/2013 by Market Insight Consultant and 2013/2014 by Absolute Market Research and Consultants Private Ltd. contracted by Grütter Consulting AG[13]. The survey design as used in the period 2011/2012 was followed. The survey objectives are:

- Determine the mode of transport passengers of the Metro would have used in absence of the project activity.
- Determine the distance per mode used in the baseline situation.
- Determine the project trip modes to/from the metro and their trip distance.

For all details concerning the survey see section D.3.

ELECTRICITY CONSUMPTION

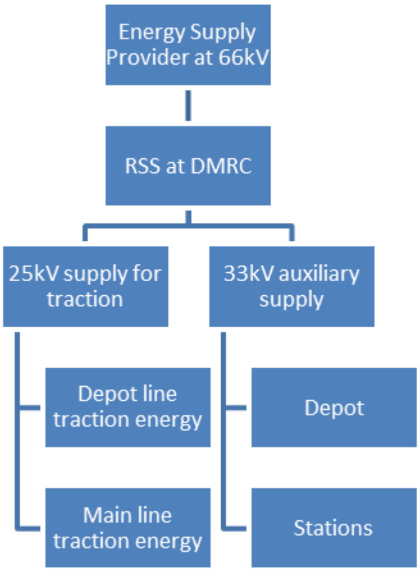
DMRC takes power from various distribution companies of Delhi and the National Capital Region. The electricity is received at 220KV, 132 KV or 66 KV level as per availability and contract agreement with the distribution companies. The electricity is stepped down at the RSS (Receiving Sub Station) of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

[13] File 5a to 5c including also information on the survey companies

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-kilometre are determined for Phase I and for Phase II 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).The TE meters of 25 KV are tested in 50Hz and 240 V. A full list of all calibrations realized including sites and calibration certificates is included in File 7.

SECTION D. Data and parameters

D.1. Data and parameters fixed ex ante or at renewal of crediting period

Data/Parameter	**$SFC_{C,\ G/D/CNG}$**
Unit	g/km
Description	Specific fuel consumed of passenger cars using gasoline, diesel or CNG
Source of data	Passenger car with gasoline or diesel fuel: ADB, Breaking the Trend, Table 12, 2008 Passenger car using CNG: Based on taxis using CNG, 2008
Value(s) applied	Cars gasoline: 53.98 Cars diesel: 48.59 Cars CNG: 64.00
Purpose of data	Baseline, Project, Leakage
Additional comment	For gasoline and diesel cars based on national literature. This is conservative as only cars are considered and not SUVs which have a higher fuel consumption (31% more in gasoline and 43% more in diesel cars according to same source table 12) while representing according to the same report (table 13) for 2010 17% of all passenger vehicles. For CNG cars the value of taxi CNG vehicles is taken which is based on a large fleet. Taxi fleets manage new vehicles and maintain these well, thus the data is conservative.

Data/Parameter	$N_{C,G/D/CNG}$
Unit	%
Description	Percentage of passenger cars using fuel type: gasoline, diesel or CNG
Source of data	Department of Transport, Delhi, 2008 and Centre for Science and Environment (CSE), 2008
Value(s) applied	Gasoline: 81.8% Diesel: 10.6% CNG: 7.6%
Purpose of data	Baseline, Project, Leakage
Additional comment	Official data adjusted in the case of CNG for converted vehicles

Data/Parameter	SFC_T
Unit	g/km
Description	Specific fuel consumed of taxis
Source of data	Easy Cab, 2008
Value(s) applied	64 g/km CNG plus 6.07 g/km gasoline
Purpose of data	Baseline, Project, Leakage
Additional comment	

Data/Parameter	N_T
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 (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)
Value(s) applied	100%
Purpose of data	Baseline, Project, Leakage
Additional comment	Official regulation of Delhi asking for public transport vehicles to be CNG

Data/Parameter	SFC_{TR}
Unit	g/km
Description	Specific fuel consumed of motorized auto-rickshaws
Source of data	Grütter Consulting AG, 2009
Value(s) applied	32.00
Purpose of data	Baseline, Project, Leakage
Additional comment	Based on sample realizing measurements of fuel consumption. The lower 95% confidence interval was taken. The sample size required for a 95% confidence level and a 5% maximum error bound of a point estimation of simple random sample is 3 (due to the very low variance of data) while the actual sample size taken was 50 units.

Data/Parameter	N_{TR}
Unit	%
Description	Percentage of motorized auto-rickshaws using CNG
Source of data	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)
Value(s) applied	100%
Purpose of data	Baseline, Project, Leakage
Additional comment	Official regulation of Delhi asking for public transport vehicles to be CNG

Data/Parameter	SFC_M
Unit	g/km
Description	Specific fuel consumed of motorcycles
Source of data	Grütter Consulting AG, 2008 and 2009
Value(s) applied	13.43
Purpose of data	Baseline, Project
Additional comment	Based on sample realizing measurements of fuel consumption. The lower

	95% confidence interval was taken. The sample size required for a 95% confidence level and a 5% maximum error bound of a point estimation of simple random sample is 23 while the actual sample size taken was 30 units.

Data/Parameter	**N_M**
Unit	%
Description	Percentage of motorcycles using gasoline
Source of data	ARAI, Emission Factor Development for Indian Vehicles, 2007 only reports gasoline motorcycles and scooters
Value(s) applied	100%
Purpose of data	Baseline, Project
Additional comment	Official data source

Data/Parameter	**N_B**
Unit	%
Description	Percentage of buses using CNG
Source of data	Supreme Court of India mandated that in Delhi, all commercial passenger vehicles including buses 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)
Value(s) applied	100%
Purpose of data	Baseline, Project, Leakage
Additional comment	Official regulation of Delhi asking for public transport vehicles to be CNG

Data/Parameter	**EF_{Grid}**
Unit	$kgCO_2/kWh$
Description	Emission factor for the grid
Source of data	Government of India, CEA, Version 5.0, 11-2009, NEWNE grid
Value(s) applied	0.8409
Purpose of data	Baseline, Project
Additional comment	Official data; follows procedures as in "Tool to calculate baseline, project and/or leakage emissions from electricity consumption", newest version of tool.

Data/Parameter	**TDL**
Unit	---
Description	Average technical transmission and distribution losses for providing electricity
Source of data	Powergrid corporation of India, 3.2010, http://www.nldc.in/NLDC/updateloss/webdata.htm
Value(s) applied	3.91%
Purpose of data	Baseline, Project
Additional comment	Northern Grid Based on average value for entire year 2009 from the National Dispatch Center.

Data/Parameter	**OC_C**
Unit	Passengers
Description	Average occupation rate of passenger cars
Source of data	Grütter Consulting AG, 2008
Value(s) applied	1.60
Purpose of data	Baseline, Project, Leakage
Additional comment	Survey realized using upper 95% confidence interval. The sample size required for a 95% confidence level and a 5% maximum error bound of a point estimation of simple random sample is 454 while the actual sample size taken was 46,945 units. Procedure followed TORs for occupation rate studies described in methodology.

Data/Parameter	**OC_T**
Unit	Passengers

Description	Average occupation rate of taxis
Source of data	Grütter Consulting AG, 2008
Value(s) applied	1.16
Purpose of data	Baseline, Project, Leakage
Additional comment	Survey realized using upper 95% confidence interval. The sample size required for a 95% confidence level and a 5% maximum error bound of a point estimation of simple random sample is 1,537 while the actual sample size taken was 6,744 units. Procedure followed TORs for occupation rate studies described in methodology.

Data/Parameter	**OC_M**
Unit	Passengers
Description	Average occupation rate of motorcycles
Source of data	Central Road Research Institute (CRRI) Delhi, 2007, Table 3.4
Value(s) applied	1.40
Purpose of data	Baseline and Project
Additional comment	Recognized research institute in India; realized on various locations

Data/Parameter	**OC_{MR}**
Unit	Passengers
Description	Average occupation rate of motorized auto-rickshaws
Source of data	Central Road Research Institute (CRRI) Delhi, 2007, Table 3.4
Value(s) applied	1.40
Purpose of data	Baseline, Project, Leakage
Additional comment	Recognized research institute in India; realized on various locations

Data/Parameter	**OC_B**
Unit	Passengers and %
Description	Average occupation rate of buses
Source of data	Central Road Research Institute (CRRI) Delhi, 2007, Table 3.4
Value(s) applied	43 passengers and 57%
Purpose of data	Baseline, Project, Leakage
Additional comment	Recognized research institute in India; realized on various locations Percentage based on 43 passengers on average and an average bus capacity of 75 passengers based on Leyland CNG buses used by DTC with capacities between 60 and 92 passengers (average 75)

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
Purpose of data	Baseline and Project
Additional comment	Same year as for data passenger on rail system and electricity consumption of rail system Upper 95% confidence interval

Data/Parameter	**AD_B**
Unit	Km
Description	Average annual distance driven of buses (kilometre)
Source of data	Delhi Transport Corporation (DTC), 2008
Value(s) applied	53,325
Purpose of data	Leakage
Additional comment	Based on total distance driven of 183 million km and the average fleet of the same year of 3,439 units

Data/Parameter	**AD_T**
Unit	Km
Description	Average annual distance driven of taxis

Source of data	Easy Cab, 2008
Value(s) applied	91,250
Purpose of data	Leakage
Additional comment	Based on records of taxi company with 250km per car per day and 365 days per year.

Data/Parameter	AD_{TR}
Unit	Km
Description	Average annual distance driven of motorized rickshaws
Source of data	Report Expert Committee on Auto Rickshaw for GOI, p.10, 2003
Value(s) applied	43,800
Purpose of data	Leakage
Additional comment	Based on 120 km per vehicle per day and 365 days per year.

Data/Parameter	$NIZ_{C,T,BL}$
Unit	Vehicles
Description	Number of cars/taxis on roads affected per annum in the baseline
Source of data	Grütter Consulting AG, 2009
Value(s) applied	See Table 4 below
Purpose of data	Leakage
Additional comment	Visual counting on the identified roads. Based on measurements realized 6AM to 10PM both directions during 3 different days. No expansion factor for remaining hours. 365 days per annum. Exact locations of monitoring are defined for each affected road.

Table 4: Number of Vehicles Baseline on Affected Roads (per annum)

Affected Road	Number of cars	Number of taxis
Mehrauli-Gurgaon Road	14,820,217	1,351,960
New Noida Link Road / Dadri Road	18,555,505	771,123
Rohtak Road	8,418,360	171,063
Aurangzeb Road	6,864,555	871,133
INA Market Road	10,317,455	1,143,180
Grand Trunk Road	7,079,297	307,695
Bhisham Pitamah Marg	6,615,990	301,612
Vikas Marg	7,844,093	583,757
Mathura Road	13,311,428	444,935

Data/Parameter	V_B
Unit	Km/h
Description	Vehicle baseline speed on affected roads.
Source of data	Grütter Consulting AG, 2009
Value(s) applied	See Table 5 below
Purpose of data	Leakage
Additional comment	On-board measurements determining the average speed when circulating.

Table 5: Baseline Moving Speed on Affected Roads

Affected Road	Average moving speed
Mehrauli-Gurgaon Road	31
New Noida Link Road / Dadri Road	36
Rohtak Road	40
Aurangzeb Road	50
INA Market Road	28
Grand Trunk Road	30
Bhisham Pitamah Marg	36
Vikas Marg	27
Mathura Road	35

The PDD includes in this section the parameters SFC_B (specific fuel consumption of buses), $EC_{EL,R}$ (quantity of electricity consumed by the baseline rail system), and $P_{EL,R}$ (passengers transported by the baseline rail system). However, as also indicated in the PDD, these parameters are monitored and therefore listed under D.2.

D.2. Data and parameters monitored

Data/Parameter	$NCV_{G/D}$
Unit	MJ/kg
Description	Net calorific value of gasoline and diesel
Measured/Calculated /Default	Default
Source of data	India Oil Corporation Ltd. (File 8)
Value(s) of monitored parameter	Gasoline: 43.9 Diesel: 42.7
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	Verify if the value is within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. The IPCC default values for Gasoline are between 42.5 and 44.8.The reported value is therefore inside the IPCCC uncertainty range. The IPCC default values for Diesel are between 41.4 and 43.3. The reported value is therefore inside the IPCCC uncertainty range.
Purpose of data	Baseline and Project
Additional comment	Same value as recorded in baseline. Therefore no need to adjust emission factor of vehicles.

Data/Parameter	NCV_{CNG}
Unit	MJ/m^3
Description	Net calorific value of CNG
Measured/Calculated /Default	Default
Source of data	India Oil Corporation Ltd. (File 8)
Value(s) of monitored parameter	35.6
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	Verify if the value is within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. The IPCC default values for CNG are between 46.5 and 50.4 MJ/kg. The density of CNG in India is 0.717 kg/m^3 (File 8) and therefore the reported value for India is 49.7 MJ/kg. The reported value is therefore inside the IPCCC uncertainty range.
Purpose of data	Baseline and Project
Additional comment	Same value as recorded in baseline. Therefore no need to adjust emission factor of vehicles.

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	Baseline and Project
Additional comment	Same value as recorded in baseline. Therefore no need to adjust emission factor of vehicles.

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 http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html
Value(s) of monitored parameter	162.0 until 31.12.2012 192.9 from 1.1.2013
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Adjusted based on the relation old to new GWP (21 to 25)
QA/QC procedures	Control with new IPCC report for GWP (emission factor no new report, only GWP)
Purpose of data	Baseline and Project
Additional comment	According to Annex 3 of EB69, “Standard for application of the global warming potential to clean development mechanism project activities and programmes of activities for the second commitment period of the Kyoto Protocol”, all emission reductions and removals achieved by CDM project activities in the second commitment period shall be calculated using the global warming potentials (GWPs) adopted by the Conference of the Parties serving as the meeting of the Parties at its seventh session in accordance with decision 4/CMP.7, and this requirement shall apply from 1 January 2013. The proposed monitoring period starts before 31 December 2012 and ends on 25 June 2014, thus covers the 1st commitment period and 2nd commitment period. Therefore from 1.1.2013 the new GWP of CH_4 is used.

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 http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html
Value(s) of monitored parameter	9.9 until 31.12.2012 11.8 from 1.1.2013
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Adjusted based on the relation old to new GWP (21 to 25)
QA/QC procedures	Control with new IPCC report for GWP (emission factor no new report, only GWP)
Purpose of data	Baseline and Project
Additional comment	According to Annex 3 of EB69, “Standard for application of the global warming potential to clean development mechanism project activities and programmes of activities for the second commitment period of the Kyoto Protocol”, all emission reductions and removals achieved by CDM project activities in the second commitment period shall be calculated using the global warming potentials (GWPs) adopted by the Conference of the Parties serving as the meeting of the Parties at its seventh session in accordance with decision 4/CMP.7, and this requirement shall apply from 1 January 2013. The proposed monitoring period starts before 31 December 2012 and ends on 25 June 2014, thus covers the 1st commitment period and 2nd commitment period. Therefore from 1.1.2013 the new GWP of CH_4 is used. The baseline emission factor of taxis, passenger cars and motorized rickshaws, all of which use CNG, therefore had to be adjusted.

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, 2013 and 2014 (File 16)
Value(s) of monitored parameter	2012-2013: Diesel: 69,596 (40.3%) Gasoline: 82,203 (47.6%) CNG: 20,979 (12.1%) 2013-2014: Diesel: 64,458 (42.2%) Gasoline: 73,111 (48.0%) CNG: 14,828 (9.7%)
Monitoring equipment	Registration statistics
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. LPG vehicles constitute less than 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	Baseline, Project, Leakage
Additional comment	The emission factor is calculated based on relative values per fuel. The corresponding relative value for fuels used by cars in the baseline was (see section above): Gasoline: 81.8% Diesel: 10.6% CNG: 7.6% Percentages have changed and therefore the baseline emission factor for passenger cars and the EF per PKM for cars is re-calculated in Section E1 based on ACM0016 Vs 1 p.10 which states: “The emission factor per kilometer is re-calculated annually based on the recorded (last available official records) share of fuels per category”. No bio-fuels are used in diesel whilst in gasoline a share of 1.4% was used in 2012, 2.9% in 2013 and 2.1% in 2014[14]. This bio-fuel share has been included to determine the new EF cars.

[14] See File 9

Data/Parameter	$\mathbf{N_{x,T}}$
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 11)
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	Baseline, Project, Leakage
Additional comment	The Supreme Court Decision was already valid as of baseline determination and therefore no change relative to baseline fuel composition of taxis. The emission factor of taxis is therefore not re-calculated.

Data/Parameter	$\mathbf{N_{x,TR}}$
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 11)
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	Baseline, Project, Leakage
Additional comment	The Supreme Court Decision was already valid as of baseline determination and therefore no change relative to baseline fuel composition of motorized rickshaws. The emission factor of motorized auto-rickshaws is therefore not re-calculated.

Data/Parameter	**P**
Unit	Passengers
Description	Total passengers transported by the project
Measured/Calculated /Default	Measured
Source of data	DMRC, 2014 (File 25)
Value(s) of monitored parameter	849,084,174
Monitoring equipment	Turnpike controls at stations and electronic smart cards. Only passengers are included which enter stations of the lines include in the project. Passengers entering line 1 and line 2 stations of Phase I are not included. See Section C for detailed description.
Measuring/Reading/ Recording frequency	Daily
Calculation method (if applicable)	Not applicable
QA/QC procedures	Controlled with income
Purpose of data	Project and Baseline
Additional comment	

Data/Parameter	**EC_{PJ}**
Unit	kWh
Description	Electricity consumed by MRTS (trains)
Measured/Calculated /Default	Measured and calculated
Source of data	DMRC (File 19)
Value(s) of monitored parameter	406,665,813
Monitoring equipment	Traction energy is recorded by DMRC per line. File 7 lists all calibration certificates of the TE meters, all of which have been calibrated during the monitoring period.
Measuring/Reading/ Recording frequency	Continuously, aggregated monthly
Calculation method (if applicable)	Traction energy is read from traction meter. The car-km for phase I and phase II are calculated for all lines. TE for Phase II is Total TE consumed for each line minus the TE consumed by Phase I 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	Project
Additional comment	

Table 6: Traction Energy (monitoring period)

Year	Total car-km	Phase II car-km	Total traction energy in kWh	Phase II traction energy in kWh
01/07/2012 to 31/12/2012	189,073,132	69,230,374	38,060,445	103,866,324
2013	372,955,322	146,852,605	80,049,360	203,275,179
01/01/2014 to 30/06/2014	187,013,432	77,651,606	41,339,374	99,524,310
Total	749,041,886	293,734,585	159,449,179	**406,665,813**

Source: File 6 based on File 19

Data/Parameter	**$NIZ_{C,T}$**
Unit	Vehicles
Description	Number of cars/taxis using affected roads
Measured/Calculated /Default	Measured and Calculated
Source of data	Grütter Consulting, 2013 (File 15)
Value(s) of monitored parameter	See Table 7 below

Table 7: Number of Cars and Taxis on Affected Roads per Annum

Road	Cars 2012/13	Taxis 2012/13
Mehrauli Gurgaon	24,047,295	329,960
New Noida Link Road	26,280,000	468,417
Rohtak Road	14,217,115	216,445
Aurangazeb Road	13,010,182	235,060
INA Market Road	16,851,928	386,657
Grand Trunk Road	12,611,115	178,485
Bhisham Pitamah Marg	12,392,602	179,945
Vikas Marg	10,961,315	221,798
Mathura Road	14,604,380	337,382

Monitoring equipment	None
Measuring/Reading/ Recording frequency	Yearly if required
Calculation method (if applicable)	Visual counting on the identified roads. Based on measurements realized 6AM to 10PM both directions during 3 different days. No expansion factor for remaining hours. 365 days per annum. Exact locations of monitoring are defined for each affected road. Daily numbers of Northbound and Southbound added and multiplied with 365. The same expansion factor of 365 was used of the baseline.
QA/QC procedures	The same roads, the same survey points, the same time period and the same number of days were monitored as in the baseline study, thus making data comparable.
Purpose of data	Leakage
Additional comment	Data is only required if the speed study shows differences of speed baseline and project case. This is only the case 2012/13 in Aurangazeb Road. 2013/2014 this is not the case on any road. Therefore only data for Aurangazeb Road for 2012/13 is required. However 2012/13 data on all roads was collected whilst 2013/14 no data was collected as not required.

Data/Parameter	**$TDIZ_{C,T}$**
Unit	Kilometres
Description	Distance driven by taxis and passenger cars on affected roads
Measured/Calculated /Default	Measured and Calculated
Source of data	Grütter Consulting, 2013 (File 15)
Value(s) of monitored parameter	Aurangazeb Road: 1.60 km
Monitoring equipment	GPS for distance measuring
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	The maximum distance on the affected road was taken. Actual driving distance of cars and/or taxis on the affected road is ≤1.6km which is the maximum distance. Taking the maximum distance instead of monitoring actual trip distance on the affected road is conservative. This version has been taken to reduce monitoring costs as the impact on leakage is marginal.
QA/QC procedures	
Purpose of data	Leakage
Additional comment	Only Aurangazeb Road is required as only this road has a higher average speed in the baseline than the project and thus a speed leakage effect in the year 2012/13.

Data/Parameter	**V_P**
Unit	Km/h
Description	Vehicle project speed on affected roads; Average speed and average moving speed is recorded.
Measured/Calculated /Default	Measured and Calculated
Source of data	Grütter Consulting, 2012 (File 15)
Value(s) of monitored parameter	**Table 8: Average Speed and Average Moving Speed in km/h**

Road	**Average Speed 2012/13 and 2013/14**	**Average Moving Speed 2012/13 and 2013/14**
Mehrauli Gurgaon	20 / 22	43 / 30
New Noida Link Road	39 / 28	43 / 36
Rohtak Road	22 / 33	32 / 40
Aurangazeb Road	35 / 41	40 / 50
INA Market Road	19 / 21	27 / 28
Grand Trunk Road	19 / 23	32 / 30
Bhisham Pitamah Marg	20 / 30	30 / 36
Vikas Marg	15 / 20	27 / 27
Mathura Road	17 / 27	28 / 35

Monitoring equipment	GPS, chronometer
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	For average speed as well as average moving speed the measurement is made on board a moving car which moves in traffic ("fish in the water approach"). Average speed: The time is measured between starting and end point with a chronometer. The distance between the start and the end point is measured with a GPS. Average speed is distance/time. The average speed is always equal to or lower than the average moving speed as the average speed includes also stopping time e.g. due to traffic jam or traffic lights. The average moving speed is based on GPS record when the car is moving.
QA/QC procedures	The same roads, same data points and same hours are monitored as in the baseline study. The GPS calibrates itself automatically and on a continuous base with 3 satellites and triangulates its position with these 3 satellites. The procedure of determining a 2-D position is based on using signals received from the best (or only) three available GPS satellites. Altitude is assumed to be known and constant. A 2-D position solution will only be determined if signals from three or more satellites are available.
Purpose of data	Leakage
Additional comment	

Data/Parameter	**SFC_B**
Unit	g/km
Description	Specific fuel consumed of buses
Measured/Calculated /Default	Measured
Source of data	Delhi Transport Corporation (DTC) Operational Statistics, 11/2013 Table 2.6 C.III (File 12)
Value(s) of monitored parameter	403.23
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annually
Calculation method (if applicable)	The report states 2.48km per kg. This is equivalent to 403.23 g/km
QA/QC procedures	External report based on total registered fuel consumed and total distance driven all DTC buses.
Purpose of data	Baseline, Project and Leakage
Additional comment	All buses are CNG

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	India Railways, IR Yearbook 2012-13 EMU statistics, Northern Line suburban p. 404 (File 20)
Value(s) of monitored parameter	2,963
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	
Purpose of data	Baseline and Project
Additional comment	Required to establish the emission factor per PKM for suburban rail

Data/Parameter	**$P_{EL,R}$**
Unit	Passengers
Description	Total passengers transported by baseline rail-system per year
Measured/Calculated /Default	Measured
Source of data	Indian Railways, IR Yearbook 2012-13 passenger revenue statistics, Northern Line suburban p. 74 (File 21)
Value(s) of monitored parameter	3,086,500
Monitoring equipment	None
Measuring/Reading/ Recording frequency	
Calculation method (if applicable)	None
QA/QC procedures	
Purpose of data	Baseline and Project
Additional comment	Required for the emission factor suburban rail system

Data/Parameter	**$BTD_{p,i}$**
Unit	Kilometre
Description	Baseline trip distance of the cluster *p* of surveyed passengers using mode *i*
Measured/Calculated /Default	Measured
Source of data	Market Insight Consultant (2012/2013) and Absolute Market Research and Consultants Private Ltd. (2013/2014) (File 18 and 17)
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 18 and 17
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annually with 1 test and one re-test
Calculation method (if applicable)	Based on distance between starting point and end 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	Baseline
Additional comment	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	Market Insight Consultant (2012/2013) and Absolute Market Research and Consultants Private Ltd. (2013/2014) (File 18 and 17)
Value(s) of monitored parameter	Calculated for each passenger surveyed for each mode used to and form the metro. See for values per passenger per mode File 18 and 17
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annually with 1 test and one re-test
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	Project
Additional comment	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 Market Insight Consultant (2012/2013) and Absolute Market Research and Consultants Private Ltd. (2013/2014), (File 18 and 17)
Value(s) of monitored parameter	Calculated for each passenger surveyed; see File 18 and 17 excel sheet FEX
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annually with 1 test and one re-test
Calculation method (if applicable)	See Section D.3. for survey details
QA/QC procedures	See Section D.3. for survey details
Purpose of data	Baseline and Project
Additional comment	See Section D.3. for survey details

Data/Parameter	**P_{SPER}**
Unit	Passengers
Description	Number of passengers in the time period of the survey (1 week)
Measured/Calculated /Default	measured
Source of data	DMRC, File 22
Value(s) of monitored parameter	Value per station per hour per day for each survey week; see File 22
Monitoring equipment	Turnpike controls at stations and electronic smart cards.
Measuring/Reading/ Recording frequency	Annually twice during the 2 survey weeks
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	Baseline and Project
Additional comment	See Section D.3. for survey details

The following monitoring parameters are not required:

$N_{B,T,TR}$: Only required for leakage change of occupation rate which is measured in year 1 and 4 and not in theîs monitoring period.

MS_i: The project has a no rebound effect due to non-changed speeds. Therefore this parameter, required only for calculation of a rebound effect (see formulae 16 of registered PDD), is not required.

$OC_{B,T,TR}$: Only monitored in years 1 and 4 and not in this monitoring period.

D.3. Implementation of sampling plan

Sampling is used for the following parameters:

1. Determination of speed and number of vehicles on affected roads (partially).
2. Passenger survey to determine indirect project emissions as well as baseline emissions. This includes the parameters MS_i, FEX, BTD, and IPTD.

NUMBER OF VEHICLES ON AFFECTED ROADS

This data is in fact not really a sample as measurements were made of all affected roads and of all vehicles which passed during the entire time period between 6AM and 10PM idem to the baseline study. The same site, same location, same procedure and same times were used. Thereafter an expansion factor to get vehicles per annum is used (based on 365). The same expansion factor is used for the project and for the baseline. Thus the number of vehicles is not considered as a sample.

SPEED MEASUREMENT ON AFFECTED ROADS

The speed measurement is based on a sample. The speed measurements are made using a technique called “fish in the water” i.e. the vehicle which is used to determine the speed moves idem to other vehicles on the affected road between the defined starting and end point and has thus the same speed as many other vehicles which it follows. Therefore the sample of vehicles is in fact not the the vehicle used technically to realize the measurement but the amount of vehicles driving on the same road at the same time during measurement.

Sampling Design

The sampling design is based on the registered PDD as Annex A.7. The PDD details the sites, the time and the days for sampling.

The objective of the study is to determine the average speed and the average moving speed of cars/taxis (taken as uniform). The procedures are:

- Affected roads to be monitored are listed in the PDD.
- Locations for vehicle counts are listed in the PDD.
- Vehicle counts are made in both directions during from 6AM to 10PM. The speed survey was conducted on 4 different days per site. The average of the 4 weekdays summing both directions is taken.
- A passenger car is used to realise the study. The car moves itself in the normal traffic flow just as other vehicles (“fish in the river”). The moving and the total speed are recorded by GPS.
- Minimum 6 measurements are made per road per day.
- The average speed is the simple average of all recorded speeds on the respective road.
- The moving speed excludes standstill times.
- The route (starting and final point) is based on MRTS affected roads identified.

The study was carried out on different days of February / March 2013 and between January 24 and 31 2014. Days immediately before and after holidays were avoided. Atypical seasons (school or university vacations) were avoided.

Collected Data

Data collected is the average and the moving speed of cars/taxis. The following table shows the results (see File 15 for details).

Table 9: Average Speed Survey, 2013

Road	Average Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	20	2	18.9-21.6
New Noida Link Road	39	9	34.2-43.9
Rohtak Road	22	5	19.6-25.2
Aurangazeb Road	35	7	31.3-38.2
INA Market Road	19	6	15.4-21.6
Grand Trunk Road	19	5	16.9-22.0
Bhisham Pitamah Marg	20	3	18.2-21.7
Vikas Marg	15	3	13.7-16.9
Mathura Road	17	5	14.2-19.5

Table 10: Moving Speed Survey, 2013

Road	Average Moving Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	43	8	38.7-48.3
New Noida Link Road	43	10	38.4-48.3
Rohtak Road	32	4	29.8-33.8
Aurangazeb Road	40	7	36.6-43.5
INA Market Road	27	5	24.3-29.5
Grand Trunk Road	32	4	29.8-33.7
Bhisham Pitamah Marg	30	5	27.5-32.1
Vikas Marg	27	2	25.7-28.0
Mathura Road	28	4	26.3-30.6

Table 11: Average Speed Survey, 2014

Road	Average Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	22	2	20.2-23.0
New Noida Link Road	28	10	23.4-33.5
Rohtak Road	33	4	30.8-35.1
Aurangazeb Road	41	7	37.2-44.5
INA Market Road	21	6	17.7-24.1
Grand Trunk Road	23	5	20.5-25.5
Bhisham Pitamah Marg	30	4	27.6-31.4
Vikas Marg	20	3	18.6-21.9
Mathura Road	27	5	24.7-29.8

Table 12: Moving Speed Survey, 2014

Road	Average Moving Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	30	4	27.8-32.7
New Noida Link Road	36	10	31.3-41.5
Rohtak Road	40	4	37.9-41.7
Aurangazeb Road	50	7	46.4-53.7
INA Market Road	28	5	25.8-31.0
Grand Trunk Road	30	3	28.5-31.9
Bhisham Pitamah Marg	36	4	33.5-38.0
Vikas Marg	27	2	25.9-28.1
Mathura Road	35	4	32.6-37.0

The baseline speeds in their upper and lower range are compared with the project monitored speed in the upper and lower range to determine if the 2 speeds are statistically distinct or not.

As mentioned the SD has to be taken with some care as in fact the sample number is much larger than the measurement number due to the fact that the measurement vehicle moves along with many other vehicles.

SURVEY

The methodological design of the survey is presented in detail. The 4 surveys were made by external survey companies.

Table 13: 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)[15]	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.
Coverage	Urban area where the Metro Delhi operates.
Size of Universe	Generally, in one day Metro Delhi transports around 1.2 million passengers on the Phase II lines[16].
Sample size	The sample size is around 4,000 surveys with a re-test sample size of around 50% of the original sample.
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. During the 1st monitoring year 2011-12 a survey plus re-test survey was realized. This survey showed the resultant CV and was therefore also the base for re-adjustment of the survey sample size.
Sample frequency	Once annually during an entire week plus one re-test per annum.
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.

Survey Realization

The survey and re-test of 2012-2013 was realized by Market Insight Consultant and 2013/2014 by Absolute Market Research and Consultants Private Ltd. contracted by Grütter Consulting AG[17].

[15] 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.

[16] See File 25

[17] File 5a to 5c including also information on the survey companies

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 survey for 2012-2013 was realized 18-24/11/2012 with the re-test being made 17-23/02/2013. The survey for 2013-2014 was realized 27/1/2014 to 02/02/2014 with the re-test being made 27/03/2014 to 2/04/2014. The survey took place during an entire week. The selected week does not correspond to a public holiday and is 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

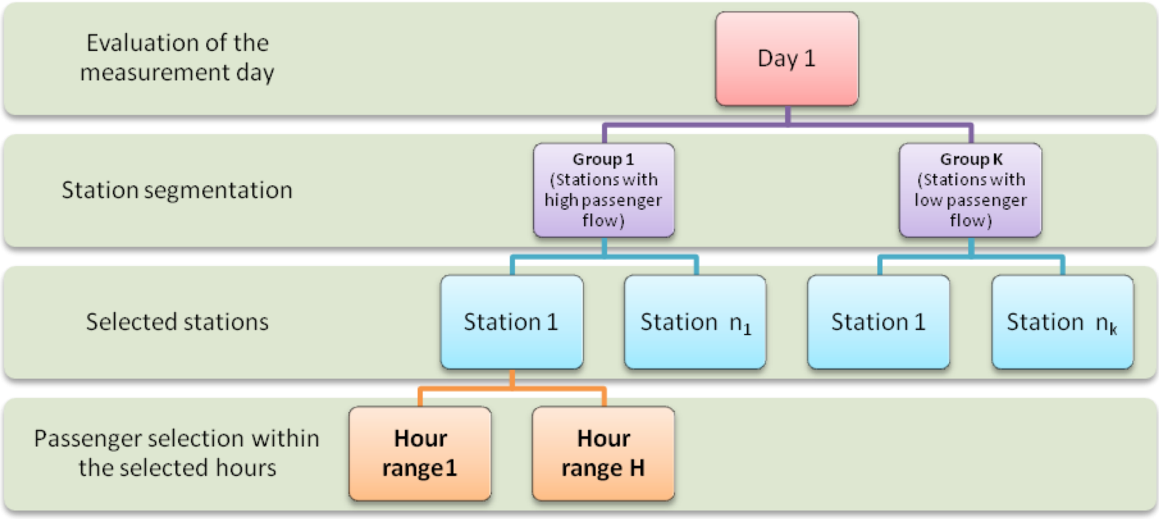
The survey was conducted among Delhi Metro commuters at DMRC phase-2 stations. The survey design was identical to the 2 surveys realized 2011-2012 in the 1st monitoring year of DMRC. To get a better representation and complete coverage of target population, this target sample was distributed among stations, days and time slots:

- **Target Population:** DMRC Commuters (Above 12 years)
- **Total Sample Size:** 4,000 and 2,000
- **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 first full survey and re-test realized in 2011/12 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 4,000 users of Metro for the full survey and 50% for the re-test showed to be sufficient based on the CV and the statistical analysis of the surveys realized in 2011/2012.

Data Analysis and Calculation

For each surveyed passenger, the distance trip per transport mode is determined for the baseline as well as for the project, with the help of Google map.Trip distances need to be determined for each surveyed passenger. The following procedures are applied:

- For Cycle/by Foot, distance calculation is not required as the applied EF is “0”.
- For users of buses, passenger cars, taxis, motorcycles, motorized rickshaws and other modes of motorized transport based on the shortest possible geographical distance based on electronic maps.

The expansion factor is calculated in two stages[18]. In the first stage the expansion factor is calculated according to the sample design, this is called the “expansion factor of design”, and in the second stage this factor is adjusted in accordance with the passenger flow of the survey week and subsequently with the total passenger flow in the year. The expansion factor of design (FEX_Design) is the inverse of the probability of selection of a passenger. According to the sample design, the probability of selection of a passenger is the resultant from the multiplication of two probabilities: 1. The probability of the selection of the station in the day in which the passenger was surveyed, and 2. The probability of selection of the passenger in accordance with the passenger flow within the hour range in which the passenger was surveyed:

- The first probability takes into account the groups of stations (main strata) and the random selection of stations of each group per day. Thus, the probability of selection per day for each station is 1 in this case; as all 84 stations of DMRC-Phase 2 were covered for each day of the survey.
- The second probability is calculated as the total selected passengers within the hour range in the station divided by the passenger flow in the same hour range.

The expansion factor of design is adjusted (also called post-stratified sampling) with the passenger flow of the survey week and with the total passenger flow in the year:

- The adjustment per week is elaborated based on the total passenger flow in the survey week according to the day, groups of stations and hour range. For each combination of day, groups of stations and hour range the following process is realized:

$$Factor(adjust\_week)_{DGH} = \frac{Flow\_week_{DGH}}{\sum_{k=1}^{n_{DGH}} (FEX_{design})_k}$$

$$FEX\,(Week\_end)_k = FEX\,(Design)_k \times Factor(adjust\_week)_{DGH}$$

Where:

DGH	combination of day, groups of stations and hour range
k	k^{th} individual passenger selected and surveyed in the station *sp*, per day, per groups of stations and hour range
sp	stations of the system
n_{DHG}	total number of passengers selected per day, per groups of stations and per hour range
$Flow\_week_{DGH}$	total number of passengers in the station *sp*, per day, per groups of stations and

[18] See for calculations Files 18a/b and 17c/d sheet FEX

	per hour range within the survey week
FEX (Week_end)	Expansion factor adjusted according to the weekly flow of passengers
FEX $(Design)_k$	Expansion factor of sample design for each for each surveyed passenger
Factor $(adjust\_week)_{DGH}$	Factor adjusted according to the weekly flow of passengers

- The adjustment per year is calculated based on the adjusted expansion factor per week obtained and the total number of passenger per station per year with the following equations:

$$Factor(adjust\_year)_{sp} = \frac{Flow\_year_{sp}}{\sum_{k=1}^{n_{sp}} (FEX(Week\_end)_k)}$$

$$FEX(year_{End})_k = FEX(Week\_end)_k \times Factor(adjust\_year)_{sp}$$

Where:

sp	stations of the system
k	k^{th} individual passenger selected and surveyed in the station *sp*
n_{sp}	total number of passengers selected in the station *sp*
$Flow\_year_{sp}$	total number of passenger in the station *sp* in the year
FEX $(year_{End})_k$	Expansion factor for each surveyed passenger *k* adjusted according to the weekly and yearly flow of passengers
$Factor(adjust\_year)_{sp}$	Factor adjusted according to the yearly flow of passengers in the station *sp*

The share per the mode of transport is differentiated by the modes of transport that the surveyed passengers would have used:

- Baseline Trip Modes: In the absence of the project
- Project Trip Modes: from their trip origin to the entry station of the project and from the exit station of the project to their final destination.

For calculating the frequency for each used mode of transport the share per used mode of transport using the expansion factor is estimated as follows:

$$S(Mode\_i) = \frac{\sum_{k=1}^{n_{Mi}} FEX(year_{End})_k}{\sum_{k=1}^{n} FEX(year_{End})_k}$$

Where:

S (Mode i)	share per mode of transport
k	k^{th} individual passenger selected
n_{Mi}	total number of passengers using mode i^{th}
n	total number of passengers selected
i	mode of transport

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:

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

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

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 14: Survey Parameter Results Period 2012-2013

Survey	Parameter	07-12/2012		01-06/2013	
		Baseline	Project	Baseline	Project
Full survey	emissions per passenger expanded gCO_2	1,482	300	1,465	298
	Cv (%)	1.4%	1.8%	1.4%	1.8%
	STDEV (per passenger)	21	5	21	5
	Lower 95% boundary gCO_2/passenger	1,441	290	1,424	288
	Upper 95% boundary gCO_2/passenger	1,523	310	1,505	309
Re-test	emissions per passenger expanded gCO_2	1,941	185	1,920	184
	Cv (%)	1.6%	3.3%	1.6%	3.3%
	STDEV (per passenger)	31	6	31	6
	Lower 95% boundary gCO_2/passenger	1,880	174	1,860	172
	Upper 95% boundary gCO_2/passenger	2,002	197	1,981	196

Source: File 18a/b

Table 15: Survey Parameter Results Period 2013-2014

Survey	Parameter	07-12/2013		01-06/2014	
		Baseline	Project	Baseline	Project
Full survey	emissions per passenger expanded gCO_2	2,219	222	2,198	220
	Cv (%)	0.7%	1.7%	0.7%	1.7%
	STDEV (per passenger)	16	4	16	4
	Lower 95% boundary gCO_2/passenger	2,188	214	2,167	212
	Upper 95% boundary gCO_2/passenger	2,251	229	2,230	227
Re-test	emissions per passenger expanded gCO_2	2,134	249	2,116	247
	Cv (%)	1.1%	2.3%	1.1%	2.3%
	STDEV (per passenger)	23	6	23	6
	Lower 95% boundary gCO_2/passenger	2,088	238	2,071	235
	Upper 95% boundary gCO_2/passenger	2,179	260	2,161	258

Source: File 17c/d

STATISTICAL TESTS SURVEY 2012-2013[19]

The test and re-test is used – amongst others - to identify if the system has seasonality.

To evaluate the seasonality of passenger flows; an analysis of the autocorrelation functions and partial autocorrelation of the residuals for the first difference of the time series (removing the trend component of the series) is realized. The analysis is done for 2 seasons from July/2012 to December/2012 and from January/2013 to June/2013. The results are presented in the following Figures.

Figure 4: Seasonality from July/2012 to December/2012

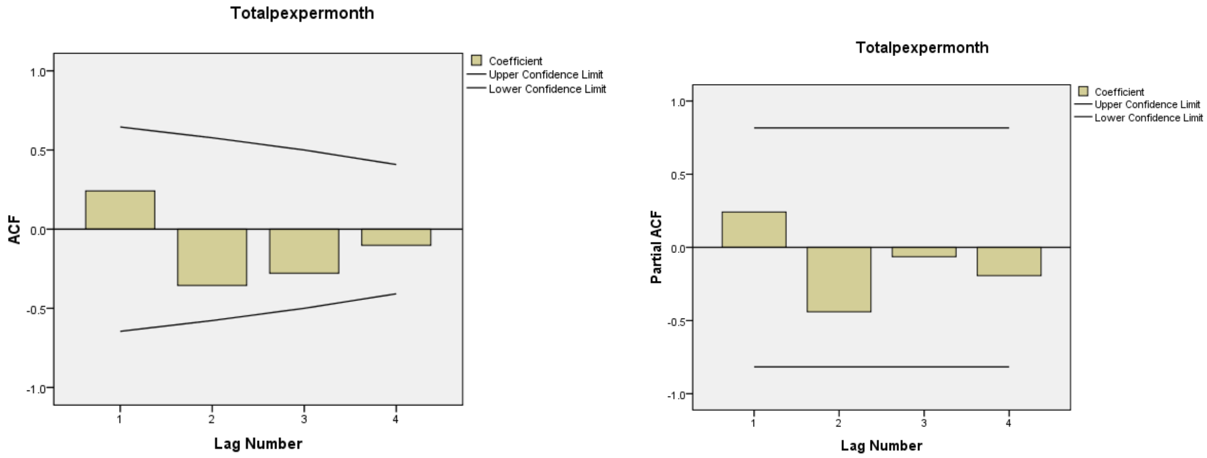
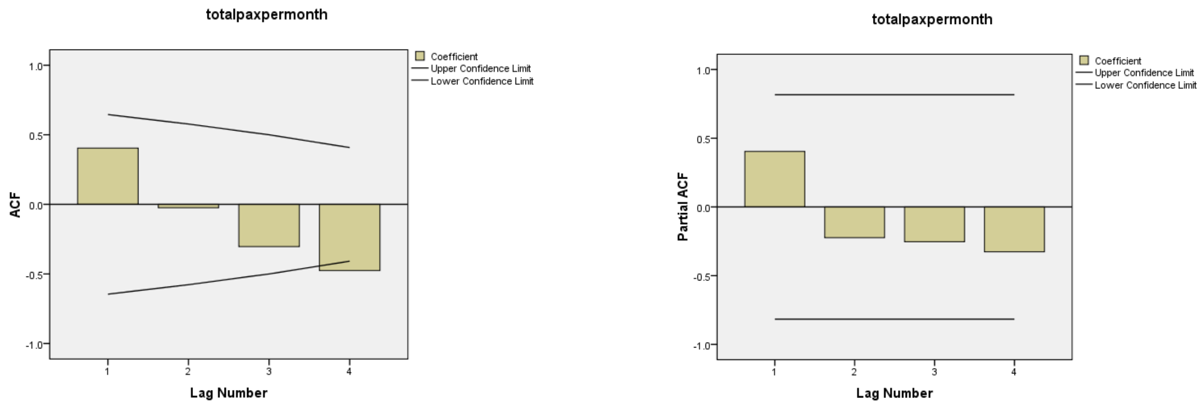


Figure 5: Seasonality from January/2013 to June/2013



When the lag functions exceed either limit of the confidence interval associated, this indicates that this order is the seasonality of the series. Thus, if the last lag exceeds the confidence limits this indicates that the series has a semi-annual seasonality. In the case of passenger data of DMRC (July/2012 to December /2012), all the lags are under the confidence level, thus, this shows that this order has no seasonality of the series. However, in the case of passenger data of DMRC (Jan/2013 to June/2013), the boundary line cut the lag 4 however only very slightly. However this was not observed in the year before nor in the year thereafter and is therefore not considered as relevant.

[19] See Tests in File 13

Evaluation of Data consistency

For the assessment of consistency a mean difference test is performed through a t – Student test, where the differences presented between both measurements are evaluated, for:

- Proportion of users that use each type of modes of transport and
- 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. The test is carried out for average emissions, which implicitly compares the use of transport modes and the average distance per mode, since these are the parameters used for estimation of total emission and average emissions per passenger. The mean difference test for the average emissions between the initial sample and test-retest is performed with a t-Student test corresponding to parametric statistical methods and assuming that the two populations are independent and come from a normal distribution. With robust sample sizes, as is the case with a sample of more than 4,000 surveys and more than 2,000 surveys in the re-test, the normal distribution assumption comes under the Central Limit Theorem. Therefore, it becomes unnecessary to carry out tests on the empirical distribution of the sample with methods such as the Mann Whitney non-parametric U test and the Wilcoxon T test.

For 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. The test applied is performed in two steps. The first step determines whether the variability between measurements is similar or different, for which a test of variances is performed between the two measurements. The second step according to the results of the variances test is done with a mean difference test (average emissions per passenger) between the two measurements to the homogeneity of variances (similar variances) or heterogeneity of variances (different variances).

Step 1: Hypothesis Test for Homogeneity of Variances

The hypothesis proposed system is as follows:

$$H_0: \sigma_1^2 = \sigma_2^2 \quad \text{Vs.} \quad H_A: \sigma_1^2 \neq \sigma_2^2$$

The test statistic is:

$$f_c = \frac{s_1^2}{s_2^2}, \text{where } f_c \sim F(n-1, m-1)$$

Where:

$s_1^2 y s_2^2$	variance sample for the first and second measurements, respectively
n and m	sample sizes of the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $f_c < f_{\frac{\alpha}{2}}(n-1, m-1)$, $\text{where } \alpha = 0{,}05$

where $f_{\frac{\alpha}{2}}$: corresponds to the $\frac{\alpha}{2}$ percentile of the Fisher's probability distribution

Step 2: Hypothesis Test for Mean Difference

a. Under homogeneity of variances between both samples

The hypothesis proposed system is as follows:

$$H_0: \mu_1 = \mu_2 \quad \text{Vs.} \quad H_A: \mu_1 \neq \mu_2$$

The test statistic is:

$$T_c = \frac{\overline{X}_n - \overline{Y}_m}{\sqrt{\left(\frac{1}{n} + \frac{1}{m}\right) S_p}}, \text{ where } T_c \sim t(m+n-2)$$

Where:

$$S_p = \frac{\sum_{i=1}^{n}(X_i - \overline{X}_n)^2 + \sum_{i=1}^{m}(Y_i - \overline{Y}_m)^2}{n+m-2}$$

n and m	simple sizes of the first and second measurements, respectively
X_n and Y_m	average emissions of the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $|T_c| > t_{1-\frac{\alpha}{2}}(n+m-2)$, where $\alpha = 0{,}05$

Where:

$t_{1-\frac{\alpha}{2}}$	corresponds to the $1 - \frac{\alpha}{2}$ percentile of the T-Student's probability distribution

b. Under heterogeneity of variances between both samples

The hypothesis proposed system is as follows:

$H_0: \mu_1 = \mu_2$ Vs. $H_A: \mu_1 \neq \mu_2$

The test statistic is:

$$T_c = \frac{\overline{X}_n - \overline{Y}_m}{\sqrt{\left(\frac{s_{1,n}^2}{n} + \frac{s_{2,m}^2}{m}\right)}}, \text{ donde } T_c \sim t(f-1)$$

Where:

$f = \min\{m; n; m+n-2\}$

n and m	sample sizes of the first and second measurements, respectively
X_n and Y_m	average emissions of the first and second measurements, respectively
s_1^2 and s_2^2	variance sample for the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $|T_c| > t_{1-\frac{\alpha}{2}}(f-1)$, where $\alpha = 0{,}05$

Where.

$t_{1-\frac{\alpha}{2}}$ corresponds to the $1 - \frac{\alpha}{2}$ percentile of the T-Student's probability distribution

The following Tables show the results for the tests of variances and mean difference, respectively. The result of the test for variances indicates that two measurements have equal variances for the project emissions and different variances for baseline emissions. Due to these results a test of mean difference under equal variance assumed (project line) and another under equal variance not assumed (project) was realized.

Table 16: Results of Test for Equality of Variances

Parameter	H_0: The variance of the BE is idem 1st and 2nd measurement in 2012/2013	H_0: The variance of the PE is idem 1st and 2nd measurement in 2012/2013
F- Value	15.231	73.427
Sig	0.000	0.000
Decision	Variance is statistically different between both measurements	Variance is statistically different between both measurements

Table 17: Results of Test for Mean Difference

Parameter	H_0: The average baseline emission per passenger is idem 1st and 2nd measurement in 2012/2013	H_0: The average indirect project emissions per passenger is idem 1st and 2nd measurement in 2012/2013
t- value	-12.121	14.427
Sig	0.000	0.000
Decision	Average baseline emissions per passenger are statistically different for both measurements	Average indirect project emissions per passenger are statistically different for both measurements

Table 34: Results of Test for Equality of Variances

Parameter	H_0: The variance of the BE is idem 1st and 2nd measurement in 2013	H_0: The variance of the PE is idem 1st and 2nd measurement in 2013
F- Value	15.868	73.500
Sig	0.000	0.000
Decision	Variance is statistically different between both measurements	Variance is statistically different between both measurements

Table 18: Results of Test for Mean Difference

Parameter	H_0: The average baseline emission per passenger is idem 1st and 2nd measurement in 2013	H_0: The average indirect project emissions per passenger is idem 1st and 2nd measurement in 2013
t- value	-12.249	14.543
Sig	0.000	0.000
Decision	Average baseline emissions per passenger are statistically different for both measurements	Average indirect project emissions per passenger are statistically different for both measurements

To evaluate the users' proportion per modes of transport, the Pearson's Chi Square test is realized, where categories are defined for each mode of transport. The test Pearson's Chi Square is used to evaluate whether the two measurements are related in terms of distribution in the use of modes. Below is the system of hypotheses, the test statistic and the decision criteria.

The hypothesis proposed system is as follows:

H_0: the measurements are not related Vs. H_A: the measurements are related

The test statistic is:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{\left(O_{ij}-E_{ij}\right)^2}{E_{ij}}, \text{where } \chi^2 \sim \chi(r-1, c-1)$$

Where:

O_{ij}	the observed frequency of row *i* and column *j*
E_{ij}	the expected frequency of row *i* and column *j*
r and c	number of categories in the rows and columns, respectively (degrees of freedom)

Decision criterion:

H_0 is rejected if $\chi^2 < \chi_{1-\alpha}(r-1, c-1)$, where $\alpha = 0{,}05$

Where:

$\chi_{1-\alpha}$ corresponds to the $1-\alpha$ percentile of the Chi-Square probability distribution

The following Tables show the contingency tables and the results of the Chi-Square. The results indicate that, for the baseline as well as for the project, the two measurements show distribution patterns using similar modes (rejection of the null hypothesis). This confirms the consistency of results considering that the two measurements come from the same population. Differences in the use of some modes affect the estimation of emissions.

Table 19: Results of Pearson´s Chi Square Test for Modes Used in the Baseline

			Survey Phase		Total
			Phase 1	Phase 2	
Baseline	passenger cars	Count	728	24	752
		Expected Count	497.8843571	254.1156429	752
	taxis	Count	317	148	465
		Expected Count	307.8673219	157.1326781	465
	bus	Count	1225	31	1256
		Expected Count	831.5728092	424.4271908	1256
	motorcycle	Count	377	397	774
		Expected Count	512.4501229	261.5498771	774
	Bike or per foot	Count	1027	1081	2108
		Expected Count	1395.665192	712.3348075	2108
	Auto	Count	368	382	750
		Expected Count	496.5601966	253.4398034	750
Total		Count	4042	2063	6105
		Expected Count	4042	2063	6105

Table 20: Pearson's Chi Square Test Result

Pearson's Chi Square	2340.662
p-value	.000

Based on the result, it is clear that Assymp.sig.=0.000<0.05 so Ho is rejected.

Table 21: Results of Pearson´s Chi Square Test for Modes Used from Origin to Entry Station of Project

phase * Mode origin to entry Cross-Tabulation

			phase		Total
			1.00	2.00	
Mode origin to entry	Bus	Count	1225	57	1282
		Expected Count	848.8	433.2	1282.0
	Taxi	Count	317	46	363
		Expected Count	240.3	122.7	363.0
	Passenger car	Count	728	57	785
		Expected Count	519.7	265.3	785.0

	Motorcycle	Count	377	318	695
		Expected Count	460.1	234.9	695.0
	Bicycle or by foot	Count	1027	1295	2322
		Expected Count	1537.4	784.6	2322.0
	Auto	Count	368	290	658
		Expected Count	435.6	222.4	658.0
Total		Count	4042	2063	6105
		Expected Count	4042.0	2063.0	6105.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1389.714[a]	5	.000
Likelihood Ratio	1609.711	5	.000
Linear-by-Linear Association	1117.421	1	.000
N of Valid Cases	6105		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 122.66.

The mode used from origin to project entry of phase 1 and phase 2 are independent. Assymp.sig.=0.000<0.05 →rejected Ho

Table 22: Results of Pearson´s Chi Square Test for Modes Used in the Project- Exit Station to Destination (Cross-tabulation)

phase * mode exit to destination Cross-Tabulation

			phase		Total
			1.00	2.00	
Mode exit to destination	Bus	Count	817	31	848
		Expected Count	561.4	286.6	848.0
	Taxi	Count	466	148	614
		Expected Count	406.5	207.5	614.0
	Passenger car	Count	220	24	244
		Expected Count	161.5	82.5	244.0
	Motorcycle	Count	53	397	450
		Expected Count	297.9	152.1	450.0
	Bicycle or by foot	Count	1490	1081	2571
		Expected Count	1702.2	868.8	2571.0
	Auto	Count	996	382	1378
		Expected Count	912.3	465.7	1378.0

Total	**Count**	4042	2063	6105
	Expected Count	4042.0	2063.0	6105.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1129.458[a]	5	.000
Likelihood Ratio	1257.080	5	.000
Linear-by-Linear Association	241.049	1	.000
N of Valid Cases	6105		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 82.45.

The mode used from origin to project entry of phase 1 and phase 2 are not independent. Assymp.sig.=0.000<0.05→rejected Ho

All results after the test showed that Ho was rejected. It presents that both the baseline and project show the distribution modes and phases are related. This confirms the consistency of results considering that the two measurements come from the same population.

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.

Although the Cronbach Alpha is a measurement to measure the reliability of a measurement scale or assessment tool, this measure can be adapted for the analysis of reliability and consistency of the comparative results of two or more measurements. In this case, this tool is used to assess whether the two measurements under the same instrument and methodological approach are concordant and consistent results in the estimation of emissions before and after the project. This involves the comparison of results for the two measurement periods on the same unit of analysis. For this purpose, and considering that the application of the instrument is made to different users for both measurements the units of analysis are stations of DMRC. Thus, the comparison reduces the contrast between the average emissions for the two measurement periods.

Cronbach Alpha can be calculated using two different but complementary methods: 1. Method of variance, and 2. Method of linear correlation.

Method of Variance

$$\alpha = \frac{K}{K-1}\left|1 - \frac{\sum_{i=1}^{K} Var_i}{Var\left(\sum_{i=1}^{K} EP_i\right)}\right|$$

Where:
α: Cronbach alpha
K : Number of measurements (in this case K=2)
Var_i: Variance of the i^{th} measurement
EP_i: Result of the i^{th} measurement (average emissions per passenger)

Method of Linear Correlation

$$\alpha = \frac{K\rho}{1 + \rho(K-1)}$$

Where:
α: Cronbach alpha
K : Number of measurements (in this case K=2)
ρ : Average linear correlations between measurements

The following Table presents the results for the two versions of Cronbach Alpha. According to these results it is evident that the instrument and its results (measurements) are consistent and reliable for measuring emissions. It has been empirically established that values above 0.7 means adequately consistent measurements.

Table 23: Results of Cronbach Alpha Test in 2012/2013

Measurement	Baseline	Project
Linear correlation	0.567	0.561
Number of measurements (K)	2	2
Cronbach Alpha (Method of variance)	0.715	0.704
Cronbach Alpha (Method of linear correlation)	0.723	0.718

According to these results it is evident that the instrument and its results (measurements) are consistent for measuring emissions.

Conclusion Survey 2012/2013

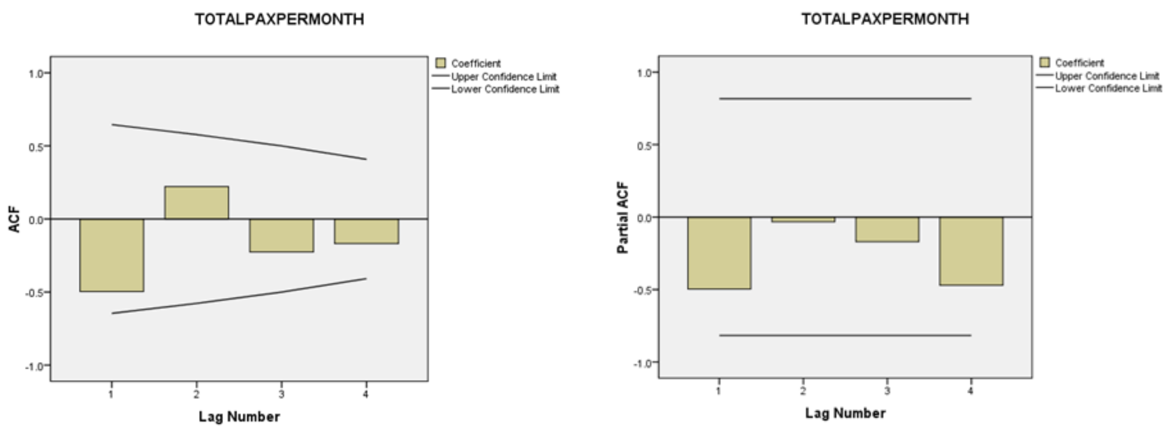
Following the results above, the statistical analysis shows that the emissions for both baseline and indirect project emissions are statistically different between two measurements. However, the Cronbach's alpha presents that these differences are not due to the inconsistency or methodological error and due to changes of use of transport modes only. This implies that the measurements for the project and baseline are fully reliable and consistent.

STATISTICAL TESTS SURVEY 2013-2014[20]

The test and re-test is used – amongst others - to identify if the system has seasonality.

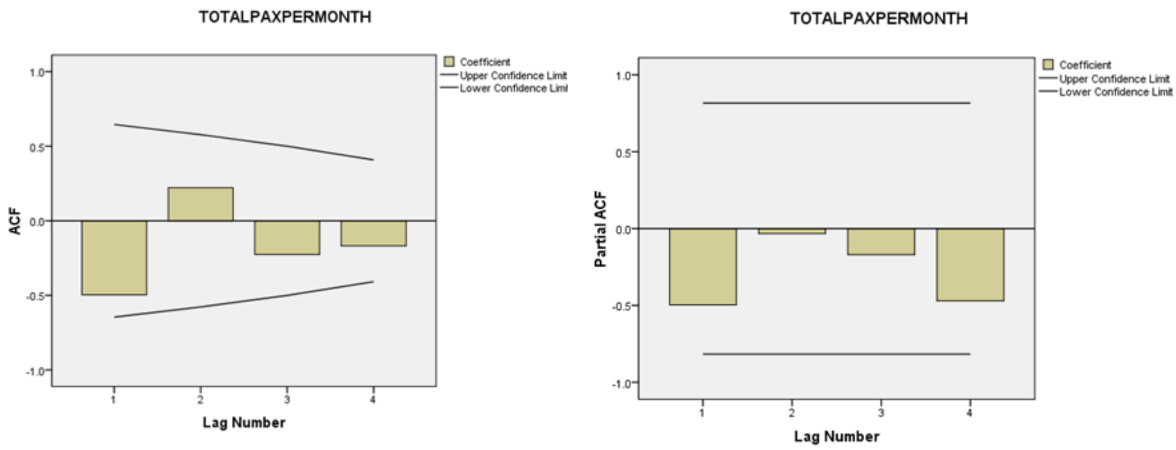
To evaluate the seasonality of passenger flows; an analysis of the autocorrelation functions and partial autocorrelation of the residuals for the first difference of the time series (removing the trend component of the series) is realized. The analysis is done for 2 seasons from July/2013 to December/2013 and from January/2014 to June/2014. The results are presented in the following Figures.

Figure 6: Seasonality from July/2013 to December/2013



[20] See Tests in File 14

Figure 7: Seasonality from January/2014 to June/2014



When the lag functions exceed either limit of the confidence interval associated, this indicates that this order is the seasonality of the series. Thus, if the last lag exceeds the confidence limits this indicates that the series has a semi-annual seasonality. In the case of passenger data of DMRC (July/2013 to December/2013) and January/2014 to June/2014, all lags are under the confidence interval so no repetition of a series and no seasonality can be observed.

For the assessment of consistency a mean difference test is performed through a t – Student test, where the differences presented between both measurements are evaluated, for:

- Proportion of users that use each type of modes of transport and
- 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. The test is carried out for average emissions, which implicitly compares the use of transport modes and the average distance per mode, since these are the parameters used for estimation of total emission and average emissions per passenger. The mean difference test for the average emissions between the initial sample and test-retest is performed with a t-Student test corresponding to parametric statistical methods and assuming that the two populations are independent and come from a normal distribution. With robust sample sizes, as is the case with a sample of more than 4,000 surveys and more than 2,000 on the re-test survey, the normal distribution assumption comes under the Central Limit Theorem. Therefore, it becomes unnecessary to carry out tests on the empirical distribution of the sample with methods such as the Mann Whitney non-parametric U test and the Wilcoxon T test.

For 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. The test applied is performed in two steps. The first step determines whether the variability between measurements is similar or different, for which a test of variances is performed between the two measurements. The second step according to the results of the variances test is done with a mean difference test (average emissions per passenger) between the two measurements to the homogeneity of variances (similar variances) or heterogeneity of variances (different variances).

Step 1: Hypothesis Test for Homogeneity of Variances

The hypothesis proposed system is as follows:

$$H_0: \sigma_1^2 = \sigma_2^2 \quad \text{Vs.} \quad H_A: \sigma_1^2 \neq \sigma_2^2$$

The test statistic is:

$$f_c = \frac{s_1^2}{s_2^2}, \text{where } f_c \sim F(n-1, m-1)$$

Where:

$s_1^2 y s_2^2$	variance sample for the first and second measurements, respectively
n and m	sample sizes of the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $f_c < f_{\frac{\alpha}{2}}(n-1, m-1)$, where $\alpha = 0{,}05$

where $f_{\frac{\alpha}{2}}$: corresponds to the $\frac{\alpha}{2}$ percentile of the Fisher's probability distribution

Step 2: <u>Hypothesis Test for Mean Difference</u>

a. Under homogeneity of variances between both samples

The hypothesis proposed system is as follows:

$H_0: \mu_1 = \mu_2 \quad \text{Vs.} \quad H_A: \mu_1 \neq \mu_2$

The test statistic is:

$$T_c = \frac{\overline{X}_n - \overline{Y}_m}{\sqrt{\left(\frac{1}{n} + \frac{1}{m}\right) S_p}}, \text{ where } T_c \sim t(m+n-2)$$

Where:

$$S_p = \frac{\sum_{i=1}^{n}(X_i - \overline{X}_n)^2 + \sum_{i=1}^{m}(Y_i - \overline{Y}_m)^2}{n+m-2}$$

n and m	simple sizes of the first and second measurements, respectively
X_n and Y_m	average emissions of the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $|T_c| > t_{1-\frac{\alpha}{2}}(n+m-2)$, where $\alpha = 0{,}05$

Where:

$t_{1-\frac{\alpha}{2}}$	corresponds to the $1 - \frac{\alpha}{2}$ percentile of the T-Student's probability distribution

b. Under heterogeneity of variances between both samples

The hypothesis proposed system is as follows:

$H_0: \mu_1 = \mu_2 \quad \text{Vs.} \quad H_A: \mu_1 \neq \mu_2$

The test statistic is:

$$T_c = \frac{\overline{X}_n - \overline{Y}_m}{\sqrt{\left(\frac{s_{1,n}^2}{n} + \frac{s_{2,m}^2}{m}\right)}}, \text{ donde } T_c \sim t(f-1)$$

Where:

$f = \min\{m; n; m+n-2\}$

n and m	sample sizes of the first and second measurements, respectively
X_n and Y_m	average emissions of the first and second measurements, respectively
s_1^2 and s_2^2	variance sample for the first and second measurements, respectively

Decision criterion:

H_0 is rejected if $|T_c| > t_{1-\frac{\alpha}{2}}(f-1)$, where $\alpha = 0{,}05$

Where.

$t_{1-\frac{\alpha}{2}}$ corresponds to the $1-\frac{\alpha}{2}$ percentile of the T-Student's probability distribution

The following Tables show the results for the tests of variances and mean difference, respectively.

The following Tables show the results for the tests of variances and mean difference, respectively. The result of the test for variances indicates that two measurements have equal variances for the project emissions and different variances for baseline emissions. Due to these results a test of mean difference under equal variance assumed (project line) and another under equal variance not assumed (project) was realized. Results indicate that surveys are consistent.

Table 24: Results of Test for Equality of Variances

Parameter	**H_0: The variance of the BE is idem 1st and 2nd measurement in 2013**	**H_0: The variance of the IPE is idem 1st and 2nd measurement in 2013**
F- Value	2.021	0.456
Sig	0.155	0.499
Decision	Variance is statistically similar between both measurements	Variance is statistically similar between both measurements

Table 25: Results of Test for Mean Difference

Parameter	**H_0: The average baseline emission per passenger is idem 1st and 2nd measurement in 2013**	**H_0: The average indirect project emissions per passenger is idem 1st and 2nd measurement in 2013**
t- value	3.383	-2.401
Sig	0.001	0.016
Decision	Average baseline emissions per passenger are statistically different for both measurements	Average indirect project emissions per passenger are statistically different for both measurements

Table 26: Results of Test for Equality of Variances

Parameter	**H_0: The variance of the BE is idem 1st and 2nd measurement in 2014**	**H_0: The variance of the PE is idem 1st and 2nd measurement in 2014**
F- Value	2.028	0.442
Sig	0.154	0.506
Decision	Variance is statistically similar between both measurements	Variance is statistically similar between both measurements

Table 27: Results of Test for Mean Difference

Parameter	**H_0: The average baseline emission per passenger is idem 1st and 2nd measurement in 2014**	**H_0: The average indirect project emissions per passenger is idem 1st and 2nd measurement in 2014**
t- value	3.384	-2.397
Sig	0.001	0.017
Decision	Average baseline emissions per passenger are statistically different for both measurements	Average indirect project emissions per passenger are statistically different for both measurements

To evaluate the users' proportion per modes of transport, the Pearson's Chi Square test is realized, where categories are defined for each mode of transport. The test Pearson's Chi Square is used to evaluate whether the two measurements are related in terms of distribution in the use of modes. Below is the system of hypotheses, the test statistic and the decision criteria.

The hypothesis proposed system is as follows:

H_0: the measurements are not related Vs. H_A: the measurements are related

The test statistic is:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{ij}-E_{ij})^2}{E_{ij}}, \text{where } \chi^2 \sim \chi(r-1, c-1)$$

Where:

O_{ij}	the observed frequency of row *i* and column *j*
E_{ij}	the expected frequency of row *i* and column *j*
r and c	number of categories in the rows and columns, respectively (degrees of freedom)

Decision criterion:

H_0 is rejected if $\chi^2 < \chi_{1-\alpha}(r-1, c-1), \text{ where } \alpha = 0{,}05$

Where:

$\chi_{1-\alpha}$ corresponds to the $1-\alpha$ percentile of the Chi-Square probability distribution

The following Tables show the contingency tables and the results of the Chi-Square. The results indicate that, for the baseline as well as for the project, the two measurements show distribution patterns using similar modes (rejection of the null hypothesis). This confirms the consistency of results considering that the two measurements come from the same population. Differences in the use of some modes affect the estimation of emissions.

Table 28: Results of Pearson´s Chi Square Test for Modes Used in the Baseline

			survey phase		
	Code		**phase 1**	**phase 2**	**total**
Bus	1	count	18	10	28
		expected count	18.66820886	9.331791	28
Train	2	count	0	0	0
		expected count	0	0	0
Taxi	3	count	102	43	145
		expected count	96.67465301	48.32535	145
Passenger Car	4	count	3452	1691	5143
		expected count	3428.949934	1714.05	5143
Motorcycle	5	count	199	124	323
		expected count	215.3511236	107.6489	323
Auto	6	count	264	149	413
		expected count	275.3560806	137.6439	413
Bicycle or by foot	7	count	0	0	0

		expected count	0	0	0
		total	**4035**	**2017**	**6052**

Table 29: Pearson's Chi Square Test

Pearson's Chi Square	**6.5472552**
p-value	**0.6841405**

Calculated p-value (or Asymp. Sig) is 0.684 > α=0.05 as a reason Ho is accepted.

Table 30: Results of Pearson´s Chi Square Test for Modes Used from origin to entry station of Project Mode origin entry * phase Cross-tabulation

			phase		Total
			1	2	
Mode origin entry	1	Count	134	55	189
		Expected Count	126.0	63.0	189.0
	3	Count	70	38	108
		Expected Count	72.0	36.0	108.0
	4	Count	308	144	452
		Expected Count	301.4	150.6	452.0
	5	Count	1171	594	1765
		Expected Count	1176.8	588.2	1765.0
	6	Count	1058	630	1688
		Expected Count	1125.4	562.6	1688.0
	7	Count	1294	556	1850
		Expected Count	1233.4	616.6	1850.0
Total		Count	4035	2017	6052
		Expected Count	4035.0	2017.0	6052.0

Table 31: Results of Pearson´s Chi Square Test for Modes Used in the Project- Origin to Entry Station (Cross-tabulation)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.256[a]	5	.000
Likelihood Ratio	23.229	5	.000
Linear-by-Linear Association	.158	1	.691
N of Valid Cases	6052		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 35.99.

Pearson's Chi Square Test

The mode used from origin to project entry of phase 1 and phase 2 are independent. Assymp.sig.=0.000<0.005 →rejected Ho

Table 32: Results of Pearson´s Chi Square Test for Modes Used in the Project- Exit Station to Destination (Cross-tabulation)

Mode exit destination * phase Cross-tabulation

	phase	Total

			1	2	
Mode exit destination	1	Count	109	35	144
		Expected Count	96.0	48.0	144.0
	3	Count	143	88	231
		Expected Count	154.0	77.0	231.0
	4	Count	14	7	21
		Expected Count	14.0	7.0	21.0
	5	Count	221	241	462
		Expected Count	308.0	154.0	462.0
	6	Count	1460	826	2286
		Expected Count	1524.1	761.9	2286.0
	7	Count	2088	820	2908
		Expected Count	1938.8	969.2	2908.0
Total		Count	4035	2017	6052
		Expected Count	4035.0	2017.0	6052.0

Table 33: Results of Pearson´s Chi Square Test for Modes Used in the Exit- station to Destination

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.239E2[a]	5	.000
Likelihood Ratio	120.491	5	.000
Linear-by-Linear Association	20.931	1	.000
N of Valid Cases	6052		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.00.

The mode used from origin to project entry of phase 1 and phase 2 are not independent. Assymp.sig.=0.000<0.000→rejected Ho

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.

Although the Cronbach Alpha is a measurement to measure the reliability of a measurement scale or assessment tool, this measure can be adapted for the analysis of reliability and consistency of the comparative results of two or more measurements. In this case, this tool is used to assess whether the two measurements under the same instrument and methodological approach are concordant and consistent results in the estimation of emissions before and after the project. This involves the comparison of results for the two measurement periods on the same unit of analysis. For this purpose, and considering that the application of the instrument is made to different users for both measurements the units of analysis are stations of DMRC. Thus, the comparison reduces the contrast between the average emissions for the two measurement periods.

If a correlation between BE and IPE exists 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:

$Var(X\text{-}Y) = Var(X) + Var(Y) - 2\ Cov\ (X,Y)$, 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.

Table 34: Results of Cronbach Alpha Test

Measurement	Baseline	Project
Linear correlation	0.935	0.89
Number of measurement	2	2
Cronbach alpha (method of variance)	0.966	0.942
Cronbach Alpha (Method of linear correlation)	0.966	0.941

The result of Cronbach alpha test for baseline and project in 2013 & 2014 are 0.966 and 0.941 respectively. These evidences prove clearly that the instrument and its results (measurements) are consistent for measuring emission. According to method of linear correlation, the Cronbach alpha value of baseline and project are higher than 0.7. Thus it implies that there are adequately consistency between two measurements for both baseline and project.

Conclusion Survey 2013/2014

Statistical analysis presents the differences between two measurements. Regarding about the emission for the both baseline and project, the estimates also consider that the average baseline emission and average indirect project emission in both measurements are different. The Cronbach's alpha shows that the measurements are consistent and reliable. Differences between the surveys in baseline and project emission are not due to the inconsistency or methodological error and due to changes of use of transport modes only. This implies that the measurements for the project and baseline are fully reliable and consistent.

SECTION E. Calculation of emission reductions or GHG removals by sinks

E.1. Calculation of baseline emissions or baseline net GHG removals by sinks

PROCEDURE

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

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)

The expansion factor is applied to each surveyed passenger in accordance with the survey sample design to get the total baseline emissions of the period (week) surveyed. To get the baseline emissions for 07-12/2012 and 01-06/2013 the average of the baseline emissions per passenger of the period (week) of the two surveyed periods (week) are calculated and multiplied with the total passengers transported in the monitoring period 07-12/2012 and 01-06/2013. For baseline emissions the lower limit of the 95% confidence interval is taken for the expanded baseline emissions per passenger. The same approach is taken for the period 07-12/2013 and 01-06/2014.

The baseline emission per surveyed passenger is calculated based on the mode used, the trip distance per mode and the emission factor per mode:

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

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

For the suburban rail (electricity-based vehicle category), the following equation is used:

$$EF_{PKM,i,y} = \frac{TE_{EL,i,y}}{P_{EL,i,y} \cdot TD_{EL,i}}$$

Where:

$EF_{PKM,i,y}$	Emission factor per passenger-kilometre of suburban rail for year *y* (gCO_2/PKM)
$TE_{EL,i,y}$	Total emissions from suburban rail for year *y* (tCO_2)
$P_{EL,i,y}$	Total passengers transported per year by suburban rail for year *y* (passengers)
$TD_{EL,i}$	Average trip distance of passengers using suburban rail prior to project start (km)
i	Suburban rail
y	Year of the crediting period

For all other fuel-based vehicle categories, the emission factor per PKM is calculated as:

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

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

For buses the following formula applies as option (1) of the methodology was chosen in the PDD i.e. annual determination of the EF:

$$EF_{KM,i,y} = \frac{\sum_x \left(SFC_{i,x,y} \cdot NCV_{x,y} \cdot EF_{CO2,x,y} \cdot N_{x,i}\right)}{N_i}$$

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)
i	Relevant vehicle category
x	Fuel type
y	Year of the crediting period

For all other vehicle categories except buses and suburban rail option (2) was chosen with the EF being fixed for the crediting period but with an annual improvement factor (IR) and therefore the following formula applies:

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

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

For train (idem for metro) using electricity the EF is calculated as.

$$EF_{KM,i} = SEC_{KM,i} \times EF_{grid,CM} \times (1 + TDL)$$

Where:

$EF_{KM,i}$	Emission factor per kilometre of vehicle category i (train/metro) (gCO_2/km)
$SEC_{KM,i}$	Quantity of electricity consumed per kilometre of vehicle category i train/metro (kWh/km)
$EF_{grid,CM}$	Emission factor for electricity generation in the grid based on combined margin (gCO_2/kWh)
TDL	Average technical transmission and distribution losses for providing electricity

The EF i.e. also cars, taxis, motorcycles and motorized rickshaws is updated based on ACM0016 p. 10:

- If the bio-fuel share changes
- If the share of fuel types used per vehicle category changes
- NCV or EF data have changed as these are monitored parameters (see formulae 6). This includes changes of the GWP.

DETERMINATION OF EF CARS, MOTORIZED RICKSHAWS, TAXIS AND MOTORCYCLES FOR MONITORING PERIOD

The following table shows the share per fuel type baseline in the registered PDD and as monitored.

Table 35: Share per Fuel Type Cars

Fuel Type	Registered PDD	Monitored 2012	Monitored 2013/14
Gasoline	81.8%	47.6%	48.0%
Diesel	10.6%	40.3%	42.2%
CNG	7.6%	12.1%	9.7%

Source: Registered PDD section B.6.2., Monitored: File 16, Gov. of NCT, Transport Department, 2013/2014

In the case of taxis and motorized rickshaws due to government regulations all vehicles are CNG[21]. Motorcycles are all gasoline. Therefore no change of vehicle fuel share took place in these types of vehicles.

According to Annex 3 of EB69, “Standard for application of the global warming potential to clean development mechanism project activities and programmes of activities for the second commitment period of the Kyoto Protocol”, all emission reductions and removals achieved by CDM project activities in the second commitment period shall be calculated using the global warming potentials (GWPs) adopted by the Conference of the Parties serving as the meeting of the Parties at its seventh session in accordance with decision 4/CMP.7, and this requirement shall apply from 1 January 2013. The proposed monitoring period starts before 31 December 2012 and ends on 25 June 2014, thus covers the 1st commitment period and 2nd commitment period. Therefore from 1.1.2013 the new GWP of CH_4 is used. The baseline emission factor of taxis, passenger cars and motorized rickshaws, all of which use CNG, therefore had to be adjusted[22].

[21] The Supreme Court of India mandated that all commercial passenger vehicles including taxis and motorized 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 11)

[22] CH4 emissions are only accounted for in vehicles powered by gaseous fuels in accordance with ACM0016 and the registered PDD.

The bio-fuel share remains in 0% for diesel and is 1.4% biofuel in gasoline in 2012, 2.9% in 2013 and 2.1% in 2014[23] and the NCV as well as other EF have not changed.

The following table lists all parameters used for the calculations of the new EF for cars, taxis and motorized rickshaws.

Table 36: Parameters for Determination EF Cars, Taxis and Motorized Rickshaws 2012, 2013 and 2014

Parameter	Description	Unit	Value	Source
$SFC_{C,G}$	Specific fuel consumption gasoline cars	g/km	54.0	PDD B.6.2. based on year 2008
$SFC_{C,D}$	Specific fuel consumption diesel cars	g/km	48.6	PDD B.6.2. based on year 2008
$SFC_{C,CNG}$	Specific fuel consumption CNG cars	g/km	64.0	PDD B.6.2. based on year 2008
$N_{C,G}/N_C$	Share gasoline, diesel, CNG cars	%	See table above	File 16
OC_C	Occupation rate cars	passengers	1.60	PDD B.6.2.
NCV_G	Net calorific value gasoline	MJ/kg	43.9	File 8
NCV_D	Net calorific value diesel	MJ/kg	42.7	File 8
NCV_{CNG}	Net calorific value CNG	MJ/m^3	35.6	File 8
$EF_{CO2,G}$	Emission factor CO_2 gasoline	gCO_2/MJ	67.5	IPCC 2006, table 1.4
$EF_{CO2,D}$	Emission factor CO_2 diesel	gCO_2/MJ	72.6	IPCC 2006, table 1.4
$EF_{CO2,CNG}$	Emission factor CO_2 CNG	gCO_2/MJ	54.3	IPCC 2006, table 1.4
GWP_{CH4}	GWP for CH_4 valid until 31.12.2012		21	PDD B.6.2.
GWP_{CH4}	GWP for CH_4 valid from 1.1.2013		25	IPCC, 2013
$EF_{CH4,CNG,C}$	Emission factor CH_4 of CNG cars	gCO_{2eq}/km	Until 31.12.2012: 9.9 From 1.1.2013: 11.8	IPCC 2006, table 3.2.4
$SFC_{TR,CNG}$	Specific fuel consumption CNG motorized rickshaws	g/km	32.0	PDD B.6.2. based on year 2008
$SFC_{T,CNG}$	Specific fuel consumption CNG taxis	g/km	64.0	PDD B.6.2. based on year 2007
$SFC_{T,G}$	Specific fuel consumption CNG taxis of gasoline (dual-fuel vehicles)	g/km	6.07	PDD B.6.2. based on year 2007
OC_{TR}	Occupation rate motorized rickshaws	passengers	1.40	PDD B.6.2.
OC_T	Occupation rate taxis	passengers	1.16	PDD B.6.2.
None	Specific weight of gasoline	kg/l	0.759	PDD B.6.2.
None	Specific weight of CNG	kg/m^3	0.717	PDD B.6.2.
ITR	Technology improvement factor	no unit	0.99	ACM0016, table 2
	Biofuel share in diesel	%	0%	File 9, table 4
	Biofuel share in gasoline	%	1.4% 2012 2.9% 2013 2.1% 2014	File 9,table 2

Buses

Based on the PDD the EF buses is updated based on updated data of SFC. The following table includes all data required for the calculation of EF buses.

[23] File 9

Table 37: Parameters for Determination EF_{PKM} Buses

Parameter	Description	Unit	Value 2012	Value 2013/14	Source
$SFC_{B,CNG}$	Specific fuel consumption CNG buses	g/km	403	403	File 12
OC_B	Occupation rate buses	passengers	43	43	PDD B.6.2.
NCV_{CNG}	Net calorific value CNG	MJ/m^3	35.6	35.6	File 8
$EF_{CO2,CNG}$	Emission factor CO_2 CNG	gCO_2/MJ	54.3	54.3	IPCC 2006, table 1.4
$EF_{CH4,CNG,B}$	Emission factor CH_4 of CNG buses	gCO_{2eq}/km	162.0	192.9	IPCC 2006, table 3.2.4 with old and new GWP
None	Specific weight of CNG	kg/m^3	0.717	0.717	PDD B.6.2.

All urban buses due to government regulations all vehicles are CNG[24].

Suburban Rail

Based on the PDD the EF suburban rail is updated based on updated data of passengers and electricity consumption. The following table includes all data required for the calculation of EF suburban rail.

Table 38: Parameters for Determination EF_{PKM} Suburban Rail

Parameter	Description	Unit	Value 2012-2014	Source
EC_{EL}	Electricity consumption per annum	MWh	2,963	File 20
P_{EL}	Passengers transported per annum	passengers	3,086,500	File 21
TD_{EL}	Average trip distance of passenger	km	28.8	PDD B.6.2.
$EF_{grid,CM}$	Emission factor of the grid based on the Combined Margin	tCO_2/MWh	0.8409	PDD B.6.2.
TDL	Transmission losses grid	None	3.91%	PDD B.6.2.

The following table summarizes the EF_{PKM} used for 2012, 2013 and 2014 per mode.

The following table shows the new EF for the vehicle categories.

Table 39: EF per PKM per Mode 2012, 2013 and 2014 (gCO_2/pkm)

Mode	2012	2013	2014
Passenger cars	95	93	92
Taxis	166	164	163
Motorized rickshaws	67	67	66
Motorcycles	28	27	27
Bus	29	30	30
Sub-urban rail	29	29	29

Source: File 14

Baseline Results

Table 40: Baseline Emission Calculation

Parameter	07-12/2012	01-06/2013	07-12/2013	01-06/2014
Passengers	196,423,542	201,852,202	227,071,786	223,736,644
Baseline emissions per passenger (lower 95% confidence interval)[25] in gCO_{2e}	1,671	1,647	2,138	2,119
Baseline emissions tCO_2	**328,224**	**332,451**	**485,479**	**474,098**

Source: CER spreadsheet

[24] The Supreme Court of India mandated that all commercial passenger vehicles including taxis and motorized 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 11)

[25] Average of 2 surveys

The total baseline emissions of the monitoring period are **1,620,252 tCO_{2eq}**

E.2. Calculation of project emissions or actual net GHG removals by sinks

Project emissions are calculated as follows:

$$PE_y = DPE_y + IPE_y$$

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

The indirect project emissions per surveyed passenger are calculated based on the transport mode used, the trip distance per mode and the emission factor per mode. The expansion factor is applied to each surveyed passenger in accordance with the survey sample design to get the total indirect project emissions of the period (week) surveyed. To get the indirect project emissions for 07-12/2012 and 01-06/2013 the average of the indirect project emissions per passenger of the period (week) of the two surveyed periods (week) are calculated and multiplied with the total passengers transported in the monitoring period 07-12/2012 and 01-06/2013. For indirect project emissions the upper limit of the 95% confidence interval is taken for the expanded indirect project emissions per passenger. The same approach is taken for the period 07-12/2013 and 01-06/2014.

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

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 DPE.

Table 41: Project Parameters

Parameter	Description	Unit	Value	Source
EC_{PJ}	Traction electricity consumption project	kWh	406,665,813	File 19
$EF_{grid,CM}$	Emission factor of the grid based on the Combined Margin	$kgCO_2/kWh$	0.8409	PDD B.6.2.
TDL	Transmission losses grid	None	3.91%	PDD B.6.2.

The following table lists the parameters required for calculating IDPE. For IDPE the same EFPKM are used as for the baseline.

Table 42: Parameters for Indirect Project Emission Calculation

Parameter	07-12/2012	01-06/2013	07-12/2013	01-06/2014
Passengers	196,423,542	201,852,202	227,071,786	223,736,644
Indirect project emissions per passenger (upper 95% confidence interval)[26] in gCO_{2e}	254	253	245	243
Indirect Project Emissions tCO_2	**49,892**	**50,968**	**55,519**	**54,256**

Source: CER spreadsheet

Table 43: Project Emissions in tCO_{2e}

Parameter	07-12/2012	01-06/2013	07-12/2013	01-06/2014
Direct project emissions	90,756	86,015	91,602	86,962
Indirect project emissions	49,892	50,968	55,519	54,256
Total Project Emissions	**140,648**	**136,983**	**147,121**	**141,218**

Source: CER spreadsheet

The total project emissions of the monitoring period are **565,971 tCO_{2eq}**

For details see CER spreadsheet.

E.3. Calculation of leakage

$$LE_y = LE_{LFB,y} + LE_{LFT,y} + LE_{LFMR,y} + LE_{CON,y}$$

Where:

LE_y	Leakage emissions in the year *y* (tCO_2)
$LE_{LFB,y}$	Leakage emissions due to change of load factor buses in the year *y* (tCO_2)
$LE_{LFT,y}$	Leakage emissions due to change of load factor taxis in the year *y* (tCO_2)
$LE_{LFMR,y}$	Leakage emissions due to change of load factor motorized rickshaws in the year *y* (tCO_2)
$LE_{CON,y}$	Leakage emissions due to reduced congestion in the year *y* (tCO_2)
y	Year of the crediting period

If LE_y < 0, then leakage is not included
If LE_y > 0, then leakage is included

Leakage load factor buses, motorized rickshaws and taxis is only monitored in the year 1 and 4 and therefore not included in this report which includes years 2 and 3.

Leakage Congestion

Two effects resulting from reduced congestion are considered:

- Induced traffic effect (or rebound effect), i.e. more trips of passenger cars on the “affected roads”;
- Changes in vehicle speed effect, i.e. change of emissions due to reduced or increased speed of cars on “affected roads”.

[26] Average of 2 surveys

The corresponding emissions are calculated as:

$$LE_{CON,y} = LE_{REB,y} + LE_{SP,y}$$

Where:
$LE_{CON,y}$ Leakage emissions due to reduced congestion in the year *y* (tCO_2)
$LE_{REB,y}$ Leakage emissions due to induced traffic / rebound effect in the year *y* (tCO_2)
$LE_{SP,y}$ Leakage emissions due to changing vehicle speed in the year *y* (tCO_2)

Leakage Rebound

As prior condition to measuring the rebound effect thus for each affected road the average speed of cars/taxis is monitored and compared with the baseline (ACM0016 p.17). If the average speed monitored is lower than the speed prior project then no rebound effect occurs as latter is related to time savings which provoke additional trips. If the average speed is lower more time is used and thus no rebound effect occurs. The following table relates the upper and lower average speed boundaries prior project and monitored based on a 95% confidence interval.

Table 44: Average Speed Prior Project and Monitored (km/h) on Affected Roads[27]

Road	Average speed range prior project	Average speed range monitored 2012/13	Average speed range monitored 2013/14
Mehrauli Gurgaon	18-27	19-22	20-23
New Noida Link Road	21-35	34-44	23-34
Rohtak Road	25-42	20-25	31-35
Aurangazeb Road	35-46	31-38	37-45
INA Market Road	17-25	15-22	18-24
Grand Trunk Road	18-28	17-22	21-26
Bhisham Pitamah Marg	25-34	18-22	28-31
Vikas Marg	15-25	14-17	19-22
Mathura Road	22-33	14-20	25-30

Source: File 15

In all roads the average speed range measured prior project and the monitored average speed range overlap except in Bhisham Pitamah Marg and Marthura Road for 2012/13. This means no statistically significant difference between the two values can be identified except on these 2 roads. For these roads the monitored average speed is however lower than the average speed prior project which means that the rebound effect would be negative as more (not less) time is used than prior project. Not including negative rebound is conservative. Therefore the LE_{REB} is 0.

Speed Effect

$$LE_{SP,y} = \frac{1}{10^6} \cdot \sum_i \left(NIZ_{i,y} \cdot TDIZ_{i,y} \cdot \left(EF_{KM,VP,i,y} - EF_{KM,VB,i} \right) \right)$$

Where:
$LE_{SP,y}$ Leakage emissions due to changes in vehicle speed of cars and taxis in year *y* (tCO_2)
$NIZ_{i,y}$ Number of cars/taxis using the affected roads in the year *y* (cars, taxis)
$TDIZ_{i,y}$ Average trip distance made by cars/taxis on the affected roads in the year *y* (km)
$EF_{KM,VP,,i,y}$ Emission factor per kilometre of cars/taxis at project speed in the year *y* (g CO_2/km)
$EF_{KM,VB,i}$ Emission factor per kilometre of cars/taxis at baseline speed (g CO_2/km)
i Cars, taxis
y Year of the crediting period

The project speed on the determined routes is monitored annually on the affected roads. Vehicle speed is monitored under moving conditions. The speed dependent EF_{KM} is based on Corinair. In the speed category[28] as registered by the project the EF is lower with a higher moving speed (see registered PDD

[27] Speed range based on upper and lower boundary using a 95% confidence interval

[28] Corinair speed category 10-130km/h

formulaes 18-21). ACM0016 on p. 18 states “If speed measurements for cars/taxis show that the EF for cars/taxis for the year y is lower than the baseline emission factor (thus leading to negative leakage) the project proponent can choose not to include this factor and thus avoid measurements of numbers of cars/taxis and trip distance of cars/taxis”. As the EF is lower if the moving speed increases the following table relates the moving speed prior project and the monitored moving speed, again as speed ranges.

Table 45: Moving Speed Prior Project and Monitored (km/h) on Affected Roads[29]

Road	Moving speed range prior project	Moving speed range monitored 2012/13	Moving speed range monitored 2013/14
Mehrauli Gurgaon	27.1-35.6	38.7-48.3	27.8-32.7
New Noida Link Road	29.7-42.7	38.4-48.3	31.3-41.5
Rohtak Road	32.0-48.3	29.8-33.8	37.9-41.7
Aurangazeb Road	43.7-56.2	36.6-43.5	46.4-53.7
INA Market Road	23.9-32.8	24.3-29.5	25.8-31.0
Grand Trunk Road	24.6-34.4	29.8-33.7	28.5-31.9
Bhisham Pitamah Marg	32.0-40.0	27.5-32.1	33.5-38.0
Vikas Marg	21.3-32.2	25.7-28.0	25.9-28.1
Mathura Road	30.2-39.7	26.3-30.6	32.6-37.0

Source: File 15

In all roads the moving speed range measured prior project and the monitored moving speed range overlap except in Mehrauli Gurgaon for 2012/13 and in Aurangazeb Road for 2012/13. This means no statistically significant difference between the two values can be identified except for these roads. In Mehrauli Gurgaon the monitored speed is higher and thus the emissions are in the project case lower than in the baseline case. Not including this leakage is thus conservative For Aurangazeb Road the monitored moving speed is lower than the moving speed prior project which means that a leakage effect occurs on this road.

$$EF_{KM,VB,i,G} = \left[\frac{a + c \times V_B}{1 + b \times V_B + d \times V_B^{\ 2}} \right] \times NCV_G \times EF_{CO2,G}$$

$$EF_{KM,VP,i,G} = \left[\frac{a + c \times V_P}{1 + b \times V_P + d \times V_P^{\ 2}} \right] \times NCV_G \times EF_{CO2,G}$$

Where:

$EF_{KM,VB,i}$	Emission factor per kilometre of gasoline cars/taxis at baseline speed (g CO_2/km)
V_B	Average moving speed of cars/taxis prior to project start (km/h)
$EF_{KM,VP,i}$	Emission factor per kilometre of gasoline cars/taxis at project speed (g CO_2/km)
$V_{P,y}$	Average moving speed of cars/taxis in the year *y* (km/h)
i	Cars, taxis
a,b,c,d	CORINAIR parameters based on Table 8-9, B. 710-45, CORINAIR 2007
$NCV_{G,y}$	Net calorific value of gasoline in the year *y* (J/g)
$EF_{CO2,G,y}$	Carbon emission factor for gasoline in the year *y* (g CO_2/J)

$$EF_{KM,VB,i,D} = \left[\frac{a + c \times V_B + e \times V_B^{\ 2}}{1 + b \times V_B + d \times V_B^{\ 2}} \right] \times NCV_D \times EF_{CO2,D}$$

$$EF_{KM,VP,i,D} = \left[\frac{a + c \times V_P + e \times V_P^{\ 2}}{1 + b \times V_P + d \times V_P^{\ 2}} \right] \times NCV_D \times EF_{CO2,D}$$

[29] Speed range based on upper and lower boundary using a 95% confidence interval

Where:

$EF_{KM,VB,i}$	Emission factor per kilometre of gasoline cars/taxis at baseline speed (gCO_2/km)
V_B	Average moving speed of cars/taxis prior to project start (km/h)
$EF_{KM,VP,i}$	Emission factor per kilometre of gasoline cars/taxis at project speed (gCO_2/km)
$V_{P,y}$	Average moving speed of cars/taxis in the year *y* (km/h)
i	Cars, taxis
a,b,c,d,e	CORINAIR parameters based on Table 8-15, B. 710-49, CORINAIR 2007
$NCV_{D,y}$	Net calorific value of diesel in the year *y* (J/g)
$EF_{CO2,D,y}$	Carbon emission factor for diesel in the year *y* (gCO_2/J)

For CNG vehicles the same emission factor as for gasoline vehicles is assumed (see registered PDD).

The following table lists the parameters required to determine the leakage speed effect on the Aurangazeb Road.

Table 46: Parameters for Leakage Speed Effect Aurangazeb Road

Parameter	Description	Unit	Value	Source
a b c d e	CORINAIR parameters for gasoline or CNG cars	none	191 0.129 1.17 -0.00072 0	PDD p. 52/53
a b c d e f	CORINAIR parameters for diesel cars	none	145 0.0673 -0.188 -0.00032 0.00947 0	PDD p. 54
$N_{C,G/CNG}/N_C$	Share gasoline and CNG cars	%	60%	File 14
$N_{C,D}/N_C$	Share diesel cars	%	40%	File 14
$N_{T,CNG}/N_T$	Share CNG taxis	%	100%	File 14
NCV_G	Net calorific value gasoline	MJ/kg	43.9	File 8
NCV_D	Net calorific value diesel	MJ/kg	42.7	File 8
$EF_{CO2,G}$	Emission factor CO_2 gasoline	gCO_2/MJ	67.5	IPCC 2006, table 1.4
$EF_{CO2,D}$	Emission factor CO_2 diesel	gCO_2/MJ	72.6	IPCC 2006, table 1.4
VB	Moving speed baseline for Aurangazeb Road (average)	km/h	50	PDD, Table A10
VP	Moving speed project for Aurangazeb Road (average)	km/h	40	File 15
NIZ_C	Number of cars using Aurangazeb Road per annum	cars	13,010,182	File 15
NIZ_T	Number of taxis using Aurangazeb Road per annum	cars	235,060	File 15
$TDIZ_{C/T}$	Trip distance on affected Aurangazeb Road for Cars and Taxis	Km	1.60	File 15

TDIZ is not monitored. The maximum trip distance on the affected road between start and end point as defined which is 1.6km. This is conservative as the actual trip length of cars or taxis on the affected road cannot be more than the maximum distance of the affected road stretch.

The following table summarizes all leakage effects:

Table 47: Leakage (tCO_2)

Concept	07-12/2011	2012	01-07/2014	Total
Leakage congestion: Leakage rebound Leakage speed	 0 105	 0 105	 0 0	 0 210
Total leakage	**105**	**105**	**0**	**210**

Total leakage for the monitoring period is thus **210 tCO_{2e}.**

E.4. Summary of calculation of emission reductions or net anthropogenic GHG removals by sinks

Item	Baseline emissions or baseline net GHG removals by sinks (t CO_2e)	Project emissions or actual net GHG removals by sinks (t CO_2e)	Leakage (t CO_2e)	Emission reductions or net anthropogenic GHG removals by sinks (t CO_2e)
Total	1,620,252	565,971	210	1,054,071

E.5. Comparison of actual emission reductions or net anthropogenic GHG removals by sinks with estimates in registered PDD

Item	Values estimated in ex-ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions or GHG removals by sinks (t CO_2e)	996,408[30]	1,054,071

E.6. Remarks on difference from estimated value in registered PDD

The difference between PDD and actual is marginal with 6%. In fact it can be expected that the emission reductions will increase and be significantly higher than the PDD estimates due to three reasons:

- At the time of PDD writing a survey was realized of passengers on Phase I metro lines, as Phase II lines were not yet operational. This means that results were a gross estimate.
- The existence of a network with the possibility of making the entire trip on metro makes the metro more attractive for mode switch thus leading to higher baseline emission factors. The average baseline emission factor per passenger was estimated for 2013 to be around 1,250 gCO_2 whilst the monitored one is around 1,900 gCO_2 thus reflecting the increasing mode shift of passengers. This could not be projected well at the writing of the PDD as only Phase I was operational.
- The economic growth of India has enabled more people to own a car or use taxis. This again entails an increased potential of mode shift of the metro over time. Again the PDD was established conservatively and assumed a constant mode shift over time based on the available survey.
- City growth results in on average longer trip distances. Longer trip distances again result in higher baseline emissions per passenger and higher offsets.

The slightly higher than projected emission reductions are therefore not surprising but a result of economic growth in India and the establishment of a metro network. This could not be assessed ex-ante in a conservative manner, like demanded from the UNFCCC, due to not having survey results of Phase II due to the logic that the PDD was prepared ex-ante project establishment. Also no reliable mode-shift factors, less even over over time, exist, resulting in only very gross ex-ante estimates of such parameters

E.7. Actual emission reductions or net anthropogenic GHG removals by sinks during the first commitment period and the period from 1 January 2013 onwards

Item	Actual values achieved up to 31 December 2012	Actual values achieved from 1 January 2013 onwards
Emission reductions or GHG removals by sinks (t CO_2e)	187,471	866,600

[30] 2012 according to PDD 477,389tCERs (actual ½ year and therefore 238,695tCERs), 2013 full year (497,989 tCERs) and 2015 519,448 tCERs (actual ½ year and therefore 259,724tCERs)

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Appendix 1. Contact information of project participants and responsible persons/ entities

Project participant and/or responsible person/ entity	☒ Project participant ☐ Responsible person/ entity for completing the CDM-MR-FORM
Organization name	Delhi Metro Rail Corporation Ltd.
Street/P.O. Box	Fire Brigade Lane, Barakhamba Road,
Building	Metro Bhawan
City	New Delhi
State/Region	Delhi
Postcode	110001
Country	India
Telephone	+91-011- 22484743
Fax	+91-011- 22484743
E-mail	saverma@dmrc.org
Website	www.delhimetrorail.com
Contact person	S.A.Verma
Title	Additional General Manager
Salutation	Mr.
Last name	Verma
Middle name	Adhar
First name	Sant
Department	Environment
Mobile	09811106868
Direct fax	+91-011- 22484743
Direct tel.	+91-011- 22484743
Personal e-mail	saverma_rs@yahoo.com

Project participant and/or responsible person/ entity	☒ Project participant ☒ Responsible person/ entity for completing the CDM-MR-FORM
Organization name	Grütter Consulting AG
Street/P.O. Box	Thiersteinerstr 22/5
Building	
City	Reinach
State/Region	
Postcode	4153
Country	Switzerland
Telephone	++442085637463
Fax	
E-mail	jgruetter@transport-ghg.com
Website	www.transport-ghg.com
Contact person	
Title	CEO
Salutation	Mr.
Last name	Grütter
Middle name	Michael
First name	Jürg
Department	
Mobile	++447534241558
Direct fax	
Direct tel.	++442085637463
Personal e-mail	jgruetter@gmail.com

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Document information

Version	*Date*	*Description*
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.

Version	*Date*	*Description*
03.1	2 January 2013	Editorial revision to correct table in section E.5.
03.0	3 December 2012	Revision required to introduce a provision on reporting actual emission reductions or net anthropogenic GHG removals by sinks for the period up to 31 December 2012 and the period from 1 January 2013 onwards (EB70, 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	28 May 2010	EB 54, Annex 34. Initial adoption.

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