A Report on

Base Year Travel Demand Model – Delhi

Prof.Dr.Sanjay Gupta, Sandhya Dhameniya

School of Planning and Architecture, New Delhi

October 2016

Contents

List of Tables

List of Figures

1. Introduction

1.1 Background

Delhi is located in northern India between the latitudes of 28°-24'-17" and 28°-53'-00" North and longitudes of 76°-50'-24" and 77°-20'-37" East. It has an area 1,483 sq.kms with a maximum length of 51.90 kms and greatest width of 48.48 kms. It shares borders with the states of Uttar Pradesh, Rajasthan and Haryana. Delhi has experienced a significantly high growth of population since independence. The population of Delhi was 17.44 lakh in 1951, which has grown by more than seven times to 167.5 lakh in 2011. It is observed that the population has been growing at the rate of approximately 4% per annum since 1961. The city has been showing the trend of increasing urbanization and 93% of population was urbanized as per the 2001 census.

1.2 Economic Profile of Delhi

Delhi is rapidly emerging as a world-class metropolis. With a 13% average compounded growth rate, it has one of the fastest growing economies in the country, among cities with million plus population. As with all metros, Delhi's economy is driven by the services sector, which accounts for 79% of its GSDP and provides employment to 58% of the labour force. Gross State Domestic Product of Delhi at current prices was estimated at Rs. 143911 crores during 2007-08. It has registered annual compound growth rate of 12.72% over the estimates of Rs. 55220 crores in 1999-00. Similarly, annual compound growth rate at 1999-00 prices has been 8.9% for the corresponding period.

Estimates indicate an annual growth of 12.0% during 2007-08. The analysis of sector wise growth in Gross State Domestic Product reveals that contribution of primary sector (comprising of agriculture, livestock, forestry, fishing, mining & quarrying) and the tertiary sector, also called the service sector (comprising of trade, hotels and restaurants, transport, storage, communication, financing & insurance, real estate, business services, public administration and other services) in the economy of Delhi is showing declining trend whereas contribution of the secondary sector (comprising of manufacturing, electricity, gas, water supply and construction) is enhancing regularly. The contribution of primary sector, which was 1.38% during 1999 - 2000 has come down to 0.69% in 2007-08 at current prices. The contribution of secondary sector recorded at 18.26% in the base year has enhanced to 20.68% in 2007-08. On the other hand, contribution of tertiary sector which worked out to 80.36% in 1999-00 has declined to 79.05% in 2007-08.

1.3 Transport system

1.3.1 Road Network System

The existing transport network in Delhi is "Ring and radial' in nature. The transportation network in Delhi is predominantly road based with 1284 km of road per 100 Sq.km. The total road length (km. lane) which was 14,316 km in 1981 which increased to 28,508 km in 2001 and 31,373 km in 2009 respectively.

1.3.2 Registered Vehicles and Trends in Motorisation

Delhi had a registered vehicle population of 7.45 million in 2011 having increased from 5.21 million in 1981 at a CAGR of 1.20%. Two-wheelers (63%) followed by passenger cars (32%) have major share in the fleet. Mass Transport System

1.3.3 Urban Bus Transport System

For years, the Delhi Transport Corporation (DTC) operated its bus services with 5,500 buses in use, in a city where the requirements have surpassed a 10,000-strong bus fleet. The existing network of 650 routes was re-modelled into 17 clusters. Under the Delhi Integrated Multi Modal Transit System (DIMTS), each cluster will be served by the DTC and the private stage carriage in a 40:60 ratio. Around 1300 buses are operating under the Cluster bus system. About 218 km per bus per day is vehicle utilization of cluster buses while it is about 190 km in case of DTC buses

1.3.4 Delhi Metro Rail System

Delhi Metro today has a current operational network covering 192.81 kms approx. in Delhi and the National Capital Region (Gurgaon and Noida) with 146 operational stations. The Delhi Metro is being built in phases. Phase I completed 58 stations and 65.0 km of route length of which 13.0 km is underground and 52.1 km surface or elevated. The inauguration of the Dwarka–Road corridor of the Blue Line marked the completion of Phase I on October 2006. Phase II of the network comprises 124.6 km of route length and 85 stations, and is fully completed, with the first section opened in June 2008 and the last line opened in August 2011. Phase III (103 km, 69 stations) and Phase IV (113.2 km) are planned to be completed by 2016 and 2021 respectively, with the network spanning 413 km by then. **Figure 1.1** shows the trends in daily ridership on metro which increased from 82,000 in 2002 to 23.38 lakhs in 2015.

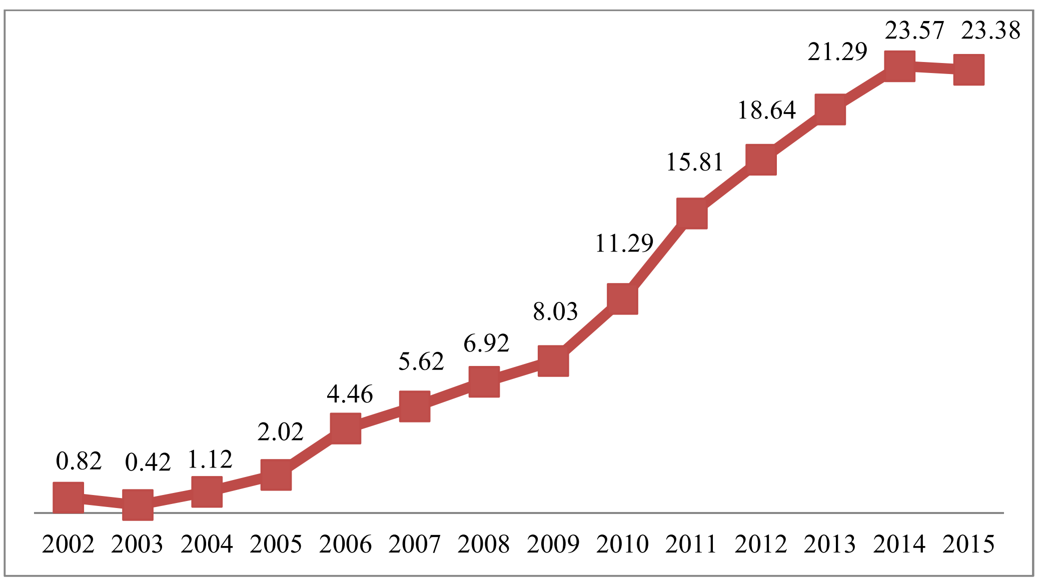


Figure 1-1 : Ridership/Day (in Lakhs)

Source: Statistical Abstract Delhi 2015, DMRC Annual Report2014-15

1.4 Travel demand

1.4.1 Per capita Trip Rate (PCTR)

The per capita trip rate (excluding walk trips) in the city has increased from 0.72 in 1981 to 0.87 in 2001. Per capita trip rate is increasing at the CAGR 1.8% per annum. It is estimated that per capita trip rate may reach to 1.2 by 2021 in Delhi. **Table 1.1** shows PCTR growth trend in Delhi.

Table 1-1 : Per capita trip rate (veh.) growth trends in Delhi

Purpose	1969	1981	1986	2001	2007	2021(Estimated)
Work	0.29	0.31	0.65	-		-
Education	0.08	0.22	0.29	-		-
Others	0.12	0.19	0.14	-		-
All	0.49	0.72	1.08	0.87	0.70	1.2

Source: RITES 1994; RITES, Planning for Mass Transit System for Delhi 1989; Transport Demand Forecast Study and Development of an Integrated Road cum Multi-Modal Public Transport Network for NCT of Delhi – RITES. 2010.

1.4.2 Average trip length (ATL)

In Delhi observed average trip lengths of bus and car in the city in were 10.7 km and 11.3 km respectively. **Table 1.2** shows the ATL for motorized vehicles for 1969, 1994 and 2007.

Table 1-2 : Average Trip Length growth trends in Delhi (km)

Year	Overall	Motorised Mode
1969	-	5.4
1994	4.88	7.87
2007	-	10.2

Source: Report of the Working Group On Urban Transport. Ministry of Urban Affairs and Employment, Government of India, New Delhi, February 1996; Wilburg Smith report 2008; RITES 1994.

1.4.3 Motorized Trips

An estimated 15.1 million motorised trips were performed in the city by 2007 of which the share of public transport was 54.7% while two wheelers and cars accounted for 25.5 % and 15.5 % share respectively. The intra-city motorized person trips are expected to increase from 15.1 million in 2007 to 17.4 million in 2021. **Table 1.3** shows motorised trips trend in Delhi.

Table 1-3 : Motorised Trips growth trends in Delhi

Year	1994	2001	2007	2021
Motorised trips	7.57	10.8	15.1	17.4

Source: RITES 1994; RITES, Planning for Mass Transit System for Delhi 1989.

1.4.4 Modal Shares of trips

In 2001 about 33% trips were estimated to be walk trips. Among the vehicular trips, the maximum (60%) trips were being performed by buses while the personalized modes of transport

were carrying about 27% of vehicular trips in the study area. The modal split in favour of public transport has increased from 41 % in 1969 to 52.5% in 2007 (**Table 1.4**)

Table 1-4 : Modal Split trends in Delhi

Year	1969	1981	1986	1994	2001	2007
Public transport	41	62	62	62	60.5	52.5
Private	59	38	38	38	39.5	47.5

Source: Wilbur Smith report 2008; RITES 1994; RITES, Planning for Mass Transit System for Delhi 1989; Transport Demand Forecast Study and Development of an Integrated Road cum Multi-Modal Public Transport Network for NCT of Delhi – RITES.

2. Base Year Travel Demand Model

2.1 General

For the present study, operational models requiring household and available land use parameters have been adopted. The conventional Urban Transport Planning system (UTPS) process has been adopted to simulate the travel behaviour pattern of residents in the study area. These models has been calibrated and validated before using them for estimation of travel demand for the horizon years. This shall include, synthesizing the present day movement patterns using the model and adjusting them till they represent the observed conditions. Base network and the traffic & Travel survey is adopted from the RITES – Transport demand forecast (2007) study to develop an aggregated zone model to simulate various policy level interventions impact in Delhi.

The basic inputs used (at Zonal levels) to build the models include;

- Population
- Employment
- Speed & Delays and paths
- Travel pattern
- Road network characteristics

2.2 Estimation of Base Year Travel

The base year travel pattern in the form of Origin-Destination matrices has been established based on the Household Survey and OD surveys conducted at outer cordon locations by RITES study. The trips in the study area are performed by various modes including Walk and Bicycle. For modelling purpose, all the passenger modes of movement have been suitably grouped as follows:

Private Vehicle Trips - 2 Wheeler, Car & SUV, Van, Passenger Pickup

Public Vehicle Trips - Taxi, Shared Auto, & Mini Bus

Other Trips - Cycle and Walk

For the better understanding of travel pattern, the study area has been divided into a system of 288 internal traffic zones (TAZ), aggregated 360 municipal wards zones. In addition 18 traffic zones have been developed as External Zones. The zone map is provided in the **Fig 2.1** given below:-

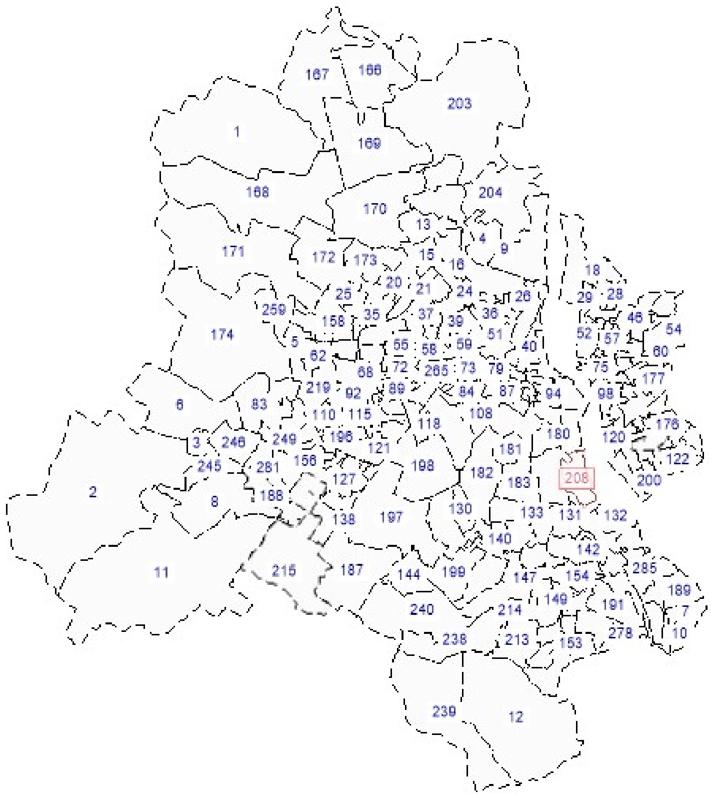


Figure 2-1: Traffic Analysis Zones (TAZ) for Delhi

The total number passenger trips performed in the study area in a day are estimated to be 116 lakhs (excluding walk trips). The majority of the trips (about 53.71%) are made by Public Transport Trips. Two wheeler trips contribute to about 25.63% of the total trips The distributions of trips made in the study area by various modes are presented in **Table 2.1** given below:-

Table 2-1: Estimated Base Year Travel (2007)

Modes	Base Year Trips	% of Trips
Car	1912963	16.46%
Tw	2977341	25.63%
Auto	387668	3.34%
Share auto	99893	0.86%
Metro	506702	4.36%
Bus	5733903	49.35%

The per capita trip rate (PCTR) was estimated to be 0.70 excluding walk trips.

2.3 Purpose-wise Distribution of Trips

The distributions of base year trips by purpose are presented in **Table 2.2**Error! Reference source not found. given below**.** Nearly 45.7% of the trips are performed for Work & Business. The educational and other trips are 38.7% and 15.6% respectively of the total trips in a day.

Table 2-2: Purpose-wise Distribution of Trips

Purpose	No of Trips	%
Work	3565076	30.7%
Business	1744187	15.0%
Education	4493185	38.7%
Other	1816619	15.6%
Total	**11619067**	100.0%

Table 2-3: Purpose-wise Distribution of Trips wrt to Mode wise

Trip Purpose	Car	Tw	Auto	IPT	Bus	Metro	Total
Govt. Service	19.50	32.10	1.43	0.12	42.45	4.40	100
Private service	11.80	30.62	2.11	0.42	51.40	3.65	100
Business	29.43	45.24	2.20	0.44	18.01	4.69	100
Education	6.97	8.04	2.14	1.88	78.02	2.95	100
Shopping/ Recreation	28.00	15.20	11.47	2.40	33.60	9.33	100
Medical	13.88	10.63	15.18	1.95	52.71	5.64	100
Social/ Others	23.12	12.98	13.18	1.01	43.20	6.49	100

2.4 Transport Network

In order to develop the transport networks for the base year (2007), data collected as part of road network inventory and speed and delay survey has been used. All the zone centroids have been connected to the nearest road node (dummy links). The network has been coded so that it is compatible to the zoning system adopted. The coded base year transport network is shown in **Figure 2.5.**

2.5 Travel Demand Modelling Approach

Four stage model has been adopted for the present study. This model is the conventional method of Urban Transport Planning System (UTPS), where-in the distribution of land use in terms of population and employment allocation is done exogenously. This modelling approach is popularly known as sequential travel demand modelling which has four stages namely;

Trip generation, the number of trips generated at a zone for a given purpose

Trip Distribution, the choice of trip destination

Modal Split, the choice of mode for making the trip, and

Trip Assignment, the choice of travel route on the transport network

In this approach, quantifiable relationships are being established between travel pattern, population and opportunity (employment) distribution system, purpose wise mode choice and socio economic characteristics of the population in the study area. The models are being calibrated to exhibit the observed trip making behaviour in the city and the associated socio economic characteristics. The calibrated model can be adopted for assessing the future travel demand for the given or estimated distribution of population, opportunities and socio-economic characteristics in the study area.

UTPS has been widely used in the past and contemporary transportation planning studies across the globe. The accuracy in calibrating this model has tremendously increased since the past, by using the latest computing tools and complex modelling software. It is proposed to use VISUM – an advanced transport planning software to calibrate the conventional four-stage transport planning system. The overall methodology of the proposed travel demand model is provided in the **Figure 2-2** given below:-

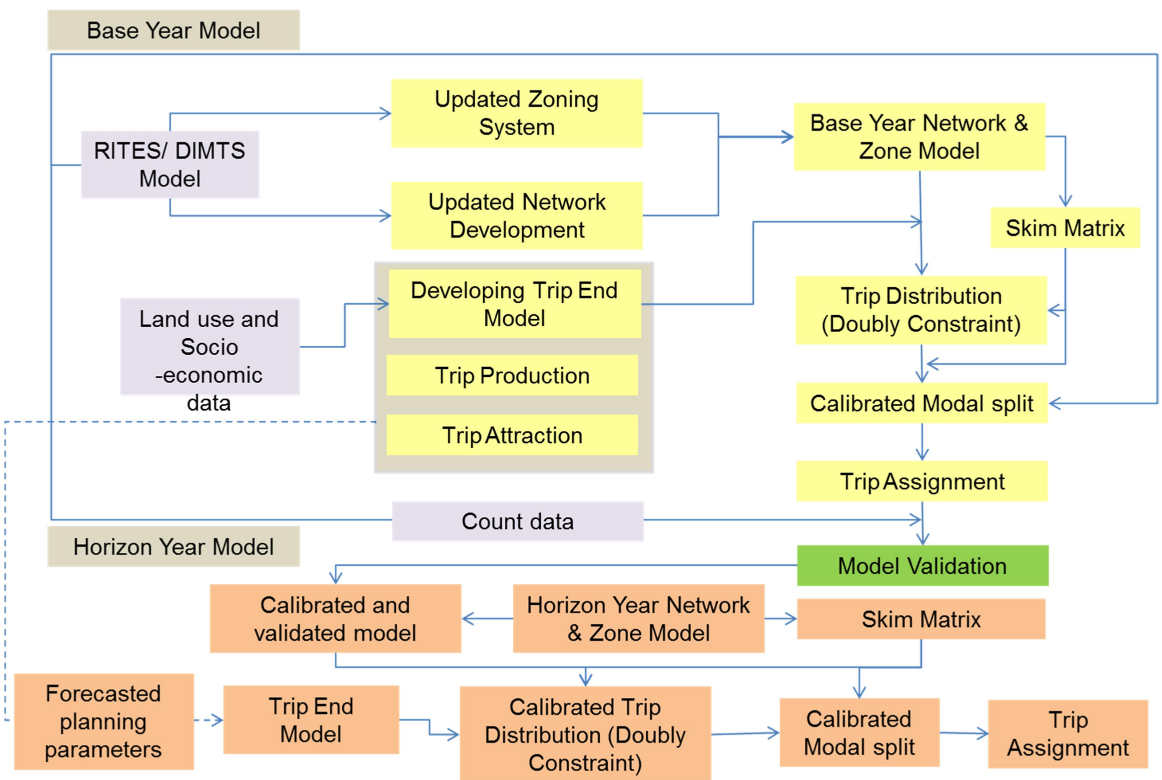


Figure 2-2: Flow Chart of TDM

The analysis of information obtained from the roadside interview surveys, home interview surveys, traffic counts and travel demand data together with socio-economic data aggregated at the zonal level forms the database to develop various components of travel demand model in the present study..

2.6 Travel Demand Modelling Results

2.6.1 Trip Generation

This is the first stage of the travel demand modelling process. Two types of trip generation analysis normally are carried out which are referred to as Trip Production and Trip Attraction. Trip Generation is performed using Multiple Regression Analysis technique to develop prediction equation for zonal trip ends. Typically the functional form of multiple linear regression models is:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \cdots \ldots \ldots \ldots \ldots .. + b_n x_n + e$$

Given a simple one variable model:

$$y = b_0 + b_1 x_1 + e$$

Where:

y_i = dependent variable value for observation *i*
x_i = independent variable value for observation *i*
b_0 = constant term
b_1 = coefficient of independent variable
e = error term
n = number of observations

The independent variables selected should not have co-linearity and should be capable of interpretability and be measurable. The independent variables should be capable of explaining the variability of dependant variable. The relation or the equation should satisfy the statistical requirements for its goodness of fit and the coefficient should have logical sign for acceptability. Trip generation has two facets namely, Trip Production and Trip Attraction.

2.6.1.1 Trip Production

The term trip production is used for trips generated by traffic zones and is associated with trips generated at residential end. The trip production usually depends on explanatory variables like family size and composition, household income etc. In the present study, a number of variables have been considered for developing regression models for estimating future trip productions. These are presented in **Table 2.4**

Table 2-4: List of Independent and Dependent Variables for Trip Production

Independent Variables	Dependent Variables
Population	Trip Production (Work Trips)
Population	Trip Production (Non Work Trips)
Employment	Trip Attraction (Work Trips)
Employment	Trip Attraction (Non Work Trips)

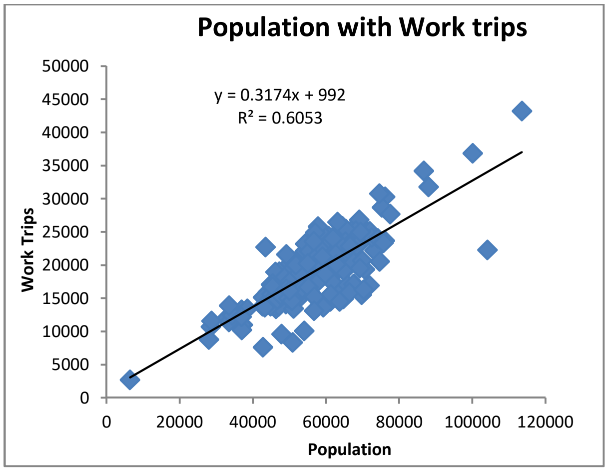
Trip generation equations for the work trips and non-work trips are generated separately as the characteristics of these area are different. The trip generation equations for Delhi work trips and

non-work trips with population and trip productions shows good correlation and are found statistically significant as shown below:

Total Trips

*Trip Productions (Work Trips) = 0.3174 * population + 992* $(R^2=0.61)$

*Trip Productions (Non work Trips) = 0.379 * population + 446* $(R^2=0.52)$



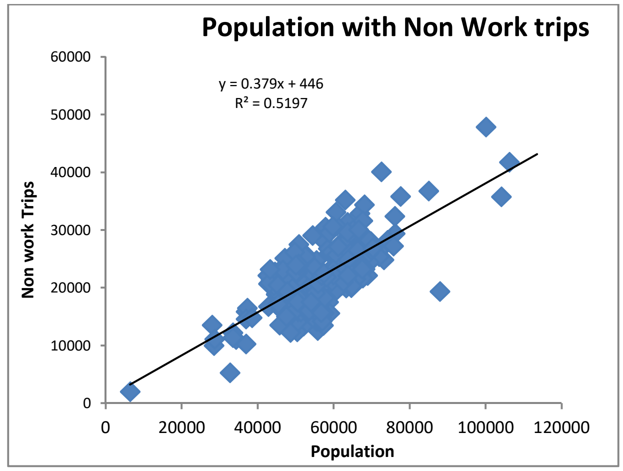


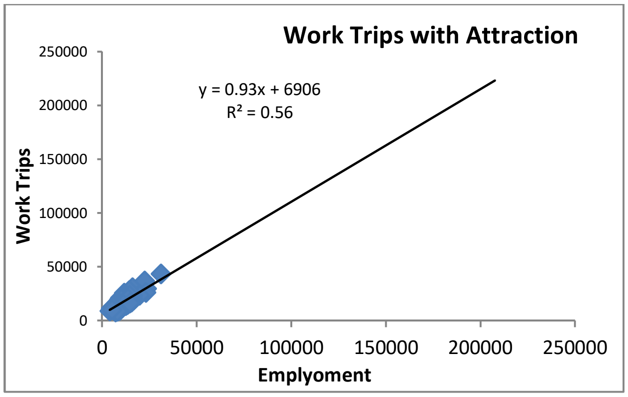
Figure 2-3 : Trip Production Equations

2.6.1.2 Trip Attraction

Trip attraction is associated with trips attracted to the non-residential end like work places, schools, colleges, shopping area, etc. The main variables, which affect trip attraction rates are employment, student enrolment, land use etc. In case of present study, existing land use is extracted from secondary sources and future land use from the Master Plan 2021. The land use (area other than residential land use is considered) as derived will be utilized for developing correlation with trip attraction.

*Trip Attractions (Work Trips) = 0.93 * Employment + 6906* $(R^2=0.56)$

Trip Attractions (Non – Work Trips) = 1.125 Employment + 9680* $(R^2=0.48)$



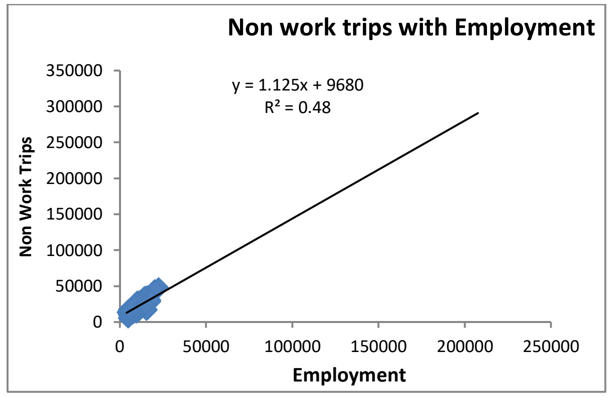


Figure 2-4 : Trip Attraction Equations

Trip generation Model calibration

Trip Production and attractions were calculated using the equation and a comparative analysis has been carried out between the equation predicted values and actual values (survey results). It was observed that the model values and the actual values are within the acceptable range. The Table 2.5 below shows the trip generation for both actual and predicted values.

Table 2-5 : Trip generation Validation

Trip Generation	Parameters	Trip Types	Equation	Actual	Model	GEH
Trip Production	16686494	Work	0.3174x + 992	5309183	5297285.2	5.2
		Non Work	0.379x + 446	6309288	6324627.2	6.1
		Over all	**0.6964x+1438**	**11618471**	**11621912**	**1.0**
Trip Attraction	5589347	Work	0.93x + 6906	5204544	5204998.7	0.2
		Non Work	1.125x + 9680	6298619	6303284.7	1.9
		Over all	**2.055x+16766**	**11503163**	**11508283**	**1.5**

2.6.2 Trip Distribution

Trip Distribution in this study has been carried out adopting Gravity Model. The Gravity Model is a heuristically derived expression for synthesizing trip interchanges. The basic premises of Gravity Model is that the trip magnitude between two zones i and j is directly proportional to the number of trips produced in zone i.e., number of trips attracted to zone j, and inversely proportional to some function of the spatial separation of the two zones

$$t_{ij} \; \alpha \; p_i a_i \left[\frac{1}{f(d_{ij})}\right]$$

The equation can be rewritten as

$$T_{ij} = A_i B_j P_i A_j F(C_{ij})$$

Where

T_{ij} = Trips between zone i to zone j

P_i = Production from zone j

A_i = Attraction to zone j

$A_i \& B_j$ = Row/column balancing factor

$F(C_{ij})$ = Cost Deterrence from zone i to zone j

$$F(C_{ij}) = e^{-\alpha t_{ij}} (t_{ij})^{-\beta}$$

Where

t_{ij} = *Travel time / distance / generalised cost from zone i to zone j*

α, β = *Parameter to be calibrated.*

The calibration of Gravity Model in the present study is carried out through VISUM software which requires some basic inputs in terms of:

i) Observed OD matrix by mode
ii) Network Parameters, speed and capacity by link, restrictions on entry of commercial vehicles, heavy vehicles etc.
iii) Zone-zone time/ cost Matrix by mode

The main criteria for calibration checks are:

- Shape and position of observed and simulated trip length frequency distribution should be relatively close to one another
- The difference between the average trip lengths should be within ±3%

For the present study, gravity model calibration was carried out based on the OD matrices derived from the HIS surveys by work & non work trips and the generalized time function based on the speed and delay surveys. The friction factors are being developed based on the trip length frequency diagram developed for the study.

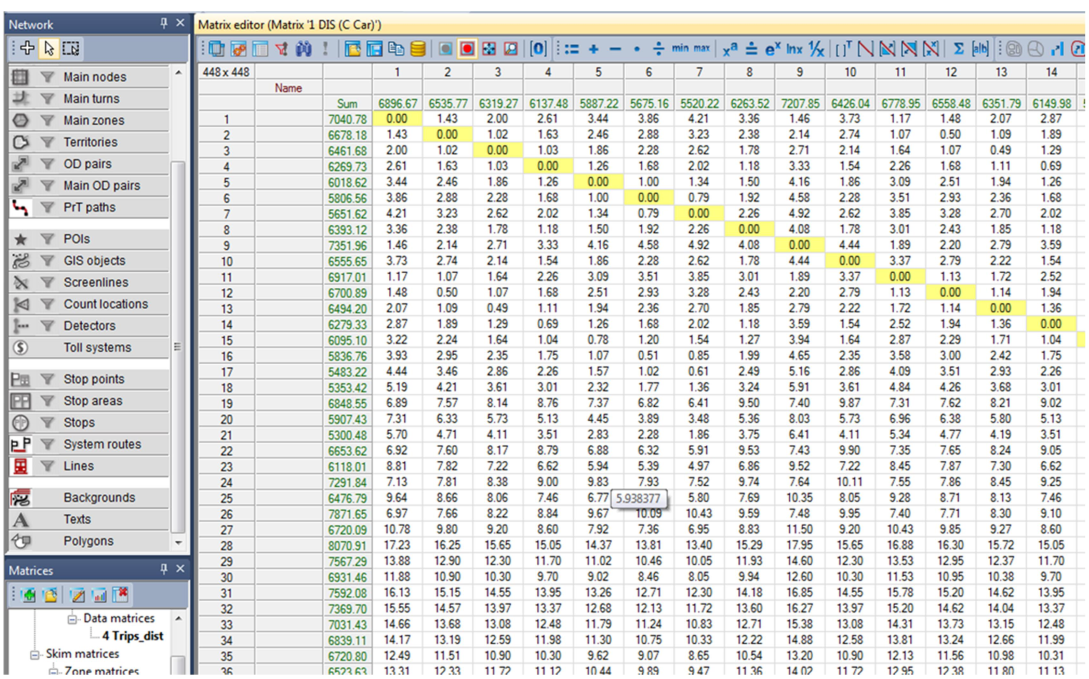
Transport Network

Transport network and its characteristics for both road and transit (bus and metro) have been coded for input to the model. Additional road network characteristics like, divided carriageway, undivided carriageway, one way or two way are also been coded. The capacities of links for various link configurations have been adopted adopting the guidelines from IRC 106. The speeds obtained from the speed flow studies adopted from RITES study..

Figure 2-5: Road Network

Cost Matrix

Travel time has been considered as the deterrence parameter for the calibration of Gravity Modal. The speeds obtained for each link have been converted in to time parameter and has been used for developing zone to zone cost (skim) matrix.



448 x 448	Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Sum	6896.67	6535.77	6319.27	6137.48	5887.22	5675.16	5520.22	6263.52	7207.85	6426.04	6778.95	6558.48	6351.79	6149.98
1		7040.78	0.00	1.43	2.00	2.61	3.44	3.86	4.21	3.36	1.46	3.73	1.17	1.48	2.07	2.87
2		6678.18	1.43	0.00	1.02	1.63	2.46	2.88	3.23	2.38	2.14	2.74	1.07	0.50	1.09	1.89
3		6461.68	2.00	1.02	0.00	1.03	1.86	2.28	2.62	1.78	2.71	2.14	1.64	1.07	0.49	1.29
4		6269.73	2.61	1.63	1.03	0.00	1.26	1.68	2.02	1.18	3.33	1.54	2.26	1.68	1.11	0.69
5		6018.62	3.44	2.46	1.86	1.26	0.00	1.00	1.34	1.50	4.16	1.86	3.09	2.51	1.94	1.26
6		5806.56	3.86	2.88	2.28	1.68	1.00	0.00	0.79	1.92	4.58	2.28	3.51	2.93	2.36	1.68
7		5651.62	4.21	3.23	2.62	2.02	1.34	0.79	0.00	2.26	4.92	2.62	3.85	3.28	2.70	2.02
8		6393.12	3.36	2.38	1.78	1.18	1.50	1.92	2.26	0.00	4.08	1.78	3.01	2.43	1.85	1.18
9		7351.96	1.46	2.14	2.71	3.33	4.16	4.58	4.92	4.08	0.00	4.44	1.89	2.20	2.79	3.59
10		6555.65	3.73	2.74	2.14	1.54	1.86	2.28	2.62	1.78	4.44	0.00	3.37	2.79	2.22	1.54
11		6917.01	1.17	1.07	1.64	2.26	3.09	3.51	3.85	3.01	1.89	3.37	0.00	1.13	1.72	2.52
12		6700.89	1.48	0.50	1.07	1.68	2.51	2.93	3.28	2.43	2.20	2.79	1.13	0.00	1.14	1.94
13		6494.20	2.07	1.09	0.49	1.11	1.94	2.36	2.70	1.85	2.79	2.22	1.72	1.14	0.00	1.36
14		6279.33	2.87	1.89	1.29	0.69	1.26	1.68	2.02	1.18	3.59	1.54	2.52	1.94	1.36	0.00
15		6095.10	3.22	2.24	1.64	1.04	0.78	1.20	1.54	1.27	3.94	1.64	2.87	2.29	1.71	1.04
16		5836.76	3.93	2.95	2.35	1.75	1.07	0.51	0.85	1.99	4.65	2.35	3.58	3.00	2.42	1.75
17		5483.22	4.44	3.46	2.86	2.26	1.57	1.02	0.61	2.49	5.16	2.86	4.09	3.51	2.93	2.26
18		5353.42	5.19	4.21	3.61	3.01	2.32	1.77	1.36	3.24	5.91	3.61	4.84	4.26	3.68	3.01
19		6848.55	6.89	7.57	8.14	8.76	7.37	6.82	6.41	9.50	7.40	9.87	7.31	7.62	8.21	9.02
20		5907.43	7.31	6.33	5.73	5.13	4.45	3.89	3.48	5.36	8.03	5.73	6.96	6.38	5.80	5.13
21		5300.48	5.70	4.71	4.11	3.51	2.83	2.28	1.86	3.75	6.41	4.11	5.34	4.77	4.19	3.51
22		6653.62	6.92	7.60	8.17	8.79	6.88	6.32	5.91	9.53	7.43	9.90	7.35	7.65	8.24	9.05
23		6118.01	8.81	7.82	7.22	6.62	5.94	5.39	4.97	6.86	9.52	7.22	8.45	7.87	7.30	6.62
24		7291.84	7.13	7.81	8.38	9.00	9.83	7.93	7.52	9.74	7.64	10.11	7.55	7.86	8.45	9.25
25		6476.79	9.64	8.66	8.06	7.46	6.77	5.938377	5.80	7.69	10.35	8.05	9.28	8.71	8.13	7.46
26		7871.65	6.97	7.66	8.22	8.84	9.67	10.09	10.43	9.59	7.48	9.95	7.40	7.71	8.30	9.10
27		6720.09	10.78	9.80	9.20	8.60	7.92	7.36	6.95	8.83	11.50	9.20	10.43	9.85	9.27	8.60
28		8070.91	17.23	16.25	15.65	15.05	14.37	13.81	13.40	15.29	17.95	15.65	16.88	16.30	15.72	15.05
29		7567.29	13.88	12.90	12.30	11.70	11.02	10.46	10.05	11.93	14.60	12.30	13.53	12.95	12.37	11.70
30		6931.46	11.88	10.90	10.30	9.70	9.02	8.46	8.05	9.94	12.60	10.30	11.53	10.95	10.38	9.70
31		7592.08	16.13	15.15	14.55	13.95	13.26	12.71	12.30	14.18	16.85	14.55	15.78	15.20	14.62	13.95
32		7369.70	15.55	14.57	13.97	13.37	12.68	12.13	11.72	13.60	16.27	13.97	15.20	14.62	14.04	13.37
33		7031.43	14.66	13.68	13.08	12.48	11.79	11.24	10.83	12.71	15.38	13.08	14.31	13.73	13.15	12.48
34		6839.11	14.17	13.19	12.59	11.98	11.30	10.75	10.33	12.22	14.88	12.58	13.81	13.24	12.66	11.99
35		6720.80	12.49	11.51	10.90	10.30	9.62	9.07	8.65	10.54	13.20	10.90	12.13	11.56	10.98	10.31
36		6523.63	13.31	12.33	11.72	11.12	10.44	9.89	9.47	11.36	14.02	11.72	12.95	12.38	11.80	11.13

Figure 2-6: Cost Matrix

Gravity Model Calibration

Determination of each of the constants in the distribution model is termed as calibration. The basic input for calibration is zone-zone cost matrix file as obtained from HIGHWAY and OD matrix as obtained from MATRIX of VISUM software module. Trips by different modes (Private and Public modes) have been modelled.

The Calibration process includes comparison of observed and simulated mean trip lengths as well as shapes of the trip length frequency distribution curves. The observed trip length frequency distribution has been obtained from the household survey data. For simulated trip length frequency distributions, the parameter values (negative exponential) have been varied over a number of iterations until the simulated and observed trip length frequency distributions for each purpose exhibit similar characteristics in terms of the shape and position when compared .Gravity modal has been calibrated using friction factors. As per the guidelines to validate the calibration model the observed and the modelled trip length should not be more than +/- 3%.. **Fig. 2.7** shows the model calibration results for work and non- work trip purposes.

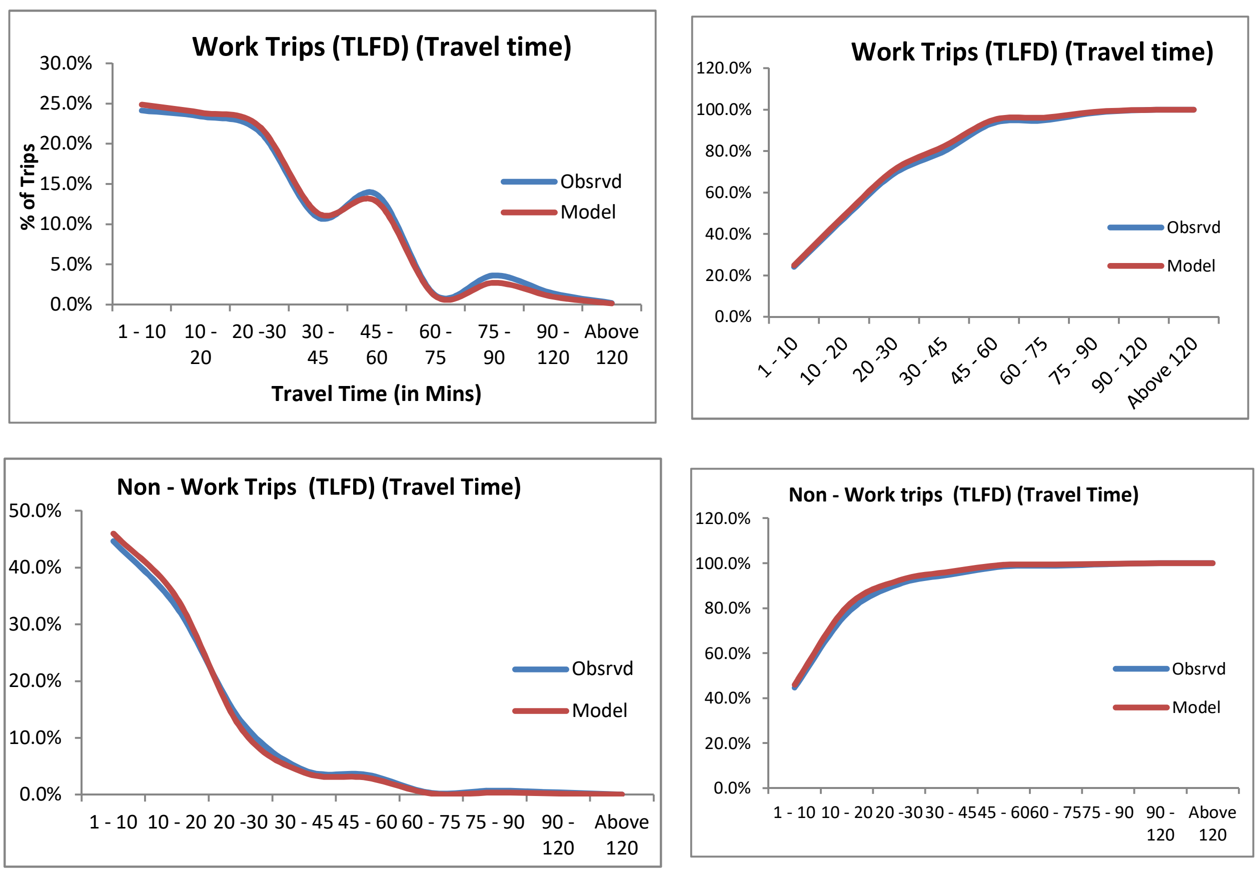


Figure 2-7 : Trips length frequency distribution of work and Non work Trips

The difference between the modelled and surveyed is 0.07 % which is less than the permissible value.

2.6.3 Modal Split

In this study a multinomial logit model has been adopted to model the modal split based on utility function of each mode under consideration. A discrete distribution model is used which specifies the probability of mode choice. For this modelling purpose mode wise skim matrices have been developed for various parameters such as in- vehicle time, aces, egress, fare, etc.

The multi nominal logit based form of modal split model being developed is as under:

$$P_{ij}^{m} = \frac{f(u_{ij}^{m})}{\sum_{k=1}^{M} f(u_{ij}^{k})}$$

$$f(u_{ij}^{m}) = e^{c\,u_{ij}^{m}}$$

Where:

I, j is the Indices of the traffic zones
M is the Index of Modes (M = total number)
P is the Probability of selecting the mode m for trip from i to j
U is the utility when choosing the mode m for trip i to j
C is the calibration factor.

Table 2.6 and 2.7 shows the mode choice model results for work and non- work purposes respectively. It is observed that there the variations between actual and observed modal shares are within the acceptable range as indicated by GEH statistics

Table 2-6: Daily trips modal share of Work Trips

Mode	Model Trips	Actual Trips	% of Trips Model	Observed Trips %	GEH	C value
Mode choice HW x Car	1074335	1074708	20.2%	20.2%	0.4	-0.2799
Mode choice HW x PT	2214452	2222400	41.7%	41.9%	5.3	
Mode choice HW x Auto	103115	101402	1.9%	1.9%	5.4	
Mode choice HW x TW	1917282	1910672	36.1%	36.0%	4.8	
Total	**5309183**	**5309183**	**100.0%**	**100.0%**		

Table 2-7: Daily trips model share of Non-Work Trips

Mode	Model Trips	Actual Trips	% of Trips Model	Observed Trips %	GEH	C value
Mode choice HNW x Car	1134224	1135311	18.0%	18.0%	1.0	-0.9352
Mode choice HNW x PT	3769948	3772777	59.8%	59.8%	1.5	
Mode choice HNW x Auto	663149	662166	10.5%	10.5%	1.2	
Mode choice HNW x TW	741966	739034	11.8%	11.7%	3.4	
Total	**6309288**	**6309288**	**100.0%**	**100.0%**		

2.6.4 Traffic Assignment

Traffic Assignment is the fourth and the final phase of four stage Urban Transport Planning Process. The purpose of the traffic assignment is to develop a technique that simulates the way in which the trips between each origin and destination pair distribute over the links of their respective networks.

There are three traffic assignment techniques used in urban transport planning. These are:

1. *All or Nothing Assignment*
2. *Capacity Restrained Assignment*,
3. *Multipath Traffic Assignment*

The incremental ***Capacity Restrained Assignment*** technique using **VISUM** software has been adopted for the present study. The assignment is based on the generalised cost of travel between two zones. The generalised cost has mainly two parameters namely Value of Time and Vehicle Operating Cost (VOC) which has been estimated for various modes. Conversion of passenger trip matrix in to peak hour vehicular trip matrix has been done using the average occupancy for each passenger mode and the peak hour traffic as a percentage of total traffic.

2.6.5 Travel Demand of Commercial Vehicles

The Commercial Vehicle (CV) matrix has been estimated based on the OD survey data conducted at outer cordon and inner cordon points in the RITES study..

2.6.6 External Trips

All the synthesised internal matrices have been expanded by adding the O-D flows for the external zones (‘L’ portion of the matrix) to obtain the comprehensive passenger and commercial vehicle matrices for the study area. These matrices were used for final assignment. The ‘L’ portions of the matrices were applied with external growth factors for the horizon years.

2.6.7 Peak Hour Factors and Directional Distribution

For the purpose of traffic assignment, the peak hour factor has been established on the basis of traffic flow data from primary surveys. The peak hour factor has been taken as 10 percent based on observed peak hour factor at various locations and considering future perspective.

2.6.8 Assigned Traffic Volume

The traffic assignment has been carried out in the following sequence:

- Commercial Vehicles
- Bus & Mini Bus (City and Regional Buses)
- Private Vehicles Trips

The model has been developed to include the transit routes with all the relevant information like the routes grouped by operator, frequency of each route, capacity of each public transit mode and each transit stop

After assignment of each mode matrix, the network speeds are updated. After assigning of all modes on to the network, the assigned traffic streams will be compared with those observed on ground along the screen lines .The peak hour Traffic Assignment in PCU, passengers and vehicle for the base year is presented in **Fig. 2.8 to Fig. 2.11** for public transport trips, metro trips, private trips and all trips respectively.

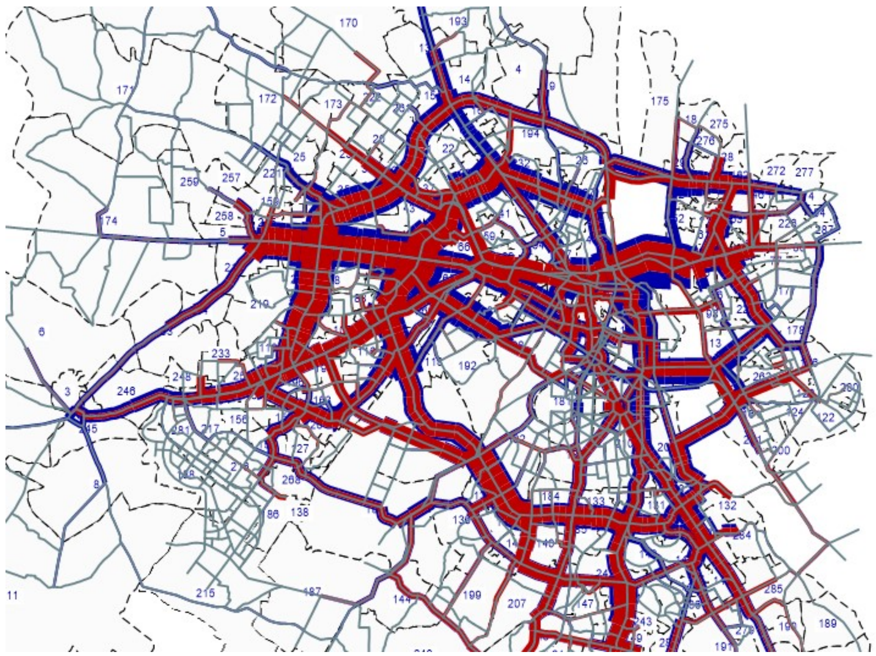


Figure 2-8: Assignment Result for private vehicles and Public transport in passengers for Base Year

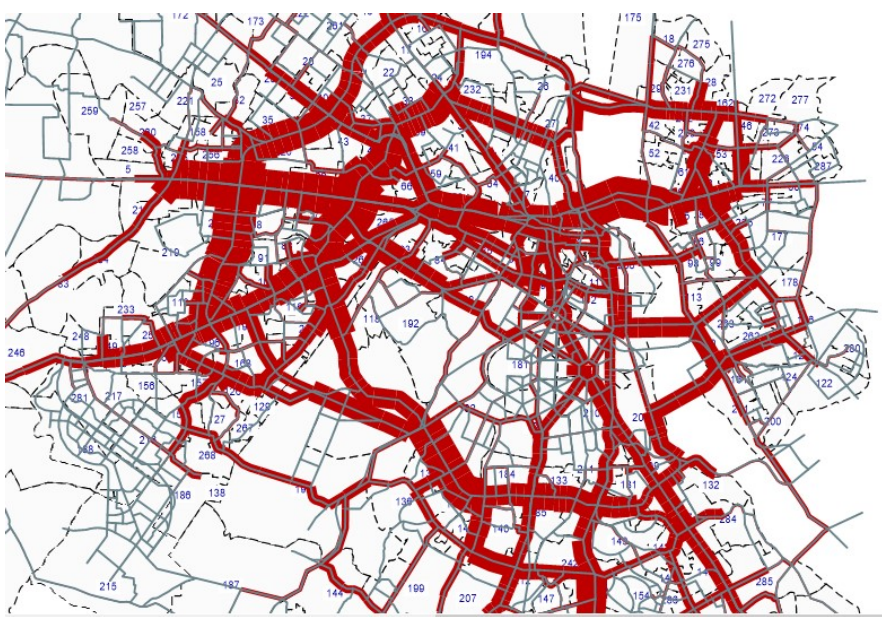


Figure 2-9: Assignment Result for Private Vehicles in Base Year (PCU)

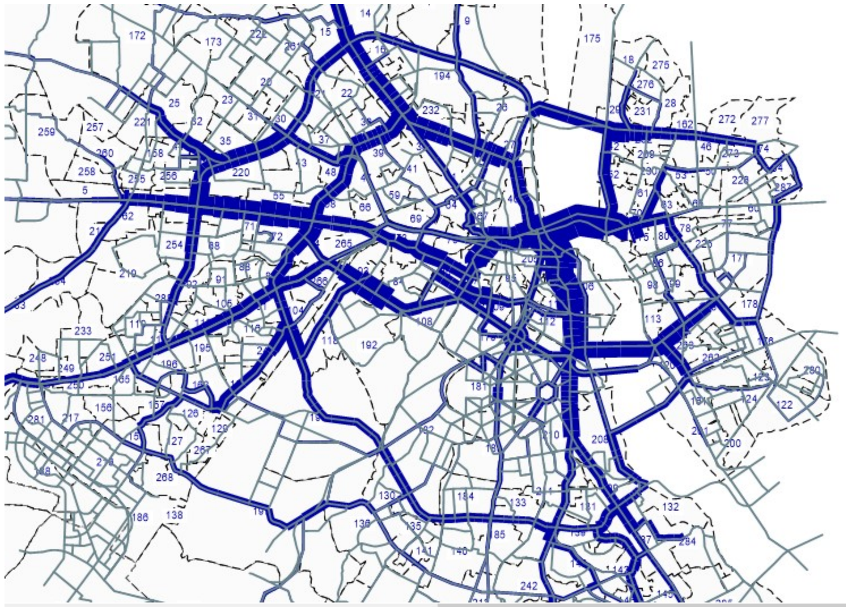


Figure 2-10: Assignment Result for public transport in Base Year (passenger)

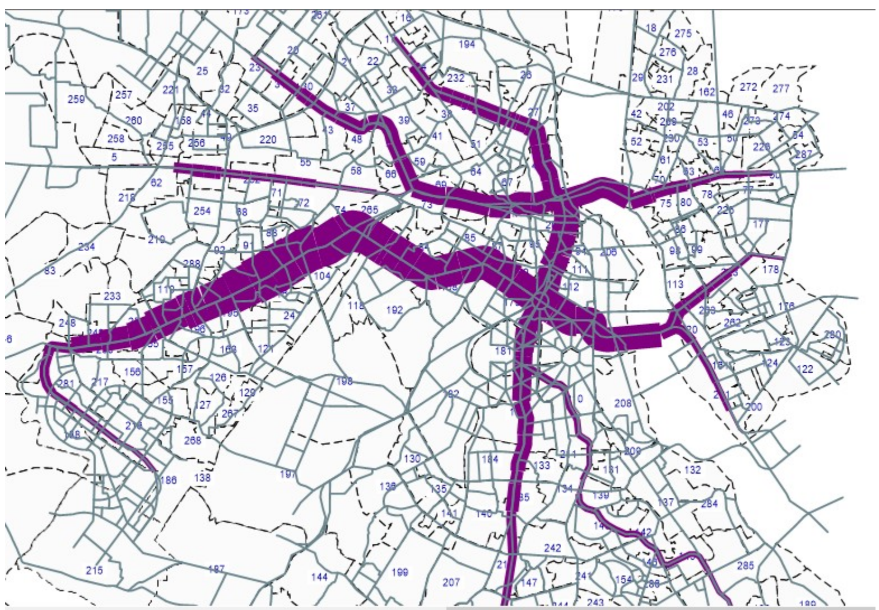


Figure 2-11: Assignment Result for Metro in Base Year (passenger)

2.6.9 Model Calibration and Validate

The model will be termed as calibrated once the traffic loadings on to the network are matching with the observed traffic counts at the selected check points termed as screen lines on the road network.

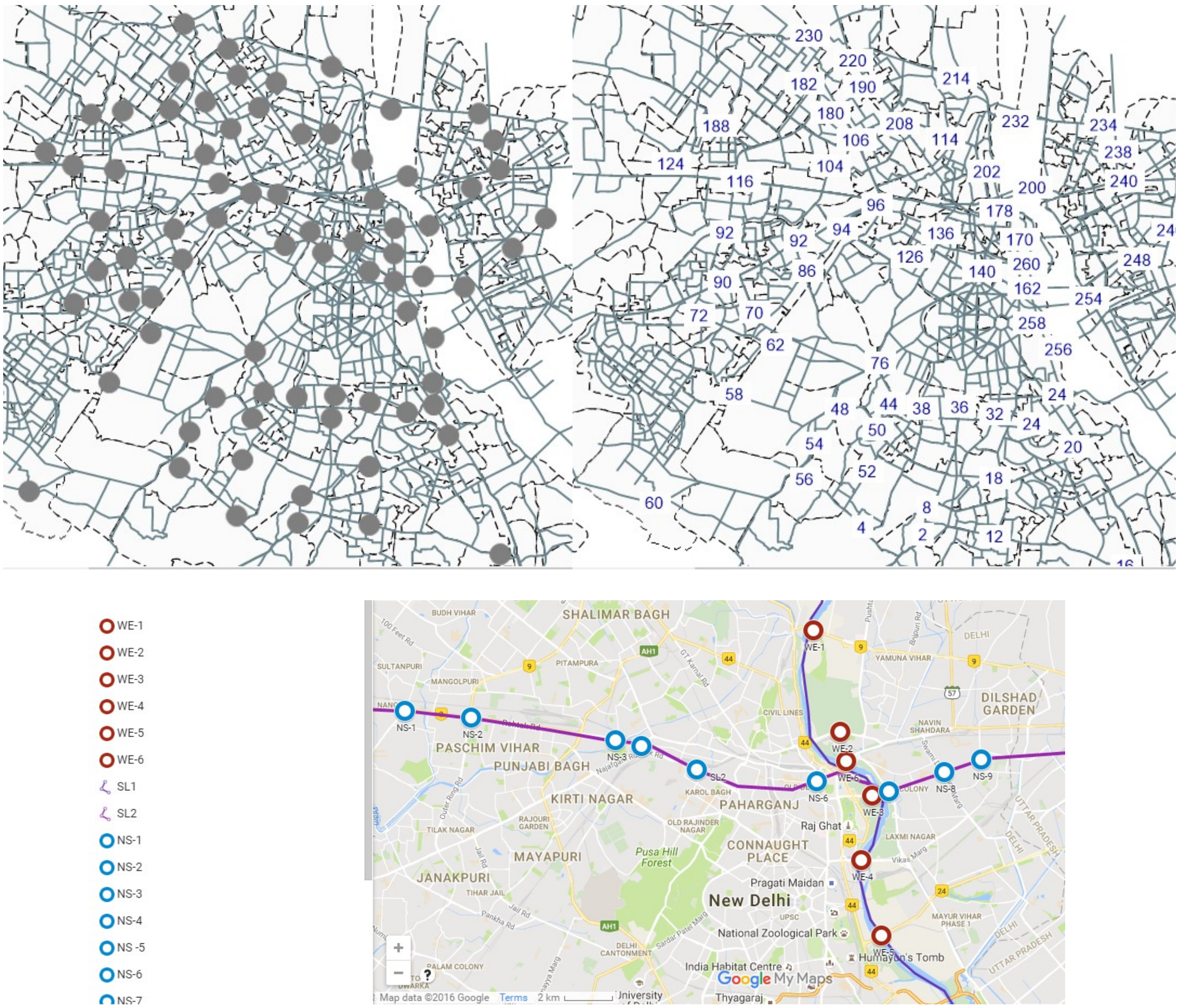


Figure 2-12: Screen Lines and Cordon Line

The model will be calibrated based on the GEH parameter and % error between the model and actual values.

$$GEH = \sqrt{\frac{2*(M-O)^2}{(M+O)}}$$

Where,

M - Modelled Value

O - Observed Value

It the GEH values are below 10 or within +/- 25% variation between observed and modelled assigned flows then the model is considered robust for future application. T**able 2.8 and Table 2.9** respectively shows the location wise and direction wise trip assignment calibration results.

Table 2-8: Model Calibration Results

Location. No	Model	Actual	GEH	Variation %
120	3244	3229	0.3	0%
116	3094	3257	2.9	5%
115	466	625	6.8	25%
112	4594	4179	6.3	-10%
107	2501	2958	8.7	15%
92	4907	4394	7.5	-12%
83	5184	4161	15.0	-25%
80	6060	7108	12.9	15%
79	2672	3552	15.8	25%
69	2749	2359	7.7	-17%
67	4167	3638	8.5	-15%
63	2361	2374	0.3	1%
50	4018	3926	1.5	-2%
49	4091	4110	0.3	0%
47	6282	6736	5.6	7%
43	2533	2056	10.0	-23%
42	6721	8760	23.2	23%
39	6224	5682	7.0	-10%
32	2746	2544	3.9	-8%
31	2859	3132	5.0	9%
28	2373	2532	3.2	6%
22	4305	4067	3.7	-6%
21	9309	10056	7.6	7%
17	3487	4199	11.5	17%
14	3494	2938	9.8	-19%
13	5018	6744	22.5	26%
6	4054	3718	5.4	-9%
4	3806	3464	5.7	-10%
1	3630	3822	3.1	5%

Table 2-9 : Traffic calibration results along the screen lines

Screen Line	Model	Actual	GEH	Error %
SL 1 North South (Yamuna Bank)	25656	26346	4.3	2.6%
SL 2 East West (metro line)	41715	35850	29.8	-16.4%