2. TRAVEL DEMAND ASSESSMENT

2.1 PRIMARY TRAFFIC SURVEYS AND DATA ANALYSIS

A number of traffic & travel surveys were conducted to appreciate and quantify the traffic and transport characteristics of commuter travel within the Study Area. This data analysis has helped us in accessing existing traffic characteristics and developing the Travel Demand Model.

In order to analyse the nature and pattern of public and private traffic/ transport characteristics, comprehensive field surveys and house hold survey were carried out within the study area and are listed as under:

i. Road Network Inventory Surveys
ii. Speed & Delay Surveys
iii. Classified Traffic Volume Count Surveys (Mid-blocks / Screen lines, Intersections & Outer Cordons)
iv. Origin-Destination Surveys at Outer Cordon Locations
v. Terminal Passenger (in + out counts) & OD Surveys including Opinion and Willingness to Pay Survey at Bus, Rail Terminals and Airport
vi. Bus stops/Auto Stand/IPT Surveys (boarding + alighting + OD) including Opinion and Willingness to Pay Survey
vii. Pedestrian Movement Counts
viii. Parking Surveys
ix. Household Interview Surveys
x. Work Centre Surveys

The data collected from field traffic surveys have been analysed and presented in *'Feasibility Report'* submitted in September 2015.

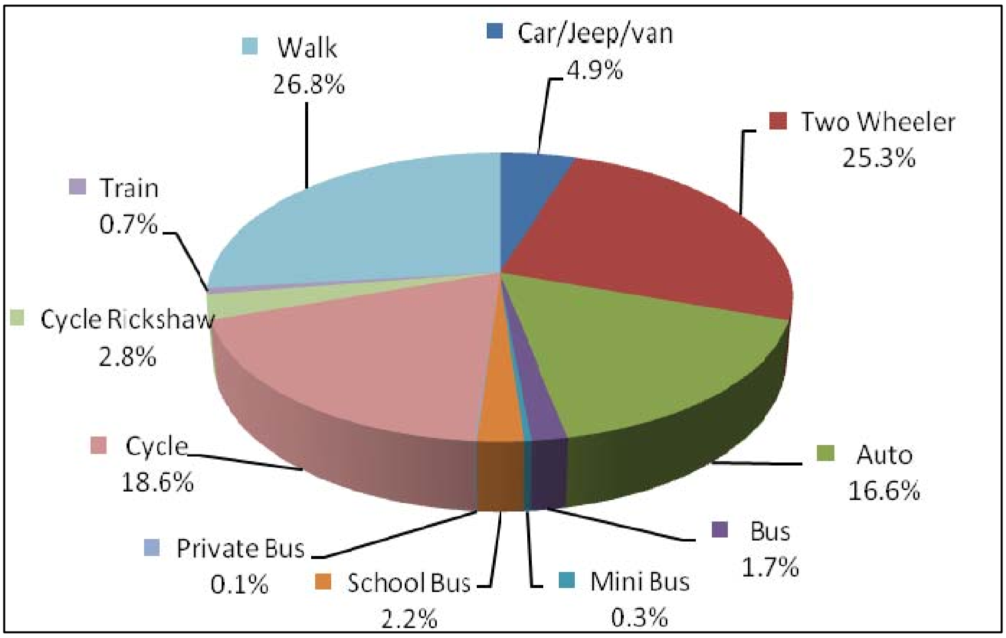
Analysis of household interview surveys (HIS) shows that at present the modal share of public transport and intermediate public transport is about 37% of the total trips excluding walk.

Distribution of daily trips by modes from HIS is presented in **TABLE 2.1** and **FIGURE 2.1**. About 70% of these are vehicular trips while 30% are walk trips. About 12.9 Lakh motorized internal trips have been made in the Study Area by various modes e.g. Car, Two Wheeler, Auto and PT/IPT modes. The per capita trip rate (including walk) is found to be 1.40, whereas the per capita trip rate is 0.98 for the trips excluding walk trips.

TABLE 2.1: DISTRIBUTION OF DAILY PASSENGER TRIPS BY MODE

Mode		No. of Trips	Percentage
Vehicular Trips	Car/Jeep/van	54001	1.96
	Two Wheeler	575085	20.91
	Auto	531271	19.32
	Bus	45878	1.67
	Mini Bus	4441	0.16
	School Bus	74863	2.72
	Private Bus	835	0.03
	Cycle	575992	20.94
	Rickshaw	54804	1.99
	Train	4265	0.16
Walk Trips	Walk	829082	30.14
Total Trips		**2750516**	**100.00**
PCTR Including Walk		1.40	
Total Trip without walk		**1921435**	
PCTR Excluding Walk		0.98	

FIGURE 2.1: DISTRIBUTION OF DAILY PASSENGER TRIPS BY MODE



2.2 APPROACH FOR DEMAND MODELING

The travel demand assessment in urban environment is a complex exercise involving a large number of parameters and warrants the development of a transport model at the City level.

The transportation modeling process consists of development of formulae (or models), enabling forecast of travel demand, and development of alternative strategies for handling this demand. It is not just one model, but a series of inter-linked and inter-related models of varying levels of complexity, dealing with different facets of travel demand. Through these models, the transportation study process as a whole is checked and calibrated before it is used for future travel predictions.

Whilst a large number of commercially acceptable softwares are available for the purpose of modelling travel demand, due heed was paid to the observed traffic heterogeneity in the study area. After analyzing the specific requirements of the model and the software, RITES has used CUBE software developed by Citilabs for the modelling exercise.

The software can address the impact of new landuse developments as envisaged by master plan control policies. Cube is fully capable of modeling typical mixed traffic flow conditions such as private transport (car and 2wheeler) and public transport (shared auto rickshaw, bus and rail based mass transit systems).

An operational travel demand model is required to enable estimation of future travel demand that will help towards identifying transport requirements for the study area. The said model is also a pre-requisite to the fact that the consultants are able to validate the actual travel patterns (as observed) within an acceptable error range (+-15%).

The standard 4 stage Urban Transport Planning System model has been adopted that inter-alia consists of:

- Trip Generation and Attraction Sub Model
- Trip Distribution Sub Model
- Modal Split Sub Model
- Assignment Sub Model

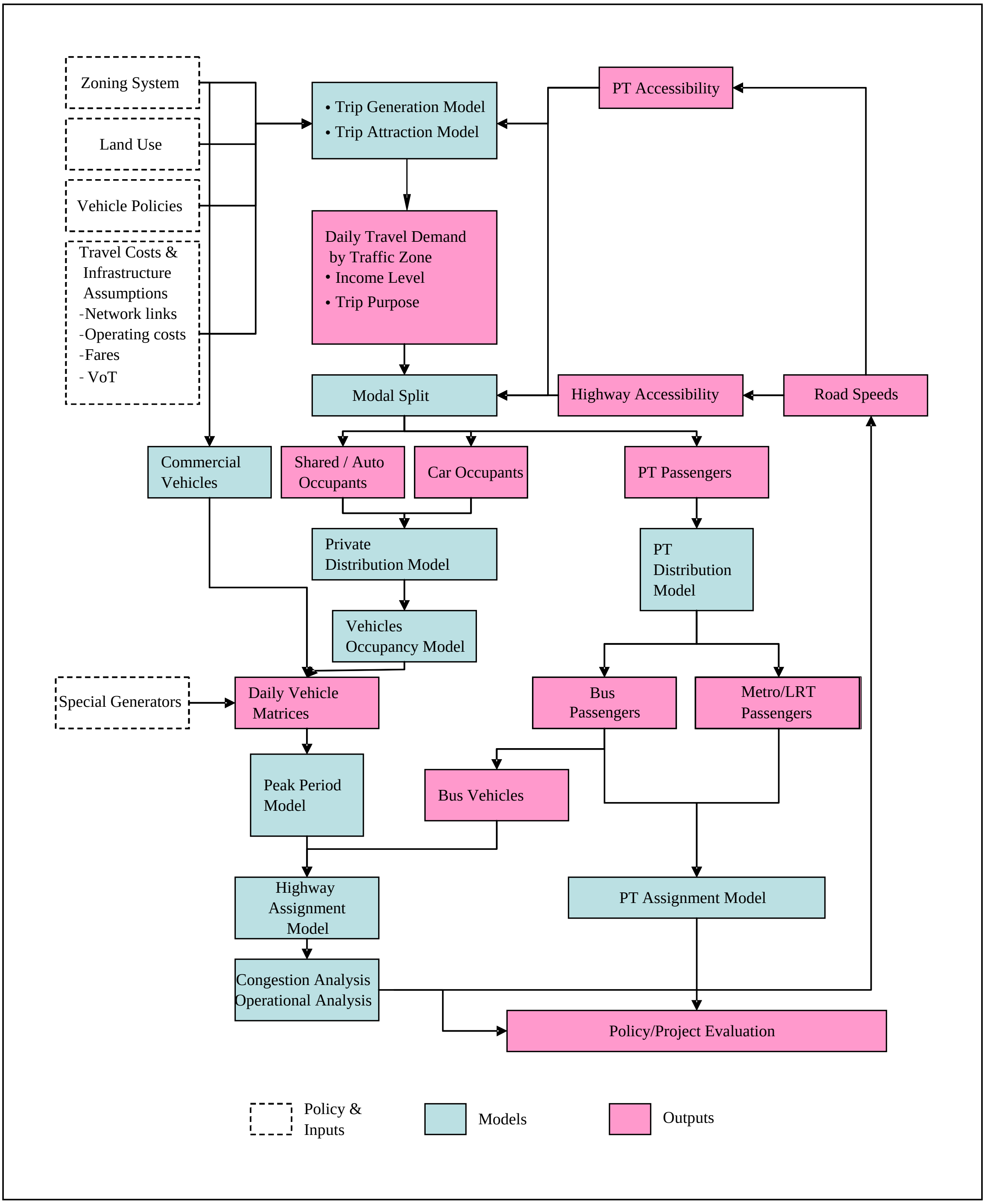
The parameters involved in the model development are population, employment, school enrolments and transport systems (with their accessibility, speed & capacity) of the study area. A commuter decides on his/ her selection of travel mode considering a number of parameters including accessibility of travel mode from the house, total travel time, total cost of travel, convenience/ comfort of travel and cost/ convenience for reaching the destination at the other end of the main journey. The commuter evaluates the merits and demerits of all possible alternative modes and their combinations before deciding on the final selection of travel mode(s).

Transport demand is a function of landuse and the growth of demand in various years vary depending upon the interrelationship of various landuse and traffic intensity in future years. Some of the major inputs to an urban transport demand model are:

- Delineation of study area into smaller traffic zones
- Population (existing and proposed at traffic zone level)
- Employment (existing and proposed at traffic zone level)
- School enrolment data
- Transport network and system (alongwith their respective carrying capacity and speed of each type of network/ system)
- Speed and frequency of operation of the proposed System.
- Intermodal integration facilities available and time required for passengers to interchange from one mode to another. This will also include the walking time required to access a particular System.

The sequence of activities involved in the model is depicted in **FIGURE 2.2**

FIGURE 2.2: FOUR STAGE TRAVEL DEMAND MODEL



2.3 BASE YEAR TRANSPORT NETWORK AND TRAFFIC ZONE SYSTEM

Updated base maps for identified locations, areas, junctions and intersections collected from the respective agencies as a part of secondary data collection exercise helped in the development of base year transport network of the Study Area. The transport network consisting of primary, secondary, tertiary road network was coded & developed in Cube. The link attributes such as Speed, Carriageway, ROW, Length etc are derived from the Road Network Inventory and Speed and Delay survey data.

The base map contains all the secondary data such as zone boundaries, ward boundaries and road/rail network details. A traffic zone system is developed for the Study Area on the base map based on the existing ward boundaries and natural physical barriers. The proposed traffic zoning system gives due consideration to zoning system adopted by previous studies, road and public transportation network distribution. It is sufficiently detailed to capture inter zonal trips.

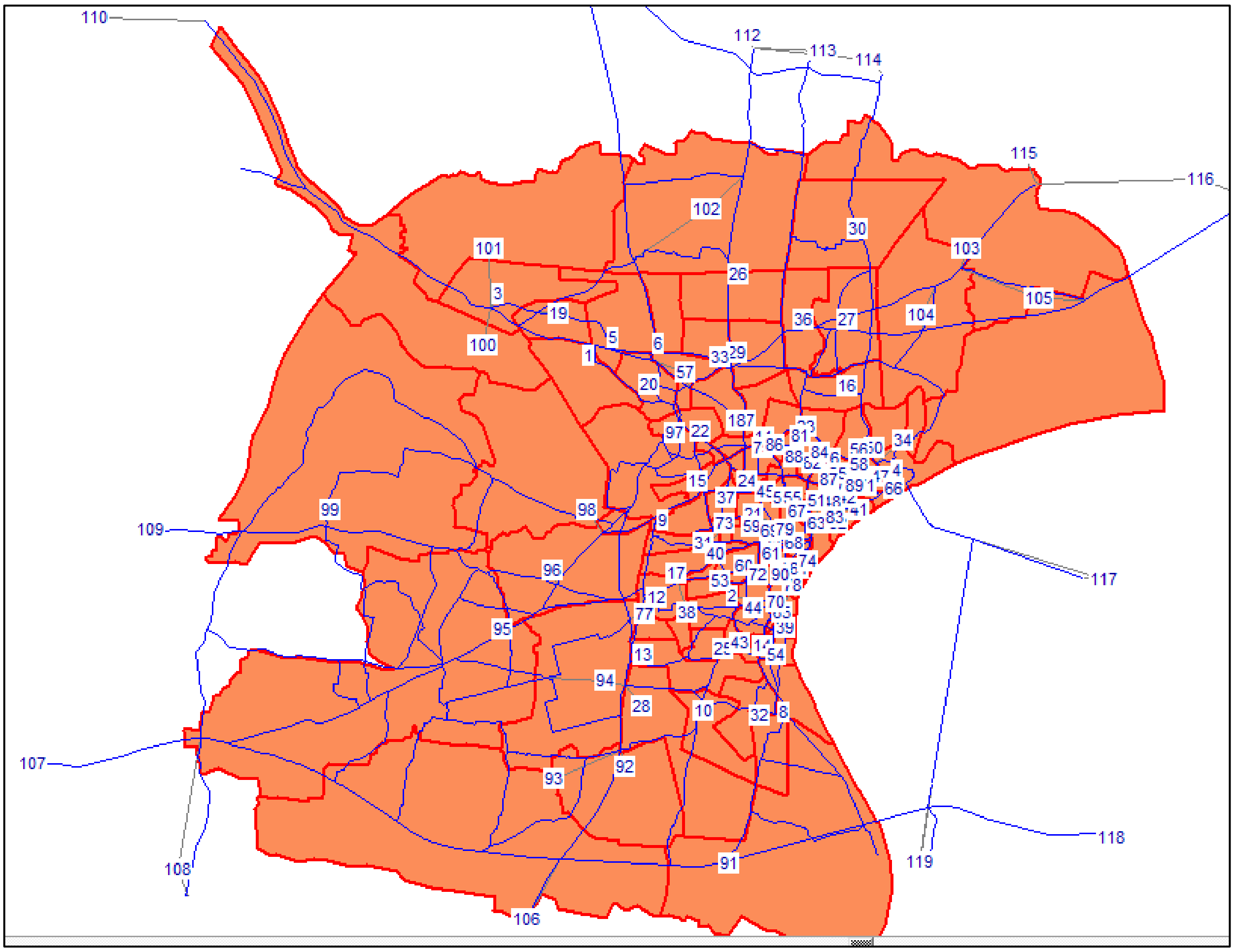
To understand the travel pattern of the city, a total of 119 zones called traffic analysis zones have been identified. Considering the ease of getting required zonal information, administrative wards were considered as zones within the Municipal Area. The areas that fall within Varanasi Development Authority but outside the Municipal Boundary have been divided into zones based on homogenous land use and traffic generation points. A total of 105 internal zones inside VDA area and 14 external zones have been considered for the study.

Zone connectors are included in the model to allow the trip matrices to be assigned to the Road network. All zones were provided with at least one zone connector. The location and definition of connector is intended to assimilate, as far as possible, the actual connectivity of trip generation centers to the Road network. The zoning system and the coded road network of the study area is presented in **FIGURE 2.3.**

2.4 MODEL STRUCTURE

The model developed is a traditional four-stage transportation model, as illustrated in **FIGURE 2.4**, with the following characteristics:

FIGURE 2.3: ZONING SYSTEM AND CODED BASE YEAR ROAD NETWORK



The model is based on motorised trip productions / attractions and internal trips of Varanasi Development Authority area residents. These modes of travel (ie. Car, Two wheelers, Auto-rickshaw and Public Transport including Shared Auto, Bus & Mini bus) comprise about 12.32 Lakh daily trips. The remaining trips are those relating to non-mechanised trips (walk, cycle and cycle rickshaw).

Four sub models are developed viz. Generation, Attraction, Distribution, Modal choice and Assignment models

- Generation and Attraction models calculate trips generated and attracted by each zone;
- Distribution models distribute trips generated into the possible destinations and provide matrix of total trips;
- Modal choice models split total trip matrix by mode;
- Assignment models represent the last stage of the model, build paths, assign origin / destination (OD) matrices, and finally provide loaded networks (average hour and peak hour);

The model development is largely based on the Households Interview Survey (HIS) and other traffic surveys after expansion from survey sample to total population. This is calculated at a zonal level.

The next step was to build the base year Road matrices necessary to obtain costs for the model development (distribution and modal choice).

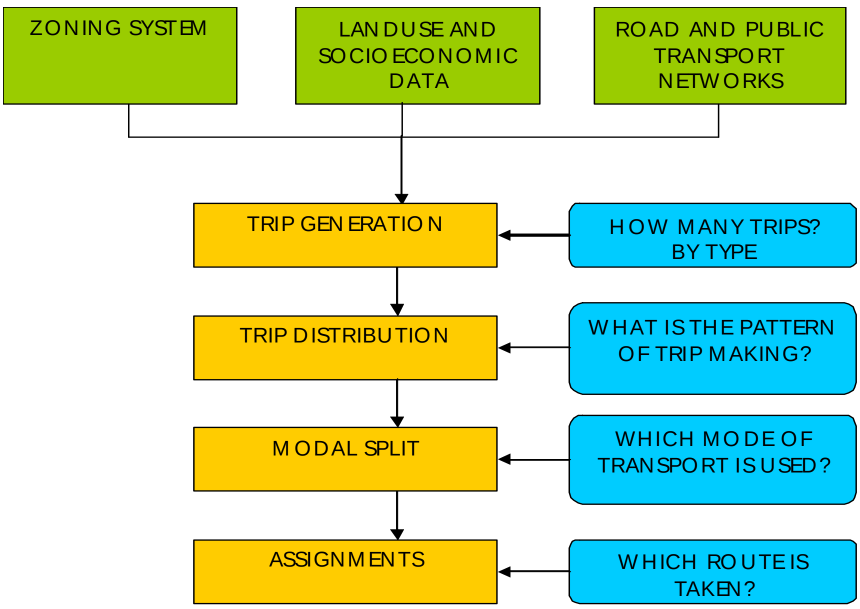
The base year HIS person matrices converted to vehicles using occupancy factors, external zones trip matrices from road side interview at Outer Cordon locations and special generators (bus and railway station) matrices to get total traffic across the study area.

A total of about 15 thousand daily tourists (Total 54.9 Lakh per annum) are expected to use the existing transport facilities. It is assumed that each tourist will make average 3.5 trips per day (assuming the tourist attraction centers trips including return trips). Thus about 52 thousand passenger daily trips are added to total trips. Total daily traffic to the tune of about 16.9 Lakh has been assigned to the coded network of the study area in the base year 2015. These trips further divided into Intracity & Intercity trips **Table 2.2** represents the Total intracity & Intercity trips assigned in base year.

TABLE 2.2: INTRACITY & INTERCITY TRIPS ASSIGNED IN BASE YEAR - 2015

Intracity		Intercity		Total
Trips	%age	Trips	%age	Trips
1302674	76.9	392301	23.1	1694975

FIGURE 2.4: FOUR STAGE MODEL STRUCTURE



2.5 TRIP GENERATION & ATTRACTION

Trip generation is the first stage of the travel demand estimation process. Trip Generation modeling aims at predicting the total number of trips generated by and attracted to each zone of the study area from the estimated future land use activities. Thus, the two components of trip generation modeling are:

Trip Production: This is defined as the home end of a home based trip or as the origin of a non-home based trip. It thus gives the total trips produced by a zone.

Trip Attraction: This is defined as the non-home end of a home-based trip or as the destination of a non-home based trip. It thus, gives the total trips attracted to a zone.

2.5.1 Factors Affecting Trip Generation

The factors that affect Trip Generation can be categorized into following categories:

- Land Use Factors: Population, Indicators of Intensity of Residential Activity, Intensity of Employment Opportunities, Land Values etc.
- Household Factors: Household Income, Vehicle Ownership, Family Size, Family Structure etc.
- Urbanization Factors: Degree of Urbanization, Distance from CBD, Accessibility etc.

2.5.2 Trip Purposes

The purpose of the trip can be broadly categorized in home based trips & non-home based trips. Home based trips are those in which one of the either trip ends is at the home while the non-home based are those in which neither end is at home. Different transportation studies have adapted different classification systems for trip purpose depending upon the planning issues involved and the size of the city. The trip generation model has been developed for home based trips in aggregation while the trip attraction model incorporates the 4 trip purposes of home base work (HBW), home base business (HBB), home base education (HBE) and home base other (HBO) trips for the study.

2.5.3 Mathematical Forms

- **Trip Production Equations**

The general form of the work trip production equation developed is

$$Ti = a + b*(IVi)$$

Where,

Ti = Trips produced from zone i
a = constant (unexplained part of the relationship)
b=parameter explaining the dependency on the independent variable and representing the Trip Rate
IVi = Independent Variable in zone i

- **Trip Attraction Equations**

The general form of the trip attraction equation developed is

$$Tj = a + b*(IVj)$$

Where,

Tj = Trips attracted to zone j
a = constant (unexplained part of the relationship)
b = parameter explaining the dependency on the independent variable
IVj = Independent Variable in zone j

2.5.4 Trip Generation Model

The linear regression analysis was used to develop the trip production and trip attraction equations. A zonal regression model was used in which each traffic zone is treated as one observation. The aggregated analysis has been applied for developing the model which is based on the assumption that contiguous households exhibit a certain amount of similarity in travel characteristics. This assumption allows the data in a zone to be grouped and the mean value of the independent variable used in further calculations. The trip production and attraction output in terms of the correlation coefficients are given in **Table 2.3.**

TABLE 2.3: TRIP GENERATION SUBMODELS - 2015

Dependent Variable	Independent Variable	Regression Coefficient (Trip Rate)	(R^2) Co-efficient of Determination
(Y)	(X)	(b)	
Trip Production			
All Modes	Population	0.7033	0.92

- **Independent Variable: Zonal Population**

Figure 2.5 shows the scatter plotting between population and production. **Table 2.4** details the summary of the output for Trip Production Model. The trip production model developed for Varanasi is stated below:

Trips Produced = 0.7033* (Population), **R^2 = 0.92**
Where,
P = Population
R^2 = Coefficient of Determination

FIGURE 2.5: SCATTER PLOT: POPULATION VS TRIP PRODUCTION

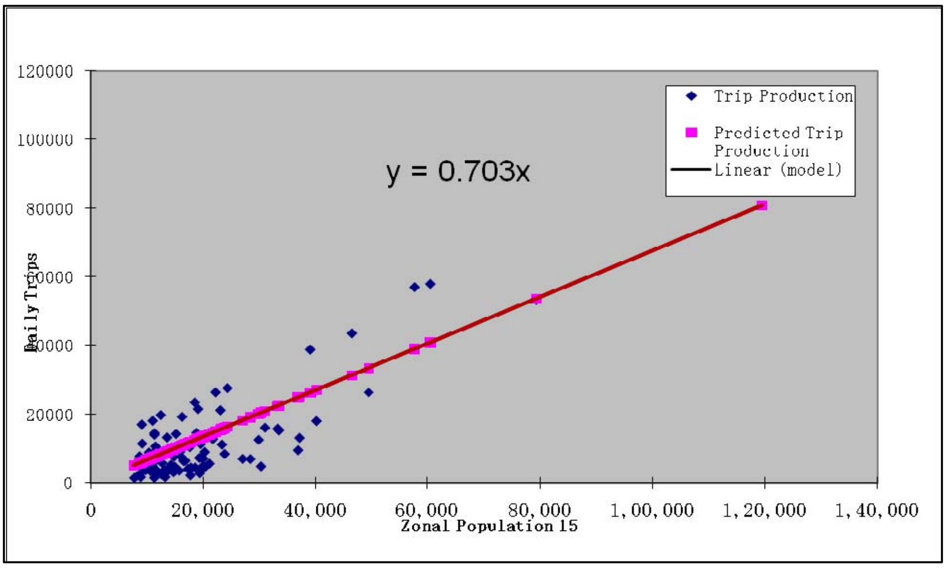


TABLE 2.4: SUMMARY OF OUTPUT OF TRIP PRODUCTION MODEL

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.9204							
R Square	0.8471							
Adjusted R	0.8374							
Std. Error	7175.02							
Observations	105.0							
ANOVA								
	df	***SS***	***MS***	***F***	***Significance F***			
Regression	1	29652285779	29652285779	575.985	5.62035E-44			
Residual	104	5354021712	51480978					
Total	105	35006307491						
	Coeff	***Std. Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.7033	0.0282	23.9997	0.0000	0.6199	0.7316	0.6199	0.7316

2.5.5 Trip Attraction Model

The Generation model produces daily person trips (all purpose combined) generated by zone, whilst the attraction model estimates daily person trips attracted by zone. For each of the 4 purpose groups, a linear regression was estimated, explaining the number of trips attracted by the socio-economic data, total employment for HBW, HBB & HBO and school enrolments for HBE. To be consistent with the generation model, the attraction model is based on PA.

The coefficient of Determination R^{2} is the deciding factor for linear regression analysis. The more R^2 is near to 1, more the linear regression is reliable. For instance, **Figure 2.6** presents the linear regression of HBW trips with R-square value equal to 0.92 showing a good match between the data from HIS and the estimated values from the linear regression. **Table 2.5** details the summary of the output for Trip Production Model.

FIGURE 2.6: ATTRACTION MODEL (HBW – LINEAR REGRESSION)

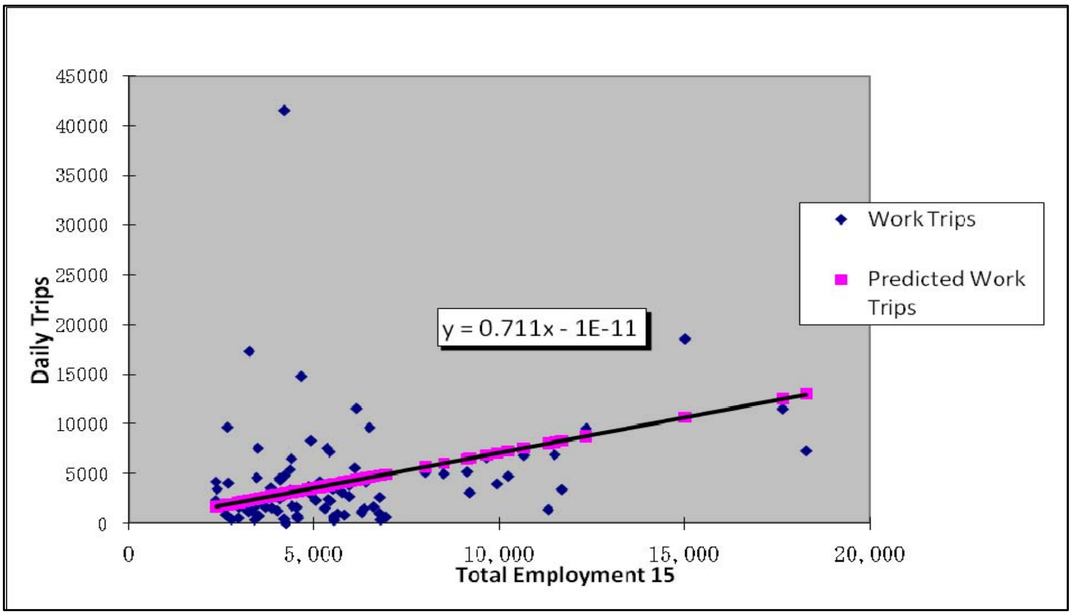


TABLE 2.5: SUMMARY OF OUTPUT OF TRIP ATTRACTION FOR HBW TRIPS

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.6941							
R Square	0.4818							
Adjusted R Square	0.4722							
Standard Error	4635.57							
Observations	105							
ANOVA								
	df	***SS***	***MS***	***F***	***Significance F***			
Regression	1	2078129913	2078129913	96.70888	1.73E-16			

Residual	104	2234805314	21488512.6					
Total	105	4312935227						
	Coefficients	***Standard Error***	***t Stat***	***P-value***	***Lower 95%***	***Upper 95%***	***Lower 95.0%***	***Upper 95.0%***
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	0.7115	0.0723	9.8340	1.58E-16	0.5680	0.8550	0.5680	0.8550

The Attraction Model calibration is summarized in **Table 2.6,** by purpose, HIS and model figures are very similar, showing a very close correspondence between modeled and observed values.

TABLE 2.6: ATTRACTION MODEL CALIBRATION RESULTS

Group	HIS	Model	Difference
HBW	4,21,261	4,19,517	-0.4%
HBB	2,99,295	3,00,270	0.3%
HBE	3,32,602	3,32,909	0.1%
HBO	1,79,518	1,80,134	0.3%
Total	**12,32,676**	**12,32,830**	**0.0%**

2.6 TRIP DISTRIBUTION MODEL

After determining the trip productions (Ti) and trip attraction (Tj), the next stage is to link the productions with attractions in order to quantify how the trips are produced in a zone and are distributed among or attracted to all other zones (Tij).

A number of methods are available which explains and predicts the distribution of trips. These are:

- Growth Factor Models
- Gravity Models
- Opportunity Models
- Stochastic Behavioral Models

2.6.1 Model Method and Description

Of the above four types of models available for trip distribution stage of travel demand modeling, Gravity Model has been most widely used in previous studies and suits the present study most due to data availability and its better applicability in the future.

The more recent trip models have the least resemblance with this original version, but the generic name still continues. The basic philosophy is to relate productions and attractions of different zones with quantum of trip modeling between individual zone pairs.

$$T_{ij}=R_iC_j\,P_i\,A_j\,f\,(\,W_{ij}\,)$$

Where,

Tij= Trips between zonal pairs i and j
Pi=Trip Production at zone i = Σi Tij
Aj= Trip Attractions at zone j = Σj Tij
f (Wij) = Function separating zonal pairs i & j typically known as Friction Factor
Ri and Cj = Constants of proportionality

2.6.2 Gravity Model Types

Gravity models can be run in Cube with/ without constraints. The types of Gravity Models are:

a. Unconstrained
b. Production Constrained (Singly Constrained)
c. Attraction Constrained (Singly Constrained)
d. Fully Constrained (Doubly Constrained)

The variations in the Gravity Models mentioned above are the result of variations in satisfying these productions and attractions conditions.

a. Unconstrained Gravity Model

This takes the following shape

$$T_{ij}=K\,P_i\,A_j\,f\,(\,W_{ij}\,)$$

Where,

K =Constant of proportionality which ensures that the total number of trips from the model output equals to the total number of trips in the survey matrix. But there is no guarantee that the sums of the rows and columns of the matrix will balance individually with the survey total.

b. Production Constrained Gravity Model

This model is of the form

$$T_{ij} = \frac{P_i A_j f(W_{ij})}{\Sigma A_j f(W_{ij})}$$

This ensures that when summed across the rows of the model T_{ij} matrix, the individual zone trip origin totals equal the corresponding observed trip totals.

c. Attraction Constrained Gravity Model

They are of the following type

$$T_{ij} = \frac{A_i p_j f(W_{ij})}{\Sigma P_j f(W_{ij})}$$

Here the constant of proportionality guarantees that when summed down the columns of the model Tij matrix the zonal trip destinations equal the corresponding observed trip destination total.

d. Fully constrained Gravity Models

They are as follows:

$$T_{ij} = R_i C_j P_i A_j f(W_{ij})$$

$$R_i = \frac{1}{\Sigma R_i P_i f(W_{ij})}$$

The constant of proportionality now becomes the joint product of R_i and C_j. It is known as balancing or normalizing factor. The purpose is to ensure that the model T_{ij} Attractions and Productions match the observed T_{ij} Attractions and Productions.

2.6.3 Gravity Model Development and Calibration

For the practical purpose of gravity model application in the study area and distribution of the observed Tij for other zone pairs where zero trips were observed in sample matrix, fully constrained gravity model has been chosen for the base year of 2015. The models were developed based on the HIS database and the generalized costs (GC) produced from the private and public transport cost models implemented in Cube Voyager software. The main features of the models are as follows:

- **Unit:** person (productions / attractions – PA);
- **Period:** daily;
- **Model formulation:** gravity model, based on composite GC presented in **Figure 2.7.**

FIGURE 2.7: GRAVITY MODEL FORMULATION

$$T_{ij} = a_i b_j P_i A_j F(C_{ij})$$

Where

T_{ij} = trips estimated from zone i to zone j

P_i = productions from zone i

A_j = attractions to zone j

a_i, b_j = row/column balancing factors

$F(C_{ij})$ = cost deterrence from zone i to zone j

$$F(C_{ij}) = C_{ij}^{X_1} \exp(X_2 C_{ij})$$

Where

$F(C_{ij})$ = cost deterrence for zone i to zone j

C_{ij} = generalised cost for zone i to zone

X_1, X_2 = coefficients to be calibrated.

The composite GC is the average of the GC for individual modes weighted by modal split proportions (produced by modal split models) by origin / destination movements.

The measure of deterrence is the perceived inter-zonal generalised cost (this is what the traveller unconsciously thinks it costs him to travel from one place to another). For each pair of zones, generalised cost by different modes is determined. For any inter-zonal trip, the cost between each of the two zone centroids and between them and the appropriate actual network nodes is added to establish the least cost journey through the whole network between the zones. For example, for a trip including one or more public transport links and walk links thereto, the public transport generalised cost is made up of:

- Walking time to bus stop (from notional centroid link)
- Waiting time at bus stop
- Travelling time on bus
- Interchange waiting time – where appropriate
- Walking time from bus stop to destination (by notional centroid link)

For individual modes, the **GC** represents perceived costs, where the unit is minute equivalent, implying the use of values of time (VOT, 2015 prices, Rupees / hour) by mode to convert monetary costs (fare, vehicle operating cost - VOC) into minutes. Occupancy factors (OCC) are also used for car, 2w, and auto to obtain person based GC. The GC by mode is described below:

- **Car GC** = Time + [((VOC) / OCC) / VOT] x 60;
- **2W GC** = Time + [((VOC) / OCC) / VOT] x 60;
- **Auto GC** = Time + 1.5 x Wait Time + [(Fare / OCC) / VOT] x 60;
- **PT GC** = IVT + 1.5 x Walk Time + 2 x Wait Time + (Fare / VOT) x 60 + Transfer Time;

2.6.4 Gravity Model – Calibration Results

The sequence of activities involved in the calibration of Gravity Model is shown in **Figure 2.8.** This section provides the distribution models calibration results by the segments: X1 and X2 parameters, average GC (in minutes), and trip GC distribution. As illustrated by **Table 2.7** the overall models results are almost similar to the HIS database.

FIGURE 2.8: SEQUENCES OF ACTIVITIES FOR CALIBRATING GRAVITY MODEL

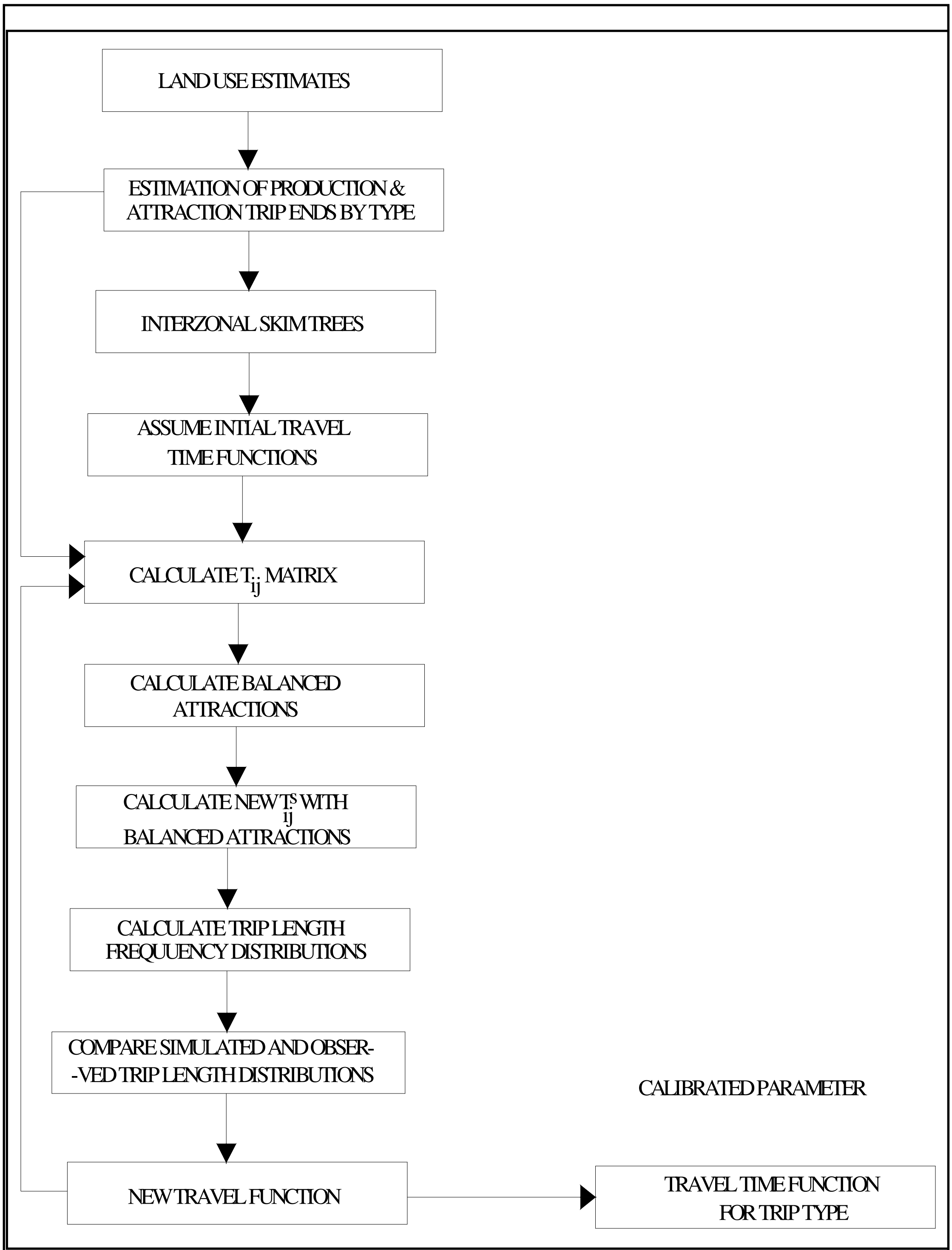


TABLE 2.7: DISTRIBUTION MODELS CALIBRATION RESULTS

Trip	HIS	Model				Difference in Trips
	Daily Trips	X1	X2	GC	Trips	
Total Trips	1232676	-0.394	-0.034	7.5	1232823	-0.01%

Calibration process included comparison of observed and simulated mean trip time (minutes) as well as shapes of the trip time frequency distribution.

For developing speed flow relationship, data from Road User Cost Study was adopted and used to calculate calibration factors of Curve. The form of equation (power curve) used for the study is as under;

t(v) = t0 + (tc – t0) (v/c)n

Where tc = t0 + acn is the travel time at capacity. This form is sometimes easier for user manipulation since it uses only basic variables and removes the necessity to calculate the value of the coefficient 'a'.

2.7 MODAL SPLIT MODEL

The modal split model is developed based on the HIS database and the Generalised Costs (GC) produced from the private and public transport cost models implemented in Cube Voyager software.

The total trips are split into two major group of private and public mode of travel. Then private modes are further divided into car, 2w, and auto. PT trips are separated between bus, shared auto and metro services during the assignment stage. It should be noted that the PT matrix produced by the modal split model contains trips using school, chartered, and public buses, but only the last category is retained for the PT assignment, the other two groups (school and chartered buses) not using the public network. However, these are taken into account in the Road assignment.

The main features of the modal split model are as follows:

- **4 modes:** Car, two wheelers, auto, and PT (including shared auto);
- **Unit:** person (productions / attractions – PA);
- **Period:** daily;
- **Model formulation:** Combined Split, Multi-Logit Formulas (equations provided in **Figure 2.9**, where P means Probability and C is the Generalised Cost);

FIGURE 2.9: MULTI-LOGIT FORMULAS (COMBINED SPLIT)

$$P_{Car+taxi} = \frac{e^{(-\lambda C_{Car+taxi})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

$$P_{2W} = \frac{e^{(-\lambda C_{2W})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

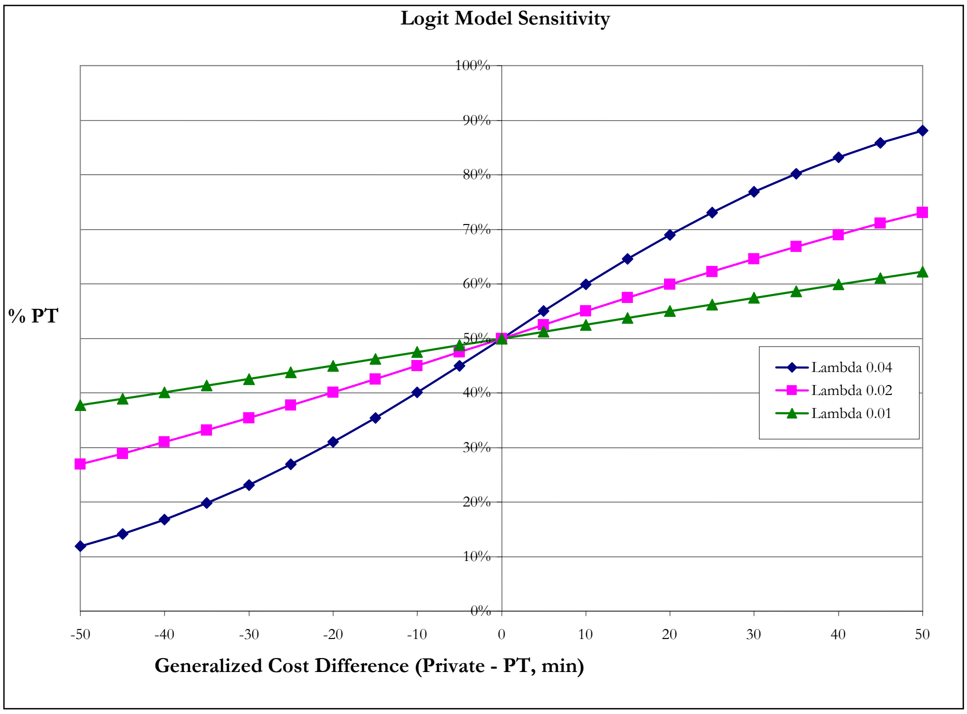
$$P_{Auto} = \frac{e^{(-\lambda C_{Auto})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

$$P_{PT} = \frac{e^{(-\lambda C_{PT})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

- **Logit Parameters Estimation:** The mode choice sensitivity revealed by the model is mainly determined by the parameter λ. This model parameter was developed based on statistical regression analysis, which also provided some initial estimates on the mode biases between private and public modes of travel. As shown by **FIGURE 2.10** for illustrative purpose only (example with Private versus Public Travel modes), when λ increases, the model becomes more responsive to the difference in cost.

The GC represents perceived costs, where the unit is minute equivalent, implying the use of Values of Time (VOT, 2015 prices, Rupees / hour) by mode to convert monetary costs (fare and vehicle operating cost - VOC) into minutes.

FIGURE 2.10: LOGIT MODEL SENSITIVITY



Occupancy factors (OCC) are also used for car, 2w, and auto to obtain person based GC. Below are described the GC by mode:

- **Car+Taxi GC** = Time + [(VOC/OCC) / VOT] x 60;
- **2W GC** = Time + [(VOC/OCC) / VOT] x 60;
- **Auto GC** = Time + 1.5 x Wait Time (4) + [(Fare / OCC) / VOT] x 60;
- **PT GC** = IVT + 1.5 x Walk Time + 2 x Wait Time + (Fare / VOT) x 60 + Transfer Time

2.8 MODAL SPLIT CALIBRATION RESULTS

TABLE 2.8 demonstrates that there is close correspondence between the synthesized and observed values from the HIS. The following observations can be made:

In theory, for any multi-logit model with two possible choices, there is one bias factor available. Calibrated Modal Choice Model has been developed with the Lambda parameters between private & public as (-) 0.059 and further between buses and shared autos as (-) 0.079.

TABLE 2.8: MODAL SPLIT MODEL CALIBRATION RESULTS

Modes	HIS Trips	Model Trips	% diff
Car	49487	49456	0.06%
2W	549381	549214	0.03%
Auto	52068	52052	0.03%
PT including Shared Auto	581740	582101	-0.06%
Total Trips	**1232676**	**1232823**	**-0.01%**

2.9 TRIP ASSIGNMENT MODEL

The trip assignment procedure determines the route choice of trip maker to whole or a part of a network and is the last part of travel demand modeling process where the inter-zonal modal trips are assigned to the various links of the network. There are at least four factors that lead people to choose one route over another. They are travel time, generalized travel cost, Travel distance and level of service. Taking a single parameter to determine the shortest path between each zone pair assumes that there is only one preferred path between each origin and destination. The traffic assignment itself can be of various type like All or Nothing Assignment, Capacity Restrain Assignment and Multipath Assignments.

The Road assignment is a multiple user class assignment using equilibrium algorithm and capacity constraint. In this method of assignment, trip matrices are loaded onto the network, using an incremental assignment method. The trip matrices are assigned to the shortest paths generated successively after assignment of small lots each of 15-20% increment of the trips matrices. The incremental assignment proceeds by updating the transport networks using the speed flow relationships of the links. The assignment is largely controlled by alternative paths, which are built by the shortest path algorithm through the network. The output of the assignment is a loaded Road network with volumes (PCU unit) by link and vehicle type, and network speeds.

For the public transport assignment, the person trips unit is retained. The public transport network is developed from the Road network following the Road assignment, a process which produces a loaded road network representing congested travel times on the road network.

The public transport assignment considers multiple routes at an origin / destination level, and includes the modeling of fares for different modes. The selection of public transport route choice is based on the travel costs, including walk access time to bus or metro stops, wait time, in vehicle time and fare, transfer or interchange walk times and subsequent wait times, and the time to reach the final destination. The output of the assignment is a loaded public transport network with patronage by service.

The PT assignment is based on the PT lines file built in Cube Voyager software, which contains a total of existing 58 “real” lines of buses and shared auto (considering the directionality) in the study area.

The 4-stage model produces daily matrices therefore a standard average hour factor of 7% is applied to the matrices for both the daily private and public transport assignments. Peak hour model assignment is done separately to exhibit the constrained level of services during the peak hour.

2.10 PEAK HOUR MODEL VALIDATION

The 4-stage model finally provides Daily & Peak Hour person matrices by mode at the end of the process including the peak hour external and special generators matrices.

2.10.1 Peak Hour Assignments Validation Result

The travel demand model needs to be validated to determine whether it is reproducing existing traffic conditions. Model validation has been undertaken by comparing the observed data collected from the traffic volume count surveys with their equivalent synthesized results as produced by the Cube model. The discrepancies observed at most of the survey locations are within 0-15% of the actual counts.

Table 2.9 shows comparison of observed and assigned flows across the identified Midblock locations. The validation results are quantified thorough GEH Statistics using the 'Validation' option in Cube. The GEH Statistic is a formula used in traffic modelling to compare two sets of traffic volumes. Although its mathematical form is similar to a chi-square test, is not a true statistical test. Rather, it is an empirical formula that has proven useful for a variety of traffic analysis purposes.

The formula for the "GEH Statistic" is:

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

Where, M is the hourly traffic volume from the traffic model (or new count) and C is the real-world hourly traffic count (or the old count).

Using the GEH Statistic avoids some pitfalls that occur when using simple percentages to compare two sets of volumes. This is because the traffic volumes in real-world transportation systems vary over a wide range. For traffic modelling work in the "baseline" scenario, a GEH of less than 7.0 is considered a good match between the modelled and observed GEHs in the range of 7.0 to 10.0 may warrant investigation. GEH greater than 10.0 is not acceptable.

For the present study the traffic flows at identified midblock locations are within the acceptable error range.

The model validation results as presented above show that the model accurately replicates the existing travel situation in the study area (base year 2015) since the model figures are close to the observed data, HIS database and traffic counts. Therefore, the step following the model development, calibration, and validation, is to provide travel demand forecasts for the future years.

Assigned peak hour traffic volume on the network in base year is presented in **Figure 2.11.**

FIGURE 2.11: ASSIGNED PEAK HOUR TRAFFIC VOLUME ON NETWORK IN PCU - 2015

TABLE 2.9: COMPARISON OF OBSERVED AND MODELED FLOWS AT SCREENLINE LOCATIONS

SN	Mid-Block / Screenline Location	Survey Peak	Modeled	%	GEH
1	DLW Manduadih Road (Near_Temple)	1180	1133	-4.1%	1.4
2	Lanka Road (Near_Hanuman Mandir)	1004	1103	9.0%	3.1
3	SH-74 Chunar Road(Near_Jeevan Hospital)	1073	1112	3.5%	1.2
4	DLW Road (Near_Life Line Hospital)	2017	1841	-9.6%	4.0
5	Lohta Road (Near_Agriculture Seeds Vibhag)	1113	1298	14.3%	5.3
6	Vidhya Peeth Road (Near_Mahatma Gandi Jai Mata Mandir)	2342	2695	13.1%	7.0
7	Laharabeer Road (Near_Beniya Bagh)	2778	2412	-15.2%	7.2
8	Ravinder Nath Tagore Road (Near Heera Medical Store)	1667	1516	-10.0%	3.8
9	Panch Koshi Road (Near Laxmi Mandir)	1185	1333	11.1%	4.2
10	Azamgarh Road(Near_LalaPur Village)	1238	1430	13.4%	5.3
11	Panch Koshi Road (Near_Mahavir Temple)	713	774	7.9%	2.2
12	Sindhaura Road (Near Indi Cash ATM)	1138	1099	-3.5%	1.2
13	Shiv Pur Road (Near _Shitala Mandir)	1147	1303	12.0%	4.5
14	Sarnath Road (Near_Sarnath Temple)	432	475	9.1%	2.0
15	Ashok Nagar Road (Near_Nakki Ghat)	1330	1341	0.8%	0.3

2.11 FORECAST OF PLANNING PARAMETERS

2.11.1 Future Growth Scenario

Master Plan for Varanasi 2021 gives the likely growth to take place within the various areas of study area. The development plan also gives locations of various land uses such as residential, commercial, industrial uses etc.

The population of surrounding towns of Varanasi is also expected to grow rapidly due to its close proximity to Varanasi. This will result in higher traffic interaction between the city and these towns. It is expected that the inter-city traffic to/from Varanasi will grow at growth rate of 3% per annum upto the horizon year of 2041 in various adjoining towns.

2.11.2 Population – Trends and Forecast

RITES has also forecasted the population based on the growth trends taken separately for Core, Middle, Outer and special areas collectively forming the study area in addition to existing growth pattern from Census Data. The population in the study area in the base year 2015 is 20.64 Lakh. Accordingly, the population in the study area for the horizon years 2021, 2031 and 2041 is presented in **Table 2.10.**

TABLE 2.10: FORECASTED POPULATION OF STUDY AREA FOR HORIZON YEARS

Year	Forecasted Population (lakh)
2021	25.7
2031	31.4
2041	37.6

The distribution of population in horizon years amongst various traffic zones would be based on land use and population density for core, middle and outer areas as derived from Master Plan for Varanasi.

2.11.3 Employment – Trends and Forecast

WFPR as observed in the base year 2015 is 28.0%. The employment for year 2011 has been worked out from the census data figures and has been extrapolated to obtain base year 2015 employment figures. Keeping in view the economic profile of the study area, development prospects and transport intervention policies, WFPR of 29.5%, 31% and 32% has been assumed from Varanasi Master Plan for the Horizon years 2021, 2031 and 2041 respectively. Thus, it has been estimated that 12.0 lakh workers would comprise the workforce in the study area by 2041. **Table 2.11** shows the growth trend in employment in the study area. **Table 2.12** gives the forecasted population and employment for the horizon years.

TABLE 2.11: WORK FORCE PARTICIPATION IN STUDY AREA FOR BASE AND HORIZON YEARS

Year	Workers (Lakh)	WFPR (%)
2015	5.8	28.0
2021	7.6	29.5
2031	9.7	31.0
2041	12.0	32.0

Source: Census 2011 & Varanasi Master Plan 2031

TABLE 2.12: ZONEWISE FORECASTED POPULATION AND EMPLOYMENT FOR HORIZON YEARS

Zone No.	2021		2031		2041	
	Population	Employment	Population	Employment	Population	Employment
1	25078	6508	31025	11669	35400	14258
2	21643	3240	25767	5174	28804	6078
3	30146	6622	37294	11872	42553	14506
4	13042	4865	16135	8722	18410	10657
5	24903	3470	30808	6221	35152	7602
6	18572	4079	22976	7314	26215	8936

Zone No.	2021		2031		2041	
	Population	Employment	Population	Employment	Population	Employment
7	25249	4546	31236	8151	35641	9959
8	29542	5152	35171	8228	39317	9666
9	22835	5529	27186	8829	30391	10372
10	22457	5437	26736	8683	29888	10200
11	19160	4208	23703	7546	27045	9219
12	28351	2364	33754	3775	37732	4435
13	34522	4358	41100	6960	45945	8176
14	10480	5769	11590	7675	12804	8582
15	13083	5956	14469	7924	15985	8861
16	19106	4197	23637	7524	26970	9194
17	36320	6293	43240	10050	48337	11806
18	20063	6407	24820	11487	28320	14035
19	29194	4913	36117	8808	41210	10762
20	20529	6509	25397	11670	28978	14259
21	12722	5361	14069	7132	15544	7975
22	24135	6801	29858	12194	34069	14899
23	27974	6144	34607	11017	39487	13460
24	11097	5932	12272	7891	13558	8824
25	40707	3855	48464	6157	54176	7233
26	22302	2399	27590	4301	31480	5255
27	24407	3361	30195	6026	34452	7363
28	28018	6783	33357	10833	37289	12726
29	23467	5155	29032	9242	33126	11292
30	20122	4420	24893	7924	28404	9682
31	24593	5954	29279	9509	32731	11170
32	32863	5457	39126	8714	43737	10237
33	28097	4672	34759	8376	39661	10234
34	26704	4366	33036	7827	37695	9564
35	15440	4079	17075	5427	18864	6068
36	27450	3529	33958	6328	38747	7732
37	22633	5979	25029	7955	27652	8895
38	21512	3208	25611	5123	28630	6019
39	12609	3331	13944	4432	15405	4956
40	12598	5828	13932	7754	15392	8671
41	12340	3260	13647	4337	15077	4850
42	15207	4017	16817	5345	18579	5977
43	16441	3980	19574	6357	21881	7468
44	14396	6303	15920	8386	17588	9377
45	13636	6102	15080	8119	16660	9078
46	18632	4922	20605	6549	22764	7323
47	15895	4199	17578	5587	19420	6247
48	14655	3872	16207	5151	17905	5760
49	8934	2360	9880	3140	10916	3511
50	25297	5556	31295	9962	35708	12172
51	15499	4094	17140	5447	18936	6091
52	17334	4579	19169	6092	21178	6813

Zone No.	2021		2031		2041	
	Population	Employment	Population	Employment	Population	Employment
53	13405	3245	15959	5183	17840	6088
54	10034	5651	11097	7518	12260	8407
55	16508	6361	18256	8463	20168	9463
56	24527	5387	30343	9659	34622	11802
57	22490	6940	27823	12443	31747	15203
58	19116	5050	21140	6719	23355	7513
59	13647	3605	15091	4796	16673	5363
60	13314	3517	14724	4679	16267	5233
61	16652	4399	18416	5853	20345	6545
62	11279	2980	12474	3964	13781	4433
63	12220	3228	13514	4295	14930	4803
64	13130	3469	14521	4615	16042	5160
65	15203	4016	16813	5343	18574	5975
66	17287	4567	19118	6076	21121	6794
67	12539	5312	13866	7068	15319	7903
68	13095	3459	14482	4602	15999	5147
69	14556	3845	16098	5116	17784	5721
70	9943	2627	10996	3495	12148	3908
71	20032	5292	22153	7041	24475	7873
72	14294	6776	15808	9015	17464	10081
73	13064	3451	14447	4591	15961	5134
74	12890	3405	14255	4531	15749	5066
75	18193	6806	20119	9055	22228	10126
76	15869	4192	17549	5577	19388	6237
77	20393	2937	24279	4691	27140	5510
78	11764	3108	13010	4135	14373	4624
79	10006	2643	11065	3517	12225	3932
80	13245	3499	14647	4655	16182	5206
81	12258	3238	13556	4308	14977	4818
82	12879	3402	14242	4526	15735	5062
83	14026	3705	15511	4930	17136	5512
84	10141	2679	11215	3564	12390	3986
85	16070	4245	17771	5648	19633	6316
86	15281	5537	16899	7366	18670	8237
87	10548	2787	11665	3707	12887	4146
88	10226	2701	11309	3594	12494	4019
89	13343	3525	14755	4690	16302	5244
90	11228	2966	12417	3946	13718	4413
91	52949	9943	70141	21656	92465	29478
92	26672	8008	35332	17443	46577	23743
93	76264	11321	101027	24658	133180	33564
94	65347	18271	86565	39796	114116	54169
95	157911	17652	209184	38449	275761	52335
96	79941	15011	105897	32696	139600	44505
97	15596	12344	17228	14699	19030	16573
98	48624	9131	64411	19887	84911	27070

Zone No.	2021		2031		2041	
	Population	Employment	Population	Employment	Population	Employment
99	104888	11696	138945	25475	183166	34675
100	39924	11497	52887	25041	69719	34086
101	48972	9196	64873	20029	85520	27264
102	51479	9667	68194	21055	89898	28659
103	40861	10673	54129	23247	71356	31643
104	43844	10233	58080	22288	76565	30339
105	61291	8509	81192	18534	107033	25228
Total	**2571256**	**577992**	**3144646**	**974840**	**3758803**	**1202817**

2.12 ASSUMPTIONS FOR TRANSPORT DEMAND FORECASTING

The following assumptions have been made for forecasting transport demand for the years 2021, 2031 and 2041.

(i) Calibrated and validated travel demand model has been used.

(ii) Land use parameters (population, employment and student enrolment) have been distributed in various traffic zones for 2021, 2031 and 2041.

(iii) Fare levels of buses and vehicle operating costs of different vehicles have been taken as same as in the year 2015.

(iv) Inter-city passenger to/from the study area will grow at the growth rate of 3% in various adjoining towns.

(v) The special generator passenger traffic of bus terminals and railway stations in Varanasi is expected to grow at 6% per annum respectively.

(vi) Inter and Intra-city goods traffic is expected to grow at 5% per annum up to 2041.

2.13 TRANSPORT DEMAND FORECAST FOR BUSINESS AS USUAL (BAU) SCENARIO, 2041

Considering the above assumptions and calibrated / validated traffic demand model, forecasting of transport demand has been carried out for 'Business as Usual' (BAU) scenario in the year 2041. Overall modal split for various modes in this scenario for the year 2041 is given in **Table 2.13**. The intra city motorized trips modal split (% of trips by public transport to total motorized trips) in favor of public transport in 2041 is expected to be about 46% which is even lower than the existing modal share. The total no. of PT trips (including shared auto trips) will increase from 5.8 Lakh to about 11.6

Lakh indicating a high capacity mass transport network will be needed to address the travel demand requirements in the study area in the horizon years.

TABLE 2.13: DAILY MOTORISED INTRACITY TRIPS BY VARIOUS MODES IN BAU SCENARIO, 2041

SN	Mode	2015		2041 BAU	
		Trips	Modal Share	Trips	Modal
1	Car	49456	4.0%	110750	4.5%
2	Two Wheeler	549214	44.5%	1117793	44.9%
3	Auto	52052	4.2%	95526	3.8%
4	PT + Share Auto	582101	47.2%	1163395	46.8%
	Total	**12,32,823**	**100.0%**	**2487464**	**100.0%**

2.14 TRANSPORT DEMAND FORECAST ON MASS TRANSIT NETWORK

2.14.1 Horizon Year Trip Assignment

To represent pictorially the results of the trip distribution matrices, desire line diagrams have been drawn for all purpose trips. **FIGURES 2.12** to **FIGURE 2.14** show the horizon year trip assignments on the road network in terms of peak hour PCUs for 2021, 2031 and 2041.

2.14.2 Ridership on Metro System for 2021, 2031 & 2041

Daily ridership on the entire metro system for the years 2021, 2031 and 2041 is expected to be 5.1 Lakh, 6.7 Lakh and 9.2 Lakh passengers respectively. Line wise daily passenger boardings (including the interchanges between metro stations) and trips for 2021, 2031 and 2041 are shown in **TABLE 2.14.** Beyond 2041, daily ridership will grow @ 3%.

TABLE 2.14: DAILY RIDESHIP ON METRO SYSTEM IN YEAR 2021, 2031 & 2041

S No.	Corridor Name	Daily Boarding (Lakh)			Daily Trips (Lakh)		
		2021	2031	2041	2021	2031	2041
1	BHU to BHEL	3.81	5.07	7.25	3.18	4.20	5.97
2	Beniabagh to Sarnath	2.29	3.05	3.86	1.91	2.52	3.18
	Total Daily Boardings / Trips	**6.10**	**8.13**	**11.11**	**5.09**	**6.72**	**9.15**

FIGURE 2.12: ASSIGNED PEAK HOUR TRAFFIC ON NETWORK IN PCU - 2021

FIGURE 2.13: ASSIGNED PEAK HOUR TRAFFIC ON NETWORK IN PCU - 2031

FIGURE 2.14: ASSIGNED PEAK HOUR TRAFFIC ON NETWORK IN PCU - 2041

2.14.3 Peak Hour Section Loads and Station Boarding & Alighting on Phase-I Metro Corridors

The trips made between two adjacent stations of proposed metro corridors have been worked out for the horizon years of 2021, 2031 and 2041. The section loads for the horizon years are presented in **TABLE 2.15.**

TABLE 2.15: PEAK HOUR SECTION LOADS ON PHASE-I METRO CORRIDORS

From	To	2021		2031		2041	
		Dir1	Dir2	Dir1	Dir2	Dir1	Dir2
Corridor 1: BHU to BHEL							
BHU	Tulsi Manas Mandir	5,000	4,600	8,100	5,200	12,800	12,100
Tulsi Manas Mandir	Ratnakar Park	5,200	5,800	8,200	6,200	12,900	13,300
Ratnakar Park	Kali Bari	6,500	6,700	9,700	6,900	14,400	14,100
Kali Bari	Kashi Vishwanath	7,300	7,400	10,200	7,400	14,900	14,800
Kashi Vishwanath	Benia Bagh	8,500	8,600	11,200	8,500	16,000	15,900
Benia Bagh	Rathyatra Chowk	14,800	15,600	18,700	17,400	22,500	22,600
Rathyatra Chowk	Kashi Vidyapeeth	14,500	15,300	18,200	16,800	22,400	20,700
Kashi Vidyapeeth	Varanasi Junction	12,400	10,700	15,600	15,500	22,100	17,500
Varanasi Junction	Nadesar	8,500	6,800	12,400	9,700	16,300	12,100
Nadesar	Collectorate	7,100	6,400	10,300	9,400	13,800	11,900
Collectorate	Bhojubeer	5,700	5,700	8,600	7,000	12,000	11,100
Bhojubeer	Gilat Bazar	5,600	5,400	7,000	6,500	8,400	7,700
Gilat Bazar	Sangam Colony	4,400	4,100	5,500	5,000	6,800	6,000
Sangam Colony	Shivpur	3,900	3,500	4,900	4,300	6,100	5,200
Shivpur	Tarna	3,300	2,900	4,200	3,600	5,300	4,600
Tarna	BHEL	2,100	2,100	2,600	2,600	3,300	3,300
Corridor 2: Benia Bagh to Sarnath (Akashwani)							
Beniabagh	Kotwali	11,600	11,100	15,700	14,600	17,400	17,500
Kotwali	Machodari Park	11,200	11,000	14,800	14,300	15,200	15,700
Machodari Park	Kashi Depot	10,100	10,100	13,500	13,100	13,400	14,000
Kashi Depot	Jalalipura	7,500	8,300	9,800	10,600	10,600	11,300
Jalalipura	Panch Koshi Chauraha	7,200	8,000	9,400	10,100	9,400	10,000
Panch Koshi Chauraha	Ashapur Chauraha	7,000	7,800	9,200	9,900	9,100	9,700
Ashapur Chauraha	Havelia	3,100	3,000	4,300	4,300	3,400	3,100
Havelia	Sarnath	2,100	2,300	3,100	3,400	1,600	1,900

Peak hour station loads (two way boarding & alighting) on Phase-I metro corridors for various horizon years of 2021, 2031 and 2041 are given in **TABLE 2.16.**

TABLE 2.16: PEAK HOUR STATION LOADS ON PHASE-I METRO CORRIDORS

Station	Peak Hour 2021*		Peak Hour 2031*		Peak Hour 2041*	
	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Corridor 1: BHU to BHEL						
BHU	5000	4600	8100	5200	12800	12100
Tulsi Manas Mandir	600	1600	800	1700	800	1800
Ratnakar Park	1700	1300	2300	1400	2500	1700
Kali Bari	1100	1100	1600	1700	2200	2500
Kashi Vishwanath	2200	2300	2500	2500	2800	2800

Station	Peak Hour 2021*		Peak Hour 2031*		Peak Hour 2041*	
	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
Benia Bagh	11600	12300	15200	16600	17400	17600
Rathyatra Chowk	1800	1700	2100	2000	5000	3200
Kashi Vidyapeeth	9100	6700	10000	11300	14300	11500
Varanasi Junction	9000	8900	12700	10100	13200	13500
Nadesar	1000	2100	1100	2900	1400	3700
Collectorate	1400	2000	3200	2500	3800	4800
Bhojubeer	1400	1200	1900	3000	5100	5300
Gilat Bazar	1600	1600	1900	1900	2100	2200
Sangam Colony	1100	1000	1300	1100	1400	1200
Shivpur	800	800	900	1000	1000	1100
Tarna	1400	1800	1600	2200	1900	2700
BHEL	2100	2100	2600	2600	3300	3300
Corridor 2: Benia Bagh to Sarnath (Akashwani)						
Beniabagh	11600	11100	15700	14600	16400	16500
Kotwali	2500	2900	2700	3400	3000	3500
Machodari Park	3200	3300	3500	3600	3900	4000
Kashi Depot	3800	4700	5000	6300	6400	6500
Jalalipura	600	500	700	600	1600	1500
Panch Koshi Chauraha	500	500	600	600	800	700
Ashapur Chauraha	5500	4700	6400	5700	7600	6700
Havelia	900	1200	1100	1500	1400	1900
Sarnath	2300	2100	3400	3100	3900	3600

* Two way boardings/alightings

2.15 DESIGN RIDERSHIP

In view of the estimated section loads and the changes in the traffic along the corridors, the MRTS Corridor from BHU to BHEL is being designed for 13000 PHPDT in 2021, 15500 in 2031, 20000 in 2041 where as Beniabagh to Sarnath Corridor is being designed for 10000 PHPDT in 2021, 13500 in 2031, 15500 in 2041 respectively. The metro system phase I is expected to be operational by the year 2022. Desired shifting of passengers from other modes of transport to proposed metro system is a slow & continuous process. Metro ridership gradually increases over period of time and initially 2023 ridership can be assumed same as that of the year 2021. The materialisation of these PHPDT figures will depend on the proposed developments as envisaged in Master Plan of Varanasi and realization of other planned transport infrastructure projects.

MRTS system however, will serve the city much beyond 2041. The design ridership for the two corridors have been taken as PHPDT of 24000 (BHU to BHEL) and PHPDT of 18000 (Beniabagh to Sarnath) respectively to take care of traffic growth beyond 2041 (**Table 2.17**).

TABLE 2.17: DESIGN SECTION LOAD ON METRO CORRIDORS IN YEARS 2021, 2031 & 2041

Corridor No.	Corridor details	Design PHPDT			
		2021	2031	2041	Design
1	BHU to BHEL	13000	15500	20000	24000
2	Beniabagh to Sarnath	10000	13500	15500	18000

Ridership realization however depends on a number of factors including the type/ intensity/ direction of development, various policies of the government and a number of unforeseen issues that could appear during next 20-40 years. The system will start operating with initial estimated ridership and the capacity will be increased depending on the ridership growth.

In order to boost the metro ridership and make the project financially viable, some land parcels along both the metro corridors have been identified for Transit Oriented Development in the form of property development after joint site visits with VDA officials. This is presented in detail in Chapter 5.