MONITORING REPORT FORM (F-CDM-MR)
Version 02.0

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	24/07/2012
Registration date of the project activity	30/06/2011
Monitoring period number and duration of this monitoring period	1st monitoring period 30/06/2011 – 30/06/2012
Project participant(s)	Delhi Metro Rail Corporation Ltd. Grütter Consulting AG
Host Party(ies)	India
Sectoral scope(s) and applied methodology(ies)	7: Transport “Baseline Methodology for Mass Rapid Transit Projects” ACM0016 Version 01
Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD	467,502[1]
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period	45,501

[1] Based on 6 months 2011 (estimated in PDD for 8 months 305,077 tCO_2) and 6 months 2012 (estimated in PDD for entire year 477,389 tCO_2)

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
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. As of registration only the line Anand Vihar – Vaishali was not yet fully operational. However also latter entered into full operations as of 14/07/2011.

The project operated continuously during the entire crediting period.

The total emission reductions achieved in this monitoring period are **45,501 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

[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.

A.4. Reference of applied methodology

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

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

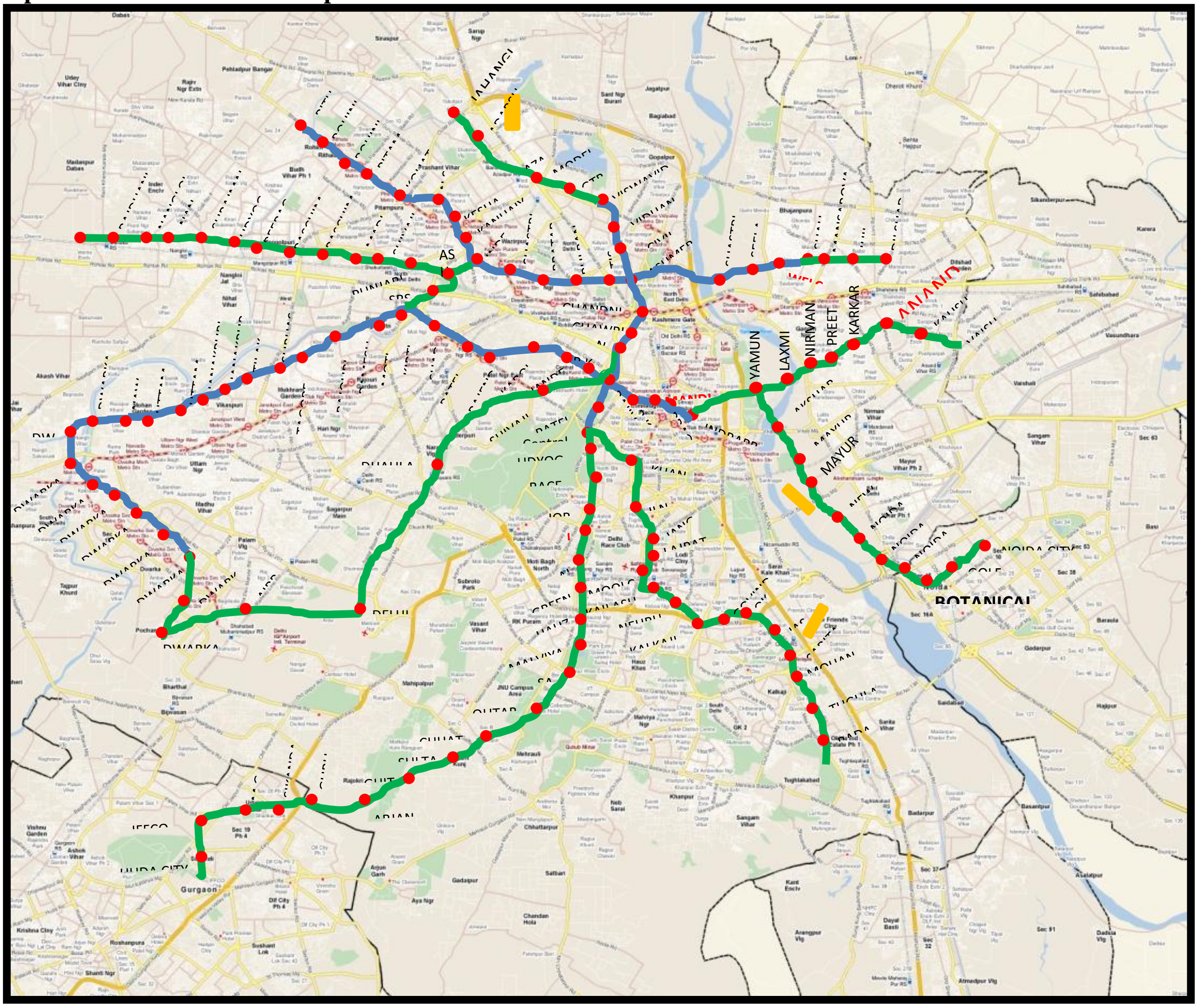
Corridor	Length (km)	Commissioning date
Shahadara-Dilshad Garden	3.09	04/06/2008
Vishwavidyalaya-Jhahangirpuri	6.36	04/02/2009
Indraprastha-New Ashok Nagar	7.72	13/11/2009
New Ashok Nagar-Noida	7.00	13/11/2009
Inderlok – Kirtinagar –Mundka	18.47	02/04/2010
Yamuna Bank –Anand Vihar ISBT	6.17	07/01/2010
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 CDM project registration date all except 1 corridor had been commissioned with latter entering into operations 14/07/2011.

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, Akshardham, Mayur Vihar 1, Mayur Viha 1 Extension, New Ashok Nagar	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[5], Satguru Ram Singh Marg, Kirtinagar [6], Ashok Park Main (repeated station) [7],	Line 5 (green line)

[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
[6] Station shared with Phase I line
[7] Station shared with Phase I line

	Punjabi Bagh, Shivaji Park, Madi Pur, Paschim Vihar (East), Paschim Vihar (West), Peeragarhi, Udyog Nagar, Surajmal Stadium, Nangloi, Nangloi Railway Station, Rajdhani Park, Mundka	
Yamuna Bank –Anand Vihar ISBT	Yamuna Bank, Laxmi Nagar, Nirman Vihar, Preet Vihar, Karkarduma, Anand Vihar ISBT	Part of Line 3 (blue line)
Anand Vihar – Vaishali	Anand Vihar ISBT (repeated station), Kaushambi, Vaishali	Part of Line 3 (blue line)
QM-Gurgaon	Qutab Minar, Chhattarpur, Sultanpur, Ghitorni, Arjangarh, Guru Dronacharge, Sikandarpur, MG Road, IFFCO Chowk, Huda City Centre	Part of Line 2 (yellow line)
Central Secretariat –QM	Central Secretariat[8], 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)[9], 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[10]	Part of Line 3 (blue line)

In total the project has 84 stations with 4 stations shared with a Phase I line and 1 station shared with the Airport Link line.

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[11].

[8] Station shared with Phase I line
[9] Station shared with Phase I line
[10] Station shared with Airport Link line
[11] See also File 23

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 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[12].

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)[13]. 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 or applied methodology

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 submitted with this monitoring report.

B.2.3. Permanent changes from registered monitoring plan or applied methodology

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

[12] See File 4 for detailed system description
[13] See File 31 for contract

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 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 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.

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[14]. It defines all responsibilities and procedures. DMRC was trained on the manual 06/2012[15]. 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 is preparing the certification for ISO 9001, ISO 140001 and OHSAS 18001 for the operations of Phase I and Phase II corridors[16].

Table 4 lists the data parameters monitored and the data source.

Table 4: Monitored Parameters and Data Source

Index	Parameter	Description	Data source
1	$N_{x,C/T/TR}$	Fuel types used by cars, taxis and motorized rickshaws	Government of National Capital Territory of Delhi; Transport Department
2	P	Passengers transported	DMRC
3	EC_{PJ}	Traction electricity consumption	DMRC
4	MS_i $BTD_{p,i}$ $IPTD_{p,i}$ P_{SPER} FEX_P	Passenger survey for indirect project and baseline emission per passenger and mode share baseline	Survey realized by external survey company

[14] File 2
[15] File 24
[16] File 3a/b

5	$N_{B,T,TR}$	Number of buses, taxis and motorized rickshaws	For buses: DTC (Delhi Transport Corporation) For taxis and motorized rickshaws: Government of National Capital Territory of Delhi; Transport Department
6	$OC_{B,T,TR}$	Occupation rate buses, taxis and motorized rickshaws	Survey realized by Grütter Consulting AG
7	$NIZ_{C,T}$	Number of cars/taxis using affected roads	survey realized by Grütter Consulting AG
8	$TDIZ_{C,T}$	Trip distance of cars/taxis on affected roads	survey realized by Grütter Consulting AG
9	V_P	Speed of cars/taxis on affected roads	survey realized by Grütter Consulting AG
10	$NCV_{G/D/CNG}$	Net Calorific Value	India Oil Corporation Ltd.
11	$EF_{CO2,G/D/CNG}$ $EF_{KM,B,CH4}$ $EF_{KM,C/T,CH4}$	Emission factors of fuels	IPCC
12	SFC_B	Specific fuel consumption buses	DTC
13	$EC_{EL,R}$	Electricity consumption suburban rail	Northern Railway
14	$P_{EL,R}$	Passengers transported suburban rail	Northern Railway

PARAMETER PASSENGERS

Passenger flow data is based on the AFC system (Automatic Fare Collection System)[17] 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

[17] See File 4

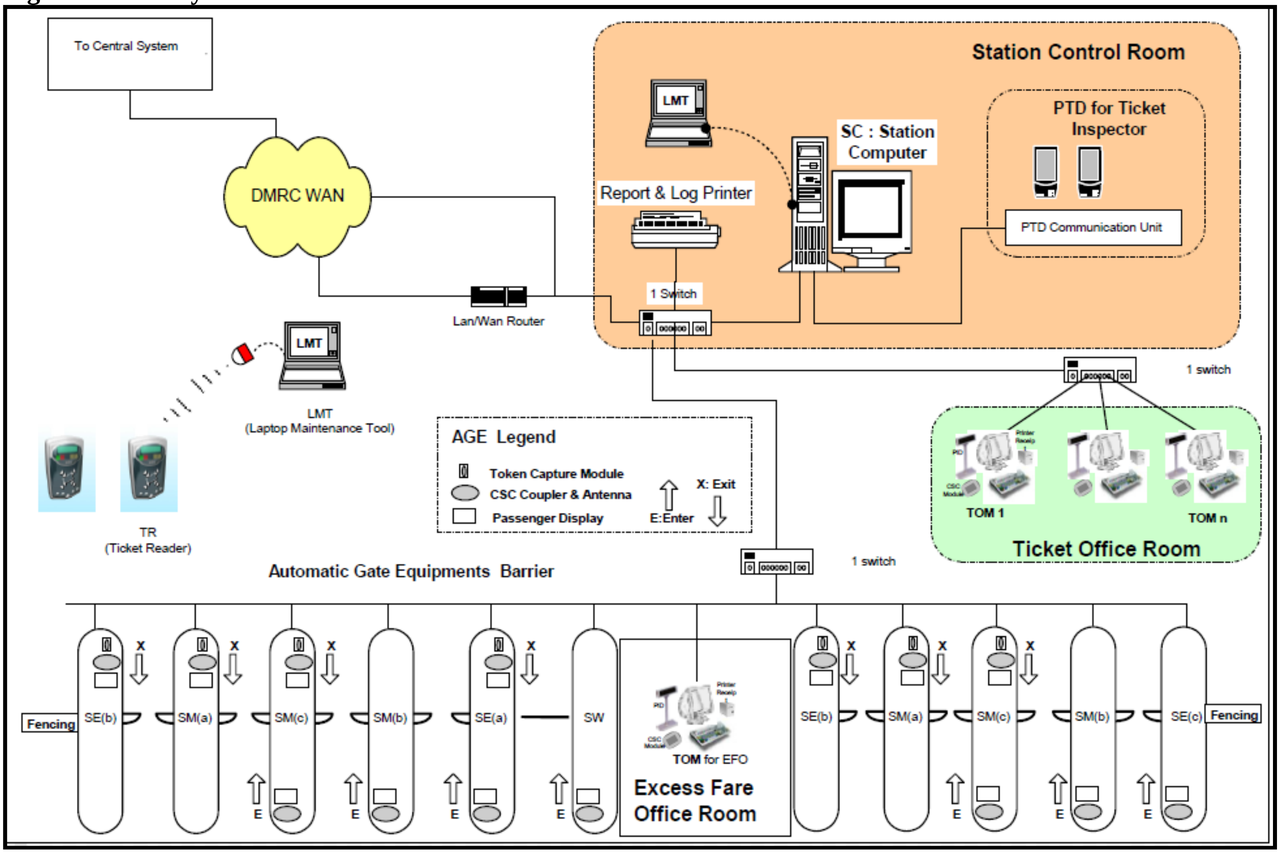
Picture 2: Ticket Office Machine

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 are realized by RS Market Research Solutions Pvt ltd. (RSMRS) contracted by Grütter Consulting AG[18]. RSMRS has over 3,500 projects, has conducted more than 600,000 interviews and has more than 200 full-time staff[19]. RSMRS is also ISO 9001 certified[20].

A survey trial had been made prior PDD realization with 804 passengers[21] which was used for the determination of the final survey design and the determination of the survey sample (see registered PDD). The survey objectives are:

[18] File 5
[19] File 6
[20] File 22
[21] File 7

- 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.

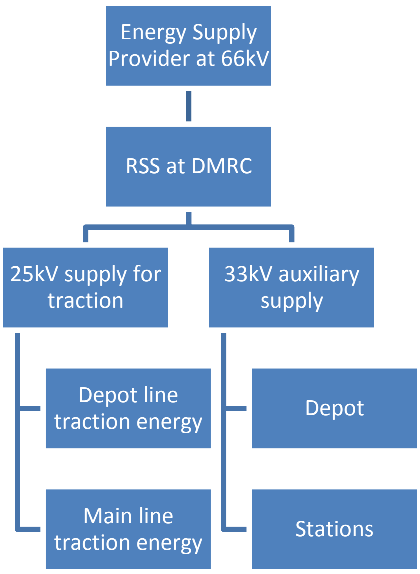
ELECTRICITY CONSUMPTION

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.

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 station distances between phase I and phase II are calculated for all lines 1. TE for Phase II is Total TE consumed for each line minus the TE consumed by Phase I based on station distances for each phase. 2 Lines are entirely Phase II and therefore 100% of the traction energy is accounted for Phase II whilst 3 lines have a Phase I and Phase II segment. The allocation based on distance driven is justified and conservative as the Phase II part of these lines is at the ends of the Phase I part i.e. prolongations of Phase I lines. However more passengers are transported in the center part of lines than at the ends and therefore distance proportional allocation is conservative. 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. The calibration/testing was done by Bharthi Automation Pvt. Ltd. for 2012. These meters will be calibrated once a year by DMRC (in-house) from 2013. See the following Table for a list of all traction meters including calibration date.

Table 5: Traction Energy Meters

ID No.	Model No.	Make	Certificate No	Calibration Date	Location
25 KV \ I/C-02	ELI 02257	Swift/ Elite	BA/2K12/175	06/06/2012 (File 32h)	Dwaraka
25 KV \ I/C-01	ABB01646	Secure	BA/2K12/180	06/06/2012 (File 32i)	Sarita Vihar
25 KV \ I/C-01	ABB1650	Secure/Entity	BA/2K12/184	09/06/2012 (File 32f)	JGPI (Jahangirpuri)
25 KV \ I/C-01	ABB03285	Secure/Entity	BA/2K12/192	16/06/2012 (File 32g)	Chhatarpur
25 KV \ I/C-01	ABB01647	Secure/Entity	BA/2K12/196	17/06/2012 (File 32a)	Mundka
25 KV \ I/C-01	ABB01470	Secure/Entity	BA/2K12/188	08/06/2012 (File 32b)	Huda City Centre
CB202/I/C-02	65428/698-6305	Enercon	BA/2K12/200	07/06/2012 (File 32c)	ND (New Delhi)
25 KV/PO1	ELI04623	Secure	BA/2K12/205	03/06/2012 (File 32e)	IP (Indraprasth)
CB200/I/C	142814/11691-0808	Conzerv	BA/2K12/201	19/06/2012 (File 32d)	ND (New Delhi)
25 KV/CB/06	256570	Satec	BA/2K12/160	31/05/2012 (File 32j)	Kashmere Gate
25 KV/CB/04	994575	Satec	BA/2K12/161	31/05/2012 (File 32k)	Rithala
25 KV I/C-03	229694	Satec	BA/2K12/164	31/05/2012 (File 32l)	Rithala
25 KV	ABB01648	Secure/Entity	BA/2K12/168	05/06/2012 (File 32m)	Botanical Garden
25 KV \ I/C-02	ECI 02447	SEMS/ Swift/ Elite	BA/2K12/173	06/06/2012 (File 32n)	Subhash Nagar

Note: All calibrations realized by Bharthi Automation Pvt. Ltd

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 6

Table 6: 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

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.

Data/Parameter	**VD_T**
Unit	Km
Description	Annual average distance driven of taxis in Chongqing
Source of data	Chongqing Taxi Company, 2008
Value(s) applied	144,000
Purpose of data	Leakage

Additional comment	

Data/Parameter	**V_B**
Unit	Km/h
Description	Vehicle baseline speed on affected roads.
Source of data	Grütter Consulting AG, 2009
Value(s) applied	**Table 7: Baseline Moving Speed on Affected Roads** (see table below)
Purpose of data	Leakage
Additional comment	On-board measurements determining the average speed when circulating.

Table 7: 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

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	$\mathbf{NCV_{CNG}}$
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	$\mathbf{EF_{CO2,G/D/CNG}}$
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 IPCC report
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.
Value(s) of monitored parameter	162.0
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	No new IPCC report
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	**$EF_{KM,C/T/TR,CH4}$**
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)
Value(s) of monitored parameter	9.9
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annual
Calculation method (if applicable)	Not applicable
QA/QC procedures	No new IPCC report
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	$N_{x,C}$
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, 2012 (File 16)
Value(s) of monitored parameter	Diesel: 104,582 (22.6%) Gasoline: 311,707 (67.3%) CNG: 47,141 (10.2%)
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. Sum private 4-wheelers all classes: Diesel: 103,964+11+237+370 = 104,582 Gasoline: 310,962+1+15+322+407 = 311,707 CNG: 756+23,359+4+1+23,011+3+1+2+3+1 = 47,141 (includes CNG only, Petrol/CNG, retrofit CNG kit and retrofit CNG/Petrol) Total of Diesel, gasoline and CNG vehicles (for % calculation): 463,430 LPG vehicles constitute less than 1% of total (861/464,429 = 0.2%) and are thus not considered. Electric vehicles constitute less than 0.1% of total (119/464,429 = 0.02%) 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[22].

[22] See National Bio-fuel Policy of 24/12/2009 which has an indicative bio-fuel target for 2017 (point 2.2. p.4) (File 9). See however the annual 2010 bio-fuels report on India which states that no biodiesel is blended and that ethanol blending at 5% as targeted has not been implemented (File 10, p.2). Also the 2017 target is considered not realistic in this report (p. 2)

Data/Parameter	$N_{x,T}$
Unit	Vehicles
Description	Number of Taxis (T) using fuel type *x*
Measured/Calculated /Default	Measured
Source of data	Government of National Capital Territory of Delhi, Transport Department, 2012 (File 16) 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	CNG: 6,530 (100%)
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. Includes local taxis and radio taxis: 24+1,118+644+2,229+2,471+44 = 6,530
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	$N_{x,TR}$
Unit	Vehicles
Description	Number of motorized auto-rickshaws (TR) using fuel type *x*
Measured/Calculated /Default	Measured
Source of data	Government of National Capital Territory of Delhi, Transport Department, 2012 (File 16) 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	CNG: 4,234 (100%)
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. Includes 3-wheelers: 4,217+17 = 4,234
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	$N_{x,M}$
Unit	Vehicles
Description	Number of Motorcycles (M) using fuel type *x*
Measured/Calculated /Default	Measured
Source of data	Government of N.C.T of Delhi, Transport Department, cited in Delhi Statistical Handbook 2011[23] (Registered as of 31/03/2011) (File 18)
Value(s) of monitored parameter	Gasoline: 4,342,403 (100%)
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. Electric 2-wheelers represent 0.01% of all 2-wheelers[24]. 2-wheelers include scooters, motorcycles, mopeds and electric 2-wheelers (based on SIAM, File 17).
QA/QC procedures	None
Purpose of data	Baseline, Project
Additional comment	ACM0016 states on p. 10 that the share of fuels per vehicle category must be identified and if relevant the emission factor must be re-calculated. Percentages have not changed and therefore the baseline emission factor for motorcycles needs not be recalculated. No bio-fuels are used[25].

[23] http://www.delhi.gov.in/wps/wcm/connect/doit_des/DES/Our+Services/Statistical+Hand+Book/

[24] Total domestic sales of electric 2 wheelers was 2010 and 2011 2,711 units versus a total of 2-wheelers in the same period of 21,161,256 i.e.0.01%; SIMA File 17

[25] See National Bio-fuel Policy of 24/12/2009 which has an indicative bio-fuel target for 2017 (point 2.2. p.4) (File 9). See however the annual 2010 bio-fuels report on India which states that no biodiesel is blended and that ethanol blending at 5% as targeted has not been implemented (File 10, p.2). Also the 2017 target is considered not realistic in this report (p. 2)

Data/Parameter	**P**
Unit	Passengers
Description	Total passengers transported by the project
Measured/Calculated /Default	Measured
Source of data	DMRC, 2012 (File 26 and 27)
Value(s) of monitored parameter	295,114,393
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)	30/06/2011 to 31/12/2011: 126,647,263 passengers 01/01/2012 to 30/06/2012: 168,467,130 passengers
QA/QC procedures	
Purpose of data	Project and Baseline
Additional comment	

Data/Parameter	$\mathbf{EC_{PJ}}$
Unit	kWh
Description	Electricity consumed by MRTS (trains)
Measured/Calculated /Default	Measured and calculated
Source of data	DMRC (File 28)
Value(s) of monitored parameter	202,749,599
Monitoring equipment	Traction energy is recorded by DMRC per line. Table 5 lists all traction energy meters. File 32 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 thereafter read from traction meter. The station distances between phase I and phase II are calculated for all lines 1. TE for Phase II is Total TE consumed for each line minus the TE consumed by Phase I based on station distances for each phase. 30/06/2011 to 31/12/2011: 97,425,483 kWh 01/01/2012 to 30/06/2012: 105,324,116 kWh The table below shows the consumption per line total and per Phase II part of each line.
QA/QC procedures	Control with electricity invoices for total energy. The TE meters have all been calibrated by Bharthi Automation Pvt. Ltd.
Purpose of data	Project
Additional comment	

Table 8: Traction Energy per Line

Line	Time Period	Phase I Distance (km)	Phase II Distance (km)	Total TE	Phase II TE[26]
Line 1	07-12/2011	20.69 (Rithala-Shahdara)	3.14 (Shahdara-Dilshad Garden)	23,785,029	3,134,074
	01-06/2012			23,248,404	3,063,365
Line 2	07-12/2011	9.75 (Vishwavidyalaya-Central Secretariat)	6.35 + 27.35 (Jahangirpuri-Vishwavidyalaya and Central Secretariat-HUDA City Centre)	53,184,732	41,250,298
	01-06/2012			65828753	51,057,053
Line 3 / 4	07-12/2011	31.42 (Dwarka Sector 9-Yamuna Bank)	2.76 + 13.26 + 8.81 (Dwarka Sector 21-Dwarka Sector 9 and Yamuna Bank-City Centre and Yamuna Bank-Valshali[27])	64,844,062	28,623,610
	01-06/2012			60,831,956	26,852,577
Line 5	07-12/2011	0	14.87	11,137,500	11,137,500
	01-06/2012			12,172,000	12,172,000
Line 6	07-12/2011	0	19.64	13,280,000	13,280,000
	01-06/2012			12,179,120	12,179,120

Source: File 28a/b

Data/Parameter	N_B
Unit	Buses
Description	Number of buses circulating in the city
Measured/Calculated /Default	Measured
Source of data	Delhi Transport Corporation (DTC), Operational Statistics, 10/2011, Table 3.2 (File 12)
Value(s) of monitored parameter	6,031
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Year 1, 4 and 7 of crediting period
Calculation method (if applicable)	Not applicable
QA/QC procedures	
Purpose of data	Leakage (only required if a change of occupation rate buses was registered)
Additional comment	All urban buses are CNG (see File 12, Table 2.5). The Supreme Court of India mandated that all commercial passenger vehicles including urban 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; File 11)

[26] Calculated as Distance Phase II / (Distance Phase I + Phase II) * Total TE
[27] Yamuna Bank-Valshali

Data/Parameter	**OC_B**
Unit	%
Description	Average occupancy rate of buses
Measured/Calculated /Default	Measured and calculated
Source of data	Grütter Consulting, 2012 (File 25)
Value(s) of monitored parameter	61%
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Year 1,4, and 7
Calculation method (if applicable)	See CRI 2007 p. 24 ff for procedure followed baseline. The average occupancy rate is based on the average capacity of buses surveyed (low floor buses capacity 55 and standard buses 70 passengers; see File 19) and the average number of passengers on buses. The occupancy rate is based on a visual occupation study in line with A.6.3. of the registered PDD.
QA/QC procedures	See Section D.3. The sample size required for a 95% confidence level and a 10% maximum error bound (relative precision level) of a simple random sample is 72 while the actual sample size taken was 7,676 units.
Purpose of data	Leakage
Additional comment	The baseline rate was 57%. The methodology states on page 15 that "Leakage from load factor change of buses is only included if the load factor of buses has decreased by more than 10 percentage points comparing the monitored value with the baseline value." This means leakage is included if the occupation rate is below 47% (57%-10 percentage points). This is not the case and therefore not leakage for change of occupation rate buses is included.

Data/Parameter	**OC_T**
Unit	passengers
Description	Average occupancy rate of taxis
Measured/Calculated /Default	Measured and calculated
Source of data	Grütter Consulting, 2012 (File 13 and 13a)
Value(s) of monitored parameter	1.19
Monitoring equipment	none
Measuring/Reading/ Recording frequency	Year 1,4, and 7
Calculation method (if applicable)	The following table compares the baseline and the project monitored values. **Table 9: Occupation Rate Taxis** (see table below)
QA/QC procedures	Survey realized using upper 95% confidence interval. The sample size required for a 95% confidence level and a 10% maximum error bound (relative precision level) of a simple random sample is 318 while the actual sample size taken was 2,553 units. The procedure followed the TORs for occupation rate studies described in methodology. The same procedure was followed as for the baseline study with the same sites and the same number of days. Baseline study see File 13b.
Purpose of data	Leakage
Additional comment	The load factor taxis has not worsened. Therefore leakage taxis based on formulae (16) of ACM0016 Vs.1.0 would be negative and non-inclusion of the leakage is thus conservative and in accordance with the methodology as stated on p.15

Table 9: Occupation Rate Taxis

	Simple average	Upper 95% confidence interval
Baseline study	1.13	1.16
Project monitoring	1.15	1.19

Data/Parameter	**OC_{TR}**
Unit	Passengers
Description	Average occupancy rate of motorized auto-rickshaws
Measured/Calculated /Default	Measured and calculated
Source of data	Grütter Consulting, 2012 (File 14 and 14a)
Value(s) of monitored parameter	1.41
Monitoring equipment	none
Measuring/Reading/ Recording frequency	Year 1,4, and 7
Calculation method (if applicable)	Average value of sites and days (same as in baseline study)
QA/QC procedures	The sample size required for a 95% confidence level and a 10% maximum error bound (relative precision level) of a simple random sample is 222 while the actual sample size taken was 5,277 units. The procedure followed the TORs for occupation rate studies described in methodology. The same locations as used in the baseline study were taken (Baseline study see File 14b).
Purpose of data	Leakage
Additional comment	The load factor motorized auto-rickshaws has not worsened. The baseline value was 1.40 and the monitored project value was 1.41. Therefore leakage motorized auto-rickshaws based on formulae (16) of ACM0016 Vs.1.0 would be negative and non-inclusion of the leakage is thus conservative and in accordance with the methodology as stated on p.14

Data/Parameter	$\mathbf{NIZ_{C,T}}$
Unit	Vehicles
Description	Number of cars/taxis using affected roads
Measured/Calculated /Default	Measured and Calculated
Source of data	Grütter Consulting, 2012 (File 15 and 15a)
Value(s) of monitored parameter	**Table 10: Number of Cars and Taxis on Affected Roads per Annum** (see table below)
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Yearly
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 (baseline study see File 15b).
Purpose of data	Leakage
Additional comment	

Table 10: Number of Cars and Taxis on Affected Roads per Annum

Road	Cars	Taxis
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

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, 2012 (File 15 and 15a)
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.

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 and 15a)
Value(s) of monitored parameter	**Table 11: Average Speed and Average Moving Speed in km/h** (see table below)
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 (File 15c is the baseline speed 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	

Table 11: Average Speed and Average Moving Speed in km/h

Road	Average Speed	Average Moving Speed
Mehrauli Gurgaon	30	38
New Noida Link Road	29	35
Rohtak Road	27	36
Aurangazeb Road	31	38
INA Market Road	28	35
Grand Trunk Road	28	37
Bhisham Pitamah Marg	28	36
Vikas Marg	21	30
Mathura Road	25	34

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, 10/2011, Table 2.6, Row CIII (File 12)
Value(s) of monitored parameter	380.23
Monitoring equipment	None
Measuring/Reading/ Recording frequency	Annually
Calculation method (if applicable)	The report states 2.63km per kg. This is equivalent to 380.23 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	Indian Railways, 2012, p.518, row 32.25 Suburban EMU 2010-2011, column Northern Railway (File 20)
Value(s) of monitored parameter	3,616
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	$\mathbf{P_{EL,R}}$
Unit	Passengers
Description	Total passengers transported by baseline rail-system per year
Measured/Calculated /Default	Measured
Source of data	Indian Railways, 2012, p.121, row Northern Railway Suburban 2010-2011 (File 20)
Value(s) of monitored parameter	3,029,700
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	$\mathbf{BTD_{p,i}}$
Unit	Kilometre
Description	Baseline trip distance of the cluster *p* of surveyed passengers using mode *i*
Measured/Calculated /Default	Measured
Source of data	RSMRS, 2012 (File 29 and 30)
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 29 and 30
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	RSMRS, 2012 (File 29 and 30)
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 29 and 30
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	RSMRS, 2012 (File 33a/b)
Value(s) of monitored parameter	Calculated for each passenger surveyed. See for values per passenger File 33a/b
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

The following monitoring parameters are not required:

MS_i: The project has a negative rebound effect. Therefore this parameter, required only for calculation of a rebound effect if positive (see formulae 16 of registered PDD), is not required.

P_{SPER}: This is not reported as included in the parameter P. Passengers are recorded daily per station for the entire time period and not only for the survey week.

TC_{PJ}, DD_{PJ} and **SFC_{PJ}** are not monitored as the project uses only electricity as fuel.

DPE is a calculated value and not a monitored parameter based on the electricity consumption and the grid emission factor including transmission losses based on the "Tool to calculate baseline, project and/or leakage emissions from electricity consumption".

D.3. Implementation of sampling plan

Sampling is used for the following parameters:

- Occupation rate surveys for taxis, motorized rickshaws and buses.
- Determination of speed and number of vehicles on affected roads (partially).
- Passenger survey to determine indirect project emissions as well as baseline emissions. This includes the parameters MS_i, FEX, BTD, and IPTD.

OCCUPATION RATE SURVEY TAXIS

Sampling Design

The sampling design is based on ACM0016 Annex 3 which is also included in the registered PDD as Annex A.6.1. The PDD details the sites, the time and the days for sampling. This to ensure that the baseline occupation rate is comparable to the monitored project occupation rate. Both occupation rate studies where performed with the same principles[28].

The objective of the study is to determine the occupancy rate of taxis. The actual number of passengers is counted in a given point within a given time period. Only taxis are included. Only 4-wheel taxis are included. Only persons aged 2 and above are counted i.e. infants are excluded. The counting is based on visual occupation i.e. counting the number of passengers occupying the vehicle excluding the driver. The procedures to establish visual occupation are:

- Locations, days and times for field study are defined, avoiding days immediately after or before a holiday. Atypical seasons (school or university vacations) should be avoided. The study is done on weekdays.
- The occupation rates are: 0 passengers (only taxi driver), 1, 2, 3, 4, 5 or more passengers.
- Field data is collected. Coverage of the occupation counts should be higher than 95% of the number of taxis that cross the checkpoint. One hundred per cent coverage is desired.
- Occupancy is the number of passengers using the vehicle. The occupancy is determined of all taxis passing the control points.
- The total number of vehicles and the total number of passengers is reported. The average occupation rate of vehicles is the total number of passengers divided by the total number of vehicles in which counts were performed.

The study was carried out during the following working days 19/12/2011 (Tuesday), 20/11/2011 (Wednesday), 21/12/2011 (Thursday), 16/01/2012 (Monday), 17/01/2012 (Tuesday), 18/01/2012 (Wednesday). Days immediately before and after holidays were avoided. Atypical seasons (school or university vacations) were avoided. The selected sites were Sansad Marg, Connaught Place, opposite to Janter Manter and Panchkuin Road (opposite Metro pillar 26), towards Connaught Place, idem to the baseline sites.

[28] See File 13 for project study and File 13b for baseline study

Collected Data

Data collected is the number of passengers per taxi. The following table shows the results.

Table 12: Results Occupation Rate Study Taxis, 2012[29]

Number of passengers	Number of taxis with the indicated number of passengers	percentage
0 passenger	802	31%
1 passenger	907	36%
2 passengers	577	23%
3 passengers	211	8%
4 passengers	39	2%
5 passengers	17	1%
> 5 passengers	0	0%

Analysis of Collected Data

The following table shows the analysis of the collected data.

Table 13: Calculations Occupation Rate Taxis, 2012[30]

Parameter	Value
Total number of passengers	2,935
Total number of taxis	2,553
Average occupation rate	1.15
Standard deviation	1.0
Standard error of average	0.021
Upper and lower 95% confidence interval	1.11 and 1.19

The baseline occupation rate as fixed for the emission factor as registered in the PDD is the upper 95% confidence interval (to have a conservative baseline emission factor). Therefore for comparison purposes also the upper 95% confidence interval of the project study must be taken.

Demonstration of Confidence and Precision

The sampling size has been checked for a 95% confidence interval and a 10% relative precision level in accordance with the "Standard for Sampling and Surveys for CDM Project Activities and Programme of Activities", EB 65 Annex 2, p.2 point 9, based on the following formulae[31]:

$$N = \frac{1.96^2 \times \left(\frac{SD}{AV}\right)^2}{0.1^2}$$

Where:

N	sample size
SD	Standard deviation
AV	Average (mean)

[29] File 13 and 13a
[30] File 13a
[31] See "Best Practices Examples Focusing on Sample Size and Reliability Calculations", EB 67, Annex 6, p.12, paragraph 56

1.96	95% confidence interval
0.1	relative precision level

The required sample size calculated ex-post based on actual SD is 318 units whilst the actual sample size was 2,553 units i.e. around 7x more thus showing compliance with the confidence level and precision level required.

To check the reliability of the sample the relative precision level is calculated using the following formulae[32]:

$$R = \frac{0.5 \times (CIW)}{AV} \times 100\%$$

Where:

R	Reliability (relative precision level)
CIW	width of confidence interval
AV	Average (mean)

CIW is the difference of the upper and the lower 95% confidence interval as listed in table 13 being 0.081. Reliability or the relative precision level is therefore 4% which is far better than the 10% required by EB 65 Annex 2, p.2 point 9.

OCCUPATION RATE SURVEY MOTORIZED RICKSHAWS

Sampling Design

The sampling design is based on ACM0016 Annex 3 which is also included in the registered PDD as Annex A.6.1. The PDD details the sites, the time and the days for sampling.

The objective of the study is to determine the occupancy rate of motorized rickshaws. The actual number of passengers is counted in a given point within a given time period. Only motorized rickshaws are included. Only persons aged 2 and above are counted i.e. infants are excluded. The counting is based on visual occupation i.e. counting the number of passengers occupying the vehicle excluding the driver. The procedures to establish visual occupation are:

- Locations, days and times for field study are defined, avoiding days immediately after or before a holiday. Atypical seasons (school or university vacations) should be avoided. The study is done on weekdays.
- The occupation rates are: 0 passengers (only motorized rickshaws driver), 1, 2, 3 and more passengers.
- Field data is collected. Coverage of the occupation counts should be higher than 95% of the number of motorized rickshaws that cross the checkpoint. One hundred per cent coverage is desired.
- Occupancy is the number of passengers using the vehicle. The occupancy is determined of all motorized rickshaws passing the control points.
- The total number of vehicles and the total number of passengers is reported. The average occupation rate of vehicles is the total number of passengers divided by the total number of vehicles in which counts were performed.

[32] See "Best Practices Examples Focusing on Sample Size and Reliability Calculations", EB 67, Annex 6, p.41, paragraph 205

The study was carried out during the following working days 12/01/2012 (Thursday), 19/01/2012 (Thursday), 20/01/2012 (Friday), 01/02/2012 (Wednesday), 15/02/2012 (Wednesday), 17/02/2012 (Friday). Days immediately before and after holidays were avoided. Atypical seasons (school or university vacations) were avoided. The selected sites were Sansad Marg, Patel Road, Najafgarh Road, GT Road and Vikas Marg, idem to the baseline sites.

Collected Data

Data collected is the number of passengers per motorized rickshaws. The following table shows the results.

Table 14: Results Occupation Rate Study Motorized Rickshaws, 2012[33]

Number of passengers	Number of taxis with the indicated with the indicated number of passengers	percentage
0 passenger	1,404	27%
1 passenger	1,417	27%
2 passengers	1,346	26%
3 passengers	1,110	21%

Analysis of Collected Data

The following data shows the analysis of the collected data.

Table 15: Calculations Occupation Rate Motorized Rickshaws, 2012[34]

Parameter	Value
Total number of passengers	7,439
Total number of motorized rickshaws	5,277
Average occupation rate	1.41
Standard deviation	1.1
Standard error of average	0.015
Upper and lower 95% confidence interval	1.38 and 1.44

The baseline occupation rate as fixed for the emission factor as registered in the PDD is the average value as reported in the baseline study.

Demonstration of Confidence and Precision

The sampling size has been checked for a 95% confidence interval and a 10% relative precision level in accordance with the “Standard for Sampling and Surveys for CDM Project Activities and Programme of Activities”, EB 65 Annex 2, p.2 point 9, based on the following formulae[35]:

$$N = \frac{1.96^2 \times \left(\frac{SD}{AV}\right)^2}{0.1^2}$$

[33] File 14 and 14a
[34] File 14a
[35] See “Best Practices Examples Focusing on Sample Size and Reliability Calculations”, EB 67, Annex 6, p.12, paragraph 56

Where:

N	sample size
SD	Standard deviation
AV	Average (mean)
1.96	95% confidence interval
0.1	relative precision level

The required sample size calculated ex-post based on actual SD is 222 units whilst the actual sample size was 5,277 units i.e. around 23x more thus showing compliance with the confidence level and precision level required.

To check the reliability of the sample the relative precision level is calculated using the following formulae[36]:

$$R = \frac{0.5 \times (CIW)}{AV} \times 100\%$$

Where:

R	Reliability (relative precision level)
CIW	width of confidence interval
AV	Average (mean)

CIW is the difference of the upper and the lower 95% confidence interval as listed in table 15 being 0.059. Reliability or the relative precision level is therefore 2% which is far better than the 10% required by EB 65 Annex 2, p.2 point 9.

OCCUPATION RATE SURVEY BUSES

Sampling Design

The sampling design is based on ACM0016 Annex 3 which is also included in the registered PDD as Annex A.6.3. The PDD details the sites, the time and the days for sampling. This to ensure that the baseline occupation rate is comparable to the monitored project occupation rate. The objective of the study is to determine the occupancy rate of buses. The approach is based on visual occupation estimating the number of passengers occupying the bus by establishing stages of occupation.

Procedures to establish visual occupation:

1. Locations, days and times for field study are defined, avoiding days immediately after or before a holiday:

    a. Panchkuian Road (Ekant Hotel) in direction Jhandewalan to C.P. and C.P. to Jhandewalan
    b. Sansad Marg (Jantar Mantar) in direction C.P. to Parliament House and Parliament House to C.P.
    c. Patel Road (Vivek Cinema) in direction Shadipur to Pusha and Pusha to Shadipur
    d. Najafgarh Road (Janakpuri District Centre) in direction Uttam Nagar to Subhash Nagar and Subhash Nagar to Uttam Nagar

[36] See "Best Practices Examples Focusing on Sample Size and Reliability Calculations", EB 67, Annex 6, p.41, paragraph 205

e. GT Road Sahadra (Shyamlal College) in direction Sahadra to Seelampur and Seelampur to Sahadra
f. Vikas Marg (ITO Barrage) in direction ITO to Laxmi Nagar and Laxmi Nagar to ITO

2. Measurements are made for weekdays between 6AM and 10PM.

3. The number of passengers on the bus are estimated based on 6 occupation categories. Two bus categories are identified with 2 different passenger capacities.

5. Occupation is the number of passengers using the bus. The occupation rate in percentage is the number of buses divided by the bus carrying capacity.

Collected Data

Data collected is the number of passengers per bus. This number is calculated based on the average bus capacity and the number of buses per occupation bracket. The average bus capacity is calculated in the following table.

Table 16: Bus Capacity DTC Buses

Type of Bus	Passenger Capacity	Number of Units Monitored
Standard	70 (50 seated and 20 standing)	2,484
Low-floor	55 (35 seated and 20 standing)	5,192

Source: File 19 for capacity per bus, File 25 for number of monitored units per type

The weighted average passenger capacity per bus is therefore 60 passengers total[37]. The following table shows the number of passengers assigned to each bracket of the visual occupation survey.

Table 17: Number of Passengers and Survey Brackets Standard Buses

	<50% seated, 0% standing	50-100% seated, 0% standing	100% seated, 0% standing	100% seated, 50% standing	100% seated, 50-100% standing	Full
Nu. of buses	491	570	650	453	257	63
Average number of passenger on bus	12.5	37.5	50	65	65	70
Total passengers	6,138	21,375	32,500	16,705	16,705	4,410

Source: calculation based on average capacity and mean between maximum and minimum of bracket; example: 50-100% seated and 0% standing = 0.75*50+0*20 = 37.5

Table 18: Number of Passengers and Survey Brackets Low Floor Buses

	<50% seated, 0% standing	50-100% seated, 0% standing	100% seated, 0% standing	100% seated, 50% standing	100% seated, 50-100% standing	Full
Nu. of buses	866	1,014	1,401	1,197	632	82
Average number of passenger on bus	8.75	26.25	35	45	50	55
Total passengers	7,578	26,618	49,035	53,865	31,600	4,510

Source: calculation based on average capacity and mean between maximum and minimum of bracket; example: 50-100% seated and 0% standing = 0.75*35+0*20 = 26.25

The total number of buses monitored was 7,676 units with total 281,513 passengers, an average capacity

[37] Calculated as (70*2,484+55*5,192)/(2,484+5,192)

of 60 passengers per bus and an actual monitored occupancy of 37 passengers per bus resulting in an occupation rate of 61%[38] of buses.

Analysis of Collected Data

The following data shows the analysis of the collected data.

Table 19: Calculations Occupation Rate Buses, 2012[39]

Parameter	Value
Total number of passengers	281,513
Total number of buses	7,676
Average occupation rate	61%
Standard deviation	15.89
Standard error of average	0.18
Upper and lower 95% confidence interval	60.7% and 61.9%

The baseline occupation rate as fixed for the emission factor as registered in the PDD is the average as reported in the baseline study.

Demonstration of Confidence and Precision

The sampling size has been checked for a 95% confidence interval and a 10% relative precision level in accordance with the "Standard for Sampling and Surveys for CDM Project Activities and Programme of Activities", EB 65 Annex 2, p.2 point 9, based on the following formulae[40]:

$$N = \frac{1.96^2 \times \left(\frac{SD}{AV}\right)^2}{0.1^2}$$

Where:

N	sample size
SD	Standard deviation
AV	Average (mean)
1.96	95% confidence interval
0.1	relative precision level

The required sample size calculated ex-post based on actual SD is 72 units whilst the actual sample size was 7,676 units or more than 10x more than required thus showing compliance with the confidence level and precision level required.

To check the reliability of the sample the relative precision level is calculated using the following formulae[41]:

[38] Calculated as 37/60

[39] File 25a

[40] See "Best Practices Examples Focusing on Sample Size and Reliability Calculations", EB 67, Annex 6, p.12, paragraph 56

[41] See "Best Practices Examples Focusing on Sample Size and Reliability Calculations", EB 67, Annex 6, p.41, paragraph 205

$$R = \frac{0.5 \times (CIW)}{AV} \times 100\%$$

Where:

R	Reliability (relative precision level)
CIW	width of confidence interval
AV	Average (mean)

CIW is the difference of the upper and the lower 95% confidence interval being 0.711. Reliability or the relative precision level is therefore 1% which is far better than the 10% required by EB 65 Annex 2, p.2 point 9.

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. Next to this the parameter is not used in the leakage calculations as the surveyed average speed in no case was higher in the project compared to the baseline thus not resulting in a rebound effect.

SPEED MEASUREMENT ON AFFECTED ROADS

The speed measurement is based on a sample. However the registered sample number is in fact much lower than what the actual measurement is. The speed measurements are made using a technique called “fish in the water” i.e. the vehicle which is used to determine the sped 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.

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 during the following working days 13/02/2012 (Monday), 14/02/2012 (Tuesday), 15/02/2012 (Wednesday), 16/02/2012 (Thursday), 17/02/2012 (Friday), 20/02/2012 (Tuesday), 21/02/2012 (Wednesday), 22/02/2012 (Thursday), 01/03/2012 (Thursday), 02/03/2012 (Friday), 05/03/2012 (Monday), 06/03/2012 (Tuesday), 12/03/2012 (Monday), 13/03/2012 (Tuesday), 14/03/2012 (Wednesday), 15/03/2012 (Thursday), 16/03/2012 (Friday), 17/03/2012 (Saturday), 09/04/2012 (Monday), 10/04/2012 (Tuesday), 11/04/2012 (Wednesday), 12/04/2012 (Thursday), 13/04/2012 (Friday), 16/04/2012 (Monday), 17/04/2012 (Tuesday), 18/04/2012 (Wednesday), 19/04/2012 (Thursday), 20/04/2012 (Friday), 23/04/2012 (Monday), 24/04/2012 (Tuesday), 25/04/2012 (Wednesday), 26/04/2012 (Thursday), 27/04/2012 (Friday), 30/04/2012 (Monday), 02/05/2012 (Tuesday), 03/05/2012 (Wednesday). 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.

Table 20: Results Speed Survey, 2012[42]

Road	Average Speed (km/h)	Moving Speed (km/h)
Mehrauli Gurgaon	30	38
New Noida Link Road	29	35
Rohtak Road	27	36
Aurangazeb Road	31	38
INA Market Road	28	35
Grand Trunk Road	28	37
Bhisham Pitamah Marg	28	36
Vikas Marg	21	30
Mathura Road	25	34

Analysis of Collected Data

The following data shows the analysis of the collected data.

Table 21: Calculations Average Speed Survey, 2012[43]

Road	Average Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	30	16	25-35
New Noida Link Road	29	16	23-35
Rohtak Road	27	8	24-30
Aurangazeb Road	31	7	28-33
INA Market Road	28	10	25-32
Grand Trunk Road	28	13	24-33
Bhisham Pitamah Marg	28	10	25-32
Vikas Marg	21	10	17-24
Mathura Road	25	12	21-29

Table 22: Calculations Moving Speed Survey, 2012[44]

Road	Average Moving Speed (km/h)	Standard Deviation	Upper and lower 95% CI
Mehrauli Gurgaon	38	14	33-42

[42] File 15 and 15a
[43] File 15a
[44] File 15a

New Noida Link Road	35	12	31-39
Rohtak Road	36	7	33-38
Aurangazeb Road	38	7	35-40
INA Market Road	35	8	32-38
Grand Trunk Road	37	9	34-40
Bhisham Pitamah Marg	36	9	33-39
Vikas Marg	30	9	27-33
Mathura Road	34	9	31-37

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 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 2 surveys were made by an external survey company.

Table 23: 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)[45]	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.

[45] 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.

Size of Universe	Generally, in one day Metro Delhi transports around 800,000 passengers on the Phase II lines[46].
Sample size	The sample size is around 8,000 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. The sample was distributed according to the average flow along the 3 operating lines of DMRC at the moment of the survey (Phase I lines, not part of the project).
Sample frequency	Once annually during an entire week plus one re-test per annum. The first survey was made in December 2011 and the re-test in March 2012.
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

Both surveys were realized through the same professional survey company with sufficient experience[47].

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).

[46] See File 26/27
[47] See Files 5 and 6 for company experience and contract

Sample Frequency

The survey was realized 12-18/12/2011 with the re-test being made 19-25/03/2012. 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 target sample size was estimated at 8,000 commuter surveys in December, 2011 and 4,000 commuter surveys in March, 2012 at 84 stations of DMRC phase-2.

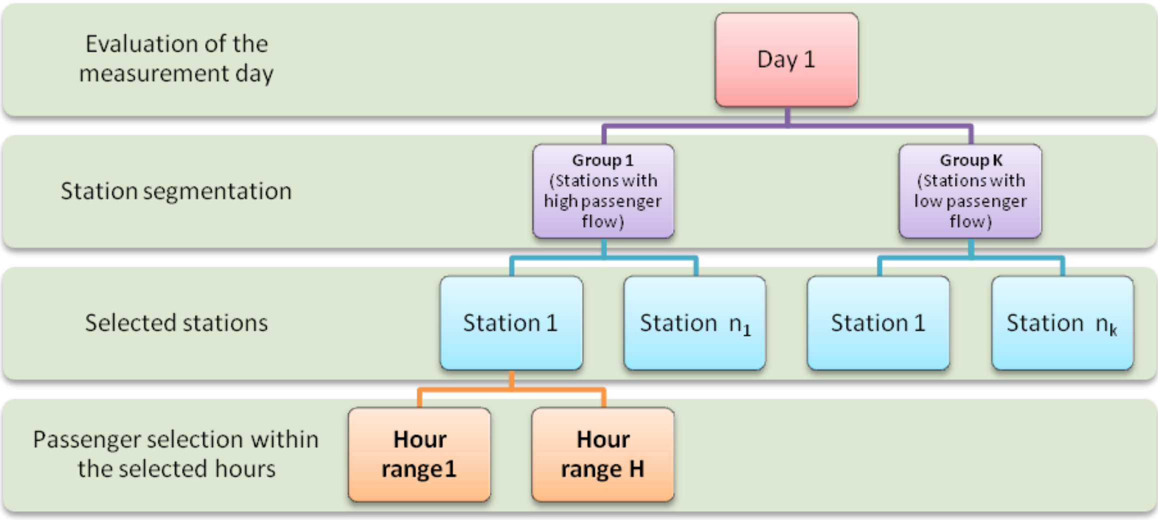
To get a better representation and complete coverage of target population, this target sample was be distributed among stations, days and time slots:

- **Target Population:** DMRC Commuters (Above 12 years)
- **Total Sample Size:** 8,000 and 4,000
- **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, as shown in the following table.

Table 24: Station Stratification

Heavy Traffic		Medium Traffic		Low Traffic	
Station Name	**Weekly Flow**	**Station Name**	**Weekly Flow**	**Station Name**	**Weekly Flow**
Laxmi Nagar	204,731	Green Park	130,402	Adarsh Nagar	65,703
Shahdara	194,463	Noida Sect-18	129,889	Nangloi	65,322
Kaushambi	193,932	Anand Vihar I.S.B.T	129,581	Golf Course	65,081
Saket	193,921	INA	127,740	New Ashok Nagar	61,831
Noida City Centre	192,851	Chattarpur	124,074	Guru Droanacharya	57,764
Huda CityCentre	184,024	Vishwavidhyalaya	124,025	Jhilmil	56,774
G.T.B Nagar	182,786	Malviya Nagar	117,984	Peera Garhi	54,521
M.G.Road	173,436	Botanical Garden	115,727	Kailash Colony	53,076
Dilshad Garden	172,715	Govind Puri	112,130	InderPrastha	50,895
Hauz Khas	171,000	Mayur Vihar Ph-I	105,990	Moolchand	48,085
AIIMS	154,336	Central Secrtariat-1	98,062	Jasola	47,773
Nirman Vihar	152,522	Sikanderpur	95,460	J.L.N.Stadium	45,853
Badarpur	152,387	Akshardham	93,123	Dwarka Sec-09	45,335
Noida Sect-15	142,435	Nehru Place	88,048	Udyog Bhawan	44,903
		Noida Sect-16	82,613	Mundka	44,515
		Lajpat Nagar	81,875	Arjan Garh	44,120
		Vaishali	79,372	Jor Bagh	43,722
		IFFCO Chowk	77,128	Model Towm	43,175
		Jahangir Puri	76,967	Tuklagabad	42,298
		Azadpur	71,959	Sarita Vihar	37,548
		Preet Vihar	70,292	Qutab Minar	34,521
		Karkardooma	69,941	Mansarovover Park	33,585
				Dwarka Sec-21	33,365
				Race Course	33,013
				Khan Market	31,561

				Pachim Vihar (West)	30,956
				Mohan Estate	30,006
				Kalkaji Mandir	29,790
				Nangloi Railway	28,220
				Inderlok	28,039
				Madi Pur	27,102
				Mayur Vihar Ph-I EXT	26,667
				Shivaji Park	26,621
				Jangpura	26,418
				Pachim Vihar (East)	25,599
				Sultanpur	25,552
				Ghitroni	24,187
				Ashok Park Main	23,056
				Okhla	23,044
				Dwarka Sec-08	22,745
				Udyog Nagar	18,391
				Punjabi Bagh	15,678
				Rajdhani Park	15,436
				Surajmal	15,258
				Satguru Ramsingh	14,146
				Yamuna Bank	7,516
				Central Secrtariat-2	4,285
				Kirti Nagar	3,933

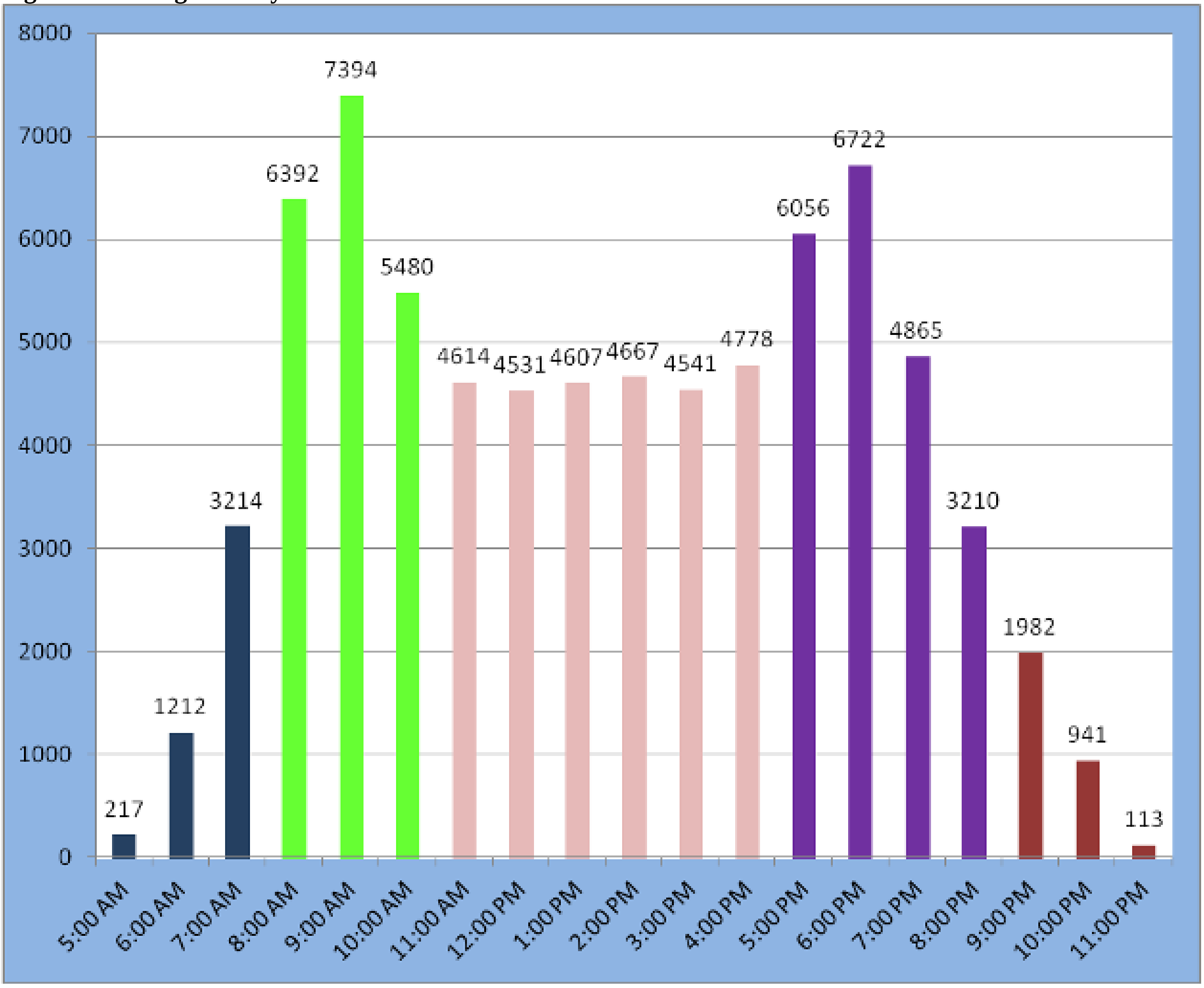
On the basis of that distribution, the sampling fraction for each stratum was determined and the target sample size was distributed in respect to the same sampling fraction, as shown in the following table.

Table 25: Sample Fraction

Station Stratum	Weekly Flow	Sampling Fraction	Sample Distribution
Heavy	2,465,539	39%	3,109
Medium	2,202,382	35%	2,777
Low	1,676,984	26%	2,114
Total Universe	**6,344,905**	**100**	**8,000**

For the timeslot stratification, the average hourly traffic flow for all 7 days was calculated. The variation in average hourly flow can be observed through the below graph.

Figure 4: Average Hourly Flow Commuters DMRC



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 (see Table below).

Table 26: Time Slot Clustering

Time	Average Flow	Time Stratification	Recommended Time Slots
5:00 AM	217	5 to 8 AM	Early morning
6:00 AM	1,212		
7:00 AM	3,214		
8:00 AM	6,392	8.01 to 11 AM	Morning peak hour
9:00 AM	7,394		
10:00 AM	5,480		
11:00 AM	4,614	11.01 AM to 5 PM	Mid slumber
12:00 PM	4,531		
1:00 PM	4,607		
2:00 PM	4,667		
3:00 PM	4,541		
4:00 PM	4,778		
5:00 PM	6,056	5.01 to 9 PM	Evening peak hour

6:00 PM	6,722		
7:00 PM	4,865		
8:00 PM	3,210	9.01 PM onwards	Late night
9:00 PM	1,982		
10:00 PM	941		
11:00 PM	113		

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.

Table 27: Sampling Fraction per Day

	Total Flow	Sampling Fraction (Total Flow of Day / Total Flow of Week)	Total Sample
Sunday	661,191	0.10	834
Monday	972,916	0.15	1,227
Tuesday	946,694	0.15	1,194
Wednesday	909,900	0.14	1,147
Thursday	943,838	0.15	1,190
Friday	994,320	0.16	1,254
Saturday	916,046	0.14	1,155
Total week	6,344,905	1.0	8,001

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. A centralized briefing session with all surveyors, supervisors and line managers was conducted 3 days before the actual survey week. In the briefing session, the questionnaire was explained in the detail and mock sessions were taken by the supervisors to ensure the understanding of interviewers.

Picture 5: Survey Training Session

A one day pilot phase of the survey was also conducted just before the December week survey i.e. on 11th December, 2011 to ensure the practical feasibility and DMRC stations working systems. The random selection of individuals, as well as the sufficiency in the sample size, enables obtaining dispersion and representation of the study population through the sample. Further, it allows controlling factors that may affect the user type, in terms of use of modes of transport and distance in these travels.

Picture 6: Survey Execution

Sample Size Determination

The results of the pilot test are used to determine the size of the sample. The estimated coefficient variation for the baseline and the project emissions was calculated for this purpose. On the other hand to get precise results for each potential mode of transit it is necessary to have a sufficiently large sample to also have a representative sample of the least used transport mode (in this case passenger cars).

For the calculation of the sample size, a global desired level of precision (relative standard error or coefficient of variation – CV) between 5% and 10% for the parameters of interest, which implies at the same time having precision levels of 90/10, i.e. a minimum confidence level of 90% and a maximum precision level of 10% was determined. In general determining the sample size is done by simulation following the Särndal methodology (1992), in which a CV is fixed and the sample size is found by

solving n of the formula of the estimator variance according to the design used in each case.

$$CV = \left(\frac{\sqrt{V(\hat{t}_y)}}{\hat{t}_y} \right) \cdot 100$$

Where *t̂ y* is the estimate of the average for parameter of interest *y* and *V*(*t̂ y*) is the variance of this estimate.

The stratification structure complies with the principles of independence and invariance, reason for which in the formula for the CV of this study, the estimated variance of the estimator results from adding those obtained in each stratum.

The main parameter of interest is the distance per mode of transport for each passenger. The distance per mode is one parameter i.e. D(i) indicating distance of mode i used by the passenger.

In practical terms, the procedure for determining the sample size is:

1. The results of the pilot test are taken as reference for the simulation (mean and standard deviation); This is especially important concerning share of modes for passengers as this determines the sample size to a considerable extent as some modes have a low frequency (e.g. passenger cars, potentially taxis and motorcycles).
2. Simulation is subject to the modification of standard deviations larger than the one found in the pilot test, with the objective of obtaining an optimum sample size even under high variability conditions (limitation of the maximum variability level);
3. The simulation process is first done under a SRS design (Simple Random Sampling), and under the multistage design (see the formulae described in section 10) and thereafter the design effect (Deff) is simulated corresponding to the ratio between the variance of a multi-stage design, and the variance of a SRS design;
4. Finally, based on the simulation and the presentation of different scenarios corresponding to different sampling sizes and various assumptions about the standard deviations of parameters of interest (for instance by using a deff factor between 2 and 3), the sample size that best adjusts to the expected error levels is taken.

Design Effect (Deff):

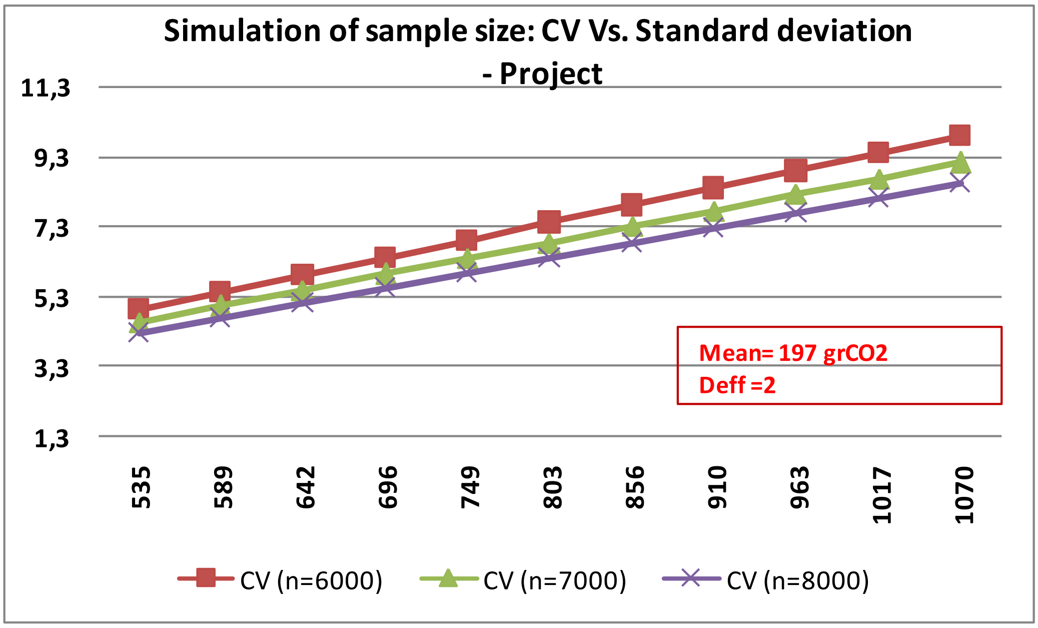
$$Deff(p, \hat{t}_y) = \frac{V_p(\hat{t}_y)}{V_{MAS}(\hat{t}_y)} = \frac{\sum\sum_U \Delta_{kl} \check{y}_k \check{y}_l}{N^2 \left(\frac{1}{n} - \frac{1}{N} \right) S^2_{yU}}$$

The ratio between the variance of the particular design and the variance under a SRS design, is called the design effect (Deff). In this way, when Deff is less than 1 it implies that the selected design has more precision than the SRS one, and when it is larger than 1, the proposed design is less efficient than the SRS one. In the simulation case, the Deff value was assumed between 1 and 3.5, in such a way that the sample size is considered under the worst scenario i.e. when the variance associated to the multi-stage design was factor 2.5 fold the SRS. Sample size simulation were performed considering the variation coefficient (less than 10%), the design effects (deff) (value between 1.5 and 3.5) and the lowest frequencies for the modal proportions (between 5 and 10%) to be estimated.

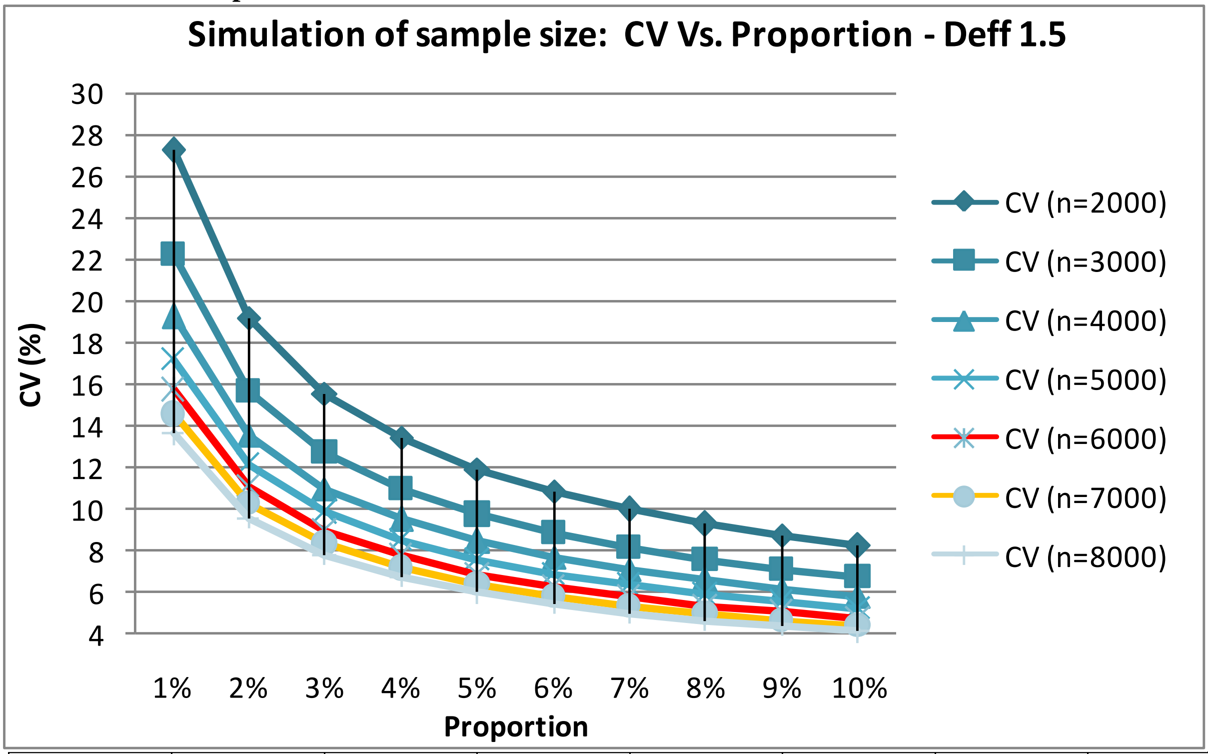
Based on the pilot test the simulation of the simple size for average baseline and project emissions per passenger trip and thereafter the simulation for mode shares is realized to ensure representativeness for both aspects.

The simulation of the sample size starts off from the standard deviation (SD) of the pilot test and then augments this progressively by 10% up to doubling it. Also in these scenarios a deff of 2 is taken in accordance with the 4 stratus identified when grouping stations. The simulation results indicate that even with an extreme scenario of the SD, the estimated coefficient variation is not higher than 5% concerning the average baseline and 12% concerning the average project emissions if the sample size is between 6,000 and 8,000 Metro users. On the other hand simulation results concerning the sample or proportions of mode users to obtain a acceptable level of representativeness (CV minor to 15%) a sample size of 8,000 Metro users is required.

The sample size of 8,000 users of Metro is thus sufficient to cover both aspects of the survey. The graphs below provided for illustrative purposes only present the result of such simulations. They show that a sample size of 6,000-8,000 would be sufficient even facing extreme scenarios such as with a deff of 3.5.

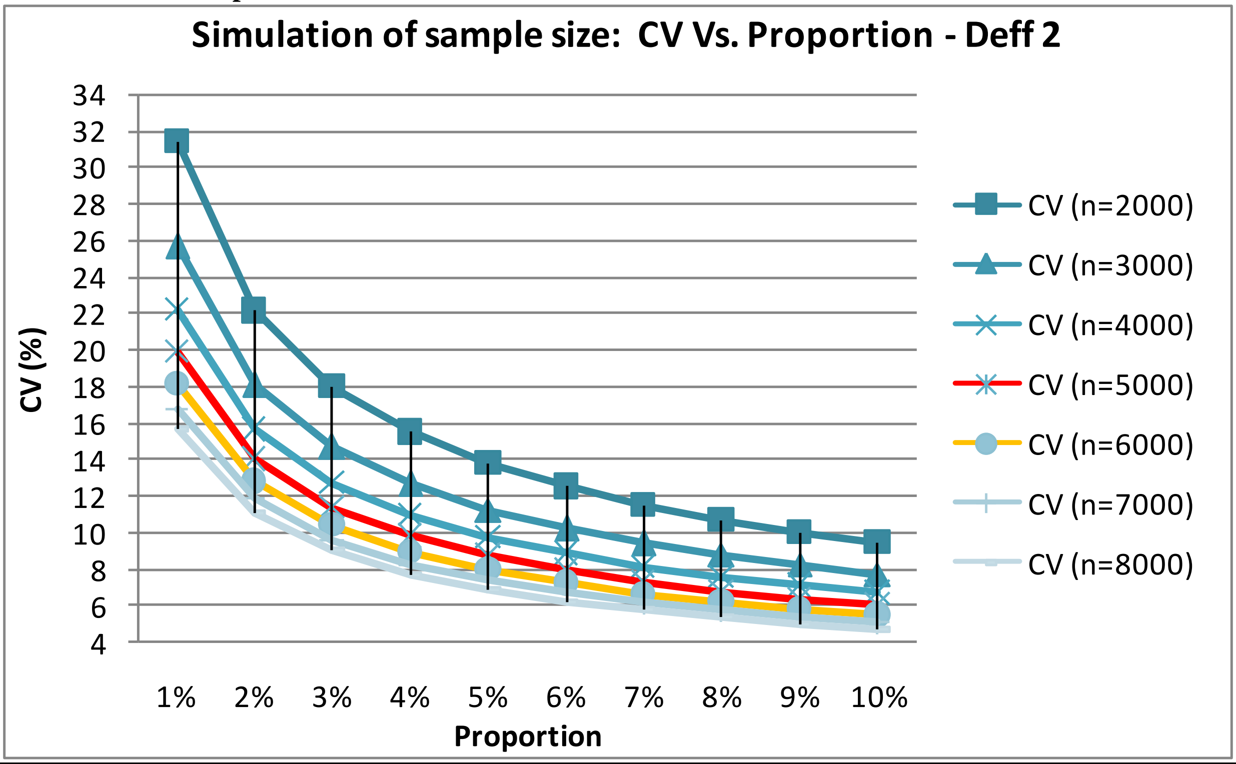


Simulation of Sample Size with Deff 1.5



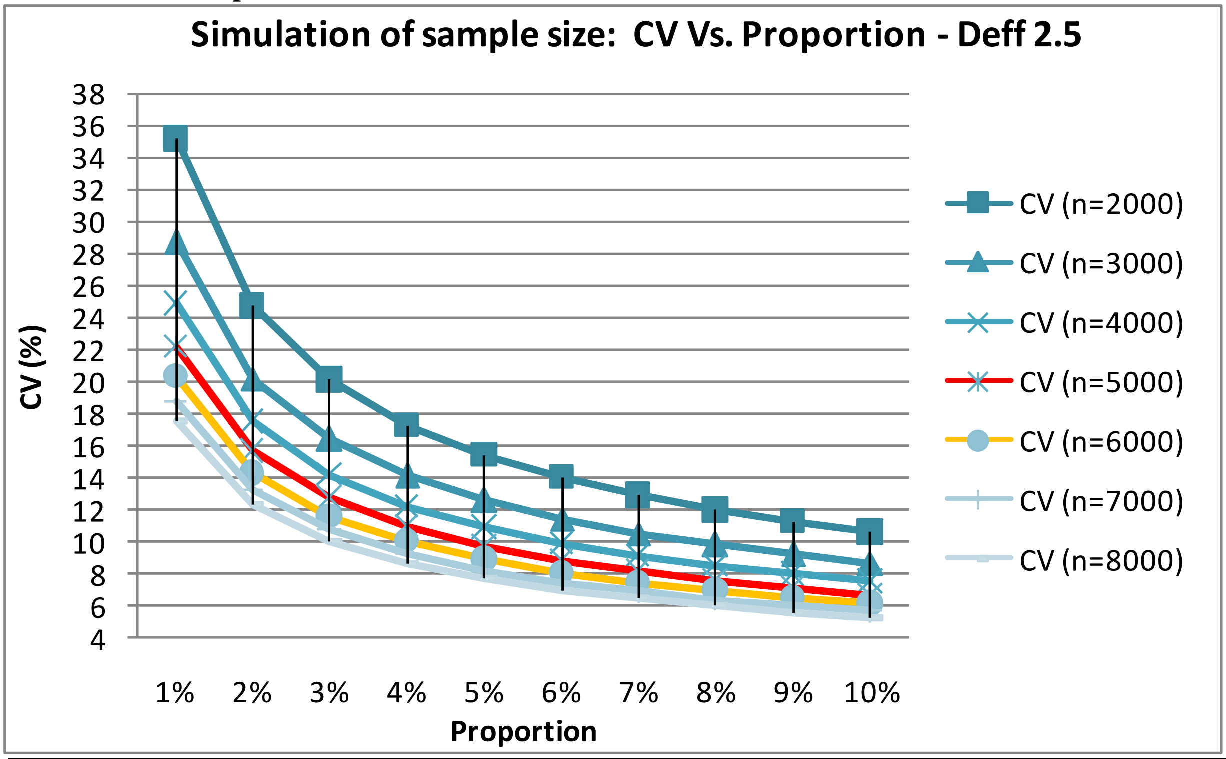
Proportion	CV (n=2000)	CV (n=3000)	CV (n=4000)	CV (n=5000)	CV (n=6000)	CV (n=7000)	CV (n=8000)
1%	27.2	22.2	19.3	17.2	15.7	14.5	13.6
2%	19.2	15.6	13.5	12.1	11.1	10.2	9.6
3%	15.6	12.7	11.0	9.8	9.0	8.3	7.8
4%	13.4	10.9	9.5	8.5	7.7	7.2	6.7
5%	11.9	9.7	8.4	7.5	6.9	6.4	6.0
6%	10.8	8.8	7.7	6.8	6.3	5.8	5.4
7%	10.0	8.1	7.1	6.3	5.8	5.3	5.0
8%	9.3	7.6	6.6	5.9	5.4	5.0	4.6
9%	8.7	7.1	6.2	5.5	5.0	4.6	4.3
10%	8.2	6.7	5.8	5.2	4.7	4.4	4.1

Simulation of Sample Size with Deff 2.0



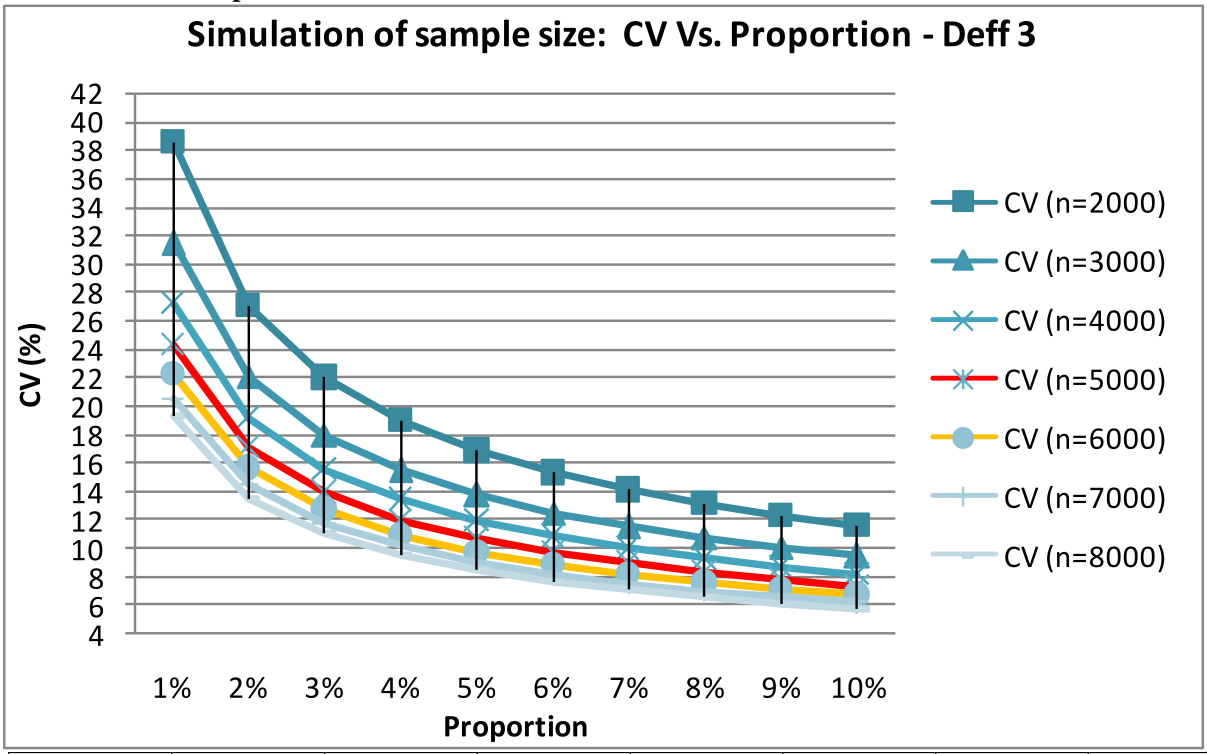
Proportion	CV (n=2000)	CV (n=3000)	CV (n=4000)	CV (n=5000)	CV (n=6000)	CV (n=7000)	CV (n=8000)
1%	31.5	25.7	22.2	19.9	18.1	16.8	15.7
2%	22.1	18.1	15.6	14.0	12.8	11.8	11.1
3%	18.0	14.7	12.7	11.4	10.4	9.6	9.0
4%	15.5	12.6	10.9	9.8	8.9	8.3	7.7
5%	13.8	11.2	9.7	8.7	8.0	7.4	6.9
6%	12.5	10.2	8.8	7.9	7.2	6.7	6.2
7%	11.5	9.4	8.1	7.3	6.6	6.2	5.8
8%	10.7	8.8	7.6	6.8	6.2	5.7	5.4
9%	10.1	8.2	7.1	6.4	5.8	5.4	5.0
10%	9.5	7.7	6.7	6.0	5.5	5.1	4.7

Simulation of Sample Size with Deff 2.5



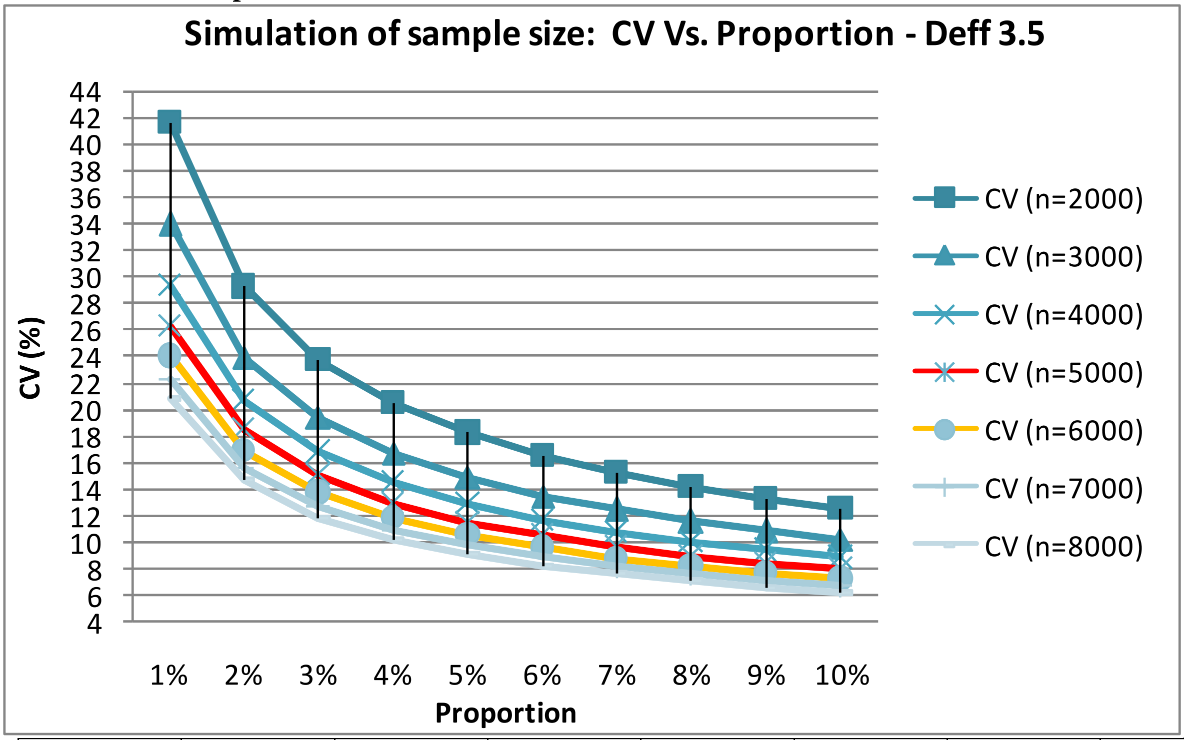
Proportion	CV (n=2000)	CV (n=3000)	CV (n=4000)	CV (n=5000)	CV (n=6000)	CV (n=7000)	CV (n=8000)
1%	35.2	28.7	24.9	22.2	20.3	18.8	17.6
2%	24.7	20.2	17.5	15.6	14.3	13.2	12.4
3%	20.1	16.4	14.2	12.7	11.6	10.7	10.0
4%	17.3	14.1	12.2	10.9	10.0	9.2	8.6
5%	15.4	12.6	10.9	9.7	8.9	8.2	7.7
6%	14.0	11.4	9.9	8.8	8.1	7.5	7.0
7%	12.9	10.5	9.1	8.1	7.4	6.9	6.4
8%	12.0	9.8	8.5	7.6	6.9	6.4	6.0
9%	11.2	9.2	7.9	7.1	6.5	6.0	5.6
10%	10.6	8.7	7.5	6.7	6.1	5.7	5.3

Simulation of Sample Size with Deff 3.0



Proportion	CV (n=2000)	CV (n=3000)	CV (n=4000)	CV (n=5000)	CV (n=6000)	CV (n=7000)	CV (n=8000)
1%	38.5	31.4	27.2	24.4	22.2	20.6	19.2
2%	27.1	22.1	19.2	17.1	15.6	14.5	13.5
3%	22.0	18.0	15.6	13.9	12.7	11.8	11.0
4%	19.0	15.5	13.4	12.0	10.9	10.1	9.5
5%	16.9	13.8	11.9	10.7	9.7	9.0	8.4
6%	15.3	12.5	10.8	9.7	8.8	8.2	7.7
7%	14.1	11.5	10.0	8.9	8.1	7.5	7.0
8%	13.1	10.7	9.3	8.3	7.6	7.0	6.6
9%	12.3	10.1	8.7	7.8	7.1	6.6	6.1
10%	11.6	9.5	8.2	7.3	6.7	6.2	5.8

Simulation of Sample Size with Deff 3.5



Proportion	CV (n=2000)	CV (n=3000)	CV (n=4000)	CV (n=5000)	CV (n=6000)	CV (n=7000)	CV (n=8000)
1%	41.6	34.0	29.4	26.3	24.0	22.2	20.8
2%	29.3	23.9	20.7	18.5	16.9	15.6	14.6
3%	23.8	19.4	16.8	15.0	13.7	12.7	11.9
4%	20.5	16.7	14.5	13.0	11.8	10.9	10.2
5%	18.2	14.9	12.9	11.5	10.5	9.7	9.1
6%	16.6	13.5	11.7	10.5	9.6	8.8	8.3
7%	15.2	12.4	10.8	9.6	8.8	8.1	7.6
8%	14.2	11.6	10.0	9.0	8.2	7.6	7.1
9%	13.3	10.9	9.4	8.4	7.7	7.1	6.6
10%	12.5	10.2	8.9	7.9	7.2	6.7	6.3

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. 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 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 28: Survey Parameter Results

Survey	Parameter	Emissions gCO_2 (2011) Baseline	Emissions gCO_2 (2012) Project	Emissions gCO_2 (2011) Baseline	Emissions gCO_2 (2012) Project
Survey 12/ 2011	average emissions per passenger expanded	976	234	964	230
	Cv (%)	1.07%	2.13%	1.06%	2.13%
	STDEV (per passenger)	10	5	10	5
	Lower boundary (95%) per passenger	955.7	223.8	943.6	220.8
	Upper boundary (95%) per passenger	996.5	243.4	983.7	239.9
Survey 03/ 2012	average emissions per passenger expanded	1,063	241	1,066	236
	Cv (%)	1.45%	2.73%	1.45%	2.72%
	STDEV (per passenger)	15	7	15	6
	Lower boundary (95%) per passenger	1,032.6	228.0	1,035.9	223.8
	Upper boundary (95%) per passenger	1,093.2	253.8	1,096.4	248.9

Source: File 29 and 30

Seasonality Analysis

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 2011 as well as 2012 passenger data.

The results are presented in the following Figures.

Figure 5: Seasonality Results for 2011

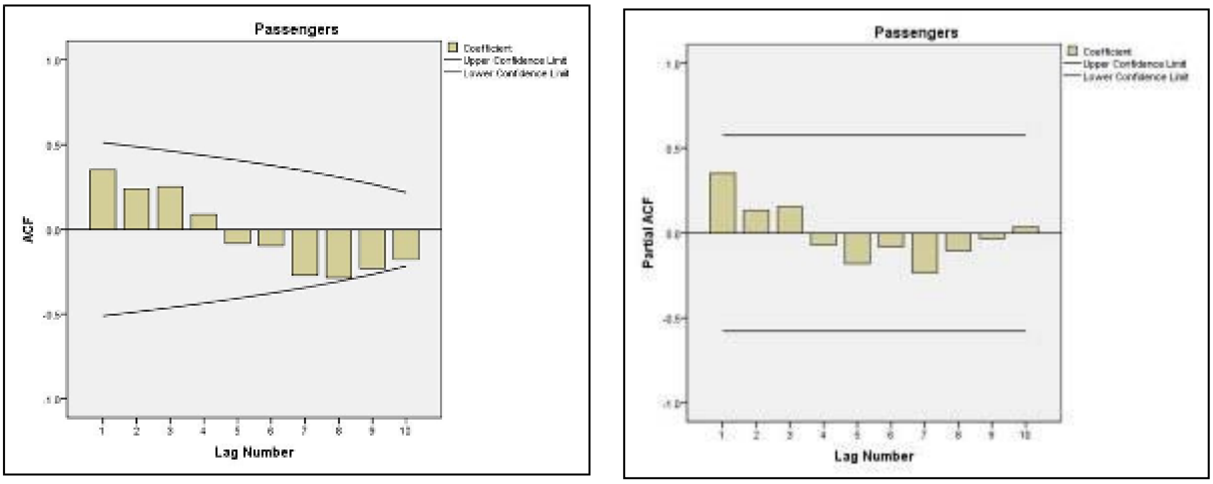
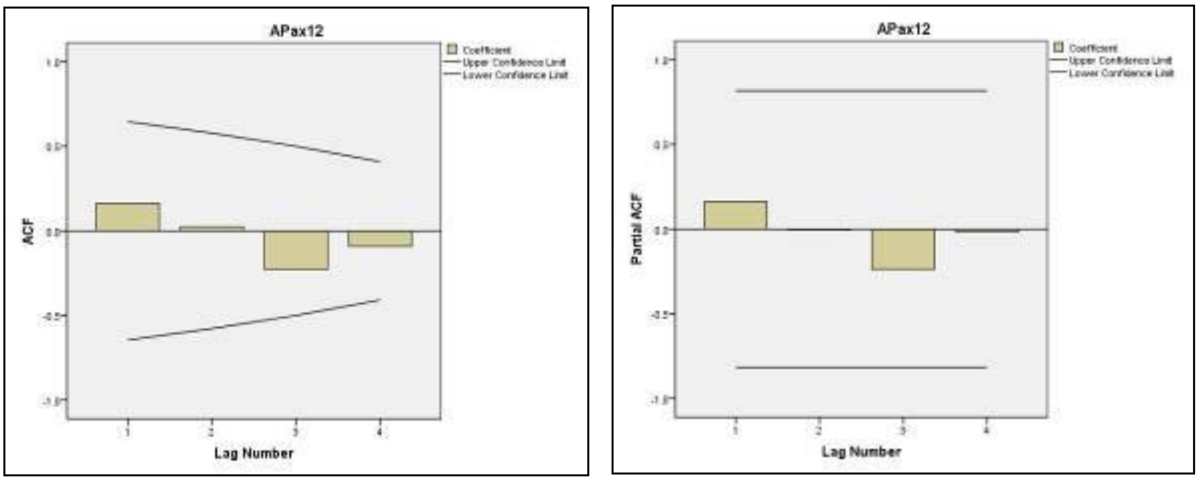


Figure 6: Seasonality Results for 2012



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, i.e. the series repeats its pattern of behaviour every six months. In the case of passenger data of DMRC for 2011 (July 2011 to December 2011) and 2012 (Jan 2012 to June 2012), all legs are under the confidence intervals, i.e., no repetition of a series i.e. no seasonality can be observed.

Consistency Checks

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 8,373 and 4,189 surveys, 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:

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

The test statistic is:

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

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: Hypothesis Test for Mean Difference

a. Under homogeneity of variances between both samples

The hypothesis proposed system is as follows:

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

The test statistic is:

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

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:

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

The test statistic is:

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

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 29: Results of Test for Equality of Variances

Parameter	H_0: The variance of the BE is idem 1st and 2nd measurement	H_0: The variance of the PE is idem 1st and 2nd measurement
F- Value	28.874	3.571
Sig	.000	.059
Decision	Different variances between the two measurements	Variance is not statistically different between both measurements

Table 30: Results of Test for Mean Difference

Parameter	H_0: The average baseline emission per passenger is idem 1st and 2nd measurement	H_0: The average indirect project emissions per passenger is idem 1st and 2nd measurement
t- value	-5.301	.006
Sig	.000	.995
Decision	Average indirect project emissions are higher in the 2nd Survey	Average baseline emissions per passenger are statistically same 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 31: Results of Pearson´s Chi Square Test for Modes Used in the Project- Origin to Entry Station (Cross-tabulation)

			Survey Phase		Total
			Phase - 1	Phase - 2	
From Origin to Entry - Project	Bus	Count	1,527	541	2,068
		Expected Count	1,378.4	689.6	2,068.0
	Taxis	Count	263	94	357
		Expected Count	238.0	119.0	357.0
	Passenger Cars	Count	214	145	359
		Expected Count	239.3	119.7	359.0
	Motorcycles	Count	360	196	556
		Expected Count	370.6	185.4	556.0
	NMT	Count	4,922	2,434	7,356
		Expected Count	4,903.0	2,453.0	7,356.0
	Motorized Rickshaws	Count	1,080	775	1,855
		Expected Count	1,236.4	618.6	1,855.0
	Suburban Rail	Count	7	4	11
		Expected Count	7.3	3.7	11.0
Total		**Count**	**8,373**	**4,189**	**12,562**
		Expected Count	**8,373.0**	**4,189.0**	**12,562.0**

Table 32: Pearson's Chi Square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	124.482[a]	6	.000
Likelihood Ratio	124.521	6	.000
Linear-by-Linear Association	77.282	1	.000
N of Valid Cases	12,562		

In the same way, the consistency checks are done for other modes (Project-exit station to destination, Baseline trip), distances traveled and CO_2 emissions per trip. These results are provided in File 34.

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-Phase2. 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

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

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

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

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 33: Results of Cronbach Alpha Test

Measurement	Baseline	Project
Linear correlation	0.570	0.669
Number of measurements (K)	2	2
Cronbach Alpha (Method of variance)	0.70	0.80
Cronbach Alpha (Method of linear correlation)	0.73	0.80

The results show that based on the variance method, the value of Cronbach's alpha is 0.7 for the project and 0.80 for the baseline, and the correlation method have values of 0.73 and 0.80, respectively. 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 each 2011 and for 2012 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 of the year 2011 and 2012. For baseline emissions the lower limit of the 95% confidence interval is taken for the expanded baseline emissions per passenger.

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

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

Where:

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

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.

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

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).

DETERMINATION OF EF_{PKM} FOR MONITORING PERIOD

Cars

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

Table 34: Share per Fuel Type Cars

Fuel Type	Registered PDD	Monitored
Gasoline	81.8%	67.3%
Diesel	10.6%	22.6%
CNG	7.6%	10.2%

Source: Registered PDD section B.6.2., Monitored: File 16, Gov. of NCT, Transport Department, 2012

Changes have occurred and therefore the EF_{PKM} for cars needs to be re-calculated. The following table lists all parameters used for the calculations.

Table 35: Parameters for Determination EF_{PKM} Cars 2011 and 2012

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 cars	%	67.3%	File 16
$N_{C,D}/N_C$	Share diesel cars	%	22.6%	File 16
$N_{C,CNG}/N_C$	Share CNG cars	%	10.2%	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
$EF_{CH4,CNG,C}$	Emission factor CH_4 of CNG cars	gCO_{2eq}/km	9.9	IPCC 2006, table 3.2.4
None	Specific weight of CNG	kg/m^3	0.717	File 8
ITR	Technology improvement factor	no unit	0.99	ACM0016, table 2

The NCV and the EF have not changed in relation to the PDD. The bio-fuel share remains in 0%[48]. NCV and EF are idem 2011 and 2012. SFC and OC are not updated based on the PDD. The ITR for 2011 is based on t=3 (2011-2008).

Calculation for $EF_{KM,C,2011}$

$$EF_{KM,C,2011} = (IR_C)^{t+y} \cdot \frac{\sum_x (SFC_{C,x} \cdot NCV_{x,2011} \cdot EF_{CO2,x,2011} \cdot N_{x,C,2011})}{N_{C,2011}} =$$
$$\left[(54.0 \times 43.9 \times 67.5 \times .673 \times 10^{-3}) + (48.6 \times 42.7 \times 72.6 \times .226 \times 10^{-3}) + (64.0 / .717 \times 35.6 \times 54.3 \times .102 \times 10^{-3} + .102 \times 9.9)\right] \times .99^3$$
$$= 156$$

For CNG cars the CH_4 emission factor needs to be added in accordance with the methodology.

For 2012 the $EF_{KM,C}$ is the EF 2011 multiplied with their 4 instead of 3 which results in a value of $EF_{KM,C,2012}$ of 154 gCO_2/km.

The EF_{PKM} is determined:

$$EF_{PKM,C,2011} = \frac{EF_{KM,C,2011}}{OC_C} = \frac{155.5}{1.60} = 97$$

For 2012 the value is 96 gCO_2/PKM.

The original values as reported in the PDD in table A3. were identical. This is due to the fact that the CO_2 emissions between the three fuel types are nearly identical and that the shift of fuels was not significant.

Taxis, Motorcycles and Motorized Rickshaws

The fuel share for these three categories has remained the same as in the registered PDD being 100% gasoline for motorcycles[49], 100% CNG for taxis[50] and 100% CNG for motorized rickshaws[51]. Also the NCV and the EF_{CO2} as well as the bio-fuel contents has not changed (see section "Cars" above)

The EF_{PKM} for these vehicle categories is thus as in the registered PDD.

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.

Table 36: Parameters for Determination EF_{PKM} Buses

Parameter	Description	Unit	Value	Source
$SFC_{B,CNG}$	Specific fuel consumption CNG buses	g/km	380.2	File 12
$N_{B,CNG}/N_B$	Share CNG buses	%	100%	File 16

[48] See National Bio-fuel Policy of 24/12/2009 which has an indicative bio-fuel target for 2017 (point 2.2. p.4) (File 9). See however the annual 2010 bio-fuels report on India which states that no biodiesel is blended and that ethanol blending at 5% as targeted has not been implemented (File 10, p.2). Also the 2017 target is considered not realistic in this report (p. 2)

[49] PDD section B.6.2. for original value and File 17/18 for monitored value

[50] PDD section B.6.2. for original value and File 11/16 for monitored value

[51] PDD section B.6.2. for original value and File 11/16 for monitored value

OC_B	Occupation rate buses	passengers	43	PDD B.6.2.
NCV_{CNG}	Net calorific value CNG	MJ/m^3	35.6	File 8
$EF_{CO2,CNG}$	Emission factor CO_2 CNG	gCO_2/MJ	54.3	IPCC 2006, table 1.4
$EF_{CH4,CNG,B}$	Emission factor CH_4 of CNG buses	gCO_{2eq}/km	162.0	IPCC 2006, table 3.2.4
None	Specific weight of CNG	kg/m^3	0.717	File 8

The NCV and the EF have not changed in relation to the PDD. OC is not updated in accordance with the methodology and the PDD.

$$EF_{KM,B,2011} = \frac{\sum_{NCV}\left(SFC_{B,NCV,2011} \cdot NCV_{NCV,2012} \cdot EF_{CO2,NCV,2011} \cdot N_{NCV,B}\right)}{N_B}$$

$$= 380.2 / 0.717 \times 35.6 \times 54.3 \times 10^{-3} + 162 = 1{,}187$$

The CH_4 emission factor needs to be added in accordance with the methodology. The same factor is used for 2011 and 2012.

The EF per km is around 11% higher than the one calculated in the PDD. This is not surprising due to the fact that the PDD is based on data of the year 2008. 2008 DTC had only 25 buses with AC (Air Conditioning) while as of 2012 the number of AC buses is 1,275 units or 1/5 of all buses. Buses equipped with AC have stronger engines and consume more fuel.

The EF per PKM is for 2011 and 2012:

$$EF_{PKM,B,2011} = \frac{EF_{KM,B,2011}}{OC_B} = \frac{1{,}187}{43} = 28$$

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 37: Parameters for Determination EF_{PKM} Subruban Rail

Parameter	Description	Unit	Value	Source
EC_{EL}	Electricity consumption per annum	MWh	3,616	File 18
P_{EL}	Passengers transported per annum	passengers	3,029,700	File 18
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.

This results in the following EF per PKM for 2011:

$$EF_{PKM,R,2011} = \frac{EC_{EL,R,2011} \times EF_{grid,CM} \times (1 + TDL)}{P_{EL,R,2011} \times TD_{EL,R}} = \frac{3{,}616 \times 0.8409 \times (1 + 0.0391)}{3{,}029{,}700 \times 28.8} \times 10^6 = 36$$

The same EF is taken for 2012. This value is lower than the one calculated in the registered PDD (Table A.4.; value 41) for 2011/2012.

The following table summarizes the EF_{PKM} used for 2011 and 2012 per mode.

Table 38: EF_{PKM} per Mode in gCO_2/PKM

Parameter	Description	2011	2012
$EF_{PKM,C}$	Emission factor per PKM cars	97	96
$EF_{PKM,T}$	Emission factor per PKM taxis	168	166
$EF_{PKM,MR}$	Emission factor per PKM motorized rickshaws	67	67
$EF_{PKM,M}$	Emission factor per PKM motorcycles	28	28
$EF_{PKM,B}$	Emission factor per PKM buses	28	28
$EF_{PKM,R}$	Emission factor per PKM suburban rail	36	36

Source: File 21

Baseline Results

The total baseline emissions of the monitoring period are 292,646 tCO_{2eq}

Table 39: Parameters for Baseline Emission Calculation

Parameter	2011	2012
Passengers	126,647,263	168,467,130
Average baseline emissions per passenger expanded survey 1	976 gCO_2	964 gCO_2
Average baseline emissions per passenger expanded survey 2	1,063 gCO_2	1,066 gCO_2
Coefficient of Variance CV survey 1	1.07%	1.06%
Coefficient of Variance CV survey 2	1.45%	1.45%
STDEV per passenger survey 1	10	10
STDEV per passenger survey 2	15	15
Lower 95% confidence interval emissions per passenger survey 1	955.7 gCO_2	943.6 gCO_2
Lower 95% confidence interval emissions per passenger survey 2	1,032.6 gCO_2	1,035.9 gCO_2
Average lower 95% confidence interval for monitoring period	994.15 gCO_2	989.8 gCO_2

Source: Files 26, 27, 29, 30

Calculation:

$$BE_{2011} = 126{,}647{,}263 * 994.15 / 10\text{^}6 = 125{,}906 tCO_2$$

$$BE_{2012} = 168{,}467{,}130 * 989.75 / 10\text{^}6 = 166{,}740 tCO_2$$

Table 40: Baseline Emissions

Parameter	Unit	30/06/2011 to 31/12/2011	01/01/2012 to 30/06/2012	Total
Baseline Emissions	**tCO_{2eq}**	**125,906**	**166,740**	**292,646**

Source: CER spreadsheet

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 each 2011 and for 2012 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 of the year 2011 and 2012. For indirect project emissions the upper limit of the 95% confidence interval is taken for the expanded indirect project emissions per passenger.

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

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	2011: 97,425,483 2012: 105,324,116	File 28a/b
$EF_{grid,CM}$	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.

$$DPE_{2011} = EC_{PJ,2011} \times EF_{grid,CM} \times (1+TDL) = 97{,}425{,}483 \times 0.8409 \times (1+0.0391)/10\text{^}3 = 82{,}170 tCO_2$$

$$DPE_{2012} = EC_{PJ,2012} \times EF_{grid,CM} \times (1+TDL) = 105{,}324{,}116 \times 0.8409 \times (1+0.0391) = 92{,}030 tCO_2$$

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	2011	2012
Passengers	126,647,263	168,467,130
Average indirect project emissions per passenger expanded survey 1	234 gCO_2	230 gCO_2
Average indirect project emissions per passenger expanded survey 2	241 gCO_2	236 gCO_2
Coefficient of Variance CV survey 1	2.13%	2.13%
Coefficient of Variance CV survey 2	2.73%	2.72%
STDEV per passenger survey 1	5	5
STDEV per passenger survey 2	7	6
Upper 95% confidence interval emissions per passenger survey 1	243.4 gCO_2	239.9 gCO_2
Upper 95% confidence interval emissions per passenger survey 2	253.8 gCO_2	248.9 gCO_2
Average lower 95% confidence interval for monitoring period	248.60 gCO_2	244.40 gCO_2

Source: Files 26, 27, 29, 30

Calculation:

$$IPE_{2011} = 126{,}647{,}263 * 248.60 / 10\text{^}6 = 31{,}485 tCO_2$$

$$BE_{2012} = 168{,}467{,}130 * 244.40 / 10\text{^}6 = 41{,}173 tCO_2$$

Project Results

The total project emissions of the monitoring period are **246,858 tCO_{2eq}**

Table 43: Project Emissions

Parameter	Unit	30/06/2011 to 31/12/2011	01/01/2012 to 30/06/2012	Total
Direct Project Emissions	tCO_{2eq}	82,170	92,030	174,200
Indirect Project Emissions	tCO_{2eq}	31,485	41,173	72,658
Total Project Emissions	**tCO_{2eq}**	**113,655**	**133,203**	**246,858**

Source: 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

$$LE_{LFB,y} = \frac{1}{10^6} \cdot N_{B,y} \cdot AD_B \cdot EF_{KM,B,y} \cdot \left(1 - \frac{OC_{B,y}}{OC_B}\right)$$

Where:

$LE_{LFB,y}$	Leakage emissions due to change of load factor of buses in the year *y* (tCO_2)
$N_{B,y}$	Number of baseline buses in the year *y* (buses)
AD_B	Average annual distance driven by baseline buses (km/bus)
$EF_{KM,B,y}$	Emission factor per kilometre of baseline buses in the year *y* (g CO_2/km)
$OC_{B,y}$	Average occupancy rate of baseline buses in the year *y* (passengers)
OC_B	Average occupancy rate of baseline buses prior project start (passengers)
y	Year of the crediting period

Leakage from load factor change of buses is only included if the load factor of buses has decreased by more than 10 percentage points comparing the monitored value with the baseline value. The occupation rate of buses monitored is 61%[52] whilst the baseline occupation rate baseline is 57% (PDD B.6.2.) i.e. leakage needs only be included if the monitored value is lower than 47% which is not the case. Therefore LE_{LFB} is 0.

Leakage Load Factor Taxis

This leakage is calculated as:

$$LE_{LFT,y} = N_{T,y} \cdot AD_T \cdot EF_{KM,T,y} \cdot \left(1 - \frac{OC_{T,y}}{OC_T}\right) \cdot \frac{1}{10^6}$$

Where:

$LE_{LFT,y}$	Leakage emissions due to change of load factor of taxis in the year *y* (tCO_2)
$N_{T,y}$	Number of taxis in the year *y* (taxis)
AD_T	Average annual distance driven per taxi (km/taxi)
$EF_{KM,T,y}$	Emission factor per kilometre of taxis in the year *y* (g CO_2/km)
$OC_{T,y}$	Average occupancy rate of taxis in the year *y* (passengers)
OC_T	Average baseline occupancy rate of taxis prior project start (passengers)
y	Year of the crediting period

Leakage is only included if the monitored value is lower than the baseline value (otherwise leakage would be negative). The monitored value is with 1.19[53] however higher than the baseline value which is 1.16 (PDD, B.6.2.)[54]. Therefore LE_{LFT} is 0.

[52] File 25
[53] File 13
[54] Both values upper 95% confidence interval

Leakage Load Factor Motorized Rickshaws

This leakage is calculated as:

$$LE_{LFMR,y} = N_{MR,y} \cdot AD_{MR} \cdot EF_{KM,R,y} \cdot \left(1 - \frac{OC_{MR,y}}{OC_{MR}}\right) \cdot \frac{1}{10^6}$$

Where:

$LE_{LFMR,y}$	Leakage emissions due to change of load factor of motorized rickshaws in the year *y* (tCO_2)
$N_{MR,y}$	Number of motorized rickshaws in the year *y* (motorized rickshaws)
AD_T	Average annual distance driven per motorized rickshaws (km/ motorized rickshaws)
$EF_{KM,MR,y}$	Emission factor per kilometre of motorized rickshaws in the year *y* (g CO_2/km)
$OC_{MR,y}$	Average occupancy rate of motorized rickshaws in the year *y* (passengers)
OC_{MR}	Average baseline occupancy rate of motorized rickshaws prior project start (passengers)
y	Year of the crediting period

Leakage is only included if the monitored value is lower than the baseline value (otherwise leakage would be negative). The monitored value is with 1.41[55] however higher than the baseline value which is 1.40 (PDD, B.6.2.)[56]. Therefore LE_{LFMR} is 0.

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".

The corresponding emissions are calculated as:

$$\mathrm{LE}_{\mathrm{CON,y}} = \mathrm{LE}_{\mathrm{REB,y}} + \mathrm{LE}_{\mathrm{SP,y}}$$

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 however lower then 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[57].

[55] File 14
[56] Both values average
[57] See File 15a sheet "rebound effect" for calculations

Table 44: Average Speed Prior Project and Monitored (km/h) on Affected Roads[58]

Road	Average speed range prior project	Average speed range monitored
Mehrauli Gurgaon	18-27	25-35
New Noida Link Road	21-35	23-35
Rohtak Road	25-42	24-30
Aurangazeb Road	35-46	28-33
INA Market Road	17-25	25-32
Grand Trunk Road	18-27	24-33
Bhisham Pitamah Marg	25-34	25-32
Vikas Marg	15-25	17-24
Mathura Road	22-33	21-29

Source: File 15a; baseline speed range based on File 15c and project speed range based on File 15a sheet "rebound effect"

In all roads the average speed range measured prior project and the monitored average speed range overlap except in Aurangazeb Road. This means no statistically significant difference between the two values can be identified except in Aurangazeb Road. For this road 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[59] as registered by the project the EF is lower with a higher moving speed (see registered PDD 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[60]

Road	Moving speed range prior project	Moving speed range monitored
Mehrauli Gurgaon	27-36	33-42
New Noida Link Road	30-43	31-39
Rohtak Road	32-48	33-38

[58] Speed range based on upper and lower boundary using a 95% confidence interval
[59] Corinair speed category 10-130km/h
[60] Speed range based on upper and lower boundary using a 95% confidence interval

Aurangazeb Road	44-56	35-40
INA Market Road	24-33	32-38
Grand Trunk Road	25-34	34-40
Bhisham Pitamah Marg	32-40	33-39
Vikas Marg	21-32	27-33
Mathura Road	30-40	31-37

Source: File 15a; baseline speed range based on File 15c and project speed range based on File 15a sheet "speed effect"

In all roads the moving speed range measured prior project and the monitored moving speed range overlap except in Aurangazeb Road. This means no statistically significant difference between the two values can be identified except in Aurangazeb Road. For this 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)

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

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

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	%	77.5%	File 16
$N_{C,D}/N_C$	Share diesel cars	%	22.6%	File 16
$N_{T,CNG}/N_T$	Share CNG taxis	%	100%	File 16
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	38	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 in the PDD Table 18, 0.46 (from-to column) is taken which 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 EF per kilometre at the average moving speed baseline for cars is therefore:

$$EF_{KM,VB,C} = \left[\frac{191 + 1.17 \times 50}{1 + 0.129 \times 50 - 0.00072 \times 50^2} \times 43.9 \times 67.5 \times 0.775 \times 10^{-3}\right] +$$
$$\left[\frac{145 + 0.0673 \times 50 + 0.00947 \times 50^2}{1 + 0.0673 \times 50 - 0.00032 \times 50^2}\right] \times 42.7 \times 72.6 \times .226 \times 10^{-3} = 133$$

The EF per kilometre at the average moving speed baseline for taxis is:

$$EF_{KM,VB,T} = \left[\frac{191 + 1.17 \times 50}{1 + 0.129 \times 50 - 0.00072 \times 50^2} \times 43.9 \times 67.5 \times 0.775 \times 10^{-3} \right] = 131$$

The EF per kilometre at the average moving speed project for cars is:

$$EF_{KM,VP,C} = \left[\frac{191 + 1.17 \times 38}{1 + 0.129 \times 38 - 0.00072 \times 38^2} \times 43.9 \times 67.5 \times 0.775 \times 10^{-3} \right] +$$

$$\left[\frac{145 + 0.0673 \times 38 + 0.00947 \times 38^2}{1 + 0.0673 \times 38 - 0.00032 \times 38^2} \right] \times 42.7 \times 72.6 \times .226 \times 10^{-3} = 146$$

The EF per kilometre at the average moving speed project for taxis is:

$$EF_{KM,VP,T} = \left[\frac{191 + 1.17 \times 38}{1 + 0.129 \times 38 - 0.00072 \times 38^2} \times 43.9 \times 67.5 \times 0.775 \times 10^{-3} \right] = 144$$

The Leakage speed on Aurangazeb Road is therefore:

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

$$[13{,}010{,}182 \times 1.6 \times (148 - 133)] + [235{,}060 \times 1.6 \times (144 - 131)] \times 10^{-6} = 287$$

This is the leakage effect for an entire year corresponding to 1 year monitoring period (the number of cars and taxis taken for the affected road is based on 1 year). The distribution 2011 and 2012 is 50% each as the monitoring period is ½ year 2011 and ½ year 2012.

The following table summarizes all leakage effects:

Table 47: Leakage (tCO_2)

Concept	2011	2012	Total
Leakage load factor buses	0	0	0
Leakage load factor taxis	0	0	0
Leakage load factor motorized rickshaws	0	0	0
Leakage congestion: Leakage rebound Leakage speed	 0 144	 0 143	 0 287
Total leakage	**144**	**143**	**287**

Total leakage for the monitoring period is thus **287** tCO_2.

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

Time Period	Baseline emissions or baseline net GHG removals by sinks (tCO_2e)	Project emissions or actual net GHG removals by sinks (tCO_{2e})	Leakage (tCO_2e)	Emission reductions or net anthropogenic GHG removals by sinks (tCO_2e)
30/06/2011 to 31/12/2011	125,906	113,655	144	12,107

01/01/2012 to 30/06/2012	166,740	133,203	143	33,394
Total	292,646	246,858	287	45,501

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 (tCO_2e)	467,502[61]	45,501

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

Monitored ERs are much lower than projected ERs. This is basically due to the following factors:

- The number of projected passengers was around 700 million[62] whilst the actual amount of passengers was around 300 million i.e. only 43% of projected. However it is expected that this number will grow – this can already be seen in the 1st semester 2012 which has more passengers than the 2nd semester 2011.
- The electricity consumption (direct project emissions) on the other hand was only slightly more than 13% lower than projected i.e. electricity consumption was not correlated directly to passenger transport.
- The average indirect project emission factor per passenger was around 25% higher than projected whilst the baseline emission factor was around 20% lower than projected resulting in an average emission reduction per passenger transported excluding direct project emissions of around 750 gCO_2 instead of 1,075 gCO_2 i.e. around 45% less reduction per passenger than projected. This is due to the fact that ex-ante the survey was conducted on Phase I lines operational as of PDD writing and a limited survey number was made. Also this number can change over future time due to changing travel patterns and mode usage.

[61] Based on 6 months 2011 (estimated in PDD for 8 months 305,077 tCO_2) and 6 months 2012 (estimated in PDD for entire year 477,389 tCO_2)

[62] Basd on PDD data 2011 and 6 months 2012

FILES USED

File 1, DMRC, Corridor Details with Commissioning Dates, 2012
File 2, Grütter Consulting, CDM Project DMRC, Monitoring Manual, Version 2.1., 05/2010
File 3a, DMRC, EMS certificates, 2012
File 3b, DMRC, LOI for ISO and OHSAS certificates, 2012
File 4, DMRC, AFC system overview
File 5, Grütter Consulting and RSMRS, survey contract, 05/10/2011
File 6, RSMRS, survey proposal DMRC
File 7, Grütter Consulting, test survey, 2007
File 8, India Oil, NCV of fuels, 2012
File 9, GOI, Ministry of New and Renewable Energy, National Policy on Biofuels, 2009
File 10, USDA, India Biofuels Annual 2010, 2010
File 11, U. Narain et.al., The Impact of Delhi's CNG Program on Air Quality, 2007
File 12, DTC, operational Statistics, 10/2011
File 13 and 13a, Grütter Consulting, Report on Occupation Rate Study Taxis, 2012
File 13b, Grütter Consulting, Report on Baseline Occupation Rate Study Taxis, 2008
File 14 and 14a, Grütter Consulting, Report on Occupation Rate Study Motorized Rickshaws, 2012
File 14b, CRRI, Quantification of Benefits Achieved from the Implementation of Phase I of Delhi Metro, 2007
File 15 and 15a, Grütter Consulting, Report on Vehicle Count and Speed Study, 2012
File 15b, Grütter Consulting, Report on Baseline Vehicle count and Speed Study, 2008
File 16, GNCT, Transport Department, vehicle registration data, 2012
File 17, SIAM, Motorcycle data, 2012
File 18, GNCT, Transport Department, vehicle registration data, 2007-2011
File 19, DTC, bus capacity, 2012
File 20, IR, Annual report 2010-2011
File 21, Grütter Consulting, EF vehicles 2011 and 2012
File 22, RSMRS, ISO 9001 certificate
File 23, DMRC, data on trains, 2012
File 24, Grütter Consulting, Report on training DMRC, 2012
File 25 and 25a, Grütter Consulting, Report on Bus Occupation Rate, 2012
File 26, DMRC, 2011 passenger data
File 27, DMRC, 2012 passenger data
File 28a/b, DMRC traction energy 2011 and 2012
File 29, RSMRS, survey 12.2011
File 30, RSMRS, survey 03.2012
File 31, DMRC and ABB, SCADA contract, 2007
File 32a-n, Bharti, Certificates of calibration
File 33a/b, RSMRS, expansion factors survey 12/2011 and 03/2012 for the years 2011 and 2012
File 34, RSMRS, consistency checks survey, 2012
File 35, RSMRS, survey analysis, 2012

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History of the document

Version	Date	Nature of revision
02.0	EB 66 13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01	EB 54, Annex 34 28 May 2010	Initial adoption.
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