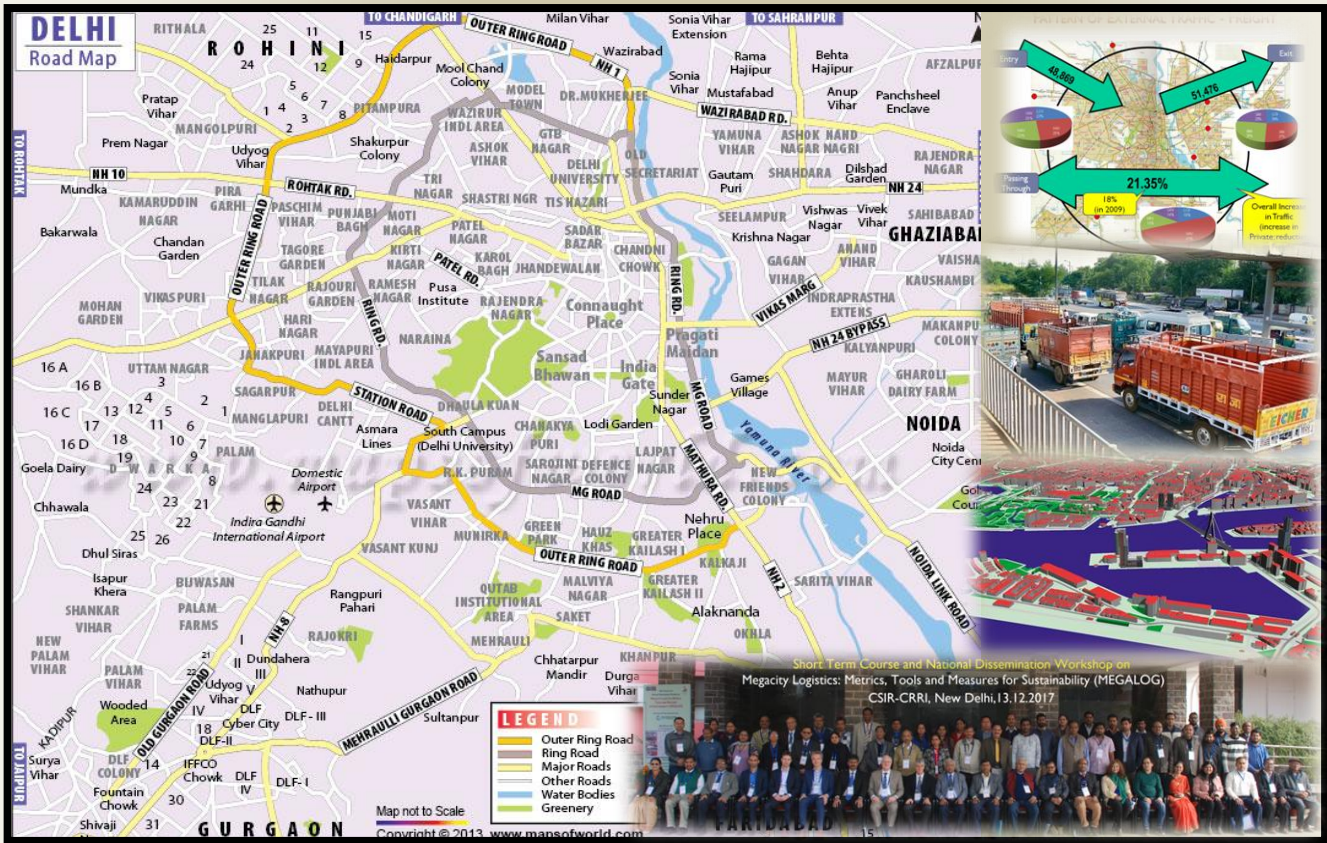


Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG)

Final Report

Submitted to



May 2018

CSIR-Central Road Research Institute (CRRI), New Delhi, INDIA



In association with

TNO, The Netherlands



Delft University of Technology,
The Netherlands



Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG)

Final Report

Submitted to
The World Bank Group

May 2018

CSIR-Central Road Research Institute (CRRI), New Delhi, INDIA

TNO, The Netherlands

In association with

*Delft University of Technology,
The Netherlands*


FOREWORD

India spends 15-20% of its GDP on transport and logistics and Indian freight transport market is expected to grow at a Compound Annual Growth Rate (CAGR) of about 13% by 2020. Road freight constitutes around 63% of the total freight movement and the average speed of trucks on Indian roads is about 20 km/hr covers only 250-300 km a day compared to 700-800 km in developed countries. Moreover, on an average, total trip expenses increases about 15% due to the delays at check-posts and on-road for filling in forms required by various government departments, checking of documents and physical checking of the vehicles, drivers and consignments by Regional Transport Offices and traffic police, and collecting highway toll and taxes. The working conditions for the truck drivers also deteriorating and they work for long hours, resulting in high stress and fatigue, which leads to accidents. The need is recognized for collaboration amongst stakeholders to identify optimal freight policies and pursue a rapid deployment of improvements. Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies.

Considering the above, the World Bank Group has funded research project on "Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG)" which is to be carried out by this institute in association with TNO, Netherlands and TU Delft, Netherlands. The present study mainly focused on development of city logistics metrics, capacity development for Sustainable City Logistics (SCL), development of freight transport demand model and logistics flow model for the city of New Delhi and knowledge sharing among stakeholders. By organising the meetings, short course and workshops as part of the present study, the need for city logistics, current limitations and problems for sustainable logistics have been discussed with the potential stakeholders and accordingly devised and the way forward to achieve sustainable city logistics. As the transport logistics and administrative setups of different cities more or less matches with present study area i.e. Delhi, the methodology adopted can be replicated to achieve sustainable city logistics for the other cities as well. It is hoped that the study findings would be helpful to all transport related actors in city logistics, including infrastructure management, transport sector and the government.

Date: 30th May 2018

Place: New Delhi


(Prof. Satish Chandra) 30/05/18
Director, CSIR-CRRI

STUDY TEAM**Director**

Prof. Satish Chandra

Project Leader

Dr. Errampalli Madhu, Principal Scientist and Head (TP Division)

CSIR-CRRI, New Delhi

Dr. Errampalli Madhu, Principal Scientist, HoD (TP Division)

Dr. Kayitha Ravinder, Principal Scientist

Dr. Ch. Ravi Sekhar, Principal Scientist

Ms. Minal, Scientist

TU-Delft, The Netherlands

Prof. Lorant A. Tavasszy

Dr. Jaap M. Vleugel

Ms. Jolijn van Dijk

TNO, The Netherlands

Mr. Jeroen Borst

Mr. Spencer W. Milburn

Dr. Hans J. Quak

External Advisers

Prof. Russell G. Thompson, University of Melbourne, Australia

Dr. Nilesh Anand, (on behalf of TU Delft, The Netherlands)

Traffic Surveys and Assistance in Workshops

Sh. S. Kannan, Senior Technical Officer

Sh. Satish Kumar, Technical Officer

Sh. Sanjay Kumar, Senior Technician

Sh. Jagdish S. Jangpangi, Senior Technician

Sh. Rajan Varma, Technical Assistant

Sh. Amit Kumar Dubey, Project Assistant

Sh. Vikas Kumar Thakur, Project Assistant

Assistance in Project Execution

Sh. D. Ravinder, Technical Officer

Sh. P. V. Pradeep Kumar, Senior Principal Scientist

Secretarial Assistance

Ms. Krishna Verma

EXECUTIVE SUMMARY

Understanding and forecasting freight movements is critical to plan for future transportation in terms of capacity augmentation, operation, preservation, safety and security, energy and economy investment needs. Many demand forecasting models and data sources are more appropriate for passenger transportation than for freight transportation in terms of understanding freight travel behaviour. Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies. In view of this, the present study have been conceptualised on Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG) and submitted a proposal on the same by CSIR-CRRI, New Delhi, TNO, The Netherlands and TU-Delft, The Netherlands to the World Bank Group under the Multi Donor Trust Fund - Sustainable Logistics (MDTF-SL) Scheme. Subsequently, The World Bank Group has sanctioned the proposed research study (Contract No. 7182067).

Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies which is lacking in India at present

An important goal of the project is to create an impact in practice. An extensive pilot study is carried out for the city of New Delhi, India with a transferable modelling approach. The city of New Delhi i.e. National Capital Territory of Delhi (NCTD) has been selected as study area for this study. By conducting extensive field surveys, metrics of city logistics, design of measurement system and data acquisition in the city of Delhi have been developed. The metrics are focused on logistics activity indicators (external and internal flows), logistics efficiency (vehicular and trip characteristics) and city livability (traffic loads in terms of vehicle kilometers travelled and emissions of pollutants).

The activities carried out in the present study include:

- ▶ *Development of city logistics metrics*
- ▶ *Capacity Development for Sustainable City Logistics (SCL)*

- ▶ *Development of freight transport demand model and logistics flow model for the city of New Delhi*
- ▶ *Knowledge Sharing*

In the present study, NCT of Delhi has been taken as study area and measured possible freight metrics from the various field studies and the summary is given below:

- ❖ The journey speed of traffic stream is varying between 17 and 40 kmph and average journey speeds are around 27 kmph on the road network of Delhi. The journey times are around 2.3 minutes per km which shows that the road network of Delhi is moderately congested all the time.

About 1.24 million vehicles (about 10% Freight and 4% of SMVs) enter and leave Delhi city daily which has grown with about 3% per annum

- ❖ On a normal working day, a total of about 1.24 million vehicles enter and leave Delhi city which has grown with 3% per annum (about 1.02 million vehicles in 2009). The freight traffic forms about 10% of the total traffic with another 4% of traffic is composed of slow moving vehicles (SMV) like bicycle, cycle rickshaws, animal carts etc.
- ❖ Maximum number of vehicles in the order of about 354 thousands entering and exiting through Rajokri Border followed by Ghazipur Border with an entry/ exit traffic volume of about 163 thousands and Kalindi Kunj Border with an entry/ exit

About 100 thousand Freight vehicles enter and leave Delhi city daily and about 21% of these just passing through the city due to absence of adequate bypasses around Delhi

traffic volume of about 126 thousands.

- ❖ A total of about 100 Thousand freight vehicles enter and leave Delhi city on a normal working day and about 21% of these freight vehicles are found to be passing through the city which was almost same in 2009. Though the total traffic increased, freight traffic remain stagnated at outer cordons because of new

bypass roads come around the city of Delhi such as Noida-Greater Noida Expressway, Yamuna Expressway, Kundli-Manesar-Palwal (KMP) Expressway etc.

- ❖ The freight vehicle types namely Goods Auto (GA), Goods Van (GV), Light Truck (LT), Heavy Truck (HT) and Multi-Axle Truck (MT) are observed at entry and exit locations of outer cordons. In case of passing through traffic, HT has almost 50% share followed by MT and LT has share of about 18% each. Smaller Goods Vehicles (GA and GV) has a share of about 14% of passing through traffic. This can be attributed to the fact that the heavy vehicles travel long distances compared to light and small vehicles.
- ❖ From focal points studies within the city, it has been observed that maximum number of vehicles per day in the order of about 8 thousands entering and exiting through Ghanta Ghar Sabzi Mandi followed by Azadpur Sabzi Mandi with an entry/ exit volume of about 7 thousands and Chandini Chowk Area with an entry/ exit volume of about 5 thousands. It has also been found that about 40% are consisting of Goods Auto (GA) and Goods Van (GV) in that. The vehicle types of LT, HT and MT are in the range of 24%, 11% and 8% respectively. The other freight vehicles are about 18%.
- ❖ The mid block traffic studies revealed that the total daily volume (24 hours) on Ring Road (Naraina) is almost 190 thousands with a peak volume of about 16 thousands (19:00 ~ 20:00 Hrs). The summary of traffic on all the mid block locations shows about 80% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 7% mainly consist of Goods Autos, LT, HT and MT.
- ❖ The mean age of different freight vehicles is almost same at outer cordons and within the city varying between 4.5 and 5.0 years and the share of 10 year and more old vehicles within the city is ranging from 1 to 6% and 5 to 9% at outer cordons.
- ❖ The fuel usage distribution of different freight vehicles at outer cordons and within the city results shows that Heavy Vehicles (HT and MT) mostly use Diesel where as Goods Auto and Goods Van almost use CNG as fuel. In case of LT, about 45% and 75% use Diesel as fuel at outer cordons and within city respectively.

The mean age of freight vehicles ranging between 4.5 and 5.0 years and the share of 10 year and more old vehicles is ranging from 1 to 6% (within the city) and 5 to 9% (outer cordons)

- ❖ The ownership of different freight vehicles at outer cordons and within the city has been analysed and found that private company freight vehicles are high in case of heavy vehicles (HT and MT) at outer cordons and within the city. The private company and personal freight vehicle share is almost same for light vehicles (LT, GA and GV) within the city whereas private company freight vehicle share is higher at outer cordons.
- ❖ The mileage (fuel efficiency in terms of km/litre) of different freight vehicles has been observed that light vehicles (LT, GA and GV) have higher fuel efficiency which is mostly run on CNG. Heavy freight vehicles have fuel efficiency about 6.5 and 4.8 km/litre for HT and MT respectively. Light vehicles namely LT has about 11 km/litre, where as GA and GV has more than 14 km/kg of CNG.
- ❖ The freight vehicle travels about 20-25 km within the city and the maximum average distance travelled in a day by these freight vehicle types is about 200 km. This clearly indicates that these freight vehicles face lot of congestion and other problems to travel more distances in a day experiencing lot of delays and increased operating costs.
- ❖ The frequency of trips of different freight vehicles analysis shows that Light Vehicles are having more daily trips and Heavy Vehicles are more in Occasional trips.

On an average, the freight vehicle travels about 200 km/day and this clearly indicates that these vehicles face lot of congestion, delays and other problems leading to increased travel times and operating costs

Estimated total weight carried by freight vehicles on the road network of Delhi is about 2.480 Million Metric Tonne (MMT) per day

- ❖ From the results of weight carried by different freight vehicles, it has been observed that MT Vehicles are carrying average weight more than 13 tonne where as HT vehicle is carrying average load of 5-6 tonne. The LT is carrying average weight about 2 tonne and smaller vehicles like GA and GV are carrying less than a tonne.

- ❖ The share of empty vehicles is about 10-20% across different freight vehicle types. Further the total weight carried by these freight vehicles on the entire road network of Delhi has been estimated to be about 2.480 Million Metric Tonne (MMT) per day.

- ❖ In the present study, freight transport demand model has been developed considering same traditional approach of four-stage modelling (Freight Trip Generation, Freight Modal Split, Freight Trip Distribution and Freight Traffic Assignment). Accordingly, the total trips generated daily in the city of Delhi from all the zones are estimated to be about 500 thousands of freight trips. The final freight modal split for different freight vehicles namely GA, LT, HT and MT shows almost equal share varying between 22-25% where as GV has about 5% share. The Freight O-D Matrix estimated from Freight Trip Distribution adopting Gravity Model.
- ❖ The majority of freight trips are Internal - Internal (I-I) which is almost 80%. The Internal-External (I-E) and External-Internal (E-I) are almost same about 8% each and External-External (E-E) trips (passing through) are about 4%.
- ❖ The analysis of modal split of these freight trips shows that heavy freight vehicle share is about 26% in case of I-I Trips, about 43% in case of I-E Trips, about 53% in case of E-I Trips and about 61% in case of E-E Trips.
- ❖ The share of freight trips is only about 3% and passenger trips are about 97% in the city of Delhi. Though the share of freight trips is very insignificant, it is going to influence huge in traffic congestion, air pollution and road safety related issues of the city of Delhi.

Total freight trips generated daily in the city of Delhi are estimated to be about 500 thousands (share of empty freight vehicles is about 10-20%) which is 3% of total trips generated in Delhi and it is increasing with a growth rate of 4% per year

The VKT by freight vehicles are going to be 13 Millions in 2020 increasing with a growth rate of about 8% per annum

- ❖ The freight trips are estimated to increase to about 572 thousands by the year 2021 with a growth rate of 4% per annum.

- ❖ The estimated traffic loads in terms of vehicle kilometers travelled (VKT) on the road network of Delhi for the year 2017 and forecasted VKT for the year 2021

are about 240 Millions and 300 Millions respectively. The VKT by freight vehicles are going to be about 10 Million and 13 Millions in 2017 and 2020 respectively which

is having a share of about 4%. The growth of total VKT is increasing with 7% per annum growth whereas freight vehicles growth is about 8% per annum.

Taking into account the findings from the inventory of the literature, a list of indicators to measure New Delhi's performance in the area of SCL has been proposed which also included suggested units and sources for measurement. A questionnaire has been designed and proposed to use the same for assessment of the level of knowledge in the area of SCL among all the local authorities and policy makers, freight operators and experts.

With respect to decision support systems, the Urban Strategy (Software developed by TNO) has been customised to visualise freight patterns and to model the impacts of different traffic measures in the city of Delhi. In the present study, it has been demonstrated that Urban Strategy is able to use the available data to construct a basic working model and distribute traffic on the basis of that model. The appropriate data collected in this study has been successfully uploaded, and in combination with open-source data from OpenStreetMaps, Urban Strategy has been used to carry out an initial traffic assignment, and the results displayed in the 2D and 3D interfaces and the Web interface. It can be concluded that the developed system can be utilised as decision support system to evaluate various transport policies by estimating traffic loads and emission loads from vehicular traffic.

Present study has shown that a Decision Support System on the basis of Urban Strategy (Software developed by TNO) is feasible for Delhi for evaluation of different scenarios

The following findings have emerged in the present study through the development of the decision support system for the city of Delhi and evaluation of different scenarios:

- ▶ Based on the results of estimated traffic loads and emission loads from vehicular traffic, it can be said that the contribution of passenger car movements to road transportation emissions is dominant in comparison to road freight movements.
- ▶ On the basis of these findings it appears that some measures, such as freight hubs, will only be effective if they are combined with measures to lower fleet emissions, such as the use of electric vehicles.

- ▶ Removal of diesel vehicles older than 10 years shows 4 – 11% decrease in total CO_x, NO_x and PM₁₀ emissions, and negligible difference in Benzene or Hydrocarbon levels caused by freight traffic.
- ▶ Freight hubs and heavy vehicle restrictions may lead to increased overall emissions if there is no change to the emissions profile for the vehicles that replace them.
- ▶ Introduction of electric freight vehicles shows promising results for reduction in emissions, dependent on the penetration rate achieved.
- ▶ The impact of measures only targeting freight movements will be limited, due to its relatively small contribution to air pollution. Therefore, it would be valuable to apply this system on the integrated challenge of the city of Delhi with regards to air pollution and traffic noise.

Removal of diesel vehicles older than 10 years shows 4 - 11% decrease in total CO_x, NO_x and PM₁₀ emissions

Some measures, such as freight hubs and heavy vehicle restrictions, will only be effective if they are combined with measures to lower fleet emissions, such as the use of electric vehicles

In the present study, an attempt has been made to see the feasibility to apply Agent Based Modelling (ABM) for City Logistics. A large variety of activities (e.g. freight vehicle movements, parking, loading/unloading goods) and stakeholders (consumer, retail, forwarding, trade, and manufacturing) is associated with urban freight transportation, which differ with respect to location, types of goods and stakeholders' characteristics. Altogether this creates a complex system that is difficult to manage. The emerging system is a direct result of colliding decisions and often conflicting objectives of different stakeholders. A well-designed agent based modelling approach that includes the business models and perception of multiple stakeholders of the domain would be useful to identify effective solutions (e.g. policy, regulation, facilitating schemes) for the above mentioned problems.

By collecting and synthesizing information about individual stakeholders and entities at micro level, an agent-based model (ABM) for Delhi can be created to analyse the interactions between urban freight entities to understand the background of movements of freight delivery vehicles and responses of these agents to policies for urban freight related problems. Furthermore, a role-playing game can be developed using an ABM as an interactive tool for urban freight stakeholders to understand the decision-making processes and complexity of urban freight activities. Such a role-playing game can act as platform to experience the complexity and emergence effect of decision-making by different stakeholders. As data collection is challenging part of ABM development, we recommend that, initially, a proof-of-concept model is developed for a zone in Delhi. A conceptual framework provided in this report as starting point for model development. Data collection for a small area should be relatively easy and allow addressing the research challenges of ABM development.

An agent-based model (ABM) for Delhi can be created to analyse the interactions between urban freight entities to understand the background of movements of freight delivery vehicles and responses of these agents to policies for urban freight related problems.

From the above, it can be said that agent-based modelling can be useful for many unrequited policy analysis problems in the urban freight domain. However, the time and precision required for developing such a system is a challenging task. Overcoming these challenges requires painstaking efforts but assures in-depth understanding about urban freight transportation process for successful urban freight policy analysis.

In conclusion, in the present study, four important priorities for the future have been identified, which could be part of a joint mission statement of the collective of stakeholders to achieve sustainable urban freight systems:

- *Reduction of negative effects of urban freight transport while maintaining productivity.*
- *Identification of workable urban freight solutions including roadmaps towards data, tools and appropriate research.*
- *Increase of the knowledge base including data collection, models and scenarios.*

- *Collaboration with other stakeholders to realize solutions towards sustainability.*

In the final workshop of the project, these points were signed symbolically by all participants, as an expression of the start of a shared effort to create a follow-up to this project including further elaborated policy information, based on a process of joint fact finding and alignment of ideas by industry, governmental and knowledge partners.

*Mission statement of the collective of stakeholders
to achieve sustainable urban freight systems*

- Reduction of negative effects of urban freight transport while maintaining productivity*
- Identification of workable urban freight solutions including roadmaps towards data, tools and appropriate research*
- Increase of the knowledge base including data collection, models and scenarios*
- Collaboration with other stakeholders to realize solutions towards sustainability*

TABLE OF CONTENTS

<i>Foreword</i>	<i>i</i>
<i>Study Team</i>	<i>iii</i>
<i>Executive Summary</i>	<i>v</i>
<i>Table of Contents</i>	<i>xv</i>
<i>List of Figures</i>	<i>xix</i>
<i>List of Tables</i>	<i>xxiii</i>
1. BACKGROUND	1
1.1. Freight Transport in India	1
1.2. Delhi City as Study Area	2
1.3. Need for the Present Study	4
2. OBJECTIVES AND SCOPE OF THE RESEARCH STUDY	7
2.1 Objectives	7
2.2 Scope of the Study	7
3. METHODOLOGY	9
3.1. Consortium of Organisations	9
3.2. Work Packages (WP).....	9
3.2.1. <i>WP-1: Development of city logistics metrics</i>	9
3.2.2. <i>WP 2: Capacity Development for Sustainable City Logistics</i>	10
3.2.3. <i>WP 3: Decision Support Systems</i>	10
4. SUSTAINABILITY CITY LOGISTICS (SCL)	13
4.1. Introduction.....	13
4.2. Sustainable City Logistics: Definitions	13
4.2.1. <i>City Logistics</i>	13
4.2.2. <i>Sustainability</i>	14
4.2.3. <i>CL Impacts on the Triple Bottom Line</i>	17
4.3. Additional Contextual Factors for Delhi.....	18
4.3.1. <i>Policy on Urban Development and City Logistics</i>	18
4.3.2. <i>Transport Vehicles, Air Quality and Air Pollution Abatement</i>	19
4.3.3. <i>Developing Country Challenges</i>	20
4.4. SCL – A Review of the Literature	21

4.4.1.	<i>Introduction</i>	21
4.4.2.	<i>Literature on Criteria, Indicators and Frameworks</i>	21
4.4.3.	<i>Discussion</i>	24
4.5.	Proposed Metrics for SCL	24
5.	LOGISTIC METRICS FOR CITY OF DELHI.....	29
5.1.	General.....	29
5.2.	List of Field Surveys.....	29
5.3.	Speed Data	30
5.4.	Outer Cordon (OC) Traffic Volume Data.....	34
5.5.	Outer Cordon Interview Data.....	40
5.6.	External Travel.....	42
5.7.	Focal Point Freight Traffic Survey	44
5.8.	Focal Point Interview Data	48
5.9.	Mid Block Traffic Volume Survey	49
5.10.	Freight Vehicular and Travel Characteristics	52
5.9.1.	<i>Age Distribution</i>	52
5.9.2.	<i>Fuel Used</i>	55
5.9.2.	<i>Ownership of Freight Vehicle</i>	55
5.9.3.	<i>Fuel Efficiency</i>	56
5.9.4.	<i>Distance Travelled</i>	57
5.9.5.	<i>Frequency of Trips</i>	58
5.9.6.	<i>Weight Carried</i>	58
5.11.	Development of Freight Transport Demand Models	59
5.11.1	<i>Background</i>	59
5.11.2.	<i>Traffic Zones, Road Network and Socio-economic Data</i>	60
5.11.3	<i>Freight Trip Generation Models</i>	62
5.11.4.	<i>Freight Modal Split</i>	65
5.11.5.	<i>Freight Trip Distribution Models</i>	66
5.11.6.	<i>Freight Trip Assignment</i>	68
5.12.	Pattern of Total Freight Trips	69
5.13.	Forecasting of Freight Trips from Freight Transport Demand Models	71
5.14.	Estimation of Traffic Loads on the Road Network.....	72

6.	CAPACITY DEVELOPMENT FOR SUSTAINABLE CITY LOGISTICS	75
6.1.	Capacity Assessment	75
6.2.	Knowledge Development Plan	77
6.3.	Stakeholders Meetings and 1 st Workshop on MEGALOG.....	80
6.4.	Organizing Short Courses	83
6.5.	National Level Dissemination Workshops	84
6.6.	Design of Booklet on Sustainable City Logistics	90
6.7.	Future Capacity Building Process on Sustainable City Logistics.....	91
7.	DECISION SUPPORT SYSTEM: POLICY ANALYSIS AND VISUALIZATION TOOLSET	93
7.1.	Introduction.....	93
7.1.1.	<i>Background</i>	93
7.1.2.	<i>Policy Analysis and Visualization Toolset</i>	94
7.1.3.	<i>Urban Strategy</i>	95
7.2.	Technical Background of Urban Strategy.....	95
7.2.1.	<i>Software architecture</i>	95
7.2.2.	<i>Interfaces</i>	97
7.2.3.	<i>Data model and data store</i>	100
7.3.	Setup of Urban Strategy for Delhi City	101
7.3.1.	<i>Methodology</i>	101
7.3.2.	<i>Choice of coordinate system</i>	102
7.3.3.	<i>Assignment method</i>	103
7.3.4.	<i>Emission Factors and Emission Loads</i>	103
7.3.5.	<i>Uploading the data into a new database</i>	103
7.3.6.	<i>Input data</i>	104
7.4.	Policy Evaluation with Urban Strategy.....	107
7.4.1.	<i>Freight Transport Policies/ Scenarios</i>	107
7.4.2.	<i>Evaluation Results of Policies</i>	111
7.5.	Summary of Findings.....	119
7.5.1.	<i>Urban Strategy for Delhi</i>	119
7.5.2.	<i>Policy Findings</i>	120
7.5.3.	<i>Suggestion for further research</i>	120
7.5.4.	<i>Discussion</i>	121

8.	FEASIBILITY OF AGENT BASED SIMULATION MODEL FOR URBAN FREIGHT ACTIVITIES IN DELHI	123
8.1	Complexity in Urban Freight Transportation	123
8.2	Agent Based Modelling Approach.....	123
8.3	ABM for Urban Freight Activities in Delhi NCR	124
8.3.1.	<i>Conceptual Framework</i>	124
8.3.2.	<i>Application</i>	127
8.3.3.	<i>Proof of concept ABM for Delhi</i>	128
8.3.4.	<i>Data needed for urban freight ABM in Delhi</i>	128
8.3.5.	<i>Research capabilities for ABM development</i>	129
8.3.5.	<i>Challenges for ABM development for Delhi</i>	129
8.4	Summary	130
9.	CONCLUDING REMARKS	133
10.	ANNEXURES	141

LIST OF FIGURES

Figure 1.1: Typical View of Trucks entering Delhi after the end of restriction time	2
Figure 1.2: Typical View of Light Trucks moving on Delhi Roads	3
Figure 1.3: Typical View of Different Types of Goods Vehicles (Heavy Trucks, Light Trucks, Goods Autos etc.) moving on Delhi Roads	3
Figure 1.4: Typical View of Other Modes of Goods Transportation in Delhi	4
Figure 2.1: The Selected Study Area of National Capital Territory of Delhi (NCTD)	8
Figure 5.1: Selected Arterial Roads for Journey Speed Data Collection.....	30
Figure 5.2: VBOX Equipment used for Journey Speed Data Collection on Selected Corridors	31
Figure 5.3: Average Journey Time on Selected Stretches of Delhi Road Network	33
Figure 5.4: Selected Locations of Outer Cordons for Freight Traffic Data Collection	35
Figure 5.5: Typical Views of Traffic Volume Count Survey at Different Locations of Outer Cordons for Freight Traffic Data Collection	36
Figure 5.6: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajokri Border	38
Figure 5.7: Traffic Composition at Different Outer Cordons of Delhi.....	39
Figure 5.8: Typical Views of Interview Survey at Different Locations of Outer Cordons for Freight Traffic Data Collection.....	41
Figure 5.9: Pattern of Total External Traffic at Outer Cordons of Delhi	42
Figure 5.10: Pattern of Freight External Traffic at Outer Cordons of Delhi	43
Figure 5.11: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours).....	45
Figure 5.12: Hourly Distribution of Classified Freight Traffic Volume and Traffic Composition Azadpur Sabzi Mandi.....	46
Figure 5.13: Freight Traffic Composition at Different Focal Points of Delhi.....	48
Figure 5.14: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajghat on Ring Road.....	51
Figure 5.15: Traffic Composition at Different Mid Block Locations of Delhi	52
Figure 5.16: Age Distribution of Different Freight Vehicles at Outer Cordons in Delhi	53

Figure 5.17: Age Distribution of Different Freight Vehicles within the City of Delhi (Focal Point).....	54
Figure 5.18: Fuel Usage Age Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi.....	55
Figure 5.19: Ownership Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi	56
Figure 5.20: Fuel Efficiency of Different Freight Vehicles.....	56
Figure 5.21: Distance Travelled by Different Freight Vehicles	57
Figure 5.22: Frequency Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi	58
Figure 5.23: Frequency Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi	59
Figure 5.24: Share of Empty Vehicles in Different Typed of Freight Vehicles	59
Figure 5.25: Traffic Analysis Zones (TCZ) considered for the City of Delhi.....	61
Figure 5.26: Created Road Network (Links and Nodes) for the City of Delhi.....	62
Figure 5.27: Estimated Total Freight Trip Productions and Attractions in Delhi (2017).....	65
Figure 5.28: Modal Split of Total Freight Trips	65
Figure 5.29: Typical View of Estimated Total Freight O-D Matrix for the City of Delhi	67
Figure 5.30: Desire Line Diagram of O-D Matrices for Freight Trips	68
Figure 5.31: Pattern of Total Freight Trips i Delhi.....	69
Figure 5.32: Freight Modal Split for Different Types of Trips in Delhi.....	70
Figure 5.33: Share of Freight Trips in the Total Trips of Delhi	70
Figure 5.34: Forecasted Total Freight Trips for the Year 2021 in Delhi.....	71
Figure 5.35: Estimated Vehicle Kilometers Travelled /Day for different Vehicle Types for Different Years.....	72
Figure 6.1: Description of Different Levels of Organisations with Different Objectives and Requirements	76
Figure 6.2: Some of the News Clippings on Delhi Air Pollution and Entry/ Ban of Trucks in the City.....	77
Figure 6.3: Road Map towards Zero Emission in the City of Rotterdam, The Netherlands ...	78
Figure 6.4: Existing (without Consolidation) and Proposed Situation of Trips into the city with Consolidation.....	79

Figure 6.5: Agenda of 1 st Workshop on MEGALOG held on 9 th May 2017 at CSIR-CRRI, New Delhi	81
Figure 6.6: Some Views of 1 st Workshop on MEGALOG held on 9 th May 2017 at CSIR-CRRI, New Delhi.....	82
Figure 6.7: Agenda of Short Course on Sustainable City Logistic held on 12 th December 2017 at CSIR-CRRI, New Delhi.....	85
Figure 6.8: Some Views of Short Course on Sustainable City Logistics held on 12 th December 2017 at CSIR-CRRI, New Delhi	87
Figure 6.9: Agenda of National Dissemination Workshop on MEGALOG held on 13 th December 2017 at CSIR-CRRI, New Delhi	88
Figure 6.10: Some Views of National Dissemination Workshop on MEGALOG held on on 13 th December 2017 at CSIR-CRRI, New Delhi	90
Figure 6.11: View of Designed Booklet on Sustainable City Logistics	91
Figure 7.1: Screenshot of Urban Strategy outputs (Source: TNO).....	94
Figure 7.2: Software architecture for Urban Strategy.....	96
Figure 7.3: Indicators implemented in Urban Strategy such as Noise Annoyance, Travel Times or the Total Emissions	97
Figure 7.4: 2D interface with GIS (Geographical Information System) in Urban Strategy	98
Figure 7.5: 3D interface with GIS (Geographical Information System) in Urban Strategy	99
Figure 7.6: Screenshot of Web Interface of Urban Strategy.....	100
Figure 7.7: Overview of the Decision Support System on the basis of Urban Strategy.....	102
Figure 7.8: Screenshot from the 2D module analysed in Urban Strategy for New Delhi City	106
Figure 7.9: City of Delhi loaded in the 3D interface of Urban Strategy.....	107
Figure 7.10: Considered Locations of Freight Hubs in Scenario 2.....	109
Figure 7.11: Considered Closed-off Area in New Delhi City Center under Scenario 3.....	110
Figure 7.12: Proposed High Capacity Elevated Corridor in Scenario 4	111
Figure 7.13: Web Interface of Urban Strategy of New Delhi.....	112
Figure 7.14: Result of Traffic Flows In Relation To Capacity in Base Scenario.	113
Figure 7.15: Spatial Distribution of NOx Emissions due to Road Traffic in the Base Scenario	113
Figure 7.16: Spatial Distribution of NOx Emission Reduction due to Scenario 1	114

Figure 7.17: Spatial Distribution of Change in NO _x Emission due to Scenario 2	115
Figure 7.18: Spatial Distribution of Change in NO _x Emission due to Scenario 3	115
Figure 7.19: Spatial Distribution of Change in NO _x Emission due to Scenario 4	116
Figure 7.20: Spatial Distribution of Change in NO _x Emission due to Scenario 6	117
Figure 7.21: Breakdown of Emission Totals for Road Transport Vehicle Types in Delhi for Different Substances	118
Figure 7.22: Comparison of Emission Totals for Road Transport in Delhi for Different Scenarios	118
Figure 7.23: Comparison of emission totals for road freight transport in Delhi for different scenarios.....	119
Figure 8.1: Conceptual framework of agent based model for urban freight domain in Delhi NCR	125
Figure 8.2: Development stages of agent based model for urban freight in Delhi NCR.....	126

LIST OF TABLES

Table 4.1: List of Indicators to Measure New Delhi’s Performance in the area of SCL.....	25
Table 5.1: Selected Stretches for Journey Speed Data Collection.....	31
Table 5.2: Observed Journey Speed on Inner Ring Road (S-8) in Up Direction.....	32
Table 5.3: Observed Journey Speed on Inner Ring Road (S-8) in Down Direction.....	32
Table 5.4: Summary of Observed Journey Speed on Selected Stretches	33
Table 5.5: Selected Outer Cordon Locations for Freight Traffic Data Collection for 24-Hour Duration	35
Table 5.6: Selected Vehicles Types Considered under Freight Transport in the Present Study	37
Table 5.7: Classified Traffic Volume at Rajokri Border	38
Table 5.8: Summary of Classified Traffic Volume (24 hours) at Different Outer Cordons of Delhi.....	39
Table 5.9: Sample Size of Freight Vehicles Collected at Different Outer Cordons of Delhi (24 hours)	40
Table 5.10: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours)	44
Table 5.11: Classified Freight Traffic Volume at Azadpur Sabzi Mandi.....	46
Table 5.12: Summary of Classified Freight Traffic Volume (24 hours) at Different Focal Points of Delhi	47
Table 5.13: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours)	49
Table 5.14: Selected Mid-Block (MB) Locations to Conduct Traffic Volume Survey in Delhi (24 hours).....	50
Table 5.15: Classified Traffic Volume at Naraina on Ring Road.....	51
Table 5.16: Summary of Classified Traffic Volume (24 hours) at Different Mid Block Locations of Delhi.....	51
Table 5.17: Share of 10 Year and More Old Vehicles within the City and at Outer Cordons	54
Table 7.1: Mapping of OSM data to Urban Strategy categorization	104

1. BACKGROUND

1.1. Freight Transport in India

Transport is a key element in the infrastructure of a nation as it provides services essential for promoting economic and social development and plays a significant role in influencing the pattern of distribution of economic activities and improving productivity. India spends 15 to 20% of its GDP on transport and logistics compared to an average 8 to 10% in other developing countries. Indian freight transport market is expected to grow at a Compound Annual Growth Rate (CAGR) of about 13% by 2020 driven by the growth in the manufacturing, retail, Fast-moving consumer goods (FMCG) or consumer packaged goods (CPG) and e-commerce sectors which have large freight transport requirements across the country which is generally done by road transportation. In India, road freight constitutes around 63% of the total freight movement consisting of 2.2 million heavy duty trucks and 0.6 million light duty trucks covering more than 18,00,000 km of road length carrying more than 3000 MMT (million metric ton) of load annually.

Owing to poor road conditions and check-post delays, trucks in India travel for 20 days a month on an average compared to 25 days in developing countries (TCI and IIM, 2016). The delays could range from five per cent of time taken in a journey to a high of 25%. The average speed of trucks on Indian roads is about 20 km/ hour and a truck in India can cover only 250-300 km a day compared to 700-800 km in developed countries such as the US and Europe. Moreover, on an average, total trip expenses increases about 15 per cent due to the delays at check-posts and on-road for filling in forms required by various government departments, checking of documents and physical checking of the vehicles, drivers and consignments by Regional Transport Offices and traffic police, and collecting highway toll and taxes. The working conditions for the truck drivers also deteriorating and they work for long hours, resulting in high stress and fatigue, which leads to accidents.

There is increasing recognition in India that transport infrastructure could become a serious bottleneck for future economic growth. The need is recognized for collaboration amongst stakeholders to identify optimal policies and pursue a rapid deployment of improvements.

1.2. Delhi City as Study Area

The present study considers Delhi urban road network as object of study. As per the Census of India (2011), Delhi has 16.75 million population which recorded a decennial population growth of about 20%. The increase in urbanization leads to growth of vehicular population in urban areas and this scenario accelerates various traffic problems such as congestion, air pollution, and reduction in safety. There is significant momentum in government to take the city logistics system as sustainable development priority. Recent verdict by National Green Tribunal (NGT) of India on banning 10 years old trucks to enter into the city of Delhi in view of high pollution emission by these vehicles. In order to study and understand these issues, new policies are needed and innovation needs to be promoted. The roads of Delhi have number of time restrictions for goods vehicles and there is 24 hours ban for some roads. The restriction is from 7:00 AM to 11:00 AM and 5:00 PM to 11:00 PM for most of the roads in Delhi. Some of the view of freight transportation in Delhi is shown in Figure 1.1 to 1.5.



Figure 1.1: Typical View of Trucks entering Delhi after the end of restriction time



Figure 1.2: Typical View of Light Trucks moving on Delhi Roads



Figure 1.3: Typical View of Different Types of Goods Vehicles (Heavy Trucks, Light Trucks, Goods Autos etc.) moving on Delhi Roads



Figure 1.4: Typical View of Other Modes of Goods Transportation in Delhi

1.3. Need for the Present Study

Delhi is known as one of the most air polluted cities in the world as the air quality index (AQI) of most areas is above 150 (Delhi Air Pollution: Real-time AQI, 2017). AQI from 0 to 100 is in range of good to moderate. AQI more than 150 is considered unhealthy (Air Now, 2017). Emission from motor vehicles is one of the major reasons for poor quality in Delhi. The traffic congestion on Delhi road is as intimidating as the polluted air. It was also revealed from the past studies that about 100,000 freight vehicles crossed 10 count stations at the borders of Delhi in a day (CRRI, 2009). Clearly, freight transportation has its fair share in pollution and congestion of Delhi. The average share of freight transportation vehicles in Delhi is relatively low in overall situation. However, due to time window restrictions by local authorities, the share of freight vehicles varies during different time of the day/night. For instance, certain types of freight activities (e.g. furniture delivery, milk van, etc.) are allowed between 8 am and 4 pm. During that time the share of freight vehicle increases to 15-20%. In

the night after 12 am, all freight vehicles are allowed in the city resulting in majority of freight vehicles on Delhi road network. LCVs, trucks and auto rickshaws form backbone of urban goods movement in Delhi for longer distances. For short distances, non-motorised vehicles (e.g. animal cart, hand cart, head load, cycle Rickshaw) are extensively used, especially in highly congested parts of the Delhi (Gupta, 2017). Another interesting fact is that with online shopping spree companies are using Motorized Two Wheeler (MTW) trips, used as a way to navigate the high density and congestion of Delhi (Nilanjena, et. al., 2016).

Understanding and forecasting freight movements is critical to plan for future transportation in terms of capacity augmentation, operation, preservation, safety and security, energy and economy investment needs. Many demand forecasting models and data sources are more appropriate for passenger transportation than for forecasting freight movements and understanding freight travel behaviour. Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies. In view of this, the objectives of the study have been conceptualised on Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG) and submitted a proposal on the same by CSIR-CRRI, TNO and TU-Delft to the World Bank Group under the Multi Donor Trust Fund - Sustainable Logistics (MDTF-SL) Scheme. Subsequently, The World Bank Group has sanctioned the proposed research study (Contract No. 7182067) and the defined objectives are presented in the next Chapter.

References

Census of India (2011), Government of India.

TCI and IIM Calcutta (2016), “Operational Efficiency of Freight Transportation by Road in India” Joint Study Report, 3rd Edition, 2016.

<http://www.novonous.com/publications/freight-transport-market-india-2015-2020>

<http://www.thehindubusinessline.com/todays-paper/tp-logistics/average-speed-of-trucks-on-indian-roads-is-20-kmhr-study/article1069670.ece>

Delhi Air Pollution: Real-time Air Quality Index (2017). <http://aqicn.org/city/delhi/>

Air Now (2017). <https://airnow.gov/index.cfm?action=aqibasics.aqi>

MoUD (2016), “Decongesting Traffic in Delhi”, Report of the High Powered Committee, Ministry of Urban Development, Govt. of India, June 2016.

- CRRI. (2009). Urban Road Traffic and Air Pollution in Delhi, Central Road Research Institute (CRRI), Final Report Submitted to Society of Indian Automobile Manufacturers (SIAM), 2009.
- Gupta, S. (2017), “Role of Non -Motorized Transport in Distribution of Goods in the Metropolitan City of Delhi”, *Transportation Research Procedia*, Elsevier Publishers, Vol. 25, pp. 978–984
- Nilanjana De-Bakshi, Nomesh B. Bolia, Geetam Tiwari and Jose Holguin-Veras, (2017) “Urban Freight in Delhi: Characteristics and Mobility Restrictions”, VREF Research Brief 8 (RB08-2017), Volvo Research and Educational Foundations (VREF).

2. OBJECTIVES AND SCOPE OF THE RESEARCH STUDY

2.1 Objectives

The objective of the initiative is twofold:

- 1) Capacity development for R&D in the area of sustainable logistics for cities, in two areas:
 - ❖ Metrics for measurement of city logistics sustainability in livability and logistics efficiency and
 - ❖ Tools for policy design
- 2) Development, transfer and application of decision support system specifications for public policies and strategies related to sustainable megacity logistics.

2.2 Scope of the Study

An important goal of the project is to create an impact in practice. An extensive pilot study is carried out for New Delhi with a transferable modelling approach. The city of Delhi i.e. National Capital Territory of Delhi (NCTD) has been selected as study area for this study. The geographical area coverage and the road network for the study area of NCTD have been shown in the Figure 2.1.

This initiative will cover development of city logistics metrics, design of the measurement system and a pilot for data acquisition. The metrics will be focused on logistics activity indicators (flows, warehouses), logistics efficiency (lead times and costs) and city livability (emissions of pollutants). It will allow to benchmark results with other megacities globally. The study will be conducted in close collaboration with policy-makers, local authorities, firms and local organizations. The activities to be carried out include:

- ▶ *Development of city logistics metrics - measurements of key performance indicators of a city, in relation to freight transportation and logistics processes such as storage and handling;*
- ▶ *Capacity Development for Sustainable City Logistics - assessment carried out among key stakeholders, including public and private parties. Evaluation including policy*

objectives, work programmes and general knowledge position in the field of sustainable logistics for megacities;

- ▶ Development of freight logistics flow model for the city of New Delhi - visualization of the city logistics metrics for monitoring purposes done in 3D city model;
- ▶ Knowledge Sharing - short courses on sustainable city logistics (strategies, metrics, and tools).

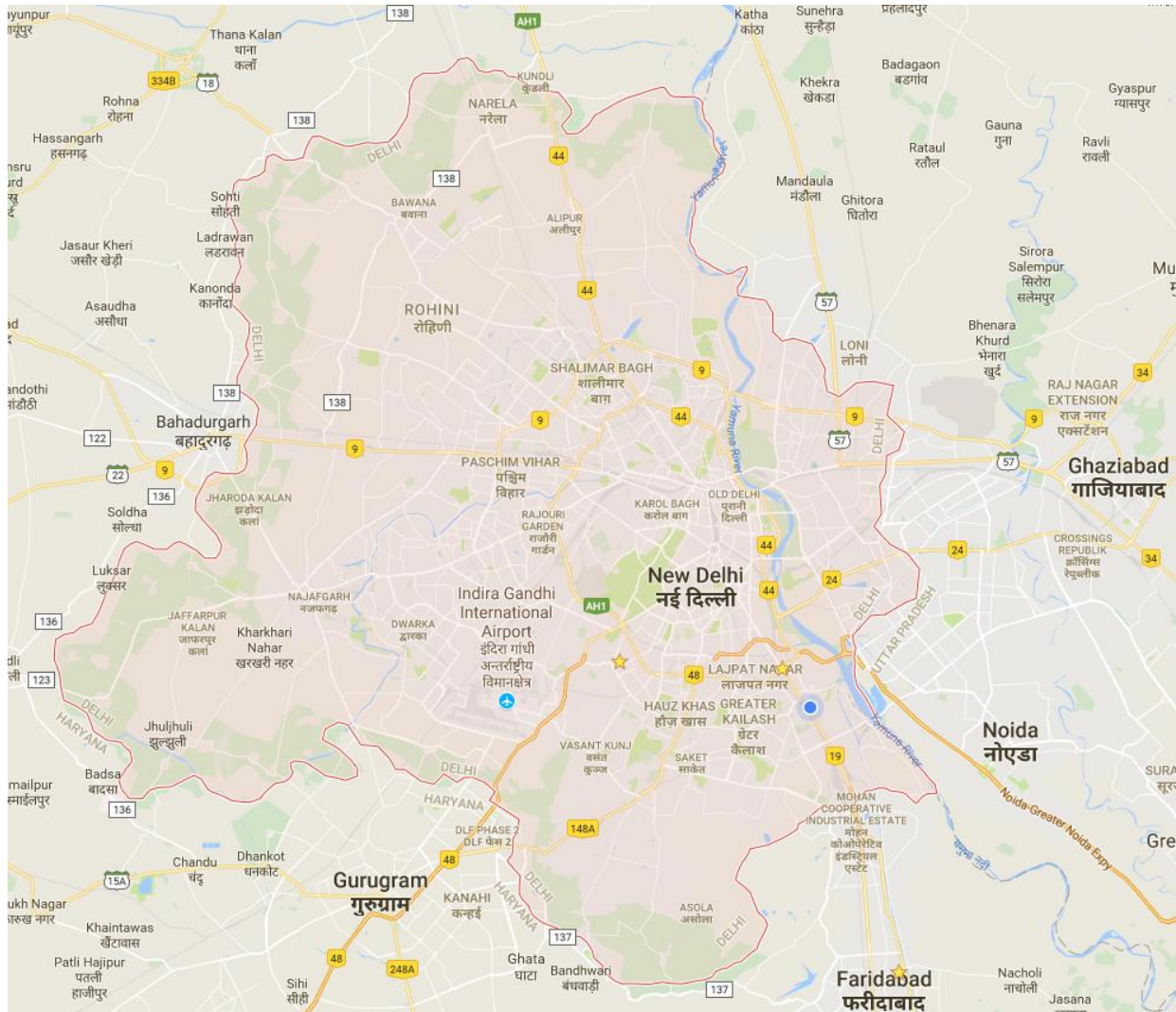


Figure 2.1: The Selected Study Area of National Capital Territory of Delhi (NCTD)

(Source: Google Maps)

3. METHODOLOGY

3.1. Consortium of Organisations

In order to achieve the objectives of the study mentioned in the previous section and to implement the project for the city of New Delhi, the consortium has been proposed to form which include following research institutes:

- ❖ CSIR-CRRI (Central Road Research Institute, Transportation Planning Division), New Delhi, India as Lead Organisation
- ❖ TNO (Netherlands Organisation for Applied Scientific Research: section Sustainable Transport and Logistics) as Partnering Institute
- ❖ Delft University of Technology (TU Delft, Section Transport and Logistics) as Partnering Institute

Apart from that, the external advisors will be associated from within the VREF-CoE SUFS network.

3.2. Work Packages (WP)

The initiative will be deployed in three work packages

- WP1 – Sustainable city logistics metrics
- WP2 – Knowledge transfer between R&D institutes for capacity development
- WP3 – Decision Support Systems

3.2.1. WP-1: Development of city logistics metrics

In order to arrive at sound city logistics, measurements are important of the key performance indicators of a city, in relation to freight transportation and related logistics processes such as storage and handling. This work package will develop the metrics, design the measurement system and do a pilot for data acquisition. The metrics will be focused on logistics activity indicators (flows, warehouses), logistics efficiency (lead times and costs) and city liveability (mainly: emissions of pollutants). They will allow benchmarking with other cities globally, that are part of the CoE-SUFS network (Volvo Research and Education Foundation). This

approach will provide data on Delhi and serve as proof of concept in order to allow continuous monitoring and benchmarking in other cities.

3.2.2. WP 2: Capacity Development for Sustainable City Logistics

This work package builds on the latest experiences of the Dutch partners TNO and TU Delft in large Global programmes (VREF Coe-SUFS), European R&D projects (CITYLAB, STRAITGHTSOL, FREVUE, CITYLOG, CIVITAS, AMITRAN) and national R&D projects (Rotterdam City Dashboard and Living Lab, Cross Chain Control Centers for City Distribution, Lean & Green) in city logistics (2014 running budget > 2 M Euro). Firstly a capacity assessment will be carried out among the key stakeholders of New Delhi City Logistics, including public and private parties. A scan and evaluation will be done of policy objectives, work programmes and the general knowledge position in the field of sustainable logistics for megacities. Subsequently a proposal is developed for knowledge development via educational programmes and knowledge organization. Two short courses on sustainable city logistics (sustainable logistics strategies, metrics, and tools) will be delivered locally.

3.2.3. WP 3: Decision Support Systems

Decision support system specifications and pilot systems to be delivered are twofold. Firstly, the visualisation of the city logistics metrics for monitoring purposes is done via a Planning Support System (PSS) using the 3D city model 'Urban Strategy' of TNO. This PSS (www.tno.nl/urbanstrategy) has been applied in different cities around the world (Rotterdam, Dubai, and Shenzhen) and allows tracing the generation and propagation of traffic and air pollutants.

On the basis of data specified by TNO and provided by CSIR-CRRI, TNO will build a structured piloting database and demonstrator of a PSS based on Urban Strategy. The functioning of Urban Strategy application will be demonstrated for a number of policy scenarios that directly affect freight flows within the city (such as selective use of lanes, time windows, off hour deliveries etc.) and results will be visualised with Urban Strategy. The specifications, the process and follow-up recommendations will be laid down in a report.

Subsequently, CSIR-CRRI and TU Delft will work together to develop specifications and a first prototype for a freight logistics flow model (freight travel demand model) for the city of New Delhi. This model will be designed in a way that it can function inside Urban Strategy. This will include trip generation models, OD synthesis / trip distribution models and simple tour building models.

Finally, a feasibility study will be done for the transfer of a serious game, the Agent Based Model (ABM) for City Logistics developed by TU Delft. The feasibility study will address software, skills and data needs and will provide recommendations to the CSIR-CRRI for further development of a research program on this topic.

The result of WP3 includes:

- specification and demonstration of the model system i.e. the Urban Strategy pilot application and the prototype freight model, including recommendations for full implementation.
- developed database for Urban Strategy and the prototype freight flow model
- feasibility study for agent based modelling

The above will be aligned with the performance management system of WP1.

4. SUSTAINABILITY CITY LOGISTICS (SCL)

4.1. Introduction

One of the aims of the MEGALOG project is to contribute to the building of local management and scientific capacity concerning city logistics in New Delhi. Our focus lies on relevant contextual and city logistics specific data, together with the tools needed to transform this data into information and effective local policy-making.

In this section, the measurement of performance of the city logistics processes which is an important input to management and scientific activities have been discussed. Along with that an overview of scientific papers which are relevant for the design of a Sustainable City Logistics (SCL) metrics framework has also been provided. Such a framework will allow quantification of urban logistics (UL) movements in (part of) New Delhi city and of its impact on congestion and emissions (pollutants, CO₂ etc.).

The definitions of city logistics processes and the relationship with sustainability frameworks have been provided in Section 4.2. Additional contextual factors for city logistics in New Delhi are given in Section 4.3. A description of the most common UCL metrics used in the literature is given in Section 4.4. This section has been finalized with a proposal for metrics for SCL which is given in Section 4.5.

4.2. Sustainable City Logistics: Definitions

4.2.1. City Logistics

City logistics refers to the management and planning of delivering and collecting goods in urban areas (towns and city centres) by professional transport, storage and transshipment of goods. This excludes consumer shopping (C2B) but includes home deliveries (B2C).

Urban freight transport (UFT) may be divided into a range of subcategories [1]:

- Raw materials and semi-manufactured articles for industries;
- Consumer goods for wholesalers;
- Consumer goods for shops;

- In- and outbound consumer goods produced in the area;
- Professional home deliveries;
- Transit of goods through the city.
- Construction site related traffic

The movement of goods has substantial economic, social and environmental impacts, both positive and negative. In the next section, the relations between city logistics and economics and the social and environmental impact will be briefly discussed. All these elements are of direct relevance in a discussion about sustainability, as can be seen in Section 5.3.

4.2.2 Sustainability

In the famous Brundtland Report [2, page 54], sustainable development is defined as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” This implies that the economic, social and environmental impacts of a certain activity are jointly considered (‘Triple bottom line’) and public and private instruments are chosen and applied in order to enable (or stimulate) the positive impact of the respective activity and reduce the negative impact. There is a caveat in this way of thinking, because it ignores the role of power, i.e. vested interests, which has created a situation where economic and social objectives major over environmental objectives. Economic development is in this view regarded as a necessary condition for social development. Environmental policies should not restrict economic development. A country should be able to afford such policies. As [3] mentions: “development carries the dynamic tension between poverty and environmental concerns; pollution, non-renewable resource depletion and population growth.” Economic growth goes along with a larger impact on nature and natural resources, unless deliberate use of technology and efficiency improvements are able to provide clean(er) economic growth. This is the so-called decoupling of economic growth and environmental/ecological impact. The term sustainability is used to describe a situation where human activities take place within environmental ‘boundaries’, instead of a human-centered approach, where the environment may effectively be seen as a ‘prisoner’ of economic development. In the past few decades, environmental concerns receive growing attention in policy-making, which led to the introduction of policy instruments to reduce these impacts, in particular in developed countries. Developing

countries are lagging far behind the former countries, while the necessity is rising in developing countries. Nowadays, cleaner technologies, such as trucks with more fuel-efficient and cleaner engines, have become available and more is to be expected. Growing use of such technologies helps to lower their cost hence increases their affordability. It also reduces payback time and makes it easier to develop a positive business case for them. Legal instruments may support the introduction of cleaner technologies and business practices as well.

The UNDP Development Agenda

In 2007, UNDP published a Development Agenda [4]. It is especially relevant for developing countries, because it identifies their social, economic and environmental challenges.

The following (policy) topics in this Development Agenda are relevant for this project:

- a) Social progress, social justice and inclusion. Despite the progress made in the last half century, a majority of the population is living in poor circumstances in India. The institutional factors responsible for this status (culture, religion, politics, education and other) are beyond this project. The relationship between improved city logistics and social progress is in the scope of this project, however. An efficient city logistics system gives more people access to basic resources like food. Time spent to acquire goods and carry these manually could also be used for activities of a higher social and economic value. Reducing transport time helps to preserve the quality of the goods transported and helps to prevent waste.
- b) Reducing inequality between countries. Social and economic development could help countries that lag behind to raise their level to that of more developed countries. Efficient city logistics is a means to achieve this aim. In a country where the population is relatively young and rapidly growing, the necessary pace of growth is very high. In an open economy, the direction and pace of development are also dependent on factors beyond the scope of India's policy makers.
- c) Sustainable development. The tension between social/economic development and environmental/ecological concerns has already been mentioned in the previous section.

Importance of sustainable transport

A transport system is sustainable if “it contributes to economic growth and social equity without systematically increasing concentration of substances in the atmosphere and degrading nature.” [5, page 697]. Urban freight transport movements are a subset of all transport movements in a city, both passenger and freight. To give an example, estimates from the European Union from the beginning of 2000 are as follows. UFT had a share of 18% in terms of kilo meters driven in an average city. UFT was responsible for 31% of the energy use and 31% of the emissions in the year 2005 [7]. The share of UFT is thus disproportionate. Yet, the world is not the same as two decades ago. Logistics has changed considerably, both regionally (development of regional or city distribution centers) and well as at the street level (the infamous last mile). Internet ordering and home deliveries are on a steep growth path, partially replacing conventional shopping at retail stores. Technology has also changed in response to higher emission standards by the government (EU, national and local regulation) like environmental zoning and restricted access for delivery vehicles. Demands from business customers are also rising. Green transport has become a marketing tool as well. These demands and the requirement from transport operators to reduce operating costs (fuel and maintenance) have helped to increase energy efficiency of modern engines and to reduce emissions to the air to a very low level. For engines relying on conventional (fossil) fuels, Euro-6 is the current top tier. With fossil fuels, CO₂-emissions remain a major problem. To deal with these, electrification of UFT is a likely route. In some cases combined transport might work as well. Noise abatement has also been successful. This allows delivery in mixed-use zones and during off-peak hours and nights.

In developed countries, UFT frequently takes place with a very modern fleet of delivery vehicles. Modern logistic practices are commonplace. Both factors explain why several of these nuisances could be reduced substantially. EU countries are at the forefront of this development. Less developed countries face a much more complex situation. Probably many of the following statements hold: Operators may use outdated delivery vehicles. Emission standards may be lagging far behind the technology frontier, not available or hard to maintain. At the same time (freight) traffic is growing rapidly. Traffic regulation is frequently difficult. Logistic practices are very traditional and inefficient. Tailpipe emissions and noise emissions are probably high. Finally, the combined impact of traffic and other emission

sources, like (home) industries, agricultural practices etc. explains why cities like New Delhi, Beijing and Shanghai suffer from large-scale air pollution and smog.

4.2.3. CL Impacts on the Triple Bottom Line

Economic impacts

Goods delivery and pick-up can be regarded a micro-, meso- and macro-economic level. At the micro level, a city logistics operator intends to deliver ordered goods on time at the required location. *Accessibility, average speed, reliability* and *delivery costs* are thus important KPI's in city logistics. By keeping logistic costs down, goods prices stay attractive for buyers. This stimulates demand for goods and services, which in turn stimulates investments and development of economic sectors (meso impact). This in turn contributes to economic development and to the tax income of the government (macro-economic impact).

With a growing number of people living in cities, both passenger and freight transport will grow substantially. The city's government may spend part of the *tax income* on *infrastructure* in order to keep the economy on its growth path. However, if these investments cannot keep up with the growth in traffic, then traffic intensity rises. Then *congestion* starts or becomes worse. This makes it more difficult to deliver goods on time etc. A negative cycle may start. Economic development may slow-down. Companies and people may migrate to less congested areas. Congestion also leads to an increase of certain emissions (e.g. of CO).

Social impacts

City logistics has an important social impact as well, both positive and negative. A positive impact is that city logistics provides many jobs, either directly or indirectly. Having a job means a higher standard of living and more diverse spending opportunities (on education etc.). Another positive impact is that efficient city logistics allows people to consume a wider range of goods. The negative social impacts of city logistics refer to the externalities: air pollution, noise and *safety hazards* (citizens are hurt or killed on the road or as bystander). City logistics is also a source of visual intrusion, damage to buildings and infrastructure. All these impacts can be translated into monetary terms. Since not everyone is affected in a similar manner, there is also an aspect of *social imbalance (equity)* involved.

Environmental impacts

City logistics takes place with motorized and non-motorized vehicles and equipment. In most cases roads are used to transport the goods, but there are also examples where inland waterways and railways are used to ship goods in and out of cities.

A growing use of motorized transport vehicles leads to a growing use of (fossil) fuels. This has many negative environmental impacts. One of these is the depletion of natural resources. The emission of CO₂ contributes to *climate change*. Mining and production of conventional vehicle fuels damages and pollutes the environment as well. *Air pollution* with NO_x, CO, PM₁₀ and SO₂ is also a well-known side effect of the use of (fossil) fuels in engines. Particles smaller than PM₁₀ result from the wear of tires and brakes.

There are also other environment effects, for instance a dissection of the (rural) landscape, loss of green areas, etc. *Contamination of land* with toxic or other hazardous materials may occur during production, maintenance and use of vehicles (e.g., loss of fluids, wear of brake pads). It may also occur during construction, maintenance and use (e.g. run-offs) of infrastructure. Finally, there is *waste* produced during the lifecycle of vehicles and infrastructure.

4.3. Additional Contextual Factors for Delhi

4.3.1. Policy on Urban Development and City Logistics

India's population is growing rapidly. New Delhi is India's second largest metropolis, after Mumbai. Delhi's population was 9.4 million in 1991. It is already over 19 million people at the beginning of 2017 and expected to rise towards 25 million (40%) by 2020 [9].

This population growth can be explained by a combination of factors. Two of them stand out in our opinion. First, a growing number of people want to live in urban areas, because they offer better living conditions, education facilities, (better) jobs, and better transport networks than non-urban areas. Migration from other states within India is the major reason for the strong population growth of New Delhi. Every year 200,000-300,000 people become a

permanent resident of New Delhi. Metropolitan areas like New Delhi also attract many temporary visitors, most notably tourists and business people.

Second, the Government of National Capital Territory of Delhi (GNCTD) has improved the road and rail infrastructure, education facilities etc., which improve the economic structure and -climate in the city. More jobs go hand in hand with more passenger and freight transport and -traffic in and around the city.

India's Central Government considers city logistics as an important enabler of urban development. It has to achieve objectives in the following six areas [8; page. 57]:

- Efficiency objectives: high quality of transport services at a low cost.
- Economic objectives: provide income, mitigate prices, give India's companies a certain market share and create business opportunities.
- Road safety objectives: minimize or reduce the number and severity of traffic accidents.
- Environmental objectives: reduce air pollution, noise, risk, physical hindrance and vibration, manage use of space and reduce the contribution to climate change.
- Infrastructure objectives: mitigate cost of construction and maintenance of infrastructure.
- Urban structure objectives: Protect urban heritage in and outside cities.

4.3.2. Transport Vehicles, Air Quality and Air Pollution Abatement

The number of registered vehicles more than tripled from 2.2 million to 7.6 million between 1994 and 2016 [10] in New Delhi (details given in *Appendix 1*). A growing number of people, activities and more traffic is a recipe for an increase in externalities, unless mitigating policies are put in place. Air pollution is a very serious problem in New Delhi and Transport is attributed as a major cause (most recent pollution data given in *Appendix 2*).

The GNCTD has implemented instruments to curb the problem of air pollution [11]:

- Public awareness campaigns;
- Prescription of catalytic converters;
- Enlargement of mass rapid transport systems using electricity or CNG;

- Phasing out of old (> 15 years) commercial vehicles. This relates to autos and taxi's driven on conventional fuels and buses driven on Diesel. Fiscal incentives (subsidy arrangement) are used to stimulate this phasing out;
- Introduction of emission standards for new vehicles; First introduced in 1991, tightened in 1996 and 2000. Current standard is Bharat Stage IV/Euro IV for 4 or more wheelers in Delhi and other major metropolitan cities. In contrast, the European Union prescribes Euro 6 for new vehicles;
- A complete phase-out of leaded petrol
- Introduction of Low Sulphur Diesel and Low Benzene Petrol;
- Broadening of the emissions test procedure (with CO, HC, oil temperature & RPM measurement for Diesel vehicles);
- Instalment of improved emission measurement equipment at vehicle maintenance centers

4.3.3. Developing Country Challenges

There are a few important challenges to consider that are typical to developing countries. First, there is the problem of non-compliance due to the high share of the informal sector in the local economy and cultural practices. Another factor is the high cost of replacement of vehicles, etc. Second, many measures have been introduced quite late or in moderate form compared to Europe or the USA, where air pollution has never been at the level of New Delhi. Third, the growing numbers of vehicles and kilometers driven have counteracted the achieved reduction in air pollution per average vehicle. Fourth, emissions are measured at a very small number of measurement points and not for an extensive period of time, hence the collected emission data are not representative for the whole city or a whole year. Still, the available data indicate that emissions of PM_{2.5}, which is a critical parameter for the health impact of air pollution, are 100-300 mg per m³ at three monitoring stations. This translates to a 'normal' situation where the emission standard is exceeded by 4-10 (data Oct 2013- Jan 2014) [12].

Measuring performance is important and problematic at different levels. At the lowest level of interest, traffic data and in particular logistic data are scarce and not collected on a regular basis, mainly due to lack of regular funding [6]. This leads to a situation where available

public policies are based on scattered, incidentally available historic data, either locally collected or from other cities or even countries (in other parts of the world). This limits the practical value of such data. One may speak of ‘rules of thumb or expert guesses’. Generalization or extrapolation of such data is of limited use.

4.4. SCL – A Review of the Literature

4.4.1. Introduction

In this section the results are presented on relevant methods and parameters used or suggested by different studies to determine the performance of city logistics in (comparable) other cities around the world.

Three sub-questions were used to structure this section:

1. What can be learned from other researchers working in the area of city logistics about measurement, estimation and analysis of logistics practices in other cities all over the world?
2. What were the pros and cons of their approaches?
3. Can these approaches (with some amendment) also be applied to New Delhi?

The literature review has been carried out keeping above questions in mind and is accordingly discussed in the next sections.

4.4.2. Literature on Criteria, Indicators and Frameworks

Nicolas, *et. al.* [16] carried out a study for Renault in the city of Lyon, the second largest city in France, to compare different transport strategies within an urban area; between different urban contexts and through time. Goods and non-daily trips account for 45% (51% in rush hours) of total vehicle * kilometers in Lyon city. They distinguished three dimensions of sustainability and discussed feasibility and usefulness of indicators. With respect to data about emissions in a city, the authors mention that these come from multiple sources; hence no general (city) data can be used. In order to find the mobility-related emissions, it is necessary to concentrate on trip-related data. It is important to realize that O-D data don't give detailed information about the itinerary. This means that a traffic assignment model is needed to provide that level of detail. A second study in this area was by Jeon, *et. al.* [17].

This policy-oriented study compares sustainability policies in many states of the USA. It contains definitions, a framework and indicators. These are at a very high-level, not operational. Haghshenas, *et. al.* [18] provides a comparison of “world cities” by means of indicators. The intent is to deal with transport in general. The authors define composite indices and use a Z-score to normalize the indicators (weights). They distinguish four sustainability indicators: ITE = Environmental composite index, ITC = Economical composite index, ITS = Social composite index, IOST = Overall sustainable transport composite index. The data collected allowed a comparison of cities worldwide. Meers, *et. al.* [19] distinguish between 85 indicators for passenger and freight transport in Deinze (Belgium). Regarding freight transport, the authors mention modal split, vehicle type, efficiency, fleet, energy consumption, emission standards and emissions (PM10, PM2.5, NOx, and GHG), safety. Guerlain, *et. al.* [20] describe the use of a GIS to model complex urban freight situations including last mile deliveries. The tool has been used in several workshops in European cities. Data was collected about population, economy, freight transport networks, access restriction, transport facilities, urban logistic spaces. Public GIS data was limited, hence the authors decided to complement this data with their own background research. The benefit of GIS system is that it allows layering and integration of multiple data sources. The results are shown in GIS maps. A nice example is a map that shows where weak spots in services exist, such as a lack of electric charging points or pick-up points. Toilier, *et. al.* [25] carried out a study about passenger transport movements and city logistics in the Paris region. The survey involved all the logistic companies (at 1200 establishments) and their activities in city logistics. A self-administered driver-deliverer survey was employed to identify the main LSP’s. Ducret, *et. al.* [26] in a similar application which evaluates and develops guidelines to improve UFT management [24]. Policy goals found in all these cases were attractiveness, sustainability and economic competitiveness. Ducret, *et. al.* [26] found 8 criteria to be critical:

- Formalisation of freight policy;
- Quantitative diagnosis;
- Public-private consultation or partnership;
- Political support and commitment;
- Traffic and parking regulations and the efficiency of the control system;
- Urban planning regulations;

- Delivery bays (number, location, design);
- Human and financial resources are allocated in the policy.

Zheng, *et. al.* [21] propose guidelines for the development of a composite index called TISP (Transport Index for Sustainable Places) for the USA. The paper discusses the way to select indicators, requirements and construction of a composite index, explore existing rating systems. A key issue is that sustainability is difficult to operationalize due to conflicting goals. A key issue with the index is how to weigh the components (equal, MCA-AHP?). This depends on the policy goals and objectives. The work of Ambrosini, *et. al.* [22] is an international comparison of UFT studies and surveys. Despite logical differences in approaches and methods, the authors see similar economic and environmental trends emerging worldwide. It is important to realize that although UFT problems are rather similar between countries, the definition of UGM differs per country. This is related with the way city logistics is treated in policy-making. There is also a difference in the local versus regional dimension of problems and solutions. Their exploration of various countries is about impact of policies, without quantification. Zenezini, *et. al.* [23] discuss UFT initiatives and the barriers that pilot projects frequently fail to pass before they can expand to a scale that allows optimization of UFT activities. The paper contains a classification of existing assessment methodologies based on scope and methods. The paper discusses pros and cons of these methodologies. It contains definitions, research gaps, methods and future trends. According to the authors, UFT is about measures (public and private), stakeholders (shippers, receives, carriers, citizens, authorities) and impact area (economical, social and operational). They mention that the 4-step modelling approach overlooks the tour-based nature of urban commercial traffic (multi-stop trips). Analysis is time and data intensive. They suggest aggregation and probabilistic methods using a limited percentage of the tours. The paper continues with a discussion of agent-based methods: agents interact; they have different with objectives and decision-making attributes. Now the analysis is about changing patterns. This requires significantly less data for simulation, but the interactions have to be modelled.

Bader [24] contains an extensive overview of tools developed worldwide by and for sustainable urban transport experts. Although mainly devoted to non-freight movements and

impacts it makes a reference to a Green Trucks Toolkit by Clean Air Alaska (see also [7]). The environmental toolkits, or at least their criteria, could also be used for freight transport.

4.4.3. Discussion

The development of a framework with consistent criteria and indicators is a basis to compare local UFT policies and to carry out an overall assessment of such policies. This is a departure from the past approaches, which were fragmented/ partial, while non-comparable criteria and indicators were used. With the new indicators cities can evaluate their own policies, compare their (planned) policies with those by other cities and improve the efficiency of their own local policies. The main users of the framework will likely be local engineers and transport specialists, policy auditors, freight transport operators. The research methods included case studies and stakeholder analysis. The use of a limited list of criteria improves time- and resource efficiency. The current practice of very different local policies and instruments, lack of harmonization and consistency affects UFT operators negatively. The urban logistic function should be clearly identified in the technical departments of the government; technical experts should act as contact point for stakeholders. In this way the government becomes aware of their needs.

The recent initiative by the Indian government to initiate a Sustainable Urban Transport Project (GEF-SUTP) headed by the Ministry of Urban Development [27] is also a step in that direction. This document deals with passenger transport, but part of the data collected is also relevant for UFT, in particular the city characteristics (demography, traffic and travel characteristics, travel demand forecast, road network characteristics, stakeholder analysis).

4.5. Proposed Metrics for SCL

Taking into account our findings from the inventory of the literature and with the aim to arrive at a reasonably complete but manageable list of indicators to measure New Delhi's performance in the area of SCL, we arrived at the list of indicators has been arrived as presented in Table 4.1 which also included suggested units and sources for measurement. The survey has been proposed to conduct among all the local authorities and policy makers, freight operators and experts through a predesigned questionnaire are given in *Appendix 3*.

Table 4.1: List of Indicators to Measure New Delhi's Performance in the area of SCL

Category	Indicator	Parameter [unit]	Notes on Data and Sources
Economic - General transport system	Level of road infrastructure	Road infrastructure density [lane-kms/km ²]	GIS/Statistics: Road and lane length [km] GIS/Statistics: City area [km ²] Source: urban planning agency, transport agency
	Availability of intermodal transport access	Number of intermodal hubs according to type (rail, inland waterway, sea, air) [#]	GIS/Statistics: Counts of intermodal hubs within urban area from transport agency
	Cost of congestion	Average congestion delay [veh-hours/year]	Calculate using traffic model: compare travel time of 10 kms during peak-hour and free flow
	Road quality	Percentage of road undergoing maintenance per year [%]	Statistics: Road length undergoing maintenance [km] Statistics: total road length [km]
	Financial health	Transport budget [RP]	Finance department
Economic – logistics service quality	Level of service for roads	Mean speed of freight vehicles [km/h]	Survey: mean travel time for 10 km trip
	Reliability of travel time	% trips deviating from mean travel time	Survey: Mean travel time deviation according to the deviation categories
	Costs of transport services/ Total costs of delivery	Mean costs (fixed and running costs) per deliveries	Survey: Total costs for delivery (using activity-based accounting approach and total cost of ownership) Survey: Total number of deliveries
	Accessibility for freight vehicles	Percentage of accessible roads per vehicle category [%]	GIS/statistics: Vehicle access road length GIS/statistics: Total road length
Environmental	Greenhouse gasses	Well to wheels GHG emissions for UFT [ton-CO ₂ eq/year]	Statistics/traffic model: Fuel used per vehicle category
	Energy efficiency	Total energy used according to freight traffic volume [MJ/ton-km]	Statistics/traffic model: Freight traffic volume [ton-kms] Statistics/traffic model: Fuel used per vehicle category
	Air pollution	Total emissions of air pollutants (PM10, NOx) [kg/year]	Statistics/traffic model: Fuel used per vehicle category
	Urban area used for UFT	Percentage of urban area used for UFT out of total city area	GIS/statistics: Area for direct (road, rail, inland ports/water ways) indirect: parking, warehouse, loading bay, logistic center. GIS/statistics: Total city area
Social	Traffic safety	Injuries and fatalities involving freight vehicles [#]	Traffic safety statistics
	Jobs	Employment in city logistics (#)	Employment statistics

In the Table 4.1, the “total costs of delivery” under Economic - logistics service quality has been given which includes handling and storage costs as part of the activity based accounting mentioned in the rightmost cell. With the perspective of city logistics, storage costs are a part of total logistics costs. However, our present model and measurements are not directed at logistic optimization for shopkeepers. The focus of the present study is descriptive, i.e. to capture all the freight traffic in the city (not just retail) and assess its impacts on the environment. However, a next step could be to provide more logistical detail in order to extend the focus towards an explanatory model. This would need to include additional surveying of shipment sizes and frequencies, shop locations with land prices, etc.

References

- [1] Behrends, S., Lindholm, M., Woxenius, J., 2008. The impact of urban freight transport: A definition of sustainability from an actor’s perspective, *Transportation Planning and Technology*, 31 (6), pp. 693-713.
- [2] World Commission on Environment and Development (WCED), Oxford UP, 1987.
- [3] Robinson, J., 2004. Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics*, 48, pp. 369-384.
- [4] UNDP, 2007. The United Nations Development Agenda, <http://www.un.org/esa/devagenda/UNDA1.pdf>.
- [5] Merchán, D.E., Blanco, E.E. and Bateman, A.H., 2015. Urban metrics for urban logistics: Building an atlas for urban freight transport policy makers, paper presented at 14th International Conference on Computers in Urban Planning and Urban Management CUPUM 2015, July 7-10, 2015, Cambridge, MA USA.
- [6] Browne, M., Allen, J., Woodburn, A., Patier, D., Routhier, J. L., & Ambrosini, C. (2007, June). Comparison of urban freight data collection in European countries. In Proceedings of the 11th World Conference on Transport Research, Berkeley CA, USA.
- [7] Dablanc, L., 2009, Freight transport for development toolkit: Urban freight, World Bank TRS and DFID, report no. 57971, Washington DC.
- [8] Government of India, Ministry of Urban Development & UNDP, Urban Freight Transport Planning and Management, Development of Toolkits under the “Sustainable Urban Transport Project”, New Delhi, 2015.
- [9] Population of Delhi 2017, <http://www.indiaonlinepages.com/population/delhi-population.html>

- [10] Govt. of NCT of Delhi, Vehicular pollution in Delhi, http://www.delhi.gov.in/wps/wcm/connect/doit_transport/Transport/Home/Pollution+Control/Vehicular+Pollution+in+Delhi.
- [11] Govt. of NCT of Delhi, http://www.delhi.gov.in/wps/wcm/connect/doit_transport/Transport/Home/Pollution+Control/Steps+Taken+by+Delhi+Govt.+to+reduce+the+Pollution+in+Delhi.
- [12] Delhi needs policy for air pollution, Times of India, Feb 6, 2014. <http://www.hindustantimes.com/delhi-news/air-pollution-new-epca-plan-to-cut-pm2-5-levels-in-delhi-by-70/story-m43bCoJ12N7RYnhmeGPn2I.html>
- [13] Behrends, S., 2011, Urban freight transport sustainability – The interaction of urban freight transport and intermodal transport, PhD Chalmers University of Technology, Gothenburg, Sweden.
- [14] Lammgard, C., Hagberg, J., 2013, Designing for sustainable logistics in urban areas – What do we know?, *Proc. 13th World Conference of Transport Research (WCTR)*, July 15-18, 2013, Rio de Janeiro, Brazil.
- [15] Kin, B., Verlinde, S., Macharis, C., 2017, Sustainable urban freight transport in megacities in emerging markets, *Sustainable Cities and Society*, 32, pp. 31-41.
- [16] Nicolas, J.-P., Pochet, O., Poimboeuf, H., 2003, towards sustainable mobility indicators: application to the Lyons conurbation, *Transport Policy*, 10, pp. 197-208.
- [17] Jeon, C.M., Amekudzi, A., 2005, Addressing sustainability in transportation systems: Definitions, indicators, and metrics, *J. Infrastructure Systems*, 11(1), pp. 31-50.
- [18] Haghshenas, H., Vaziri, M., 2012, Urban sustainable transportation indicators for global comparison, *Ecological Indicators* 15 (2012), 115-121.
- [19] Meers, D., Hermans, E., Buldeo Rai., H., Lier, T. van, Shen, Y., Macharis, C., 2016, Using indicators to disentangle the transport-related sustainability of a city, paper presented at Vervoerslogistieke Werkdagen (congress), Mechelen, 2016.
- [20] Guerlain, C., Cortina, S., Renault, S., 2015, Towards a collaborative geographical information system to support collective decision making for urban logistics initiative, *Transportation Research Procedia*, 12 (2016), pp. 634-643.
- [21] Zheng, J., Garrick, N.W., Atkinson-Palombo, C., McCahill, C., Marshall, W., 2013, Guidelines on developing performance metrics for evaluating transportation sustainability, *Research in Transportation Business & Management*, 7 (2013), pp. 4-13.
- [22] Ambrosini, C., Routhier, J.L., 2004, Objectives, methods and results of surveys carried out in the field of urban freight transport: An international comparison, *Transport Reviews*, January 2004, 24 (1), pp. 57-77.

- [23] Zenezini, G., De Marco, A., 2016, A review of methodologies to assess urban freight initiatives, IFAC-Papers On Line 49-12 (2016), 1359-1364.
- [24] Bader, N., 2014, Tools for sustainable urban transport experts, GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Germany.
- [25] Toilier, F., Serouge, M., Routhier, J.-L., Patier, D., Gardrat, M., 2016, How can urban goods movements be surveyed in a megacity? The case of the Paris region, *Transportation Research Procedia*, 12 (2016), 570-583.
- [26] Ducret, R., Diziain, D., Plantier, Th., 2016, Proposal for an evaluation grid for analysing local public urban freight policies: strengths, weaknesses and opportunities for French cities, *Transportation Research Procedia*, 12 (2016) 105-118.
- [27] Delhi IMTS Ltd., TRL UK, DINTS, Kimley-Horn Consulting & Engineering India Pvt. Ltd., 2016, Delhi National Urban Transport Helpline (NUTH), Operations Document for the Ministry of Urban Development.
- [28] Rogers, P., Karolin Kokaz, 2000, Transportation and Environment: Problems in Delhi and Beijing. www.seas.harvard.edu/TransportAsia/Presentations/UCeSept28.pdf.
- [29] Indian Institute of Ecology and Environment (IIEE), Environmental policy and institutional provisions in India, www.ecology.edu.pdf.
- [30] Anand, N. (2015). An Agent Based Modelling Approach for Multi-Stakeholder Analysis of City Logistics Solutions. PhD Thesis Delft University of Technology, Delft: TRAIL Research School.

5. LOGISTIC METRICS FOR CITY OF DELHI

5.1. General

As mentioned in the previous sections, one of the objectives is to develop logistics metrics for city of Delhi and also develop a freight travel demand model. In that direction, the first and foremost task is to collect the necessary data and a database needed to be created by collecting freight travel behaviour data, road network, economic data etc. For this purpose, a number of traffic surveys have been proposed to be carried out. The details of the field studies carried out in the present study are explained in detail in the following section.

5.2. List of Field Surveys

Keeping the objectives of the study in view, the following traffic surveys have been undertaken in the present study:

1. Outer Cordon Traffic Survey

This survey would be to estimate the quantum of traffic entering or exiting city of Delhi and the share of freight traffic

2. Origin-Destination Survey at Outer Cordons

This survey would be to collect the travel behaviour of freight traffic entering or exiting city of Delhi so as to develop OD matrix

3. Focal Point Survey at Commercial Areas/ Market Places

This survey would be to collect the travel behaviour of freight traffic plying within Delhi so as to develop OD matrix

4. Journey Speed Survey on Arterial Road Network

This survey would be to collect the journey speed which would be utilised in making road network and skim matrix for developing travel demand model for freight traffic

5. Mid Block Traffic Survey

This survey would be to estimate the quantum of traffic and share of freight traffic on the road network city of Delhi

The details of the above surveys and data collected have been described in the following sections.

5.3. Speed Data

In order to collect the prevailing speed on the road network on city of Delhi, the first step is to identify the road network where freight vehicles usually ply on it. Accordingly this road network where freight traffic primarily plies has been identified and shown in Figure 5.1. This network has been divided into different stretches and the details have been given in the Table 5.1. From the Figure 5.1 and Table 5.1, it can be observed that the major arterial road network has been selected in terms of circular and radial roads and total selected road network is about 418 km. The speed survey has been carried out using VBOX equipment as shown in Figure 5.2.

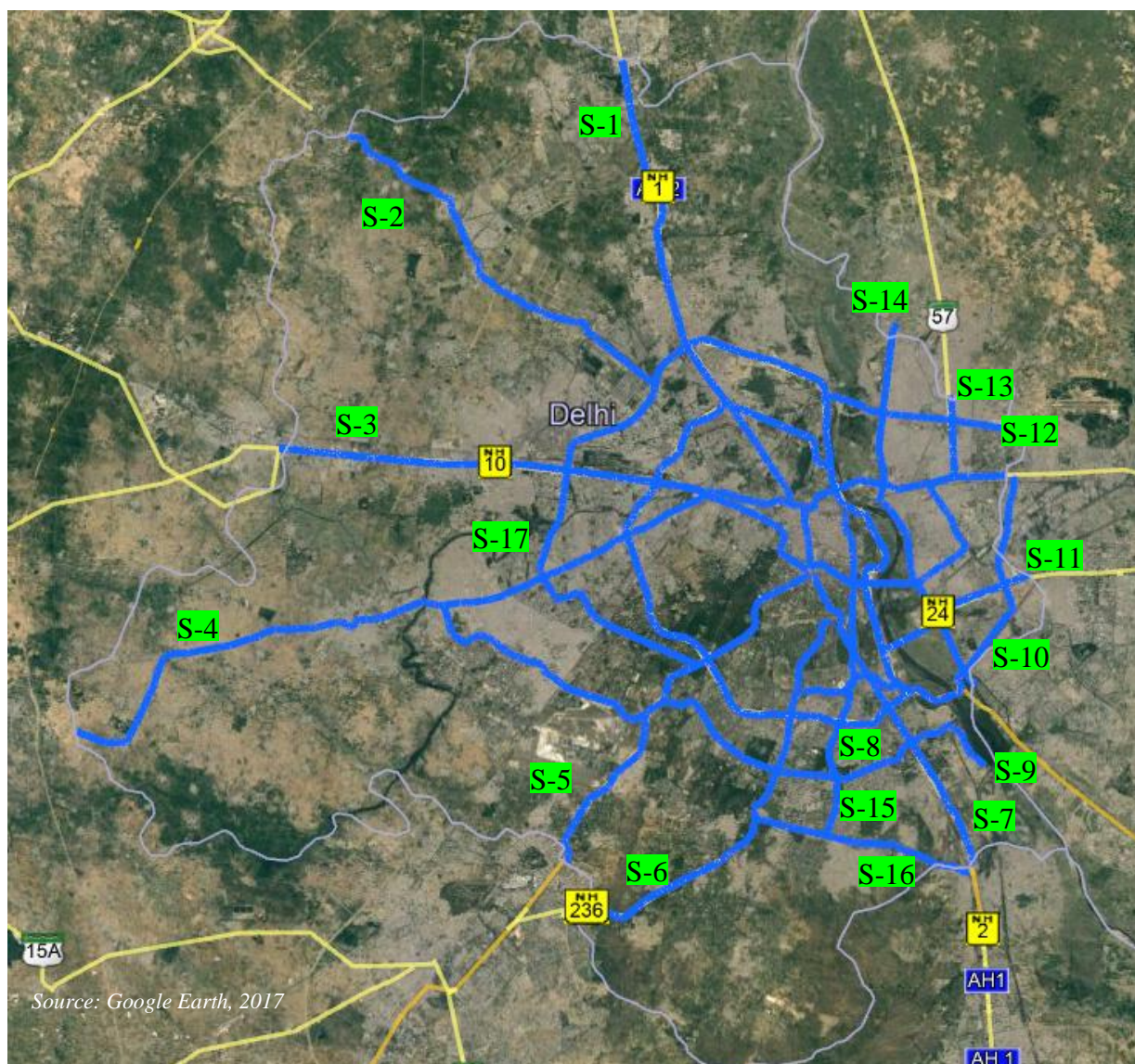


Figure 5.1: Selected Arterial Roads for Journey Speed Data Collection

Table 5.1: Selected Stretches for Journey Speed Data Collection

S. No	Stretch Code	Name of the Stretch	Length (Km)
1	S-1	Tees Hazari to Kundli	28.90
2	S-2	Prashant Vihar (Ring Road Crossing) to Ferozpur Bangar	20.57
3	S-3	GT Road Shahadara to Bahadurgarh (Tikri Border)	36.94
4	S-4	Dhansa (Najafgarh Road) to Rajeev Chowk (Connaught Place)	43.05
5	S-5	Rajokri Border (Delhi-Gurgoan Expressway) to Rajeev Chowk	18.10
6	S-6	Arjan Garh (Aya Nagar Border) to Aurobindo marg	19.46
7	S-7	Badarpur Border to Rajeev Chowk (Connaught Place)	17.78
8	S-8	Inner Ring Road (Ashram Chowk to Ashram Chowk)	47.81
9	S-9	Outer Ring Road (Kalindi Kunj Border to Dwarka Mor Metro Station)	33.76
10	S-10	GT Road Shahadara to INA (via Gazipur, DND, Barapulla Elevated Road)	20.65
11	S-11	Ghazipur to Nizamudding Bridge	7.90
12	S-12	Wazirabad Road to Mandoli Border	9.80
13	S-13	Loni Border to Old Delhi Railway Station (via Vikas Marg, Sadar Bazar)	21.10
14	S-14	Bhagpat Road to Chilla Border	18.80
15	S-15	Khanpur Junction to Kashmere gate	18.41
16	S-16	Badarpur Border to Lado Sarai	15.26
17	S-17	Outer Ring Road (Station Road to ISBT)	39.65
Total			417.94



Figure 5.2: VBOX Equipment used for Journey Speed Data Collection on Selected Corridors

The VBOX equipment has been fixed in the subject vehicle (car) and travelled with traffic stream especially in the peak hours to know the prevailing journey speeds in those periods. The journey speed data of the traffic stream has been collected for the stretches that are shown in Table 5.1. The VBOX equipment records the position of subject vehicles in terms of latitude in each time interval and longitude and journey speed has been calculated from distance and time. The collected journey speed data has been analysed in the direction wise for different stretches is given in *Appendix 4*. The typical journey speed data for Inner Ring

Road (Stretch S-8) for up and Down directions is given in Table 5.2 and 5.3 respectively. The Summary of average journey speeds and travel times of the entire selected road network is given in Table 5.4 and Figure 5.3 respectively.

Table 5.2: Observed Journey Speed on Inner Ring Road (S-8) in Up Direction

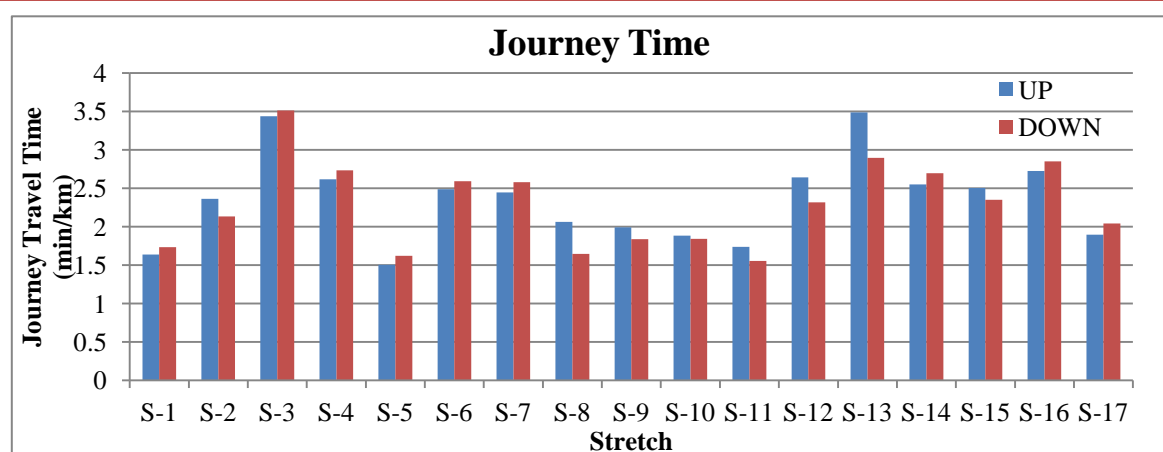
S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Maharani Bagh to Vikas Marg	3.83	29.26
2	Vikas Marg to Rose Garden	3.48	24.73
3	Ross Garden to Vijayghat	0.75	53.56
4	Vijayghat to Indira Gandhi IT	2.76	29.11
5	Indira Gandhi IT to Matkaf Metro Station	1.98	22.29
6	Matkaf Metro Station to Naya Azadpur	0.99	15.69
7	Naya Azadpur to Pitampura	6.61	20.95
8	Pitampura to Britania Chowk	2.11	53.48
9	Britania Chowk to Punjabi Bagh Chowk	3.60	14.01
10	Punjabi Bagh Chowk to Punjabi Bagh Bus Stop	0.64	12.03
11	Punjabi Bagh Bus Stop to Sardana Eye Institute	2.42	24.90
12	Sardana Eye Institute to Army Medical College	4.59	32.53
13	Army Medical College to Sardar Patel Marg	3.48	32.51
14	Sardar Patel Marg to Safdarjung	3.68	20.77
15	Safdarjung to AIIMS Metro	1.90	52.32
16	AIIMS Metro to Moolchand Metro Station	2.54	26.21
17	Moolchand Metro Station to Ashram	2.59	30.12
Total		47.95	29.09

Table 5.3: Observed Journey Speed on Inner Ring Road (S-8) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Mathura Marg to Moolchand Metro Station	2.59	34.71
2	Moolchand to AIIMS Metro Station	2.54	15.56
3	AIIMS to Safdarjung Metro Station	1.90	40.96
4	Safdarjung to Sardar Patel Marg	3.68	35.52
5	Sardar Patel Marg to Army Medical School	3.48	43.72
6	Army Medical College to Sardana Eye Institute	4.59	50.07
7	Sardana Eye Institute to Punjabi Bagh Bus Stop	2.42	39.42
8	Punjabi Bagh Bus Stop to Punjabi Bagh Chowk	0.64	51.23
9	Punjabi Bagh Chowk to Britania Chowk	3.60	40.50
10	Britania Chowk to Pitampura	2.11	44.80
11	Pitampura to Naya Azad Pur	6.61	15.72
12	Naya Azadpur to Matkaf Metro Station	0.99	14.96
13	Matkaf Metro to Indra Gandhi I.T	1.98	24.56
14	Indra Gandhi I.T to Vijayghat	2.76	41.33
15	Vijayghat to Rose Garden	0.75	49.68
16	Rose Garden to Vikas Marg	3.40	36.38
17	Vikas Marg to Maharani Bhag	3.83	40.31
Total		47.87	36.43

Table 5.4: Summary of Observed Journey Speed on Selected Stretches

S. No	Stretch Code	Name of the Stretch	Length (Km)	Journey Speed (Kmph)	
				UP	DOWN
1	S-1	Tees Hazari to Kundli	28.90	36.70	34.66
2	S-2	Prashant Vihar (Ring Road Crossing) to Ferozpur Bangar	20.57	25.39	28.12
3	S-3	GT Road Shahadara to Bahadurgarh (Tikri Border)	36.94	17.46	17.09
4	S-4	Dhansa (Najafgarh Road) to Rajeev Chowk (Connaught Place)	43.05	22.95	21.94
5	S-5	Rajokri Border (Delhi-Gurgoan Expressway) to Rajeev Chowk (Connaught Place)	18.10	39.87	36.99
6	S-6	Arjan Garh (Aya Nagar Border) to Aurobindo Marg	19.46	24.14	23.15
7	S-7	Badarpur Border to Rajeev Chowk (Connaught Place)	17.78	24.52	23.26
8	S-8	Inner Ring Road (Ashram Chowk to Ashram Chowk)	47.81	29.09	36.43
9	S-9	Outer Ring Road (Kalindi Kunj Border to Dwarka Mor Metro Station)	33.76	30.16	32.7
10	S-10	GT Road Shahadara to INA (via Gazipur, DND, Barapulla Elevated Road)	20.65	31.90	32.58
11	S-11	Ghazipur to Nizamudding Bridge	7.90	34.58	38.62
12	S-12	Wazirabad Road to Mandoli Border	9.80	22.72	25.92
13	S-13	Loni Border to Old Delhi Railway Station (via Vikas Marg, Sadar Bazar)	21.10	17.20	20.73
14	S-14	Bhagpat Road to Chilla Border	18.80	23.52	22.27
15	S-15	Khanpur Junction to Kashmere Gate	18.41	23.98	25.53
16	S-16	Badarpur Border to Lado Sarai	15.26	22.01	21.06
17	S-17	Outer Ring Road (Station Road to ISBT)	39.65	31.65	29.42
Total			417.94	26.93	27.67

**Figure 5.3: Average Journey Time on Selected Stretches of Delhi Road Network**

From the Table 5.4, it can be observed that the journey speed is varying between 17 and 40 kmph and average journey speeds are around 27 kmph. From the Figure 5.3, the journey times are around 2.3 minutes per km which shows that the road network of Delhi city is moderately congested all the time.

5.4. Outer Cordon (OC) Traffic Volume Data

In order to achieve the envisaged objective of developing freight travel demand model, the travel behaviour data along with their vehicular data, trip data and commodity type data has to be collected. For this purpose, a questionnaire survey has been proposed to carry out to collect all the above mentioned parameters related to freight traffic. The significant amount of freight traffic enters and leaves daily city from different parts of the country, this traffic can be captured at the outer cordon locations. In the city of Delhi, there are more than 100 entry and exit locations from which the freight traffic can enter and exit from the adjoining states namely Utter Pradesh and Haryana. However, about 95% of the freight traffic enters/ exits through 10 outer cordon/ entry-exit locations and accordingly these locations have been selected for data collection purpose. The geographic locations of these points are shown in Figure 5.4. The details of these locations have been given in Table 5.5.

To collect the freight traffic volume data that are entering into or exiting from city, manual method of enumeration has been adopted in this study. The enumerators have been given sufficient training and deployed in the field to perform manual count of all the vehicles types which are entering and exiting the outer cordon location. The survey has been carried out for 24 hour duration starting from 8:00 AM to 8:00 AM and typical view of the traffic volume count survey at outer cordon location is shown in Figure 5.5. The enumeration of the traffic has been done in every 15-minute and accordingly recorded in predesigned proforma as given in **Appendix 5**. The traffic volume enumeration of vehicles has been done for all the vehicle types in order to understand the share of freight traffic in that. The typical view of traffic volume count survey at various outer cordon locations that are shown in Figure 5.4. The vehicle types mainly considered include all private vehicles, public transport, intermediate public transport, freight vehicles and non-motorised transport vehicles. The vehicles types considered for Freight Transport are given in the Table 5.6.

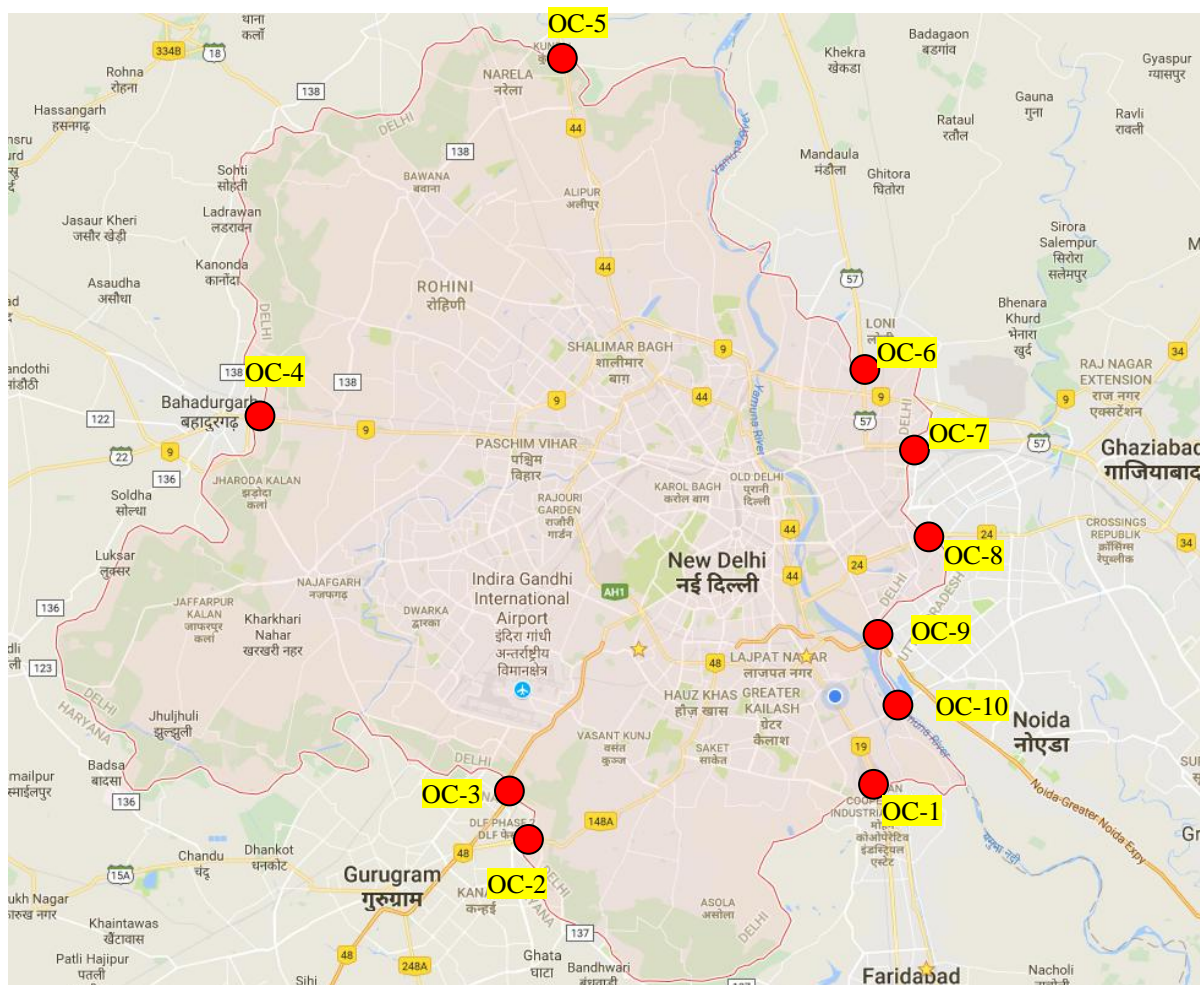


Figure 5.4: Selected Locations of Outer Cordons for Freight Traffic Data Collection

Table 5.5: Selected Outer Cordon Locations for Freight Traffic Data Collection for 24-Hour Duration

S. No	OC Code	Name of the Outer Cordon Location	Date of Survey
1	OC-1	Badarpur Border (NH -2)	10.7.2017
2	OC -2	Aya Nagar Border (Arjan Garh on Mehrauli - Gurgaon Road)	18.7.2017
3	OC -3	Rajokri Border (Delhi-Gurgaon Expressway NH-8)	26.7.2017
4	OC -4	Tikri Border (NH-10)	19.7.2017
5	OC -5	Singhu Border (NH-1)	04.7.2017
6	OC -6	Loni Border	24.7.2017
7	OC -7	Apsara Border (G.T. Road at Shahadara)	25.7.2017
8	OC -8	NH-24 Bypass (Ghaziipur)	14.7.2017
9	OC -9	Chilla Border (Mayur Vihar - Noida Link Road)	12.7.2017
10	OC -10	Kalindi Kunj Border (Sarita Vihar - Noida Road)	11.7.2017





Figure 5.5: Typical Views of Traffic Volume Count Survey at Different Locations of Outer Cordons for Freight Traffic Data Collection

Table 5.6: Selected Vehicles Types Considered under Freight Transport in the Present Study

S. No	Freight/ Goods Vehicle Type	Typical Image
1	Goods Auto Rickshaw (GA)	
2	Goods Van (GV)	
3	Light Commercial Truck (LT)	
4	Heavy Commercial Truck (HT)	
5	Multi-Axle Commercial Truck (MT)	

The collected traffic data has been analysed and the location wise hourly vehicular traffic distribution and traffic composition is given in **Appendix 6**. A typical traffic volume for 24 hour duration at Rajokri Border (NH-8) on Delhi-Gurgaon Expressway is shown in Table 5.7.

The hourly distribution of traffic volume and traffic composition at Rajokri Border (NH-8) on Delhi-Gurgaon Expressway is shown in Figure 5.6. From the Table 5.7, it can be observed that the total daily volume (24 hours) entering and exiting Delhi through Rajokri Border is in the order of 354 thousands and the peak hour is occurring in the evening between 18:00 and 19:00 Hrs with a peak volume of about 24 thousands. From the Figure 5.6, it can be inferred that about 95% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 4% mainly consist of Goods Autos, LT, HT and MT.

Table 5.7: Classified Traffic Volume at Rajokri Border

Road Name: Delhi - Gurgaon Expressway Location: Rajokri Border Date: 26.07.2017 - 27.07.2017
 Outer Cordon OC-03

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	10872	1462	40	152	64	3047	51	73	32	18	102	0	15811	102	15913	4.5%	15665
09:00-10:00	12043	2016	41	183	77	3840	71	86	12	6	81	0	18375	81	18456	5.2%	18030
10:00-11:00	10715	1916	48	154	54	3888	60	106	65	11	64	0	17017	64	17081	4.8%	16700
11:00-12:00	12291	1743	44	143	53	2877	166	215	157	32	26	0	17721	26	17747	5.0%	17979
12:00-13:00	11417	2062	29	94	23	3379	225	247	130	24	6	0	17630	6	17636	5.0%	17585
13:00-14:00	14797	2053	48	99	9	2692	284	313	118	67	1	0	20480	1	20481	5.8%	20793
14:00-15:00	11540	2289	66	103	12	3197	329	321	178	74	30	0	18109	30	18139	5.1%	18496
15:00-16:00	11611	2446	38	137	18	4417	318	241	122	63	7	0	19411	7	19418	5.5%	19354
16:00-17:00	14868	2543	39	126	49	3166	262	215	149	27	9	0	21444	9	21453	6.1%	21597
17:00-18:00	14140	2428	28	293	98	4646	117	93	32	8	13	0	21883	13	21896	6.2%	21615
18:00-19:00	15354	2236	20	234	86	5763	42	39	15	0	23	0	23789	23	23812	6.7%	22988
19:00-20:00	11456	2328	22	145	43	8085	52	41	10	6	29	0	22188	29	22217	6.3%	20606
20:00-21:00	12696	2489	23	102	17	4016	74	59	9	15	73	0	19500	73	19573	5.5%	18895
21:00-22:00	10473	1945	26	73	4	2979	75	117	25	24	93	0	15741	93	15834	4.5%	15428
22:00-23:00	9291	1652	18	37	2	1705	93	202	106	185	128	0	13291	128	13419	3.8%	14015
23:00-24:00	6520	1470	2	31	7	693	125	240	347	428	76	0	9863	76	9939	2.8%	12172
00:00-01:00	4742	1540	9	39	2	611	93	259	381	478	53	0	8154	53	8207	2.3%	10721
01:00-02:00	3096	1243	13	24	2	504	62	296	333	385	29	0	5958	29	5987	1.7%	8092
02:00-03:00	2985	1315	28	13	7	353	87	282	327	385	4	0	5782	4	5786	1.6%	7920
03:00-04:00	1601	834	6	25	18	362	67	270	254	299	0	0	3736	0	3736	1.1%	5438
04:00-05:00	2435	1387	6	76	12	597	52	222	326	233	8	0	5346	8	5354	1.5%	6970
05:00-06:00	5009	1892	14	73	12	615	34	225	303	143	52	0	8320	52	8372	2.4%	9589
06:00-07:00	7205	2191	18	96	33	862	55	123	151	45	159	0	10779	159	10938	3.1%	11420
07:00-08:00	7957	2977	16	147	52	1059	44	84	34	10	252	0	12380	252	12632	3.6%	12757
Total	225114	46457	642	2599	754	63353	2838	4369	3616	2966	1318	0	352708	1318	354026	100.0%	364826
Percentage	63.6%	13.1%	0.2%	0.7%	0.2%	17.9%	0.8%	1.2%	1.0%	0.8%	0.4%	0.0%	99.6%	0.4%	100.0%		

Peak Volume= 23812
Peak Time=18:00-19:00

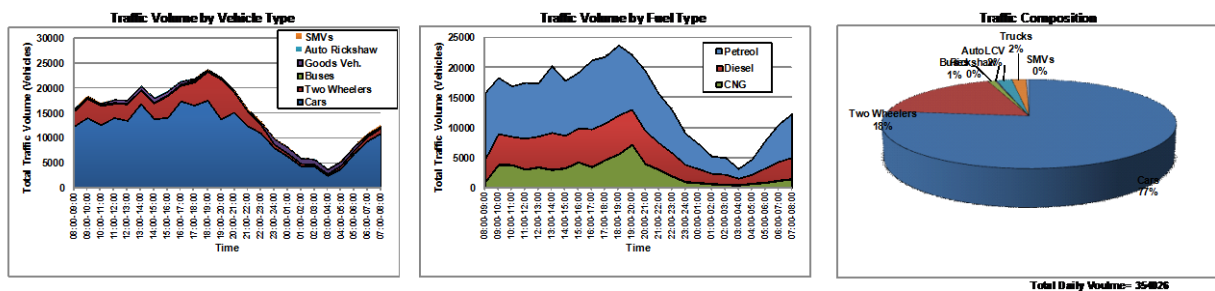


Figure 5.6: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajokri Border

The summary of all the outer cordon locations is presented in Table 5.8 and traffic composition is presented in Figure 5.7. From the Table 5.8, it can be observed that maximum number of vehicles in the order of about 354 thousands entering and exiting through Rajokri Border followed by Ghazipur Border with an entry/ exit volume of about 163 thousands and

Kalindi Kunj Border with an entry/ exit volume of about 126 thousands. From the Figure 5.7, it can be inferred that about 85% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 8% mainly consist of Goods Autos, LT, HT and MT.

Table 5.8: Summary of Classified Traffic Volume (24 hours) at Different Outer Cordons of Delhi

S. No	Outer Cordon	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Grand Total
1	Badarpur Border	31304 36.4%	16216 14.8%	15825 4.2%	1922 1.5%	763 0.6%	26380 28.5%	3753 2.8%	3754 2.8%	5369 3.2%	6221 3.3%	4123 1.5%	2910 0.4%	118540 100.0%
2	Arjun Garh (Ayanagar Border)	39688 48.3%	15668 19.1%	78 0.1%	359 0.4%	219 0.3%	24403 29.7%	357 0.4%	163 0.2%	128 0.2%	240 0.3%	718 0.9%	216 0.3%	82237 100.0%
3	Rajokari Border	225114 63.6%	46457 13.1%	642 0.2%	2599 0.7%	754 0.2%	63353 17.9%	2838 0.8%	4369 1.2%	3616 1.0%	2966 0.8%	1318 0.4%	0 0.0%	354026 100.0%
4	Tikri Border	20474 37.1%	5387 9.8%	2281 4.1%	974 1.8%	127 0.2%	17657 32.0%	1542 2.8%	2176 3.9%	1190 2.2%	1058 1.9%	1811 3.3%	451 0.8%	55128 100.0%
5	Singhu Border	25756 33.9%	19237 25.3%	1487 2.0%	1007 1.3%	525 0.7%	13829 18.2%	3304 4.3%	3085 4.1%	2812 3.7%	3319 4.4%	773 1.0%	927 1.2%	76061 100.0%
6	Loni Border	7421 10.4%	1397 2.0%	21370 29.9%	375 0.5%	183 0.3%	32100 44.9%	254 0.4%	664 0.9%	555 0.8%	123 0.2%	4666 6.5%	2456 3.4%	71564 100.0%
7	Apsara Border (Dilshad Garden)	34151 40.3%	4553 5.4%	4880 5.8%	2961 3.5%	247 0.3%	30116 35.5%	1603 1.9%	1551 1.8%	1185 1.4%	625 0.7%	1155 1.4%	1817 2.1%	84844 100.0%
8	Ghazipur Border	51534 31.6%	34695 21.3%	9567 5.9%	3390 2.1%	806 0.5%	35486 21.7%	6688 4.1%	2474 1.5%	5932 3.6%	5388 3.3%	4255 2.6%	3004 1.8%	163219 100.0%
9	Chilla Boarder	50187 49.0%	15923 15.6%	3425 3.3%	1699 1.7%	858 0.8%	24088 23.5%	1803 1.8%	1679 1.6%	1723 1.7%	708 0.7%	96 0.1%	144 0.1%	102333 100.0%
10	Kalindi Kunj Border	45808 36.4%	18596 14.8%	5237 4.2%	1891 1.5%	743 0.6%	35957 28.5%	3589 2.8%	3539 2.8%	4088 3.2%	4153 3.3%	1828 1.5%	530 0.4%	125959 100.0%

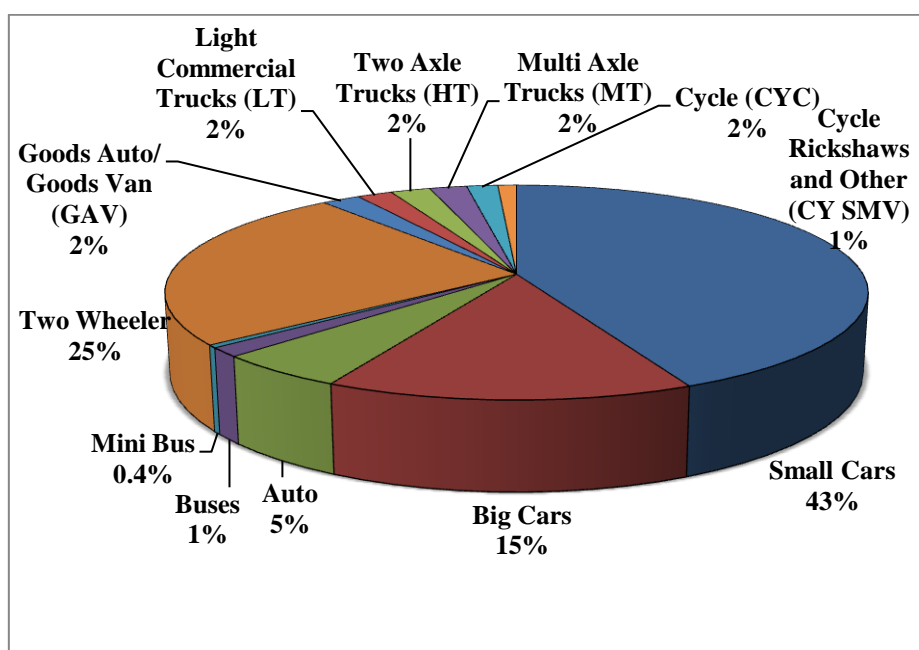


Figure 5.7: Traffic Composition at Different Outer Cordons of Delhi

5.5. Outer Cordon Interview Data

Apart from the classified traffic volume count that has been conducted at these 10 outer cordon locations, interview survey also carried out to collect the travel behaviour of the freight vehicles that are entering and exiting Delhi through these locations. The survey has been carried out using predesigned questionnaire comprising the questions related to vehicle data, trip data and commodity data. The questionnaire utilised for this survey is given in *Appendix 7*. The questionnaire survey has been carried out for 24-hour duration and collected data from the freight vehicles on sample basis. Typical views of interview survey at various outer cordon locations are shown in Figure 5.8. The sample size collected at different outer cordon locations are given in Table 5.9.

Table 5.9: Sample Size of Freight Vehicles Collected at Different Outer Cordons of Delhi (24 hours)

S. No	OC Code	Name of the Outer Cordon Location	Sample Size of Freight Vehicles		
			Entering Delhi	Exiting Delhi	Total
1	OC-1	Badarpur Border	441	459	900
2	OC -2	Aya Nagar Border	285	130	415
3	OC -3	Rajokri Border	983	208	1191
4	OC -4	Tikri Border	946	54	1000
5	OC -5	Singhu Border	580	176	756
6	OC -6	Loni Border	342	422	764
7	OC -7	Apsara Border	830	170	1000
8	OC -8	Ghazipur	428	335	763
9	OC -9	Chilla Border	521	246	767
10	OC -10	Kalindi Kunj Border	482	353	835
				Total	8391

From the Table 5.9, it can be seen that a total of 8,391 samples of freight vehicles were interviewed and collected the travel behaviour data. The data collected at the above outer cordon locations would be further analysed to understand the freight vehicular characteristics and travel behaviour of freight vehicles. The Origin and Destination (OD) data also analysed with respect to traffic analysis zones (TCZ) to assess the external travel and also to create data base primarily to estimate total freight trips and OD matrix to develop travel demand models namely trip generation and trip distribution models.



Figure 5.8: Typical Views of Interview Survey at Different Locations of Outer Cordons for Freight Traffic Data Collection

5.6. External Travel

From analysis of the roadside interview data at the selected 10 outer cordon locations, overall pattern of external traffic in the city on a normal working day along with their composition was estimated and shown in Figure 5.9. The results reveal that a total of about 1.24 million vehicles enter and leave Delhi city on normal working day which was about 1.02 million vehicles in 2009 (CRRI, 2009). From this result, it can be observed that the external traffic has grown with 3% per annum. It can also be noticed that the goods traffic forms about 10% of the total traffic with another 4% of traffic is composed of slow moving vehicles like bicycle, animal carts etc. The pattern of external freight traffic in the city on a normal working day along with their composition was estimated and shown in Figure 5.10. The results reveal that a total of about 100 Thousands freight vehicles enter and leave Delhi city on normal working day and about 21% of these freight vehicles are found to be passing through the city which was almost same in 2009 (CRRI, 2009).

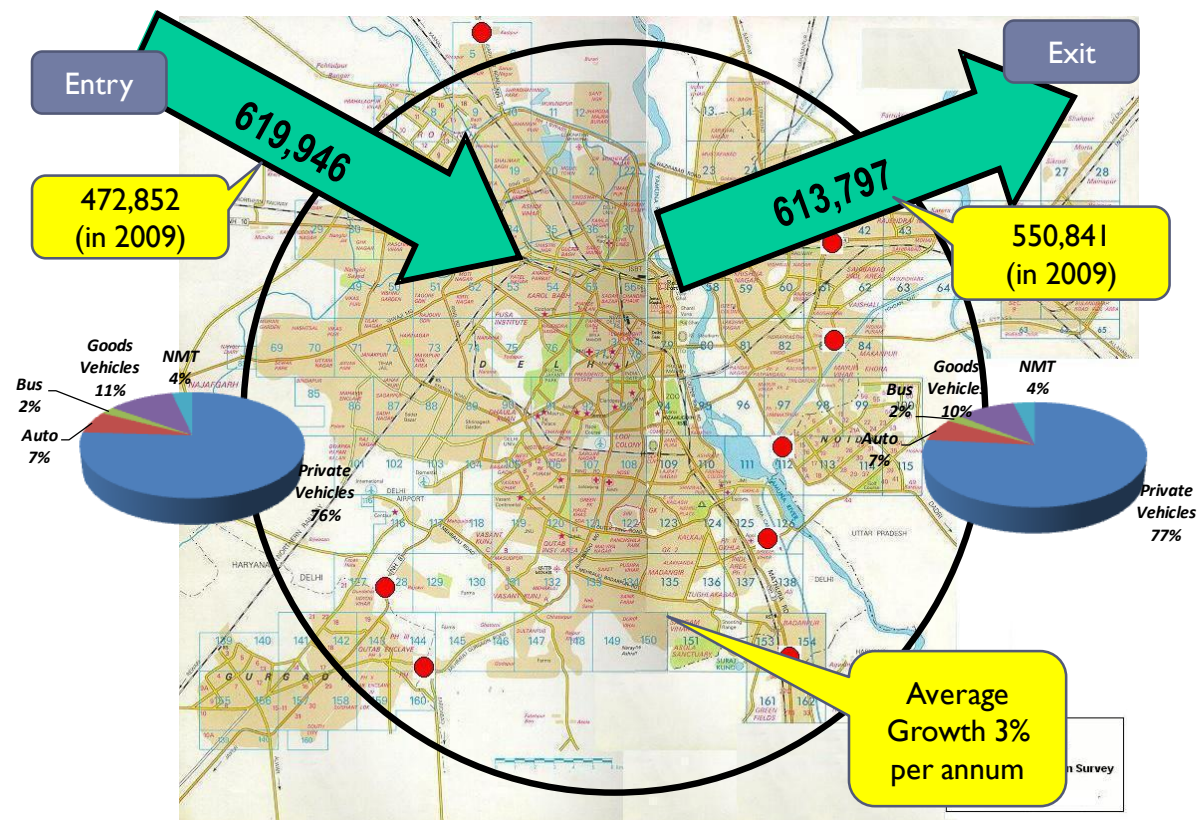


Figure 5.9: Pattern of Total External Traffic at Outer Cordons of Delhi

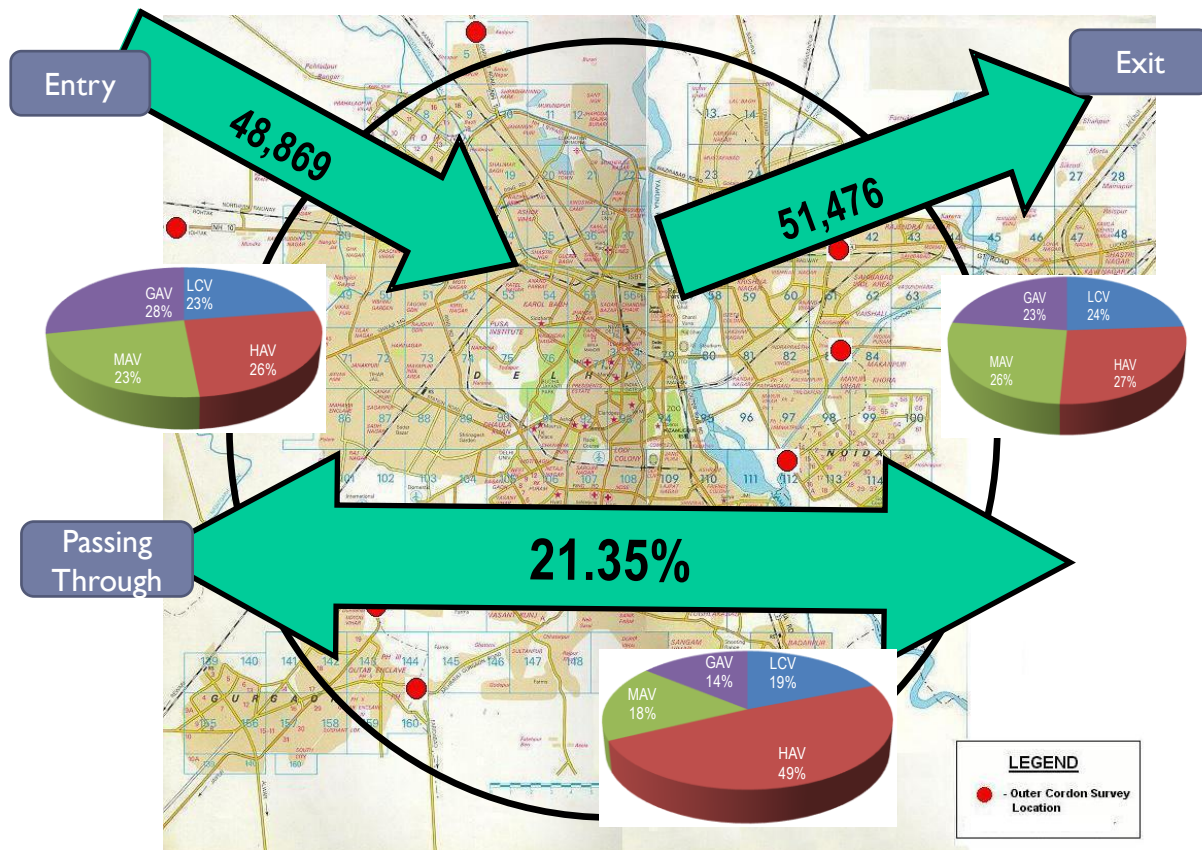


Figure 5.10: Pattern of Freight External Traffic at Outer Cordons of Delhi

From these results, it can be observed that though the total traffic increased, freight traffic remain stagnated at outer cordons because of new bypass roads come around the city of Delhi such as Noida-Greater Noida Expressway, Yamuna Expressway, Kundli-Manesar-Palwal (KMP) Expressway etc. It can also be observed that the freight vehicle types namely Goods Auto (GA), Goods Van (GV), Light Trucks (LT), Heavy Truck (HT) and Multi-Axle Truck (MT) are found at entry and exit locations of outer cordons. In case of passing through traffic, HT has almost 50% share followed by MT and LT has share of about 18% each. Smaller Goods Vehicles (GA and GV) has a share of about 14% of passing through traffic. This can be attributed to the fact that the heavy vehicles travel long distances compared to light and small vehicles.

5.7. Focal Point Freight Traffic Survey

The focal point survey has been proposed with an aim to collect travel behaviour from the freight traffic that is primarily plying within the city. The intra-city movements by various commercial vehicles can be captured in this survey. For this purpose, interview survey has been proposed to carry out at selected locations to collect the travel behaviour of the freight vehicles that are plying within Delhi. The survey would be carried out using predesigned questionnaire comprising the questions related to vehicle data, trip data and commodity data. The questionnaire utilised for this survey is given in *Appendix 7*. The questionnaire survey has been carried out for 24-hour duration and collected data from the freight vehicles on sample basis. The selected locations for this survey are given in Table 5.10. These locations have been selected considering market areas and shopping areas. The geographic locations of these points are shown in Figure 5.11.

Table 5.10: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours)

S. No	FP Code	Name of the Focal Point	Nature of Land Use/Business Activity	Date of Survey
1	FP-01	Azadpur Sabzi Mandi	Fruit & Vegetable	14.9.2017
2	FP-02	Okhla Sabzi Mandi	Fruit & Vegetable	15.9.2017
3	FP-03	Arya Pura Sabzi Mandi	Fruit & Vegetable	14.9.2017
4	FP-04	Ghanta Ghar Sabzi Mandi	Fruit & Vegetable	12.9.2017
5	FP-05	Old Delhi Sabzi Mandi	Fruit & Vegetable	16.9.2017
6	FP-06	Shahdara Sabzi Mandi	Fruit & Vegetable	18.9.2017
7	FP-07	Mandawali Sabzi Mandi:	Fruit & Vegetable	18.9.2017
8	FP-08	Shahdara	Fruit & Vegetable, Food Grains, Fodder	13.9.2017
9	FP-09	Gazipur	Fish & Poultry	19.9.2017
10	FP-10	Connaught Place	Retail Shopping areas	18.9.2017
11	FP-11	Chandni Chowk,	Retail/Whole Sale Shopping areas	14.9.2017
12	FP-12	Sarojini Nagar	Retail/Whole Sale Shopping areas	19.9.2017
13	FP-13	Lajpat Nagar	Retail/Whole Sale Shopping areas	15.9.2017
14	FP-14	Pitampura	Retail/Whole Sale Shopping areas	14.9.2017
15	FP-15	Nehru Place	Retail/Whole Sale Shopping areas	14.9.2017
16	FP-16	Gandhi Nagar	Whole Sale Shopping areas	14.9.2017
17	FP-17	Rajouri Garden	Retail/Whole Sale Shopping areas	19.9.2017
18	FP-18	Narela	Food Grain	19.9.2017
19	FP-19	Najafgarh	Food Grains	18.9.2017
20	FP-20	Keshopur	Fruit & Vegetables	14.9.2017

Note: Subzi Mandi means Fruit and Vegetable Market

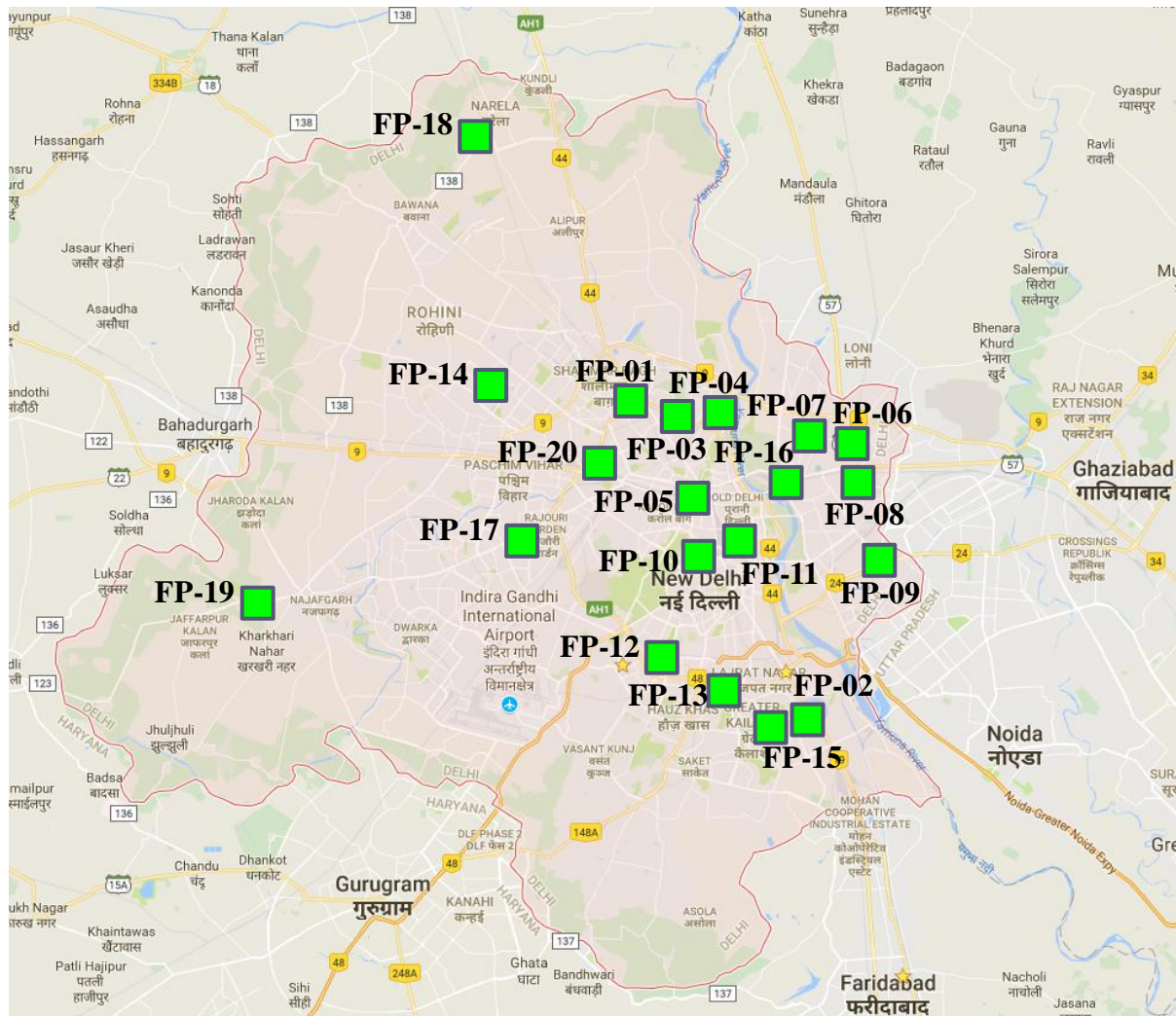


Figure 5.11: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours)

To collect the freight traffic volume data that are entering into or exiting selected focal point/market area, manual method of enumeration has been adopted in this study. The enumerators have been given sufficient training and deployed in the field to perform manual count of all freight vehicles types which are entering and exiting the selected focal point location. The survey has been carried out for 24 hour duration starting from 8:00 AM to 8:00 AM. The enumeration of the traffic has been done in every 15-minute and accordingly recorded in predesigned proforma as given in *Appendix 5*. The traffic volume enumeration of vehicles has been done for all the freight vehicle types in order to understand the quantity of freight traffic in that area. The vehicles types considered for Freight Transport are given in the Table 5.6.

The collected freight traffic data has been analysed and the location wise hourly vehicular traffic distribution and traffic composition is given in *Appendix 8*. A typical traffic volume for 24 hour duration at Azadpur Sabzi Mandi is shown in Table 5.11. The hourly distribution of traffic volume and traffic composition at Azadpur Sabzi Mandi is shown in Figure 5.12. From the Table 5.11, it can be observed that the total daily volume (24 hours) entering and exiting Azadpur Sabzi Mandi is in the order of about 7 thousands and the peak hour is occurring in the midnight between 23:00 and 24:00 Hrs with a peak volume of about 575 freight vehicles. From the Figure 5.12, it can be inferred that about 26% are consisting of Goods Autos and Goods Vans, LT is about 23% and HT and MT are 21% each. It can also be observed that Slow Moving Vehicles (SMVs) are about 9%.

Table 5.11: Classified Freight Traffic Volume at Azadpur Sabzi Mandi

Location Name: **Azadpur Sabzi Mandi** Date: **14.09.2017 - 15.09.2017**
 Focal Point Code: **FP-01**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV- Goods	Total SMV- Goods	Total Vehicles- Goods	Percentage	PCU
08:00-09:00	9	20	4	6	12	3	41	0	15	54	56	110	1.6%	222
09:00-10:00	4	25	12	12	14	4	24	0	23	71	47	118	1.7%	236
10:00-11:00	13	32	9	22	16	5	39	0	38	97	77	174	2.6%	340
11:00-12:00	7	31	2	12	5	1	18	0	31	58	49	107	1.6%	199
12:00-13:00	14	17	0	12	4	0	14	0	17	47	31	78	1.2%	140
13:00-14:00	14	7	1	3	0	0	1	0	7	25	8	33	0.5%	51
14:00-15:00	2	15	2	3	2	0	0	0	7	24	7	31	0.5%	57
15:00-16:00	2	25	1	5	2	1	2	0	12	36	14	50	0.7%	96
16:00-17:00	4	13	3	2	0	0	2	0	8	22	10	32	0.5%	54
17:00-18:00	1	16	0	2	0	0	1	0	16	19	17	36	0.5%	63
18:00-19:00	3	7	1	2	0	0	2	0	8	13	10	23	0.3%	39
19:00-20:00	0	29	0	16	18	13	3	0	4	76	7	83	1.2%	215
20:00-21:00	0	137	14	131	108	140	8	0	0	530	8	538	7.9%	1523
21:00-22:00	0	135	2	128	107	125	8	0	0	497	8	505	7.4%	1428
22:00-23:00	0	148	0	145	127	88	25	0	0	508	25	533	7.9%	1413
23:00-24:00	0	108	0	138	138	139	52	0	0	523	52	575	8.5%	1636
00:00-01:00	0	112	0	112	116	115	37	0	0	455	37	492	7.3%	1388
01:00-02:00	0	90	0	132	95	118	16	0	0	435	16	451	6.7%	1292
02:00-03:00	0	99	0	95	105	95	24	0	0	394	24	418	6.2%	1179
03:00-04:00	0	121	0	137	110	107	18	0	0	475	18	493	7.3%	1364
04:00-05:00	0	140	0	132	103	119	17	0	0	494	17	511	7.5%	1423
05:00-06:00	0	133	0	115	122	113	37	0	0	483	37	520	7.7%	1445
06:00-07:00	6	86	0	82	89	93	14	0	0	356	14	370	5.5%	1057
07:00-08:00	3	99	0	127	115	137	17	0	0	481	17	498	7.3%	1451
Total	82	1645	51	1571	1408	1416	420	0	186	6173	606	6779	100%	18307
Percentage	1.2%	24.3%	0.8%	23.2%	20.8%	20.9%	6.2%	0.0%	2.7%	91.1%	8.9%	100.0%		

Peak Volume= 575
Peak Time= 23:00-24:00

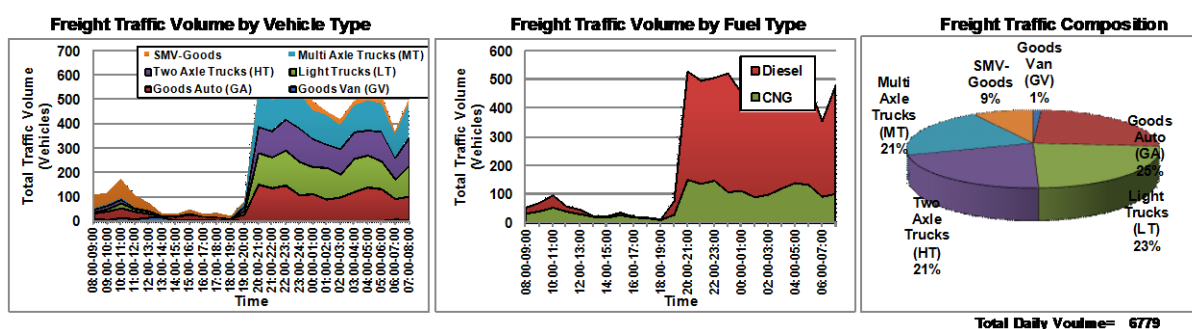


Figure 5.12: Hourly Distribution of Classified Freight Traffic Volume and Traffic Composition Azadpur Sabzi Mandi

The summary of all the focal points is presented in Table 5.12 and traffic composition is presented in Figure 5.13. From the Table 5.12, it can be observed that maximum number of vehicles per day in the order of about 8 thousands entering and exiting through Ghanta Ghar Sabzi Mandi followed by Azadpur Sabzi Mandi with an entry/ exit volume of about 7 thousands and Chandini Chowk Area with an entry/ exit volume of about 5 thousands. From the Figure 5.13, it can be inferred that about 40% are consisting of Goods Auto and Goods Van. The vehicle types of LT, HT and MT are in the range of 24%, 11% and 8% respectively. The other freight vehicles are about 18%.

Table 5.12: Summary of Classified Freight Traffic Volume (24 hours) at Different Focal Points of Delhi

S. No	FP Code	Name of the Focal Point	Goods Van (GV)	Goods Auto (GA)	Light Truck (LT)	Two Axle Truck (HT)	Multi Axle Truck (MT)	Hand Cart	Animal Cart	Cycle Rickshaw Goods	E Rickshaw Goods	Total
1	FP-01	Azadpur Sabzi Mandi	82	1645	1571	1408	1416	420		186	51	6779
2	FP-02	Okhla Sabzi Mandi	92	177	270	193	92	1		67	4	896
3	FP-03	Arya Pura Sabzi Mandi	483	1838	926	42	73	105		55	402	3924
4	FP-04	Ghanta Ghar Sabzi Mandi	452	3587	2478	912	553	0				7982
5	FP-05	Old Delhi Sabzi Mandi	155	706	603	212	242	595		0	0	2513
6	FP-06	Shahdara Sabzi Mandi	19	899	536	575	148	646				2823
7	FP-07	Mandawali Sabzi Mandi	32	200	106	196	25	8				567
8	FP-08	Shahdara	64	309	223	50	16	439				1101
9	FP-09	Gazipur	82	190	436	112	116	0		17	129	1082
10	FP-10	Connaught Place	126	85	269	71	38				15	604
11	FP-11	Chandni Chowk	106	1062	248	119	28	1278	275	771	637	4524
12	FP-12	Sarojini Nagar	44	172	119	19	0					354
13	FP-13	Lajpat Nagar	246	204	195	68	45	190				948
14	FP-14	Pitampura	77	267	170	34	17	370				935
15	FP-15	Nehru Place*	197	304	39	13	0	29				582
16	FP-16	Gandhi Nagar*	215	599	462	119	68	22				1485
17	FP-17	Rajouri Garden	116	301	361	25	22	91		0		916
18	FP-18	Narela	49	248	301	165	243	0	0		37	1043
19	FP-19	Najafgarh	145	201	343	190	119					998
20	FP-20	Keshopur	61	780	564	190	126	1114	0	0		2835

* 12-Hour

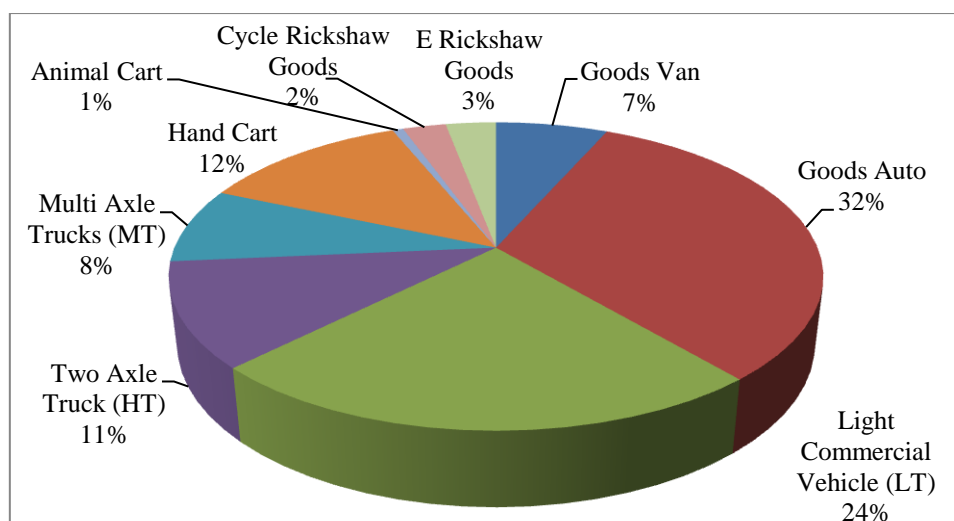


Figure 5.13: Freight Traffic Composition at Different Focal Points of Delhi

5.8. Focal Point Interview Data

Apart from the classified traffic volume count that has been conducted at these 20 focal point locations, interview survey also carried out to collect the travel behaviour of the freight vehicles that are entering and exiting these market locations. The survey has been carried out using predesigned questionnaire comprising the questions related to vehicle data, trip data and commodity data. The questionnaire utilised for this survey is given in *Appendix 7*. The questionnaire survey has been carried out for 24-hour duration and collected data from the freight vehicles on sample basis. The sample size collected at different Focal Point locations are given in Table 5.13.

From the Table 5.13, it can be seen that a total of 10,091 samples of freight vehicles were interviewed and collected the travel behaviour data. The data collected at these locations has been further analysed to understand the freight vehicular characteristics and travel behaviour of freight vehicles. The Origin and Destination (OD) data also analysed with respect to traffic analysis zones (TCZ) to assess the external travel and also to create data base primarily to estimate total freight trips and OD matrix to develop travel demand models namely trip generation and trip distribution models.

Table 5.13: Selected Locations to Conduct Focal Point Survey in Delhi (24 hours)

S. No	FP Code	Name of the Focal Point	Sample Size
1	FP-01	Azadpur Sabzi Mandi	500
2	FP-02	Okhla Sabzi Mandi	650
3	FP-03	Arya Pura Sabzi Mandi	550
4	FP-04	Ghanta Ghar Sabzi Mandi	496
5	FP-05	Old Delhi Sabzi Mandi	858
6	FP-06	Shahdara Sabzi Mandi	468
7	FP-07	Mandawali Sabzi Mandi:	250
8	FP-08	Shahdara	398
9	FP-09	Gazipur	634
10	FP-10	Connaught Place	240
11	FP-11	Chandni Chowk,	506
12	FP-12	Sarojini Nagar	202
13	FP-13	Lajpat Nagar	402
14	FP-14	Pitampura	252
15	FP-15	Nehru Place	194
16	FP-16	Gandhi Nagar	1200
17	FP-17	Rajouri Garden	461
18	FP-18	Narela	650
19	FP-19	Najafgarh	650
20	FP-20	Keshopur	458
Total			10,091

5.9. Mid Block Traffic Volume Survey

In order to assess the current traffic volume situation on the road network of Delhi, classified traffic volume count surveys at five locations has been proposed. In 2013, traffic volume studies were conducted by CSIR-CRRI at various intersections and mid-block section in Delhi. Accordingly the current traffic volume at other locations can be estimated from the determined traffic growth factors. To collect the freight traffic volume data that are plying on the selected locations in the city, manual method of enumeration has been adopted in this study. The enumerators have been given sufficient training and deployed in the field to perform manual count of all the vehicles types which are crossing that mid block location. The survey has been carried out for 24 hour duration starting from 8:00 AM to 8:00 AM. The enumeration of the traffic has been done in every 15-minute and accordingly recorded in

predesigned proforma as given in **Appendix 5**. The enumeration of vehicles has been done for all the vehicle types in order to understand the share of freight traffic in that. The vehicle types mainly considered include all private vehicles, public transport, intermediate public transport, freight vehicles and non-motorised transport vehicles. The selected locations for this survey are given in Table 5.14.

Table 5.14: Selected Mid-Block (MB) Locations to Conduct Traffic Volume Survey in Delhi (24 hours)

S. No	MB Code	Name of the Mid-Block Location	Date of Survey
1	MB-1	Ring Road (Rajghat)	7.9.2017
2	MB -2	Connaught Place Outer Circle	11.9.2017
3	MB -3	Ring Road (Naraina)	7.9.2017
4	MB -4	I.T.O. Barrage Bridge	8.9.2017
5	MB -5	Nizamuddin Bridge	8.9.2017

The collected traffic data has been analysed and the location wise hourly vehicular traffic distribution and traffic composition is given in **Appendix 9**. A typical traffic volume for 24 hour duration at Ring Road (Rajghat) is shown in Table 5.14. The hourly distribution of traffic volume and traffic composition at Ring Road (Rajghat) is shown in Figure 5.14. From the Table 5.14, it can be observed that the total daily volume (24 hours) on Ring Road (Rajghat) is almost 190 thousands and the peak hour is occurring in the evening between 19:00 and 20:00 Hrs with a peak volume of about 16 thousands. From the Figure 5.14, it can be inferred that about 80% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 12% mainly consist of Goods Autos, LT, HT and MT.

The summary of traffic on all the mid block locations is presented in Table 5.15 and traffic composition is presented in Figure 5.15. From the Figure 5.15, it can be inferred that about 80% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 7% mainly consist of Goods Autos, LT, HT and MT.

Table 5.15: Classified Traffic Volume at Naraina on Ring Road

Road Name: Ring Road Location: Naraina Date: 9/7/2017
Mid Block: MB-03

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	3438	766	290	195	43	1434	201	59	91	17	244	13	6534	257	6791	3.6%	7180
09:00-10:00	4643	1038	336	168	22	3646	161	90	110	13	131	19	10227	150	10377	5.5%	10226
10:00-11:00	4898	1057	460	245	21	5523	221	120	129	11	71	16	12685	87	12772	6.8%	12434
11:00-12:00	4009	1094	544	216	4	4217	426	145	266	18	89	23	10939	112	11051	5.9%	11389
12:00-13:00	3956	928	582	204	7	3148	531	375	352	41	91	12	10124	103	10227	5.5%	11232
13:00-14:00	2447	1077	602	225	7	3139	498	366	268	33	59	8	8662	67	8729	4.7%	9580
14:00-15:00	2599	1378	619	224	8	3375	427	294	197	19	26	15	9140	41	9181	4.9%	9733
15:00-16:00	3161	1456	727	203	11	3242	527	347	259	18	20	14	9951	34	9985	5.3%	10752
16:00-17:00	2915	1296	673	209	11	3357	473	332	192	16	23	9	9474	32	9506	5.1%	10066
17:00-18:00	4596	1650	698	219	17	3950	302	164	54	8	78	17	11658	95	11753	6.3%	11699
18:00-19:00	7636	2229	761	195	45	3875	196	166	54	7	128	4	15164	132	15296	8.2%	15166
19:00-20:00	7531	2323	718	321	33	3845	330	264	65	20	74	5	15450	79	15529	8.3%	15849
20:00-21:00	6036	1153	773	299	51	2579	417	179	120	79	30	6	11686	36	11722	6.3%	12683
21:00-22:00	3101	872	378	167	17	2087	381	248	169	164	53	0	7584	53	7637	4.1%	8742
22:00-23:00	3227	619	202	96	22	1105	290	227	248	164	10	2	6200	12	6212	3.3%	7515
23:00-24:00	1130	655	96	37	12	604	276	418	406	478	3	1	4112	4	4116	2.2%	6901
00:00-01:00	1388	518	80	5	2	235	143	321	398	533	2	1	3623	3	3626	1.9%	6488
01:00-02:00	786	301	63	5	3	62	231	293	355	427	0	0	2526	0	2526	1.3%	5003
02:00-03:00	750	149	58	0	0	47	230	245	315	414	2	0	2208	2	2210	1.2%	4525
03:00-04:00	680	175	71	3	2	185	343	300	340	424	3	0	2523	3	2526	1.3%	4986
04:00-05:00	720	345	77	17	7	128	253	278	326	396	1	2	2547	3	2550	1.4%	4878
05:00-06:00	930	569	64	65	12	245	237	239	273	263	6	5	2897	11	2908	1.6%	4706
06:00-07:00	1335	674	102	155	41	654	329	345	257	121	17	10	4013	27	4040	2.2%	5519
07:00-08:00	2436	1103	261	171	50	1035	384	271	184	41	21	5	5936	26	5962	3.2%	6978
Total	74348	23425	9235	3644	448	51717	7807	6086	5428	3725	1182	187	185863	1369	187232	100.0%	214228
Percentage	39.7%	12.5%	4.9%	1.9%	0.2%	27.6%	4.2%	3.3%	2.9%	2.0%	0.6%	0.1%	99.3%	0.7%	100.0%		

Peak Volume= 15529
Peak Time=19:00-20:00

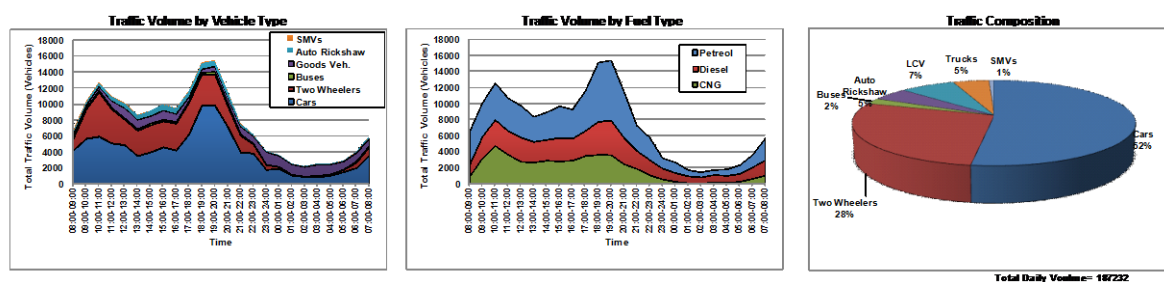


Figure 5.14: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajghat on Ring Road

Table 5.16: Summary of Classified Traffic Volume (24 hours) at Different Mid Block Locations of Delhi

S. No	Outer Cordon	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Grand Total
1	Ring Road (Rajghat)	39202 28.3%	12656 9.2%	25270 18.3%	1268 0.9%	268 0.2%	49073 35.5%	4586 3.3%	1394 1.0%	1178 0.9%	1211 0.9%	1313 0.9%	889 0.6%	138308 100.0%
2	Connaught Place (Regal Cinema)	22388 35.2%	6306 9.9%	13350 21.0%	4060 6.4%	65 0.1%	16424 25.8%	227 0.4%	130 0.2%	69 0.1%	14 0.0%	519 0.8%	84 0.1%	63636 100.0%
3	Ring Road (Naraina)	74348 39.7%	23425 12.5%	9235 4.9%	3644 1.9%	448 0.2%	51717 27.6%	7807 4.2%	6086 3.3%	5428 2.9%	3725 2.0%	1182 0.6%	187 0.1%	187232 100.0%
4	ITO Bridge	80811 46.0%	14944 8.5%	15571 8.9%	3725 2.1%	150 0.1%	53246 30.3%	1457 0.8%	1647 0.9%	1536 0.9%	417 0.2%	1843 1.0%	281 0.2%	175628 100.0%
5	NH-24 Bypass	66586 46.1%	15300 10.6%	11265 7.8%	3440 2.4%	2295 1.6%	29399 20.3%	2792 1.9%	4504 3.1%	4324 3.0%	3629 2.5%	859 0.6%	114 0.1%	144507 100.0%

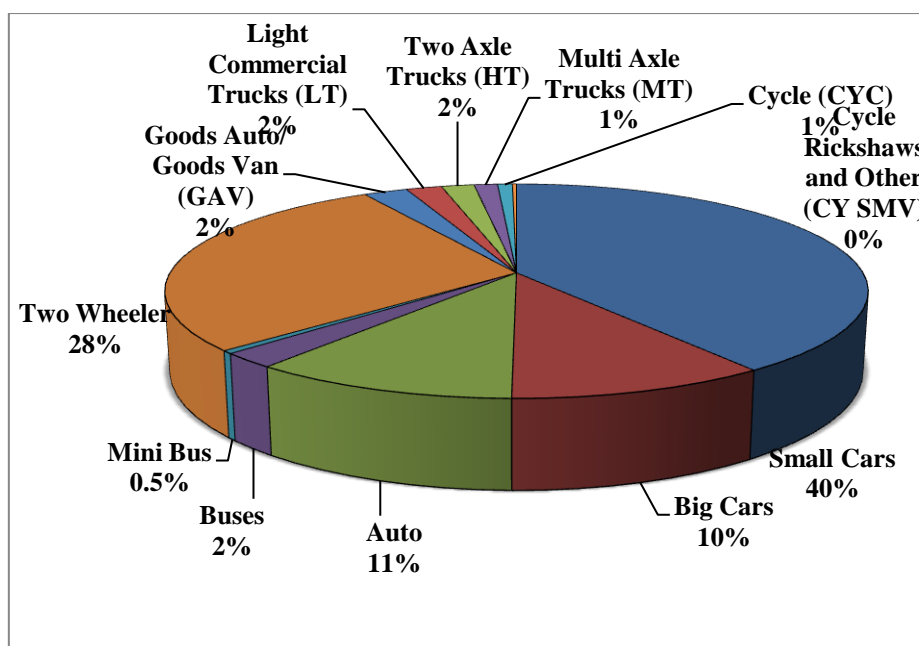


Figure 5.15: Traffic Composition at Different Mid Block Locations of Delhi

5.10. Freight Vehicular and Travel Characteristics

5.9.1. Age Distribution

A total of 8391 freight vehicles at 10 outer cordon locations and 10,091 freight vehicles at 20 focal points (within city) were intercepted and interviewed. Through the roadside interviews, age of the vehicles were recorded along with other important travel characteristics and analysed for all the sampled vehicles. From the data of model (manufacturing) year of vehicle, the age of vehicle has been determined and age distribution is developed for different freight vehicle types at outer cordons and within city. Figure 5.16 and 5.17 present the distribution of vehicles as per the year of manufacture, as obtained at the outer cordon points and focal points. From the Figure 5.16 and 5.17, it can be found that the mean age of freight vehicles is almost same at outer cordons and within the city varying between 4.5 and 5.0 years and the share of 10 year and more old vehicles within the city is ranging from 1 to 6% and 5 to 9% at outer cordons as shown in Table 5.17.

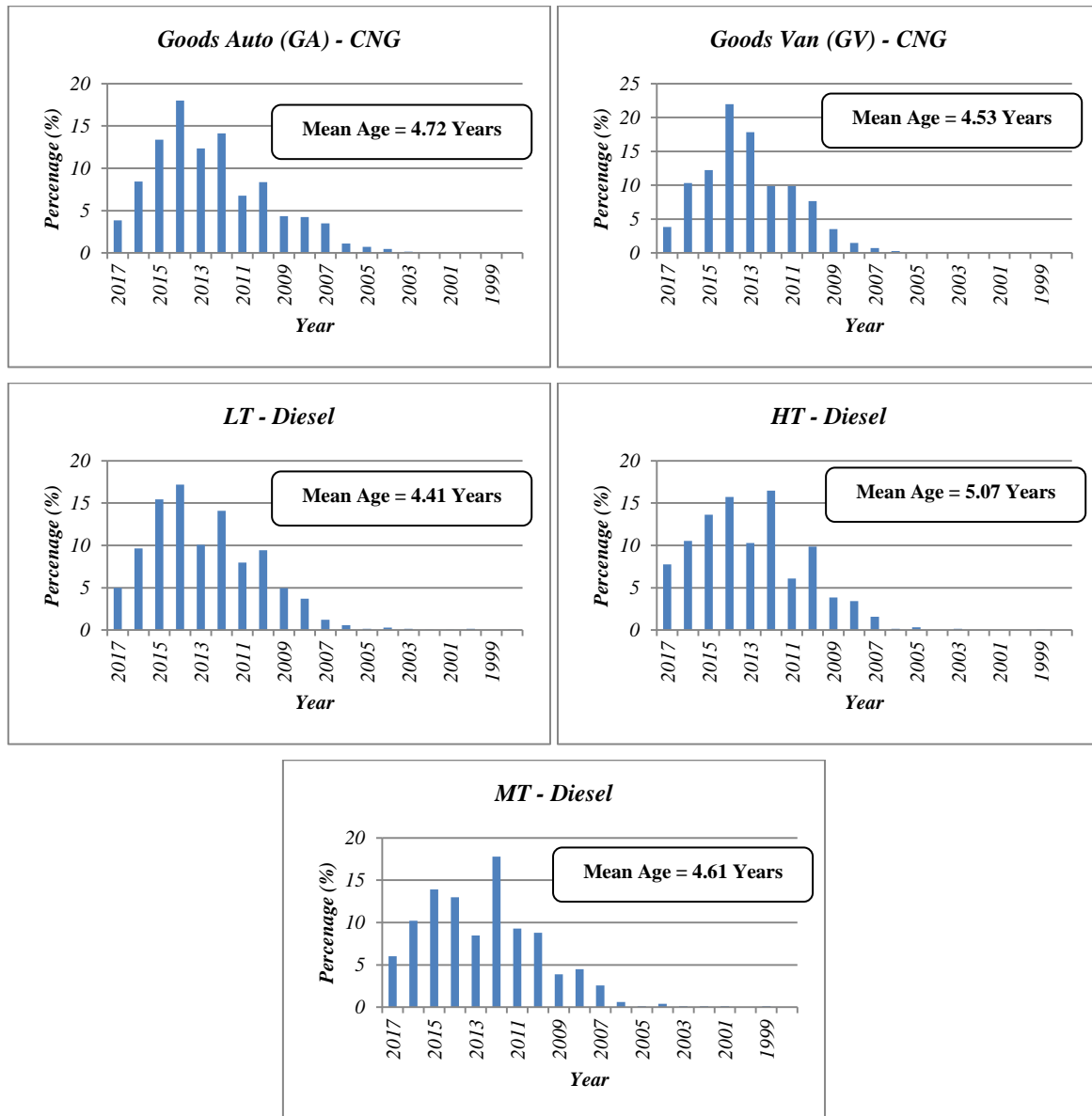


Figure 5.16: Age Distribution of Different Freight Vehicles at Outer Cordons in Delhi

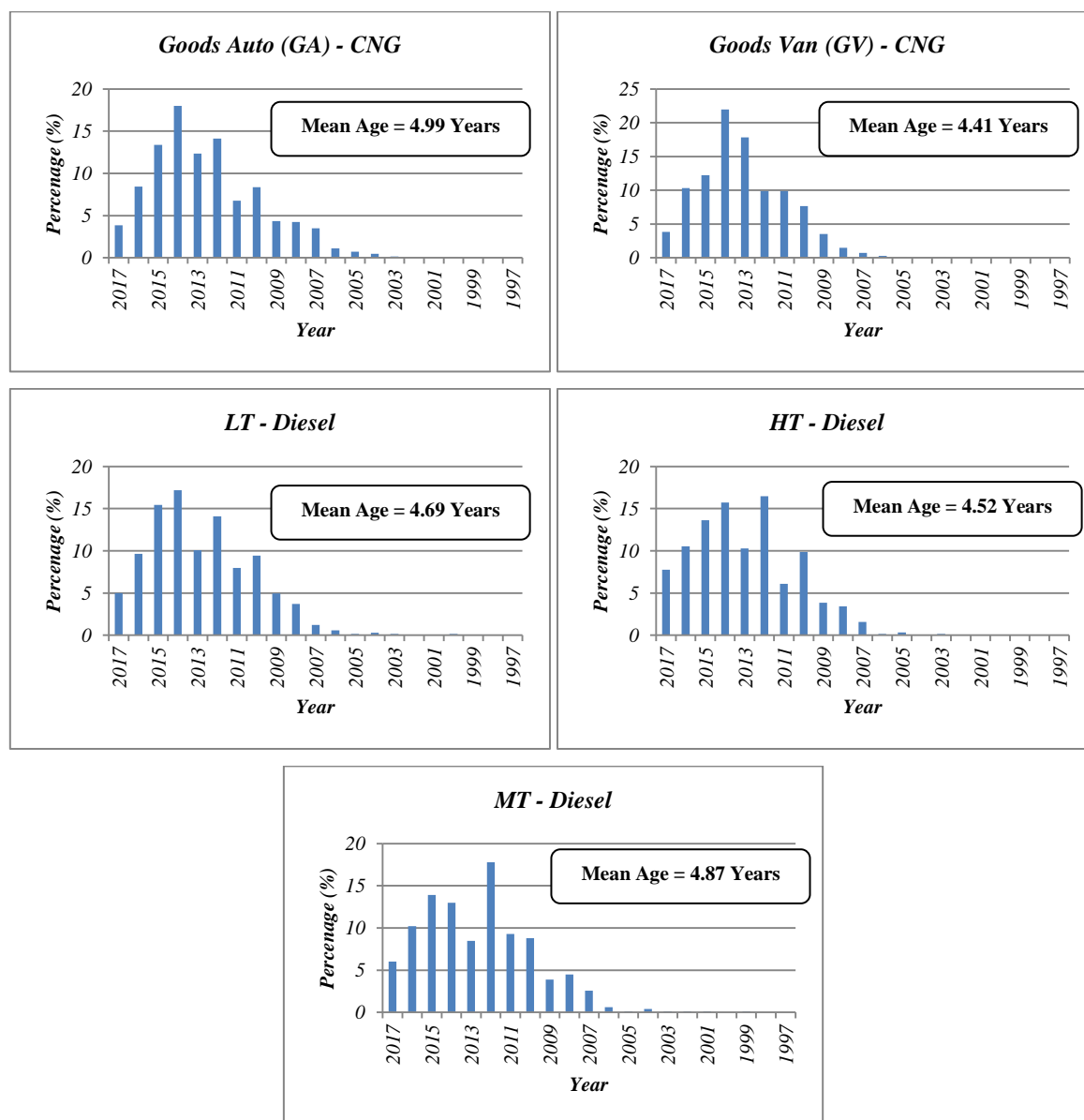


Figure 5.17: Age Distribution of Different Freight Vehicles within the City of Delhi (Focal Point)

Table 5.17: Share of 10 Year and More Old Vehicles within the City and at Outer Cordons

S. No	Location	Age	LT	HT	MT	GA	GV
1	Outer Cordons	1 - 10 Years	94.3%	92.1%	94.3%	93.1%	92.1%
2		More Than 10 Years	5.7%	7.9%	5.7%	6.9%	7.9%
3	Within the City	1 - 10 Years	97.4%	97.6%	95.9%	93.8%	98.7%
4		More Than 10 Years	2.6%	2.4%	4.1%	6.2%	1.3%

5.9.2. Fuel Used

In case of freight vehicles, two types of fuels are mainly used. They are Diesel and Compressed Natural Gas (CNG). The fuel usage distribution of different freight vehicles at outer cordons and within the city is shown in Figure 5.18. From the Figure 5.18, it can be seen that Heavy Vehicles mostly use Diesel where as Goods Auto and Goods Van almost use CNG as fuel. In case of LT, about 45% and 75% use Diesel as fuel at outer cordons and within city respectively.

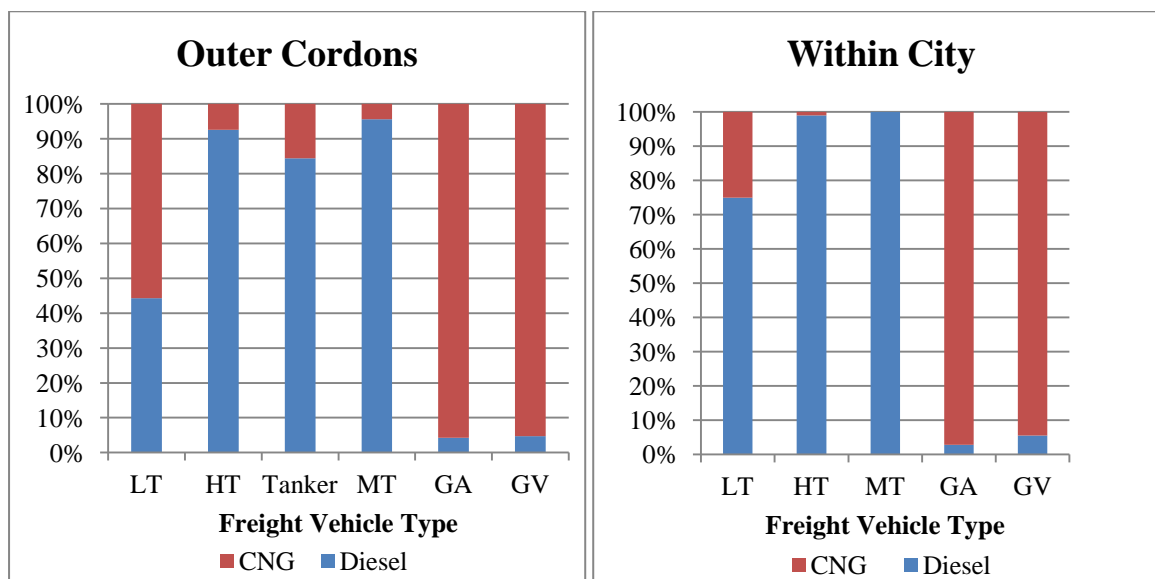


Figure 5.18: Fuel Usage Age Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi

5.9.2. Ownership of Freight Vehicle

The ownership of different freight vehicles at outer cordons and within the city has been analysed and shown in Figure 5.19. From the Figure5.19, it can be seen that private company vehicles are high in case of heavy vehicles (HT and MT) at outer cordons and within the city. The private vehicle share is almost same for light vehicles (LT, GA and GV) within the city whereas it is higher at outer cordons.

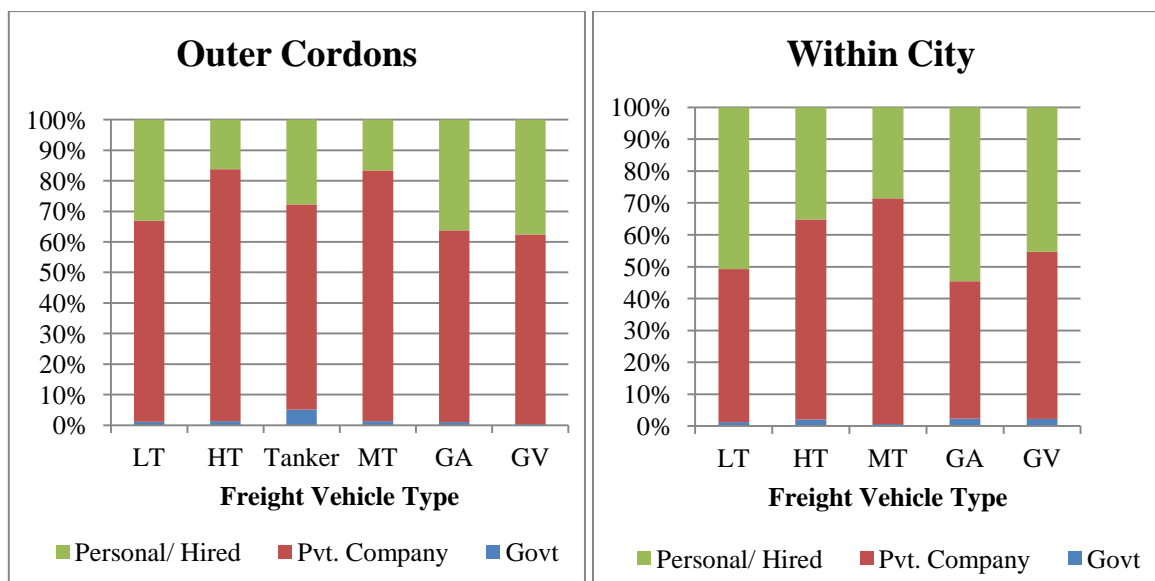


Figure 5.19: Ownership Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi

5.9.3. Fuel Efficiency

The mileage (fuel efficiency in terms of km/litre) data of different freight vehicles has been analysed and shown in Figure 5.20. From the Figure 5.20, it can be observed that light vehicles (LT, GA and GV) have higher fuel efficiency which are mostly run on CNG. Heavy freight vehicles have fuel efficiency about 6.5 and 4.8 km/litre for HT and MT respectively. Light vehicles namely LT has about 11 km/litre, whereas GA and GV has more than 14 km/litre.

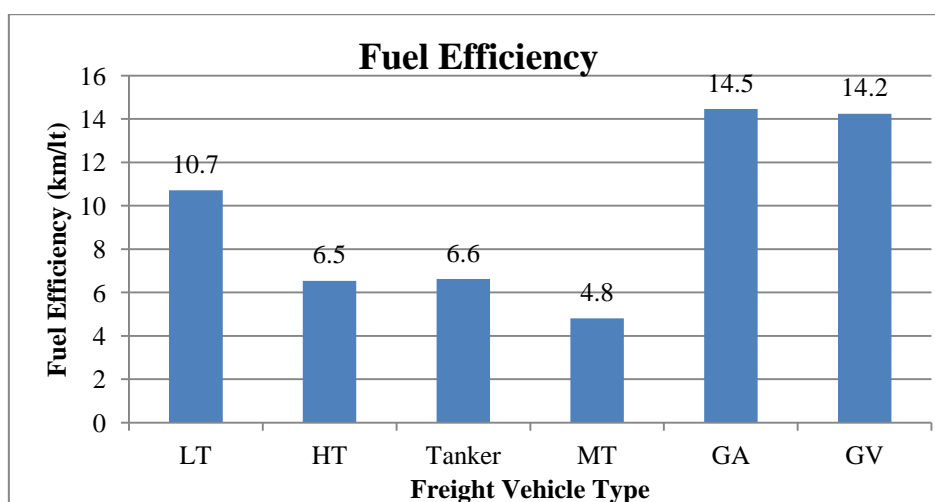


Figure 5.20: Fuel Efficiency of Different Freight Vehicles

5.9.4. Distance Travelled

The distance travelled data in terms of km/trip, km inside city and km/day of different freight vehicles has been analysed and shown in Figure 5.21. From the Figure 5.21, it can be observed that average trip distance of MT is about 228 km and for HT, it is about 112 km, whereas vehicle type LT has about 70 km and smaller vehicles are having a trip distance of about 50 km. All these vehicle types travels about 20-25 km within the city. And it can also be observed that the maximum average distance travelled in a day by these vehicle types is about 200 km. This clearly indicate that these freight vehicles face lot of congestion and other problems to travel more distances in a day experiencing lot of delays and increased operating costs.

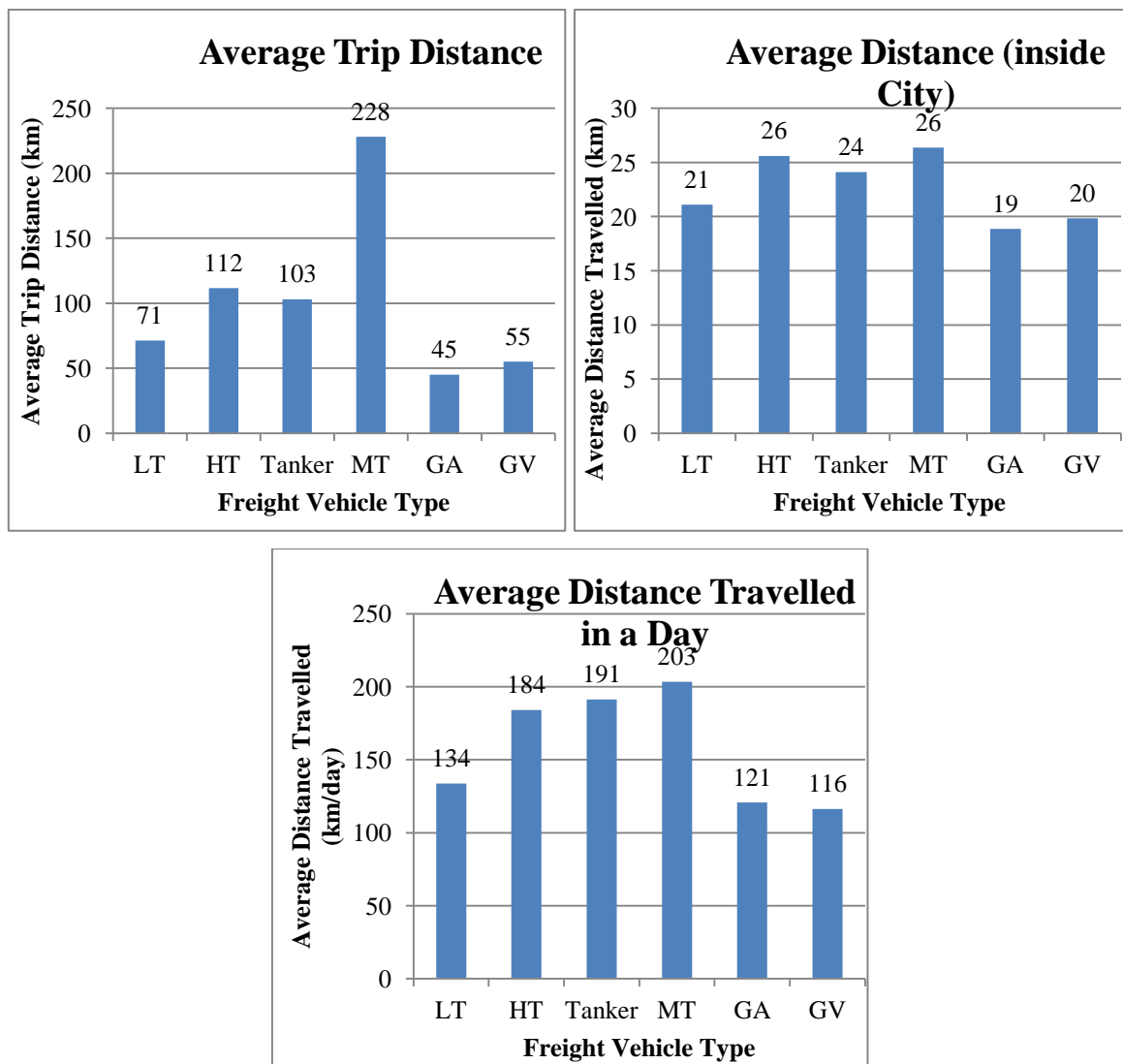


Figure 5.21: Distance Travelled by Different Freight Vehicles

5.9.5. Frequency of Trips

The frequency of trips data of different freight vehicles has been analysed and shown in Figure 5.22. From the Figure 5.22, it can be observed that Light Vehicles are having more daily trips and Heavy Vehicles are more in Occasional trips.

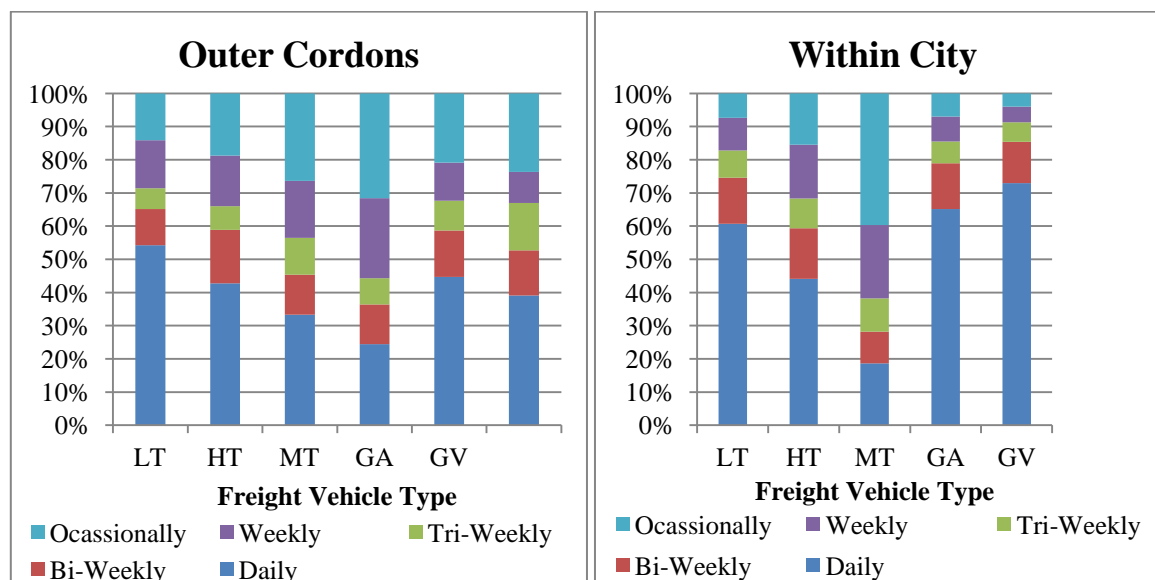


Figure 5.22: Frequency Distribution of Freight Vehicles at Outer Cordon and within the City of Delhi

5.9.6. Weight Carried

The weight carried by different freight vehicles has been analysed and shown in Figure 5.23. From the Figure 5.23, it can be observed that MT Vehicles are carrying average weight more than 13 tonne whereas HT vehicle is carrying average loads of 5-6 tonne. The LT is carrying average weight about 2 tonne and smaller vehicles like GA and GV are carrying less than a tonne. Further, an analysis has been carried out to assess the share of empty vehicles and the result is presented in Figure 5.24. From Figure 5.24, it can be seen that the 10-20% vehicles are running empty on the road network of Delhi. Further the total weight carried by these freight vehicles on the entire road network of Delhi has been estimated from average distance travelled and weight carried in a day which comes to be about 2.480 Million Metric Tonne (MMT) per day.

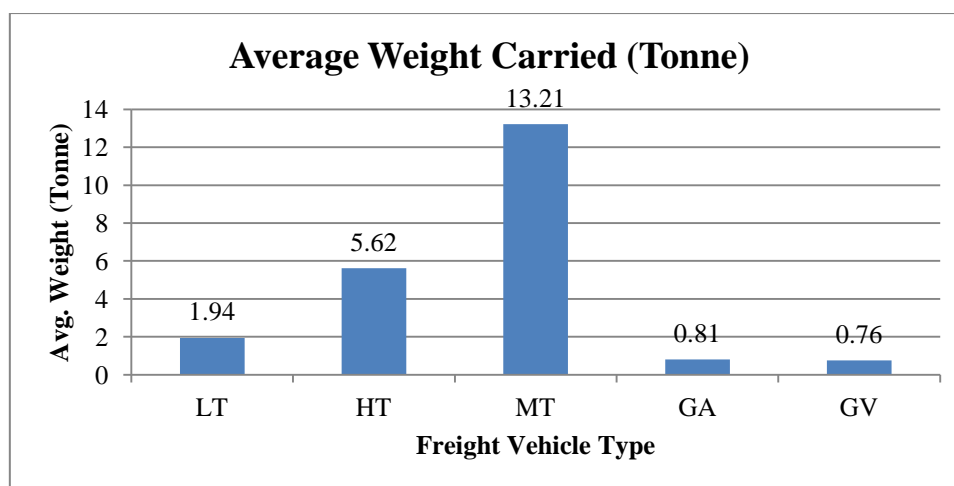


Figure 5.23: Frequency Distribution of Freight Vehicles at Outer Cordons and within the City of Delhi

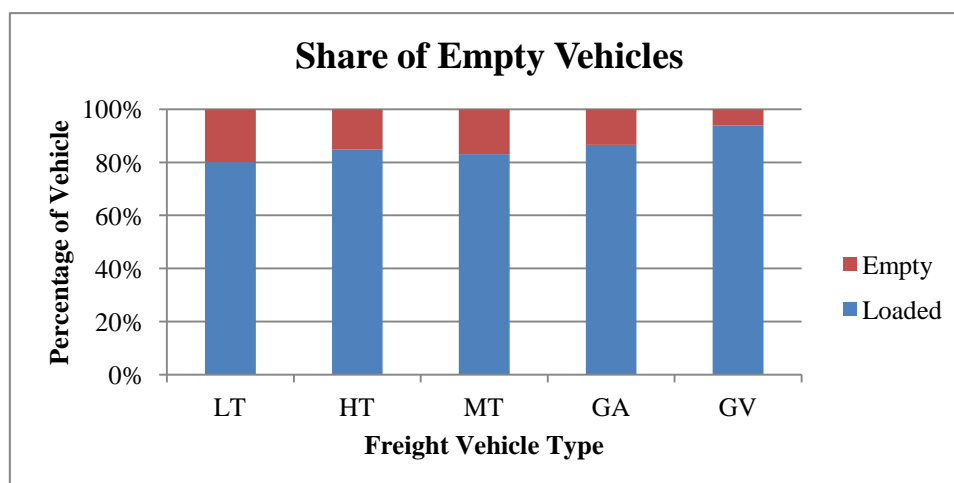


Figure 5.24: Share of Empty Vehicles in Different Typed of Freight Vehicles

5.11. Development of Freight Transport Demand Models

5.11.1 Background

Generally, passenger transport models are developed based on the observed travel pattern and the socio-economic characteristics of commuters of the city. The traditional approach of four-stage modelling has following transport sub-models are: (i) Trip Generation (ii) Modal-Split (iii) Trip Distribution (iv) Traffic Assignment. In the present study, freight transport demand model has been proposed to develop considering same traditional approach of four-stage modelling as passenger travel demand modeling. However, in this chapter, freight trip generation, freight trip distribution and freight modal split models have been discussed. The

freight traffic assignment along with passenger traffic assignment has been discussed in the Chapter 7. Prior to this, development of existing transport network is the foremost data input for the transport models besides the observed travel characteristic data and planning parameters at traffic zone level.

5.11.2. Traffic Zones, Road Network and Socio-economic Data

The study area i.e. NCT of Delhi is divided into 360 administrative wards and the same has been adopted in the present study. These zones are also called as Traffic Analysis Zones (TCZ) and these 360 zones of the study area have been shown in Figure 5.25 and the details of these zones are given in *Appendix 10*. The zone wise socio economic data such as Population, Land Use Types, Number of Households, Employment, Total Land in Hectares, Commercial Area, Industrial Area, Residential Area, Recreational Area, Public & Semi Public Area etc. which are going to be used for development of travel demand modelling is also collected from the secondary source namely Census data (Census, 2011) and Master Plan for Delhi - 2021 (DDA, 2010). The road network of study area i.e. NCT of Delhi has been created from the exiting maps and field visits. The network has been developed by creating links and nodes as shown in Figure 5.26. The Traffic Zone Centroids have been serially numbered starting from 1 onwards for each of the Traffic Zone of NCT of Delhi (1-360) and external zones (361-368). The transport network has been prepared for the whole of NCT of Delhi area including external zones.

The existing transport network of Delhi city consists of only roads as the road based mode is only considered at present. The road network has total 2263 Links and 1500 nodes and included road link characteristics: link-type, length, observed carriageway width, no. of lanes, divided/undivided, and speed, capacity, etc. The transport network of existing roads is shown in Figure 5.26. As speed and delay studies were conducted, the speeds for different links are taken from the surveys separately for different type of roads namely major roads, intermediate roads, connectors etc.

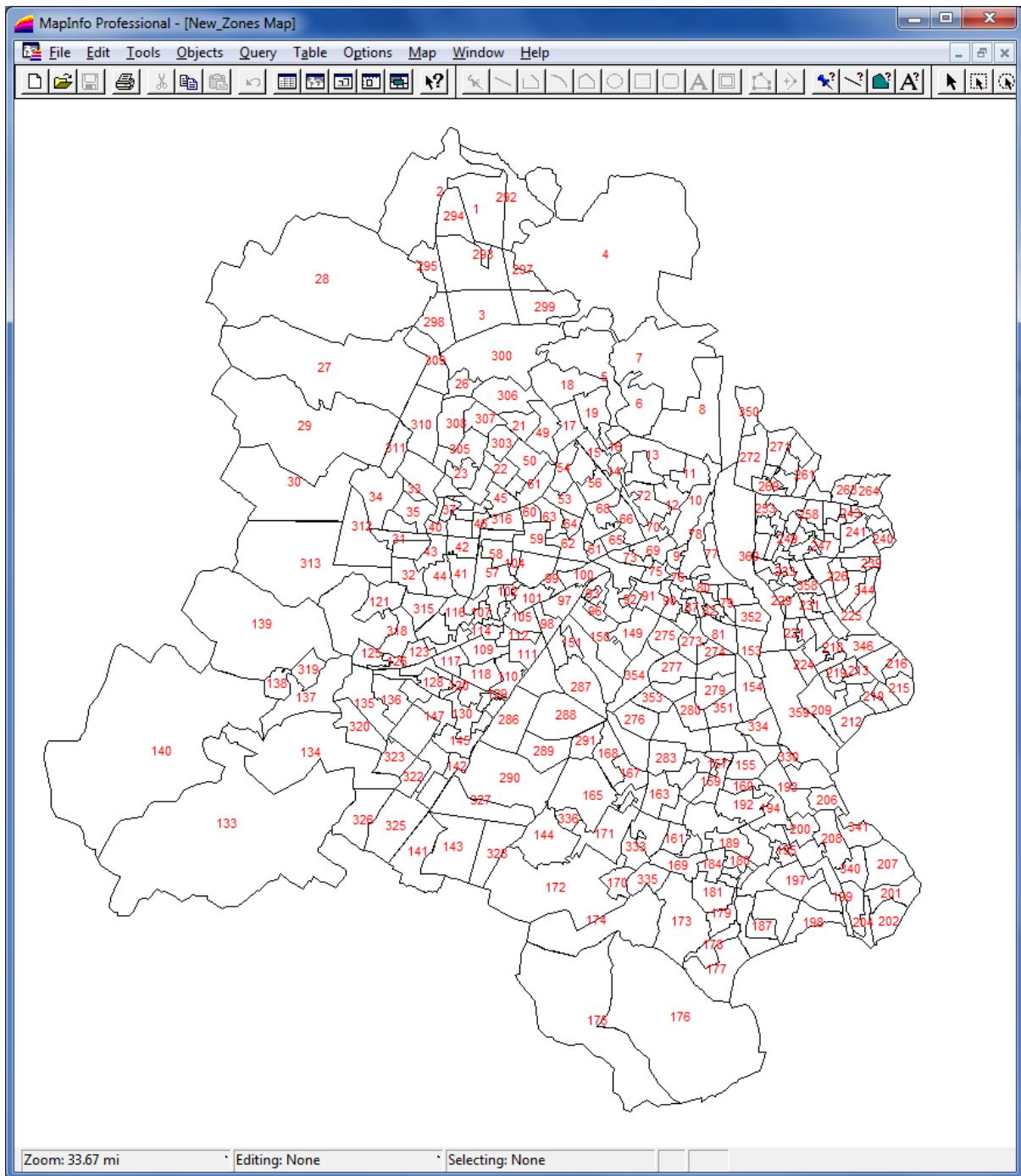


Figure 5.25: Traffic Analysis Zones (TCZ) considered for the City of Delhi

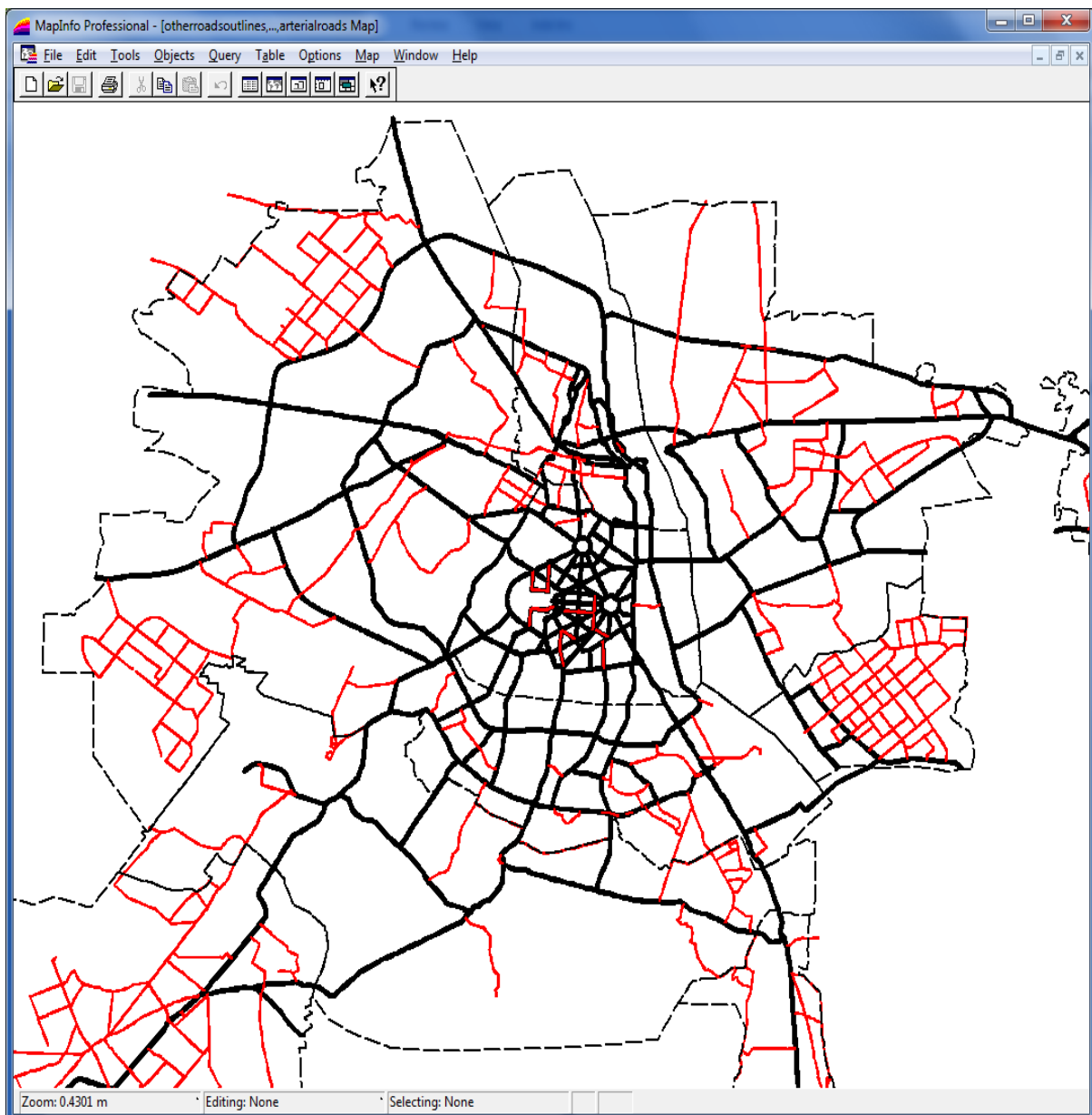


Figure 5.26: Created Road Network (Links and Nodes) for the City of Delhi

5.11.3 Freight Trip Generation Models

Freight Trip Production Models

The freight trip data has been analysed based on zone wise and estimated the trips generated from that zone. Multiple Linear Regression (MLR) Analyses technique has been used to model the Freight Trip Productions. The form of the freight trip production equation is given below:

$$T = X\beta + \varepsilon \quad \text{----- Eq. (5.1)}$$

Where, T is number of freight trips produced or attracted

X is vector of independent variables (socioeconomic and land use intensity)

β is parameter vector to be estimated

ε is unexplained error term and a constant can be considered for this

Out of the socio-economic and land use parameters discussed in the Section 5.11.2, the following variables are taken as influential parameters in estimating freight trip productions in zonal level:

- ❖ Population (P)
- ❖ Employment (E)
- ❖ Commercial Area (C)
- ❖ Industrial Area (I)

Using the above variables, the zonal trip productions are modelled and developed zonal level trip production regression models. For this purpose SPSS 18 has been utilised to estimate the parameters and statistical validation. The developed model for freight transport trip production is given below:

$$P_i^F = 0.021 * P_i + 0.003 * E_i + 14.499 * C_i - 17.858 * I_i \quad \text{----- Eq. (5.2)}$$

Where, P_i^F is Freight Trip Productions

i is zone number

The above regression equation can be considered as relatively good statistical significance as it is having R^2 Value of 0.3.

Freight Trip Attraction Models

Similar to freight trip productions, Multiple Linear Regression (MLR) Analyses technique has been used to model the Freight Trip Attractions. The form of the freight trip production equation is given in Eq. 5.1.

Out of the socio-economic and land use parameters discussed in the Section 5.11.2, the following variables are taken as influential parameters in estimating freight trip productions in zonal level:

- ❖ Population (P)
- ❖ Employment (E)
- ❖ Commercial Area (C)
- ❖ Industrial Area (I)

Using the above variables, the zonal trip attractions are modelled and developed zonal level trip production regression models. For this purpose SPSS 18 has been utilised to estimate the parameters and statistical validation. The developed model for freight transport trip production is given below:

$$A_i^F = 0.026 * P_i + 0.002 * E_i - 17.564 * C_i \quad \text{----- Eq. (5.3)}$$

Where, A_i^F is Freight Trip Attractions

i is zone number

The above regression equation can be considered as relatively good statistical significance as it is having R^2 Value of 0.38. From this analysis, it can be concluded that the developed equations for trip productions and attractions can be used to estimate trips with relatively good accuracy.

Estimation of Total Freight Trips

From the developed Freight Trip Production and Attraction Models given in Eq. 5.2 and Eq. 5.3, the total trips have been estimated from all the zones and presented in Figure 5.27. From the Figure 5.27, it can be seen that about 500 thousands of freight trips are generated daily in the city of Delhi.

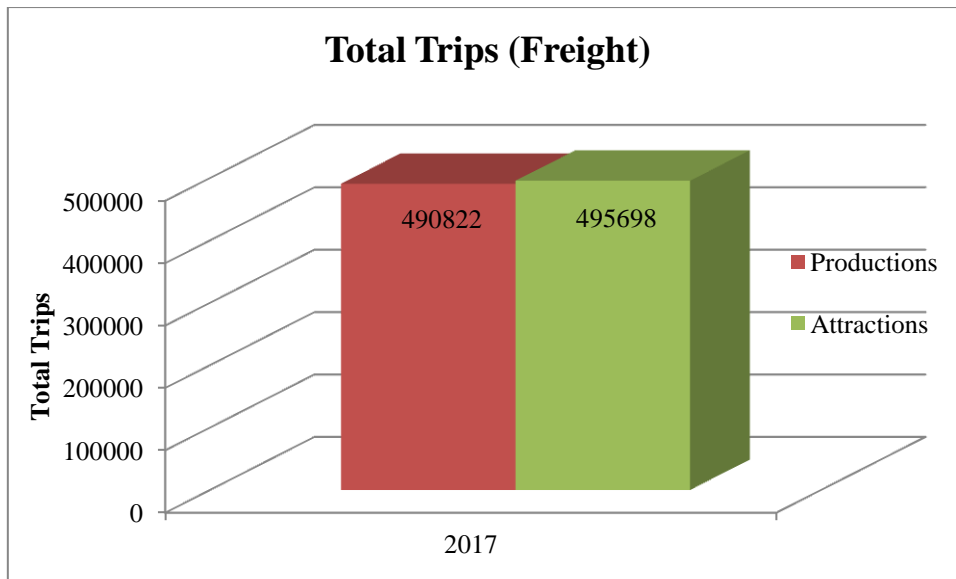


Figure 5.27: Estimated Total Freight Trip Productions and Attractions in Delhi (2017)

5.11.4. Freight Modal Split

After estimation of the total freight trips, the modal split has been estimated considering the traffic composition observed at outer cordon and within the city at focal points. The final freight modal split is shown in Figure 5.28. From the Figure 5.28, it can be observed that all different freight vehicles namely GA, LT, HT and MT form almost equal share varying between 22-25% where as GV is about 5% share.

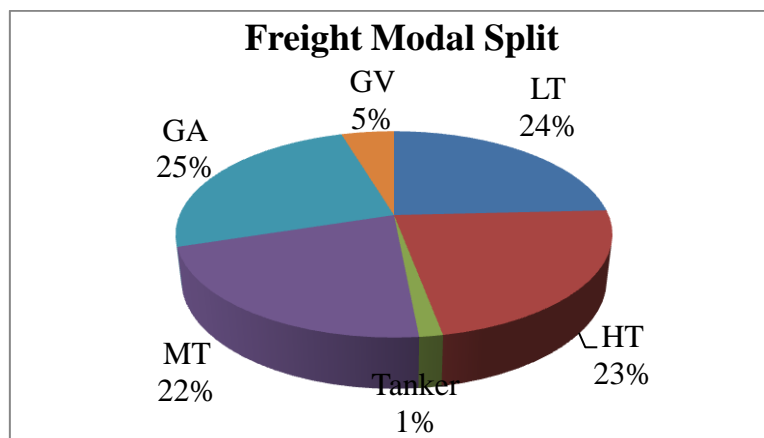


Figure 5.28: Modal Split of Total Freight Trips

5.11.5. Freight Trip Distribution Models

Gravity Model Formulation

Gravity Model formulation shown in Eq. 5.4 has been used for Trip Distribution Model calibration. The deterrence function used is Tanner's function.

$$T_{ij} = A_i * B_j * P_i * D_j * F(c_{ij}) \quad \text{-----(5.4)}$$

The $F(c_{ij})$ is used from Tanner's function as shown in Eq. 5.5.

$$F(c_{ij}) = (c_{ij} ** X_1) * (e ** X_2 * c_{ij}) \quad \text{----- (5.5)}$$

where: $A_i * B_j$: Balancing factors

P_i : Production from i^{th} Zone

D_j : Attraction to j^{th} Zone

$F(c_{ij})$: Deterrence Function

c_{ij} : Generalized Cost of Travel from 'i' to 'j' Zone

X_1 and X_2 : Calibration Parameters

Gravity Model Calibration and Estimation of Freight O-D Matrices

Freight trip distribution models have been calibrated using the Distance and Time Skim matrices generated from the coded network of existing roads. The observed Origin Destination (O-D) - Trip matrices have been separately calibrated for each mode. For this purpose, VISUM 11 Software has been utilised and estimated freight O-D matrices for different freight vehicle types. In the present study, the total number of zones taken as 368, out of which 360 are internal zones and 8 are external zones. The size of O-D Matrix would be 368 X 368. A typical view of estimated total freight O-D matrix has been shown in Figure 5.29. The desire line drawings have been developed in order to see the trend and intensity of trips between origin and destination using VISUM Software and shown in Figure 5.30.

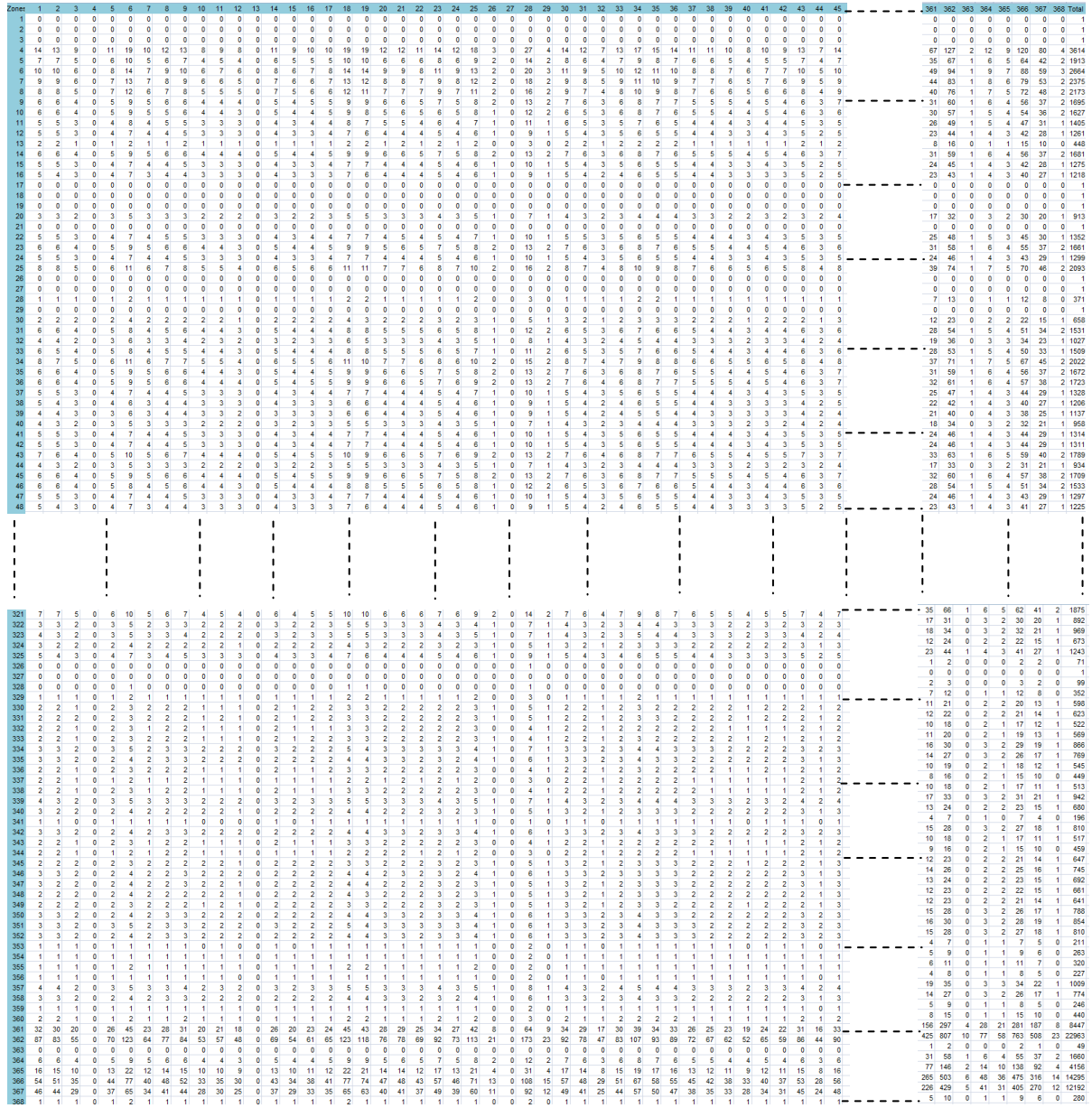


Figure 5.29: Typical View of Estimated Total Freight O-D Matrix for the City of Delhi

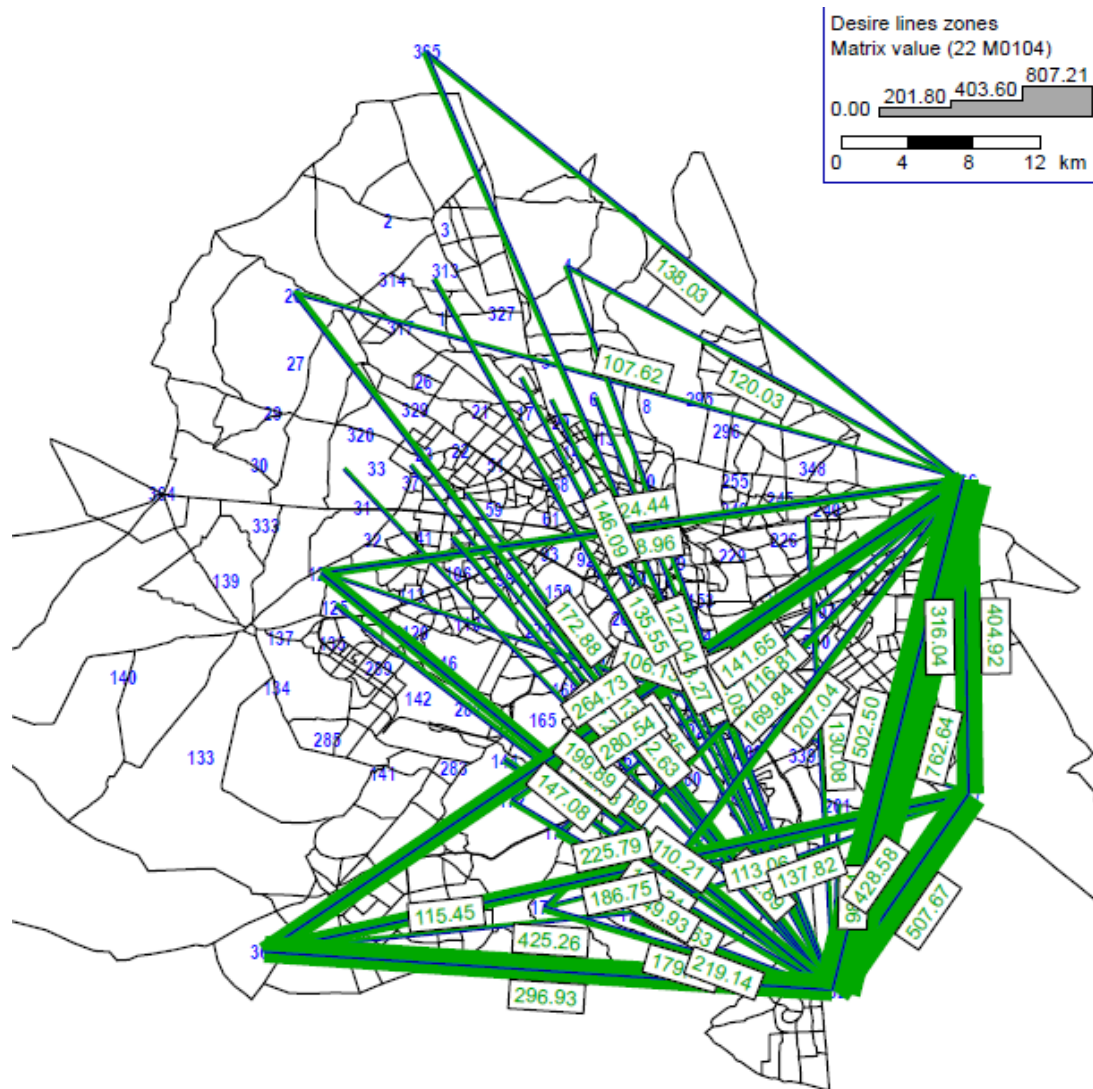


Figure 5.30: Desire Line Diagram of O-D Matrices for Freight Trips

5.11.6. Freight Trip Assignment

The trip assignment has been performed using Urban Strategy Software tool developed TNO. For this, purpose, the developed O-D Matrices for freight traffic has been submitted to TNO. When the assignment of freight trips made on the network, there would be passenger trips already on the network. Hence it is essential to consider all the trips including freight and passenger trips together to perform trip assignment. The passenger trips which are developed in the project of SUSTRANS (CRRI, 2017) for the city of Delhi has been considered in the present study and carried out the trip assignment in Urban Strategy by TNO which is discussed in Chapter 6.

5.12. Pattern of Total Freight Trips

The pattern of total freight trips are classified under four categories. They are:

- ❖ External - External (E-E)
- ❖ External - Internal (E-I)
- ❖ Internal to External (I-E)
- ❖ Internal - Internal (I-I)

Accordingly the freight trips are analysed and results are shown in Figure 5.31. From the Figure 5.31, it can be seen that the majority of freight trips are Internal - Internal which is almost 80%. The Internal-External and External-Internal are almost same about 8% each and External-External trips (passing through) are about 4%.

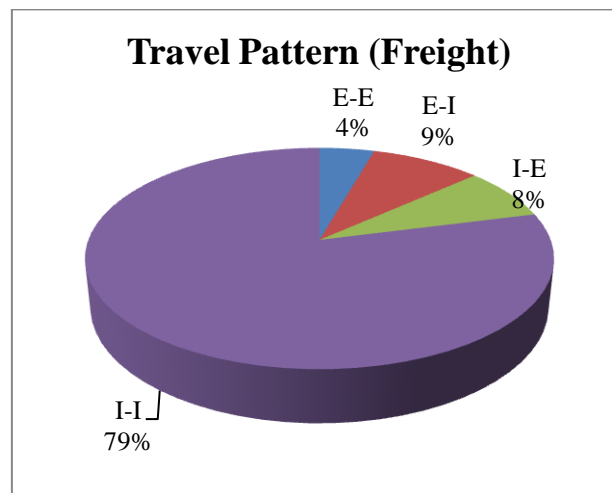


Figure 5.31: Pattern of Total Freight Trips i Delhi

The modal split of these freight trips has been analysed and presented in Figure 5.32. From the Figure 5.32, it can be observed that heavy freight vehicle share is about 26% in case of I-I Trips, about 43% in case of I-E Trips, about 53% in case of E-I Trips and about 61% in case of E-E Trips. The comparison of total freight trips are made with passenger trips in order to understand the share of freight trips in the city of Delhi and shown in the Figure 5.33. From the Figure 5.33, it can be observed that the share of freight trips is only about 3% which is very insignificant, however it is going to influence huge in traffic congestion, air pollution and road safety related issues of the city of Delhi.

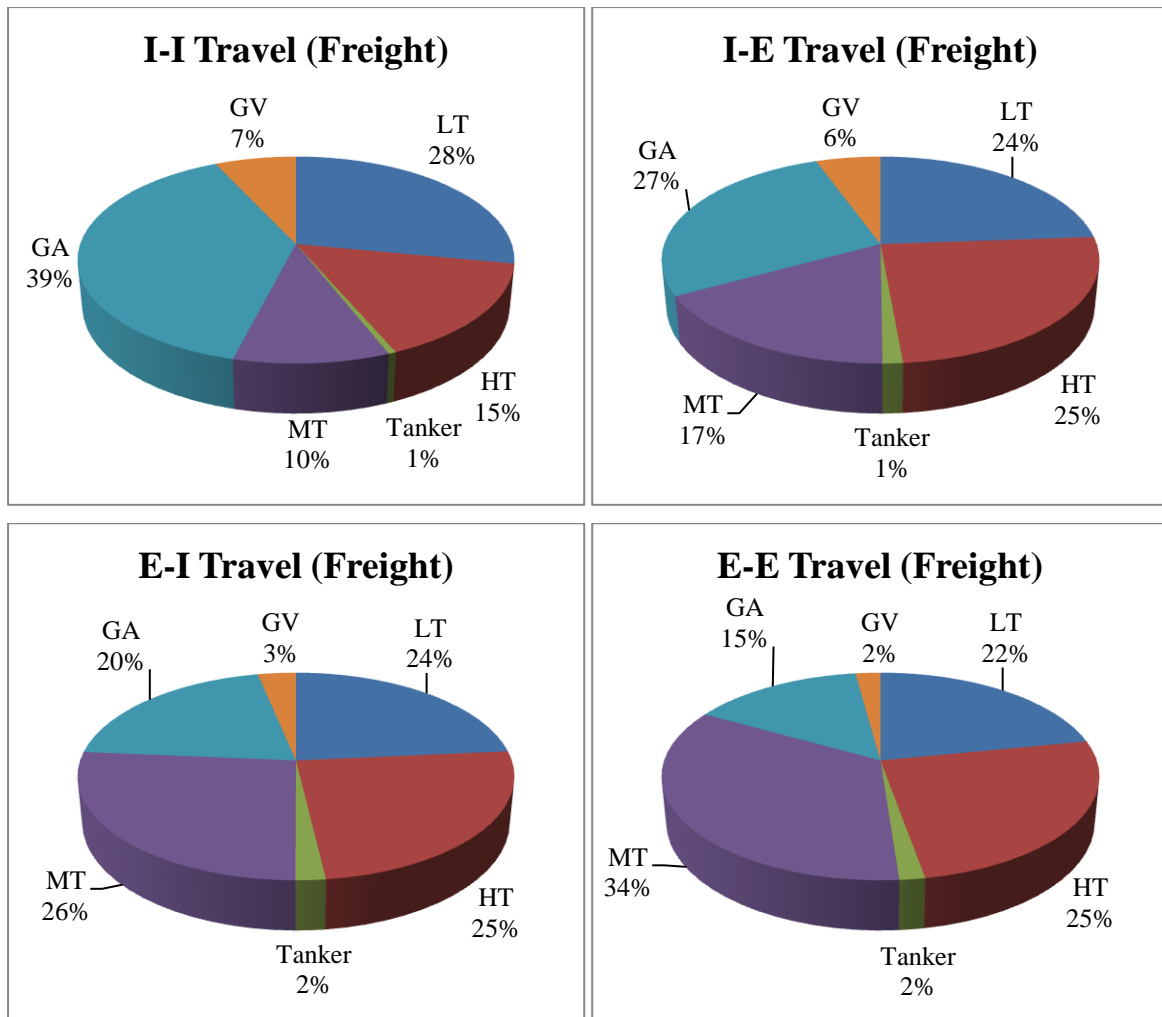


Figure 5.32: Freight Modal Split for Different Types of Trips in Delhi

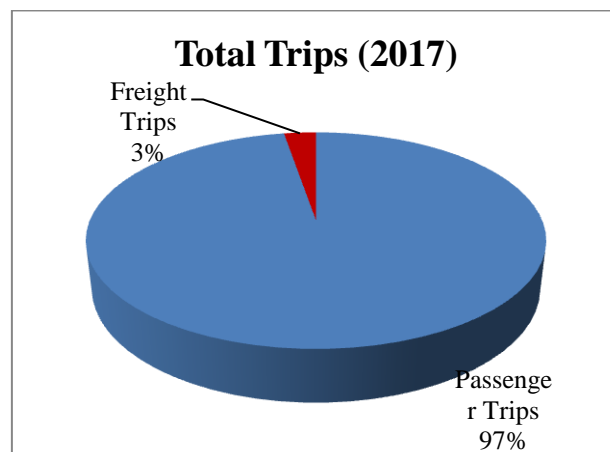


Figure 5.33: Share of Freight Trips in the Total Trips of Delhi

5.13. Forecasting of Freight Trips from Freight Transport Demand Models

The developed freight transport models are utilised to forecast the trips that going to be generated in the City of Delhi. As it was already discussed in Section 5.11.3 that the trip productions and attractions are depend on certain variables which are intern considered in equation development. The variables are:

- ❖ Population (P)
- ❖ Employment (E)
- ❖ Commercial Area (C)
- ❖ Industrial Area (I)

Out of all these variables, the population data over the years is available and limited data for the other variables namely employment available for the year 2021 which is related to Census Updation year in India. Using the growth factors for these variables, growth factors for other variables have been appropriately considered. From this exercise, the total trips productions and attractions for the year 2021 are estimated. The estimated trips for the year 2017 and 2021 are shown in the Figure 5.34.

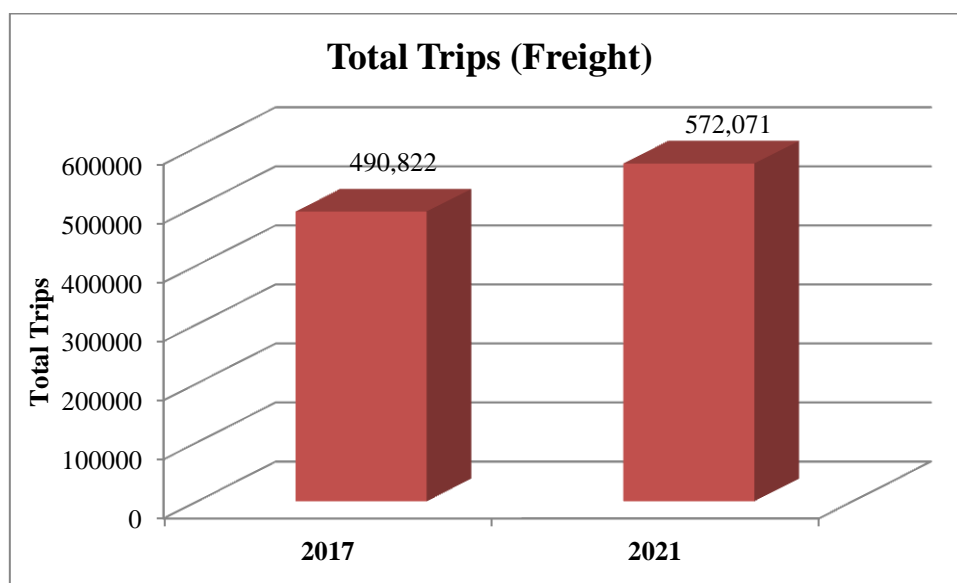
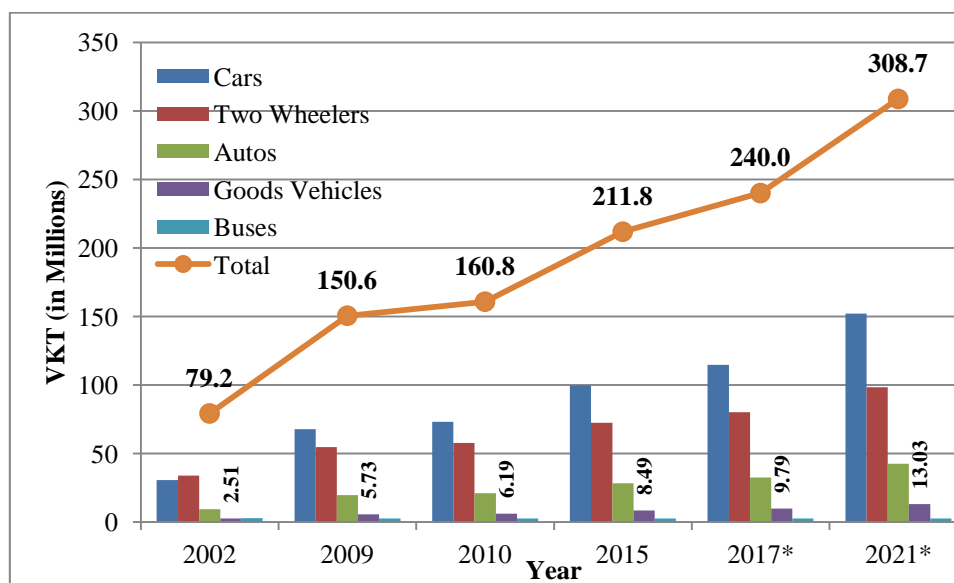


Figure 5.34: Forecasted Total Freight Trips for the Year 2021 in Delhi

From the Figure 5.34, it can be seen that the forecasted trips have increased to about 572 thousands with a growth rate of 4% per annum.

5.14. Estimation of Traffic Loads on the Road Network

In 2002 and 2009, CSIR-CRRI has conducted a study to estimate traffic loads in terms of vehicle kilometers travelled (VKT) on the road network of Delhi and accordingly projected for the years 2010 and 2015 (CRRI, 2009). Utilising this data, the projections have been made from the growth factors for all the vehicle types. The estimated VKT for 2017 and forecasted VKT for the year 2021 are presented in Figure 5.35. From the Figure 5.35, it can be observed that the estimated total traffic loads in terms of VKT are about 240 Millions and 300 Millions in 2017 and 2020 respectively. The VKT by freight vehicles are going to be about 10 Million and 13 Millions in 2017 and 2020 respectively which is having a share of about 4%. The growth of total VKT is increasing with 7% per annum growth whereas freight vehicles growth is about 8% per annum.



* Estimated in Present Study

Figure 5.35: Estimated Vehicle Kilometers Travelled /Day for different Vehicle Types for Different Years

References

CRRI. (2017). Development and Application of Technologies for Sustainable Transportation (SUSTRANS), Central Road Research Institute (CRRI), 12th Five Year Plan Project, , Transportation Module, Final Report, Planning Commission 2017.

CRRI. (2009). Urban Road Traffic and Air Pollution in Delhi, Central Road Research Institute (CRRI), Final Report Submitted to Society of Indian Automobile Manufactures (SIAM), 2009.

Census (2011), Census of India, Government of India.

DDA (2010) Master Plan for Delhi - 2021, Delhi Development Authority (DDA), Government of NCTD.

6. CAPACITY DEVELOPMENT FOR SUSTAINABLE CITY LOGISTICS

6.1. Capacity Assessment

From the literature on the subject of sustainable urban freight systems (SUFS), the following are critical capabilities for the development and deployment of solutions:

- **Process capabilities:** this includes the ability to create an institutional environment and a series of activities that allow stakeholders to go through consecutive design cycles and implement change.
- **Substantive capabilities:** this concerns data, information, models and knowledge about initiatives, necessary to be able to identify problems, design innovative solutions and implement them.

Fundamental to alleviating problems is the recognition that the SUFS problem is a multi-stakeholder problem with many interdependencies and possible conflicts. Generally, a shared understanding amongst stakeholders about the main problems or the preferred solutions is absent. As in most countries, the logistics sector is fragmented. Besides the different actors or stakeholders (think of private vs. public, supply chain actors, etc.), there are different markets in urban freight that require a differentiated approach (e.g. construction traffic having different needs than retail and waste retrieval). There seem to be no national or local NGOs working on the problem of city logistics that work towards a unifying approach. Also, as in most countries, there are fundamental difficulties with the functioning of the freight market that make governance issues non-trivial – both market and government failures in relation to sustainability are easy to identify. First and foremost, sustainability problems are largely external to these markets (i.e. non-priced, at least not on the basis of social marginal costs). Internalizing external costs through pricing has important political constraints, relating to both the economic and the social pillar of sustainability. Secondly, there are few other incentives in place for the transport industry to follow a sustainable course, such as recognition programs or fleet renewal benefits. Thirdly, innovation and experimentation costs are relatively high for the low margin business of transportation services.

Partly because of these reasons, as some countries have already demonstrated, it is good practice to develop a pro-active policy towards cohesiveness between stakeholder groups so that problems can be addressed simultaneously. There are different ways to organize this cooperation. The highest form of organization is the so-called living lab (Quak, *et. al.*, 2016), with freight partnerships and demonstration or pilot-oriented cooperation as intermediate forms as shown in Figure 6.1.

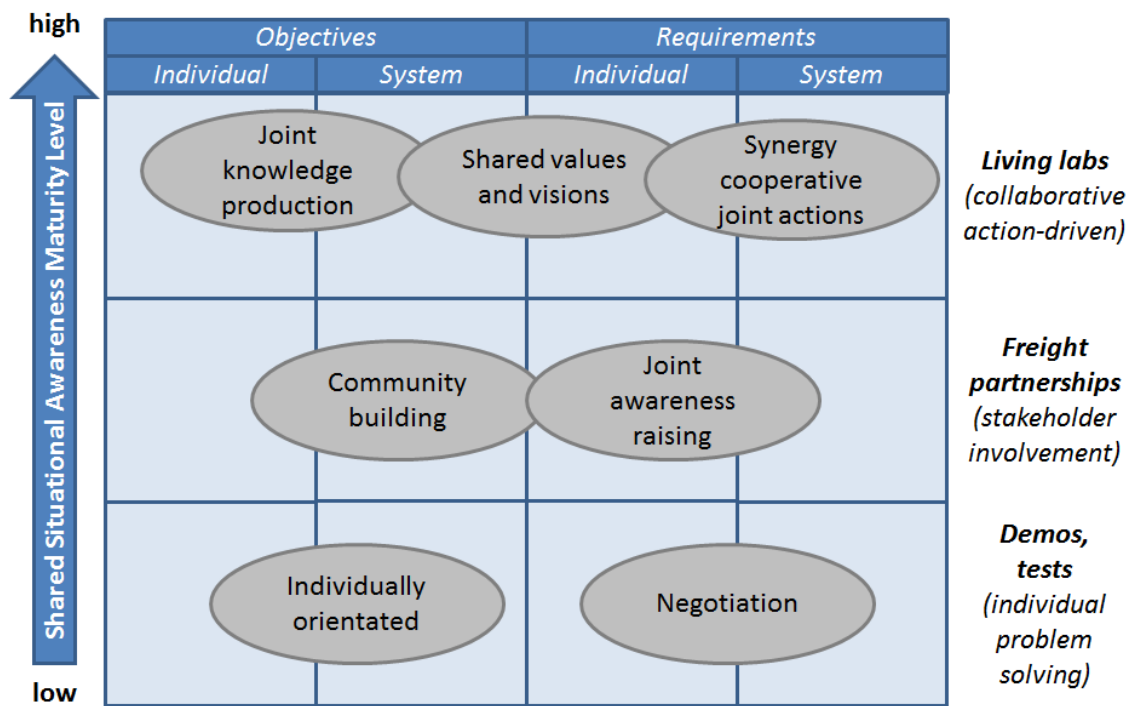


Figure 6.1: Description of Different Levels of Organisations with Different Objectives and Requirements

Currently, the city of Delhi has a very low level of organized stakeholder involvement in urban freight and, as a result, a low level of shared situational awareness. This has not been a problem for some important measures that have been successful, such as the establishment of freight markets for local distribution supported by local Master Planning, nation-wide abolition of fuel subsidies, and the massive deployment of CNG engines for auto-rickshaws and government vehicles in New Delhi. For other measures, such as the local pollution tax, the ban for trucks aged older than 10 years, or even the short term ban for all trucks during the severe smog days after 9 November 2017, still a lack of understanding and agreement can be felt from the transport sector as shown in Figure 6.2. Trucks are perceived and treated as

one of the major causes of air pollution in the city, while this perception is based on few facts and measurements.

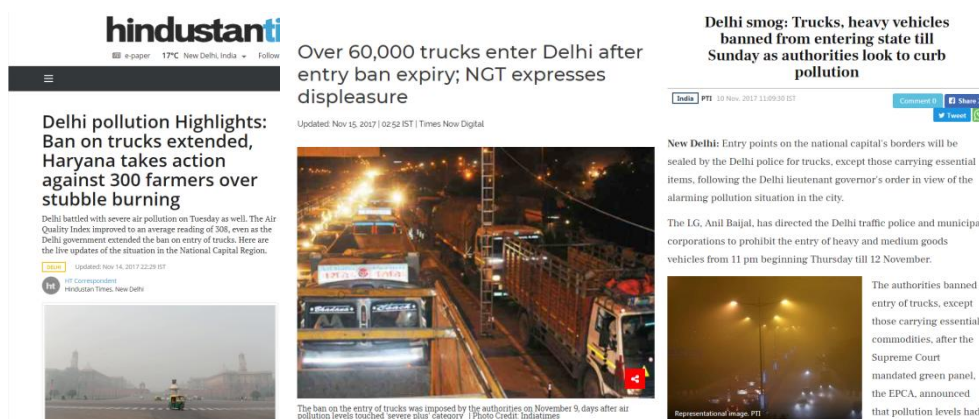


Figure 6.2: Some of the News Clippings on Delhi Air Pollution and Entry/ Ban of Trucks in the City

A dialogue between stakeholders which is based on some form of joint fact finding could be the start of a process towards shared situational awareness and broadly supported innovation measures. This confirms the need for a dual approach, resting on process and substantive aspects of the SUF problem.

6.2. Knowledge Development Plan

Given the results of this first capacity assessment, the following needs can be identified, building on the general needs statement provided in the above.

1. Process capabilities: this includes the ability to create an institutional environment and a series of activities that allow stakeholders to go through consecutive design cycles and implement change.
 - a. Organizational capabilities; understanding stakeholder positions, organizational forms, stakeholder management, forms of stakeholder cooperation.
 - b. Innovation management, including R&D management, roadmap development, strategic alliances, innovation economics and management of technology, project and process management.

A useful example in this respect is the processes followed in various European cities as described in Quak, *et. al.* (2016). Road mapping has been an important activity for the city of Rotterdam. Here, based on a shared vision to move to zero-emission transport in 2025, the community drafted a roadmap towards this goal with four chapters: technology, behaviour, logistics organization and public policy. The steps necessary to achieve the goal were found by back casting from the objective towards the present and by seeking mutual alignment between chapters. Figure 6.3 illustrates this roadmap and the process followed with stakeholders was instrumental to arrive at this result.

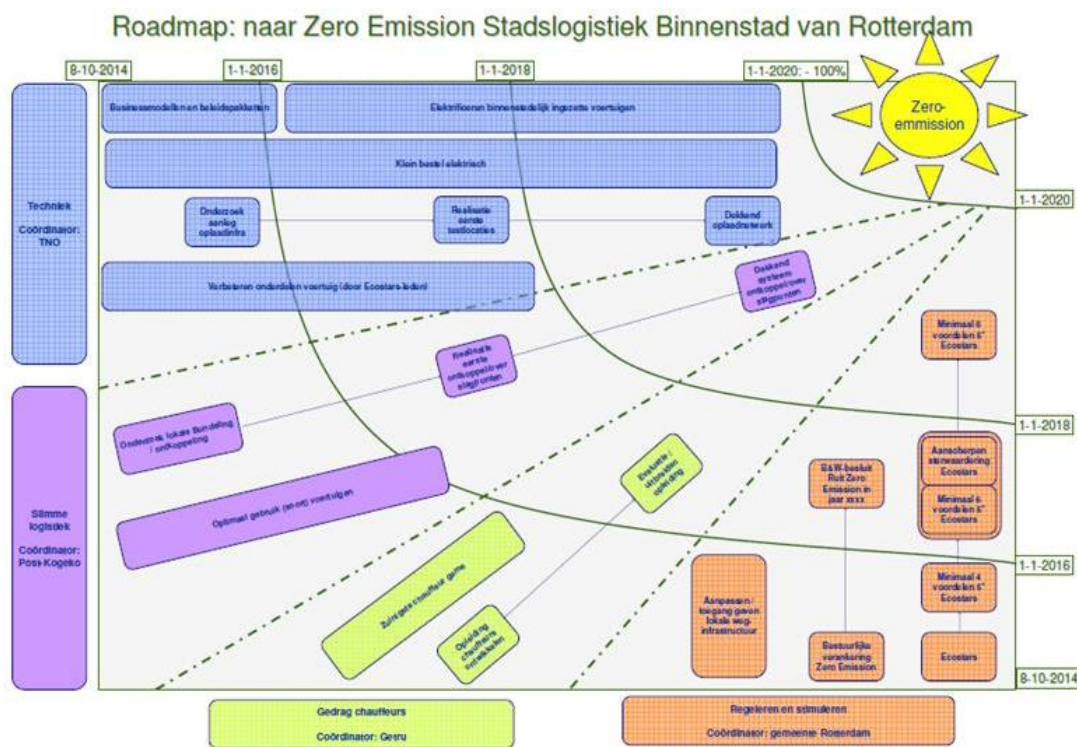


Figure 6.3: Road Map towards Zero Emission in the City of Rotterdam, The Netherlands

2. Substantive capabilities: this concerns data, information, models and knowledge about initiatives, necessary to be able to identify problems, design innovative solutions and implement them.

- a. Data acquisition, statistical analysis, visualisation, reporting: training in these skills belongs to the standard curriculum of local universities and institutes such as CRRI. Their understanding at government (outside academically trained personnel) is limited, however.
- b. Freight modelling including 4 step models; currently locally taught and practiced at Delhi's School of Planning, IIT Delhi and CRRI. Also more advanced approaches including logistics responses or methods such as agent based modelling could be adopted. These require investments in research, however.
- c. Understanding of SUF solutions, including understanding of problems, agreement about causes, knowledge of possible measures and experiences in other cities, knowledge of evaluation approaches (business modelling, cost-benefit analysis) and implementation complexities.

In order to understand how the above three points are intervened, let us look at the concrete demands of a design for future logistics in Delhi as was discussed during the national workshop for this project. Figure 6.4 shows the current situation on the left hand panel, with many criss-cross trips going into the city, without consolidation. The right hand panel, inspired by the well-documented Dutch initiative of Binnenstadsservice (Van Rooijen *et. al.*, 2011) shows how a combination of innovations can reduce the burden on a city. Consolidation takes place outside the city borders, and the last mile is done with clean vehicles. To incentivize the use of this new technology, city tax schemes directed at polluting vehicles could be employed. By recycling this tax towards subsidies for clean vehicles, the cost disadvantage of the new solution would be further reduced.

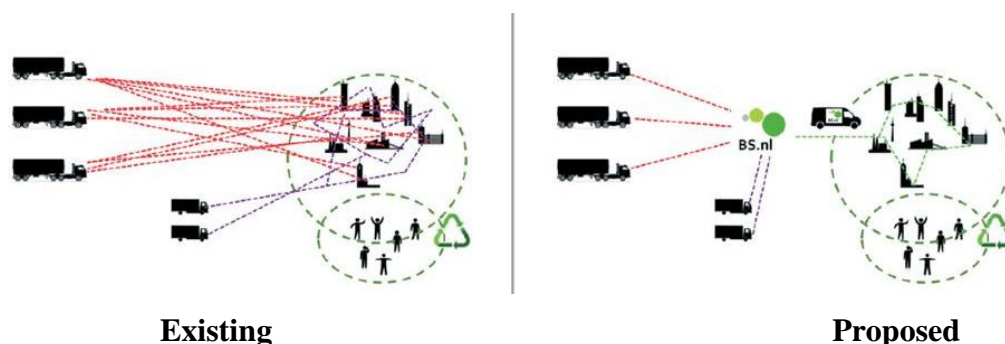


Figure 6.4: Existing (without Consolidation) and Proposed Situation of Trips into the city with Consolidation

In order to evaluate the impact of such an initiative, we need to understand how retailers, manufacturers, carriers and logistic service providers would respond to the new facilities and fiscal measures. This complex interaction of behaviours requires many data and advanced freight models to be in place. Carriers will plan their trips differently, with changes in tours and vehicle types; the operator of the urban consolidation centre will modify the price of their service to maximize their revenues; if this does not lead to a social optimum, government may decide to subsidize additionally or change the pollution taxes; retailers may adapt their ordering policies to the changes in transport costs; finally, consumers may decide to change their shopping behaviour if streets become more attractive. Anand (2015) has modelled this solution. Depending on the outcome of such an evaluation, changes in the proposed measures would need to be discussed and evaluated in a systematic way, to arrive at the best possible outcome – on paper. Implementation with all the stakeholder will not rely on analysis capabilities, but mostly on the process capabilities sketched above.

6.3. Stakeholders Meetings and 1st Workshop on MEGALOG

As part of the project, the stakeholders need to be involved in conducting meetings so as to understand and reach the actual ground level problems and difficulties in implementing transport policies related urban freight traffic. Accordingly the first meeting for this purpose has been conducted on May 9th, 2017 at the C. V. Raman Hall of CSIR - CRRI, Mathura Road, New Delhi. This meeting was attended by the policy makers, development authorities, practising engineers representing national / state level and local bodies, academia, research institutes and decision makers etc. A total of 34 delegates (list is given in *Annexure II*) were attended this 1st meeting and emphasised issues related to freight transport in India and especially in Delhi. The agenda of the program is given in Figure 6.5 and some of the views of the meeting are presented in Figure 6.6.

1st Workshop on
MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR
SUSTAINABILITY (MEGALOG)
 Research Project Funded by





May 9th, 2017
 Venue: Council Hall, CSIR-CRRI, New Delhi – 110025

AGENDA

10:00~10:30	Registration
10:30~11:00	Inaugural Session Introduction to MEGALOG - Dr. Errampalli Madhu , Principal Scientist, CSIR-CRRI Welcome Address - Prof. Satish Chandra , Director, CSIR-CRRI
11:00~12:30	Overview of MEGALOG by Prof. Lori Tavasszy (TU Delft), Netherlands <ul style="list-style-type: none"> • Role of TU Delft in MEGALOG • Development of city logistics metrics • Capacity Development for Sustainable City Logistics • Agent Based Model for City Logistics Role of CSIR-CRRI in MEGALOG by Dr. Errampalli Madhu (CSIR-CRRI), New Delhi <ul style="list-style-type: none"> • Data Collection Activities • Freight Travel Demand Modelling Role of TNO in MEGALOG by Mr. Jeroen Borst (TNO), Netherlands <ul style="list-style-type: none"> • URBAN STRATEGY® Implementation in MEGALOG Concluding Remarks by Dr. Errampalli Madhu (CSIR-CRRI), New Delhi, India <ul style="list-style-type: none"> • Expected Outcome of MEGALOG • Execution and Implementation of MEGALOG
12:30~13:00	Discussion and Suggestions by various Stakeholders
13:00~13:10	Closing Remarks - Prof. Satish Chandra , Director, CSIR-CRRI
13:10~	Lunch

Organized by:
 CSIR-Central Road Research Institute (CRRI), New Delhi

Participating Institutes

TNO, The Netherlands



Delft University of Technology, The Netherlands





Figure 6.5: Agenda of 1st Workshop on MEGALOG held on 9th May 2017 at CSIR-CRRI, New Delhi



Director (CSIR-CRRI) chairing the MEGALOG Meeting



Dr. Errampalli Madhu (CSIR-CRRI) making presentation



Prof. Lorant A. Tavasszy (TU-Delft, Netherlands) making presentation



Mr. Jeroen Borst (TNO, Netherlands) making presentation



View of the Stakeholders participated in the MEGALOG Meeting

Figure 6.6: Some Views of 1st Workshop on MEGALOG held on 9th May 2017 at CSIR-CRRI, New Delhi

During the above stakeholders meeting, the following points are discussed:

- Tuglakabad Container Depot should be considered in the freight travel demand modelling
- Impact of Goods and Service Tax (GST) may be examined

- Impact of mass housing and commercial complexes on freight generation parameters may be studied
- Stakeholders group who are related to freight operations and policies should be finalised
- Travel Planning Model and Travel Optimisation Model should be focussed
- Modelling process should focus both small haul like Pizza Delivery and large trucks
- Passenger traffic has to be taken into consideration in freight travel demand modelling especially at traffic assignment stage
- Both internal distribution and outer cordon points should be considered
- Integration with Current Government policies
- Increase in emission loads and fuel consumption from the freight traffic need to be studied
- E-commerce and Home Delivery trends can be examined with respect to travel behaviour
- City logistics mainly focus on restriction of timings and areas
- Education campaign and training workshop should be focusing on freight operators, policy makers etc.
- Drivers awareness program also should be included
- Parking requirements for trucks may be studied
- Significance of bypass for truck traffic which are passing through the city has to be studied

6.4. Organizing Short Courses

An important goal of the project is to create an impact in practice. An extensive pilot study is carried out for New Delhi with a transferable modelling approach. The city of Delhi i.e. National Capital Territory of Delhi (NCTD) has been selected as study area for this study and quantified the metrics related to freight traffic in the city. As part of fulfilment of the objective of the project, skill development training in terms of short courses to various stakeholders and operators on sustainable city logistics (SCL) has been organised on December 12th, 2017. Prior to that, capacity assessment of existing situation has been done

through a proforma of Capacity Assessment and Policy Inventory. The proformas for Policy Makers, Operators and Experts have been designed separately for these groups as the objective of these stakeholders are different however, they are all towards sustainable city logistics. The designed proformas are given in *Appendix 3*. Accordingly the short course on Sustainable City Logistics has been conducted on December 12th, 2017 at the Lecture Hall of CSIR - CRRI, Mathura Road, New Delhi. This course was attended by the policy makers, development authorities, practising engineers representing national / state level and local bodies, academia, research institutes and decision makers etc. A total of 37 delegates (list is given in *Annexure 11*) were attended this short course where issues related to sustainable city logistics, freight transport in India especially in Delhi, Activity Based Modelling approach, evaluation tools namely Urban Strategy etc are emphasised. The agenda of the program is given in Figure 6.7 and some of the views of the meeting are presented in Figure 6.8.

6.5. National Level Dissemination Workshops

Subsequently, National Dissemination Workshop on Megacity Logistics has been organised on December 13th, 2017 at CSIR-CRRI, Mathura Road, New Delhi to disseminate the findings from the project, approaches to be adopted by different policy makers/ stakeholders to achieve sustainability in the area of City Logistics in the city of Delhi. This workshop was attended by the policy makers, development authorities, practising engineers representing national / state level and local bodies, academia, research institutes and decision makers etc. A total of about 53 delegates (list is given in *Annexure 11*) were attended this workshop where issues related to good practices to achieve sustainable city logistics, freight transport in India especially in Delhi, Activity Based Modelling approach, evaluation tools namely Urban Strategy etc are emphasised. The agenda of the program is given in Figure 6.9 and some of the views of the meeting are presented in Figure 6.10.

In the workshop, the commitment towards sustainable city logistics session has been carried out in that, the participants expressed their support by signing on that banner where the goals of sustainable city logistics are mentioned as shown in Figure 3.2.



MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)

Research Project Funded by



December 12th, 2017

Venue: Council Hall, CSIR-CRRI, New Delhi – 110025



Short Course on
"Sustainable City Logistics for Policy Making and Freight Operations"

AGENDA

09:30~10:00	Registration
10:00~10:30	Opening Remarks - Dr. Errampalli Madhu , Principal Scientist, CSIR-CRRI Welcome Address - Prof. Satish Chandra , Director, CSIR-CRRI
10:30~11:00	Tea Break
11:30~13:30	Sustainable City Logistics for Policy Making Speakers: Prof. Russell G. Thompson , The University of Melbourne, Australia Dr. Hans Quak , TNO, The Netherlands Prof. Lorient A. Tavasszy , TU Delft, Netherlands Dr. Errampalli Madhu , CSIR-CRRI, New Delhi Dr. Nilesh Anand , TU-Delft, The Netherlands
13:30~14:30	Lunch
14:30~15:30	Sustainable City Logistics for Freight Operations Speakers: Dr. Hans Quak , TNO, The Netherlands Mr. Jeroen Borst , TNO, The Netherlands
15:30~16:00	High Tea
16:00~18:00	Workshop Preparations
18:00~20:00	Dinner

Organized by:

CSIR-Central Road Research Institute (CRRI), New Delhi 

Participating Institutes

TNO, The Netherlands  Delft University of Technology, The Netherlands 

Figure 6.7: Agenda of Short Course on Sustainable City Logistic held on 12th December 2017 at CSIR-CRRI, New Delhi

As the workshop was attended by some freight operators as well, the common issues faced by operators are also discussed like, time and age restrictions for freight vehicles to enter/operate in the city, entry tax/ tolls at various points etc. The policy makers need to consider the operator perspective also to achieve the sustainable city logistics as a whole.



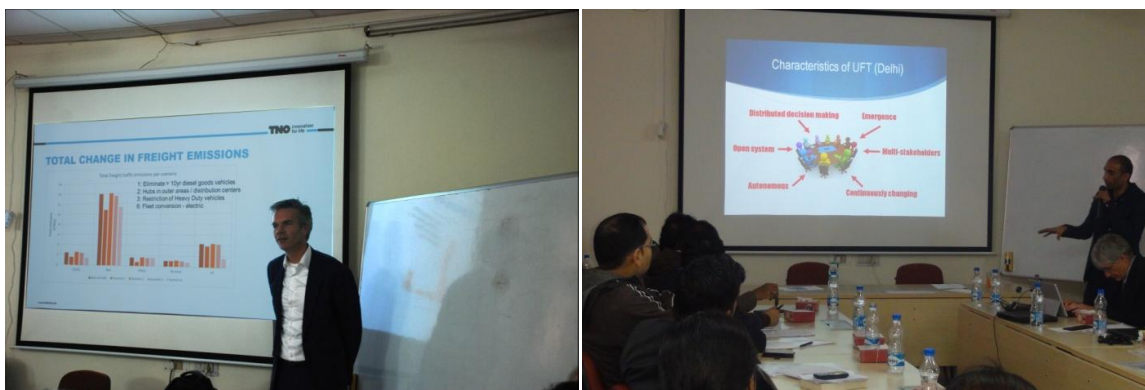
Inauguration of Short Course on "Sustainable City Logistics for Policy Making and Freight Operations" by Prof. Satish Chandra, Director (CSIR-CRRI) and Prof. Lorant A. Tavasszy (TU Delft)



Presentations by Prof. Russell G Thompson (Univ. of Melbourne, Australia) and Prof. Lorant A. Tavasszy (TU Delft, Netherlands)



Presentations by Dr. Errampalli Madhu (CSIR-CRRI) and Dr. Hans Quak (TNO, Netherlands)



Presentations by Mr. Jeroen Borst (TNO, Netherlands) and Dr. Nilesh Anand (TU Delft, Netherlands)

Figure 6.8: Some Views of Short Course on Sustainable City Logistics held on 12th December 2017 at CSIR-CRRI, New Delhi

The four important points emerged in the workshop to achieve sustainable city logistics are given below:

- Reduction of negative effects of urban freight transport while maintaining productivity
 - ❑ *Encourage to carry out appropriate research*
 - ❑ *Systematic planning of facilities*
 - ❑ *deployment of Innovative methods*
 - ❑ *Advanced Vehicular Technologies*
- Identification of workable urban freight solutions including roadmaps towards these
 - ❑ *Adequate database (upto date)*
 - ❑ *Evolving appropriate tools*
 - ❑ *Encourage to carry out appropriate research (academia, R&D institutes etc.)*
 - ❑ *Frequent meetings/ discussions among stakeholders (researchers, policy makers, freight operators etc.)*
- Increase of the knowledge base including data collection, models and scenarios
 - ❑ *Adopting advanced techniques for data collection*
 - ❑ *conducting skill development training/ short courses to various stakeholders and operators on sustainable city logistics (SCL)*
 - ❑ *Encourage to use of advanced analytical tools*
- Collaboration with other stakeholders to realize solutions towards sustainability
 - ❑ *Formulation of a organizational body with all possible stakeholders*
 - ❑ *Members with shared awareness about sustainability*

National Dissemination Workshop on
MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)
Research Project Funded by





December 13th, 2017
Venue: C. V. Raman Hall, CSIR-CRRI, New Delhi – 110025

AGENDA

09:30~10:00	Registration
10:00~11:00	Introduction to MEGALOG - Dr. Errampalli Madhu , Principal Scientist, CSIR-CRRI
Inaugural Session	Welcome Address - Prof. Satish Chandra , Director, CSIR-CRRI Opening Remarks - Prof. Lorant A. Tavasszy , TU Delft, The Netherlands Key Note Address - Prof. Russell G. Thompson , The University of Melbourne, Australia Chief Guest Address - Sh. Naresh Kumar , IAS, Chairman (NDMC), Govt. of NCTD Vote of Thanks - Dr. Kayitha Ravinder , Principal Scientist, CSIR-CRRI
11:00~11:30	High Tea
11:30~13:00	Moderator - Prof. Sanjay Gupta , SPA, New Delhi
Technical Session I:	Good Practices and Experiences of City Logistics - Dr. Hans Quak , TNO, The Netherlands Sustainable City Logistics and Capacity Development - Prof. Lorant A. Tavasszy (TU Delft), The Netherlands MEGALOG: Case Study of Delhi - Dr. Errampalli Madhu (CSIR-CRRI), New Delhi Discussion and Suggestions by various Stakeholders
13:00~14:00	Lunch
14:00~15:30	Moderator - Dr. Hans Quak , TNO, The Netherlands
Technical Session II:	Urban Strategy - A tool to evaluate the transport policies - Mr. Jeroen Borst , TNO, The Netherlands Feasibility of Activity Based Modelling for Freight Transport - Dr. Nilesh Anand , TU-Delft, The Netherlands Measures for Sustainability - Prof. Lorant A. Tavasszy , TU Delft, Netherlands Discussion and Suggestions by various Stakeholders
15:30~16:00	Tea Break
16:00~16:15	Outcome of MEGALOG - Dr. Errampalli Madhu , CSIR-CRRI
Concluding Session	
16:15~17:00	Way Forward for City Logistics - Chairman: Prof. Satish Chandra , Director, CSIR-CRRI
Panel Discussion:	Panelists: Dr. Errampalli Madhu , CSIR-CRRI, New Delhi Prof. Lorant A. Tavasszy , TU Delft, The Netherlands Prof. Russell G. Thompson , The University of Melbourne, Australia Dr. Hans Quak , TNO, The Netherlands Prof. Sanjay Gupta , SPA, New Delhi
17:00~17:30	High Tea

Organized by:
 CSIR-Central Road Research Institute (CRRI), New Delhi

Participating Institutes

TNO, The Netherlands



Delft University of Technology, The Netherlands



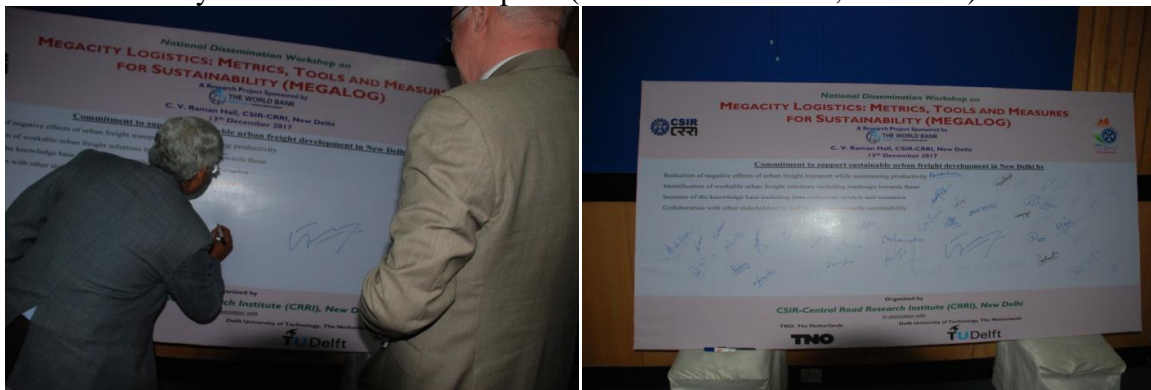





Figure 6.9: Agenda of National Dissemination Workshop on MEGALOG held on 13th December 2017 at CSIR-CRRI, New Delhi



Inaugural Address by Prof. Satish Chandra, Director (CSIR-CRRI) and Chief Guest Address by Prof. Russell G Thompson (Univ. of Melbourne, Australia)



Signing to Support Commitment towards Sustainability City Logistics



Delegates and Group Photo for the Participation in Workshop on MEGALOG



Speakers and Discussion of Technical Session I (Moderated by Prof. Sanjay Gupta, SPA)



Speakers and Discussion of Technical Session II (Moderated by Dr. Hans Quak, TNO, Netherlands)



Panel Discussion on Way Forward for City Logistics (Chairman: Prof. Satish Chandra CSIR-CRRI)

Figure 6.10: Some Views of National Dissemination Workshop on MEGALOG held on on 13th December 2017 at CSIR-CRRI, New Delhi

6.6. Design of Booklet on Sustainable City Logistics

An important goal of the project is to create an impact in practice by reaching various stakeholders and operators on sustainable city logistics (SCL). Accordingly, a technical booklet has been designed to explain the issues related to need of sustainability, current logistics situation of Delhi, approaches to achieve sustainable city logistics etc. The cover page of the designed booklet is shown in Figure 6.11 and the full booklet is given *Appendix 12*.

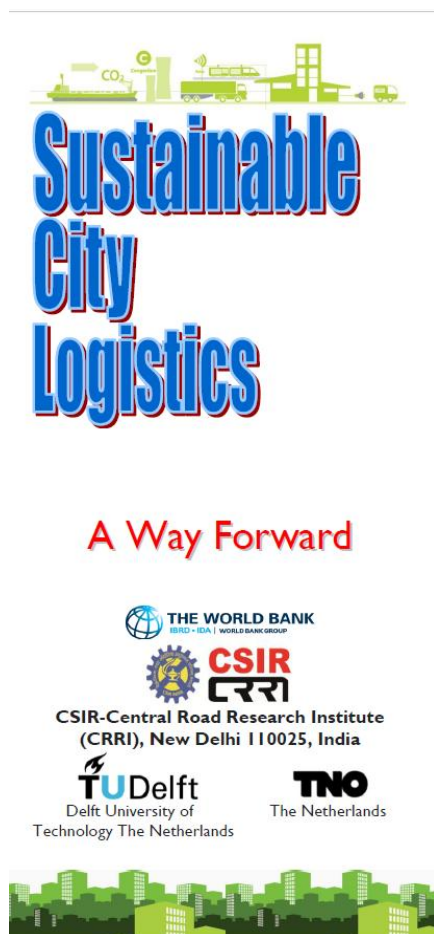


Figure 6.11: View of Designed Booklet on Sustainable City Logistics

6.7. Future Capacity Building Process on Sustainable City Logistics

The CSIR-CRRI is well connected to all transport related actors in city logistics, including infrastructure management, the transport sector and government. Through the meetings, short course and workshops, the need for city logistics, current limitations/ problems for sustainable logistics and the way forward to achieve sustainable city logistics have been discussed with the potential stakeholders and accordingly finalised as given Section 6.5. The list of participant and the persons involved (part of the local research team or external stakeholders) in workshops and short course have been given in the *Annexure 11*. Knowledge sharing at this stage was limited to the workshops and final conference. It has been proposed that all participants will receive a copy of the report including a summary

leaflet of the project highlighting sustainable city logistics for the city of Delhi. This will be followed up with meetings with high level representatives of the city region government to gauge the willingness and availability of resources to continue the process with a more elaborate modelling and evidence based policy design cycle. As the transport logistics and administrative setups of different cities more or less matches with present study area i.e. Delhi, the methodology adopted can be replicated to achieve sustainable city logistics for the other cities as well.

References

- Quak, H., Lindholm, M., Tavasszy, L., & Browne, M. (2016). From freight partnerships to city logistics living labs–Giving meaning to the elusive concept of living labs. *Transportation Research Procedia*, 12, 461-473.
- Quak, H., & Tavasszy, L. (2011). Customized solutions for sustainable city logistics: the viability of urban freight consolidation centres. In *Transitions towards sustainable mobility* (pp. 213-233). Springer Berlin Heidelberg.
- Anand, N. (2015). *An Agent Based Modelling Approach for Multi-Stakeholder Analysis of City Logistics Solutions*. PhD Thesis Delft University of Technology, Delft: TRAIL Research School.

7. DECISION SUPPORT SYSTEM: POLICY ANALYSIS AND VISUALIZATION TOOLSET

7.1. Introduction

7.1.1. Background

The road freight transport market represents a significant proportion of road use and economic activity in India. Fifteen to twenty percent of Gross Domestic Product (GDP) is spent on transport and logistics, significantly higher than for other developing countries. Around 63% of freight is sent by road, and both in cities and in rural areas, trucks can face significant delays due to poor road conditions, congestion and checkpoint delays. The average speed of trucks on Indian roads is around 20 km per hour.

The urban road network of Delhi faces these same challenges. With a decennial population growth of approximately 20%, increased urbanization has led to increasing traffic problems such as congestion, air pollution, and reductions in safety. A range of measures have recently been proposed in order to overcome these problems, including the National Green Tribunal (NGT) of India ruling on banning trucks older than 10 years from entering the city of Delhi due to the high emission levels of those vehicles. The city of Delhi currently has other restrictions on freight vehicles, including time restrictions for most of the roads of Delhi and 24-hour bans on some roads.

Urban freight in Delhi is primarily distributed by four primary types of vehicles: Heavy Commercial Vehicles (HCV) includes Heavy Truck (HT) and Multi-Axle Truck (MT), Light Commercial Vehicles (LCV) or Light Truck (LT), Goods Vans (GV), and Goods Auto Rickshaws (GA), as well as a range of animal-drawn, person-drawn and pedalled vehicles.

In this chapter, an attempt has been made to build a Proof of Concept (PoC) of a decision support system and apply it on urban freight and emissions for New Delhi. This chapter describes how:

- TNO built such a decision support system on the basis of Urban Strategy, an existing software instrument.

- The resulting decision support system was loaded with data on the current situation and possible future scenarios, including measures to limit the negative impact of freight movements.
- The findings of the application of the decision support system to this casus.

7.1.2. Policy Analysis and Visualization Toolset

The basis for the policy analysis and visualization toolset will be the instrument Urban Strategy, which has been developed by TNO.

The decision support system specifications and pilot systems to be delivered are twofold. Firstly, the visualisation of the city logistics metrics for monitoring purposes is done via a Planning Support System (PSS) on the basis of the 3D city model Urban Strategy of TNO. This PSS (www.tno.nl/urbanstrategy) has been applied in different cities around the world (Amsterdam, Dubai, and Shenzhen) and allows tracing the generation and propagation of traffic and air pollutants. The typical analysis of Urban Strategy in the form of screenshot is shown in Figure 7.1.

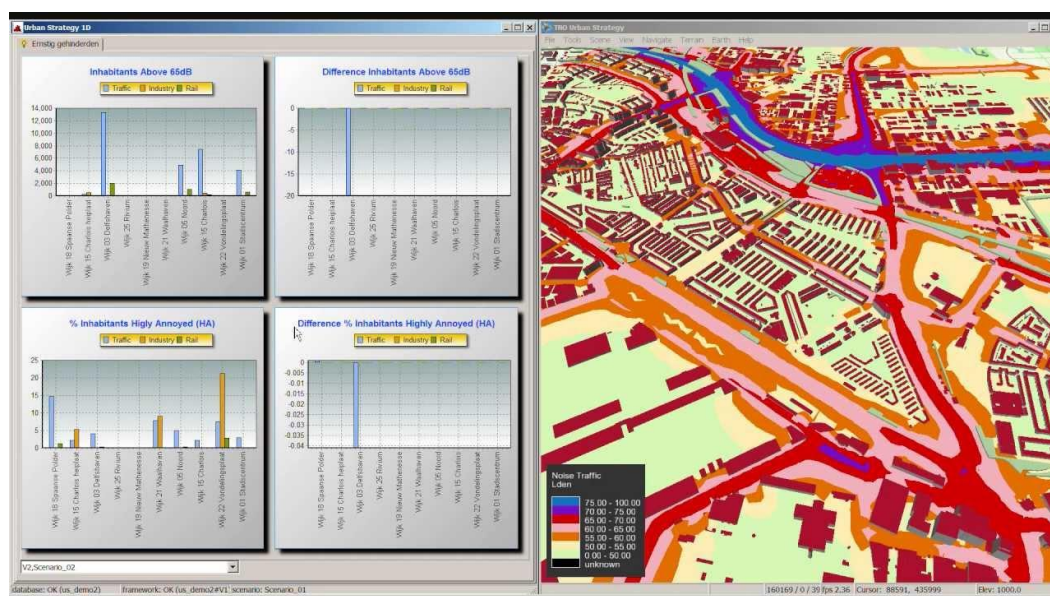


Figure 7.1: Screenshot of Urban Strategy outputs (Source: TNO)

On the basis of data specified by TNO and provided by CSIR-CRRI, TNO will build a structured piloting database and demonstrator of a PSS based on Urban Strategy. The functioning of Urban Strategy application will be demonstrated for a number of policy scenarios that directly affect freight flows within the city and results will be visualised with Urban Strategy. The specifications, the process and follow-up recommendations will be laid down in a report form at the end.

7.1.3. *Urban Strategy*

Urban Strategy is a software tool developed by TNO for interactive spatial planning, in which calculation models are linked to databases. Using a set of interfaces, it is possible to gain insight into the effects of plans and measures in the time span of a workshop. Areas covered by Urban Strategy include traffic, transport, noise, air quality, safety and sustainability.

Different scenarios and measures, such as altering traffic circulation, new buildings or land use or lowering speed limits, can be interactively explored with the system. It directly shows the updated detailed traffic calculations, air quality maps and noise contour maps as well as indicators describing the impact (such as annoyance) after a measure has been applied through the interactive interface.

Because Urban Strategy integrates different from different sources, it also allows planners to evaluate the effects of measures on many different aspects. Because response times are very short, the instrument can be used in interactive workshops with specialists and stakeholders. In this way, authorities can formulate effective noise abatement strategies in a very short time span while involving the relevant parties.

7.2. *Technical Background of Urban Strategy*

7.2.1. *Software architecture*

The starting point of the instrument Urban Strategy was to use existing state-of-the-art models that were already implemented. In order to be able to let different models cooperate, the following elements were developed: A uniform data model in order to create one shared data

ture; a communication framework for communication between the models; interfaces to view and manipulate the data. The architecture for Urban Strategy is shown in Figure 7.2.

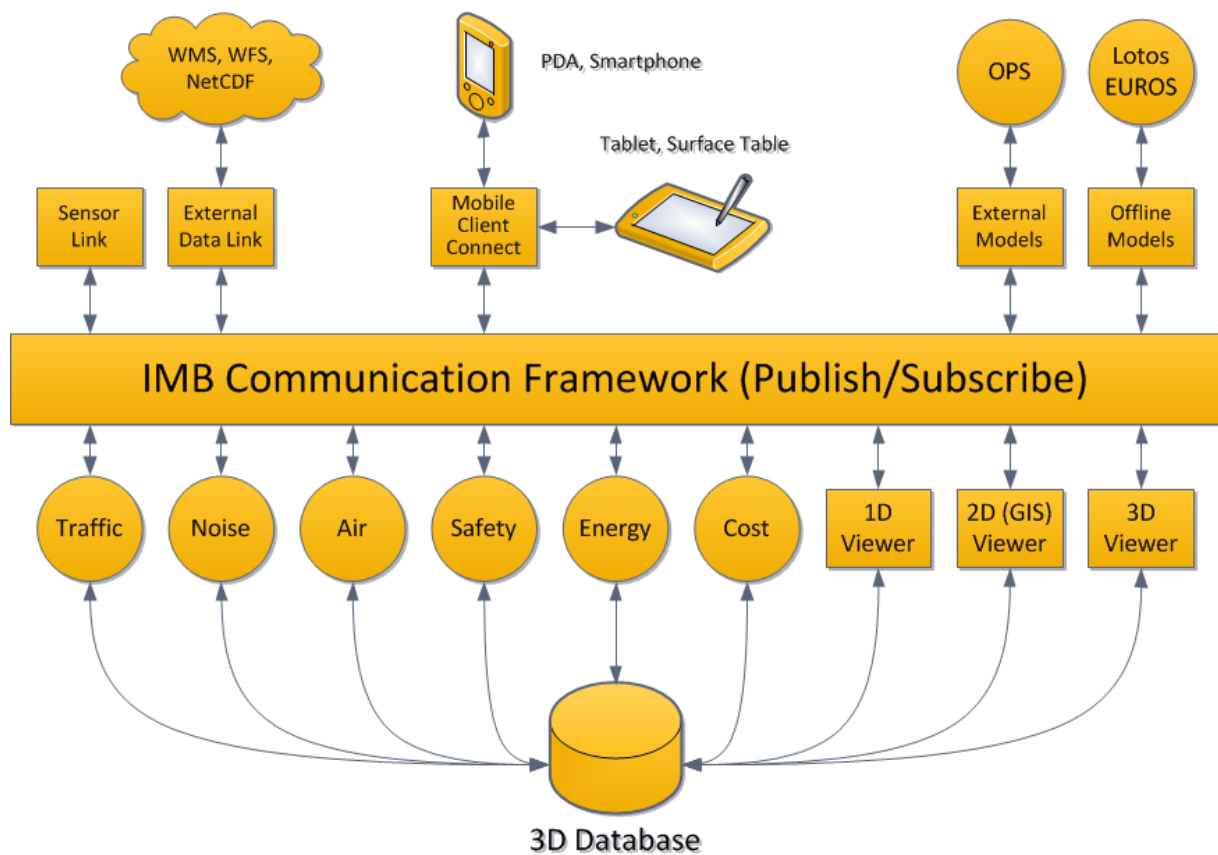


Figure 7.2: Software architecture for Urban Strategy

The framework (IMB) is based on the concept of a Service Oriented Architecture (SOA) or Enterprise Service Bus (ESB). These concepts are used in systems with a set of coupled services that interact with each other by sending messages (data) and events (signals).

The IMB framework realizes the interconnection between services by means of a Publish/Subscribe concept. Each service can register the data and/or event it outputs to other services (Publish) and also register the data and/or events it needs as an input (Subscribe).

The elements in this architecture, which are partially currently operable and partially being developed as described in the following sections.

7.2.2. Interfaces

In order to view and manipulate the data, a number of interfaces have been developed, including a interface showing a number of indicators (the 1D interface), a Geographical Information Systems (GIS - or 2D interface) and a 3D interface.

Indicators (1D) Interface

The so-called 1D interface shows different indicators produced by the different models. Examples of indicators implemented in Urban Strategy are noise annoyance, travel times or the total emissions as shown in Figure 7.3.

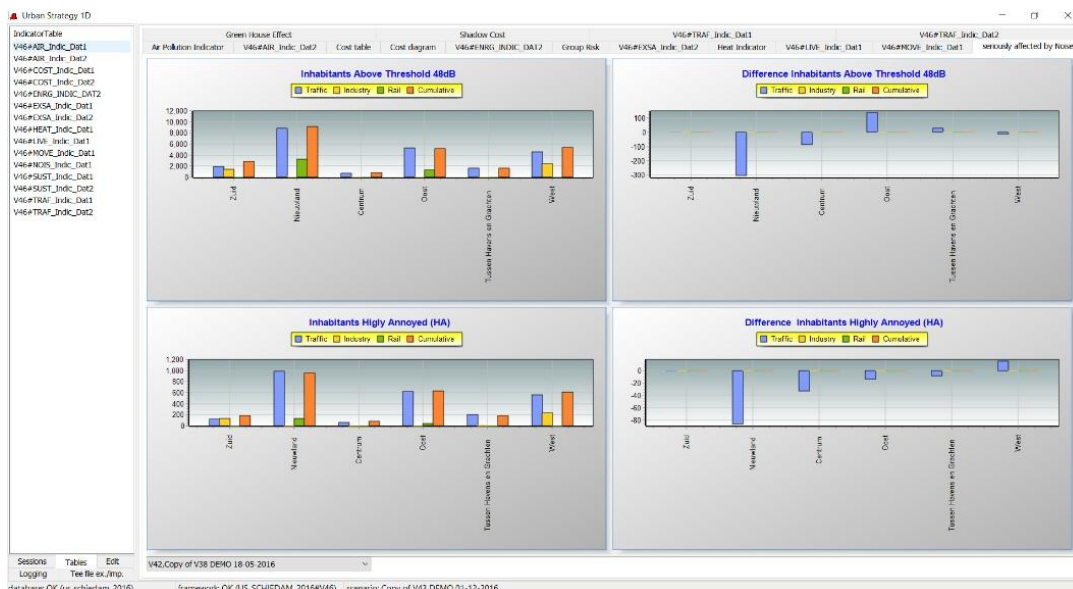


Figure 7.3: Indicators implemented in Urban Strategy such as Noise Annoyance, Travel Times or the Total Emissions

GIS (2D) interface

The 2D interface is a GIS (Geographical Information System) interface in Urban Strategy as shown in Figure 7.4 that enables the user to view, select, and edit objects in the database. With this interface, the operator can define scenarios by adding, deleting or changing objects. Road attributes can be changed (such as the road surface type or speed), roads can be added or closed. The building configuration can be altered and noise barriers can be added.

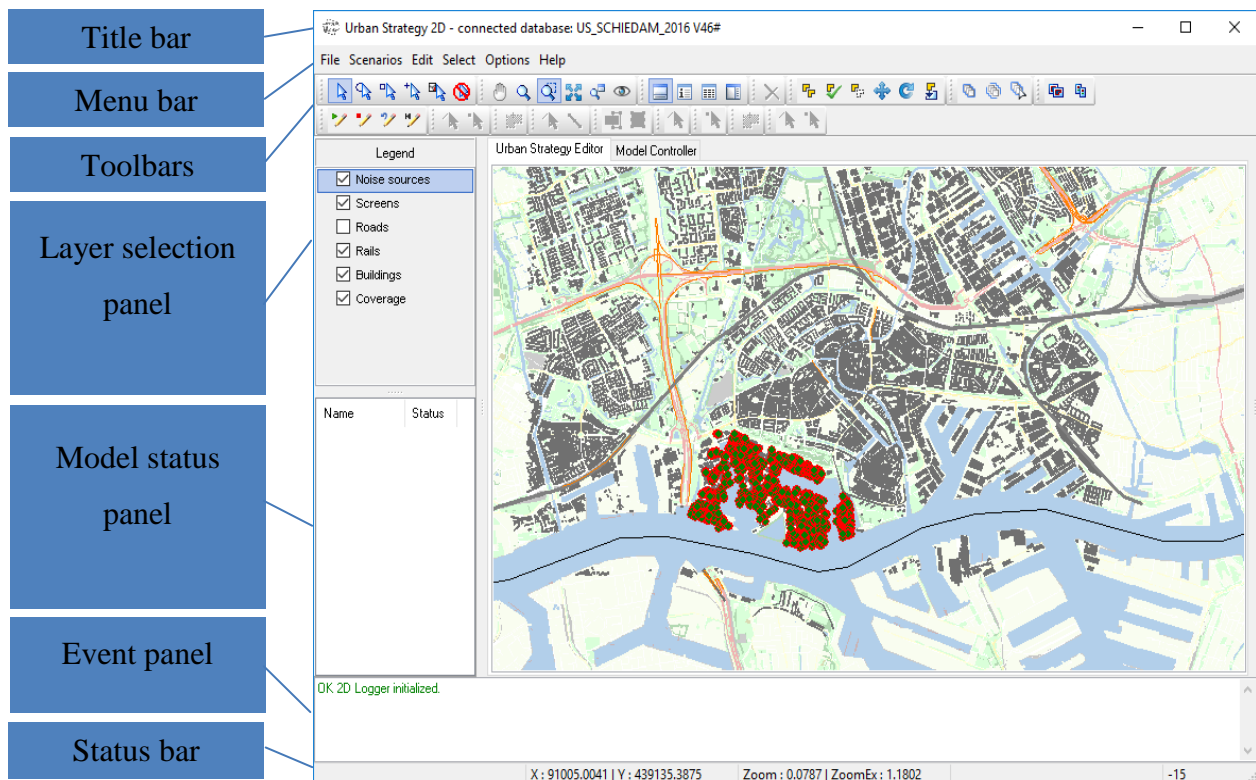


Figure 7.4: 2D interface with GIS (Geographical Information System) in Urban Strategy

3D interface

The Urban Strategy 3D interface (shown in Figure 7.5) is a viewer to show the geographic dataset and the calculation results in 3D. It allows the user to ‘fly’ around in the Urban Strategy data landscape. The calculation results are divided in layers which can be projected in the 3D world by user configurable keys.

The interface is connected to the Urban Strategy framework and can be controlled from the 2D interface (setting the viewport), but is also able to communicate with other instances of 3D interfaces running.

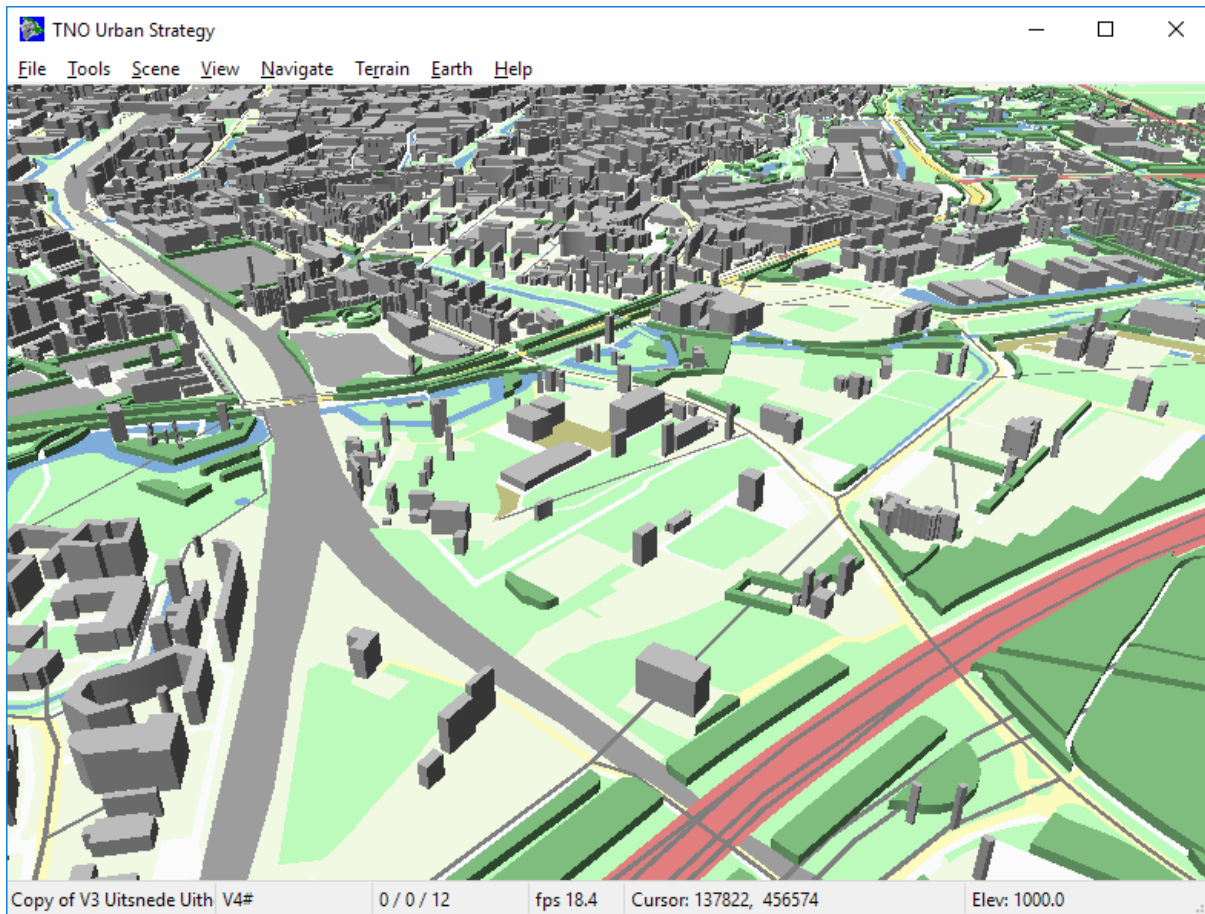


Figure 7.5: 3D interface with GIS (Geographical Information System) in Urban Strategy

Web interface

In order to share the output of calculation with a larger group of stakeholders on multiple locations, a web interface has been developed. This web interface allows multiple users to browse through the output data of multiple scenarios and calculate difference maps. The layers that can be accessed are defined in the database and generated in the ‘Mobile Client Connect’ module that is displayed in the architecture Figure 7.6

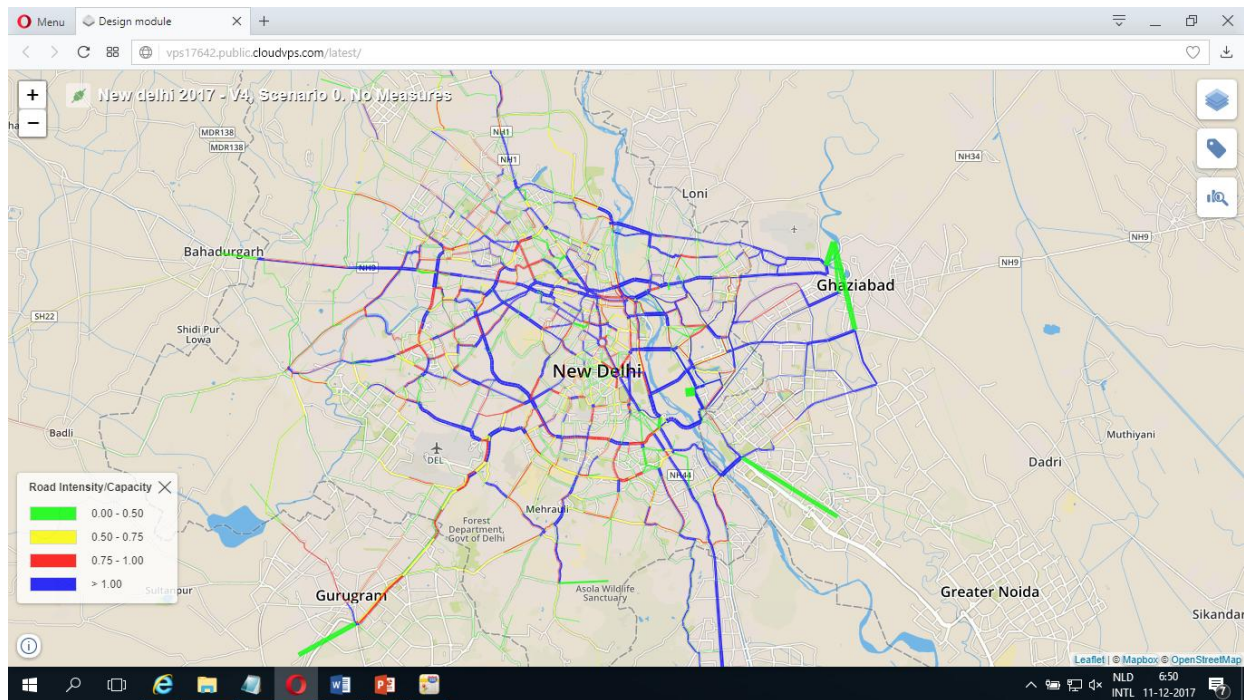


Figure 7.6: Screenshot of Web Interface of Urban Strategy

7.2.3. Data model and data store

In order to be able to interconnect different models, one data model was made to describe all the objects in the database. In this way, the definition for each object for each model is the same. For example: noise calculations require detailed and accurate information of the geography of roads while the traffic model needs travel times from node to node on a coarser network. Also the output of the traffic model (overall traffic flows during rush hours) had to be transformed into the input data required by the noise model (traffic flows per day, evening, night for different vehicle classes). Therefore, the output of the traffic model can directly be used as input for the noise model. The data in the data store is actually two dimensional with an optional z-component. Therefore a 3D model of the environment can be built up. On the basis of these starting points, a data model was made to describe all the objects in the database. This data model is based upon the ESRI shape file data model. In this way, the definition for each object for each calculation model is identical and can be easily exchanged with third parties. The data model consists of the various objects with their main attributes and different layers:

Main Attributes

- Building (polygon): height, function, inhabitants, year, central heating
- Road (line): height, width, intensity (per period, per vehicle type), road surface, speed, capacity, material
- Coverage (polygon): land use code, height
- Noise Barrier (line); height, material, width, slope, absorption
- District (polygon): name
- Node (point): traffic zone,
- Noise receptor (point): height, noise level (per period), building-id
- Air receptor (point): height, concentration level (per substance), building-id

Additional optional layers

- Link (Connection): cabling or piping energy grid part
- Railway (line): height, width, intensity (per period, per vehicle type), surface, speed, breaking fraction, material
- Noise source (point): height, emission (per frequency band, per angle, per period), description, plant
- Source of external safety hazard (point): scenario descriptions
- External safety hazards (grid): results from external safety calculations.
- Node (point): Energy supply or consumption

The technical solution that was chosen is an *Oracle 11g* database under a Windows Server System. Tables are (spatially) indexed, which enables simple spatial (GIS) queries directly on the database, such as linking buildings to districts in order to calculate indicators. More complex queries are, for reasons of performance performed by the calculation models.

7.3. Setup of Urban Strategy for Delhi City

7.3.1. Methodology

In order to conduct further analysis of the impacts of potential traffic measures to improve logistics within the city of Delhi and to achieve the stated aims of this project, the first step is to import all available data into Urban Strategy, including locating addition (public) data

where possible, and ensuring those data can be used to produce a working model within Urban Strategy.

Starting a project for an area that hasn't previously been analysed in Urban Strategy requires a number of initial steps, including the selection of an appropriate coordinate system, the preliminary input of data, and the testing of that data to ensure that all models behave as expected.

Figure 7.7 shows the overall set-up of the Decision Support System (DSS) on the basis of Urban Strategy. On the basis of the input, provided by CSIR-CRRI, traffic assignments and emission calculations are performed by the DSS. Therefore, changes in the road network can be assessed interactively.

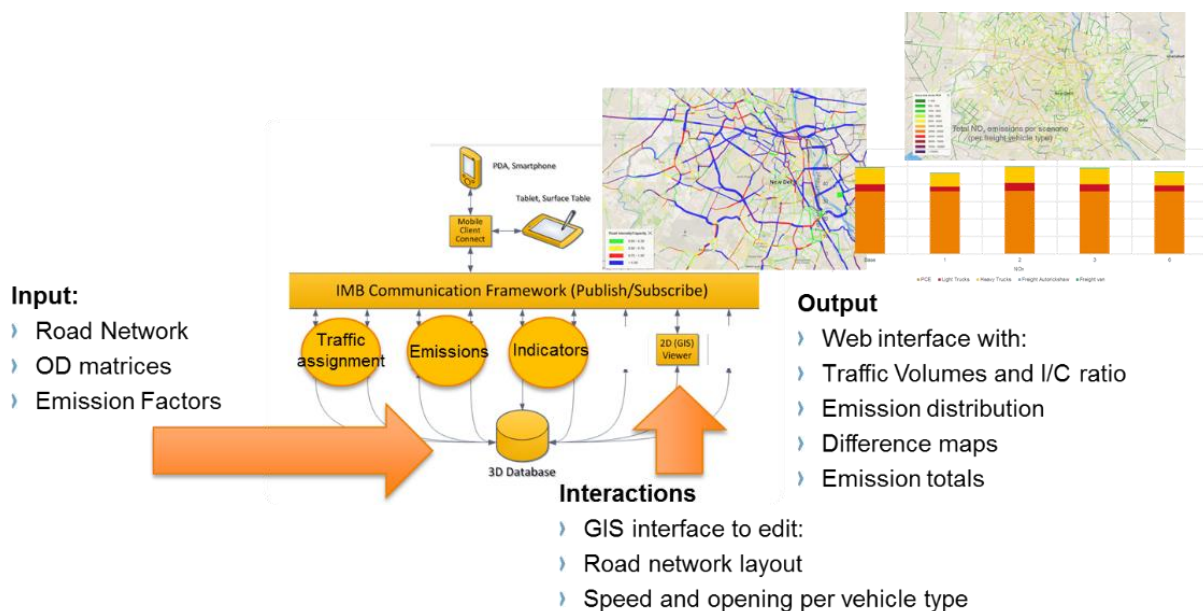


Figure 7.7: Overview of the Decision Support System on the basis of Urban Strategy

7.3.2. Choice of coordinate system

In order to start an Urban Strategy, it is important to select an appropriate coordinate system. Urban Strategy uses a coordinate system in metric units (meters). The UTM (Universal Transverse Mercator) system has been selected, as it is a universal system that can be used anywhere in the world. It divides the world in 60 x 2 zones in which coordinates are defined in metres. The city of New Delhi lies completely in zone **43N**. The EPSG code for zone 43N

(WGS-84) is **epsg:32643**. In this coordinate system, a central area of New Delhi defined by the following geographical coordinates:

Longitude: 77.19 – 77.265 deg

Latitude: 28.59 – 28.64 deg

These can be defined in UTM43N by the following UTM coordinates (in metres):

x: 714,000 – 721,500

y: 3,165,000 – 3,170,000

7.3.3. Assignment method

A volume averaging method has been used to assign the transportation demand (OD Matrix provided to the network. This means that the traffic is divided over several routes, depending on the available capacity and travel times on alternative routes. The assignment module allows multiple transportation modes to be assigned simultaneously. Therefore, roads can be opened or closed for different type of vehicles.

7.3.4. Emission Factors and Emission Loads

In the present study, CPCB (Central Pollution Control Board), India (CPCB, 2000) Emission factors for four types of freight vehicles and passenger cars in g/km for different age classes with deterioration factors have been utilised. On the basis of the age distribution, final emission factors were derived. Traffic assignment of the transportation demand yields traffic volumes on the road network [vehicles/24 hr] and multiplication of emission factors leads to emission per vehicle type per meter link [g/(km*24 hr)]. Summation over the vehicle types and links leads to the emission totals per 24 hr on entire road network.

7.3.5. Uploading the data into a new database

A new database has been created for use by Urban Strategy, with the name **US_NEW_DELHI_2017**. The database contains the following information:

- buildings
- roads
- nodes
- traffic zones
- basic coverage

7.5.6. Input data

Roads and Traffic

CSIR-CRRI provided traffic data in a number of shape files, in latitude and longitude coordinates (WGS-84). The road network, including links and nodes, with information on link speed and capacity, were then converted to UTM43N. The centres of gravity were then determined for each traffic zone.

Buildings and Basic coverage

In order to graphically represent the buildings and land coverage for the study area, data were then imported from OpenStreetMaps (OSM) based on the selection criteria that the field “building” contained a non-empty value.

The next step was to import areas into the **basic coverage** layer and assign a land use code (TDN code) to them. Mapping of OSM data to Urban Strategy categorization has been made and shown in Table 7.1. This list is used in a script file (*.ops) for the US Loader.

Table 7.1: Mapping of OSM data to Urban Strategy categorization

S. No	Query (condition)	TDN code	S. No	Query (condition)	TDN code
1	amenity='bus_station'	3902	16	landuse='recreation_ground'	5212
2	amenity='college'	5262	17	landuse='residential'	1012
3	amenity='fairgrounds'	5212	18	leisure='common'	5212
4	amenity='grave_yard'	5303	19	leisure='garden'	5212
5	amenity='hospital'	5262	20	leisure='golf_course'	5020
6	amenity='parking'	3902	21	leisure='park'	5212
7	amenity='place_of_worship'	5262	22	leisure='pitch'	5212
8	amenity='school'	5262	23	leisure='stadium'	1023
9	landuse='cemetery'	5303	24	natural='scrub'	5020
10	landuse='commercial'	1073	25	natural='water'	6112
11	landuse='farmland'	5212	26	natural='wood'	5020
12	landuse='grass'	5212	27	tourism='museum'	5262
13	landuse='industrial'	1073	28	tourism='zoo'	5020
14	landuse='railway'	5263	29	osm_id='162295'	6112
15	landuse='retail'	1073	30	boundary='administrative'	5262

Road attributes

The link details for the road network were then mapped to the appropriate fields within Urban Strategy. In order to do so, certain assumptions needed to be made:

- a. *Mismatch between the number of traffic zones between the shape file and OD matrices.* The shape file with traffic zones contained 360 traffic zones, while the OD matrices all consist of 368x368 entries. On inspection, it was determined that the 8 ‘missing’ zones were the zones (feed points) lying outside of the region of interest. These ‘external’ zones were identified from the shape file that contains the connectors (the virtual links from the zone centroid to a node that is connected to the road network). These zone ID’s were numbered 361 – 368.
- b. *Road attributes needed for assignment and further processing.* The links that form the road network have been assigned the necessary attribute values based on the following:
 - i. The **speed** values for all links (attributes V0PRT and R_V0PRT) are 50 km/h and have been assigned to the US fields SPEED_L and SPEED_R.
 - ii. The **capacity** values for all links (CAPPRT and R_CAPPRT) have been assigned to the US fields CAPACITY_L and CAPACITY_R under the assumption that R_CAPPRT is the capacity in the reverse direction.
 - iii. The values for link **length** will be recalculated on the fly (as the original data had lengths encoded as a text field including units).
 - iv. All attributes for which no data is available have been assigned default values.
 - v. Other attributes for which we have no input data are assigned default values.

2D visualisation of traffic links, nodes and traffic zone centroids

Figure 7.8 shows the screen shot from the 2D module which was analysed in Urban Strategy based on the data discussed in previous sections. From the Figure 7.8, it can be seen that nodes are denoted by red dots, and the centroids of traffic zones by blue dots. Urban Strategy is capable of showing all results in a 3D interface. The 3D graphics can be built on the basis of a range of data types, however the most basic 3D graphical representation can be built on the basis of building shapes and building heights. Building shapes have been imported from OSM, and in the absence of better data on building heights, all heights have been set to a default of 10m.



Figure 7.8: Screenshot from the 2D module analysed in Urban Strategy for New Delhi City

3D Module

Using the available data from OSM and using a nominal building height of 10m, a basic 3D view for the city of Delhi has been constructed and is shown in Figure 7.9.

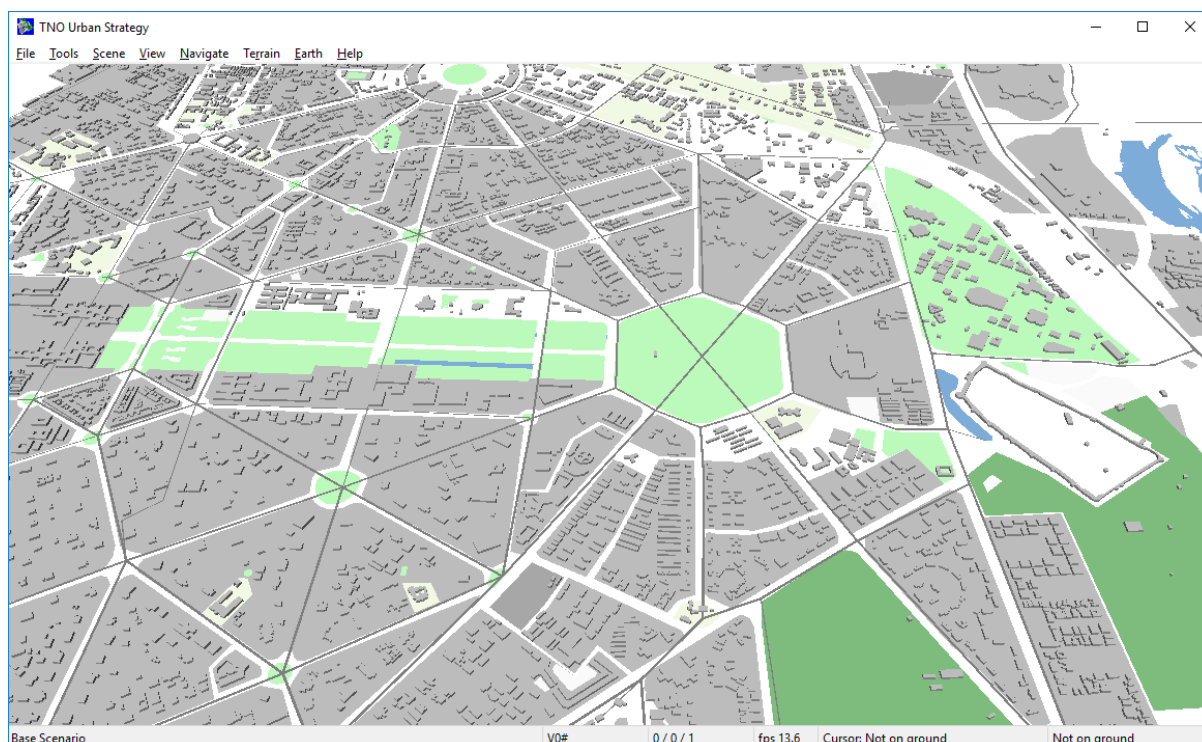


Figure 7.9: City of Delhi loaded in the 3D interface of Urban Strategy

7.4. Policy Evaluation with Urban Strategy

7.4.1. Freight Transport Policies/ Scenarios

The first step to see the effectiveness of the developed evaluation tool Urban Strategy is building up of various scenarios. A number of related scenarios have been defined, that either affect the emission factors of the traffic circulation:

Scenario 1 – Elimination of diesel goods vehicles older than 10 years

Scenario 2 – Placement of a number of freight hubs in outer areas

Scenario 3 – Restriction of heavy trucks from entering a city centre

Scenario 4 – Elevated high-density corridor

Scenario 5 – Improved connectivity to Railway Stations / Airports

Scenario 6 – Fleet conversion to low-pollution vehicles

Scenario 1: Elimination of diesel goods vehicles older than 10 years

Under this scenario, emissions factors for heavy, medium and light trucks altered based on removal of diesel vehicles older than 10 years from the vehicle fleet.

Assumptions:

- The resultant vehicle fleet would reflect the current distribution of vehicles that are either not-diesel, or younger than 10 years old.
- No other changes to the vehicle fleet composition.
- Vehicle emissions based on 2017 emission factors.

Scenario 2: Placement of a number of freight hubs in outer areas

Under this scenario, new logistics hubs at 5 locations are proposed as shown in Figure 7.10. All these locations lie outside of the city which has 360 ‘internal’ traffic zones, and correspond roughly to one of the 8 ‘external’ traffic zones.

Assumptions:

20% of the external traffic originating from (i.e. entering the city through-) the corresponding external traffic zone, travels to the hub, and the freight continues on in light trucks or goods vans. The load from one heavy truck corresponds to 4 goods vans, or 2 light/medium trucks

Scenario 3 – Restriction of heavy trucks from entering a city centre

In this, assessment of the traffic impacts of restricting a certain area of Delhi for heavy trucks have been carried out.

Assumptions:

Under this scenario, area has been selected based on the Delhi city centre as shown in Figure 7.11. From this, major roads are forming an internal ‘ring’ around the closed-off area.

All heavy traffic entering the cordon converted to light trucks and vans.

All other heavy traffic diverted around the cordon.

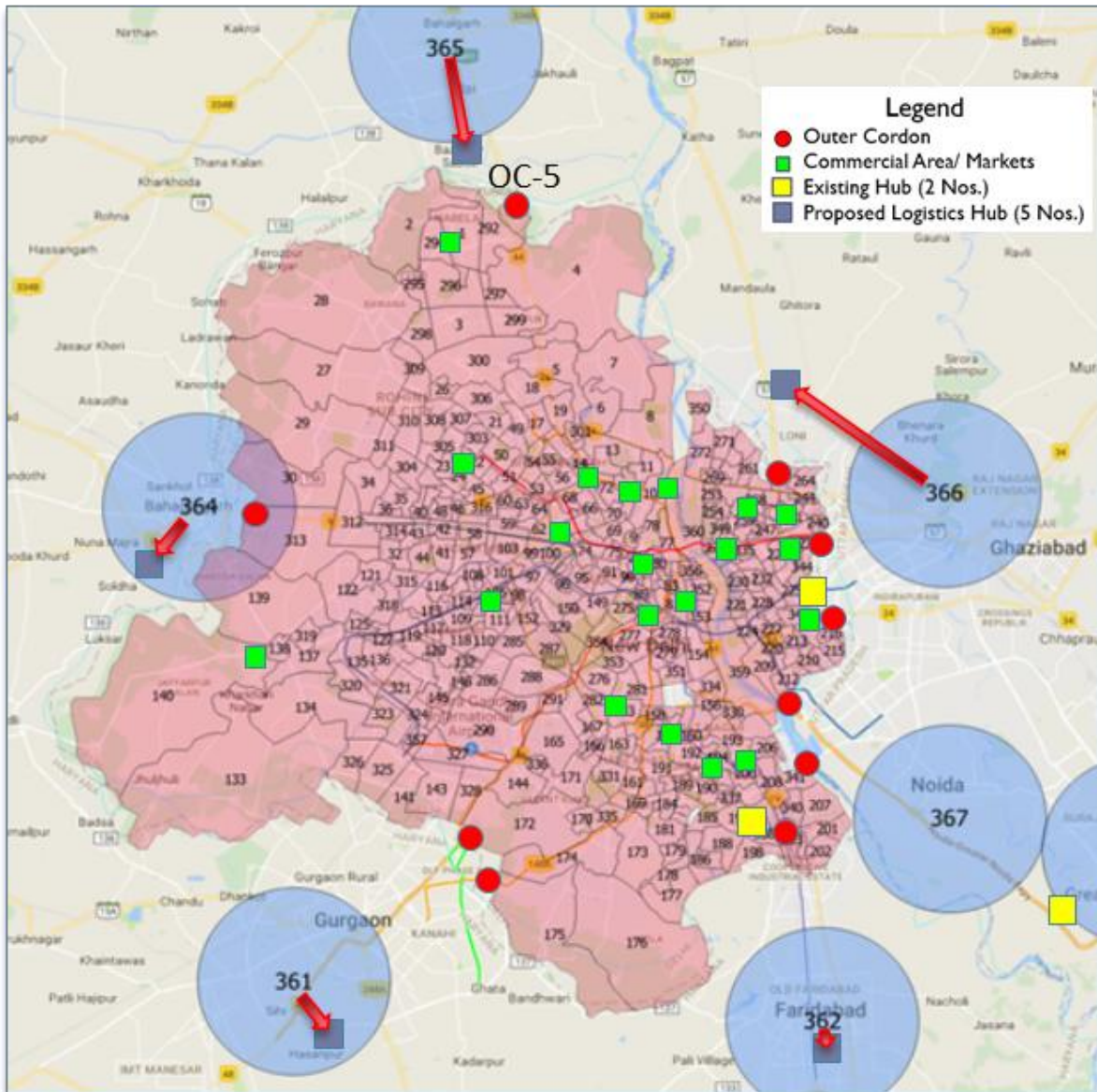


Figure 7.10: Considered Locations of Freight Hubs in Scenario 2



Figure 7.11: Considered Closed-off Area in New Delhi City Center under Scenario 3

Scenario 4 – Elevated high-intensity corridor

A North – South high capacity elevated corridor without intersections, open for all modes has been considered as shown in Figure 7.12. And the speed limit 60 km/hr has been considered for this proposed corridor.

Scenario 5 – Improved connectivity to Rail hubs and airports

- Difficulty in predicting impacts on emissions without details on intended operations.
- This could be further analysed in a future project.

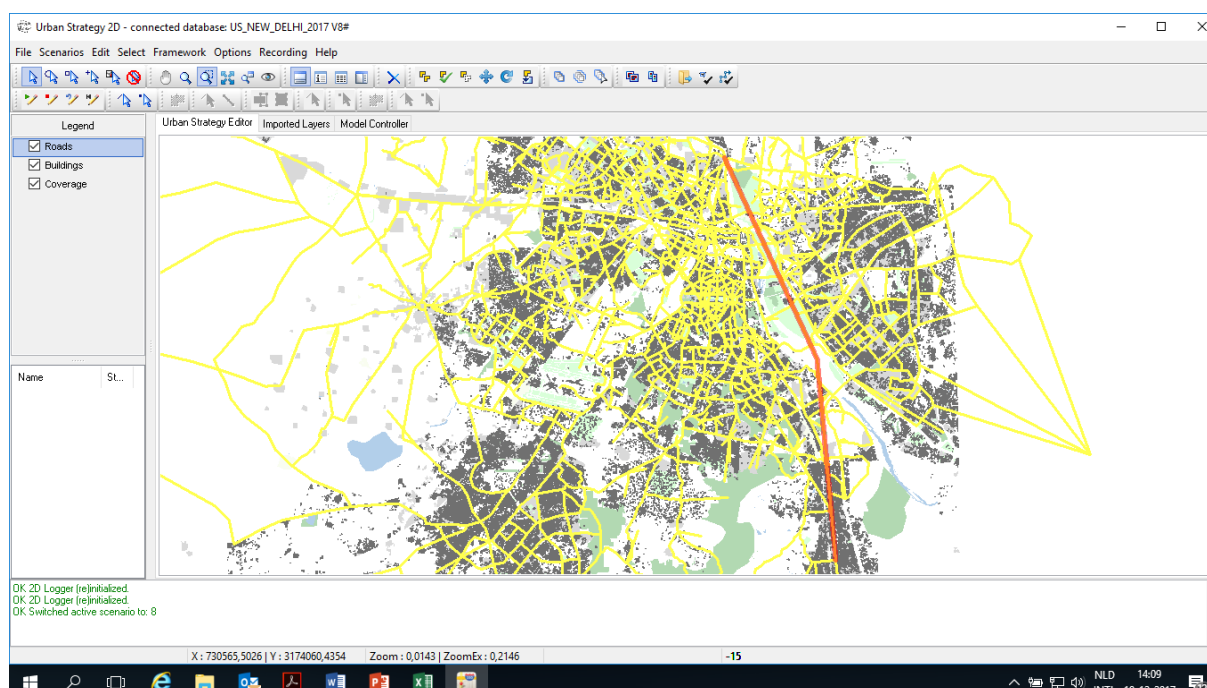


Figure 7.12: Proposed High Capacity Elevated Corridor in Scenario 4

Scenario 6 – Fleet conversion to low-pollution vehicles

In this option, conversion of freight vehicles to electric transmission, based on a future scenario where 100% of auto rickshaws to electric, along with 17% of light, medium and heavy trucks. This would correspond to a large-scale conversion of auto rickshaws, plus 4% per year converted to electric over a 4 year period.

Assumptions:

All other vehicle types and emissions stay the same (model uses 2017 emissions).

Emissions of CO, NO_x, Benzene and Hydro Carbon (HC) assumed to be zero for electric vehicles, and PM10 remaining approximately the same as for the existing vehicle fleet.

7.4.2. Evaluation Results of Policies

Base Scenario

In order to evaluate the proposed policies, it is necessary to have base scenario where it shows existing condition with no measures. Accordingly the Urban Strategy has been applied

with existing travel demand with no measures and estimated the evaluation parameters which are given below:

- Traffic volumes [# /24h]
- Traffic volume / capacity [V/C]
- emissions for each vehicle type, per substance [g/km]
- emission totals per substance [g/km]

Figure 7.13 shows the web interface that was built according to the set-up description given in Section 7.3. In this interface, spatial distributions can be viewed for the above evaluation parameters and the Traffic V/C values and NO_x Emission Loads are shown in Figure 7.14 and 7.15 respectively. From the Figure 7.14 of traffic flows with respect to capacity in the base scenario, it can be seen that the links with a high probability of congestion (blue coloured links) are very high.

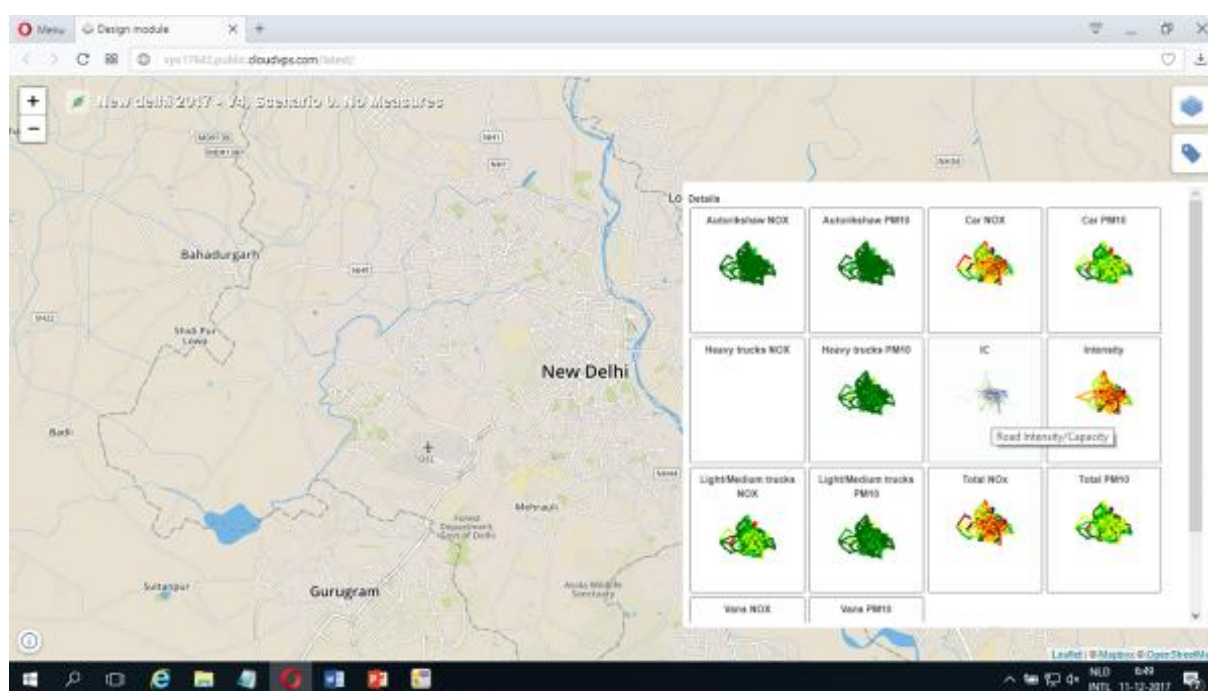


Figure 7.13: Web Interface of Urban Strategy of New Delhi

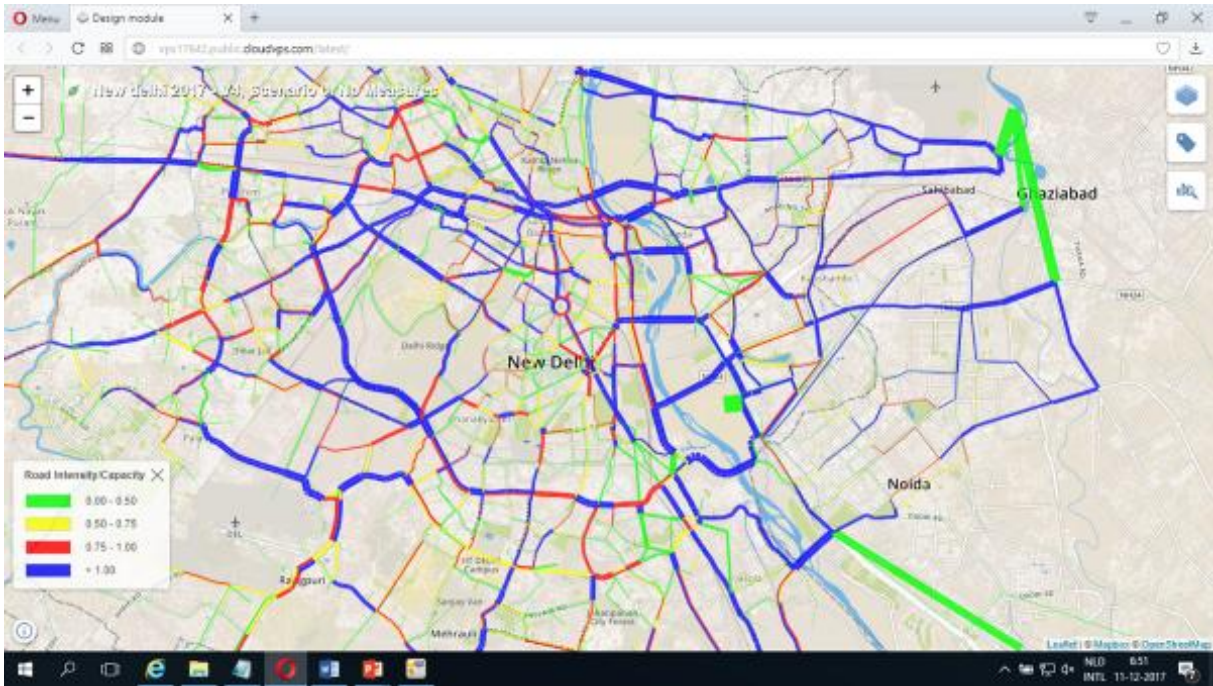


Figure 7.14: Result of Traffic Flows In Relation To Capacity in Base Scenario.

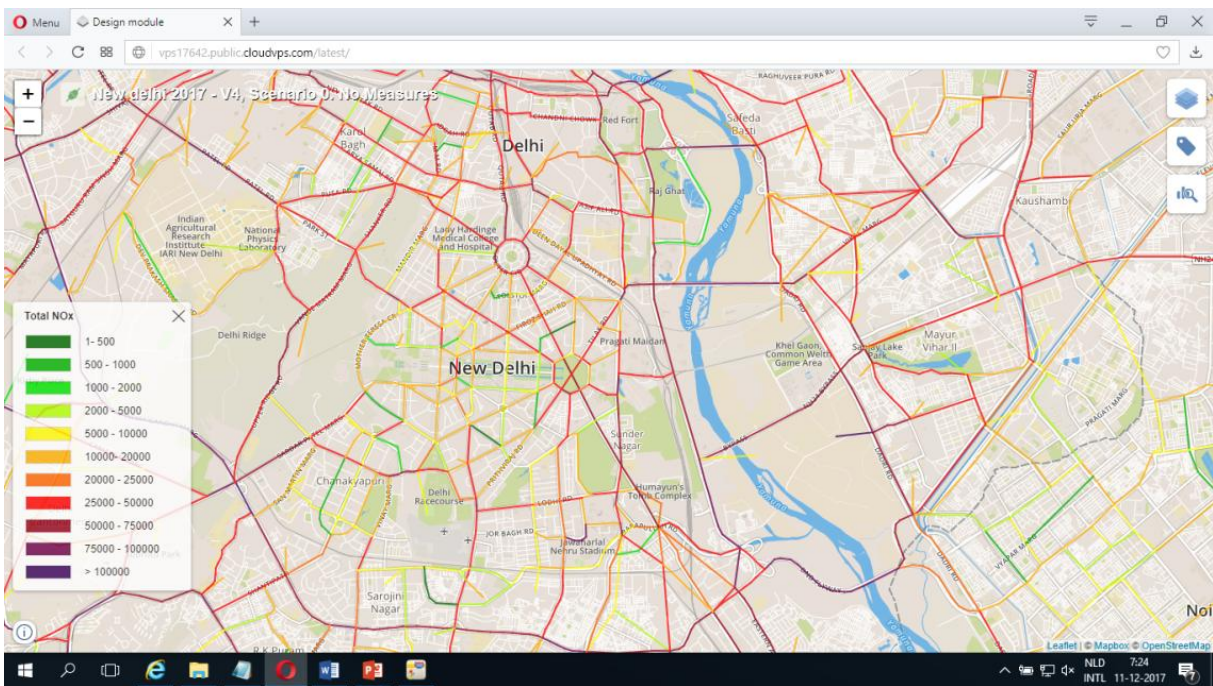


Figure 7.15: Spatial Distribution of NOx Emissions due to Road Traffic in the Base Scenario

Policy Scenarios

Scenario 1 – Elimination of diesel goods vehicles older than 10 years

Figure 7.16 shows the spatial distribution of NO_x emission reduction due to the elimination of 10 year old trucks. This measure will reduce the emissions of all substances in the entire city.

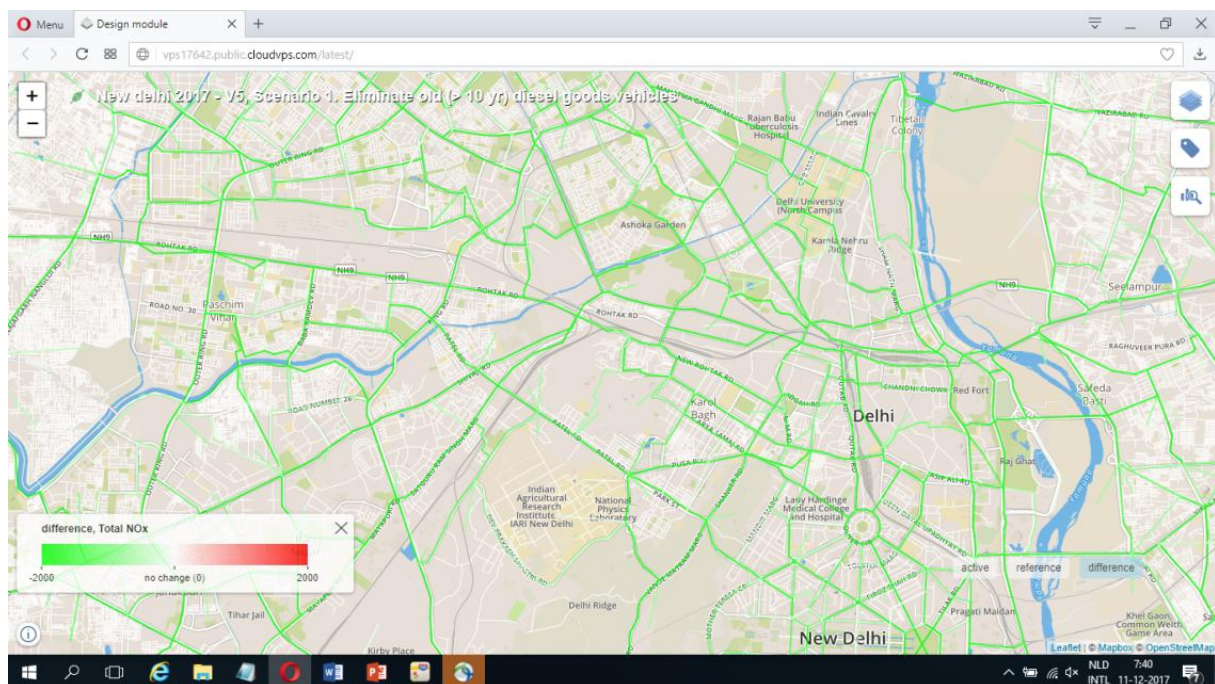


Figure 7.16: Spatial Distribution of NO_x Emission Reduction due to Scenario 1

Scenario 2 – Placement of a number of freight hubs in outer areas

Figure 7.17 shows the spatial distribution of NO_x emission change due to the placement of freight hubs in outer areas. Because the same freight is carried in smaller vehicles, the emissions will be redistributed and show a slight overall increase.

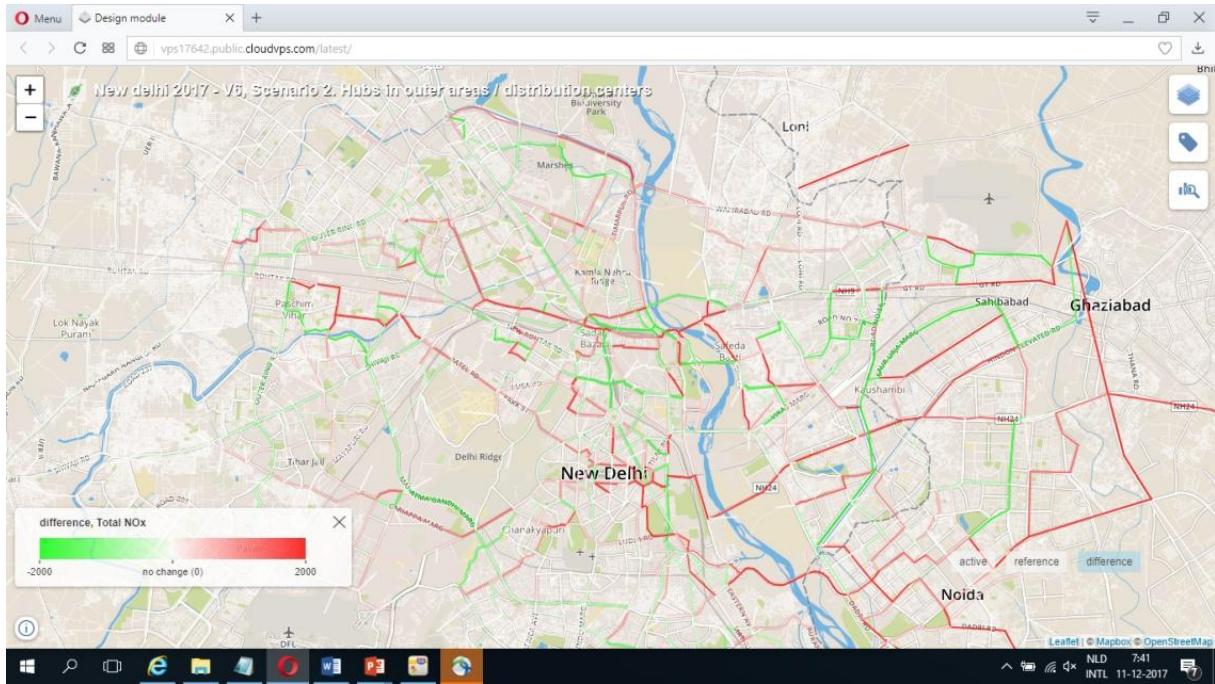


Figure 7.17: Spatial Distribution of Change in NOx Emission due to Scenario 2

Scenario 3 – Restriction of heavy trucks from entering a city centre

Figure 7.18 shows the spatial distribution of NOx emission change due to the restriction of heavy vehicles from entering the city centre. Partially because truck routes are diverted around the city emissions will be redistributed and show only slight overall decrease.

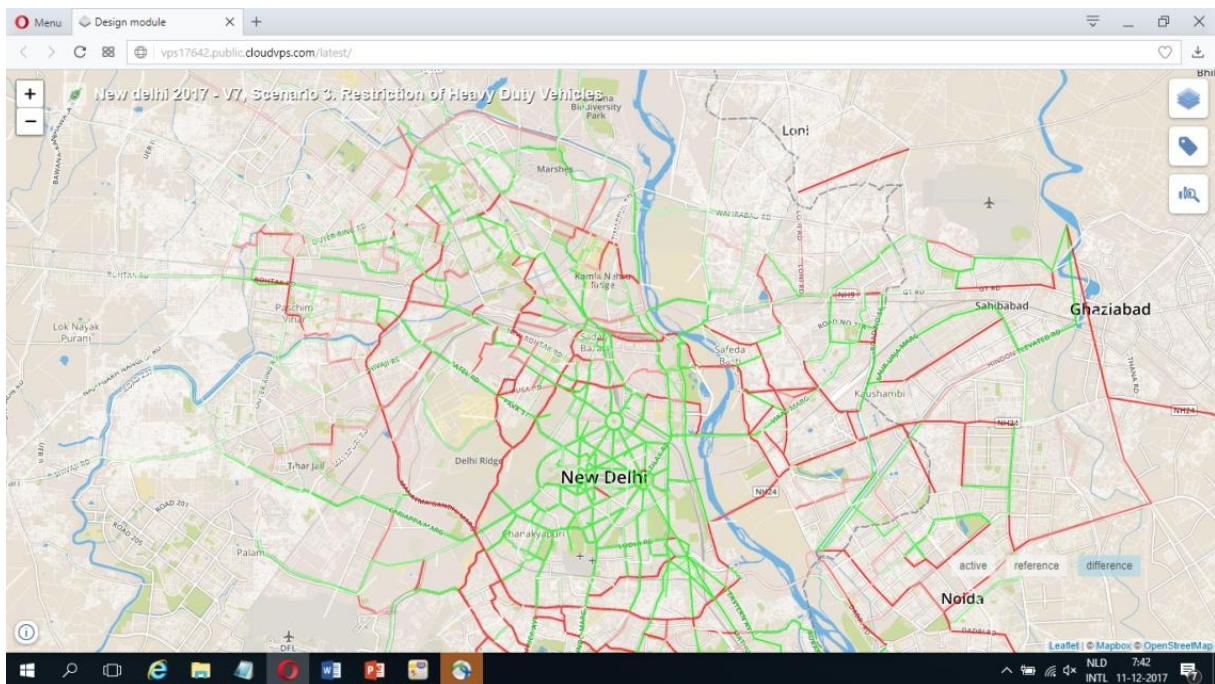


Figure 7.18: Spatial Distribution of Change in NOx Emission due to Scenario 3

Scenario 4 – Elevated high-intensity corridor

Figure 7.19 shows the spatial distribution of NO_x emission change due to the introduction of a high intensity corridor. The emission of the traffic on corridor itself is not visible on the difference map). Because the traffic will be routed more efficiently, there is a slight decrease of emissions.

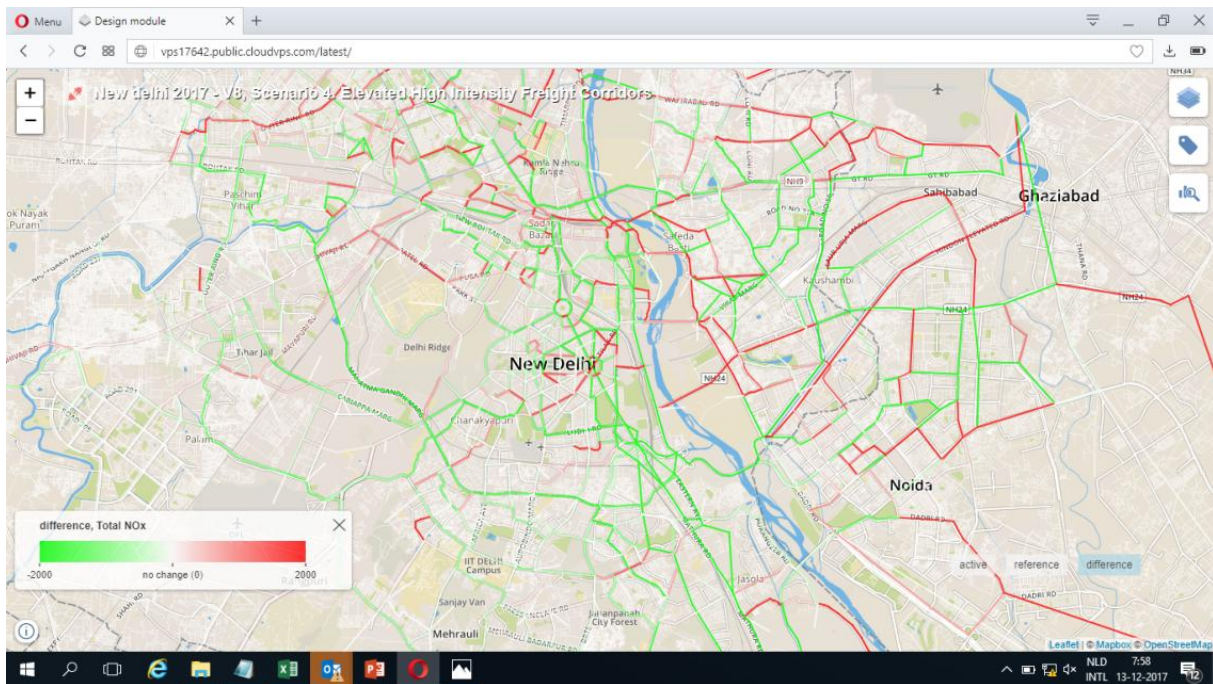


Figure 7.19: Spatial Distribution of Change in NO_x Emission due to Scenario 4

Scenario 6 – Fleet conversion to low-pollution vehicles

Figure 7.20 shows the spatial distribution of NO_x emission reduction due fleet conversion. This scenario will have an overall positive effect on the air pollution reduction.

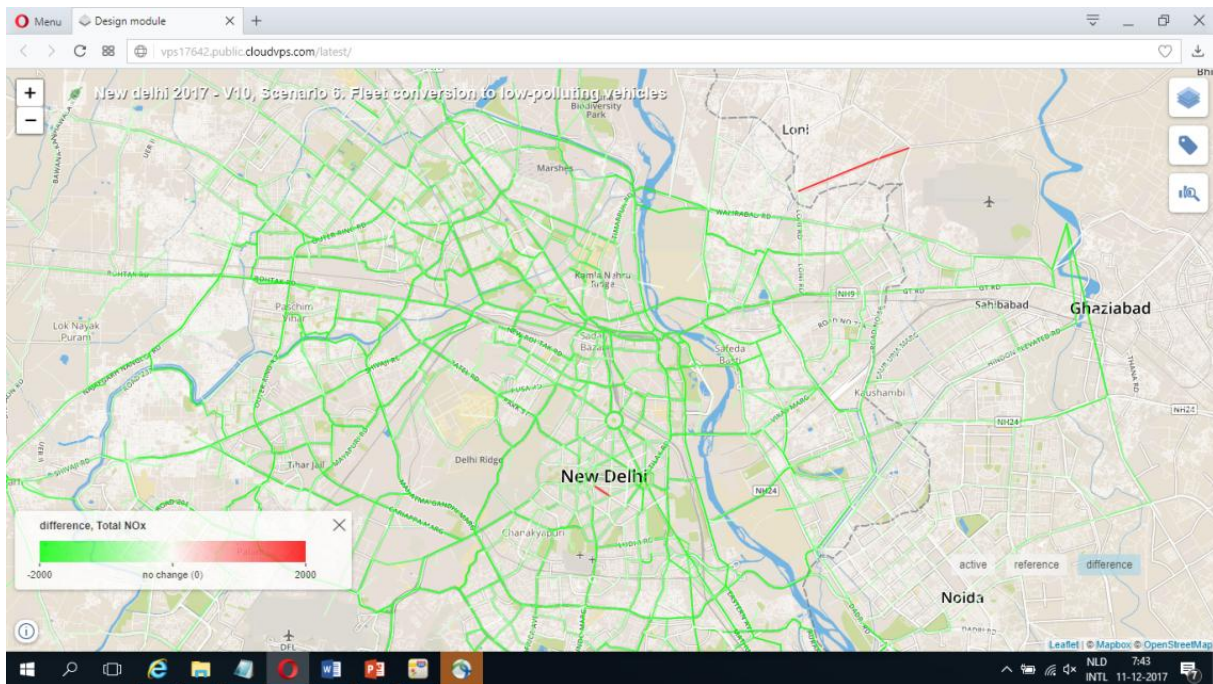


Figure 7.20: Spatial Distribution of Change in NOx Emission due to Scenario 6

Emission totals

The emissions calculated per road segment per substance per vehicle type are presented in the previous section is also summarized in the form of indicators of emission totals. Figure 7.21 shows the breakdown of the emission totals for road transport vehicle types in Delhi for different substances for base scenario. From the Figure 7.21, it can be seen that Passenger Car Equivalents (PCE) account for most of the road traffic emissions for all substances. This is due to the fact that the traffic volume of passenger transport is much larger than the other categories. The graph also shows that Heavy truck do contribute substantially to the NOx emissions, followed by the light trucks as shown in Figure 7.21.

Figure 7.22 shows the comparison of emission totals for road transport in Delhi for different scenarios. Because the contribution of freight transport is limited, the effect of the different scenarios can be seen more clearly when only looking at the freight emission totals as shown in Figure 7.23.

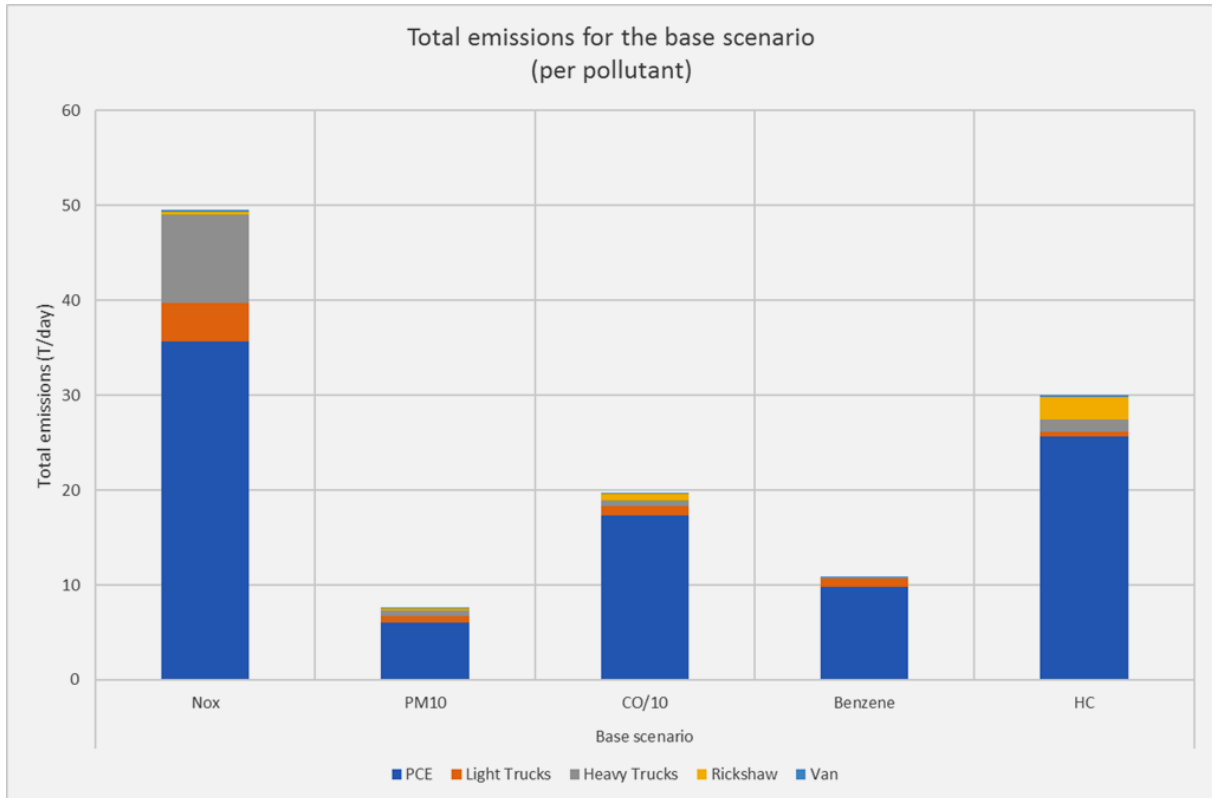


Figure 7.21: Breakdown of Emission Totals for Road Transport Vehicle Types in Delhi for Different Substances

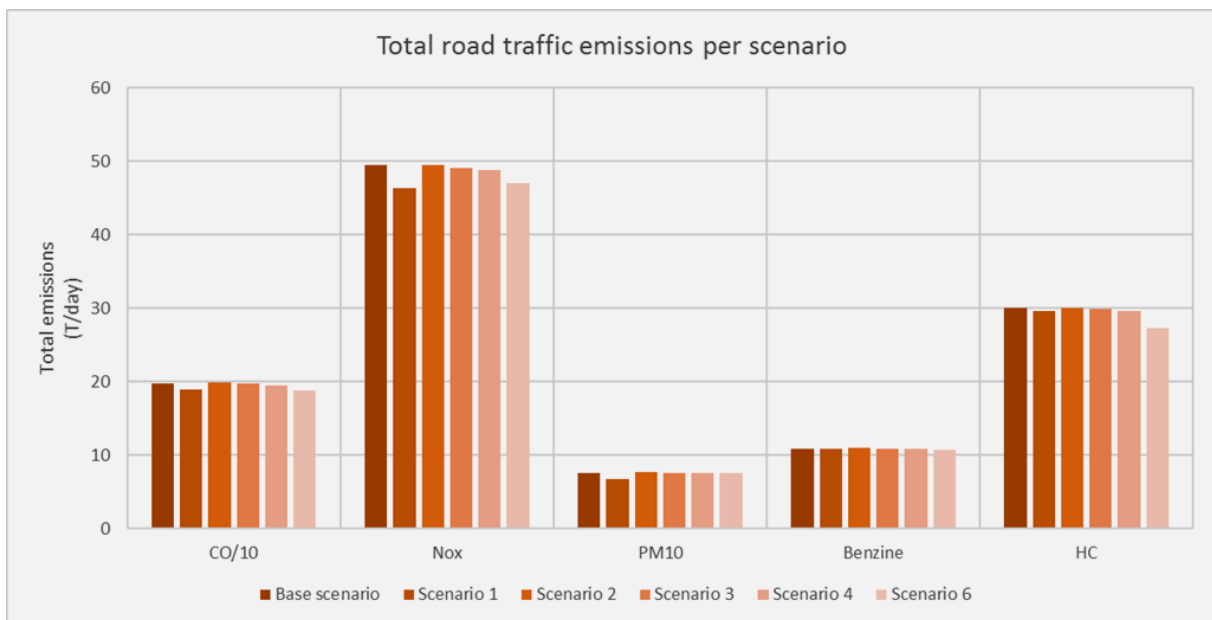


Figure 7.22: Comparison of Emission Totals for Road Transport in Delhi for Different Scenarios

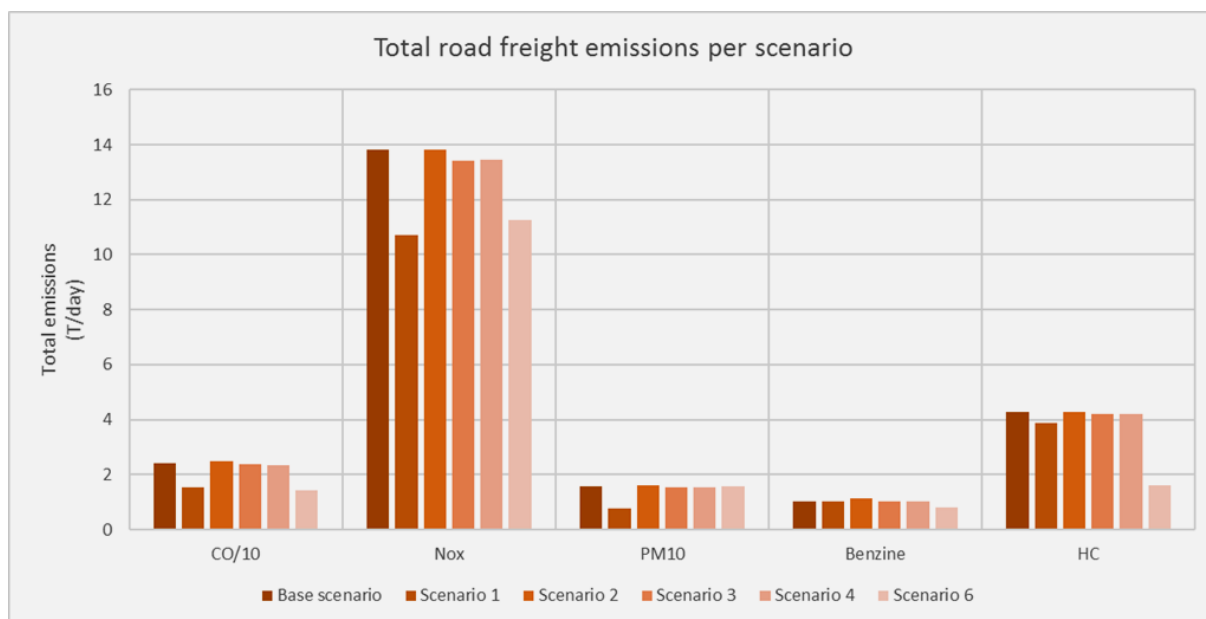


Figure 7.23: Comparison of emission totals for road freight transport in Delhi for different scenarios.

From the Figure 7.23, it can be seen that removal of diesel vehicles older than 10 years, Scenario 1, shows 4 – 11% decrease in total CO, NO_x and PM₁₀ emissions, and negligible difference in Benzene or Hydrocarbon levels. The freight hubs (Scenario 2) and heavy vehicle restrictions (Scenario 3) may lead to increased overall emissions if there is no change to the emissions profile for the vehicles that replace them. Introduction of a high capacity corridor (Scenario 4) will lead to a slight decrease of emissions. Introduction of electric freight vehicles (Scenario 6) shows promising results for reduction in emissions, dependent on the penetration rate achieved.

7.5. Summary of Findings

7.5.1. Urban Strategy for Delhi

This chapter describes Urban Strategy, the steps needed in order to use Urban Strategy to model different traffic measures in the city of Delhi, and demonstrates that TNO have been able to use the available data to construct a basic working model within Urban Strategy and distribute traffic on the basis of that model. The data provided by CRRI has been successfully uploaded, and in combination with open-source data from OpenStreetMaps, has been used to

conduct an initial traffic assignment, and the results displayed in the 2D and 3D interfaces and the Web interface. The developed system can be utilised as decision support system to evaluate various transport policies by estimating traffic loads and emission loads from vehicular traffic.

7.5.2. Policy Findings

Based on the results of estimated traffic loads and emission loads from vehicular traffic from Urban Strategy System, it can be said that the contribution of passenger car movements to the road transportation emissions is higher than the freight emissions.

Removal of diesel vehicles older than 10 years shows 4 – 11% decrease in total CO, NO_x and PM₁₀ emissions, and negligible difference in Benzene or Hydrocarbon levels.

Freight hubs and heavy vehicle restrictions may lead to increased overall emissions if there is no change to the emissions profile for the vehicles that replace them.

Introduction of electric freight vehicles shows promising results for reduction in emissions, dependent on the penetration rate achieved.

7.5.3. Suggestion for further research

The findings of this study provide insight in the effects of measures on the traffic flows and related emissions. These insights can be developed further on this topic by:

- Refinement of the link capacity and speed profiles. Measurements on actual link capacities and speed – flow diagrams, improve the output in terms of congestion prediction.
- Refinement of emission factors. In this study, fixed emission factors are used in g/km. In the actual situation, emissions are dependent on speed and congestion factors. Therefore, actual emissions are likely to be underestimated in this study. Taking this into account, scenarios that improve the traffic flow will show impact on emissions.
- In future study, concentration and exposure calculations can be added. This will provide a different comparison of scenarios, because shifting emissions out of densely populated will affect health without affecting emission totals.

- Adding noise emissions and exposure to the simulation will provide a more integrated view on the situation and the impact of scenarios.

7.5.4. Discussion

It has been shown in this chapter that a Decision Support System on the basis of Urban Strategy is feasible for Delhi. Although a number of topics for further research are identified, the study and system can already provide insight in the matter and provide insight in the effect of scenarios

On the basis of these findings it appears that some measures, such as freight hubs, will only be effective if they are combined with measures to lower fleet emissions, such as the use of electric vehicles.

Another finding is that the impact of measures only targeting freight movements will be limited, due to the relative small contribution to air pollution. Therefore, it would be valuable to apply this system on the integrated challenge of the city of Delhi with its challenges with regards to air pollution, noise traffic. More in general: balancing between urban planning, mobility planning, environmental planning in order to accommodate (economic) growth and improve the quality of life of its citizens.

References

CPCB (2000) Transport Fuel Quality for the Year 2005. Mc Graw Hill Publications, New Delhi.

8. FEASIBILITY OF AGENT BASED SIMULATION MODEL FOR URBAN FREIGHT ACTIVITIES IN DELHI

8.1 Complexity in Urban Freight Transportation

Urban freight activities involve movements of freight vehicles, loading and unloading of goods, parking of freight vehicles. Each of these activities is decided under influence of many factors and by many actors (i.e. Stakeholders). For instance, if goods to be unloaded are very heavy or high in quantity then delivery vehicle is parked in proximity to delivery point even resulting in hindrance to on-going traffic. Similarly, the delivery time of the goods is decided based on requirements of receiver even if that mean the freight vehicle has to travel during peak hours adding to congestion. There are thousands of freight vehicles coming to Delhi NCR every day driving on different routes, in different areas, possessing different characteristics (weight, size, emission) operating in different styles (parking, loading or unloading). The system that emerges from such multitude of activities is very complex and unpredictable. Urban freight transportation is concern of multiple stakeholders-who often has conflicting objectives- focusing on individual gain resulting in unorganized and inefficient freight activities. The complexity of urban freight domain and diverse interest of various stakeholders demand well designed consultation and active participation of all stakeholders for effective urban freight policy-making process.

8.2 Agent Based Modelling Approach

An Agent Based Modelling (ABM) approach can simulate the details of continuously changing urban freight characteristic in efficient way and coin emergent behaviour of the dynamically changing urban freight processes. At micro level, urban freight movement is based on supply and demand of goods whereas at macro level it is represented by traffic volume or vehicle kilometre generated by freight activities. Focusing solely on the macro level blurs all trend breaking events and consequent forecast results in major inaccuracy. Similarly micro level structure evaluation of urban freight activities describes the functioning of individual stakeholders, which, however, lacks interaction among different stakeholders. ABM focuses on understanding urban freight activities processes at ‘meso’ level – an

intermediate level – using information from macro and micro level. Accordingly, we take information about individual stakeholders at micro level and analyse the interactions between urban freight entities at meso level to understand resulting movements of freight delivery vehicles. At an abstract level ABM is a representation of the many simple agents and relationship among them. Here agents represent entities (e.g. Stakeholders, vehicles, goods) and the ways these entities are connected represent relationships.

8.3 ABM for Urban Freight Activities in Delhi NCR

8.3.1. Conceptual Framework

An ABM for urban freight activities in Delhi NCR can include a variety of agents representing stakeholders and other entities of UFT domain. Each agent is an autonomous entity that observes and acts (takes decisions and perform activities) towards achieving goals (e.g. goods ordering, delivery). The autonomous stakeholder-agents also possess other characteristics such as they can learn, move, enter and exit the system. These characteristics mirroring real life as new companies enter the urban freight market, old companies may exit etc. The parallel between ABM and urban freight domain explain suitability of agent-based simulation for modelling Delhi NCR urban freight activities.

To develop an ABM for urban freight activities in Delhi NCR, it is imperative to have knowledge about decision structure in urban freight activities. As this decision structure does not necessarily follow the hierarchy of supply chain structure, it is very important to know which stakeholder takes decisions at what level and in which conditions. For example, urban freight movement is result of decision making with respect to the asset use instead of asset control. In essence, during the interaction of stakeholders with varying preferences, the one who governs the influence structure will control the decision making process. In this view, we must integrate this relationship meticulously to get the best model. To understand the feasibility of ABM, a conceptual framework for developing ABM is proposed that is presented in Figure 8.1.

The framework begins with understanding urban freight problems in Delhi. Although urban freight activities create different issues concerning congestion, pollution, safety, different city

has different need and priority. Once the problem is clearly defined, it gives correct direction for data collection and identifying associated stakeholders. For instance, if illegally parked freight vehicles are the focus of the problem then drivers are important stakeholders. Whereas in case of pollution created by freight vehicles trucking companies and drivers are important stakeholders. With help of data and stakeholder analysis, we can get urban freight profiles for Delhi NCR. Urban freight profiles represent the supply chain structure and concerned activities for particular types of shop, product or receiver. For instance, the urban freight profile of a multi brand retail store is different than that of a store selling one type of product. An urban freight profile is a description of the existing urban freight domain showing associated details such as stakeholders, resources, relationships between entities. Knowledge from other urban freight literature (e.g. research and project reports, pilot) can be used to refine urban freight profiles generated for Delhi.

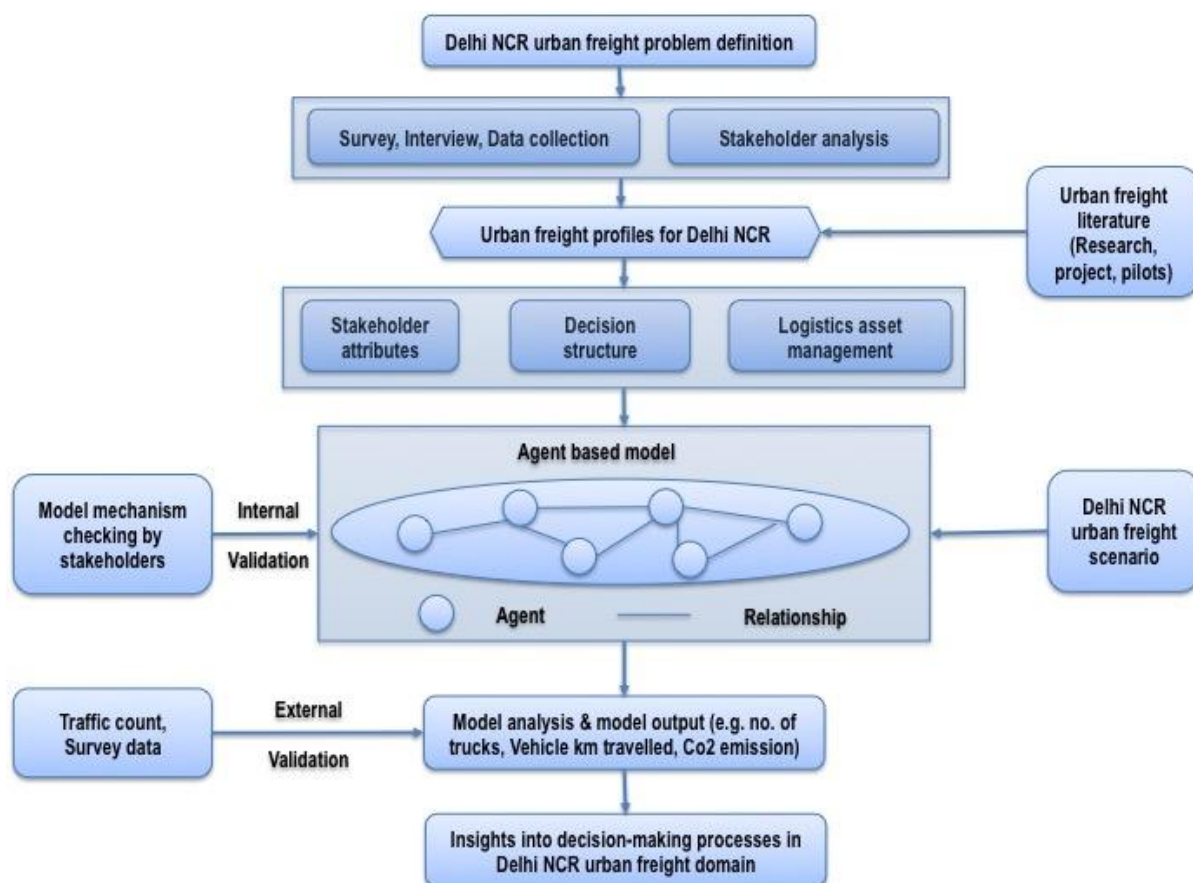


Figure 8.1: Conceptual framework of agent based model for urban freight domain in Delhi NCR

The urban freight profile is used to list stakeholder attributes, decision structures and the logistics asset management methodology, which will serve as knowledge base for ABM. Information about stakeholder attributes is used to define behaviour of stakeholder agents. Knowledge about decision structure is used to establish relationships between different stakeholders and other urban freight entities. For example, a carrier-agent is connected with receiver-agent by goods delivery process. Similarly, a freight vehicle and carrier-agent are connected by relationship of ‘owner’ and ‘resource’. Knowledge about logistics asset management helps to model decisions about urban freight activities in ABM. Accordingly, this knowledge can be used to define activities such as goods order management by a receiver-agent or vehicle assignment by a carrier-agent in ABM. With knowledge base ready in terms of stakeholder attributes, decision structure and logistics asset management methodology, development of agent-based model can be started. The proposed development stages of agent based model for urban freight domain in Delhi NCR is shown in Figure 8.2.



Figure 8.2: Development stages of agent based model for urban freight in Delhi NCR

Once we have gathered information required to develop an ABM, the first step is model specification. In this step, various important components of ABM will be laid out. For instance, main components of ABM for urban freight in Delhi NCR would comprise of (1) Numerous agents specified at various scales; (2) Decision-making heuristics; (3) Learning rules or adaptive processes; (4) An interaction topology; and (5) A non-agent environment.

Once the specification of the model is clear, the next step starts with implementing the structure of model by developing agents (e.g. stakeholders, freight vehicles) and environment (e.g. road network, interaction platform). Next, behaviour and decision-making heuristics are embedded in the agents. At this moment, the agents in the model have knowledge about ‘what to do’. Subsequently, we add communication and interactions protocols between the agents and between agents and environment. By doing so agents’ behaviour gets connected with various situations so now agents know ‘what to do when’ and ‘whom to contact’. For example, a shop-agent knows that when goods level reaches at certain point ‘place an order’ by ‘contacting the supplier-agent’. Communication and interactions between agents follow certain protocols that vary depending on the platform of software. After implementing agents,

communication protocols and environment, we can use survey data to parameterize different decision variables. Thus, after parameterization, the shop-agents also know ‘how much to order’ based on associated factors.

In the urban freight domain, knowledge about number of freight vehicle travelling in certain part of road network is very useful. The agent-based model can be designed to get different types of output. Furthermore, the model can be used for various scenario analyses in Delhi NCR. Model output and its analysis can provide with important information about impacts of certain situation, policy or event on urban freight transport for Delhi NCR. Insights and knowledge gather from ABM can be useful for policy making, pilot test preparation or facilitating urban goods movements in other ways for creating sustainable and efficient urban freight domain.

8.3.2. Application

A large variety of autonomous stakeholders operate in the urban freight domain creating a complex behaviour as collective, together creating emergent behaviour in the system that is difficult to predict due to uncertainty and dynamics. An Agent based model can explicitly model the complexity of urban freight domain arising from actions of and interactions between stakeholders. An analysis of the urban freight domain using ABM can provide insight into decision making processes to identify and evaluate the reasons, situations and phenomena that give rise to problems in the domain such as congestion. Accordingly, ABM can be used as policy analysis tool to see how different stakeholders and system will react to changes brought by certain policies such as regulations and tolls.

Feasibility of creating role-playing game from an ABM

Agents in the model are playing roles of different stakeholders. Thus, also a role playing game can be created from an ABM that can be used for educational purposes. In the game a real life stakeholder can take over decision-making activities of a representative agent through an interface. Stakeholders generally do not have clear idea as how their certain behaviour or activities leads to negative externalities in urban freight domain. In such a game, roles of agents are being played by representative stakeholders who are competing against not only agents, but also other stakeholders. By playing such game, stakeholders can learn how

decisions of other stakeholders affect their activities and *vice versa*. Such a role-playing game can act as platform to experience the complexity and emergence effect of decision-making by different stakeholders.

8.3.3. Proof of concept ABM for Delhi

A full-fledged ABM for entire Delhi region requires lot of data and may take long time to develop. It is wise to develop a proof-of concept model for a small section of the city. The pitfalls and problems arising during developments of such model can provide useful guidelines towards developing a full-scale model. ABM represents the real world in micro setting. To start with, we can select a small area of Delhi as test case. Next, we take a simplified demand model in a macro setting (e.g. the full city models described in this report) and unfold it in a top down way, breaking the system down into parts. We can replace parts of the macro level model one-by-one by autonomous entities (i.e. agent) that follow certain rules, have certain goals to achieve. The behaviours of the agents are based on data collected from the sample area. With this technique, at every stage we can replace some part of macro structure with the autonomous agents and we can (eventually) develop a fully functional agent based model depicting micro details and behavioural aspects of real world.

8.3.4. Data needed for urban freight ABM in Delhi

Due to the microscopic bottom up approach of ABM, a variety of high quality data is needed. There are many single-truck companies operating in Indian freight domain. These are highly unorganized companies and collecting data from them can be big challenge. On the other hand, with the introduction of modern information technology, many companies operating on Internet are already collecting various types of data. Such companies are doing extensive data collection and analysis to meet higher service demands of urban consumers. However, it is clear from our discussion with researchers with experience working with logistics companies that companies will share data only if they see benefits (e.g. improved service, operation) in return. Conclusively, companies should be integrated in project at early stage with clear benefits. These data may then complement what is already available and described in this report at macro level with a more detailed view at company level. Obviously, a careful sampling approach will still be needed as full data availability will not be reached.

8.3.5. Research capabilities for ABM development

India is home to some of the finest technical institutes (e.g. IITs, IISc, NITs) in Asia. There is an IIT and School of Planning and Architecture in Delhi with faculties working on transportation research. Furthermore, CSIR-CRRI, which is the lead partner in this MEGALOG project, has been carrying out research and development projects on traffic and transportation planning of mega and medium cities. Researchers at these institutes have years of experience in areas such as transportation modelling (e.g. four step approach), micro simulation and optimization. Although there is no full-fledged ABM developed for passenger/freight transportation, the researchers are familiar with ABM and some of them have worked with it. For instance, Volvo Research and Educational Foundations have Centre of Excellence in New Delhi, which has explored problems of urban freight domain for Delhi. Accordingly, there is sufficient talent for development of an ABM for urban freight in Delhi.

8.3.6. Challenges for ABM development for Delhi

The use of ABM is rewarding due to quality of analysis it provides. Nonetheless, ABM also poses certain challenges to overcome. In the text below we list important challenges.

- **Validation:** Due to characteristics such as path dependency, emergence and multiple interactions, validation is a big challenge for ABMs. Furthermore, the complexity of social processes does not guarantee that each simulation run follows the same sequence, leading to conflict in final output and making the concept of validation for ABM different than in a well-controlled experiment. Traditional validation of comparing model output can partially validate the model however validation of decision-making process is also essential. There are attempts made by researchers to validate such processes. For further reading refer to Anand (2016) and Ligtenberg (2010).
- **Clarity of agent roles:** An agent may have several roles depending on situation. For instance, a typical retailer deals differently with logistics service provider and differently with supplier. Thus it is noteworthy challenge to put different behaviour or decisional characteristics and the agent should be capable of understanding what behaviour it should adopt in what situation.
- **Agent's access to information:** As different agents have different scope and different degrees of freedom, the service and information available to them varies. By clearly

defining the access level for each agent, an ABM should be able to restrict the information flow and ability of agent to influence the whole system.

8.4 Summary

A large variety of activities (e.g. freight vehicle movements, parking, loading/unloading goods) is associated with urban freight transportation, which differs with respect to location, types of goods and stakeholders' characteristics and creates much unorganized system. The emerging complex system is a direct result of conflicting objectives of multiple stakeholders. A well-designed modelling approach that includes the perspectives of multiple stakeholders within the domain is essential to find effective solutions (e.g. policy, regulation, facilitating schemes) for the above-mentioned problems.

Agent based modelling is a promising approach to understand the urban freight domain. By taking information about individual stakeholders and entities at micro level an agent-based model (ABM) for Delhi can be created to analyse the interactions between urban freight entities to understand resulting movements of freight delivery vehicles. Such a model can be used to understand cumulative and serialized effects of the decision making by multiple stakeholders to discover effective policy for urban freight related problems. Furthermore, a role-playing game can be developed using an ABM as an interactive tool for urban freight stakeholders to understand the decision-making processes and complexity of urban freight activities. Such a role-playing game can act as platform to experience the complexity and emergence effect of decision-making by different stakeholders.

As a bottom-up approach an ABM for Delhi can use variety of data. Amount data used in the model defined the fineness of the model and therefore, the complexity of emergence can be studied using ABM with help of limited data. Data collection is the most challenging part of ABM development. Accordingly, in the beginning, a proof-of-concept model should be developed for a zone in Delhi. The conceptual framework provided in this report may be a good starting point for model development. The framework describes different stages that are comprehensive in nature and can be treated as a guide for the systematic development of an agent based model for the urban freight domain of Delhi. Data collection for small area

should be relatively easy and such small model allows understanding other challenges (e.g. research competencies) that one will face during ABM development.

In conclusion, agent-based modelling can be useful for many unrequited policy analysis problems in the urban freight domain. However, the time and precision required makes the development of such a system a challenging task. Overcoming these challenges requires painstaking efforts but assures in-depth understanding about urban freight transportation process for successful urban freight policy analysis.

References

- Delhi Air Pollution: Real-time Air Quality Index (2017). <http://aqicn.org/city/delhi/>
- Air Now (2017). <https://airnow.gov/index.cfm?action=aqibasics.aqi>
- MoUD (2016), “Decongesting Traffic in Delhi”, Report of the High Powered Committee, Ministry of Urban Development, Govt. of India, June 2016.
- Gupta, S. (2017), “Role of Non -Motorized Transport in Distribution of Goods in the Metropolitan City of Delhi”, *Transportation Research Procedia*, Elsevier Publishers, Vol. 25, pp. 978–984
- Nilanjana De-Bakshi, Nimesh B. Bolia, Geetam Tiwari and Jose Holguin-Veras, (2017) “Urban Freight in Delhi: Characteristics and Mobility Restrictions”, VREF Research Brief 8 (RB08-2017), Volvo Research and Educational Foundations (VREF).
- Nilesh Anand, David Meijer, J.H.R. van Duin, Lóránt Tavasszy, Sebastiaan Meijer, (2016) “Validation of an agent based model using a participatory simulation gaming approach: the case of city logistics”, *Transportation Research Part C: Emerging Technologies*, Vol. 71 (2016), pp. 489-499.
- Arend Ligtenberga, Ron J.A.van Lammerena, Arnold K.Bregta and Adrie J.M.Beulensb (2010), “Validation of an agent-based model for spatial planning: A role-playing approach”, *Computers, Environment and Urban Systems*, Vol. 34 (5), 2010, pp. 424-434.

9. CONCLUDING REMARKS

Understanding and forecasting freight movements is critical to plan for future transportation in terms of capacity augmentation, operation, preservation, safety and security, energy and economy investment needs. Many demand forecasting models and data sources are more appropriate for passenger transportation than for freight transportation in terms of understanding freight travel behaviour and forecasting freight movements. Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies. In view of this, the present study have been conceptualised on Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG).

An important goal of the project is to create an impact in practice. An extensive pilot study is carried out for the city of New Delhi, India with a transferable modelling approach. The city of New Delhi i.e. National Capital Territory of Delhi (NCTD) has been selected as study area for this study. By conducting extensive field surveys, metrics of city logistics, design of measurement system and data acquisition in the city of Delhi have been developed. The metrics are focused on logistics activity indicators (external and internal flows), logistics efficiency (vehicular and trip characteristics) and city livability (traffic loads in terms of vehicle kilometers travelled and emissions of pollutants).

The activities carried out in the present study include:

- ▶ *Development of city logistics metrics* - measurements of key performance indicators of a city, in relation to freight transportation and logistics, Quantification of Freight Traffic in the city of Delhi and their vehicular and travel characteristics;
- ▶ *Capacity Development for Sustainable City Logistics* - assessment carried out among key stakeholders, including public and private parties. Evaluation including policy objectives, work programmes and general knowledge position in the field of sustainable logistics for megacities;
- ▶ *Development of freight transport demand model and logistics flow model for the city of New Delhi* - visualization of the city logistics metrics for monitoring purposes done in 3D city model;

- ▶ *Knowledge Sharing* - organised short courses on sustainable city logistics (strategies, metrics, and tools), stakeholders meetings and national dissemination workshops;

In the present study, NCT of Delhi has been taken as study area and measured possible freight metrics from the various field studies and the summary is given below:

- ▶ The journey speed of traffic stream is varying between 17 and 40 kmph and average journey speeds are around 27 kmph on the road network of Delhi. The journey times are around 2.3 minutes per km which shows that the road network of Delhi is moderately congested all the time.
- ▶ On a normal working day, a total of about 1.24 million vehicles enter and leave Delhi city which has grown with 3% per annum (about 1.02 million vehicles in 2009). The freight traffic forms about 10% of the total traffic with another 4% of traffic is composed of slow moving vehicles like bicycle, cycle rickshaws, animal carts etc.
- ▶ Maximum number of vehicles in the order of about 354 thousands entering and exiting through Rajokri Border followed by Ghazipur Border with an entry/ exit traffic volume of about 163 thousands and Kalindi Kunj Border with an entry/ exit traffic volume of about 126 thousands.
- ▶ A total of about 100 Thousand freight vehicles enter and leave Delhi city on a normal working day and about 21% of these freight vehicles are found to be passing through the city which was almost same in 2009. Though the total traffic increased, freight traffic remain stagnated at outer cordons because of new bypass roads come around the city of Delhi such as Noida-Greater Noida Expressway, Yamuna Expressway, Kundli-Manesar-Palwal (KMP) Expressway etc.
- ▶ The freight vehicle types namely Goods Auto (GA), Goods Van (GV), LT, HT and MT are found at entry and exit locations of outer cordons. In case of passing through freight traffic, HT has almost 50% share followed by MT and LT has share of about 18% each. Smaller Goods Vehicles (GA and GV) has a share of about 14% of passing through traffic. This can be attributed to the fact that the heavy vehicles travel long distances compared to light and small vehicles.
- ▶ From focal points studies within the city, it has been observed that maximum number of vehicles per day is in the order of about 8 thousands entering and exiting through Ghanta Ghar Sabzi Mandi followed by Azadpur Sabzi Mandi with an entry/ exit

volume of about 7 thousands and Chandini Chowk Area with an entry/ exit volume of about 5 thousands. It has also been found that about 40% are consisting of Goods Auto (GA) and Goods Van (GV) in that. The vehicle types of LT, HT and MT are in the range of 24%, 11% and 8% respectively. The other freight vehicles are about 18%.

- ▶ The mid block traffic studies revealed that the total daily volume (24 hours) on Ring Road (Naraina) is almost 190 thousands with a peak volume of about 16 thousands (19:00 ~ 20:00 Hrs). The summary of traffic on all the mid block locations shows about 80% are consisting of private vehicles mainly cars and two wheelers. The freight transport is about 7% mainly consist of Goods Autos, LT, HT and MT.
- ▶ The mean age of different freight vehicles is almost same at outer cordons and within the city varying between 4.5 and 5.0 years and the share of 10 year and more old vehicles within the city is ranging from 1 to 6% and 5 to 9% at outer cordons.
- ▶ The fuel usage distribution of different freight vehicles at outer cordons and within the city results shows that Heavy Vehicles (HT and MT) mostly use Diesel where as Goods Auto and Goods Van almost use CNG as fuel. In case of LT, about 45% and 75% use Diesel as fuel at outer cordons and within city respectively.
- ▶ The ownership of different freight vehicles at outer cordons and within the city has been analysed and found that private company freight vehicles are high in case of heavy vehicles (HT and MT) at outer cordons and within the city. The private company and personal freight vehicle share is almost same for light vehicles (LT, GA and GV) within the city whereas private company freight vehicle share is higher at outer cordons.
- ▶ The mileage (fuel efficiency in terms of km/litre) of different freight vehicles has been observed that light vehicles (LT, GA and GV) have higher fuel efficiency which are mostly run on CNG. Heavy freight vehicles have fuel efficiency about 6.5 and 4.8 km/litre for HT and MT respectively. Light vehicles namely LT has about 11 km/litre, where as GA and GV has more than 14 km/kg of CNG.
- ▶ The freight vehicle types travels about 20-25 km within the city and the maximum average distance travelled in a day by these freight vehicle types is about 200 km. This clearly indicate that these freight vehicles face lot of congestion and other

problems to travel more distances in a day experiencing lot of delays and increased operating costs.

- ▶ The frequency of trips of different freight vehicles analysis shows that Light Vehicles are having more daily trips and Heavy Vehicles are more in Occasional trips.
- ▶ From the results of weight carried by different freight vehicles, it has been observed that MT Vehicles are carrying average weight more than 13 tonne where as HT vehicle is carrying average load of 5-6 tonne. The LT is carrying average weight about 2 tonne and smaller vehicles like GA and GV are carrying less than a tonne.
- ▶ The share of empty vehicles is about 10-20% across different freight vehicle types. Further the total weight carried by these freight vehicles on the entire road network of Delhi has been estimated to be about 2.480 Million Metric Tonne (MMT) per day.
- ▶ In the present study, freight transport demand model has been developed considering traditional approach of four-stage modelling (Freight Trip Generation, Freight Modal Split, Freight Trip Distribution and Freight Traffic Assignment). Accordingly, the total trips generated daily in the city of Delhi from all the zones are estimated to be about 500 thousands of freight trips. The final freight modal split for different freight vehicles namely GA, LT, HT and MT shows almost equal share varying between 22-25% where as GV has about 5% share. The Freight O-D Matrix estimated from Freight Trip Distribution adopting Gravity Model.
- ▶ The majority of freight trips are Internal - Internal (I-I) which is almost 80%. The Internal-External (I-E) and External-Internal (E-I) are almost same about 8% each and External-External (E-E) trips (passing through) are about 4%.
- ▶ The analysis of modal split of these freight trips shows that heavy freight vehicle share is about 26% in case of I-I Trips, about 43% in case of I-E Trips, about 53% in case of E-I Trips and about 61% in case of E-E Trips.
- ▶ The share of freight trips is only about 3% and passenger trips are about 97% in the city of Delhi. Though the share of freight trips is very insignificant, it is going to influence huge in traffic congestion, air pollution and road safety related issues of the city of Delhi.
- ▶ The freight trips are estimated to increase to about 572 thousands by the year 2021 with a growth rate of 4% per annum.

- ▶ The estimated traffic loads in terms of vehicle kilometers travelled (VKT) on the road network of Delhi for the year 2017 and forecasted VKT for the year 2021 are about 240 Millions and 300 Millions respectively. The VKT by freight vehicles are going to be about 10 Million and 13 Millions in 2017 and 2020 respectively which is having a share of about 4%. The growth of total VKT is increasing with 7% per annum growth whereas freight vehicles growth is about 8% per annum.

Taking into account the findings from the inventory of the literature, a list of indicators to measure New Delhi's performance in the area of SCL has been proposed which also included suggested units and sources for measurement. A questionnaire has been designed and proposed to use the same for assessment of the level of knowledge in the area of SCL among all the local authorities and policy makers, freight operators and experts.

With respect to decision support systems, the Urban Strategy (Software developed by TNO) has been customised to visualise freight patterns and to model the impacts of different traffic measures in the city of Delhi. In the present study, it has been demonstrated that Urban Strategy is able to use the available data to construct a basic working model and distribute traffic on the basis of that model. The appropriate data collected in this study has been successfully uploaded, and in combination with open-source data from OpenStreetMaps, Urban Strategy has been used to carry out an initial traffic assignment, and the results displayed in the 2D and 3D interfaces and the Web interface. It can be concluded that the developed system can be utilised as decision support system to evaluate various transport policies by estimating traffic loads and emission loads from vehicular traffic.

The following findings have emerged in the present study through the development of the decision support system for the city of Delhi and evaluation of different scenarios:

- ▶ Based on the results of estimated traffic loads and emission loads from vehicular traffic, it can be said that the contribution of passenger car movements to road transportation emissions is dominant in comparison to road freight movements.
- ▶ It has been shown that a Decision Support System on the basis of Urban Strategy is feasible for Delhi. Although a number of topics for further research are identified, the

study and system has already provided insight in the status quo and the effect of policy scenarios.

- ▶ On the basis of these findings it appears that some measures, such as freight hubs, will only be effective if they are combined with measures to lower fleet emissions, such as the use of electric vehicles.
- ▶ Removal of diesel vehicles older than 10 years shows 4 - 11% decrease in total CO_x, NO_x and PM₁₀ emissions, and negligible difference in Benzene or Hydrocarbon levels caused by freight traffic.
- ▶ Freight hubs and heavy vehicle restrictions may lead to increased overall emissions if there is no change to the emissions profile for the vehicles that replace them.
- ▶ Introduction of electric freight vehicles shows promising results for reduction in emissions, dependent on the penetration rate achieved.
- ▶ The impact of measures only targeting freight movements will be limited, due to its relatively small contribution to air pollution. Therefore, it would be valuable to apply this system on the integrated challenge of the city of Delhi with regards to air pollution and traffic noise. More in general: balancing between urban planning, mobility planning, environmental planning in order to accommodate (economic) growth and improve the quality of life of its citizens.

In the present study, an attempt has been made to see the feasibility to apply Agent Based Modelling (ABM) for City Logistics. A large variety of activities (e.g. freight vehicle movements, parking, loading/unloading goods) and stakeholders (consumer, retail, forwarding, trade, manufacturing) is associated with urban freight transportation, which differ with respect to location, types of goods and stakeholders' characteristics. Altogether this creates a complex system that is difficult to manage. The emerging system is a direct result of colliding decisions and often conflicting objectives of different stakeholders. A well-designed agent based modelling approach that includes the business models and perception of multiple stakeholders of the domain would be useful to identify effective solutions (e.g. policy, regulation, facilitating schemes) for the above mentioned problems.

By collecting and synthesizing information about individual stakeholders and entities at micro level, an agent-based model (ABM) for Delhi can be created to analyse the interactions

between urban freight entities to understand the background of movements of freight delivery vehicles and responses of these agents to policies for urban freight related problems. Furthermore, a role-playing game can be developed using an ABM as an interactive tool for urban freight stakeholders to understand the decision-making processes and complexity of urban freight activities. Such a role-playing game can act as platform to experience the complexity and emergence effect of decision-making by different stakeholders. As data collection is challenging part of ABM development, we recommend that, initially, a proof-of-concept model is developed for a zone in Delhi. A conceptual framework provided in this report as starting point for model development. Data collection for a small area should be relatively easy and allow addressing the research challenges of ABM development.

From the above, it can be said that agent-based modelling can be useful for many unrequited policy analysis problems in the urban freight domain. However, the time and precision required for developing such a system is a challenging task. Overcoming these challenges requires painstaking efforts but assures in-depth understanding about urban freight transportation process for successful urban freight policy analysis.

In conclusion, in the present study, four important priorities for the future have been identified, which could be part of a joint mission statement of the collective of stakeholders to achieve sustainable urban freight systems:

- *Reduction of negative effects of urban freight transport while maintaining productivity.*
- *Identification of workable urban freight solutions including roadmaps towards data, tools and appropriate research.*
- *Increase of the knowledge base including data collection, models and scenarios.*
- *Collaboration with other stakeholders to realize solutions towards sustainability.*

In the final workshop of the project, these points were signed symbolically by all participants, as an expression of the start of a shared effort to create a follow-up to this project including further elaborated policy information, based on a process of joint fact finding and alignment of ideas by industry, governmental and knowledge partners.

10. ANNEXURES

Appendix 1

Number of Registered Vehicles in New Delhi

Vehicles registered upto 31-dec-2016 class-wise
(Excl. NOC taken/ Scarpped Vehicle/ Surrendered RC/ RC Cancellation)

Class description	No. of Veh.
Agricultural Tractor	206
Ambulance	3035
Bus	35046
Cash Van	23
Construction Equipment Vehicle	1
Crane Mounted Vehicle	285
Educational Institution Bus	2
e-Rickshaw(P)	24958
e-Rickshaw with Cart (G)	1
Fire Fighting Vehicle	10
Goods Carrier	221003
Invalid Carriage	597
Luxury Cab	2255
Maxi Cab	30128
M-Cycle/Scooter	6340136
M-Cycle/Scooter-With Side Car	913
Mobile Workshop	19
Moped	113375
Motor Cab	111445
Motor Car	3044883
Motor Cycle/Scooter-With Trailer	1
Motorised Cycle (CC > 25cc)	8
Omni Bus	43
Omni Bus (Private Use)	4
Private Service Vehicle (Individual Use)	12
Recovery Vehicle	620
Three Wheeler (Goods)	66741
Three Wheeler (Passenger)	104969
Three Wheeler (Personal)	48
Tractor (Commercial)	6024
sum	10106791

(Source: www.delhi.gov.in/wps/wcm/connect/doi_transport/Transport/Home/Statistics)

Appendix 2

Estimated Vehicular Emission Load in Delhi (in 2009)

Pollutant	Pollution load (in ton/day)
Carbon Monoxide	391.52
Hydrocarbons	181.90
Nitrogen oxides	126.23
Particulate Mater	14.13

(Source: CRRI, 2009)

Appendix 3



Research Project Funded by



Form-I

CAPACITY ASSESSMENT AND POLICY INVENTORY SURVEY (PUBLIC AUTHORITIES)

Organization: _____

Name and Designation of the Contact Person: _____

Date: _____ Time: _____

Part A: General

1. Length of road infrastructure, according to different classifications in your jurisdiction:
 - a. Total road lane length in km
 - i. Local Streets _____ (lane length km)
 - ii. Collector Streets _____ (lane length km)
 - iii. Sub-Arterial Roads _____ (lane length km)
 - iv. Arterial Roads _____ (lane length km)
 - v. Highways _____ (lane length km)
 - b. Total lane length in km _____
 - c. Total road length with restricted access of following vehicle categories:
 - i. Light duty vehicle (GVW < 3.5 ton) _____
 - ii. Medium duty vehicle (3.5 < GVW < 7.5 ton) _____
 - iii. Heavy duty vehicle (GVW > 7.5 ton) _____
 - d. Total length of road designated for maintenance for the reference year in km _____
2. Land use area, according to different classifications:
 - a. Total urban area in km² _____
 - b. Total area used for roads in km² _____
 - c. Total area used for railways in km² _____
 - d. Total area used for public and private freight vehicle parking in km² _____
 - e. Total area used for loading bays in km² _____
 - f. Total area used for logistics facilities in km² _____
3. Freight vehicle accessibility
 - a. Total number intermodal hub facilities:
 - i. Rail _____
 - ii. Road _____
 - b. Total number of access links into the city:
 - i. Highway _____
 - ii. Rail _____
 - c. Total vehicle-hours delayed due to congestion in hours _____
4. Financial information at public level
 - a. Budget allocation for transport infrastructure in Road Sector

	2017-18	2016-17	2015-16
i. New construction (in Lakhs)	_____	_____	_____
ii. Maintenance (in Lakhs)	_____	_____	_____

Page 1 of 3

Part B: Knowledge and Capacity Building

5. Stakeholders and their business
 - a. How many Stakeholders are involved in city logistics (freight/ goods vehicles, their operation, policies, implementation, enforcement etc.) in New Delhi? _____
 - b. Which of these are key stakeholders (in terms of fleet size, investments, etc.)? _____

 - c. Is the government agency in regular contact with these key stakeholders? _____
 - d. How many staff members in the government agency are involved in city logistics, in policy-making as well as in the role of support staff? _____

6. Transportation and logistics
 - a. For which policy areas, does the government agency carry responsibility? _____

 - b. What general knowledge does the government agency have about city logistics? _____
 - c. What knowledge does the government agency have about city logistics in New Delhi? _____

 - d. Does the government agency regularly collect and publish data about city logistics or does it use more general (national) statistics or other sources? _____
 - e. If the agency collects its own data, what ways of data collection are used? _____

 - f. Does it regard the collected data as sufficient support for its policy-making in city logistics? _____

 - g. What essential data does the government agency not have about city logistics in New Delhi? _____

 - h. Why is this information not collected? _____

7. Methods for analysis
 - a. Which quantitative tools are known and applied by the support staff members? For which purpose? _____

 - b. Which qualitative tools are known and applied by the support staff members? For which purpose? _____

 - c. Do these tools fulfil their purpose? _____

 - d. Does the agency lack certain tools? Which are they? _____

8. Main policies and their effectiveness

- a. With which policies does the government agency intend to influence city logistics?

- b. What are the main aims of these policies?

- c. What are the main instruments of these policies?

- d. What is the policy horizon of these policies?

- e. Are these policies regularly evaluated and adapted to new requirements and understanding of practice?

- f. Are there new dedicated city logistics policies or policy instruments in the making for New Delhi?

9. Other cities approaches

- a. How is the cooperation with other government agencies of Delhi in the area of city logistics?

- b. Has the government agency applied policies, approaches or tools that were developed elsewhere, in Delhi metropolitan region or elsewhere in India?

- c. Were or are these applications successful in New Delhi?

10. Any Other Remark with respect to City Logistics in Delhi particular? the

Thank you very much for your cooperation

Page 3 of 3

**CSIR**
CRRI

CSIR-Central Road Research Institute (CRRI), New Delhi

(in association with TNO, Netherlands and TU Delft, Netherlands)

TNO
TU Delft**MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY
(MEGALOG)**

Research Project Funded by

**THE WORLD BANK**
IBRD • IDA | WORLD BANK GROUP

Form-II

CAPACITY ASSESSMENT AND POLICY INVENTORY SURVEY (OPERATORS)

Organization: _____

Name and Designation of the Contact Person: _____

Date: _____ Time: _____

Part A: General

1. How many employees does your company hire in total? _____
2. How many freight vehicles does your company use according to categories below?
 - a. Total number of vehicles _____
 - b. Total leased vehicles _____
 - c. Total refrigerated vehicles _____
3. What kind of commodities do you transport? Please name the main three.
 - a. _____
 - b. _____
 - c. _____
4. How many trips are made within the city? _____
5. How many trips are made which leave the city? _____
6. How many days in a year does your company operate? _____
7. Describe the transport operations of an average day
 - a. What is the total driving time? _____
 - b. What is the total driving distance? _____
 - c. How many deliveries are made? _____
 - d. How many deliveries take a different duration than expected in percentage?
 - i. More than 10% faster than expected _____
 - ii. More than 10% slower than expected _____
 - iii. More than 50% slower than expected _____
 - iv. More than double the expected duration _____
 - e. Estimate the amount of operating costs incurred to perform all deliveries. _____

Page 1 of 3



Part B: Knowledge and Capacity Building

1. Stakeholders and their business
 - a. How many Stakeholders are involved in city logistics (freight/ goods vehicles, their operation, policies, implementation, enforcement etc.) in New Delhi? _____
 - b. Which of these are key stakeholders (in terms of fleet size, investments, etc.)? _____
 - c. Is the government agency in regular contact with these key stakeholders? _____
 - d. How many staff members in the government agency are involved in city logistics, in policy-making as well as in the role of support staff? _____

2. Transportation and logistics
 - a. For which policy areas, does the government agency carry responsibility? _____
 - b. What general knowledge does the government agency have about city logistics? _____
 - c. What knowledge does the government agency have about city logistics in New Delhi? _____
 - d. Does the government agency regularly collect and publish data about city logistics or does it use more general (national) statistics or other sources? _____
 - e. If the agency collects its own data, what ways of data collection are used? _____
 - f. Does it regard the collected data as sufficient support for its policy-making in city logistics? _____
 - g. What essential data does the government agency not have about city logistics in New Delhi? _____
 - h. Why is this information not collected? _____

3. Methods for analysis
 - a. Which quantitative tools are known and applied by the support staff members? For which purpose? _____
 - b. Which qualitative tools are known and applied by the support staff members? For which purpose? _____
 - c. Do these tools fulfil their purpose? _____
 - d. Does the agency lack certain tools? Which are they? _____

4. Main policies and their effectiveness

a. With which policies does the government agency intend to influence city logistics?

b. What are the main aims of these policies?

c. What are the main instruments of these policies?

d. What is the policy horizon of these policies?

e. Are these policies regularly evaluated and adapted to new requirements and understanding of practice?

f. Are there new dedicated city logistics policies or policy instruments in the making for New Delhi?

5. Other cities approaches

a. How is the cooperation with other government agencies of Delhi in the area of city logistics?

b. Has the government agency applied policies, approaches or tools that were developed elsewhere, in Delhi metropolitan region or elsewhere in India?

c. Were or are these applications successful in New Delhi?

6. Any Other Remark with respect to City Logistics in Delhi particular? the

Thank you very much for your cooperation



CSIR CSIR-Central Road Research Institute (CRRI), New Delhi
(in association with TNO, Netherlands and TU Delft, Netherlands)



**MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY
(MEGALOG)**

Research Project Funded by



Form-III

CAPACITY ASSESSMENT AND POLICY INVENTORY SURVEY (EXPERTS)

Organization: _____

Name and Designation of the Contact Person: _____

Date: _____ Time: _____

1. Stakeholders and their business
 - a. How many Stakeholders are involved in city logistics (freight/ goods vehicles, their operation, policies, implementation, enforcement etc.) in New Delhi? _____
 - b. Which of these are key stakeholders (in terms of fleet size, investments, etc.)? _____
 - c. Is the government agency in regular contact with these key stakeholders? _____
 - d. How many staff members in the government agency are involved in city logistics, in policy-making as well as in the role of support staff? _____
2. Transportation and logistics
 - a. For which policy areas, does the government agency carry responsibility? _____
 - b. What general knowledge does the government agency have about city logistics? _____
 - c. What knowledge does the government agency have about city logistics in New Delhi? _____
 - d. Does the government agency regularly collect and publish data about city logistics or does it use more general (national) statistics or other sources? _____
 - e. If the agency collects its own data, what ways of data collection are used? _____
 - f. Does it regard the collected data as sufficient support for its policy-making in city logistics? _____
 - g. What essential data does the government agency not have about city logistics in New Delhi? _____
 - h. Why is this information not collected? _____

Page 1 of 2

3. Methods for analysis
- Which quantitative tools are known and applied by the support staffmembers? For which purpose?

 - Which qualitative tools are known and applied by the support staffmembers? For which purpose?

 - Do these tools fulfil their purpose?

 - Does the agency lack certain tools? Which are they?

4. Main policies and their effectiveness
- With which policies does the government agency intend to influence city logistics?

 - What are the main aims of these policies?

 - What are the main instruments of these policies?

 - What is the policy horizon of these policies?

 - Are these policies regularly evaluated and adapted to new requirements and understanding of practice?

 - Are there new dedicated city logistics policies or policy instruments in the making for New Delhi?

5. Other cities approaches
- How is the cooperation with other government agencies of Delhi in the area of city logistics?

 - Has the government agency applied policies, approaches or tools that were developed elsewhere, in Delhi metropolitan region or elsewhere in India?

 - Were or are these applications successful in New Delhi?

6. Any Other Remark with respect to City Logistics in Delhi particular? the

Thank you very much for your cooperation

Page 2 of 2

Appendix 4

Table A4.1: Observed Journey Speed on Tees Hazari to Kundli (S-1) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Tees Hazari to Mori Gate Crossing	0.9	10.59
2	Mori Gate Crossing to ISBT	1.0	19.34
3	ISBT to Matkaf	1.0	43.97
4	Matkaf to Majnu Ka Tilla	2.0	38.56
5	Majnu Ka Tilla to Nehru Vihar	1.4	38.12
6	Nehru Vihar to Gopal Pur Crossing	1.1	17.79
7	Gopal Pur Crossing to Burari Crossing	2.6	25.24
8	Burari Crossing to Mukund Pur Crossing	1.5	28.23
9	Mukund Pur Crossing to Mubarka Chowk	2.8	49.85
10	Mubarka Chowk to Swaroop Nagar	2.4	59.54
11	Swaroop Nagar to Budhpur	2.7	53.31
12	Budhpur to Palla More	2.4	12.90
13	Palla More to Khampur	2.6	63.22
14	Khampur to Singhola Crossing	2.0	49.48
15	Singhola Crossing to Kundli	2.5	40.39
Total		28.9	36.70

Table A4.2: Observed Journey Speed on Kundli to Tees Hazari (S-1) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Kundli to Singhola Crossing	2.5	18.33
2	Singhola Crossing to Khampur	2.0	48.43
3	Khampur to Palla More	2.6	18.44
4	Palla More to Budhpur	2.4	26.41
5	Budhpur to Swaroop Nagar	2.7	47.84
6	Swaroop Nagar to Mubarka Chowk	2.4	59.32
7	Mubarka Chowk to Mukund Pur Crossing	2.8	39.73
8	Mukund Pur Crossing to Burari Crossing	1.5	13.22
9	Burari Crossing to Gopal Pur Crossing	2.6	28.29
10	Gopal Pur Crossing to Nehru Vihar	1.1	29.23
11	Nehru Vihar to Majnu Ka Tilla	1.4	37.28
12	Majnu Ka Tilla to Matkaf	2.0	29.27
13	Matkaf to ISBT	1.0	41.24
14	ISBT to Mori Gate Crossing	1.0	42.21
15	Mori Gate Crossing to Tees Hazari	0.9	40.68
Total		28.9	34.66

Table A4.3: Observed Journey Speed on Prashant Vihar (Ring Road Crossing) to Ferozpur Bangar (S-2) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Prasant Vihar to Vidhya Marg Crossing	1.36	15.52
2	Vidhya Marg Crossing to DTC Rohini Depot	0.92	19.11
3	DTC Rohini Depot to BPIT	1.13	24.10
4	BPIT to St. Xavier School	1.42	32.71
5	St. Xavier School to Prahladpur	2.00	18.81
6	Prahladpur to Prahladpur School	0.90	26.82
7	Prahladpur School to Anand Vihar Barwala	1.90	20.06
8	Anand Vihar Barwala to Poot Khurd	1.25	30.96
9	Poot Khurd to Bawana Gas Agency	1.50	14.08
10	Bawana Gas Agency to Bawana Sec 1	1.25	43.66
11	Bawana Sec 1 to Bawana Chowk	1.04	23.62
12	Bawana Chowk to Daryapur	2.80	35.50
13	Daryapur to Ferozpur Bangar	3.10	25.18
	Total	20.57	25.39

Table A4.4: Observed Journey Speed on Ferozpur Bangar to Prashant Vihar (Ring Road Crossing) (S-2) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Ferozpur Bangar to Daryapur	3.10	32.46
2	Daryapur to Bawana Chowk	2.80	35.91
3	Bawana Chowk to Bawana Sec 1	1.04	17.00
4	Bawana Sec 1 to Bawana Gas Agency	1.25	44.65
5	Bawana Gas Agency to Poot Khurd	1.50	22.43
6	Poot Khurd to Anand Vihar Barwala	1.25	27.90
7	Anand Vihar Barwala to Prahladpur School	1.90	26.50
8	Prahladpur School to Prahladpur	0.90	22.71
9	Prahladpur to St. Xavier School	2.00	18.96
10	St. Xavier School to BPIT	1.42	35.08
11	BPIT to DTC Rohini Depot	1.13	27.05
12	DTC Rohini Depot to Vidya Marg Crossing	0.92	38.14
13	Vidya Marg Crossing to Prasant Vihar	1.36	16.73
	Total	20.57	28.12

Table A4.5: Observed Journey Speed on GT Road Shahdara to Bahadurgarh (S-3) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Shahdara to Jhilmil Crossing	0.40	8.90
2	Jhilmil Crossing to Mansarovar Park	1.29	24.55
3	Mansarovar Park to Kranti Nagar Extension	2.20	34.82
4	Kranti Nagar Extension to Parsavnath Metro Mall	1.10	6.69
5	Parsavnath Metro Mall to Shastri Park Crossing	1.40	8.21
6	Shastri Park Crossing to ISBT	2.00	26.10
7	ISBT to Mori Gate Crossing	1.05	37.53
8	Mori Gate Crossing to Lodhi Chowk	1.20	7.40
9	Lodhi Chowk to Sadar Bazaar Station	0.60	11.98
10	Sadar Bazaar Station to New Delhi Railway Station	1.50	6.040
11	New Delhi Railway Station to Paharganj	0.90	8.80
12	Paharganj to Jhandewalan	0.50	5.60
13	Jhandewalan to Guru Govind Singh Crossing	0.90	11.73
14	Guru Govind Singh Crossing to Karol Bhag	0.60	17.39
15	Karol Bhag to Ordinance Depot	1.52	20.13
16	Ordinance Depot to Multan Nagar	0.89	14.63
17	Multan Nagar to Peeragarhi Chowk	1.00	10.65
18	Peeragarhi Chowk to Jwalapur	1.46	9.33
19	Jwalapur to Police Station Nangoli	1.66	10.23
20	Police Station Nangoli to Nangoli Colony	1.41	17.36
21	Nangoli Colony to Mundka Crossing	1.83	14.56
22	Mundka Crossing to Mundka Main Road	1.82	36.56
23	Mundka Main Road to Ghevra Mor	2.23	14.56
24	Ghevra Mor to Sarvodaya Kanya Vidyalaya	2.92	36.56
25	Sarvodaya Kanya Vidyalaya to Nh-10	1.79	26.36
26	Nh-10 to Old Sabzi Mandi	1.49	29.63
27	Old Sabzi Mandi to Bahadurgarh	1.28	15.23
Total		36.94	17.46

Table A4.6: Observed Journey Speed on GT Road Bahadurgarh to Shahadara (S-3) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Bahadurgarh to Old Sabzi Mandi	1.28	10.61
2	Old Sabzi Mandi to Nh-10	1.49	28.59
3	Nh-10 to Sarvodaya Kanya Vidyalaya	1.79	27.41
4	Sarvodaya Kanya Vidyalaya to Ghevra Mor	2.92	41.44
5	Ghevra Mor to Mundka Main Road	2.23	7.05
6	Mundka Main Road to Mundka Crossing	1.82	33.63
7	Mundka Crossing to Nangoli Colony	1.83	15.86
8	Nangoli Colony to Police Station Nangoli	1.41	15.68
9	Police Station Nangoli to Jwalapur	1.66	6.33
10	Jwalapur to Peeragarhi Chowk	1.46	7.55
11	Peeragarhi Chowk to Multan Nagar	1.00	12.35
12	Multan Nagar to Ordinance Depot	0.89	15.65
13	Ordinance Depot to Karol Bhag	1.52	22.6
14	Karol Bhag to Guru Govind Singh Crossing	0.60	11.73
15	Guru Govind Singh Crossing to Jhandewalan	0.90	10.62
16	Jhandewalan to Paharganj	0.50	4.11
17	Paharganj to New Delhi Railway Station	0.90	11.63
18	New Delhi Railway Station to Sadar Bazaar Station	1.50	4.41
19	Sadar Bazaar Station to Lodhi Chowk	0.60	3.64
20	Lodhi Chowk to Mori Gate Crossing	1.20	10.88
21	Mori Gate Crossing to ISBT	1.05	16.74
22	ISBT to Shastri Park Crossing	2.00	36.95
23	Shastri Park Crossing to Parsavnath Metro Mall	1.40	22.09
24	Parsavnath Metro Mall to Kranti Nagar Extension	1.10	10.39
25	Kranti Nagar Extension to Mansarovar Park	2.20	28.45
26	Mansarovar Park to Jhilmil Crossing	1.29	31.98
27	Jhilmil Crossing to Shahdara	0.40	13.18
Total		36.94	17.09

Table A4.7: Observed Journey Speed on Rajeev Chowk (Connaught Place) to Dhansa (Najafgarh Road) (S-4) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Rajiv Chowk to Rama Krishna Marg	1.25	9.19
2	Rama Krishna Marg to Videocon tower	0.60	13.40
3	Videocon tower to Rani Jhansi	0.40	9.59
4	Rani Jhansi to Idgah	0.65	22.15
5	Idgah to Railway Over Bridge	2.50	11.71
6	Railway Over Bridge to Zakhira Village	1.65	18.01
7	Zakhira Village to Ashoka Park	1.05	35.74
8	Ashoka Park to Zakhira	1.30	10.48
9	Zakhira to Moti Nagar	2.00	27.32
10	Moti Nagar to Raja Garden	2.25	11.48
11	Raja Garden to Subhash Nagar	1.90	21.41
12	Subhash Nagar to Tilak Nagar	1.25	24.68
13	Tilak Nagar to Janakpuri	1.50	15.69
14	Janakpuri to Uttamnagar Bus Depot	1.50	9.36
15	Uttamnagar Bus Depot to Dwaraka More	3.00	8.50
16	Dwaraka More to Indira Park	3.00	23.34
17	Indira Park to Najafgarh	1.50	11.28
18	Najafgarh to Dansa Stand	1.10	20.43
19	Dansa Stand to Desu Office Mitraun	2.00	28.46
20	Desu Office Mitraun to Surhera Crossing	2.00	25.92
21	Surhera Crossing to Rawta Crossing	1.65	44.18
22	Rawta Crossing to Mundhela Crossing	2.00	41.05
23	Mundhela Crossing to Kazipur	2.50	33.59
24	Kazipur to Issapur Crossing	1.00	40.49
25	Issapur Crossing to Dansa Village	1.00	44.27
26	Dansa Village to Dansa Border	2.50	35.22
	Total	43.05	22.96

Table A4.8: Observed Journey Speed on Dhansa (Najafgarh Road) to Rajeev Chowk (Connaught Place) (S-4) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Dansa Border to Dansa Village	2.50	29.19
2	Dansa Village to Isapur Crossing	1.00	37.83
3	Issapur Crossing to Kazipur	1.00	43.15
4	Kazipur to Mundhela Crossing	2.50	40.28
5	Mundhela Crossing to Rawta Crossing	2.00	42.21
6	Rawta Crossing to Surhera Crossing	1.65	38.72
7	Surhera Crossing to Desu Office Mitraun	2.00	40.92
8	Desu Office Mitraun to Dansa Stand	2.00	27.68
9	Dansa Stand to Najafgarh	1.10	26.39
10	Najafgarh to Indira Park	1.50	7.45
11	Indira Park to Dwaraka More	3.00	17.34
12	Dwaraka More to Uttam Nagar Bus Depot	3.00	14.06
13	Uttam Nagar Bus Depot to Janakpuri	1.50	6.57
14	Janakpuri to Tilak Nagar	1.50	9.22
15	Tilak Nagar to Subhash Nagar	1.25	11.77
16	Subhash Nagar to Raja Garden	1.90	12.38
17	Raja Garden to Moti Nagar	2.25	18.48
18	Moti Nagar to Zakhira	2.00	14.81
19	Zakhira to Ashoka Park	1.30	14.54
20	Ashoka Park to Zakhira Village	1.05	28.78
21	Zakhira Village to Railway Over Bridge	1.65	27.27
22	Railway Over Bridge to Idgah	2.50	9.46
23	Idgah to Rani Jhansi	0.65	14.38
24	Rani Jhansi Ti Videocon tower	0.40	8.60
25	Videocon tower to Rama Krishna Marg	0.60	11.80
26	Rama Krishna Marg to Rajiv Chowk	1.25	17.18
Total		43.05	21.94

Table A4.9: Observed Journey Speed on Rajokri Border (Delhi –Gurgaon Expressway) to Rajeev Chowk (Connaught Place) (S-5) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Rajokri Border to Rose Garden Extension	2.2	47.90
2	Rose Garden Extension to Mahipalpur	0.8	68.92
3	Mahipalpur to Mahipalpur Extension	0.7	78.67
4	Mahipalpur Extension to Shankar Vihar	2.5	26.09
5	Shankar Vihar to APS	1.2	27.82
6	APS to Suborto Park	2.0	34.07
7	Suborto Park to Dhaula Kuan	1.3	46.36
8	Dhaula Kuan to Simon Bolivar Margh	2.0	38.71
9	Simon Bolivar Margh to Sardar Patel Crossing	1.3	21.63
10	Sardar Patel Crossing to Dr. Rani Hospital	2.0	47.60
11	Dr. Rani Hospital to St. Colombus School	0.9	19.05
12	St. Colombus School to Rajeev Chowk	1.2	21.71
	Total	18.1	39.87

Table A4.10: Observed Journey Speed on Rajeev Chowk (Connaught Place) to Rajokri Border (Delhi –Gurgaon Expressway) (S-5) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Rajeev Chowk to St. Colombus School	1.2	5.90
2	St. Colombus School to Dr. Rani Hospital	0.9	27.28
3	Dr. Rani Hospital to Sardar Patel Crossing	2.0	14.20
4	Sardar Patel Crossing to Simon Bolivar Margh	1.3	9.60
5	Simon Bolivar Margh to Dhaula Kuan	2.0	16.23
6	Dhaula Kuan to Subroto Park	1.3	45.56
7	Subroto Park to APS	2.0	55.95
8	APS to Shankar Vihar	1.2	56.18
9	Shankar Vihar to Mahipalpur Extension	2.5	66.05
10	Mahipalpur Extension to Mahipalpur	0.7	65.41
11	Mahipalpur to Rose Garden Extension	0.8	66.60
12	Rose Garden Extension to Rajokri Border	2.2	15.02
	Total	18.1	36.99

Table A4.11: Observed Journey Speed on Aurobindo Marg to Arjan Garh (Aya Nagar Border) (S-6) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Aurobindo Marg to Bhismpitama Margh	1.40	16.37
2	Bhismpitama Margh to Lodhi Road Crossing	0.51	16.17
3	Lodhi Road Crossing to Jor Bagh Metro Station	1.07	5.58
4	Jor Bagh Metro Station to Shri Ganga Nath Margh	1.09	14.44
5	Shri Ganga Nath Margh to INA Colony	1.03	23.83
6	INA Colony to Ina Metro Station	1.25	9.59
7	Ina Metro Station to Kidwai Nagar Metro Station	0.18	14.47
8	Kidwai Nagar Metro Station to Near AIIMS Metro	1.54	43.21
9	Near AIIMS Metro Station to Yusuf Sarai Metro	1.01	31.48
10	Yusuf Sarai Metro Station to Green Park Metro	0.56	51.72
11	Green Park Metro to Green Park	0.71	31.96
12	Green Park to Hauz Khas Metro Stn	0.47	42.06
13	Hauz Khas Metro Stn to IIT Delhi Gate	1.49	14.60
14	IIT Delhi Gate to Near Qutab Hotel	0.73	57.32
15	Near Qutab Hotel to Near Pts & Lado Sarai	0.33	16.95
16	Near Pts & Lado Sarai Crossing to Mosque Qutab	0.26	5.22
17	Mosque Qutab to Arjangarh Metro Station	5.83	15.42
Total		19.46	24.14

Table A4.12: Observed Journey Speed on Arjan Garh (Aya Nagar Border) to Aurobindo Marg (S-6) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Arjangarh Metro Station to Mosque Qutab	5.83	14.45
2	Mosque Qutab to Lado Sarai Crossing	0.26	6.52
3	Lado Sarai Crossing to Near Qutab Hotel	0.33	17.95
4	Near Qutab Hotel to IIT Delhi Gate	0.73	52.60
5	IIT Delhi Gate to Hauz Khas Metro Stn	1.49	13.45
6	Hauz Khas Metro Stn to Green Park	0.47	40.12
7	Green Park to Green Park Metro	0.71	32.45
8	Green Park Metro to Yusuf Sarai Metro Stn	0.56	45.46
9	Yusuf Sarai Metro Stn to Near AIIMS Metro	1.01	30.46
10	Near AIIMS Metro to Kidwai Nagar Metro Stn	1.54	38.21
11	Kidwai Nagar Metro Station to INA Metro Stn	0.18	15.06
12	INA Metro Station to INA Colony	1.25	10.94
13	INA Colony to Shri Ganga Nath Margh	1.03	24.63
14	Shri Ganga Nath Margh to Jor Bhag Metro Stn	1.09	15.23
15	Jor Bhag Metro Station to Lodhi Road Crossing	1.07	6.23
16	Lodhi Road Crossing to Bhismpitama Margh	0.51	15.23
17	Bhismpitama Margh to Aurobindo Marg	1.40	14.66
Total		19.46	23.15

**Table A4.13: Observed Journey Speed on Badarpur Border to Rajeev Chowk
(Connaught Place) (S-7) in Up Direction**

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Badarpur Border to Aali Gaon	2.14	26.06
2	Aali Gaon to Madanpur Khadar	1.54	35.19
3	Madanpur Khaddar to Apollo Hospital	1.40	31.39
4	Apollo Hospital to Kalka Mor	2.30	34.76
5	Kalka Mor to Ashram	2.00	15.36
6	Ashram to Hazrat Nizamuddin	2.20	16.17
7	Hazrat Nizamuddin to Golf Club	2.00	26.09
8	Golf Club to Baroda House	2.20	19.91
9	Baroda House to Rajeev Chowk	2.00	15.81
	Total	17.78	24.52

**Table A4.14: Observed Journey Speed on Rajeev Chowk (Connaught Place) to
Badarpur Border (S-7) in Down Direction**

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Rajeev Chowk to Baroda House	2.00	18.50
2	Baroda House to Golf Club	2.20	40.73
3	Golf Club to Hazrat Nizamuddin	2.00	24.61
4	Hazrat Nizamuddin to Ashram	2.20	10.15
5	Ashram to Kalka Mor	2.00	12.39
6	Kalka Mor to Apollo Hospital	2.30	35.33
7	Apollo Hospital to Madanpur Khaddar	1.40	26.39
8	Madanpur Khaddar to Aali Gaon	1.54	20.30
9	Aali Gaon to Badarpur Border	2.14	20.90
	Total	17.78	23.25

Table A4.15: Observed Journey Speed on Inner Ring Road (Ashram Chowk to Ashram Chowk) (S-8) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Ashram Chowk to Vikas Marg	3.83	29.26
2	Vikas Marg to Rose Garden	3.48	24.73
3	Ross Garden to Vijayghat	0.75	53.56
4	Vijayghat to Indira Gandhi IT	2.76	29.11
5	Indira Gandhi IT to Matkaf Metro Station	1.98	22.29
6	Matkaf Metro Station to Naya Azadpur	0.99	15.69
7	Naya Azadpur to Pitampura	6.61	20.95
8	Pitampura to Britania Chowk	2.11	53.48
9	Britania Chowk to Punjabi Bagh Chowk	3.60	14.01
10	Punjabi Bagh Chowk to Punjabi Bagh Bus Stop	0.64	12.03
11	Punjabi Bagh Bus Stop to Sardana Eye Institute	2.42	24.90
12	Sardana Eye Institute to Army Medical College	4.59	32.53
13	Army Medical College to Sardar Patel Marg	3.48	32.51
14	Sardar Patel Marg to Safdarjung	3.68	20.77
15	Safdarjung to AIIMS Metro	1.90	52.32
16	AIIMS Metro to Moolchand Metro Station	2.54	26.21
17	Moolchand Metro Station to Ashram Chowk	2.59	30.12
Total		47.95	29.09

Table A4.16: Observed Journey Speed on Inner Ring Road (Ashram Chowk to Ashram Chowk) (S-8) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Ashram Chowk to Moolchand Metro Station	2.59	34.71
2	Moolchand to AIIMS Metro Station	2.54	15.56
3	AIIMS to Safdarjung Metro Station	1.90	40.96
4	Safdarjung to Sardar Patel Marg	3.68	35.52
5	Sardar Patel Marg to Army Medical School	3.48	43.72
6	Army Medical College to Sardana Eye Institute	4.59	50.07
7	Sardana Eye Institute to Punjabi Bagh Bus Stop	2.42	39.42
8	Punjabi Bagh Bus Stop to Punjabi Bagh Chowk	0.64	51.23
9	Punjabi Bagh Chowk to Britania Chowk	3.60	40.50
10	Britania Chowk to Pitampura	2.11	44.80
11	Pitampura to Naya Azad Pur	6.61	15.72
12	Naya Azadpur to Matkaf Metro Station	0.99	14.96
13	Matkaf Metro to Indra Gandhi I.T	1.98	24.56
14	Indra Gandhi I.T to Vijayghat	2.76	41.33
15	Vijayghat to Rose Garden	0.75	49.68
16	Rose Garden to Vikas Marg	3.48	36.38
17	Vikas Marg to Ashram Chowk	3.83	40.31
Total		47.95	36.43

Table A4.17: Observed Journey Speed on Outer Ring Road (Dwarka Mor Metro Station to Kalindi Kunj Border) (S-9) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Dwarka Mor to Palam Vihar	4.50	25.24
2	Palam Vihar to Hanuman Mandir	5.40	38.31
3	Hanuman Mandir to APS Colony	3.00	20.40
4	APS Colony to Ber Sarai	3.80	43.50
5	Ber Sarai to IIT Gate	3.40	21.55
6	Iit Gate to Panchsheel Enclave	0.80	33.65
7	Panchsheel Enclave to Greater Kailash	3.50	32.10
8	Greater Kailash to Nehru Palace	1.15	41.52
9	Nehru Palace to Kalkaji Temple Bus Stop	1.50	23.55
10	Kalkaji Temple Bus Stop to Kalka Mor	1.10	19.64
11	Kalka Mor to Apollo Metro	2.81	21.85
12	Apollo Metro to Kalindi Kunj	2.80	40.61
Total		33.76	30.16

Table A4.18: Observed Journey Speed on Outer Ring Road (Kalindi Kunj Border to Dwarka Mor Metro Station) (S-9) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Kalindi Kunj to Apollo Metro Station	2.8	19.74
2	Apollo Metro Station to Kalka Mor	2.81	23.55
3	Kalka Mor to Kalkaji Temple Bus Stop	1.10	41.52
4	Kalkaji Temple Bus Stop to Nehru Palace	1.50	33.10
5	Nehru Palace to Greater Kailash	1.15	33.34
6	Greater Kailash to Panchsheel Enclave	3.50	21.55
7	Panchsheel Enclave to IIT Gate	0.80	44.23
8	IIT Gate to Ber Sarai	3.40	44.70
9	Ber Sarai to APS Colony	3.80	20.04
10	APS Colony to Hanuman Mandir	3.00	43.88
11	Hanuman Mandir to Palam Vihar	5.40	40.61
12	Palam Vihar to Dwarka Mor	4.50	26.24
Total		33.76	32.70

Table A4.19: Observed Journey Speed on GT Road INA to Shahadara (Via Ghazipur, DND, Barapulla Elevated Road) (S-10) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	INA to Sewa Nagar Railway	1.74	20.42
2	Sewa Nagar Railway to CGO Complex	1.37	40.13
3	CGO Complex to Nizamuddin	0.70	39.19
4	Nizamuddin to Gurudwara Bangla Sahib	1.72	40.98
5	Gurudwara Bangla Sahib to Mayur Place	4.16	39.38
6	Mayur Place to Kalyanpuri Temple	3.70	21.71
7	Kalyanpuri Temple to Khichdipur Crossing	1.62	20.10
8	Khichdipur Crossing to Gazipur Village	1.06	19.03
9	Gazipur Village to Anand Vihar ISBT	1.08	24.72
10	Anand Vihar ISBT to Shresta Vihar	1.56	39.21
11	Shresta Vihar to Ramprastha Mandir	0.54	40.43
12	Ramprastha Mandir to Shahadara	1.40	37.51
	Total	20.65	31.90

Table A4.20: Observed Journey Speed on GT Road Shahadara TO INA (Via Ghazipur, DND, Barapulla Elevated Road) (S-10) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Shahadara to Ramprastha Mandir	1.40	13.44
2	Ramprastha Mandir to Shrestha Vihar	0.54	14.29
3	Shrestha Vihar to Anand Vihar ISBT	1.56	41.76
4	Anand Vihar ISBT to Gazipur Village	1.08	31.19
5	Gazipur Village to Khichdipur Crossing	1.06	44.28
6	Khichdipur Crossing to Kalyanpuri Terminal	1.62	21.69
7	Kalyanpuri Terminal to Mayur Place	3.70	14.30
8	Mayur Place to Gurudwara Bangla Sahib	4.16	34.95
9	Gurudwara Bangla Sahib to Nizamuddin	1.72	33.39
10	Nizamuddin to CGO Complex	0.70	49.52
11	CGO Complex to Sewa Nagar	1.37	44.70
12	Sewa Nagar Railway to Ina	1.74	47.56
	Total	20.65	32.58

Table A4.21: Observed Journey Speed on Nizamuddin Bridge to Ghazipur (S-11) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Nizamuddin Road Crossing to PWD Office	1.4	34.24
2	PWD Office to Noida More	1.5	44.43
3	Noida More to Patparganj Crossing	0.8	40.13
4	Patparganj Crossing to Trilokpuri	0.8	32.61
5	Trilokpuri to Khichdipur Village	1.4	37.27
6	Khichdipur Village to Khichdipur Crossing	0.9	32.13
7	Khichdipur Crossing to Ghazipur	1.1	21.27
Total		7.9	34.58

Table A4.22: Observed Journey Speed on Ghazipur to Nizamuddin Bridge (S-11) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Ghazipur to Khichdipur Crossing	1.1	25.97
2	Khichdipur Crossing to Khichdipur Village	0.9	38.88
3	Khichdipur Village to Trilokpuri	1.4	46.51
4	Trilokpuri to Patparganj Crossing	0.8	40.25
5	Patparganj Crossing to Noida More	0.8	37.96
6	Noida More to PWD Office	1.5	43.8
7	PWD Office to Nizamuddin Road Crossing	1.4	36.99
Total		7.9	38.62

Table A4.23: Observed Journey Speed on Wazirabad to Mandoli Border (S-12) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Wazirabad to Nanaksha	1.4	5.50
2	Nanaksha to Khajuri Khas	1.6	22.09
3	Khajuri Khas to Bhajanpura	0.7	11.04
4	Bhajanpura to Yamuna Vihar	1.5	20.74
5	Yamuna Vihar to Yamuna Vihar Crossing	0.8	39.01
6	Yamuna Vihar Crossing to Loni Road Crossing	0.8	37.51
7	Loni Road Crossing to Mandoli Sewadham	1.0	30.28
8	Mandoli Sewadham to Gagan Cinema	1.3	23.34
9	Gagan Cinema to Mandoli Border	0.7	15.05
Total		9.8	22.72

Table A4.24: Observed Journey Speed on Mandoli Border to Wazirabad (S-12) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Mandoli Border to Gagan Cinema	0.7	22.35
2	Gagan Cinema to Mandoli Sewadham	1.3	30.15
3	Mandoli Sewadham to Loni Road Crossing	1.0	35.48
4	Loni Road Crossing to Yamuna Vihar Crossing	0.8	35.46
5	Yamuna Vihar Crossing to Yamuna Vihar	0.8	41.03
6	Yamuna Vihar to Bhajanpura	1.5	20.23
7	Bhajanpura to Khajuri Khas	0.7	39.16
8	Khajuri Khas to Nanaksha	1.6	6.09
9	Nanaksha to Wazirabad	1.4	3.40
	Total	9.8	25.92

Table A4.25: Observed Journey Speed on Loni Border to Old Delhi Railway Station (Via Vikas Marg, Sadar Bazar) (S-13) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Loni Road to Loni Road Crossing	1.1	7.80
2	Loni Road Crossing to Jyoti Nagar	1.3	11.80
3	Jyoti Nagar to DTC Shahadara Terminal	2.1	8.35
4	DTC Shahadara Terminal to Kranti Nagar	1.0	16.72
5	Kranti Nagar to Krishna Nagar A Block	1.2	6.93
6	Krishna Nagar A Block to Radhey Puri	1.1	14.96
7	Radhey Puri to Gagan Vihar	1.1	10.95
8	Gagan Vihar to Nirman Vihar	1.6	11.55
9	Nirman Vihar to Laxmi Nagar Metro Station	1.4	22.38
10	Laxmi Nagar Metro Station to ITI	2.0	45.95
11	ITO to Ram Charan Agarwal Bus Stop	0.6	12.14
12	Ram Charan Agarwal to Deen Dayal Upadhyay	1.3	18.07
13	Deen Dayal Upadhyay to Shivaji Park	0.8	38.24
14	Shivaji Park to Connaught Place	1.2	23.53
15	Connaught Place to New Delhi Railway Station	1.2	17.63
16	New Delhi Railway Station to Old Delhi Railway	2.1	8.30
	Total	21.1	17.20

**Table A4.26: Observed Journey Speed on Old Delhi Railway Station to Loni Border
(Via Vikas Marg, Sadar Bazar) (S-13) in Down Direction**

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Old Delhi Railway to New Delhi Railway Station	2.1	3.40
2	New Delhi Railway Station to Connaught Place	1.2	23.65
3	Connaught Place to Shivaji Park	1.2	14.70
4	Shivaji Park to Deen Dayal Upadhyay	0.8	45.34
5	Deen Dayal Upadhyay to Ram Charan Agarwal	1.3	12.80
6	Ram Charan Agarwal to ITO	0.6	44.08
7	ITO to Laxmi Nagar Metro Station	2.0	34.93
8	Laxmi Nagar Metro Station to Nirman Vihar	1.4	20.39
9	Nirman Vihar to Gagan Vihar	1.6	19.79
10	Gagan Vihar to Radheypuri	1.1	23.55
11	Radheypuri to Krishna Nagar A Block	1.1	3.94
12	Krishna Nagar A Block to Kranti Nagar	1.2	19.46
13	Kranti Nagar to DTC Shahadara Terminal	1.0	17.00
14	DTC Shahadara Terminal to Jyoti Nagar	2.1	16.17
15	Jyoti Nagar to Loni Road Crossing	1.3	18.16
16	Loni Road Crossing to Loni Road	1.1	14.47
	Total	21.1	20.73

**Table A4.27: Observed Journey Speed on Chilla Border to Bhagpat Road (S-14) in Up
Direction**

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Chilla to Mayur Place	1.5	13.39
2	Mayur Place to Mayur Vihar Phase-1	1.4	15.13
3	Mayur Vihar Phase-1 to Noida Mor	1.3	23.46
4	Noida Mor to Lalita Park	2.4	25.16
5	Lalita Park to Geeta Colony	1.8	22.12
6	Geeta Colony to Kailash Nagar	1.5	36.12
7	Kailash Nagar to Shastri Park	1.4	29.46
8	Shastri Park to Khajuri Khas	3.6	15.13
9	Khajuri Khas to Karwal Nagar	2.8	20.13
10	Karwal Nagar to Baghpat Road	1.1	25.13
	Total	18.8	23.52

Table A4.28: Observed Journey Speed on Bhagpat Road to Chilla Border (S-14) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Baghpat Road to Karwal Nagar	1.1	15.57
2	Karwal Nagar to Khajuri Khas	2.8	24.27
3	Khajuri Khas to Shastri Park	3.6	11.64
4	Shastri Park to Kailash Nagar	1.4	17.25
5	Kailash Nagar to Geeta Colony	1.5	23.42
6	Geeta Colony to Lalita Park	1.8	37.48
7	Lalita Park to Noida Mor	2.4	19.39
8	Noida Mor to Mayur Vihar Phase-1	1.3	22.50
9	Mayur Vihar Phase-1 to Mayur Place	1.4	31.02
10	Mayur Place to Chilla	1.5	20.16
Total		18.8	22.27

Table A4.29: Observed Journey Speed on Kashmere gate to Khanpur Junction (S-15) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Kashmere Gate to Kela Ghat Near Mori Gate	0.91	34.28
2	Kela Ghat Marg to Netaji Subhash Marg	0.36	39.22
3	Netaji Subhash Marg to Red fort Metro	0.45	7.87
4	Red fort Metro to Jama Masjid Metro	0.73	31.51
5	Jama Masjid Metro to Delhi Gate	1.06	19.50
6	Delhi Gate to Ram Charan Agarwal Chowk	1.40	21.38
7	RamCharan Agarwal Chowk to National Stadium	1.63	35.08
8	National Stadium to Oberoi Hotel	1.76	33.07
9	Oberoi Hotel to ISPAT Bhawan	0.50	35.52
10	ISPAT Bhawan to Pant Nagar	1.20	35.49
11	Pant Nagar to Moolchand Hospital	2.50	17.48
12	Moolchand Hospital to Sir fort	1.35	23.06
13	Sir fort to Panchsheel Enclave	1.50	6.82
14	Panchsheel Enclave to Sheikh Sarai	0.95	6.13
15	Sheikh Sarai to Ambedkar Nagar Terminal	2.11	13.39
Total		18.41	23.98

Table A4.30: Observed Journey Speed on Khanpur Junction to Kashmere gate (S-15) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Ambedkar Nagar Terminal to Sheikh Sarai	2.11	15.57
2	Sheikh Sarai to Panchsheel Enclave	0.95	24.27
3	Panchsheel Enclave to Sir fort	1.50	11.69
4	Sir fort to Moolchand Hospital	1.35	17.25
5	Moolchand Hospital to Pant Nagar	2.50	23.40
6	Pant Nagar to ISPAT Bhawan	1.20	37.42
7	ISPAT Bhawan to Oberoi Hospital	0.50	19.39
8	Oberoi Hospital to National Stadium	1.76	31.05
9	National Stadium to Ram Charan Agarwal Chowk	1.63	22.00
10	Ram Charan Agarwal Chowk to Delhi Gate	1.40	35.09
11	Delhi Gate to Jama Masjid Metro	1.06	33.07
12	Jama Masjid Metro to Red fort Metro	0.73	21.38
13	Red fort Metro to Netaji Subhash Marg	0.45	19.50
14	Netaji Subhash Marg to Kela Ghat Marg	0.36	32.51
15	Kela Ghat Marg to Kashmere Gate	0.91	39.41
Total		18.41	25.53

Table A4.31: Observed Journey Speed on Badarpur Border to Lado Sarai (S-16) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Badarpur Border to MCD Park	1.72	21.89
2	MCD Park to Aali Village Crossing	1.87	25.31
3	Aali Village Crossing to Suraj Kund Crossing	1.13	18.29
4	Suraj Kund Crossing to Lal Kuan Village	0.77	9.20
5	Lal Kuan Village to Okhla Mor Bus Stop	0.68	38.47
6	Okhla Mor Bus Stop to Tuglakabad Village	1.05	28.74
7	Tuglakabad Village to Hamdard Nagar	1.19	33.81
8	Hamdard Nagar to Ambedkar Nagar Terminal	2.08	12.90
9	Ambedkar Nagar Terminal to Saket Crossing	1.17	17.18
10	Saket Crossing to Dhaula Peer	1.80	27.68
11	Dhaula Peer to DDA Flat	1.10	14.61
12	DDA Flat to Lado Sarai Crossing	0.70	16.15
Total		15.26	22.01

Table A4.32: Observed Journey Speed on Lado Sarai to Badarpur Border (S-16) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Lado Sarai Crossing to DDA Flat	0.70	15.16
2	DDA Flat to Dhaula Peer	1.10	16.18
3	Dhula Peer to Saket Crossing	1.80	25.60
4	Saket Crossing to Ambedkar Nagar Terminal	1.17	20.80
5	Ambedkar Nagar Terminal to Hamdard Nagar	2.08	10.82
6	Hamdard Nagar to Tuglakabad Village	1.19	15.76
7	Tuglakabad Village to Okhla Mor Bus Stop	1.05	23.56
8	Okhla Mor Bus Stop to Lal Kuan Village	0.68	30.23
9	Lal Kuan Village to Suraj Kund Crossing	0.77	27.14
10	Suraj Kund Crossing to Aali Village Crossing	1.13	29.16
11	Aali Village Crossing to MCD Park	1.87	17.15
12	MCD Park to Badarpur Border	1.72	21.16
Total		15.26	21.06

Table A4.33: Observed Journey Speed on Outer Ring Road (Station Road to ISBT) (S-17) in Up Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	Dhula Kuan to Golf Sport	0.73	9.60
2	Golf Sport to Khimya Park	2.50	21.61
3	Khimya Park to Kirby Place	0.78	25.62
4	Kirby Place to Lajwanti Garden	2.25	33.22
5	Lajwanti Garden to Hari Nagar Depot	1.28	5.70
6	Hari Nagar Depo to Tilak Nagar	1.46	14.98
7	Tilak Nagar to Janakpuri Bus Stop	1.94	20.72
8	Janakpuri Bus Stop to CRPF	2.15	55.42
9	CRPF to Paschim Vihar	2.68	53.28
10	Paschim Vihar to Peera Garhi Chowk	1.17	28.04
11	Peera Garhi Chowk to B Block Mangolpuri	1.01	42.47
12	B Block Mangolpuri to Deepali Chowk	2.70	30.78
13	Deepali Chowk to Madhuban Chowk	1.26	12.08
14	Madhuban Chowk to Prashant Vihar	1.69	47.26
15	Prashant Vihar to Mukarba Chowk	2.45	43.86
16	Mukarba Chowk to Mukundpur Crossing	2.88	48.12
17	Mukundpur Crossing to Burari Crossing	1.44	48.77
18	Burari Crossing to Gandhi Vihar	1.91	34.61
19	Gandhi Vihar to Majnu Ka Tila	3.37	27.11
20	Majnu Ka Tila to ISBT	4	31.47
Total		39.65	31.65

Table A4.34: Observed Journey Speed on Outer Ring Road (ISBT to Station Road) (S-17) in Down Direction

S. No	Name of the Section	Distance (Km)	Avg. Speed (Km/Hr)
1	ISBT TO Majnu KA Tila	4	18.45
2	Majnu Ka Tila to Gandhi Vihar	3.37	37.68
3	Gandhi Vihar to Burari Crossing	1.91	50.29
4	Burari Crossing to Mukundpur Crossing	1.44	46.30
5	Mukundpur Crossing to Mukarba Chowk	2.88	22.08
6	Mukarba Chowk to Prashant Vihar	2.45	48.06
7	Prashant Vihar to Madhuban Chowk	1.69	26.05
8	Madhuban Chowk to Deepali Chowk	1.26	39.97
9	Deepali Chowk to B Block Mangolpuri	2.70	18.07
10	B Block Mangolpuri to Peera Garhi Chowk	1.01	21.70
11	Peera Garhi Chowk to Paschim Vihar	1.17	22.80
12	Paschim Vihar to CRPF	2.68	47.75
13	CRPF to Janakpuri Bus Stop	2.15	37.52
14	Janakpuri Bus Stop to Tilak Nagar	1.94	14.42
15	Tilak Nagar to Hari Nagar Depo	1.46	22.50
16	Hari Nagar Depot to Lajwanti Garden	1.28	40.62
17	Lajwanti Garden to Kirby Place	2.25	30.19
18	Kirby Place to Khimya Park	0.78	15.98
19	Khimya Park to Golf Sport	2.50	13.14
20	Golf Sport to Dhaula Kuan	0.73	14.98
	Total	39.65	29.42

Appendix 5



CSIR-Central Road Research Institute (CRRRI), New Delhi
(in association with TNO, Netherlands and TU Delft, Netherlands)



TNO
TU Delft

MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)

Research Project Funded by



THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Proforma V (1)

Classified Traffic Volume Count Survey (Outer Cordon/ Mid-Block)


Road/ Intersection Name: _____ Name of the Location _____

Date: _____ Time Period: From _____ To _____ Weather: _____

Direction: From _____ To _____

Name of the Enumerator: _____

Time of the Day	Two Wheelers (TW)	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycles (CYC)	Cycle Rickshaws and Other (CY-SMV)
____ : ____ : 00							
to							
____ : 15							
to							
____ : 30							
to							
____ : 30							
to							
____ : 45							
to							
____ : 00							



CSIR-Central Road Research Institute (CRRJ), New Delhi
(in association with TNO, Netherlands and TU Delft, Netherlands)



TNO
TU Delft

MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)

Research Project Funded by



THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Proforma V (2)

Classified Traffic Volume Count Survey (Outer Cordon/ Mid-Block)

Road/ Intersection Name: _____ Name of the Location _____

Date: _____ Time Period: From _____ To _____ Weather: _____

Direction: From _____ To _____

Name of the Enumerator: _____

Time of the Day	Small Cars (<1400 cc)* (CS)	Big Cars** / SUV# (CB)	Autos (A)	Buses (B)	Mini Buses (MB)
_____ : 00					
to					
_____ : 15					
to					
_____ : 30					
to					
_____ : 45					
to					
_____ : 00					

* - Maruti 800, Omni, Zen, Wagon R, Alto, Swift, i-10, Indica, Fiat Palio, Matiz, Spark etc (up to 1400 cc)
 ** - Ambassador, Maruti Esteem, Hyundai Accent, Ford Ikon, Toyota, Mitsubishi Lancer, Logan, Tata Indigo, Honda City, BSW, Mercedes Benz etc.
 # - Sports Utility Vehicle (SUV) like Mahindra Jeep, Standard, Marauder Van, Sumo, Safari, Tata, Daihatsu, Scorpio etc.

Appendix 6

Table A6.1: Classified Traffic Volume at Badarpur Border

Road Name: Mathura Road NH-2 Location: Badarpur Border Date: 07.10.2017 - 08.10.2017
Outer Cordon 1

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1664	1097	780	150	89	1591	450	138	42	15	713	251	6016	964	6980	5.9%	7327
09:00-10:00	2192	1328	1214	71	45	1971	239	171	31	39	503	259	7301	762	8063	6.8%	8282
10:00-11:00	1793	959	1071	69	25	1772	228	127	48	34	217	118	6126	335	6461	5.5%	6738
11:00-12:00	1839	1165	846	42	13	1644	289	132	145	61	100	118	6176	218	6394	5.4%	6972
12:00-13:00	1526	966	883	72	23	1431	201	116	168	95	98	167	5481	265	5746	4.8%	6593
13:00-14:00	1539	793	789	70	38	1549	304	121	207	109	64	141	5519	205	5724	4.8%	6719
14:00-15:00	1484	632	821	72	37	1692	267	162	215	129	86	166	5511	252	5763	4.9%	6821
15:00-16:00	1376	745	732	71	33	1442	205	157	166	89	85	197	5016	282	5298	4.5%	6139
16:00-17:00	1128	579	852	77	32	1468	232	195	146	86	128	205	4795	333	5128	4.3%	5962
17:00-18:00	1754	1064	1039	76	32	1654	235	191	70	46	185	199	6161	384	6545	5.5%	7044
18:00-19:00	2090	1326	1036	128	33	1689	207	195	51	32	364	278	6787	642	7429	6.3%	7875
19:00-20:00	1749	1002	1065	106	42	1548	119	146	37	12	354	269	5816	623	6439	5.4%	6723
20:00-21:00	1641	668	921	82	27	1205	72	51	63	26	341	160	4756	501	5257	4.4%	5519
21:00-22:00	1476	595	937	83	21	1371	79	68	65	45	186	91	4740	277	5017	4.2%	5362
22:00-23:00	1098	501	587	66	14	1011	102	150	301	327	66	41	4157	107	4264	3.6%	6135
23:00-24:00	827	393	281	33	23	674	114	245	400	668	49	12	3658	61	3719	3.1%	6995
00:00-01:00	686	250	166	47	15	291	66	224	469	717	13	6	2931	19	2950	2.5%	6608
01:00-02:00	521	195	108	35	13	109	37	209	534	754	14	3	2515	17	2532	2.1%	6434
02:00-03:00	534	207	67	37	6	60	47	173	636	775	1	0	2542	1	2543	2.1%	6715
03:00-04:00	509	185	76	33	12	54	39	163	526	718	2	0	2315	2	2317	2.0%	6062
04:00-05:00	559	227	111	33	15	75	42	147	506	687	7	16	2402	23	2425	2.0%	6025
05:00-06:00	675	261	249	70	34	201	42	166	267	447	37	27	2412	64	2476	2.1%	4847
06:00-07:00	953	358	530	163	54	689	74	166	221	273	124	75	3481	199	3680	3.1%	5487
07:00-08:00	1691	720	674	236	87	1189	63	141	55	37	386	111	4893	497	5390	4.5%	5991
Total	31304	16216	15825	1922	763	26380	3753	3754	5369	6221	4123	2910	111507	7033	118540	100.0%	155376
Percentage	26.4%	13.7%	13.3%	1.6%	0.6%	22.3%	3.2%	3.2%	4.5%	5.2%	3.5%	2.5%	94.1%	5.9%	100.0%		

Peak Volume= 8063
Peak Time= 09:00-10:00

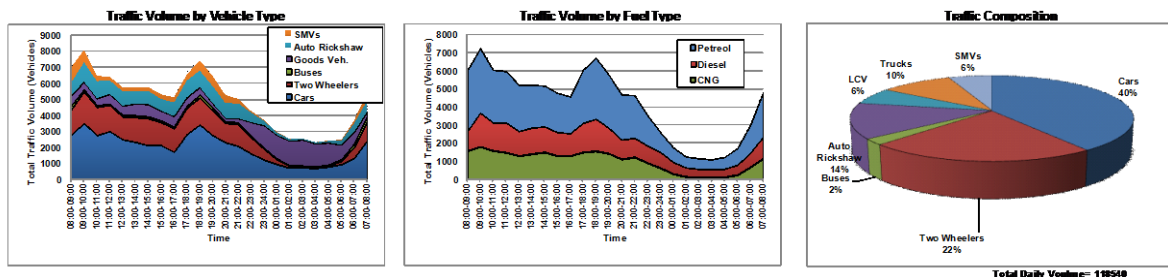


Figure A6.1: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Badarpur Border

Table A6.2: Classified Traffic Volume at Rajokri Border

Road Name: **Delhi - Gurgaon Expressway** Location: **Rajokri Border** Date: **26.07.2017 - 27.07.2017**
 Outer Cordon **OC-03**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SM V)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	10872	1462	40	152	64	3047	51	73	32	18	102	0	15811	102	15913	4.5%	15665
09:00-10:00	12043	2016	41	183	77	3840	71	86	12	6	81	0	18375	81	18456	5.2%	18030
10:00-11:00	10715	1916	48	154	54	3888	60	106	65	11	64	0	17017	64	17081	4.8%	16700
11:00-12:00	12291	1743	44	143	53	2877	166	215	157	32	26	0	17721	26	17747	5.0%	17979
12:00-13:00	11417	2062	29	94	23	3379	225	247	130	24	6	0	17630	6	17636	5.0%	17585
13:00-14:00	14797	2053	48	99	9	2692	284	313	118	67	1	0	20480	1	20481	5.8%	20793
14:00-15:00	11540	2289	66	103	12	3197	329	321	178	74	30	0	18109	30	18139	5.1%	18496
15:00-16:00	11611	2446	38	137	18	4417	318	241	122	63	7	0	19411	7	19418	5.5%	19354
16:00-17:00	14868	2543	39	126	49	3166	262	215	149	27	9	0	21444	9	21453	6.1%	21597
17:00-18:00	14140	2428	28	293	98	4646	117	93	32	8	13	0	21883	13	21896	6.2%	21615
18:00-19:00	15354	2236	20	234	86	5763	42	39	15	0	23	0	23789	23	23812	6.7%	22988
19:00-20:00	11456	2328	22	145	43	8085	52	41	10	6	29	0	22188	29	22217	6.3%	20606
20:00-21:00	12696	2489	23	102	17	4016	74	59	9	15	73	0	19500	73	19573	5.5%	18895
21:00-22:00	10473	1945	26	73	4	2979	75	117	25	24	93	0	15741	93	15834	4.5%	15428
22:00-23:00	9291	1652	18	37	2	1705	93	202	106	185	128	0	13291	128	13419	3.8%	14015
23:00-24:00	6520	1470	2	31	7	693	125	240	347	428	76	0	9863	76	9939	2.8%	12172
00:00-01:00	4742	1540	9	39	2	611	93	259	381	478	53	0	8154	53	8207	2.3%	10721
01:00-02:00	3096	1243	13	24	2	504	62	296	333	385	29	0	5958	29	5987	1.7%	8092
02:00-03:00	2985	1315	28	13	7	353	87	282	327	385	4	0	5782	4	5786	1.6%	7920
03:00-04:00	1601	834	6	25	18	362	67	270	254	299	0	0	3736	0	3736	1.1%	5438
04:00-05:00	2435	1387	6	76	12	597	52	222	326	233	8	0	5346	8	5354	1.5%	6970
05:00-06:00	5009	1892	14	73	12	615	34	225	303	143	52	0	8320	52	8372	2.4%	9589
06:00-07:00	7205	2191	18	96	33	862	55	123	151	45	159	0	10779	159	10938	3.1%	11420
07:00-08:00	7957	2977	16	147	52	1059	44	84	34	10	252	0	12380	252	12632	3.6%	12757
Total	225114	46457	642	2599	754	63353	2838	4369	3616	2966	1318	0	352708	1318	354026	100.0%	364826
Percentage	63.6%	13.1%	0.2%	0.7%	0.2%	17.9%	0.8%	1.2%	1.0%	0.8%	0.4%	0.0%	99.6%	0.4%	100.0%		

Peak Volume= **23812**
 Peak Time= **18:00-19:00**

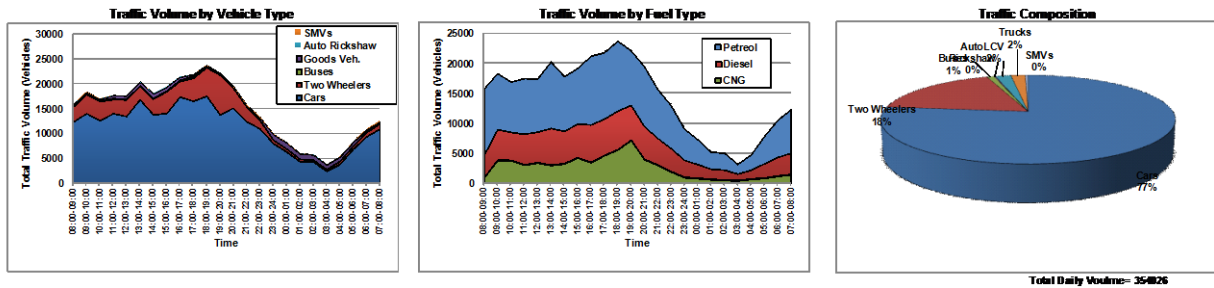


Figure A6.2: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajokri Border

Table A6.3: Classified Traffic Volume at Ayanagar Border

Road Name: Mehrauli - Gurgaon Road Location: Arjun Garh (Ayanagar Border) Date: 18.07.2017 - 19.07.2017
 Outer Cordon OC-02

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SM V)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1410	900	2	37	23	991	0	3	0	0	40	2	3366	42	3408	4.1%	3240
09:00-10:00	2216	1161	5	16	11	1606	2	5	6	2	56	5	5030	61	5091	6.2%	4731
10:00-11:00	2576	764	14	20	18	1580	12	1	0	0	27	6	4985	33	5018	6.1%	4680
11:00-12:00	2105	660	2	7	6	1052	8	0	5	13	22	15	3858	37	3895	4.7%	3708
12:00-13:00	1830	717	5	17	6	1061	29	15	18	2	12	3	3700	15	3715	4.5%	3551
13:00-14:00	2180	783	5	16	9	1185	27	1	15	13	13	6	4234	19	4253	5.2%	4085
14:00-15:00	2117	813	2	21	6	1054	62	0	7	25	17	6	4107	23	4130	5.0%	4042
15:00-16:00	2060	779	5	29	11	769	60	0	15	4	9	12	3732	21	3753	4.6%	3706
16:00-17:00	2236	804	4	18	24	799	45	0	12	8	18	5	3950	23	3973	4.8%	3902
17:00-18:00	2870	772	2	34	21	1580	5	0	0	3	42	10	5287	52	5339	6.5%	5030
18:00-19:00	3132	839	4	38	37	1399	6	0	1	0	51	1	5456	52	5508	6.7%	5252
19:00-20:00	2730	894	1	32	14	1658	2	0	0	0	51	9	5331	60	5391	6.6%	5035
20:00-21:00	2642	561	0	2	2	1342	2	0	0	0	98	32	4551	130	4681	5.7%	4320
21:00-22:00	2195	596	1	2	0	1338	3	3	0	0	65	12	4138	77	4215	5.1%	3861
22:00-23:00	1242	298	0	1	2	988	14	0	1	1	47	20	2547	67	2614	3.2%	2370
23:00-24:00	1365	236	0	0	0	1179	22	6	5	17	6	11	2830	17	2847	3.5%	2638
00:00-01:00	912	463	7	0	1	790	8	21	4	18	6	2	2224	8	2232	2.7%	2120
01:00-02:00	689	505	8	0	0	442	5	32	5	23	3	2	1709	5	1714	2.1%	1714
02:00-03:00	334	354	1	0	0	438	9	11	8	29	3	3	1184	6	1190	1.4%	1208
03:00-04:00	299	336	1	0	0	416	0	12	12	25	9	6	1101	15	1116	1.4%	1128
04:00-05:00	317	383	2	0	0	487	0	23	8	19	16	4	1239	20	1259	1.5%	1226
05:00-06:00	544	427	2	9	3	694	12	4	4	8	25	13	1707	38	1745	2.1%	1631
06:00-07:00	644	656	2	23	4	767	3	15	0	15	36	6	2129	42	2171	2.6%	2076
07:00-08:00	1043	967	3	37	21	788	21	11	2	15	46	25	2908	71	2979	3.6%	2940
Total	39688	15668	78	359	219	24403	357	163	128	240	718	216	81303	934	82237	100.0%	78194
Percentage	48.3%	19.1%	0.1%	0.4%	0.3%	29.7%	0.4%	0.2%	0.2%	0.3%	0.9%	0.3%	98.9%	1.1%	100.0%		

Peak Volume= 5508
 Peak Time=18:00-19:00

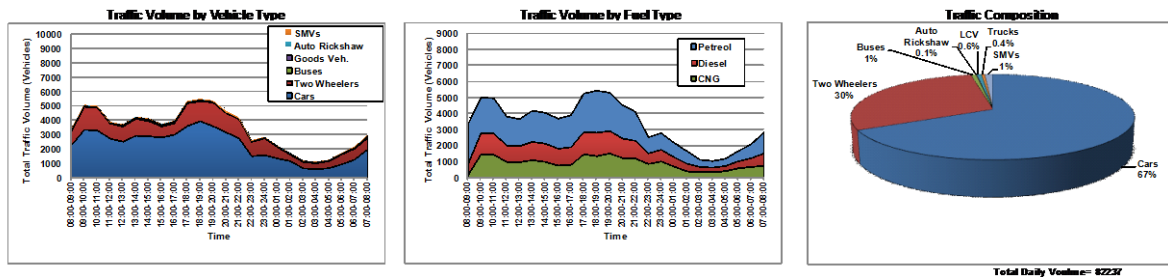


Figure A6.3: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Ayanagar Border

Table A6.4: Classified Traffic Volume at Tikri Border

Road Name: Bahadurgarh Road NH-10
Outer Cordon OC-04

Location: Tikri Border

Date: 19.07.2017 - 20.07.2017

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SM V)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1496	577	232	74	14	1442	99	83	32	9	282	33	4058	315	4373	7.9%	4283
09:00-10:00	1419	429	182	61	18	1328	87	58	32	19	188	35	3633	223	3856	7.0%	3827
10:00-11:00	1749	400	140	57	4	1347	80	109	35	26	98	28	3947	126	4073	7.4%	4103
11:00-12:00	1115	349	151	45	7	1256	70	126	37	13	41	12	3169	53	3222	5.8%	3238
12:00-13:00	1094	323	151	46	5	1360	67	77	32	19	68	32	3174	100	3274	5.9%	3246
13:00-14:00	913	225	127	51	10	1139	106	155	29	16	67	34	2771	101	2872	5.2%	2953
14:00-15:00	790	221	119	44	11	943	83	163	18	18	33	23	2410	56	2466	4.5%	2570
15:00-16:00	778	191	146	59	9	1132	67	134	23	17	21	22	2556	43	2599	4.7%	2679
16:00-17:00	835	279	94	51	3	905	77	87	28	15	25	6	2374	31	2405	4.4%	2484
17:00-18:00	1270	306	121	51	5	748	104	147	38	20	127	12	2810	139	2949	5.3%	3107
18:00-19:00	1232	310	76	49	6	833	73	168	26	10	132	16	2783	148	2931	5.3%	2991
19:00-20:00	1157	200	117	50	4	1227	63	107	24	12	155	26	2961	181	3142	5.7%	3073
20:00-21:00	1321	189	74	52	1	801	76	64	27	38	108	33	2643	141	2784	5.1%	2923
21:00-22:00	957	136	89	42	6	579	76	45	42	33	63	37	2005	100	2105	3.8%	2315
22:00-23:00	884	113	47	26	3	145	47	51	55	68	24	6	1439	30	1469	2.7%	1885
23:00-24:00	701	79	19	26	0	66	39	72	96	121	5	13	1219	18	1237	2.2%	1951
00:00-01:00	243	29	9	7	0	49	28	52	109	98	4	4	624	8	632	1.1%	1237
01:00-02:00	133	26	5	11	0	53	13	41	76	114	0	14	472	14	486	0.9%	1081
02:00-03:00	60	21	2	7	0	47	4	51	89	113	0	12	394	12	406	0.7%	1016
03:00-04:00	75	20	8	10	0	36	14	59	80	68	0	10	370	10	380	0.7%	832
04:00-05:00	177	36	11	12	0	68	27	72	68	57	6	3	528	9	537	1.0%	930
05:00-06:00	350	157	43	31	2	359	51	73	72	57	49	5	1195	54	1249	2.3%	1615
06:00-07:00	612	301	109	38	8	570	68	81	51	51	133	16	1889	149	2038	3.7%	2298
07:00-08:00	1113	470	209	74	11	1224	123	101	71	46	182	19	3442	201	3643	6.6%	3871
Total	20474	5387	2281	974	127	17657	1542	2176	1190	1058	1811	451	52866	2262	55128	100.0%	60507
Percentage	37.1%	9.8%	4.1%	1.8%	0.2%	32.0%	2.8%	3.9%	2.2%	1.9%	3.3%	0.8%	95.9%	4.1%	100.0%		

Peak Volume= 4373
Peak Time= 08:00-09:00

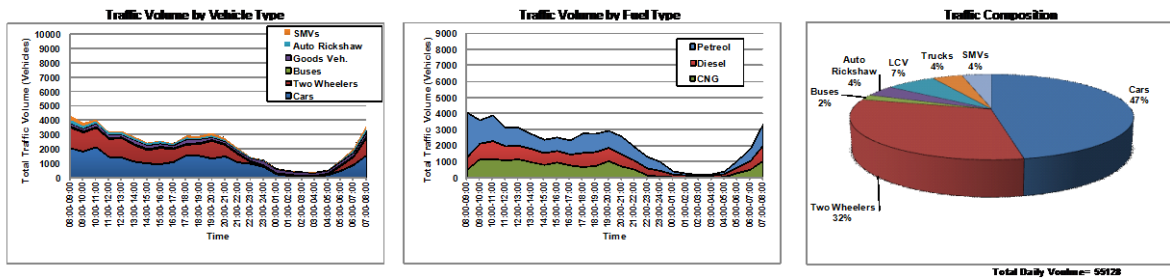


Figure A6.4: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Tikri Border

Table A6.5: Classified Traffic Volume at Singhu Border

Road Name: NH-1 Location: Singhu Border Date: 04.07.2017 - 05.07.2017
 Outer Cordon OC-05

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1356	1134	72	113	55	801	243	148	27	28	34	35	3977	69	4046	5.3%	4489
09:00-10:00	1446	1023	56	112	24	817	257	163	32	23	36	40	3953	76	4029	5.3%	4440
10:00-11:00	1357	801	66	87	27	794	201	151	17	33	31	30	3534	61	3595	4.7%	3936
11:00-12:00	1011	694	58	39	30	679	224	80	12	30	35	29	2857	64	2921	3.8%	3149
12:00-13:00	881	609	194	46	31	664	185	60	15	33	41	43	2718	84	2802	3.7%	3067
13:00-14:00	912	690	85	28	22	745	170	77	17	37	35	46	2783	81	2864	3.8%	3065
14:00-15:00	1016	701	111	34	17	758	88	54	18	37	37	41	2834	78	2912	3.8%	3068
15:00-16:00	1136	647	44	38	25	635	88	61	32	31	28	49	2737	77	2814	3.7%	3023
16:00-17:00	1458	998	81	29	15	662	94	82	25	34	43	56	3478	99	3577	4.7%	3764
17:00-18:00	1265	838	69	34	23	748	101	46	18	32	40	52	3174	92	3266	4.3%	3411
18:00-19:00	1295	988	85	29	28	715	67	39	15	18	40	33	3279	73	3352	4.4%	3419
19:00-20:00	1064	880	44	35	26	686	79	83	46	55	75	36	2998	111	3109	4.1%	3388
20:00-21:00	1055	524	40	19	11	1000	79	126	101	60	81	15	3015	96	3111	4.1%	3400
21:00-22:00	1060	794	53	26	16	717	100	158	104	35	17	5	3063	22	3085	4.1%	3438
22:00-23:00	1015	974	27	20	14	315	168	192	160	86	5	3	2971	8	2979	3.9%	3760
23:00-24:00	938	755	25	21	10	464	167	203	238	56	0	13	2877	13	2890	3.8%	3695
00:00-01:00	740	754	28	26	15	477	128	146	151	114	0	12	2579	12	2591	3.4%	3388
01:00-02:00	845	446	23	25	16	202	117	234	243	216	0	23	2367	23	2390	3.1%	3839
02:00-03:00	905	526	27	16	16	152	107	266	253	245	0	23	2513	23	2536	3.3%	4113
03:00-04:00	774	496	30	12	20	169	39	100	288	280	2	67	2208	69	2277	3.0%	3943
04:00-05:00	790	685	50	19	11	205	97	113	266	271	14	34	2507	48	2555	3.4%	4158
05:00-06:00	997	804	62	22	15	258	114	106	235	285	54	86	2898	140	3038	4.0%	4638
06:00-07:00	1190	1136	68	78	30	485	205	168	225	1005	60	72	4590	132	4722	6.2%	8960
07:00-08:00	1250	1340	89	99	28	681	186	229	274	275	65	84	4451	149	4600	6.0%	6401
Total	25756	19237	1487	1007	525	13829	3304	3085	2812	3319	773	927	74361	1700	76061	100.0%	95952
Percentage	33.9%	25.3%	2.0%	1.3%	0.7%	18.2%	4.3%	4.1%	3.7%	4.4%	1.0%	1.2%	97.8%	2.2%	100.0%		

Peak Volume= 4722
 Peak Time= 06:00-07:00

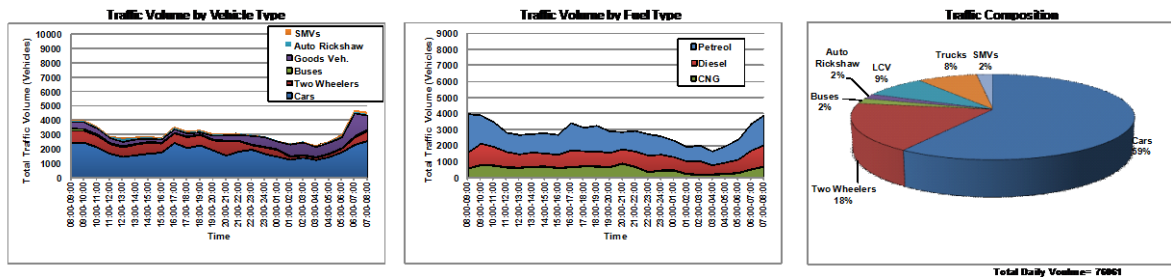


Figure A6.5: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Singhu Border

Table A6.6: Classified Traffic Volume at Loni Border

Road Name: Saharanpur road
Outer Cordon OC-06

Location: Loni Border

Date: 24.07.2017 - 25.07.2017

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	590	67	889	25	8	2036	11	45	14	0	383	78	3685	461	4146	5.8%	3776
09:00-10:00	581	61	1553	22	9	1901	8	45	7	0	497	74	4187	571	4758	6.6%	4475
10:00-11:00	440	48	1471	19	9	1911	10	32	5	0	324	57	3945	381	4326	6.0%	4087
11:00-12:00	423	56	1423	22	6	1823	3	29	8	2	179	95	3795	274	4069	5.7%	3945
12:00-13:00	449	34	1320	15	12	1909	7	38	10	0	224	158	3794	382	4176	5.8%	4014
13:00-14:00	310	61	985	9	10	2104	32	31	4	3	174	225	3549	399	3948	5.5%	3723
14:00-15:00	284	59	1029	23	18	1763	19	17	0	0	121	200	3212	321	3533	4.9%	3420
15:00-16:00	316	66	1098	24	13	1780	15	19	0	0	108	143	3331	251	3582	5.0%	3452
16:00-17:00	330	59	1187	10	14	1741	27	29	4	0	110	169	3401	279	3680	5.1%	3582
17:00-18:00	366	72	1570	11	10	2238	16	21	3	2	199	222	4309	421	4730	6.6%	4560
18:00-19:00	502	97	1641	13	9	2280	9	12	1	0	374	321	4564	695	5259	7.3%	5038
19:00-20:00	471	97	2463	14	7	1877	1	0	1	1	278	235	4931	513	5444	7.6%	5485
20:00-21:00	365	89	1483	10	10	1458	14	14	5	1	462	118	3449	580	4029	5.6%	3847
21:00-22:00	278	71	985	11	5	1585	22	22	20	1	587	73	2980	660	3640	5.1%	3272
22:00-23:00	218	69	569	7	1	1348	12	19	53	4	260	38	2300	298	2598	3.6%	2414
23:00-24:00	185	72	284	5	0	816	3	33	65	16	43	17	1479	60	1539	2.2%	1593
00:00-01:00	95	44	67	2	2	313	3	23	44	8	13	8	601	21	622	0.9%	690
01:00-02:00	66	36	43	5	0	113	3	32	45	22	5	6	365	11	376	0.5%	551
02:00-03:00	41	16	18	6	1	104	0	35	49	25	3	3	295	6	301	0.4%	485
03:00-04:00	34	20	28	1	0	59	6	22	61	10	2	68	241	70	311	0.4%	508
04:00-05:00	60	38	65	14	3	164	6	20	54	7	22	37	431	59	490	0.7%	646
05:00-06:00	223	39	158	21	6	326	6	37	43	5	43	12	864	55	919	1.3%	1027
06:00-07:00	349	48	308	28	18	778	9	37	36	9	81	33	1620	114	1734	2.4%	1778
07:00-08:00	445	78	753	58	12	1673	12	52	24	7	174	66	3114	240	3354	4.7%	3265
Total	7421	1397	21370	375	183	32100	254	664	555	123	4666	2456	64442	7122	71564	100.0%	69641
Percentage	10.4%	2.0%	29.9%	0.5%	0.3%	44.9%	0.4%	0.9%	0.8%	0.2%	6.5%	3.4%	90.0%	10.0%	100.0%		

Peak Volume= 5444
Peak Time=19:00-20:00

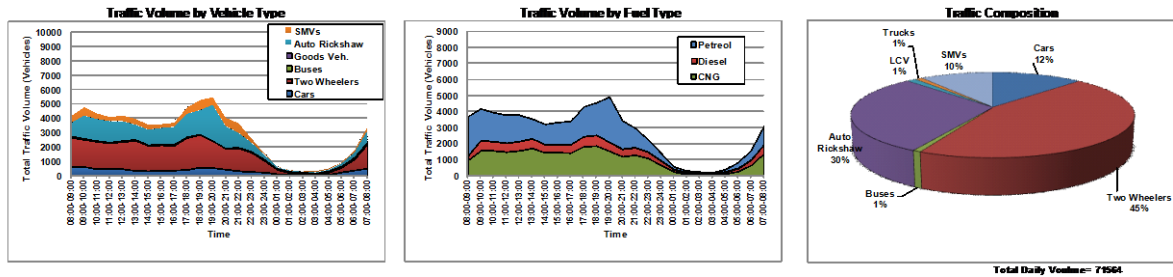


Figure A6.6: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Loni Border

Table A6.7: Classified Traffic Volume at Apsara Border

Road Name: **GT Road** Location: **Apsara Border (Dilshad Garden)** Date: **25.07.2017 - 26.07.2017**
 Outer Cordon **OC-07**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	680	146	81	88	15	790	24	18	0	0	72	91	1842	163	2005	2.4%	2045
09:00-10:00	2474	315	251	200	13	1752	72	70	8	3	82	190	5158	272	5430	6.4%	5607
10:00-11:00	2553	329	210	140	7	1851	73	104	13	2	95	126	5282	221	5503	6.5%	5506
11:00-12:00	2588	243	223	141	7	1667	146	92	2	2	51	138	5111	189	5300	6.2%	5390
12:00-13:00	2271	203	208	158	4	1721	122	84	1	1	80	143	4773	223	4996	5.9%	5067
13:00-14:00	2281	242	184	158	5	2166	105	124	3	2	73	81	5270	154	5424	6.4%	5372
14:00-15:00	1741	217	161	136	5	2119	102	138	1	1	39	108	4621	147	4768	5.6%	4707
15:00-16:00	2288	216	253	172	6	2054	134	68	3	0	62	118	5194	180	5374	6.3%	5396
16:00-17:00	2386	236	270	197	6	2438	166	103	4	0	91	142	5806	233	6039	7.1%	6052
17:00-18:00	2231	230	201	208	13	2697	142	97	1	0	110	127	5820	237	6057	7.1%	5982
18:00-19:00	2497	231	228	157	8	2410	88	11	0	0	71	176	5630	247	5877	6.9%	5744
19:00-20:00	2471	239	353	190	9	2776	105	21	6	0	148	168	6170	316	6486	7.6%	6337
20:00-21:00	1842	198	226	120	4	1773	87	15	12	3	65	83	4080	148	4228	5.0%	4168
21:00-22:00	1176	298	229	93	12	1199	63	22	41	5	31	51	3138	82	3220	3.8%	3316
22:00-23:00	658	337	233	106	6	746	26	48	140	50	3	7	2350	10	2360	2.8%	2932
23:00-24:00	602	275	159	67	4	441	18	43	97	79	0	3	1785	3	1788	2.1%	2350
00:00-01:00	345	64	110	38	1	97	23	70	112	112	1	1	972	2	974	1.1%	1711
01:00-02:00	249	39	99	24	2	36	6	52	119	52	1	4	678	5	683	0.8%	1194
02:00-03:00	147	34	74	29	0	33	4	54	86	58	4	2	519	6	525	0.6%	993
03:00-04:00	115	29	164	55	1	29	5	39	71	77	0	0	585	0	585	0.7%	1155
04:00-05:00	136	50	199	43	3	76	1	50	115	72	1	6	745	7	752	0.9%	1372
05:00-06:00	345	70	254	79	9	273	23	74	118	29	17	7	1274	24	1298	1.5%	1829
06:00-07:00	666	106	250	117	30	438	23	59	109	53	10	14	1851	24	1875	2.2%	2526
07:00-08:00	1609	206	260	245	77	534	45	95	123	24	48	31	3218	79	3297	3.9%	4174
Total	34151	4553	4880	2961	247	30116	1603	1551	1185	625	1155	1817	81872	2972	84844	100.0%	90926
Percentage	40.3%	5.4%	5.8%	3.5%	0.3%	35.5%	1.9%	1.8%	1.4%	0.7%	1.4%	2.1%	96.5%	3.5%	100.0%		

Peak Volume= **6486**
 Peak Time= **19:00-20:00**

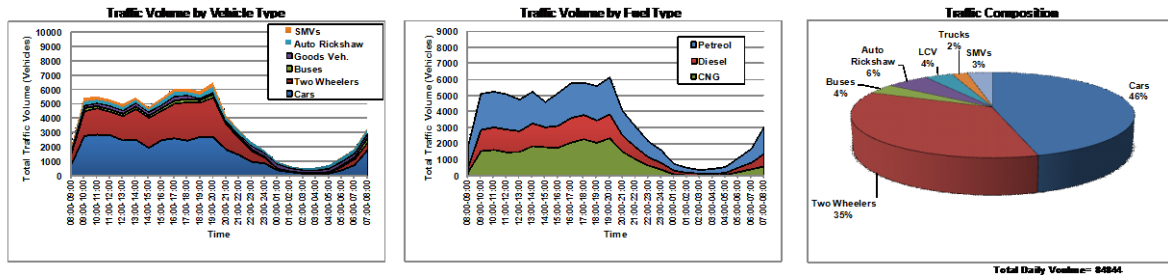


Figure A6.7: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Apsara Border

Table A6.8: Classified Traffic Volume at Ghazipur Border

Road Name: Ghazipur Road (NH-24 Bypass) Location: Ghazipur Border Date: 14.07.2017 - 15.07.2017
 Outer Cordon OC-08

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CYC)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	2934	2239	614	219	69	2173	391	106	304	52	401	227	9101	628	9729	6.0%	10767
09:00-10:00	2739	2015	701	143	23	2246	475	132	148	37	446	235	8659	681	9340	5.7%	9851
10:00-11:00	2576	2149	589	153	32	2131	350	129	196	76	326	246	8381	572	8953	5.5%	9734
11:00-12:00	2512	2348	539	127	36	2096	379	67	128	49	246	148	8281	394	8675	5.3%	9150
12:00-13:00	2016	1813	571	134	21	2049	321	134	179	100	189	191	7338	380	7718	4.7%	8545
13:00-14:00	2154	1877	530	100	21	1885	284	156	146	79	141	182	7232	323	7555	4.6%	8220
14:00-15:00	2020	1908	499	133	24	1770	348	138	82	77	124	91	6999	215	7214	4.4%	7821
15:00-16:00	1760	1198	330	109	14	1644	262	78	56	24	54	66	5475	120	5595	3.4%	5854
16:00-17:00	1981	1254	386	102	14	1530	324	63	42	67	52	38	5763	90	5853	3.6%	6271
17:00-18:00	2124	1393	404	118	17	1475	337	51	46	24	185	51	5989	236	6225	3.8%	6493
18:00-19:00	2526	1442	573	184	15	1590	320	105	65	33	282	131	6853	413	7266	4.5%	7749
19:00-20:00	2161	1456	547	272	18	1521	316	50	22	22	190	60	6385	250	6635	4.1%	7165
20:00-21:00	1940	1375	426	184	35	1206	242	140	103	67	151	80	5718	231	5949	3.6%	6732
21:00-22:00	2060	1101	362	76	38	1270	274	106	100	107	110	28	5494	138	5632	3.5%	6300
22:00-23:00	2356	1129	276	55	39	1057	222	64	140	223	105	41	5561	146	5707	3.5%	6818
23:00-24:00	1883	1011	193	87	33	985	176	63	337	257	46	40	5025	86	5111	3.1%	6800
00:00-01:00	1891	757	176	36	22	648	182	105	453	450	43	36	4720	79	4799	2.9%	7387
01:00-02:00	1832	934	123	25	18	770	204	78	544	516	44	31	5044	75	5119	3.1%	8048
02:00-03:00	1740	734	90	81	14	737	202	105	481	493	61	43	4677	104	4781	2.9%	7623
03:00-04:00	1748	784	133	105	18	748	215	92	525	543	87	47	4911	134	5045	3.1%	8197
04:00-05:00	1857	1134	169	204	40	976	204	63	499	393	112	113	5539	225	5764	3.5%	8509
05:00-06:00	2018	1245	301	203	38	1374	181	135	442	602	193	266	6539	459	6998	4.3%	10344
06:00-07:00	2016	1533	453	257	46	1705	225	175	419	549	292	285	7378	577	7955	4.9%	11135
07:00-08:00	2690	1866	582	283	161	1900	254	139	475	548	375	328	8898	703	9601	5.9%	13010
Total	51534	34695	9567	3390	806	35486	6688	2474	5932	5388	4255	3004	155960	7259	163219	100.0%	198524
Percentage	31.6%	21.3%	5.9%	2.1%	0.5%	21.7%	4.1%	1.5%	3.6%	3.3%	2.6%	1.8%	95.6%	4.4%	100.0%		

Peak Volume= 9729
 Peak Time= 08:00-09:00

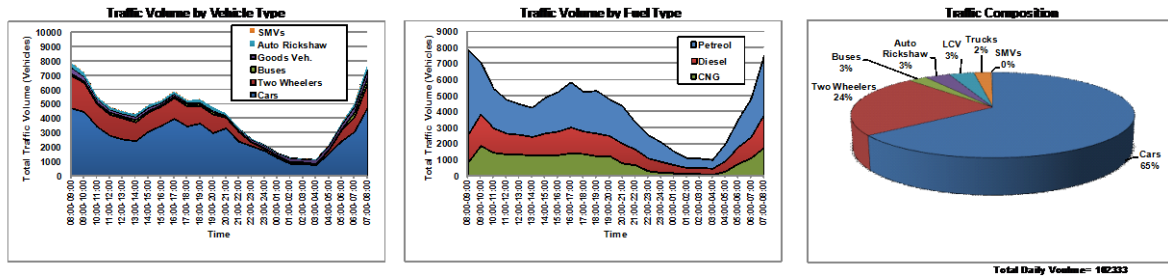


Figure A6.8: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Ghazipur Border

Table A6.9: Classified Traffic Volume at Chilla Border

Road Name: **Mayur Vihar - Noida Link Road** Location: **Chilla Boarder** Date: **12.07.2017 - 13.07.2017**
 Outer Cordon **OC-09**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SMV)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	3519	1202	313	112	17	2276	156	110	171	6	14	9	7882	23	7905	7.7%	8133
09:00-10:00	3374	1092	257	81	18	2022	129	101	113	3	7	5	7190	12	7202	7.0%	7278
10:00-11:00	2563	866	161	78	11	1571	72	107	95	10	5	9	5534	14	5548	5.4%	5671
11:00-12:00	2091	711	176	116	34	1465	74	82	45	3	4	12	4797	16	4813	4.7%	4930
12:00-13:00	1912	632	157	95	30	1472	66	103	24	11	3	10	4502	13	4515	4.4%	4573
13:00-14:00	1838	588	160	85	84	1316	76	96	45	9	3	11	4297	14	4311	4.2%	4480
14:00-15:00	2169	925	171	59	42	1337	85	96	50	5	4	8	4939	12	4951	4.8%	5021
15:00-16:00	2648	860	137	48	40	1346	88	58	23	4	3	9	5252	12	5264	5.1%	5227
16:00-17:00	3428	556	161	69	55	1450	63	53	44	5	15	9	5884	24	5908	5.8%	5931
17:00-18:00	3067	388	130	84	70	1400	60	25	35	2	12	3	5261	15	5276	5.2%	5305
18:00-19:00	3172	483	199	92	43	1242	32	38	28	6	1	2	5335	3	5338	5.2%	5407
19:00-20:00	2334	648	232	113	46	1303	72	19	30	11	3	5	4808	8	4816	4.7%	4954
20:00-21:00	2315	1006	156	30	7	757	44	30	29	8	2	0	4382	2	4384	4.3%	4415
21:00-22:00	1801	791	96	40	10	675	62	54	26	9	0	0	3364	0	3364	3.3%	3446
22:00-23:00	1463	605	65	33	1	249	73	43	41	34	0	0	2607	0	2607	2.5%	2884
23:00-24:00	1369	381	50	31	2	148	61	52	41	44	0	0	2179	0	2179	2.1%	2509
00:00-01:00	963	288	29	7	4	132	54	42	42	41	0	0	1602	0	1602	1.6%	1868
01:00-02:00	653	209	32	8	1	92	53	53	44	133	0	2	1278	2	1280	1.3%	1888
02:00-03:00	652	180	27	8	2	90	57	58	51	74	0	1	1199	1	1200	1.2%	1620
03:00-04:00	577	188	35	7	0	49	58	76	112	53	0	6	1155	6	1161	1.1%	1649
04:00-05:00	1284	265	47	22	0	246	54	71	149	36	0	5	2174	5	2179	2.1%	2660
05:00-06:00	1839	586	91	44	20	769	62	89	131	48	5	6	3679	11	3690	3.6%	4130
06:00-07:00	2039	1039	188	204	135	1023	83	99	157	63	1	16	5030	17	5047	4.9%	6005
07:00-08:00	3317	1434	365	233	186	1658	169	124	197	90	14	16	7763	30	7793	7.6%	8958
Total	50187	15923	3425	1699	858	24088	1803	1679	1723	708	96	144	102093	240	102333	100.0%	108941
Percentage	49.0%	15.6%	3.3%	1.7%	0.8%	23.5%	1.8%	1.6%	1.7%	0.7%	0.1%	0.1%	99.8%	0.2%	100.0%		

Peak Volume= **7905**
 Peak Time=**08:00-09:00**

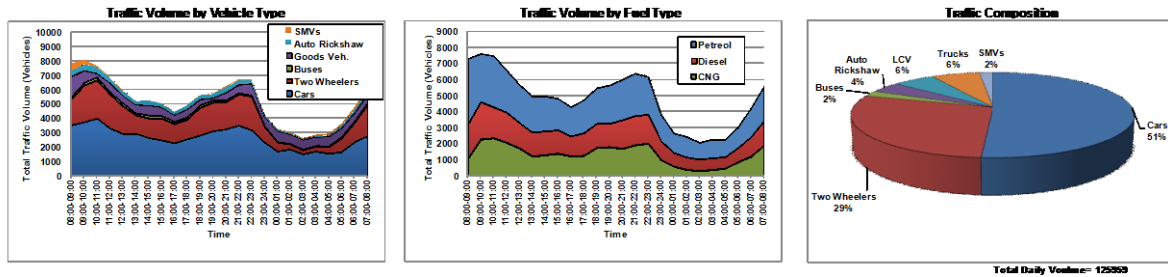


Figure A6.9: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Chilla Border

Table A6.10: Classified Traffic Volume at Kalindi Kunj Border

Road Name: **Kalindi Kunj - Sarita Vihar Link Road** Location: **Kalindi Kunj Border** Date: **11.07.2017 - 12.07.2017**
 Outer Cordon **OC-10**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/ Goods Van (GAV)	Light Commercial Vehicles (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CY SM V)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	2447	1108	337	117	37	1782	424	363	339	328	345	180	7282	525	7807	6.2%	9837
09:00-10:00	2357	1413	407	138	48	2547	580	100	81	96	285	18	7767	303	8070	6.4%	8543
10:00-11:00	2490	1539	406	162	41	2645	134	42	45	60	66	20	7564	86	7650	6.1%	7800
11:00-12:00	2030	1304	331	121	26	2358	156	235	200	69	42	14	6830	56	6886	5.5%	7454
12:00-13:00	1865	1095	309	147	46	1909	73	232	188	57	21	8	5921	29	5950	4.7%	6596
13:00-14:00	1755	1214	228	79	47	1282	84	240	231	46	3	11	5206	14	5220	4.1%	5939
14:00-15:00	1744	931	316	122	77	1353	150	254	257	53	3	8	5257	11	5268	4.2%	6218
15:00-16:00	1769	747	220	110	60	1506	161	224	197	44	13	14	5038	27	5065	4.0%	5754
16:00-17:00	1680	621	215	103	49	1327	126	155	156	35	11	14	4467	25	4492	3.6%	5035
17:00-18:00	1726	864	272	104	47	1348	94	248	193	29	16	3	4925	19	4944	3.9%	5568
18:00-19:00	1821	1017	273	98	68	1930	58	191	145	19	8	4	5620	12	5632	4.5%	5947
19:00-20:00	2030	1110	251	98	63	1971	48	56	35	34	7	9	5696	16	5712	4.5%	5770
20:00-21:00	2500	767	320	72	18	1898	313	92	59	103	79	28	6142	107	6249	5.0%	6656
21:00-22:00	2723	811	268	79	12	2157	259	59	51	217	54	22	6636	76	6712	5.3%	7401
22:00-23:00	2427	780	191	67	0	2338	230	119	156	330	52	12	6638	64	6702	5.3%	7911
23:00-24:00	1808	563	89	24	4	1095	140	100	158	261	24	15	4242	39	4281	3.4%	5422
00:00-01:00	1436	303	77	4	0	626	58	124	226	383	25	14	3237	39	3276	2.6%	5021
01:00-02:00	1690	182	60	2	6	357	32	90	181	378	56	15	2978	71	3049	2.4%	4707
02:00-03:00	1335	209	35	4	6	278	92	93	182	341	56	14	2575	70	2645	2.1%	4226
03:00-04:00	1568	168	33	3	2	355	44	84	192	318	67	28	2767	95	2862	2.3%	4329
04:00-05:00	1325	253	62	6	8	474	52	74	218	352	98	23	2824	121	2945	2.3%	4552
05:00-06:00	1353	341	121	61	18	950	82	97	219	241	133	19	3483	152	3635	2.9%	4876
06:00-07:00	1798	591	184	62	25	1328	98	125	185	201	160	21	4597	181	4778	3.8%	5747
07:00-08:00	2131	665	232	108	35	2143	101	142	194	158	204	16	5909	220	6129	4.9%	6859
Total	45808	18596	5237	1891	743	35957	3589	3539	4088	4153	1828	530	123601	2358	125959	100.0%	148169
Percentage	36.4%	14.8%	4.2%	1.5%	0.6%	28.5%	2.8%	2.8%	3.2%	3.3%	1.5%	0.4%	98.1%	1.9%	100.0%		

Peak Volume= **8070**
 Peak Time=**09:00-10:00**

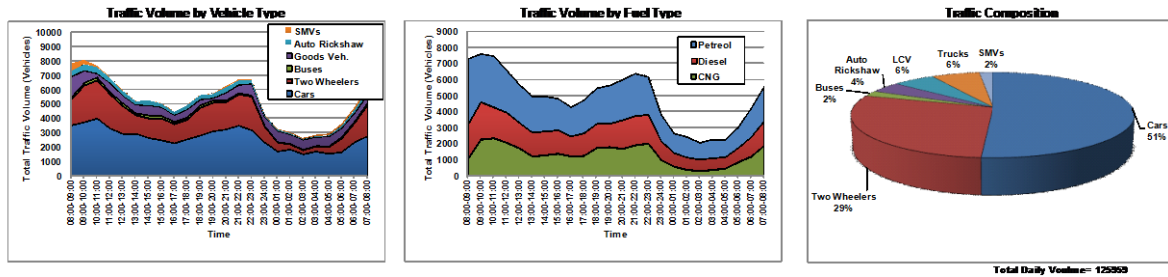


Figure A6.10: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Kalindi Kunj Border

Appendix 7

**CSIR**
CRRRICSIR-Central Road Research Institute (CRRRI), New Delhi
(in association with TNO, Netherlands and TU Delft, Netherlands)**MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY
(MEGALOG)**

Research Project Funded by

**THE WORLD BANK**
IBRD • IDA | WORLD BANK GROUP

OC

O-D SURVEY / OUTER CORDON SURVEY

Location: _____ Interviewer Name: _____

Date: _____ Time: _____

1. Vehicle Details (a) Type: (1) LCV / (2) Normal Truck / (3) Tanker / (4) MAV / (5) Goods Auto /
(6) Goods Van / (7) Others _____ (b) Model Year _____ (c) Fuel Used: (1) Petrol / (2) Diesel / (3) CNG / (4) LPG / (5) Propane (d) Registration Number: _____ (e) Vehicle Ownership: (1) Government / (2) Pvt. Company / (3) Personal / (4) Hired (f) Fuel Consumption (mileage): _____ (km/ltr) 2. Trip Details: (a) Origin of Trip: _____ Destination of Trip: _____

Place: _____ Place: _____

State: _____ State: _____

Outer Cordon Entry: _____ Outer Cordon Exit: _____

(b) Distance of this Trip: _____ (km) (c) Distance of this Trip within the City: _____ (km) (d) Distance traveled in a day: _____ (km) (e) Time taken for this Trip: _____ (Hrs) _____ (Mins) (f) Time taken for this Trip within the City: _____ (Hrs) _____ (Mins) (g) Frequency of this Trip: (1) Daily / (2) Bi-weekly / (3) Tri-weekly / (4) Weekly / (5) Occasionally (h) Purpose of Entering the City: (1) Filling Fuel / (2) Loading (or) Unloading /
(3) Passing through the city / (4) others _____

3. Commodity Detail: (a) Commodity Type:

- | | | |
|--|--------------------------|---------------------|
| 1. Fruits, Vegetables, Fish, Meat etc. | 7. Iron/Steel Products. | 13. Clothes. |
| 2. Food Grains. | 8. Finished Products. | 14. Sugar/ Jagery |
| 3. Building Materials. | 9. Tyre/Rubber Products. | 15. Paper Products. |
| 4. Milk/Milk Products. | 10. Chemicals | 16. Water |
| 5. Petroleum Products. | 11. Medicines | 17. Others |
| 6. Wood/Woods Items. | 12. Glassware. | 18. Empty |

(b) Weight: _____ Tonnes 



FOCAL POINT SURVEY (GOODS TERMINALS/ COMMERCIAL CENTERS)

Location: _____ Interviewer Name: _____

Date: _____ Time: _____

1. Vehicle Details (a) Type: (1) LCV / (2) Normal Truck / (3) Tanker / (4) MAV / (5) Goods Auto / (6) Goods Van / (7) Others _____

(b) Model Year _____

(c) Fuel Used: (1) Petrol / (2) Diesel / (3) CNG / (4) LPG / (5) Propane

(d) Registration Number: _____

(e) Vehicle Ownership: (1) Government / (2) Pvt. Company / (3) Personal / (4) Hired

(f) Fuel Consumption(mileage): _____ (km/ltr)

2. Trip Details:

(a) Origin of Trip: _____ Destination of Trip: _____

Place: _____ Place: _____

State: _____ State: _____

(b) Distance of this Trip: _____ (km)

(c) Distance of this Trip within the City: _____ (km)

(d) Distance traveled in a day: _____ (km)

(e) Time taken for this Trip: _____ (Hrs) _____ (Mins)

(f) Time taken for this Trip within the City: _____ (Hrs) _____ (Mins)

(g) Frequency of this Trip: (1) Daily / (2) Bi-weekly / (3) Tri-weekly / (4) Weekly / (5) Occasionally

3. Commodity Detail: (a) Commodity Type:

- | | | |
|--|---------------------------|---------------------|
| 1. Fruits, Vegetables, Fish, Meat etc. | 7. Iron/Steel Products. | 13. Clothes. |
| 2. Food Grains. | 8. Finished Products. | 14. Sugar/ Jagery |
| 3. Building Materials. | 9. Tyre /Rubber Products. | 15. Paper Products. |
| 4. Milk/Milk Products. | 10. Chemicals | 16. Water |
| 5. Petroleum Products. | 11. Medicines | 17. Others |
| 6. Wood/Woods Items. | 12. Glassware. | 18. Empty |

(b) Weight: _____ Tonnes

Appendix 8

Table A8.1: Classified Freight Traffic Volume at Azadpur Sabzi Mandi

Location Name: Azadpur Sabzi Mandi
Focal Point Code: FP-01

Date: 14.09.2017 - 15.09.2017

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV- Goods	Total SMV- Goods	Total Vehicles- Goods	Percentage	PCU
08:00-09:00	9	20	4	6	12	3	41	0	15	54	56	110	1.6%	222
09:00-10:00	4	25	12	12	14	4	24	0	23	71	47	118	1.7%	236
10:00-11:00	13	32	9	22	16	5	39	0	38	97	77	174	2.6%	340
11:00-12:00	7	31	2	12	5	1	18	0	31	58	49	107	1.6%	199
12:00-13:00	14	17	0	12	4	0	14	0	17	47	31	78	1.2%	140
13:00-14:00	14	7	1	3	0	0	1	0	7	25	8	33	0.5%	51
14:00-15:00	2	15	2	3	2	0	0	0	7	24	7	31	0.5%	57
15:00-16:00	2	25	1	5	2	1	2	0	12	36	14	50	0.7%	96
16:00-17:00	4	13	3	2	0	0	2	0	8	22	10	32	0.5%	54
17:00-18:00	1	16	0	2	0	0	1	0	16	19	17	36	0.5%	63
18:00-19:00	3	7	1	2	0	0	2	0	8	13	10	23	0.3%	39
19:00-20:00	0	29	0	16	18	13	3	0	4	76	7	83	1.2%	215
20:00-21:00	0	137	14	131	108	140	8	0	0	530	8	538	7.9%	1523
21:00-22:00	0	135	2	128	107	125	8	0	0	497	8	505	7.4%	1428
22:00-23:00	0	148	0	145	127	88	25	0	0	508	25	533	7.9%	1413
23:00-24:00	0	108	0	138	138	139	52	0	0	523	52	575	8.5%	1636
00:00-01:00	0	112	0	112	116	115	37	0	0	455	37	492	7.3%	1388
01:00-02:00	0	90	0	132	95	118	16	0	0	435	16	451	6.7%	1292
02:00-03:00	0	99	0	95	105	95	24	0	0	394	24	418	6.2%	1179
03:00-04:00	0	121	0	137	110	107	18	0	0	475	18	493	7.3%	1364
04:00-05:00	0	140	0	132	103	119	17	0	0	494	17	511	7.5%	1423
05:00-06:00	0	133	0	115	122	113	37	0	0	483	37	520	7.7%	1445
06:00-07:00	6	86	0	82	89	93	14	0	0	356	14	370	5.5%	1057
07:00-08:00	3	99	0	127	115	137	17	0	0	481	17	498	7.3%	1451
Total	82	1645	51	1571	1408	1416	420	0	186	6173	606	6779	100%	18307
Percentage	1.2%	24.3%	0.8%	23.2%	20.8%	20.9%	6.2%	0.0%	2.7%	91.1%	8.9%	100.0%		

Peak Volume= 575
Peak Time= 23:00-24:00

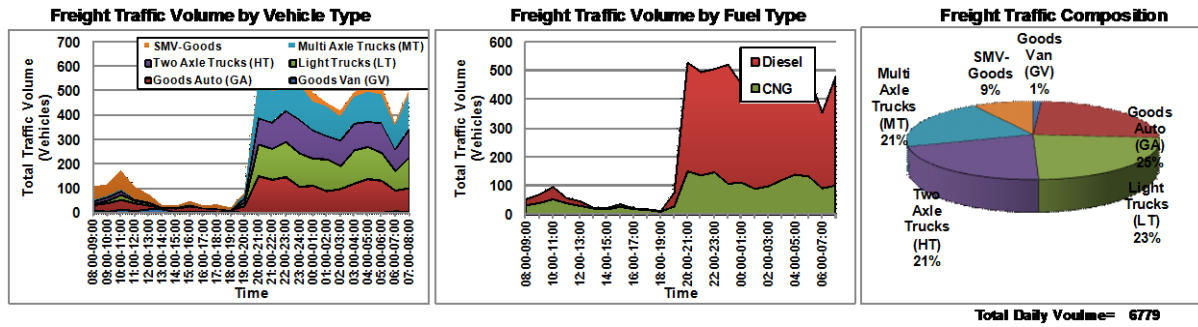


Figure A8.1: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Azadpur Sabzi Mandi

Table A8.2: Classified Freight Traffic Volume at Okhla Sabzi Mandi

Location Name: **Okhla Mandi**
Focal Point Code: **FP-02**

Date: **15.09.2017 - 16.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV- Goods	Total SMV- Goods	Total Vehicles- Goods	Percentage	PCU
08:00-09:00	10	10	0	18	5	2	0	0	4	45	4	49	5.5%	98
09:00-10:00	9	9	1	14	3	2	0	0	7	38	7	45	5.0%	87
10:00-11:00	9	3	0	12	1	0	0	0	5	25	5	30	3.3%	51
11:00-12:00	11	6	1	7	2	0	0	0	27	27	0	27	3.0%	46
12:00-13:00	9	2	0	8	0	0	0	0	8	19	8	27	3.0%	43
13:00-14:00	10	5	0	17	2	0	0	0	1	34	1	35	3.9%	64
14:00-15:00	12	4	1	13	0	0	0	0	2	30	2	32	3.6%	53
15:00-16:00	3	5	0	12	1	0	0	0	1	21	1	22	2.5%	42
16:00-17:00	3	2	0	14	1	0	0	0	5	20	5	25	2.8%	46
17:00-18:00	2	2	1	14	1	0	0	0	8	20	8	28	3.1%	51
18:00-19:00	0	1	0	4	2	0	0	0	5	7	5	12	1.3%	24
19:00-20:00	0	0	0	6	6	0	0	0	6	12	6	18	2.0%	39
20:00-21:00	6	10	0	1	0	0	1	0	0	17	1	18	2.0%	31
21:00-22:00	6	6	0	0	0	0	0	0	0	12	0	12	1.3%	19
22:00-23:00	0	11	0	8	15	0	0	0	5	34	5	39	4.4%	91
23:00-24:00	0	19	0	14	32	13	0	0	6	78	6	84	9.4%	230
00:00-01:00	0	9	0	37	19	17	0	0	4	82	4	86	9.6%	232
01:00-02:00	0	7	0	18	29	12	0	0	0	66	0	66	7.4%	191
02:00-03:00	0	10	0	8	26	12	0	0	0	56	0	56	6.3%	168
03:00-04:00	0	9	0	12	12	10	0	0	0	43	0	43	4.8%	123
04:00-05:00	0	9	0	6	8	4	0	0	0	27	0	27	3.0%	72
05:00-06:00	0	11	0	9	8	4	0	0	0	32	0	32	3.6%	82
06:00-07:00	0	19	0	6	7	8	0	0	0	40	0	40	4.5%	107
07:00-08:00	2	8	0	12	13	8	0	0	0	43	0	43	4.8%	117
Total	92	177	4	270	193	92	1	0	67	828	68	896	100%	2105
Percentage	10.3%	19.8%	0.4%	30.1%	21.5%	10.3%	0.1%	0.0%	7.5%	92.4%	7.6%	100.0%		

Peak Volume= 86
Peak Time= 00:00-01:00

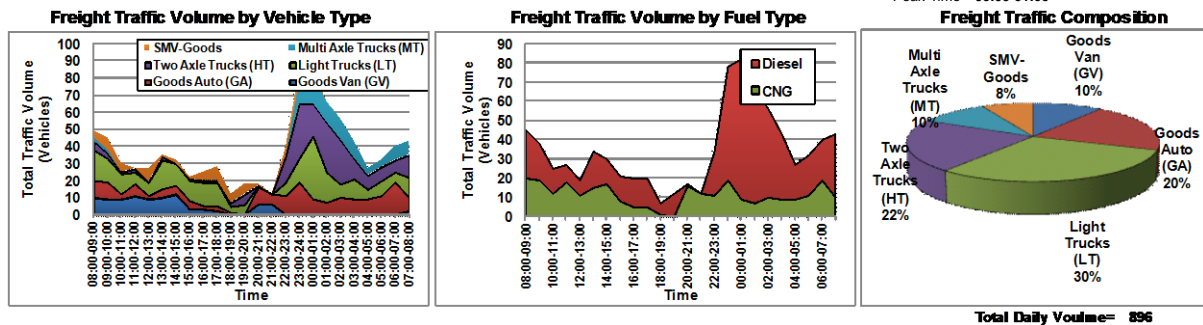


Figure A8.2: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Okhla Sabzi Mandi

Table A8.3: Classified Freight Traffic Volume at Arya Pura Sabzi Mandi

Location Name: **Arya Pura Sabzi Mandi**
 Focal Point Code: **FP-03**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV-Goods	Total SMV-Goods	Total Vehicles-Goods	Percentage	PCU
08:00-09:00	51	71	0	11	0	0	4	10	14	133	28	161	4.1%	269
09:00-10:00	29	60	0	7	0	0	3	12	39	96	54	150	3.8%	251
10:00-11:00	27	38	0	9	0	0	7	14	48	74	69	143	3.6%	233
11:00-12:00	30	64	0	28	0	0	4	3	39	122	46	168	4.3%	291
12:00-13:00	28	74	0	45	0	0	28	9	29	147	66	213	5.4%	385
13:00-14:00	45	125	0	50	0	3	17	0	32	223	49	272	6.9%	500
14:00-15:00	35	105	0	52	0	3	14	0	27	195	41	236	6.0%	438
15:00-16:00	42	136	0	67	0	0	3	0	15	245	18	263	6.7%	485
16:00-17:00	77	164	0	48	0	0	7	0	26	289	33	322	8.2%	569
17:00-18:00	30	39	0	14	0	0	0	0	31	83	31	114	2.9%	189
18:00-19:00	15	20	0	13	3	0	0	0	52	51	52	103	2.6%	171
19:00-20:00	11	44	0	20	1	1	0	0	30	77	30	107	2.7%	194
20:00-21:00	6	151	0	6	1	2	0	0	12	166	12	178	4.5%	351
21:00-22:00	19	158	0	16	2	0	1	0	1	195	2	197	5.0%	380
22:00-23:00	7	115	0	1	0	0	2	0	0	123	2	125	3.2%	244
23:00-24:00	5	91	0	33	1	7	1	0	9	137	1	138	3.5%	291
00:00-01:00	1	66	0	42	9	5	1	0	0	123	1	124	3.2%	269
01:00-02:00	0	38	0	57	12	7	0	0	0	114	0	114	2.9%	258
02:00-03:00	0	31	0	70	9	11	0	0	0	121	0	121	3.1%	279
03:00-04:00	0	24	0	49	2	7	0	0	0	82	0	82	2.1%	184
04:00-05:00	0	9	0	61	1	5	2	0	0	76	2	78	2.0%	170
05:00-06:00	0	37	0	63	1	6	1	0	0	107	1	108	2.8%	232
06:00-07:00	3	94	0	110	0	11	1	0	0	218	1	219	5.6%	463
07:00-08:00	22	84	0	54	0	5	9	7	7	165	23	188	4.8%	364
Total	483	1838	0.0%	926	42	73	105	55	402	3362	562	3924	100%	7458
Percentage	12.3%	46.8%	0.0%	23.6%	1.1%	1.9%	2.7%	1.4%	10.2%	85.7%	14.3%	100.0%		

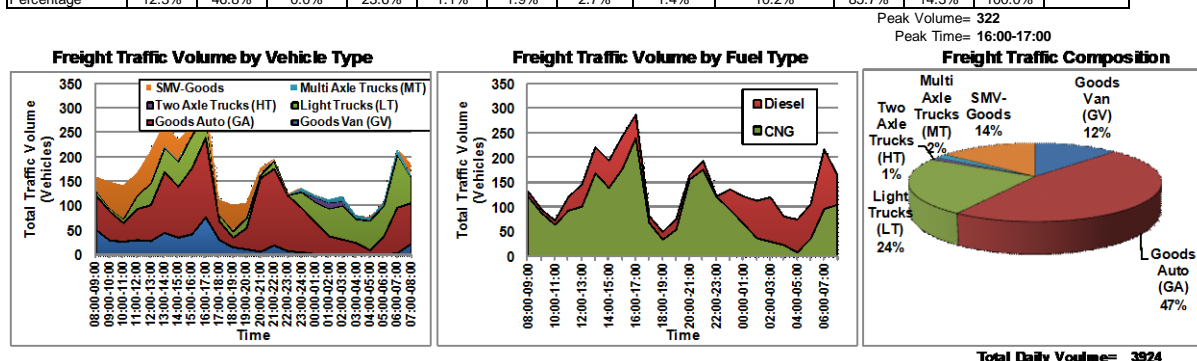


Figure A8.3: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Arya Pura Sabzi Mandi

Table A8.4: Classified Freight Traffic Volume at Ghanta Ghar Sabzi Mandi

Location Name: **Ghanta Ghar Sabzi Mandi**
 Focal Point Code: **FP-04**

Date: **12.09.2017 - 13.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV- Goods	Total SMV- Goods	Total Vehicles- Goods	Percentage	PCU
08:00-09:00	32	22	0	13	0	0	0	0	0	67	0	67	0.8%	108
09:00-10:00	37	42	0	21	1	0	0	0	0	101	0	101	1.3%	173
10:00-11:00	42	54	0	41	4	1	0	0	0	142	0	142	1.8%	257
11:00-12:00	39	211	0	100	3	1	0	0	0	354	0	354	4.4%	682
12:00-13:00	50	283	0	184	3	1	0	0	0	521	0	521	6.5%	1008
13:00-14:00	13	260	0	121	1	0	0	0	0	395	0	395	4.9%	781
14:00-15:00	35	289	0	125	0	1	0	0	0	450	0	450	5.6%	875
15:00-16:00	42	331	0	201	2	1	0	0	0	577	0	577	7.2%	1125
16:00-17:00	25	217	0	150	0	3	0	0	0	395	0	395	4.9%	778
17:00-18:00	28	197	0	127	0	1	0	0	0	353	0	353	4.4%	686
18:00-19:00	11	60	0	72	0	0	0	0	0	143	0	143	1.8%	277
19:00-20:00	8	102	0	38	0	0	0	0	0	148	0	148	1.9%	290
20:00-21:00	9	261	0	39	13	0	0	0	0	322	0	322	4.0%	650
21:00-22:00	16	261	0	55	29	0	0	0	0	361	0	361	4.5%	738
22:00-23:00	13	205	0	68	56	2	0	0	0	344	0	344	4.3%	739
23:00-24:00	12	117	0	165	120	28	0	0	0	442	0	442	5.5%	1064
00:00-01:00	4	59	0	104	115	39	0	0	0	321	0	321	4.0%	851
01:00-02:00	2	42	0	109	84	96	0	0	0	333	0	333	4.2%	988
02:00-03:00	2	28	0	110	66	69	0	0	0	275	0	275	3.4%	787
03:00-04:00	0	37	0	87	60	67	0	0	0	251	0	251	3.1%	730
04:00-05:00	5	120	0	85	98	136	0	0	0	444	0	444	5.6%	1322
05:00-06:00	4	119	0	195	95	55	0	0	0	468	0	468	5.9%	1165
06:00-07:00	12	109	0	143	92	29	0	0	0	385	0	385	4.8%	925
07:00-08:00	11	161	0	125	70	23	0	0	0	390	0	390	4.9%	899
Total	452	3587	0.0%	2478	912	553	0.0%	0.0%	0.0%	7982	0	7982	100%	17897
Percentage	5.7%	44.9%	0.0%	31.0%	11.4%	6.9%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%		

Peak Volume= 577
 Peak Time= 15:00-16:00

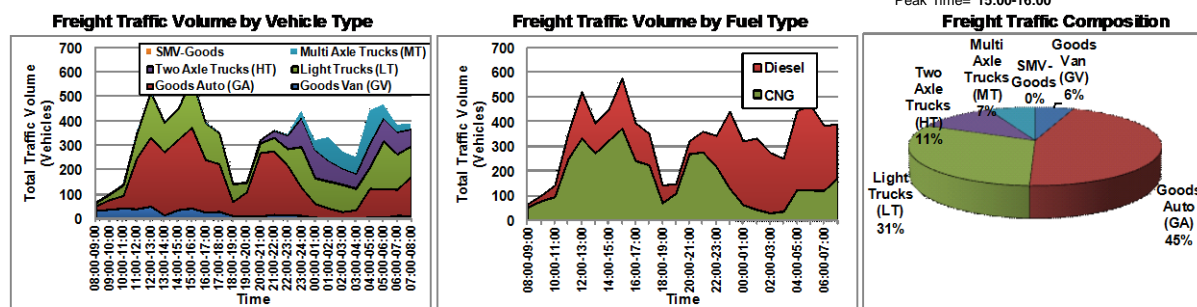


Figure A8.4: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Ghanta Ghar Sabzi Mandi

Table A8.5: Classified Freight Traffic Volume at Old Delhi Sabzi Mandi

Location Name: **Old Delhi Sabzi Mandi**
 Focal Point Code: **FP-05**

Date: **16.09.2017 - 17.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV- Goods	Total SMV- Goods	Total Vehicles- Goods	Percentage	PCU
08:00-09:00	2	15	0	8	0	0	20	0	0	25	20	45	1.8%	88
09:00-10:00	7	43	0	22	5	0	38	0	0	77	38	115	4.6%	229
10:00-11:00	13	81	0	48	6	10	80	0	0	158	80	238	9.5%	497
11:00-12:00	10	120	0	62	8	8	55	0	0	208	55	263	10.5%	546
12:00-13:00	14	78	0	48	0	0	48	0	0	140	48	188	7.5%	365
13:00-14:00	5	66	0	56	0	0	40	0	0	127	40	167	6.6%	330
14:00-15:00	11	52	0	49	0	0	32	0	0	112	32	144	5.7%	279
15:00-16:00	12	60	0	41	2	0	37	0	0	115	37	152	6.0%	296
16:00-17:00	12	45	0	24	0	0	52	0	0	81	52	133	5.3%	256
17:00-18:00	11	24	0	7	0	0	41	0	0	42	41	83	3.3%	157
18:00-19:00	14	14	0	3	0	0	42	0	0	31	42	73	2.9%	135
19:00-20:00	5	15	0	0	0	0	44	0	0	20	44	64	2.5%	124
20:00-21:00	14	26	0	5	0	0	24	0	0	45	24	69	2.7%	127
21:00-22:00	12	22	0	25	17	6	16	0	0	82	16	98	3.9%	218
22:00-23:00	7	8	0	26	26	20	9	0	0	87	9	96	3.8%	262
23:00-24:00	1	1	0	52	41	52	6	0	0	147	6	153	6.1%	476
00:00-01:00	0	0	0	36	31	41	0	0	0	108	0	108	4.3%	350
01:00-02:00	0	1	0	27	21	27	0	0	0	76	0	76	3.0%	241
02:00-03:00	0	1	0	12	20	30	0	0	0	63	0	63	2.5%	221
03:00-04:00	0	1	0	15	21	22	0	0	0	59	0	59	2.3%	194
04:00-05:00	0	5	0	9	12	15	0	0	0	41	0	41	1.6%	132
05:00-06:00	0	7	0	8	0	5	0	0	0	20	0	20	0.8%	53
06:00-07:00	0	12	0	11	2	3	0	0	0	28	0	28	1.1%	66
07:00-08:00	5	9	0	9	0	3	11	0	0	26	11	37	1.5%	78
Total	155	706	0.0%	603	212	242	595	0.0%	0.0%	1918	595	2513	100%	5719
Percentage	6.2%	28.1%	0.0%	24.0%	8.4%	9.6%	23.7%	0.0%	0.0%	76.3%	23.7%	100.0%		

Peak Volume= 263
 Peak Time= 11:00-12:00

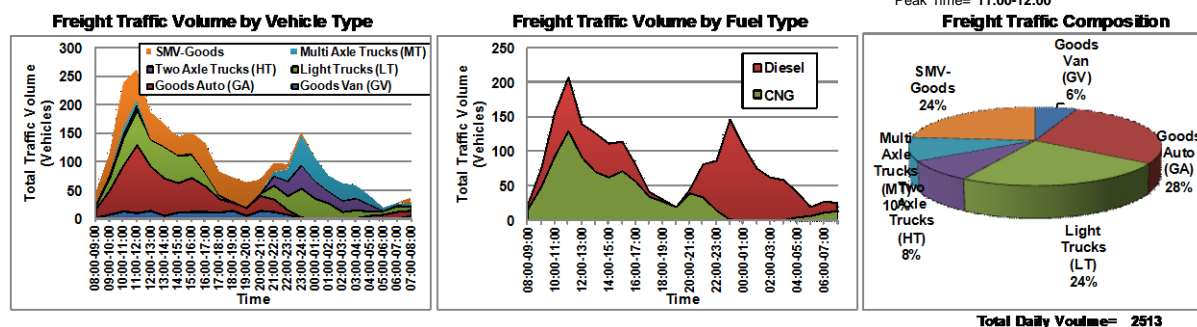


Figure A8.5: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Old Delhi Sabzi Mandi

Table A8.6: Classified Freight Traffic Volume at Shahadara Sabzi Mandi

Location Name: **Shahadara Sabzi Mandi**
 Focal Point Code: **FP-06**

Date: **18.07.2017 - 19.07.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	0	19	0	3	17	2	33	0	0	41	33	74	2.6%	170
09:00-10:00	3	43	0	36	31	14	39	0	0	127	39	166	5.9%	396
10:00-11:00	1	57	0	65	58	56	49	0	0	237	49	286	10.1%	769
11:00-12:00	2	58	0	58	36	37	48	0	0	192	48	240	8.5%	607
12:00-13:00	3	65	0	39	19	4	57	0	0	130	57	187	6.6%	401
13:00-14:00	1	59	0	50	21	5	56	0	0	136	56	192	6.8%	417
14:00-15:00	1	43	0	40	16	4	41	0	0	104	41	145	5.1%	315
15:00-16:00	2	47	0	34	20	3	45	0	0	106	45	151	5.3%	328
16:00-17:00	1	41	0	30	6	1	61	0	0	79	61	140	5.0%	288
17:00-18:00	0	45	0	25	13	1	55	0	0	84	55	139	4.9%	294
18:00-19:00	0	70	0	22	7	0	45	0	0	99	45	144	5.1%	295
19:00-20:00	0	88	0	12	4	0	25	0	0	104	25	129	4.6%	262
20:00-21:00	0	39	0	6	2	1	8	0	0	48	8	56	2.0%	117
21:00-22:00	0	50	0	5	6	0	5	0	0	61	5	66	2.3%	138
22:00-23:00	0	50	0	10	65	1	7	0	0	126	7	133	4.7%	334
23:00-24:00	0	35	0	19	95	8	1	0	0	157	1	158	5.6%	431
00:00-01:00	0	14	0	8	62	1	1	0	0	85	1	86	3.0%	237
01:00-02:00	0	15	0	14	36	1	1	0	0	66	1	67	2.4%	173
02:00-03:00	0	5	0	8	19	1	0	0	0	33	0	33	1.2%	88
03:00-04:00	0	6	0	12	15	3	5	0	0	36	5	41	1.5%	105
04:00-05:00	0	9	0	3	5	3	15	0	0	20	15	35	1.2%	83
05:00-06:00	0	17	0	10	7	2	25	0	0	36	25	61	2.2%	134
06:00-07:00	0	4	0	21	11	0	11	0	0	36	11	47	1.7%	105
07:00-08:00	5	19	0	6	4	0	13	0	0	34	13	47	1.7%	94
Total	19	899	0	536	575	148	646	0	0	2177	646	2823	100%	6576
Percentage	0.7%	31.8%	0.0%	19.0%	20.4%	5.2%	22.9%	0.0%	0.0%	77.1%	22.9%	100.0%		

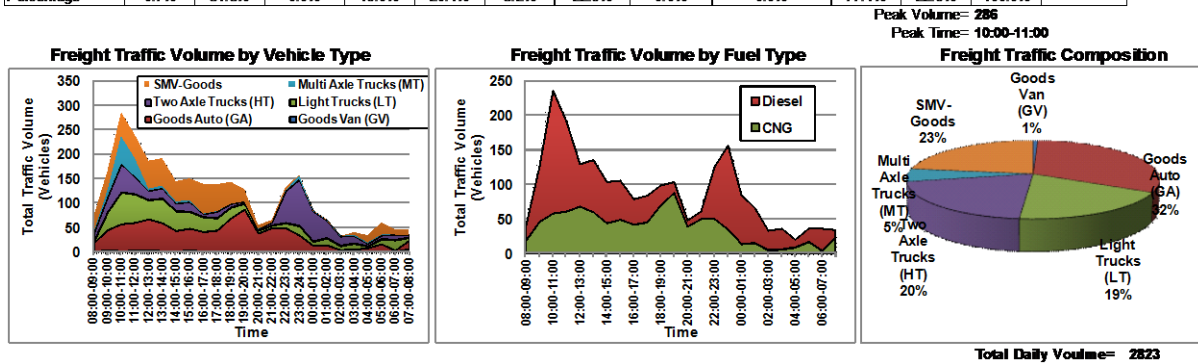


Figure A8.6: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Shahadara Sabzi Mandi

Table A8.7: Classified Freight Traffic Volume at Mandawali Sabzi Mandi

Location Name: **Mandawali Sabzi Mandi**
 Focal Point Code: **FP-07**

Date: **18.07.2017 - 19.07.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	0	6	0	1	3	0	2	0	0	10	2	12	2.1%	27
09:00-10:00	1	11	0	9	3	5	0	0	0	29	0	29	5.1%	73
10:00-11:00	4	20	0	8	6	8	1	0	0	46	1	47	8.3%	117
11:00-12:00	1	10	0	3	3	1	0	0	0	18	0	18	3.2%	41
12:00-13:00	4	3	0	3	5	2	1	0	0	17	1	18	3.2%	43
13:00-14:00	3	3	0	10	5	2	0	0	0	23	0	23	4.1%	54
14:00-15:00	2	3	0	4	4	1	0	0	0	14	0	14	2.5%	33
15:00-16:00	2	7	0	3	9	1	0	0	0	22	0	22	3.9%	54
16:00-17:00	3	12	0	6	2	0	1	0	0	23	1	24	4.2%	48
17:00-18:00	2	14	0	7	5	0	0	0	0	28	0	28	4.9%	59
18:00-19:00	3	12	0	1	2	0	1	0	0	18	1	19	3.4%	39
19:00-20:00	3	7	0	5	1	0	1	0	0	16	1	17	3.0%	33
20:00-21:00	0	6	0	3	0	0	0	0	0	9	0	9	1.6%	18
21:00-22:00	0	3	0	2	2	0	0	0	0	7	0	7	1.2%	16
22:00-23:00	0	16	0	4	32	0	0	0	0	52	0	52	9.2%	136
23:00-24:00	0	17	0	8	45	3	0	0	0	73	0	73	12.9%	199
00:00-01:00	0	6	0	4	30	0	0	0	0	40	0	40	7.1%	110
01:00-02:00	0	6	0	6	17	0	0	0	0	29	0	29	5.1%	75
02:00-03:00	0	2	0	3	8	0	0	0	0	13	0	13	2.3%	34
03:00-04:00	0	2	0	5	7	1	0	0	0	15	0	15	2.6%	40
04:00-05:00	0	4	0	2	1	0	0	0	0	7	0	7	1.2%	15
05:00-06:00	0	15	0	4	1	1	0	0	0	21	0	21	3.7%	46
06:00-07:00	0	9	0	4	5	0	0	0	0	18	0	18	3.2%	41
07:00-08:00	4	6	0	1	0	0	1	0	0	11	1	12	2.1%	21
Total	32	200	0.0%	106	196	25	8	0.0%	0.0%	559	8	567	100%	1367
Percentage	5.6%	35.3%	0.0%	18.7%	34.6%	4.4%	1.4%	0.0%	0.0%	98.6%	1.4%	100.0%		

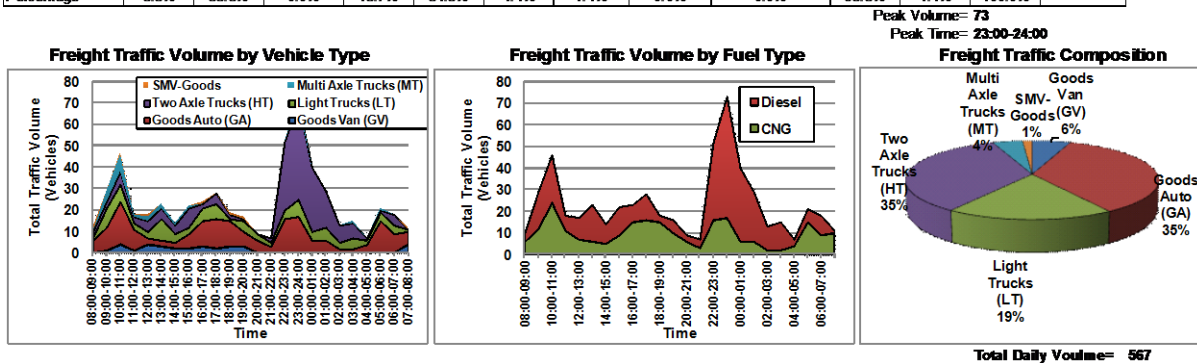


Figure A8.7: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Mandawali Sabzi Mandi

Table A8.8: Classified Freight Traffic Volume at Shahadara

Location Name: **Shahadara Market Near Ashok Nagar**
 Focal Point Code: **FP-08**

Date: **13.09.2017 - 14.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	7	12	0	13	0	0	8	0	0	32	8	40	3.6%	74
09:00-10:00	3	9	0	11	0	0	22	0	0	23	22	45	4.1%	88
10:00-11:00	5	19	0	19	0	0	43	0	0	43	43	86	7.8%	168
11:00-12:00	3	19	0	17	0	0	45	0	0	39	45	84	7.6%	166
12:00-13:00	2	17	0	11	0	0	30	0	0	30	30	60	5.4%	118
13:00-14:00	0	21	0	11	0	0	39	0	0	32	39	71	6.4%	142
14:00-15:00	2	32	0	15	0	0	46	0	0	49	46	95	8.6%	188
15:00-16:00	1	30	0	14	0	0	46	0	0	45	46	91	8.3%	181
16:00-17:00	1	25	0	18	0	0	28	0	0	44	28	72	6.5%	143
17:00-18:00	3	27	0	13	0	0	39	0	0	43	39	82	7.4%	162
18:00-19:00	1	16	0	6	0	0	23	0	0	23	23	46	4.2%	91
19:00-20:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
20:00-21:00	19	1	0	8	0	0	5	0	0	28	5	33	3.0%	51
21:00-22:00	6	11	0	8	2	0	18	0	0	27	18	45	4.1%	87
22:00-23:00	6	14	0	5	1	0	23	0	0	26	23	49	4.5%	94
23:00-24:00	0	5	0	0	5	0	11	0	0	10	11	21	1.9%	47
00:00-01:00	1	5	0	1	3	2	5	0	0	12	5	17	1.5%	41
01:00-02:00	0	3	0	2	3	0	0	0	0	8	0	8	0.7%	19
02:00-03:00	0	2	0	3	7	0	0	0	0	12	0	12	1.1%	31
03:00-04:00	0	5	0	5	6	0	0	0	0	16	0	16	1.5%	38
04:00-05:00	0	10	0	19	3	2	0	0	0	34	0	34	3.1%	76
05:00-06:00	0	11	0	13	9	1	1	0	0	34	1	35	3.2%	82
06:00-07:00	0	3	0	3	8	6	1	0	0	20	1	21	1.9%	65
07:00-08:00	4	12	0	8	3	5	6	0	0	32	6	38	3.5%	88
Total	64	309	0	223	50	16	439	0	0	662	439	1101	100%	2241
Percentage	5.8%	28.1%	0.0%	20.3%	4.5%	1.5%	39.9%	0.0%	0.0%	60.1%	39.9%	100.0%		

Peak Volume= 95
 Peak Time= 14:00-15:00

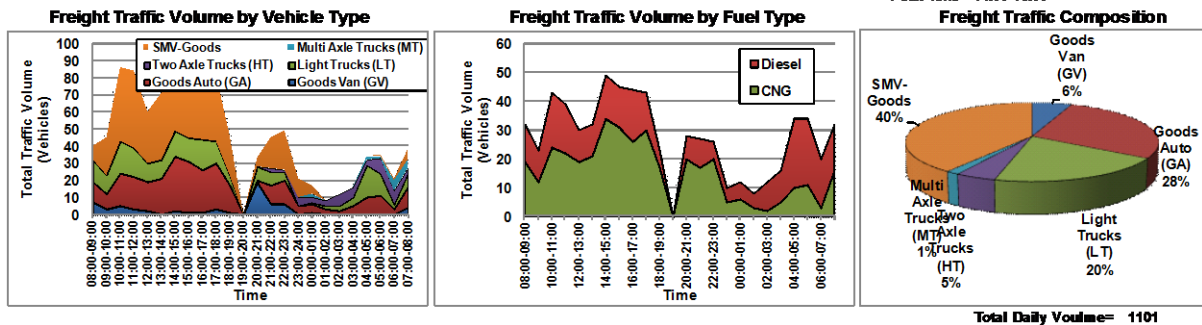


Figure A8.8: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Shahadara

Table A8.9: Classified Freight Traffic Volume at Ghazipur Sabzi Mandi

Location Name: **GAZI PUR SUBZI MANDI**
 Focal Point Code: **FP-09**

Date: **19.09.2017 - 20.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	8	8	1	28	0	0	0	0	16	45	16	61	5.6%	107
09:00-10:00	4	10	1	33	0	0	0	0	9	48	9	57	5.3%	106
10:00-11:00	3	6	0	30	0	0	0	0	10	39	10	49	4.5%	91
11:00-12:00	2	2	0	35	1	0	0	0	8	40	8	48	4.4%	91
12:00-13:00	3	1	0	15	1	0	0	0	1	20	1	21	1.9%	40
13:00-14:00	0	5	9	11	1	2	0	0	3	28	3	31	2.9%	59
14:00-15:00	2	3	2	7	1	0	0	0	2	15	2	17	1.6%	31
15:00-16:00	12	7	2	3	0	0	0	0	9	24	9	33	3.0%	50
16:00-17:00	0	3	0	4	0	0	0	0	1	7	1	8	0.7%	16
17:00-18:00	1	7	0	2	0	0	0	0	3	10	3	13	1.2%	24
18:00-19:00	4	0	0	4	0	0	0	0	0	8	0	8	0.7%	13
19:00-20:00	2	5	2	3	0	1	0	0	2	13	2	15	1.4%	28
20:00-21:00	0	2	0	3	1	1	0	0	2	7	2	9	0.8%	21
21:00-22:00	4	6	0	12	5	9	0	0	0	36	0	36	3.3%	96
22:00-23:00	18	7	0	16	14	9	0	0	0	64	0	64	5.9%	150
23:00-24:00	1	17	0	21	13	9	0	0	3	61	3	64	5.9%	161
00:00-01:00	0	8	0	14	21	12	0	0	7	55	7	62	5.7%	172
01:00-02:00	0	11	0	21	14	12	0	0	0	58	0	58	5.4%	160
02:00-03:00	1	18	0	33	3	15	0	0	9	70	9	79	7.3%	193
03:00-04:00	0	18	0	27	8	13	0	0	7	66	7	73	6.7%	183
04:00-05:00	6	11	0	26	9	4	0	0	8	56	8	64	5.9%	138
05:00-06:00	6	14	0	41	8	12	0	0	11	81	11	92	8.5%	212
06:00-07:00	0	9	0	31	9	13	0	0	11	62	11	73	6.7%	182
07:00-08:00	5	12	0	16	3	4	0	0	7	40	7	47	4.3%	100
Total	82	190	17	436	112	116	0	0	129	953	129	1082	100%	2422
Percentage	7.6%	17.6%	1.6%	40.3%	10.4%	10.7%	0.0%	0.0%	11.9%	88.1%	11.9%	100.0%		

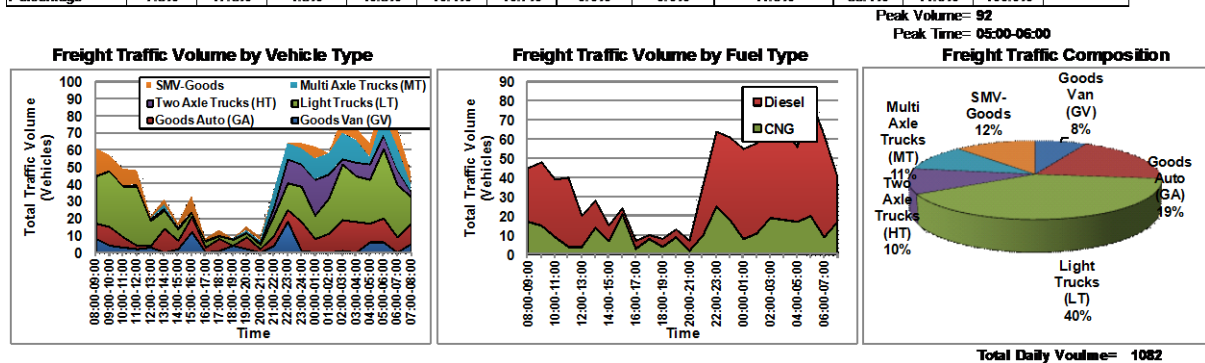


Figure A8.9: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Ghazipur Sabzi Mandi

Table A8.10: Classified Freight Traffic Volume at Connaught Place

Location Name: **CONNAUGHT PLACE**
 Focal Point Code: **FP-10**

Date: **18.07.2017 - 19.07.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	8	5	1	23	0	0	0	0	0	37	0	37	6.1%	67
09:00-10:00	13	8	1	19	0	0	0	0	0	41	0	41	6.8%	71
10:00-11:00	12	5	0	30	0	0	0	0	0	47	0	47	7.8%	84
11:00-12:00	10	2	0	20	1	0	0	0	0	33	0	33	5.5%	59
12:00-13:00	16	3	0	7	1	0	0	0	0	27	0	27	4.5%	42
13:00-14:00	4	4	7	8	1	2	0	0	0	26	0	26	4.3%	49
14:00-15:00	2	3	2	7	1	0	0	0	0	15	0	15	2.5%	28
15:00-16:00	3	6	2	3	0	0	0	0	0	14	0	14	2.3%	24
16:00-17:00	3	3	0	4	0	0	0	0	0	10	0	10	1.7%	18
17:00-18:00	9	6	0	2	0	0	0	0	0	17	0	17	2.8%	27
18:00-19:00	6	0	0	4	0	0	0	0	0	10	0	10	1.7%	15
19:00-20:00	3	5	2	3	0	1	0	0	0	14	0	14	2.3%	27
20:00-21:00	0	2	0	3	1	0	0	0	0	6	0	6	1.0%	13
21:00-22:00	3	5	0	10	4	1	0	0	0	23	0	23	3.8%	50
22:00-23:00	15	5	0	13	11	0	0	0	0	44	0	44	7.3%	87
23:00-24:00	1	1	0	16	11	4	0	0	0	33	0	33	5.5%	60
00:00-01:00	0	3	0	12	11	2	0	0	0	28	0	28	4.6%	72
01:00-02:00	0	0	0	18	6	2	0	0	0	26	0	26	4.3%	63
02:00-03:00	1	4	0	10	8	5	0	0	0	28	0	28	4.6%	76
03:00-04:00	0	3	0	8	3	4	0	0	0	18	0	18	3.0%	49
04:00-05:00	5	3	0	11	3	4	0	0	0	26	0	26	4.3%	61
05:00-06:00	5	2	0	14	1	2	0	0	0	24	0	24	4.0%	50
06:00-07:00	2	1	0	16	5	7	0	0	0	31	0	31	5.1%	83
07:00-08:00	5	6	0	8	3	4	0	0	0	26	0	26	4.3%	61
Total	126	85	15	269	71	38	0	0	0	604	0	604	100%	1261
Percentage	20.9%	14.1%	2.5%	44.5%	11.8%	6.3%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%		

Peak Volume= 47
 Peak Time= 10:00-11:00

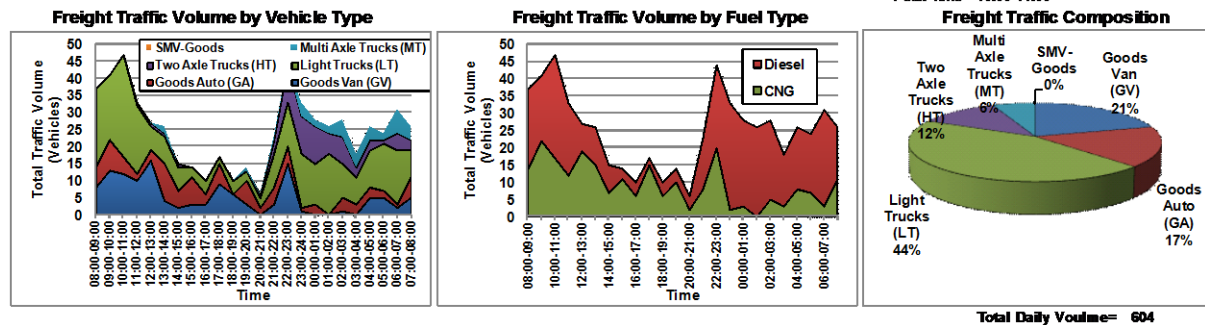


Figure A8.10: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Connaught Place

Table A8.11: Classified Freight Traffic Volume at Chandini Chowk

Location Name: **Chandini Chowk**
Focal Point Code: **FP-11**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	7	10	3	1	0	0	31	1	37	21	69	90	2.0%	153
09:00-10:00	10	37	5	0	1	0	50	11	40	53	101	154	3.4%	272
10:00-11:00	9	41	9	3	3	0	40	29	53	65	122	187	4.1%	322
11:00-12:00	11	31	12	8	1	0	43	26	31	63	100	163	3.6%	280
12:00-13:00	16	75	18	37	1	0	71	32	29	147	132	279	6.2%	501
13:00-14:00	3	110	29	13	0	0	65	28	28	155	121	276	6.1%	498
14:00-15:00	5	127	23	0	2	0	54	28	13	157	95	252	5.6%	463
15:00-16:00	4	85	11	7	0	0	46	24	11	107	81	188	4.2%	347
16:00-17:00	8	41	10	7	0	0	40	21	15	66	76	142	3.1%	252
17:00-18:00	10	49	17	9	0	0	64	7	17	84	88	172	3.8%	310
18:00-19:00	3	50	12	9	3	0	35	9	30	77	74	151	3.3%	274
19:00-20:00	2	36	16	6	0	0	58	9	30	60	97	157	3.5%	280
20:00-21:00	2	26	14	8	1	0	42	9	18	51	69	120	2.7%	215
21:00-22:00	1	64	64	27	3	0	101	27	60	159	188	347	7.7%	602
22:00-23:00	0	71	70	22	8	0	94	0	83	171	167	338	7.5%	587
23:00-24:00	0	32	51	12	3	0	89	8	63	98	160	258	5.7%	443
00:00-01:00	0	28	37	18	1	1	49	0	47	85	96	181	4.0%	312
01:00-02:00	0	16	20	11	10	3	58	1	23	60	82	142	3.1%	274
02:00-03:00	0	15	14	1	13	0	38	0	5	43	43	86	1.9%	171
03:00-04:00	0	13	14	0	17	4	30	0	4	48	34	82	1.8%	178
04:00-05:00	1	0	24	28	11	5	30	0	10	69	40	109	2.4%	217
05:00-06:00	1	19	33	6	12	7	53	0	22	78	75	153	3.4%	297
06:00-07:00	7	43	65	8	16	5	49	0	41	144	90	234	5.2%	418
07:00-08:00	6	44	66	7	13	3	58	5	61	139	124	263	5.8%	456
Total	106	1062	637	248	119	28	1278	275	771	2200	2324	4524	100.0%	8120
Percentage	2.3%	23.5%	14.1%	5.5%	2.6%	0.6%	28.2%	6.1%	17.0%	48.6%	51.4%	100.0%		

Peak Volume= 347
Peak Time= 21:00-22:00

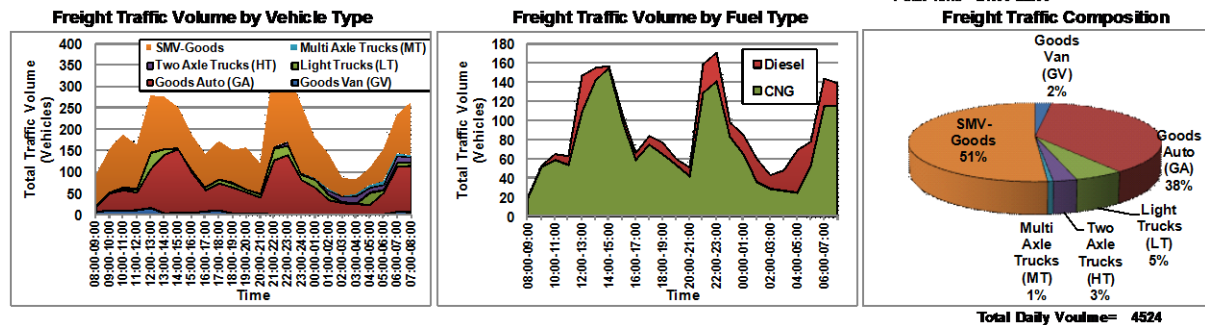


Figure A8.11: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Chandini Chowk

Table A8.12: Classified Freight Traffic Volume at Sarojini Nagar Market

Location Name: **SAROJINI MARKET**
 Focal Point Code: **FP-12**

Date: **19.09.2017 - 20.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	2	7	0	1	0	0	0	0	0	10	0	10	2.8%	18
09:00-10:00	1	6	0	7	1	0	0	0	0	15	0	15	4.2%	30
10:00-11:00	4	11	0	5	3	0	0	0	0	23	0	23	6.5%	46
11:00-12:00	1	15	0	21	1	0	0	0	0	38	0	38	10.7%	76
12:00-13:00	3	23	0	11	0	0	0	0	0	37	0	37	10.5%	72
13:00-14:00	1	13	0	4	0	0	0	0	0	18	0	18	5.1%	35
14:00-15:00	3	13	0	1	0	0	0	0	0	17	0	17	4.8%	32
15:00-16:00	1	8	0	1	0	0	0	0	0	10	0	10	2.8%	19
16:00-17:00	2	3	0	3	0	0	0	0	0	8	0	8	2.3%	14
17:00-18:00	4	5	0	14	0	0	0	0	0	23	0	23	6.5%	43
18:00-19:00	4	8	0	11	0	0	0	0	0	23	0	23	6.5%	43
19:00-20:00	1	8	0	4	0	0	0	0	0	13	0	13	3.7%	25
20:00-21:00	3	5	0	0	0	0	0	0	0	8	0	8	2.3%	14
21:00-22:00	2	1	0	2	0	0	0	0	0	5	0	5	1.4%	8
22:00-23:00	1	3	0	1	0	0	0	0	0	5	0	5	1.4%	9
23:00-24:00	0	3	0	2	0	0	0	0	0	5	0	5	1.4%	10
00:00-01:00	1	2	0	0	0	0	0	0	0	3	0	3	0.8%	5
01:00-02:00	0	6	0	1	0	0	0	0	0	7	0	7	2.0%	14
02:00-03:00	1	11	0	1	0	0	0	0	0	13	0	13	3.7%	25
03:00-04:00	0	5	0	1	1	0	0	0	0	7	0	7	2.0%	15
04:00-05:00	0	9	0	0	2	0	0	0	0	11	0	11	3.1%	24
05:00-06:00	3	3	0	1	5	0	0	0	0	12	0	12	3.4%	27
06:00-07:00	2	3	0	11	4	0	0	0	0	20	0	20	5.6%	42
07:00-08:00	4	1	0	16	2	0	0	0	0	23	0	23	6.5%	45
Total	44	172	0	119	19	0	0	0	0	354	0	354	100%	692
Percentage	12.4%	48.6%	0.0%	33.6%	5.4%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%		

Peak Volume= 38
 Peak Time= 11:00-12:00

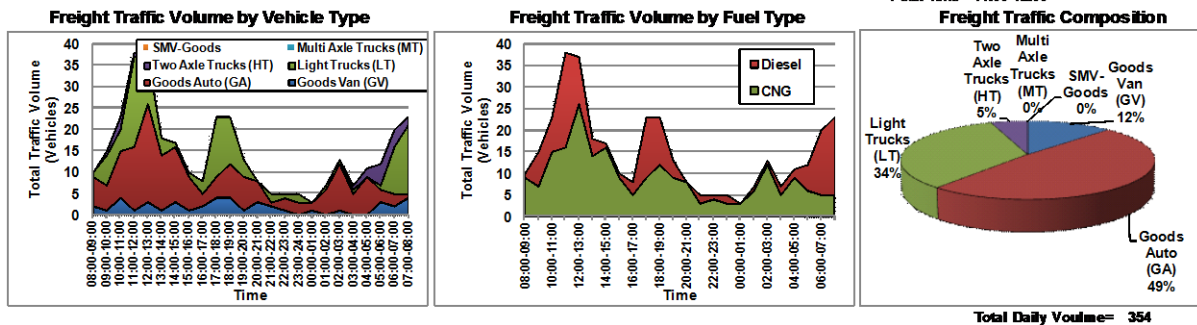


Figure A8.12: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Sarojini Nagar Market

Table A8.13: Classified Freight Traffic Volume at Lajpat Nagar Market

Location Name: **Lajpat Nagar (DNB)**
 Focal Point Code: **FP-13**

Date: **15.09.2017 - 16.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	10	14	0	5	0	8	10	0	0	37	10	47	5.0%	106
09:00-10:00	22	18	0	16	3	1	21	0	0	60	21	81	8.5%	150
10:00-11:00	20	9	0	13	1	2	10	0	0	45	10	55	5.8%	100
11:00-12:00	36	17	0	14	7	1	14	0	0	75	14	89	9.4%	159
12:00-13:00	33	24	0	12	8	7	20	0	0	84	20	104	11.0%	207
13:00-14:00	8	18	0	7	7	7	20	0	0	47	20	67	7.1%	152
14:00-15:00	22	31	0	9	9	0	12	0	0	71	12	83	8.8%	157
15:00-16:00	18	17	0	7	7	4	11	0	0	53	11	64	6.8%	131
16:00-17:00	15	8	0	3	1	6	13	0	0	33	13	46	4.9%	96
17:00-18:00	17	7	0	8	1	3	6	0	0	36	6	42	4.4%	79
18:00-19:00	12	8	0	3	0	1	12	0	0	24	12	36	3.8%	65
19:00-20:00	6	7	0	2	0	1	4	0	0	16	4	20	2.1%	38
20:00-21:00	4	4	0	4	1	0	7	0	0	13	7	20	2.1%	38
21:00-22:00	4	2	0	1	1	0	10	0	0	8	10	18	1.9%	34
22:00-23:00	1	0	0	1	1	0	2	0	0	3	2	5	0.5%	10
23:00-24:00	0	0	0	2	1	0	0	0	0	3	0	3	0.3%	7
00:00-01:00	0	3	0	1	2	0	0	0	0	6	0	6	0.6%	14
01:00-02:00	0	1	0	3	0	0	0	0	0	4	0	4	0.4%	8
02:00-03:00	0	0	0	1	0	0	0	0	0	1	0	1	0.1%	2
03:00-04:00	0	0	0	2	5	2	0	0	0	9	0	9	0.9%	28
04:00-05:00	3	1	0	15	1	0	0	0	0	20	0	20	2.1%	39
05:00-06:00	1	4	0	23	3	2	0	0	0	33	0	33	3.5%	73
06:00-07:00	1	2	0	17	6	0	1	0	0	26	1	27	2.8%	59
07:00-08:00	13	9	0	26	3	0	17	0	0	51	17	68	7.2%	129
Total	246	204	0	195	68	45	190	0	0	758	190	948	100.0%	1880
Percentage	25.9%	21.5%	0.0%	20.6%	7.2%	4.7%	20.0%	0.0%	0.0%	80.0%	20.0%	100.0%		

Peak Volume= 104
 Peak Time= 12:00-13:00

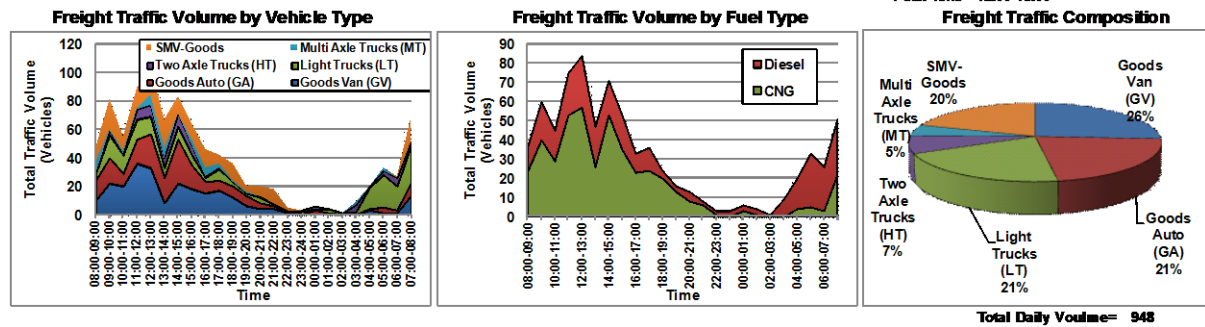


Figure A8.13: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Lajpat Nagar Market

Table A8.14: Classified Freight Traffic Volume at Pitampura Market

Location Name: **PITAMPURA**
Focal Point Code: **FP-14**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	3	5	0	2	0	0	21	0	0	10	21	31	3.3%	60
09:00-10:00	2	3	0	2	1	0	25	0	0	8	25	33	3.5%	65
10:00-11:00	10	15	0	13	1	0	32	0	0	39	32	71	7.6%	135
11:00-12:00	10	34	0	10	1	0	30	0	0	55	30	85	9.1%	163
12:00-13:00	10	26	0	20	3	0	41	0	0	59	41	100	10.7%	195
13:00-14:00	8	19	0	12	1	0	42	0	0	40	42	82	8.8%	159
14:00-15:00	11	28	0	21	0	0	35	0	0	60	35	95	10.2%	181
15:00-16:00	6	30	0	18	2	0	30	0	0	56	30	86	9.2%	169
16:00-17:00	9	30	0	12	1	0	35	0	0	52	35	87	9.3%	168
17:00-18:00	5	20	0	19	1	0	33	0	0	45	33	78	8.3%	153
18:00-19:00	1	11	0	13	0	0	22	0	0	25	22	47	5.0%	93
19:00-20:00	2	12	0	2	2	0	12	0	0	18	12	30	3.2%	60
20:00-21:00	0	6	0	3	0	0	0	0	0	9	0	9	1.0%	18
21:00-22:00	0	13	0	2	3	0	0	0	0	18	0	18	1.9%	39
22:00-23:00	0	1	0	2	2	0	0	0	0	5	0	5	0.5%	12
23:00-24:00	0	1	0	3	0	4	0	0	0	8	0	8	0.9%	26
00:00-01:00	0	1	0	2	1	1	0	0	0	5	0	5	0.5%	14
01:00-02:00	0	0	0	1	2	2	0	0	0	5	0	5	0.5%	17
02:00-03:00	0	0	0	2	2	3	0	0	0	7	0	7	0.7%	24
03:00-04:00	0	1	0	1	1	5	0	0	0	8	0	8	0.9%	30
04:00-05:00	0	3	0	1	1	0	0	0	0	5	0	5	0.5%	11
05:00-06:00	0	1	0	2	5	2	0	0	0	10	0	10	1.1%	30
06:00-07:00	0	3	0	4	2	0	1	0	0	9	1	10	1.1%	22
07:00-08:00	0	4	0	3	2	0	11	0	0	9	11	20	2.1%	42
Total	77	267	0	170	34	17	370	0	0	665	370	935	100%	1885
Percentage	8.2%	28.6%	0.0%	18.2%	3.6%	1.8%	39.6%	0.0%	0.0%	60.4%	39.6%	100.0%		

Peak Volume= 100
Peak Time= 12:00-13:00

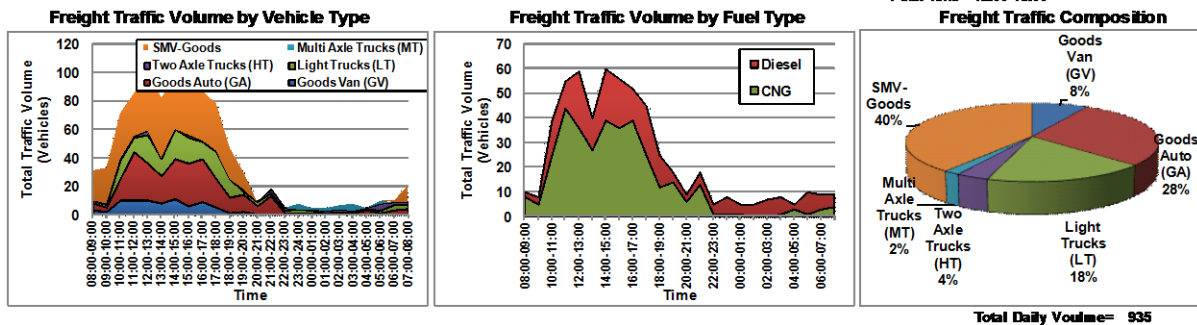


Figure A8.14: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Pitampura Market

Table A8.15: Classified Freight Traffic Volume at Nehru Place

Location Name: **Nehru Place**
Focal Point Code: **FP-15**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	23	11	0	3	0	0	3	0	0	37	3	40	6.9%	62
09:00-10:00	25	12	0	1	3	0	1	0	0	41	1	42	7.2%	67
10:00-11:00	21	25	0	5	0	0	1	0	0	51	1	52	8.9%	87
11:00-12:00	28	65	0	9	5	0	2	0	0	107	2	109	18.7%	201
12:00-13:00	12	33	0	4	2	0	6	0	0	51	6	57	9.8%	106
13:00-14:00	11	32	0	2	1	0	2	0	0	46	2	48	8.2%	88
14:00-15:00	7	19	0	2	0	0	5	0	0	28	5	33	5.7%	60
15:00-16:00	16	21	0	6	0	0	0	0	0	43	0	43	7.4%	73
16:00-17:00	17	29	0	4	0	0	1	0	0	50	1	51	8.8%	88
17:00-18:00	11	27	0	1	1	0	3	0	0	40	3	43	7.4%	78
18:00-19:00	10	11	0	0	1	0	2	0	0	22	2	24	4.1%	41
19:00-20:00	16	19	0	2	0	0	3	0	0	37	3	40	6.9%	67
20:00-21:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
21:00-22:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
22:00-23:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
23:00-24:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
00:00-01:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
01:00-02:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
02:00-03:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
03:00-04:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
04:00-05:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
05:00-06:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
07:00-08:00	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0
Total	197	304	0	39	13	0	29	0	0	553	29	582	100%	1019
Percentage	33.8%	52.2%	0.0%	6.7%	2.2%	0.0%	5.0%	0.0%	0.0%	95.0%	5.0%	100.0%		

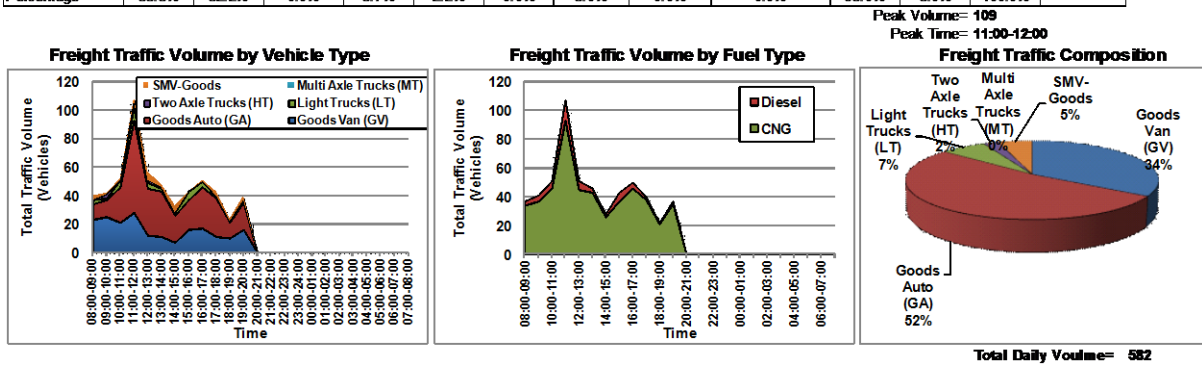


Figure A8.15: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Nehru Place

Table A8.16: Classified Freight Traffic Volume at Gandhi Nagar

Location Name: **GANDHI NAGAR**
Focal Point Code: **FP-16**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	20	12	0	10	0	1	3	0	0	43	3	46	3.1%	79
09:00-10:00	42	35	0	19	3	0	1	0	0	99	1	100	6.7%	169
10:00-11:00	36	62	0	8	0	0	1	0	0	106	1	107	7.2%	185
11:00-12:00	22	43	0	7	4	0	2	0	0	76	2	78	5.3%	142
12:00-13:00	9	59	0	4	2	0	5	0	0	74	5	79	5.3%	153
13:00-14:00	9	31	0	2	1	0	2	0	0	43	2	45	3.0%	84
14:00-15:00	6	39	0	5	0	0	4	0	0	50	4	54	3.6%	103
15:00-16:00	13	45	0	14	0	0	0	0	0	72	0	72	4.8%	134
16:00-17:00	14	45	0	3	0	0	1	0	0	62	1	63	4.2%	115
17:00-18:00	9	26	0	1	1	0	2	0	0	37	2	39	2.6%	72
18:00-19:00	8	9	0	0	1	0	1	0	0	18	1	19	1.3%	33
19:00-20:00	13	16	0	7	0	0	0	0	0	36	0	36	2.4%	62
20:00-21:00	6	10	0	36	0	0	0	0	0	52	0	52	3.5%	99
21:00-22:00	6	6	0	29	0	0	0	0	0	41	0	41	2.8%	77
22:00-23:00	0	10	0	45	13	0	0	0	0	68	0	68	4.6%	149
23:00-24:00	0	17	0	45	14	11	0	0	0	87	0	87	5.9%	216
00:00-01:00	0	8	0	34	7	11	0	0	0	60	0	60	4.0%	155
01:00-02:00	0	7	0	16	8	11	0	0	0	42	0	42	2.8%	120
02:00-03:00	0	9	0	8	3	7	0	0	0	27	0	27	1.8%	75
03:00-04:00	0	8	0	11	15	4	0	0	0	38	0	38	2.6%	101
04:00-05:00	0	8	0	26	9	4	0	0	0	47	0	47	3.2%	113
05:00-06:00	0	22	0	42	14	6	0	0	0	94	0	94	5.7%	197
06:00-07:00	0	33	0	51	15	8	0	0	0	107	0	107	7.2%	249
07:00-08:00	2	39	0	39	9	5	0	0	0	94	0	94	6.3%	208
Total	215	599	0	462	119	68	22	0	0	1463	22	1485	100.0%	3087
Percentage	14.5%	40.3%	0.0%	31.1%	8.0%	4.6%	1.5%	0.0%	0.0%	98.5%	1.5%	100.0%		

Peak Volume= 107
Peak Time= 10:00-11:00

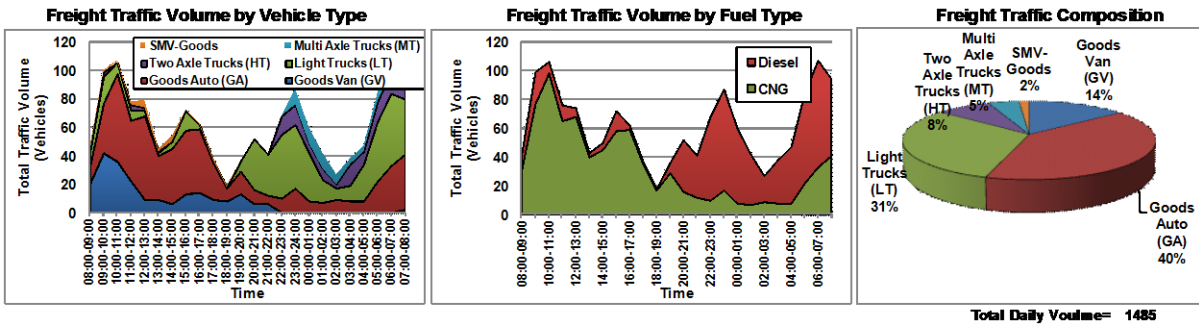


Figure A8.16: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Gandhi Nagar

Table A8.17: Classified Freight Traffic Volume at Rajouri Garden

Location Name: **RAJOURI GARDEN**
Focal Point Code: **FP-17**

Date: **19.09.2017 - 20.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	0	24	0	19	4	0	2	0	0	47	2	49	5.3%	102
09:00-10:00	10	11	0	12	0	0	6	0	0	33	6	39	4.3%	70
10:00-11:00	0	18	0	18	0	0	7	0	0	36	7	43	4.7%	86
11:00-12:00	3	22	0	26	0	0	8	0	0	51	8	59	6.4%	116
12:00-13:00	4	23	0	15	0	1	8	0	0	43	8	51	5.6%	101
13:00-14:00	8	23	0	7	0	0	6	0	0	38	6	44	4.8%	82
14:00-15:00	7	12	0	10	0	0	6	0	0	29	6	35	3.8%	64
15:00-16:00	9	11	0	11	0	0	6	0	0	31	6	37	4.0%	67
16:00-17:00	9	12	0	8	0	0	7	0	0	29	7	36	3.9%	65
17:00-18:00	6	9	0	7	0	0	0	0	0	22	0	22	2.4%	39
18:00-19:00	9	13	0	7	0	0	5	0	0	29	5	34	3.7%	61
19:00-20:00	8	15	0	9	0	0	5	0	0	32	5	37	4.0%	68
20:00-21:00	9	11	0	20	0	0	0	0	0	40	0	40	4.4%	73
21:00-22:00	3	5	0	20	0	0	2	0	0	28	2	30	3.3%	58
22:00-23:00	6	5	0	26	0	0	1	0	0	37	1	38	4.1%	71
23:00-24:00	5	7	0	15	0	1	2	0	0	28	2	30	3.3%	59
00:00-01:00	3	7	0	14	0	3	2	0	0	27	2	29	3.2%	63
01:00-02:00	2	8	0	22	0	2	4	0	0	34	4	38	4.1%	79
02:00-03:00	0	9	0	16	0	7	0	0	0	32	0	32	3.5%	62
03:00-04:00	2	8	0	19	0	3	2	0	0	32	2	34	3.7%	74
04:00-05:00	4	11	0	12	1	3	2	0	0	31	2	33	3.6%	71
05:00-06:00	3	20	0	12	8	2	2	0	0	45	2	47	5.1%	105
06:00-07:00	4	9	0	12	8	0	3	0	0	33	3	36	3.9%	77
07:00-08:00	2	8	0	24	4	0	5	0	0	38	5	43	4.7%	88
Total	116	301	0	361	25	22	91	0	0	826	91	916	100%	1819
Percentage	12.7%	32.9%	0.0%	39.4%	2.7%	2.4%	9.9%	0.0%	0.0%	90.1%	9.9%	100.0%		

Peak Volume= 59
Peak Time= 11:00-12:00

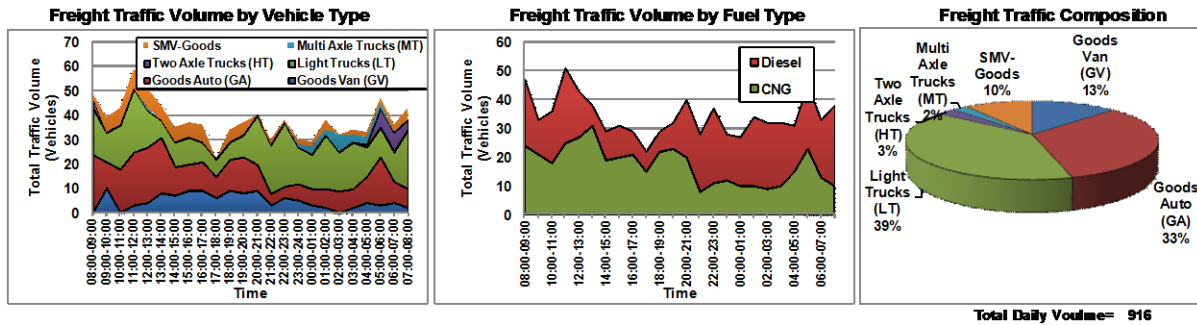


Figure A8.17: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajouri Garden

Table A8.18: Classified Freight Traffic Volume at Narela

Location Name: **NARELA FOOD GRAIN** Date: **19.09.2017 - 20.09.2017**
 Focal Point Code: **FP-18**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	2	3	1	4	5	10	0	0	0	25	0	25	2.4%	78
09:00-10:00	6	1	0	2	1	4	0	0	0	14	0	14	1.3%	34
10:00-11:00	2	2	0	1	4	7	0	0	0	16	0	16	1.5%	52
11:00-12:00	1	4	0	2	4	3	0	0	0	14	0	14	1.3%	39
12:00-13:00	3	3	0	2	4	4	0	0	0	16	0	16	1.5%	44
13:00-14:00	0	3	0	2	3	3	0	0	0	11	0	11	1.1%	33
14:00-15:00	3	2	0	2	1	4	0	0	0	12	0	12	1.2%	33
15:00-16:00	3	2	1	3	3	1	0	0	0	13	0	13	1.2%	28
16:00-17:00	0	0	2	3	2	6	0	0	0	13	0	13	1.2%	41
17:00-18:00	3	4	0	3	2	4	0	0	0	16	0	16	1.5%	42
18:00-19:00	3	2	0	2	3	5	0	0	0	15	0	15	1.4%	43
19:00-20:00	3	3	0	2	3	3	0	0	0	14	0	14	1.3%	36
20:00-21:00	3	4	1	3	3	3	0	0	0	17	0	17	1.6%	41
21:00-22:00	3	4	0	17	3	1	0	0	0	28	0	28	2.7%	59
22:00-23:00	1	2	0	21	2	6	0	0	0	32	0	32	3.1%	80
23:00-24:00	3	4	0	28	3	19	0	0	0	57	0	57	5.5%	162
00:00-01:00	0	20	0	27	9	26	0	0	0	82	0	82	7.9%	238
01:00-02:00	0	23	3	36	32	17	0	0	0	111	0	111	10.6%	294
02:00-03:00	0	27	0	38	8	30	0	0	0	103	0	103	9.9%	289
03:00-04:00	0	22	3	30	14	25	0	0	0	94	0	94	9.0%	262
04:00-05:00	0	38	0	11	19	35	0	0	0	103	0	103	9.9%	313
05:00-06:00	0	29	6	15	5	12	0	0	0	66	0	66	6.3%	162
06:00-07:00	1	18	11	26	7	5	0	0	0	68	0	68	6.5%	146
07:00-08:00	9	29	9	21	25	10	0	0	0	103	0	103	9.9%	242
Total	49	248	37	301	165	243	0	0	0	1043	0	1043	100%	2790
Percentage	4.7%	23.8%	3.5%	28.9%	15.8%	23.3%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%		

Peak Volume= 111
Peak Time= 01:00-02:00

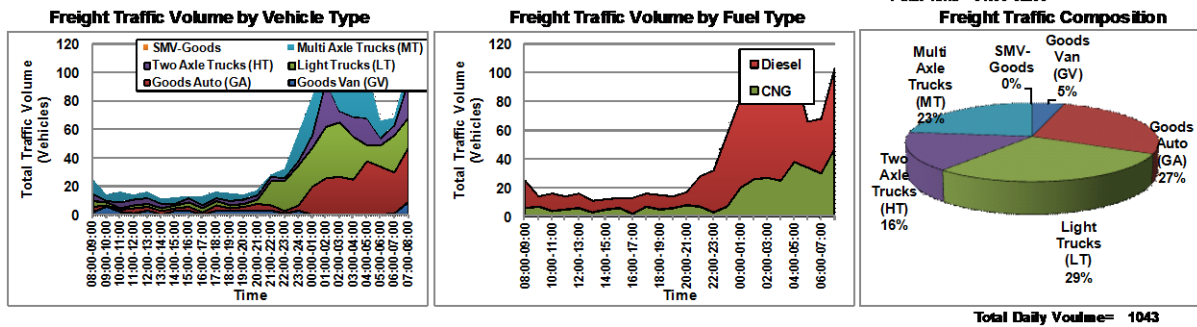


Figure A8.18: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Narela

Table A8.19: Classified Freight Traffic Volume at Najafgarh

Location Name: **NAZAFGARH**
Focal Point Code: **FP-19**

Date: **18.07.2017 - 19.07.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	7	10	0	13	3	4	0	0	0	37	0	37	3.7%	81
09:00-10:00	9	27	0	19	1	2	0	0	0	58	0	58	5.8%	115
10:00-11:00	4	14	0	21	3	1	0	0	0	43	0	43	4.3%	98
11:00-12:00	3	16	0	20	0	0	0	0	0	39	0	39	3.9%	76
12:00-13:00	8	17	0	24	5	5	0	0	0	59	0	59	5.9%	129
13:00-14:00	7	18	0	17	5	3	0	0	0	50	0	50	5.0%	107
14:00-15:00	11	6	0	12	6	4	0	0	0	39	0	39	3.9%	85
15:00-16:00	8	5	0	13	2	3	0	0	0	31	0	31	3.1%	65
16:00-17:00	12	4	0	17	2	4	0	0	0	39	0	39	3.9%	80
17:00-18:00	8	2	0	10	3	6	0	0	0	29	0	29	2.9%	70
18:00-19:00	6	5	0	4	3	4	0	0	0	22	0	22	2.2%	52
19:00-20:00	13	5	0	4	7	4	0	0	0	33	0	33	3.3%	73
20:00-21:00	10	9	0	9	0	0	0	0	0	28	0	28	2.8%	48
21:00-22:00	7	9	0	8	1	1	0	0	0	26	0	26	2.6%	50
22:00-23:00	1	1	0	2	2	0	0	0	0	6	0	6	0.6%	13
23:00-24:00	3	0	0	7	3	1	0	0	0	14	0	14	1.4%	31
00:00-01:00	6	2	0	14	6	0	0	0	0	28	0	28	2.8%	57
01:00-02:00	3	1	0	8	13	0	0	0	0	25	0	25	2.5%	61
02:00-03:00	0	3	0	21	17	14	0	0	0	55	0	55	5.5%	162
03:00-04:00	8	5	0	25	21	10	0	0	0	69	0	69	6.9%	178
04:00-05:00	0	9	0	24	8	14	0	0	0	55	0	55	5.5%	153
05:00-06:00	3	4	0	18	20	12	0	0	0	57	0	57	5.7%	162
06:00-07:00	2	12	0	20	36	17	0	0	0	87	0	87	8.7%	251
07:00-08:00	6	17	0	13	23	10	0	0	0	69	0	69	6.9%	181
Total	145	201	0	343	190	119	0	0	0	998	0	998	100%	2368
Percentage	14.5%	20.1%	0.0%	34.4%	19.0%	11.9%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%		

Peak Volume= 87
Peak Time= 06:00-07:00

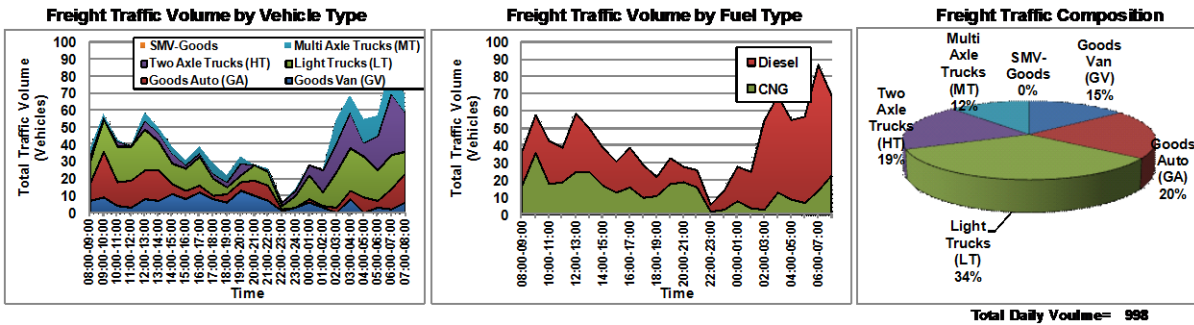


Figure A8.19: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Najafgarh

Table A8.20: Classified Freight Traffic Volume at Keshopur Sabzi Mandi

Location Name: **Keshopur Sabzi Mandi Gate No. 1**
 Focal Point Code: **FP-20**

Date: **14.09.2017 - 15.09.2017**

Time	Goods Van (GV)	Goods Auto (GA)	E-Rickshaw (EA) Goods	Light Trucks (LT)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Hand Cart (HC)	Animal Cart (AC)	Cycle Rickshaws and Other (CY SMV) Goods	Total FMV - Goods	Total SMV - Goods	Total Vehicles - Goods	Percentage	PCU
08:00-09:00	2	56	0	51	0	0	70	0	0	109	70	179	6.3%	356
09:00-10:00	11	64	0	37	2	0	122	0	0	114	122	236	8.3%	465
10:00-11:00	16	57	0	30	8	2	85	0	0	113	85	198	7.0%	396
11:00-12:00	8	62	0	33	3	2	133	0	0	108	133	241	8.5%	484
12:00-13:00	0	65	0	13	3	0	76	0	0	81	76	157	5.5%	317
13:00-14:00	2	52	0	21	3	4	75	0	0	82	75	157	5.5%	325
14:00-15:00	2	32	0	11	5	0	47	0	0	50	47	97	3.4%	197
15:00-16:00	3	8	0	13	0	0	16	0	0	24	16	40	1.4%	78
16:00-17:00	8	23	0	18	3	0	38	0	0	52	38	90	3.2%	177
17:00-18:00	0	4	0	3	0	0	19	0	0	7	19	26	0.9%	52
18:00-19:00	0	9	0	16	2	0	24	0	0	27	24	51	1.8%	104
19:00-20:00	0	20	0	5	2	0	37	0	0	27	37	64	2.3%	130
20:00-21:00	0	12	0	14	0	38	0	0	0	64	0	64	2.3%	223
21:00-22:00	0	19	0	5	10	4	14	0	0	38	14	52	1.8%	124
22:00-23:00	0	14	0	6	10	15	5	0	0	45	5	50	1.8%	148
23:00-24:00	0	19	0	12	8	9	6	0	0	48	6	54	1.9%	139
00:00-01:00	0	18	0	19	14	9	0	0	0	60	0	60	2.1%	157
01:00-02:00	0	10	0	15	17	2	1	0	0	44	1	45	1.6%	112
02:00-03:00	0	10	0	23	11	1	1	0	0	45	1	46	1.6%	106
03:00-04:00	0	12	0	21	15	21	21	0	0	69	21	90	3.2%	248
04:00-05:00	0	17	0	39	29	13	28	0	0	98	28	126	4.4%	314
05:00-06:00	0	51	0	37	13	5	79	0	0	106	79	185	6.5%	396
06:00-07:00	1	61	0	54	18	1	92	0	0	135	92	227	8.0%	474
07:00-08:00	8	85	0	68	14	0	125	0	0	175	125	300	10.6%	608
Total	61	780	0	564	190	126	1114	0	0	1721	1114	2835	100%	6126
Percentage	2.2%	27.5%	0.0%	19.9%	6.7%	4.4%	39.3%	0.0%	0.0%	60.7%	39.3%	100.0%		

Peak Volume= 300
 Peak Time= 07:00-08:00

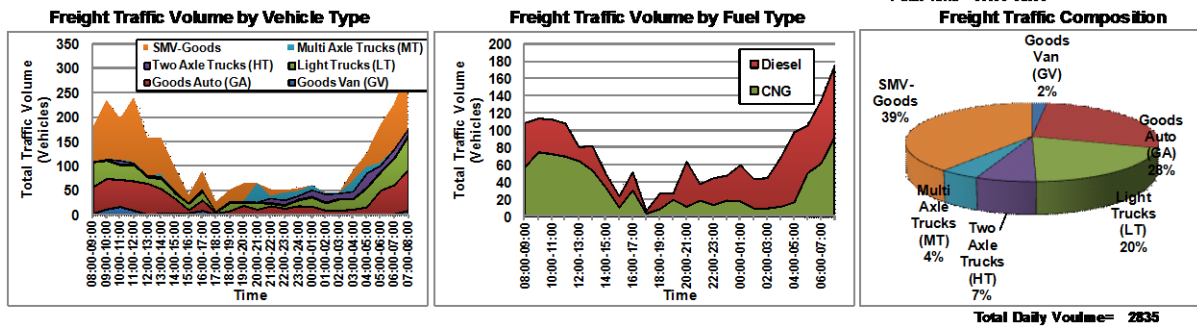


Figure A8.20: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Keshopur Sabzi Mandi

Appendix 9

Table A9.1: Classified Traffic Volume at Rajghat on Ring Road

Road Name: Ring Road Location: Rajghat Date: 9/7/2017
Mid Block: MB-01

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/Good s Va (GAV)	Light Commercial Vehicles	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1066	321	630	88	27	1663	65	13	1	2	31	21	3876	52	3928	2.8%	3884
09:00-10:00	2465	683	1020	113	60	3945	164	21	13	4	96	47	8488	143	8631	6.2%	8243
10:00-11:00	2975	939	1558	108	34	3478	188	25	7	8	86	45	9320	131	9451	6.8%	9271
11:00-12:00	2845	1028	2107	103	17	3290	300	41	12	1	77	49	9744	126	9870	7.1%	9876
12:00-13:00	2650	846	1855	95	17	2561	349	41	13	5	45	75	8432	120	8552	6.2%	8743
13:00-14:00	2628	758	2189	93	28	2401	416	28	14	6	36	58	8561	94	8655	6.3%	8989
14:00-15:00	2937	574	2077	58	12	2409	419	42	16	5	46	67	8549	113	8662	6.3%	8894
15:00-16:00	2270	505	1740	61	11	2973	394	47	17	7	71	71	8025	142	8167	5.9%	8184
16:00-17:00	2788	762	2111	63	5	3646	377	32	14	7	73	68	9805	141	9946	7.2%	9842
17:00-18:00	3128	853	1730	68	12	5118	210	24	12	7	180	83	11162	263	11425	8.3%	10757
18:00-19:00	3426	900	1664	77	14	5564	197	21	8	56	257	66	11927	323	12250	8.9%	11585
19:00-20:00	3223	1126	1921	59	7	3436	215	45	26	76	187	50	10134	237	10371	7.5%	10401
20:00-21:00	2278	606	1296	46	4	3371	305	66	101	69	23	38	8142	61	8203	5.9%	8352
21:00-22:00	1228	523	906	19	0	1980	275	95	53	69	4	34	5148	38	5186	3.7%	5458
22:00-23:00	629	363	409	8	3	1061	180	130	38	43	0	17	2864	17	2881	2.1%	3107
23:00-24:00	460	355	331	9	2	406	91	153	120	71	1	6	1998	7	2005	1.4%	2603
00:00-01:00	356	255	206	7	2	176	46	107	84	107	0	1	1346	1	1347	1.0%	1980
01:00-02:00	211	208	107	10	1	46	20	88	98	111	0	0	900	0	900	0.7%	1569
02:00-03:00	90	175	95	7	1	35	31	110	140	101	0	0	785	0	785	0.6%	1514
03:00-04:00	85	158	106	7	0	13	3	80	114	150	0	0	716	0	716	0.5%	1542
04:00-05:00	153	102	131	20	0	78	17	69	87	166	1	4	823	5	828	0.6%	1674
05:00-06:00	262	106	161	30	3	298	50	43	61	86	4	8	1100	12	1112	0.8%	1604
06:00-07:00	454	265	398	48	5	361	149	39	96	45	27	39	1860	66	1926	1.4%	2466
07:00-08:00	595	245	522	71	3	764	125	34	33	9	68	42	2401	110	2511	1.8%	2733
Total	39202	12656	25270	1268	268	49073	4586	1394	1178	1211	1313	889	136106	2202	138308	100.0%	143270
Percentage	28.3%	9.2%	18.3%	0.9%	0.2%	35.5%	3.3%	1.0%	0.9%	0.9%	0.9%	0.6%	98.4%	1.6%	100.0%		

Peak Volume= 12250
Peak Time= 18:00-19:00

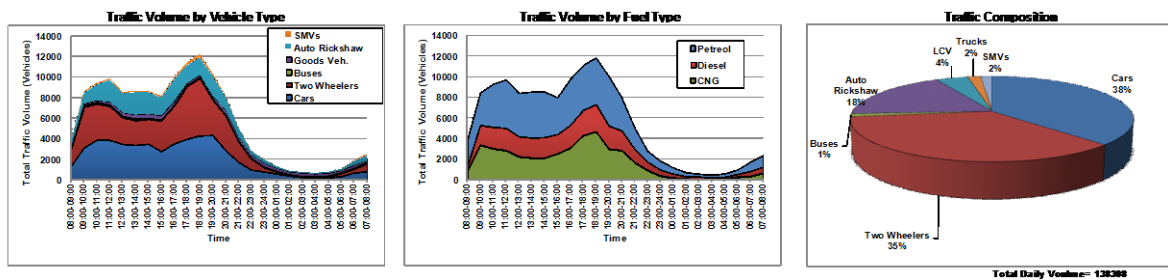


Figure A9.1: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Rajghat on Ring Road

Table A9.2: Classified Traffic Volume at Rajghat at Connaught Place (Regal Cinema)

Road Name: **Connaught Place** Location: **Regal Cinema(CP)** Date: **9/11/2017**
 Mid Block: **MB-02**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/Goods Va (GAV)	Light Commercial Vehicles (LCV)	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other (CRO)	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	859	212	541	255	2	691	4	8	0	0	35	8	2572	43	2615	4.1%	3055
09:00-10:00	1411	227	1059	272	5	1299	9	4	3	0	57	17	4289	74	4363	6.9%	4792
10:00-11:00	1354	258	1186	269	3	1096	5	4	3	0	32	3	4178	35	4213	6.6%	4713
11:00-12:00	1362	420	1011	507	2	1298	16	9	7	1	22	10	4633	32	4665	7.3%	5583
12:00-13:00	1568	409	901	458	5	894	21	3	3	0	31	2	4262	33	4295	6.7%	5176
13:00-14:00	1089	313	699	235	6	718	13	5	6	1	34	1	3085	35	3120	4.9%	3564
14:00-15:00	1276	388	779	179	1	1045	10	8	3	0	37	1	3689	38	3727	5.9%	3978
15:00-16:00	1493	329	765	109	4	1412	24	7	7	0	37	3	4150	40	4190	6.6%	4225
16:00-17:00	1680	421	826	151	3	1174	27	3	1	0	48	4	4286	52	4338	6.8%	4510
17:00-18:00	1581	384	956	269	1	1044	8	8	1	0	31	5	4252	36	4288	6.7%	4754
18:00-19:00	1706	468	971	272	1	1365	18	6	0	0	20	8	4807	28	4835	7.6%	5239
19:00-20:00	1400	578	848	306	1	1229	20	6	0	0	30	9	4388	39	4427	7.0%	4905
20:00-21:00	717	374	362	254	2	917	13	2	1	0	26	0	2642	26	2668	4.2%	3018
21:00-22:00	684	221	311	84	1	484	2	1	2	1	23	4	1791	27	1818	2.9%	1928
22:00-23:00	599	204	282	43	1	406	3	3	2	0	9	4	1543	13	1556	2.4%	1602
23:00-24:00	820	188	312	15	0	232	11	10	7	2	12	2	1597	14	1611	2.5%	1672
00:00-01:00	460	173	238	9	0	137	1	7	6	2	1	0	1033	1	1034	1.6%	1088
01:00-02:00	259	121	171	6	0	87	0	2	1	0	0	0	647	0	647	1.0%	674
02:00-03:00	232	77	91	6	0	75	0	0	1	1	0	0	483	0	483	0.8%	500
03:00-04:00	169	46	68	2	0	63	3	13	8	2	0	0	374	0	374	0.6%	407
04:00-05:00	228	57	199	9	0	70	12	14	6	1	0	2	596	2	598	0.9%	668
05:00-06:00	445	97	274	34	2	106	3	1	1	2	5	0	965	5	970	1.5%	1077
06:00-07:00	386	146	216	107	9	165	1	3	0	1	21	1	1034	22	1056	1.7%	1276
07:00-08:00	610	195	284	209	16	417	3	3	0	0	8	0	1737	8	1745	2.7%	2131
Total	22388	6306	13350	4060	65	16424	227	130	69	14	519	84	63033	603	63636	100.0%	70533
Percentage	35.2%	9.9%	21.0%	6.4%	0.1%	25.8%	0.4%	0.2%	0.1%	0.0%	0.8%	0.1%	99.1%	0.9%	100.0%		

Peak Volume= 4835
 Peak Time=18:00-19:00

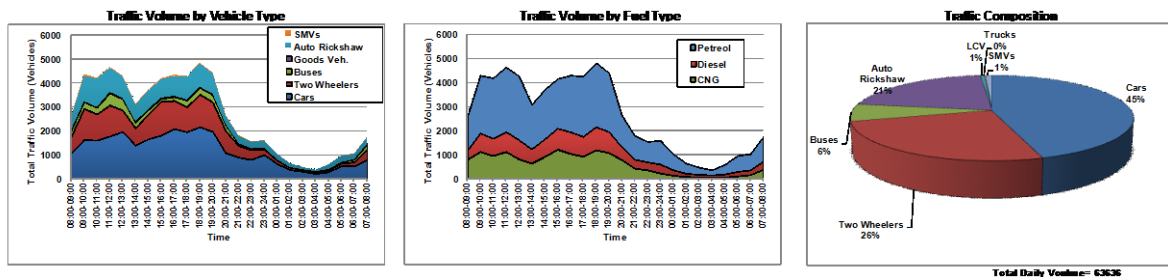


Figure A9.2: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Connaught Place (Regal Cinema)

Table A9.3: Classified Traffic Volume at Rajghat at Naraina (Ring Road)

Road Name: **Ring Road** Location: **Naraina** Date: **9/7/2017**
 Mid Block: **MB-03**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/Goods Va (GAV)	Light Commercial Vehicles	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	3438	766	290	195	43	1434	201	59	91	17	244	13	6534	257	6791	3.6%	7180
09:00-10:00	4643	1038	336	168	22	3646	161	90	110	13	131	19	10227	150	10377	5.5%	10226
10:00-11:00	4898	1057	460	245	21	5523	221	120	129	11	71	16	12685	87	12772	6.8%	12434
11:00-12:00	4009	1094	544	216	4	4217	426	145	266	18	89	23	10939	112	11051	5.9%	11389
12:00-13:00	3956	928	582	204	7	3148	531	375	352	41	91	12	10124	103	10227	5.5%	11232
13:00-14:00	2447	1077	602	225	7	3139	498	366	268	33	59	8	8662	67	8729	4.7%	9580
14:00-15:00	2599	1378	619	224	8	3375	427	294	197	19	26	15	9140	41	9181	4.9%	9733
15:00-16:00	3161	1456	727	203	11	3242	527	347	259	18	20	14	9951	34	9985	5.3%	10752
16:00-17:00	2915	1296	673	209	11	3357	473	332	192	16	23	9	9474	32	9506	5.1%	10066
17:00-18:00	4596	1650	698	219	17	3950	302	164	54	8	78	17	11658	95	11753	6.3%	11699
18:00-19:00	7636	2229	761	195	45	3875	196	166	54	7	128	4	15164	132	15296	8.2%	15166
19:00-20:00	7531	2323	718	321	33	3845	330	264	65	20	74	5	15450	79	15529	8.3%	15849
20:00-21:00	6036	1153	773	299	51	2579	417	179	120	79	30	6	11686	36	11722	6.3%	12683
21:00-22:00	3101	872	378	167	17	2087	381	248	169	164	53	0	7584	53	7637	4.1%	8742
22:00-23:00	3227	619	202	96	22	1105	290	227	248	164	10	2	6200	12	6212	3.3%	7515
23:00-24:00	1130	655	96	37	12	604	276	418	406	478	3	1	4112	4	4116	2.2%	6901
00:00-01:00	1388	518	80	5	2	235	143	321	398	533	2	1	3623	3	3626	1.9%	6488
01:00-02:00	786	301	63	5	3	62	231	293	355	427	0	0	2526	0	2526	1.3%	5003
02:00-03:00	750	149	58	0	0	47	230	245	315	414	2	0	2208	2	2210	1.2%	4525
03:00-04:00	680	175	71	3	2	185	343	300	340	424	3	0	2523	3	2526	1.3%	4986
04:00-05:00	720	345	77	17	7	128	253	278	326	396	1	2	2547	3	2550	1.4%	4878
05:00-06:00	930	569	64	65	12	245	237	239	273	263	6	5	2897	11	2908	1.6%	4706
06:00-07:00	1335	674	102	155	41	654	329	345	257	121	17	10	4013	27	4040	2.2%	5519
07:00-08:00	2436	1103	261	171	50	1035	384	271	184	41	21	5	5936	26	5962	3.2%	6978
Total	74348	23425	9235	3644	448	51717	7807	6086	5428	3725	1182	187	185863	1369	187232	100.0%	214228
Percentage	39.7%	12.5%	4.9%	1.9%	0.2%	27.6%	4.2%	3.3%	2.9%	2.0%	0.6%	0.1%	99.3%	0.7%	100.0%		

Peak Volume= **15529**
 Peak Time=**19:00-20:00**

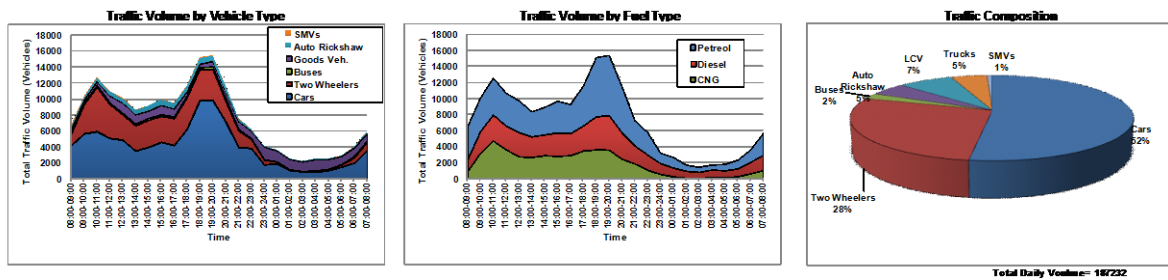


Figure A9.3: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Naraina (Ring Road)

Table A9.4: Classified Traffic Volume on ITO Bridge

Road Name: ITO Barrage Bridge Location: ITO Date: 9/8/2017
Mod Block MB-04

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/Goods Va (GAV)	Light Commercial Vehicles	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	1334	183	392	238	6	987	15	6	3	1	96	18	3165	114	3279	1.9%	3574
09:00-10:00	3969	378	740	202	4	3322	52	13	1	0	275	31	8681	306	8987	5.1%	8625
10:00-11:00	5291	619	960	267	10	5294	48	44	0	2	213	20	12535	233	12768	7.3%	12137
11:00-12:00	4467	938	1027	224	5	4262	76	44	1	1	96	14	11045	110	11155	6.4%	10772
12:00-13:00	4288	966	1170	221	8	2516	91	47	2	1	89	16	9310	105	9415	5.4%	9510
13:00-14:00	3558	856	1120	265	3	2663	144	81	4	0	35	23	8694	58	8752	5.0%	8958
14:00-15:00	4262	870	1068	181	8	2932	138	114	3	0	39	14	9576	53	9629	5.5%	9599
15:00-16:00	5096	902	920	200	14	3622	142	97	5	0	67	22	10998	89	11087	6.3%	10887
16:00-17:00	6196	925	820	273	8	4161	172	86	4	0	77	17	12645	94	12739	7.3%	12524
17:00-18:00	7977	1017	887	288	9	4014	100	57	2	0	181	15	14351	196	14547	8.3%	14305
18:00-19:00	9452	1282	881	261	8	4656	41	14	4	0	168	19	16599	187	16786	9.6%	16289
19:00-20:00	6480	1128	791	183	4	4713	26	19	36	2	169	27	13382	196	13578	7.7%	12958
20:00-21:00	3895	779	597	143	10	3030	78	43	33	10	95	5	8418	100	8518	4.9%	8292
21:00-22:00	3045	883	685	114	13	2075	43	48	47	19	36	0	6972	36	7008	4.0%	7055
22:00-23:00	2371	780	518	91	3	1049	37	89	79	21	37	0	5038	37	5075	2.9%	5377
23:00-24:00	1599	589	481	35	1	860	40	73	116	29	16	0	3823	16	3839	2.2%	4173
00:00-01:00	976	502	430	9	1	768	26	54	91	61	4	0	2918	4	2922	1.7%	3269
01:00-02:00	805	272	319	6	1	369	28	164	142	44	0	0	2150	0	2150	1.2%	2669
02:00-03:00	771	158	215	6	1	271	17	95	190	38	0	0	1762	0	1762	1.0%	2319
03:00-04:00	695	133	153	9	0	143	12	99	172	70	0	0	1486	0	1486	0.8%	2143
04:00-05:00	778	128	198	26	1	131	0	84	147	79	0	0	1572	0	1572	0.9%	2244
05:00-06:00	1008	156	371	75	7	139	33	147	242	35	24	0	2213	24	2237	1.3%	3118
06:00-07:00	1592	201	462	154	13	557	48	76	135	3	59	13	3241	72	3313	1.9%	3907
07:00-08:00	1106	299	366	254	12	712	50	53	77	1	67	27	2930	94	3024	1.7%	3628
Total	80811	14944	15571	3725	150	53246	1457	1647	1536	417	1843	281	173504	2124	175628	100.0%	178333
Percentage	46.0%	8.5%	8.9%	2.1%	0.1%	30.3%	0.8%	0.9%	0.9%	0.2%	1.0%	0.2%	98.8%	1.2%	100.0%		

Peak Volume= 16786
Peak Time=18:00-19:00

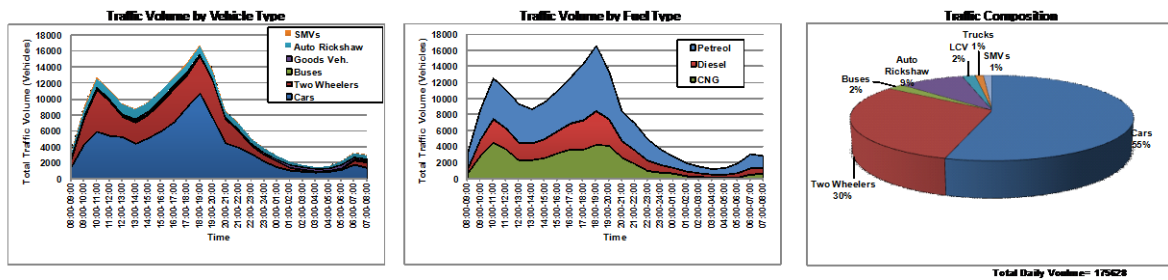


Figure A9.4: Hourly Distribution of Classified Traffic Volume and Traffic Composition on ITO Bridge

Table A9.5: Classified Traffic Volume at Toll Plaza on NH -24 Bypass

Road Name: **NH 24** Location: **UP & UK RTO Toll Tax** Date: **9/8/2017**
 Mid Block: **MB-05**

Time	Small Cars	Big Cars	Auto	Buses	Mini Bus	Two Wheeler	Goods Auto/Goods Va (GAV)	Light Commercial Vehicles	Two Axle Trucks (HT)	Multi Axle Trucks (MT)	Cycle (CYC)	Cycle Rickshaws and Other	Total FMV	Total SMV	Grand Total	Percentage	PCU
08:00-09:00	3889	421	495	156	122	2092	6	27	6	8	179	7	7222	186	7408	5.1%	7389
09:00-10:00	5621	875	566	292	206	2019	7	17	18	4	133	14	9625	147	9772	6.8%	10173
10:00-11:00	4994	867	483	247	209	2065	24	10	12	2	83	3	8913	86	8999	6.2%	9290
11:00-12:00	4119	947	544	198	181	1900	96	64	44	13	36	3	8106	39	8145	5.6%	8553
12:00-13:00	3308	982	601	210	150	1504	171	183	105	22	45	7	7236	52	7288	5.0%	8047
13:00-14:00	2903	830	537	219	211	1430	157	163	66	15	14	4	6531	18	6549	4.5%	7287
14:00-15:00	2520	780	508	231	180	1488	186	140	93	18	29	10	6144	39	6183	4.3%	6957
15:00-16:00	3282	775	667	160	137	1405	214	149	78	18	15	10	6885	25	6910	4.8%	7547
16:00-17:00	3270	815	660	195	154	1356	156	118	53	8	34	8	6785	42	6827	4.7%	7422
17:00-18:00	4083	844	774	187	171	1740	147	165	64	7	40	10	8182	50	8232	5.7%	8790
18:00-19:00	4244	782	639	204	182	2107	170	148	10	8	53	4	8494	57	8551	5.9%	8925
19:00-20:00	3908	976	457	263	180	2013	109	134	4	1	26	1	8045	27	8072	5.6%	8487
20:00-21:00	3920	887	852	209	78	2279	235	175	8	4	10	0	8647	10	8657	6.0%	8984
21:00-22:00	3226	721	705	168	41	1547	265	141	44	32	9	5	6890	14	6904	4.8%	7436
22:00-23:00	2791	539	426	101	10	935	96	151	129	101	11	6	5279	17	5296	3.7%	6082
23:00-24:00	1989	583	275	45	12	287	139	362	487	318	0	3	4497	3	4500	3.1%	6924
00:00-01:00	1371	475	255	26	6	111	107	378	571	502	0	1	3802	1	3803	2.6%	7026
01:00-02:00	968	316	145	3	0	111	86	447	619	607	0	1	3302	1	3303	2.3%	6940
02:00-03:00	478	215	97	17	1	88	64	340	520	585	0	0	2405	0	2405	1.7%	5727
03:00-04:00	417	178	153	22	6	206	26	322	423	390	0	0	2143	0	2143	1.5%	4557
04:00-05:00	399	213	164	31	5	256	32	235	388	395	8	0	2118	8	2126	1.5%	4450
05:00-06:00	933	411	242	45	5	362	82	199	295	228	4	3	2802	7	2809	1.9%	4390
06:00-07:00	1345	430	497	102	16	956	109	235	217	197	60	1	4104	61	4165	2.9%	5511
07:00-08:00	2608	438	523	109	32	1142	108	201	70	146	70	13	5377	83	5460	3.8%	6306
Total	66586	15300	11265	3440	2295	29399	2792	4504	4324	3629	859	114	143534	973	144507	100.0%	173210
Percentage	46.1%	10.6%	7.8%	2.4%	1.6%	20.3%	1.9%	3.1%	3.0%	2.5%	0.6%	0.1%	99.3%	0.7%	100.0%		

Peak Volume= **9772**
 Peak Time=**09:00-10:00**

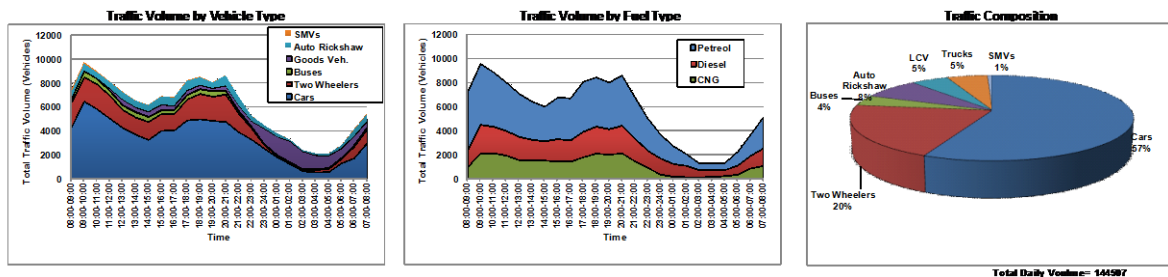


Figure A9.5: Hourly Distribution of Classified Traffic Volume and Traffic Composition at Toll Plaza on NH -24 Bypass

Appendix 10

Zone ID	Zone Name	Population (2011) in '000	Area (Km ²)	Zone ID	Zone Name	Population (2011) in '000	Area (Km ²)
1	Narela	41912	8.41	181	Khanpur	76517	3.31
2	Bankner	43928	17.10	182	Ambedkar nagar	51800	0.50
3	Alipur	29634	7.86	183	Madangir	54483	0.47
4	Bakhtawar pur	89451	56.03	184	Pushp vihar	46652	1.82
5	Bhalswa jahangir pur	58228	8.93	185	Tughlakabad extn.	50911	2.27
6	Mukund pur	92583	5.63	186	Sangam vihar west	46346	2.97
7	Burari	77533	19.48	187	Sangam vihar central	45811	1.68
8	Jharoda	82019	12.29	188	Sangam vihar east	48978	4.16
9	Malka ganj	74583	0.91	189	Chirag Delhi	50500	2.40
10	Timar pur	66949	4.42	190	Chitranjan park	63595	2.15
11	Mukaherjee nagar	60832	2.61	191	Shahpur jat	66565	4.17
12	G.T.B. nagar	54219	2.81	192	Greater kailash I	52498	3.87
13	Dhir pur	15151	4.54	193	Srinivaspuri	57154	4.03
14	Adarsh	64635	1.29	194	East of kailash	45941	2.82
15	Sarai pipal thala	54478	1.83	195	Govind puri	57441	0.49
16	Jahangir puri-1	54478	0.63	196	Kalkaji	60119	1.11
17	Samaypur badli	54517	3.07	197	Tughlakabad	19229	3.64
18	Libas pur	76100	6.04	198	Pul pehlad	50725	3.08
19	Bhalswa	78176	3.41	199	Tekhhand	47535	2.37
20	Jahangir puri-ii	63284	0.57	200	Harkesh nagar	52773	2.23
21	Rohini sec 16, 17	63114	2.23	201	Jaitpur	86765	2.97
22	Rithala	59747	2.05	202	Meetheypur	67294	3.00
23	Budh vihar	73589	1.91	203	Badarpur	57479	2.38
24	Vijay vihar	63377	1.88	204	Molarband	64789	1.25
25	Puth kalan	65000	1.18	205	Zakir nagar	63006	3.00
26	Sahibabad dault pur	12362	1.83	206	Okhla	35129	2.15
27	Begumpur	50000	34.45	207	Madanpur khadar	36953	4.90
28	Bawana	175000	56.56	208	Sarita vihar	35508	3.70
29	Karala	65000	33.30	209	Mayur vihar phase-I	51898	4.53
30	Mundaka	70000	19.56	210	Dallopura	57327	1.37
31	Nangloi jat west	63541	1.70	211	Trilok puri	61681	0.95
32	Nilothi	38030	2.66	212	New ashok nagar	58810	2.70
33	Pratap vihar	64942	0.70	213	Kalyan puri	49027	1.01
34	Nithari	70000	5.76	214	Khichripur	14925	1.23
35	Kirari suleman nagar	74981	2.74	215	Kondli	45494	1.68
36	Prem nagar	72713	1.35	216	Gharoli	56706	1.47
37	Sultanpuri east	60038	0.78	217	Vinod nagar	61249	0.64
38	Mangol puri north	55483	0.61	218	Mandaoli	66351	0.82
39	Sultanpur majra	51242	0.60	219	Mayur vihar phase-ii	63132	0.80
40	Sultanpuri south	44116	0.81	220	Patparganj	56422	0.83
41	Guru harkishan nagar	57203	2.66	221	Kishan kunj	60616	1.30
42	Peragharhi	51099	1.84	222	Laxmi nagar	50135	0.91
43	Nangloi east	68586	1.96	223	Shakarapur	62562	1.16

44	Qumruddin nagar	27000	2.69	224	Pandav nagar	65906	1.54
45	Rohini south	76811	2.09	225	Anand vihar	13654	2.81
46	Mangolpuri east	69053	0.78	226	Vilshwash nagar	35372	1.47
47	Mangolpuri	60205	0.98	227	I.P. Extension	32696	0.79
48	Mangolpuri west	54592	1.34	228	Preet vihar	30841	1.21
49	Rohini north	62990	3.42	229	Krishna nagar	59921	0.86
50	Rohini central	63481	3.08	230	Geeta colony	65356	1.12
51	Rohini east	56884	2.31	231	Ghondli	64275	0.94
52	Naharpur	58248	0.80	232	Anarkali	33778	0.85
53	Pitampura south	62398	2.45	233	Dharam pura	52024	1.05
54	Pitampura north	63781	2.31	234	Gandhi nagar	52664	0.31
55	Shalimar bagh north	61228	1.98	235	Azad nagar	63973	1.01
56	Shalimar bagh south	61501	2.23	236	Raghubar pura	58973	0.97
57	Paschim vihar south	118170	3.03	237	Shahdara	65351	1.43
58	Paschim vihar north	53900	2.07	238	Jhilmil	56570	1.00
59	Rani bagh	51399	3.03	239	Vivek vihar	54605	0.45
60	Saraswati vihar	23676	0.92	240	Dilshad colony	54049	0.96
61	Tri nagar	66752	0.96	241	Dilshad garden	28790	2.06
62	Rampura	65051	2.43	242	New seema puri	56770	1.01
63	Kohat enclave		1.99	243	Nand nagri	58091	0.68
64	Shakur pur	53124	1.00	244	Sunder nagari	58072	0.74
65	Nimri colony	62140	1.22	245	Durga puri	60211	0.92
66	Sawan park	66433	2.38	246	Ashok nagar	58384	0.91
67	Wazirpur	70293	1.70	247	Ram nagar	63444	1.60
68	Ashok vihar	70440	2.03	248	Welcome colony	58604	1.14
69	Kamla nagar	64514	2.18	249	Chauhan bangar	52328	0.54
70	Rana pratap bagh	58438	1.27	250	Zaffrabad	55833	0.51
71	Sangam park	53687	0.98	251	New usmanpur	29330	0.00
72	Model town	51920	2.81	252	Mauj pur	64370	0.67
73	Shastri nagar	70481	1.47	253	Bhajanpura	51479	1.11
74	Inder lok colony	60405	2.38	254	Brahampuri	61186	0.85
75	Kishan ganj	71983	1.28	255	Ghonda	52367	0.62
76	Deputy ganj	68098	1.00	256	Yamuna vihar	67694	1.73
77	Kashmere gate	55415	3.29	257	Subhash mohalla	59937	0.58
78	Majnu ka tilla	57142	3.53	258	Kardam puri	55848	1.42
79	Jama massjid	56086	1.05	259	Janta colony	55516	0.67
80	Chandi chowk	53701	0.99	260	Babar pur	56332	0.69
81	Minto road	51226	2.56	261	Jiwanpur	58637	1.75
82	Kuncha pandit	59922	0.34	262	Gokalpur	59311	0.99
83	Bazar sita ram	47202	0.34	263	Saboli	51163	1.65
84	Turkman gate	48370	0.26	264	Harsh vihar	56830	2.44
85	Idgah road	52179	0.81	265	Shiv vihar	63752	1.43
86	Ballimaran	55584	0.47	266	Karawal nagar east	50503	0.97
87	Ram nagar	69462	0.47	267	Nehru vihar	56968	0.28
88	Qasabpura	68349	0.76	268	Mustafabad	59949	0.99
89	Paharganj	66179	1.01	269	Khajoori khas	50291	1.14
90	Model basti	60648	1.39	270	Tukhmir pur	53843	0.45

91	Karol bhag	72524	2.15	271	Karawal nagar west	71846	2.19
92	Dev nagar	65394	0.70	272	Sonia vihar	34641	4.25
93	Baljit nagar	59479	0.38	273	C.P	10017	1.97
94	West patel nagar	66184	1.32	274	Barakamba modern school	10017	1.31
95	East patel nagar	65751	2.34	275	Birla mandir	40069	2.64
96	New ranjit nagar	64648	0.81	276	Chanakya puri	5565	3.28
97	Kirti nagar	65291	2.48	277	Rashtrapati bawan	6678	3.06
98	Man sarover garden	62223	1.53	278	Supreme court	16696	2.10
99	Moti nagar	64630	1.74	279	India gate	12021	2.90
100	Karampur	58979	2.10	280	Prithviraj road	8348	2.25
101	Raja garden	67029	2.19	281	Jor bagh	33391	4.08
102	Raghubir nagar	62909	0.55	282	Netaji nagar	33391	3.02
103	Punjabi bagh	56119	3.05	283	Sarojini nagar	73461	3.17
104	Madipur	53730	0.58	284	Kidwai nagar east/ AIIMS	35305	1.51
105	Rajouri garden	60963	2.17	285	Kirbi place	21467	3.44
106	Tagore garden	56436	0.75	286	Sadar bazaar	15944	5.99
107	Vishnu garden	61790	0.83	287	Dhauila kuan enclave	10734	4.93
108	Khyala	71808	1.25	288	Baird place, khyber lines	16100	7.17
109	Janakpuri north	65345	2.62	289	APS colony	16100	4.03
110	Nangal raya	58675	2.46	290	Nangal dairy,	20887	13.11
111	Hari nagar	61450	2.29	291	Du south campus	10734	2.26
112	Subhash nagar	55226	1.33	292	Narela (mamoor pur)	33205	7.58
113	Mahavir nagar	46775	1.29	293	Narela (hamidpur)	33205	0.62
114	Tilak nagar	56648	1.47	294	Bankner (sanath)	43928	3.91
115	Major bhaupinder singh nagar	53256	0.85	295	Alipur (iradat nagar)	11939	2.74
116	Vikaspuri east	52065	2.13	296	Alipur (holambi kalan)	49566	8.71
117	Janak puri west	63226	1.90	297	Alipur (bankoli)	10331	2.32
118	Janak puri south	51502	2.51	298	Alipur (khera khurd)	13598	3.98
119	Milap nagar	67111	1.34	299	Alipur (bijapur)	9602	5.33
120	Sitapuri	64354	0.69	300	Alipur (khera kalan)	15206	14.37
121	Kunwar singh nagar	61528	3.48	301	Bhalswa jahangir pur	24955	0.82
122	Hastal	137010	10.21	302	Dhir pur (azad pur)	45349	2.20
123	Vikas puri	66008	1.76	303	Rohini sec 11	21255	2.19
124	Vikas nagar	77190	2.21	304	Puth kalan	5366	3.74
125	Mohan garden	95000	1.80	305	Puth kalan	21671	3.70
126	Nawada	48152	0.78	306	Sahibabad daulat pur	30000	4.98
127	Uttam nagar	53122	0.88	307	Sahibabad daulat pur	45673	2.42
128	Bindapur	83158	1.71	308	Sahibabad daulat pur	20690	3.97
129	Dabri	62847	1.38	309	Begumpur (barwala)	40000	4.25
130	Manglapuri	54083	2.44	310	Begumpur (sultanpuri)	38000	6.25
131	Sagarpur	65263	0.68	311	Karala	65000	2.64
132	Sagarpur west	59176	0.64	312	Mundaka	20000	7.41
133	Chhawla	106670	74.59	313	Mundaka (tikri kalan)	45000	23.18
134	Nangli sakravati (qutab vihar)	62424	22.02	314	Nilothi	39242	1.66

135	Kakraula	59947	5.44	315	Qumruddin nagar	76660	2.79
136	Matiala	35128	3.34	316	316 saraswati vihar	24390	1.91
137	Roshanpura	78089	7.92	317	Saraswati vihar	1538	1.18
138	Najafgarh	66641	1.89	318	Kunwar singh nagar	66501	2.83
139	Dichaon kalan	85379	30.80	319	Nangli sakravati	62424	2.24
140	Khera	107521	72.20	320	Kakraula (dwaraka)	25742	3.96
141	Bijwasan	14909	6.50	321	Matiala	44930	4.12
142	Raj nagar	68380	1.16	322	Matiala	23395	2.07
143	Kapashera	23823	8.34	323	Matiala	20535	2.71
144	Mahipalpur	72776	6.67	324	Bijwasan	15087	2.16
145	Palam	62052	2.61	325	Bijwasan	15027	7.36
146	Sadh nagar	60011	0.76	326	Bijwasan	5028	5.27
147	Mahavir enclave	80775	2.33	327	Kapashera (nangal dewat)	7942	6.46
148	Madhu vihar	56698	1.28	328	Kapashera (kapas hera)	15881	5.19
149	Rajinder nagar	74646	4.06	329	Pusa (south patel nagar)	26731	4.45
150	Pusa	26731	5.04	330	Bhogal	27415	0.91
151	Inderpuri	55025	0.93	331	Malviya nagar (iit)	19428	3.17
152	Naraina	65265	1.57	332	Hauz khas	26695	1.43
153	Daryaganj	29522	2.83	333	Lado sarai (press encl.)	20291	2.01
154	Nizamuddin	29506	4.20	334	Nizamuddin	29506	2.95
155	Lajpat nagar	52495	2.67	335	Mehrauli	28011	2.57
156	Bhogal	34534	1.38	336	Vasant kunj (sec.c)	21082	1.20
157	Kasturba nagar	53407	0.90	337	Tughlakabad	21706	0.67
158	Kotla mubarak pur	57804	1.15	338	Tughlakabad(lal kuan)	28838	2.21
159	Adnewsganj	59878	1.92	339	Okhla (okhla ind.estate)	35129	1.90
160	Amar colony	50554	1.23	340	Madanpur khadar (ali vihar)	36953	2.47
161	Malviya nagar	24836	1.78	341	Sarita vihar (kalidi kunj)	15216	2.55
162	Village hauz rani	44076	1.05	342	Khichripur (kondli)	34818	2.24
163	Safdarjang enclave	57817	3.28	343	Anand vihar	21846	1.70
164	Hauz khas	26695	1.38	344	Anand vihar	19115	1.71
165	Vasant vihar	52257	9.33	345	Vilshwash nagar	29444	0.56
166	Munirka	54256	1.13	346	I.P. Extension (ghazipur)	32696	2.39
167	R.K. Puram	54683	2.17	347	Preet vihar	30841	1.15
168	Nanak pura	59737	3.20	348	Dilshad garden (j & k block)	28790	1.49
169	Lado sarai	32632	2.70	349	New usmanpur	29330	0.00
170	Mehrauli	28011	1.91	350	Sonia vihar (shubhpur)	34641	2.68
171	Vasant kunj	34331	5.65	351	India gate (CGO complex)	28047	2.60
172	Kishangarh	81833	21.78	352	Daryaganj (Rajghat)	28377	2.17
173	Sai-ul-ajajib	65774	9.76	353	Chanakya puri (diplomatic enclave)	4455	1.89
174	Chhatarpur	80000	13.39	354	Chanakya puri (malcha mahal)	1113	4.08
175	Aya nagar	82000	31.15	355	Prithviraj road (Gyaramurti)	8348	1.88

176	Bhati	85172	45.03	356	Chandi chowk (red fort)	5967	1.51
177	Sangam vihar	72370	6.33	357	Kapashera (dwarka sector21)	32142	1.75
178	Deoli	73668	2.35	358	Anarkali (krishna nagar)	33778	0.97
179	Tigri	69366	1.90	359	Akshardham	11046	13.20
180	Dakshin puri ext.	63818	1.17	360	IT park shastri park	19621	15.12
		Sub-Total	944.72			Sub-Total	479.07
						Grand Total	1423.79

Appendix 11

1st Workshop on**MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)**

Research Project Funded by

May 9th, 2017

Venue: Council Hall, CSIR-CRRI, New Delhi – 110025

List of Participants

S. No.	Name	Designation	Organisation
1	Prof. Satish Chandra	Director	CSIR-CRRI, New Delhi
2	Dr. Errampalli Madhu	Principal Scientist and HOD (TP)	CSIR-CRRI, New Delhi
3	Prof. Lorant A. Tavasszy	Professor	TU Delft, The Netherlands
4	Mr. Jeroen Borst	Manager	TNO, The Netherlands
5	Prof. P. K Sikdar	Vice President	ICT Pvt. Ltd., New Delhi
6	Dr. Neelam J. Gupta	Principal Scientist and Head (ILT)	CSIR-CRRI, New Delhi
7	Mr. D. P. Gupta	Retd. Director General	MoRTH, New Delhi
8	Dr. CH. Ravi Sekhar	Principal Scientist	CSIR-CRRI, New Delhi
9	Mr. Subhash Chand	Principal Scientist	CSIR-CRRI, New Delhi
10	Dr. S. Padma	Senior Scientist	CSIR-CRRI, New Delhi
11	Dr. Sippy Kalra	Senior Scientist	CSIR-CRRI, New Delhi
12	Dr. Neelima Chakrabarty	Principal Scientist and HOD (TES)	CSIR-CRRI, New Delhi
13	Ms. Farhat Azad	Scientist	CSIR-CRRI, New Delhi
14	Dr. Pratikana Das	Scientist	CSIR-CRRI, New Delhi
15	Ms. Kamini Gupta	STO	CSIR-CRRI, New Delhi
16	Mr. Ravi Gadepalli	Transport	Shakti Sustainable Energy Foundation, New Delhi
17	Dr. B. Kanagadurai	Chief Scientist	CSIR-CRRI, New Delhi
18	Mr. D. Ravinder	Senior Technical Officer	CSIR-CRRI, New Delhi
19	Dr. Anuradha Shukla	Chief Scientist	CSIR-CRRI, New Delhi
20	Dr. Kayitha Ravinder	Principal Scientist	CSIR-CRRI, New Delhi

21	Mr. Pradeep Kumar	Senior Principal Scientist	CSIR-CRRI, New Delhi
22	Dr. Ravinder Kumar	Principal Scientist	CSIR-CRRI, New Delhi
23	Dr. Purnima Parida	Senior Principal Scientist	CSIR-CRRI, New Delhi
24	Dr. J. Nataraju	Principal Scientist	CSIR-CRRI, New Delhi
25	Dr. A. Mohan Rao	Principal Scientist	CSIR-CRRI, New Delhi
26	Mr. Ashutosh Arun	Scientist	CSIR-CRRI, New Delhi
27	Mr. S. B. S. Tyagi	Superintending of Police (SP)	Delhi Police
28	Mr. S. L. Meena	Executive Engineer (EE)	South Delhi Municipal Corporation (SDMC)
29	Mr. Mohd. Galib	Associate Executive Engineer (AEE)	South Delhi Municipal Corporation (SDMC)
30	Mr. S. A. Khan	Associate Executive Engineer (AEE)	South Delhi Municipal Corporation (SDMC)
31	Prof. Sanjay Gupta	Professor	School of Planning and Architecture (SPA), New Delhi
32	Mr. Tejvir Singh	Executive Engineer (EE)	North Delhi Municipal Corporation (NDMC)
33	Dr. S. Velmurugan	Senior Principal Scientist	CSIR-CRRI, New Delhi
34	Dr. Mukti Advani	Senior Scientist	CSIR-CRRI, New Delhi



MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)

Research Project Funded by



December 12th, 2017

Venue: Council Hall, CSIR-CRRI, New Delhi – 110025



Short Course on "Sustainable City Logistics for Policy Making and Freight Operations"

List of Participants

S. No.	Name	Designation	Organisation
1	Prof. Satish Chandra	Director	CSIR-CRRI, New Delhi
2	Prof. Sanjay Gupta	Professor	School of Planning and Architecture (SPA), New Delhi
3	Prof. K. Ramachandra Rao	Professor	IIT Delhi, New Delhi
4	Prof. S. Bhaskar Gowd	Assistant Professor	School of Planning and Architecture (SPA), New Delhi
5	Mr. Anand Pal Singh	Regional Executive Admin	Associated Road Carriers Ltd.
6	Mr. Pankaj Kant	PhD Student	School of Planning and Architecture (SPA), New Delhi
7	Dr. Rina Singh	Senior Scientist	CSIR-CRRI, New Delhi
8	Dr. Kirti Bhandari	Principal Scientist	CSIR-CRRI, New Delhi
9	Dr. Nasim Akhtar	Principal Scientist	CSIR-CRRI, New Delhi
10	Ms. Farhat Azad	Senior Scientist	CSIR-CRRI, New Delhi
11	Dr. Pritikana Das	Scientist	CSIR-CRRI, New Delhi
12	Ms. Kamini Gupta	Senior Technical Officer	CSIR-CRRI, New Delhi
13	Mr. Ramesh Chand Majhi	Scientist	CSIR-CRRI, New Delhi
14	Mr. Satish Kumar	Senior Technical Officer	CSIR-CRRI, New Delhi
15	Dr. H. Lokeshwor Singh	Senior Technical Officer	CSIR-CRRI, New Delhi
16	Mr. Sanjay Kumar	Senior Technician	CSIR-CRRI, New Delhi
17	Dr. Ravindra Kumar	Principal Scientist	CSIR-CRRI, New Delhi

18	Dr. D. Mukhopadhyay	Advisor	Delhi Metro Rail Corporation (DMRC), New Delhi
19	Prof. Lorant A. Tavasszy	Professor	TU Delft, The Netherlands
20	Dr. Hans J. Quak	Transport Planner (Logistics)	TNO, The Netherlands
21	Dr. Nilesh Anand	Former PhD Student	TU Delft, The Netherlands
22	Ms. Leeza Malik	PhD Student	IIT Delhi, New Delhi
23	Ms. Nilanjana De Bakshi	PhD Student	IIT Delhi, New Delhi
24	Mr. Prashant Mishra	Engineer	Delhi Metro Rail Corporation (DMRC), New Delhi
25	Dr. CH. Ravi Sekhar	Principal Scientist	CSIR-CRRI, New Delhi
26	Dr. Errampalli Madhu	Principal Scientist and HOD (TP)	CSIR-CRRI, New Delhi
27	Mr. Vikash Kumar Thakur	Project Assistant(TP)	CSIR-CRRI, New Delhi
28	Mr. Amit Kumar Dubey	Project Assistant (TP)	CSIR-CRRI, New Delhi
29	Mr. Subramaniya Kannan	Senior Technical Officer	CSIR-CRRI, New Delhi
30	Dr. B. Kanagadurai	Chief Scientist	CSIR-CRRI, New Delhi
31	Dr. Mukti Advani	Senior Scientist	CSIR-CRRI, New Delhi
32	Dr. Neelima Chakrabarty	Principal Scientist and HOD (TES)	CSIR-CRRI, New Delhi
33	Dr. S. Padma	Senior Scientist	CSIR-CRRI, New Delhi
34	Dr. Kayitha Ravinder	Principal Scientist	CSIR-CRRI, New Delhi
35	Dr. J. Nataraju	Principal Scientist	CSIR-CRRI, New Delhi
36	Dr. A. Mohan Rao	Principal Scientist	CSIR-CRRI, New Delhi
37	Dr. S. Velmurugan	Senior Principal Scientist	CSIR-CRRI, New Delhi



National Dissemination Workshop on MEGACITY LOGISTICS: METRICS, TOOLS AND MEASURES FOR SUSTAINABILITY (MEGALOG)

Research Project Funded by



December 13th, 2017

Venue: C. V. Raman Hall, CSIR-CRRI, New Delhi – 110025



List of Participants

S. No.	Name	Designation	Organisation
1	Prof. Satish Chandra	Director	CSIR-CRRI, New Delhi
2	Prof. Russel G. Thompson	Professor	The University of Melbourne, Australia
3	Dr. Neelima Chakrabarty	Senior Principal Scientist and HOD (TES)	CSIR-CRRI, New Delhi
4	Ms. Farhat Azad	Senior Scientist	CSIR-CRRI, New Delhi
5	Dr. Pritikana Das	Scientist	CSIR-CRRI, New Delhi
6	Dr. CH. Ravi Sekhar	Principal Scientist	CSIR-CRRI, New Delhi
7	Dr. Sippy Kalra	Senior Scientist	CSIR-CRRI, New Delhi
8	Mr. Rajan Verma	Technical Officer	CSIR-CRRI, New Delhi
9	Mr. S. K. Biswas	Senior Technician	CSIR-CRRI, New Delhi
10	Mr. Jagdish S. Jangpangi	Senior Technician	CSIR-CRRI, New Delhi
11	Ms. Kamini Gupta	Senior Technical Officer	CSIR-CRRI, New Delhi
12	Dr. Mukti Advani	Senior Scientist	CSIR-CRRI, New Delhi
13	Dr. Errampalli Madhu	Principal Scientist HOD (TP)	CSIR-CRRI, New Delhi
14	Dr. Ravinder Kumar	Principal Scientist	CSIR-CRRI, New Delhi
15	Mr. S. Kannan	Senior Technical Officer	CSIR-CRRI, New Delhi
16	Dr. Nasim Akhtar	Principal Scientist	CSIR-CRRI, New Delhi
17	Dr. J. Nataraju	Principal Scientist	CSIR-CRRI, New Delhi
18	Mr. K. Sitaramanjaneyulu	Senior Principal Scientist	CSIR-CRRI, New Delhi
19	Mr. Pradeep Kumar	Principal Scientist	CSIR-CRRI, New Delhi
20	Mr. Manoj Kumar Shukla	Principal Scientist and HOD (FP)	CSIR-CRRI, New Delhi

21	Mr. S. S. Geharwar	Senior Principal Scientist and HOD (BES)	CSIR-CRRI, New Delhi
22	Mr. A. K. Jain	Senior Scientist and HOD (Civil)	CSIR-CRRI, New Delhi
23	Prof. Lorant A. Tavasszy	Professor	TU Delft, The Netherlands
24	Dr. Nilesh Anand	Former PhD Student	TU Delft, The Netherlands
25	Prof. Sanjay Gupta	Professor	SPA New Delhi
26	Dr. Hans J. Quak	Transport Planner (Logistics)	TNO, The Netherlands
27	Mr. Jeroen Borst	Transport Modeller	TNO, The Netherlands
28	Dr. Devesh Tiwari	Senior Principal Scientist	CSIR-CRRI, New Delhi
29	Dr. Kirti Bhandari	Principal Scientist	CSIR-CRRI, New Delhi
30	Mr. M. N. Nagabhushana	Senior Principal Scientist	CSIR-CRRI, New Delhi
31	Mr. R. S. Bharadwaj	Chief Scientist	CSIR-CRRI, New Delhi
32	Dr. Rina Singh	Senior Scientist	CSIR-CRRI, New Delhi
33	Dr. Siksha Swaroopa Kar	Senior Scientist	CSIR-CRRI, New Delhi
34	Dr. Ambika Behl	Senior Scientist	CSIR-CRRI, New Delhi
35	Mr. Dinesh Ganvir	Senior Scientist	CSIR-CRRI, New Delhi
36	Mr. Abhishek Mittal	Senior Scientist	CSIR-CRRI, New Delhi
37	Dr. Sangita	Senior Principal Scientist	CSIR-CRRI, New Delhi
38	Ms. Parvathi G. S.	Senior Scientist	CSIR-CRRI, New Delhi
39	Mr. Sudesh Kumar	Principal Scientist	CSIR-CRRI, New Delhi
40	Mr. Vikash Kumar Thakur	Project Assistant (TP)	CSIR-CRRI, New Delhi
41	Mr. G. Durgaprasad	Scientist	CSIR-CRRI, New Delhi
42	Mr. Sampath Kumar	Scientist	CSIR-CRRI, New Delhi
43	Ms. Risha Chatterjee	Journalist	Times of India
44	Mr. Subhash Chand	Principal Scientist	CSIR-CRRI, New Delhi
45	Mr. Ramesh Chand Manjhi	Scientist	CSIR-CRRI, New Delhi
46	Mr. Udit Ratna	Town and Country Planner	Town and Country Planning Organisation (TCPO), New Delhi
47	Mr. Prashant Mishra	Engineer	Delhi Metro Rail Corporation (DMRC), New Delhi
48	Dr. R. N. Dutta	Senior Principal Scientist	CSIR-CRRI, New Delhi
49	Mr. K. Sasidhar	Chief General Manager	ICT Pvt. Ltd., New Delhi
50	Dr. A. K. Sinha	Principal Scientist	CSIR-CRRI, New Delhi

51	Mr. Ravi Shankar	Scientist	CSIR-CRRI, New Delhi
52	Mr. Romeil Sagwal	Scientist	CSIR-CRRI, New Delhi
53	Mr. Amit Kumar Dubey	Project Assistant (TP)	CSIR-CRRI, New Delhi

Appendix 12



A Way Forward



CSIR-Central Road Research Institute (CRRRI), New Delhi 110025, India



TNO
The Netherlands



Further Details, Please Contact:

Prof. Satish Chandra
Director, CSIR-Central Road Research Institute (CRRRI), Mathura Road, New Delhi 110025 India.
Tel: 91-11-26832173, 26831760
Fax: 91-11-26845943, 26830480
E-Mail: director.crrri@nic.in

Dr. Errampalli Madhu
Principal Scientist and Head, Transportation Planning Division,
CSIR-Central Road Research Institute (CRRRI), Mathura Road, New Delhi 110025 India.
Tel: 91-11-26312268, 91-9958080643
E-Mail: errampalli.madhu@gmail.com, madhu.crrri@nic.in

Prof. Loran Tavasszy
Professor, Civil Engineering and Geosciences
Delft University of Technology
Stevinweg 1, 2628 CN Delft
The Netherlands
Tel/ Fax: +31(0)15 27 83346 / +31(0)15 27 83179
E-mail: l.a.tavasszy@tudelft.nl



Sustainable City Logistics

- NOx Concentration Map (Urban Strategy)
- Megacity Logistics Metrics, Tools and Measures for Sustainability (MEGALOG) (CRRRI, CSIR, New Delhi 110025)

Sustainable City Logistics (SCL)

Why SCL needed

- India spends 15-20% of GDP on transport and logistics
- Compound Annual Growth Rate (CAGR) of Indian freight transport market is expected to be about 13% by 2020

Freight Movement in India

- Speed is about 20 kmph only
- 250-300 km/day only (700-800 in developed countries)

- Total trip expenses increases about 15% due to the delays at check-posts and other procedures
- Poor working conditions and long driving hours for the truck drivers resulting in high stress and fatigue leading to more accidents

What SCL needed

- Collaboration amongst stakeholders including freight operators to identify optimal freight policies
- Pursue a rapid deployment of improvements
- Creating better data and models
 - to enable planners/ policy makers to better predict freight movement
 - to design better informed policies

MEGALOG

Considering the above, a research project on "Megacity Logistics: Metrics, Tools and Measures for Sustainability (MEGALOG)" has been carried out by CSIR-CRRI in association with TNO, Netherlands and TU Delft, Netherlands which was funded by the World Bank Group to assess metrics and way forward to achieve SCL.

Metrics on Logistics of Delhi City

Pattern of External Traffic at Outer Cordon Locations of Delhi

Traffic Composition at Outer Cordon Locations of Delhi

- Freight Share: Inner Area: 2%, Middle Area: 4%, Outer Area: 12%
- Trucks Share: At Outer Cordon: More than 50% of Total Freight
- Age of the Vehicles: Average Age is 4.5-5 years

Distance Travelled / day

- Heavy Vehicles could travel only about 200 km/day

Weight Carried about 2.5 Million Metric Tons (MMT) / day

Vehicle Kilometers Travelled (VKT)/day

- 10 Million VKT/day (8% growth per year)

Freight Trips/day

Travel Pattern (Freight)

Internal Trips are significantly High

How SCL can be achieved

Need to be aimed at following points:

- Reduction of negative effects of urban freight transport while maintaining productivity
 - Encourage to carry out appropriate research
 - Systematic planning of facilities
 - Deployment of Innovative methods
 - Advanced Vehicular Technologies
- Identification of workable urban freight solutions including roadmaps towards these
 - Adequate database (upto date)
 - Evolving appropriate tools
 - Encourage to carry out appropriate research (academia, R&D institutes etc.)
 - Frequent meetings/ discussions among stakeholders (researchers, policy makers, freight operators etc.)
- Increase of the knowledge base including data collection, models and scenarios
 - Adopting advanced techniques for data collection
 - conducting skill development training/ short courses to various stakeholders and operators on sustainable city logistics (SCL)
 - Encourage to use of advanced analytical tools
- Collaboration with other stakeholders to realize solutions towards sustainability
 - Formulation of a organizational body with all possible stakeholders
 - Members with shared awareness about sustainability

The World Bank Group
CSIR-Central Road Research Institute (CRRI), New Delhi, India,
TNO Netherlands and TU Delft Netherlands



The World Bank Group
CSIR-Central Road Research Institute (CRRI), New Delhi, India,
TNO Netherlands and TU Delft Netherlands





CSIR-Central Road Research Institute

(An ISO 9001:2008 Institution)

Delhi-Mathura Road

New Delhi - 110025, India

<http://www.crridom.gov.in/>

TNO, The Netherlands



Delft University of Technology,

The Netherlands

