TRADITIONAL FOUR-STEP TRANSPORTATION MODELING: USING A SIMPLIFIED TRANSPORT NETWORK

PROJECT NO: 02

COURSE NO: Plan 342
COURSE TITLE: Transportation Planning Workshop

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DATE OF SUBMISSION
04th May, 2006

ABSTRACT

The travel forecasting process is at the heart of urban transportation planning. Travel forecasting models are used to project future traffic and are the basis for the determination of the need for new road capacity, transit service changes and changes in land use policies and patterns. Travel demand modeling involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given system of highways, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react in a particular transportation alternative.

The travel simulation process follows trips as they begin at a trip generation zone, move through a network of links and nodes and end at a trip attracting zone. The simulation process is known as the four step process for the four basic models used. These are: trip generation, trip distribution, mode split and traffic assignments.

The traditional four steps transportation modeling system is elaborately discussed in this scientific research paper and the whole calculation process is described step by step for better understanding.

ACKNOWLEDGEMENT

At the outset, all praises belong to Almighty Allah, the most merciful, the most beneficent to all creatures and their dealings.

It is a great pleasure to acknowledge my deepest gratitude and indebtedness to my Transportation Planning Workshop course teachers Mamun Muntasir Rahman, Lecturer; Md. Aftabuzzaman, Lecturer; and Suman Kumar Mitra, Lecturer; Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET), for their careful supervision, constant guidance, thoughtful suggestions and dynamic guidance regarding to the study.

I have got a lot help from my faculty and departmental libraries and from Institute of Information and Communication Technology (IICT) of BUET.

Finally, thanks to all my classmates and to all who helped in making this scientific research possible.

Last but not least, I express profound thanks to my family for their love and kind support.

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May 04, 2006

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CHAPTER 01

INTRODUCTION

Dhaka the capital, administrative and commercial hub of Bangladesh, has seen phenomenal growth both in terms of population and motorization in the post independence period of the country. In last five years the population of the city has grown by about 50% to about 12 million, while for the same period the vehicle population has also grown by about 50% to about 350000 vehicles. This growth trend has persisted over the whole post independence period of Dhaka.

1.1 BACKGROUND OF THE STUDY

Travel forecasting models are used to predict changes in travel patterns and the utilization of the transportation system in response to changes in regional development, demographics, and transportation supply. Modeling travel demand is a challenging task, but one that is required for rational planning and evaluation of transportation systems.

Transportation planning involves the decision-making process for potential improvements to a community's roadway infrastructure. To aid in the decision-making process, several computer-based and manual tools have been developed. Two of these key tools are-

(1) Travel demand forecasting models for implementing the four-step urban planning process,
(2) Travel rate indices for providing congestion and delay information for a community.

The four-step urban planning process is comprised of the following: Trip Generation, Trip Distribution, Mode Split, and Traffic Assignment. In this research paper these four steps are taken into concern elaborately in the context of Dhaka City.

1.2 OBJECTIVES OF THE STUDY

The objectives of this paper are as follows:

a) An understanding of the different types of models used by transportation analysis to forecast and analyze policy decisions.

b) Developing skills in the calibration and application of macro-level transportation approaches.

c) To be aware of the purpose of analytic modeling in transport planning.

1.3 METHODOLOGY OF THE STUDY

1.3.1 Formulation of Objectives

The objectives mentioned in the former page have been formulated for the study.

1.3.2 Selection of the Study Area

76 wards of Dhaka City Corporation have been chosen as the study area for this particular research. Then these 76 wards are divided into 10 zones (Map 01: please go to page 44) known as TAZ (Traffic Analysis Zone).

1.3.3 Fixing Working Procedure

Now the traditional four step transportation modeling system has been taken to complete the project. This is a macro-level working procedure. The following four steps to be performed in the next stage.

1.3.3.1 Trip Generation

Trip generation is the first step in the conventional four-step transportation planning process (followed by trip distribution, mode choice, and route assignment), widely used for forecasting travel demands. It predicts the number of trips originating in or destined for a particular traffic analysis zone. In the main trip generation analysis is focused on residences, and that trip generation is thought of as a function of the social and economic attributes of households. At the level of the traffic analysis zone, the language is that of land uses "producing" or generating trips. Zones are also destinations of trips, trip attractors. The analysis of attractors focuses on nonresidential land uses.

1.3.3.2 Trip Distribution

Trip distribution (or destination choice or zonal interchange analysis), is the second component (after trip generation, but before mode choice and route assignment) in the traditional 4-step transportation planning (or forecasting) model. This step matches trip makers' origins and destinations to develop a "trip table" a matrix that displays the number of trips going from each origin to each destination.

1.3.3.3 Modal Split

Mode choice analysis is the third step in the conventional four-step transportation planning model, following trip generation and trip distribution but before route assignment. Trip distribution's zonal interchange analysis yields a set of origin destination tables which tells where the trips will be made; mode choice analysis allows the modeler to determine what mode of transport will be used.

1.3.3.4 Trip Assignment

Trip assignment, traffic assignment or route choice concerns the selection of routes (alternative called paths) between origins and destinations in transportation networks. It is the fourth step in the conventional transportation planning model, following trip generation, trip distribution, and mode choice. Mode choice analysis tells which travelers will use which mode. To determine facility needs and costs and benefits, we need to know the number of travelers on each route and link of the network (a route is simply a chain of links between an origin and destination).

1.3.4 Data Collection

Most of the data are collected from different organizations, reports and census book while some are supplied by the course teachers.

1.3.5 Calculation Process

The whole calculation procedure has been described in detail in chapter 03.

1.3.6 Preparation of Report

Finally a report is prepared combining all the above steps.

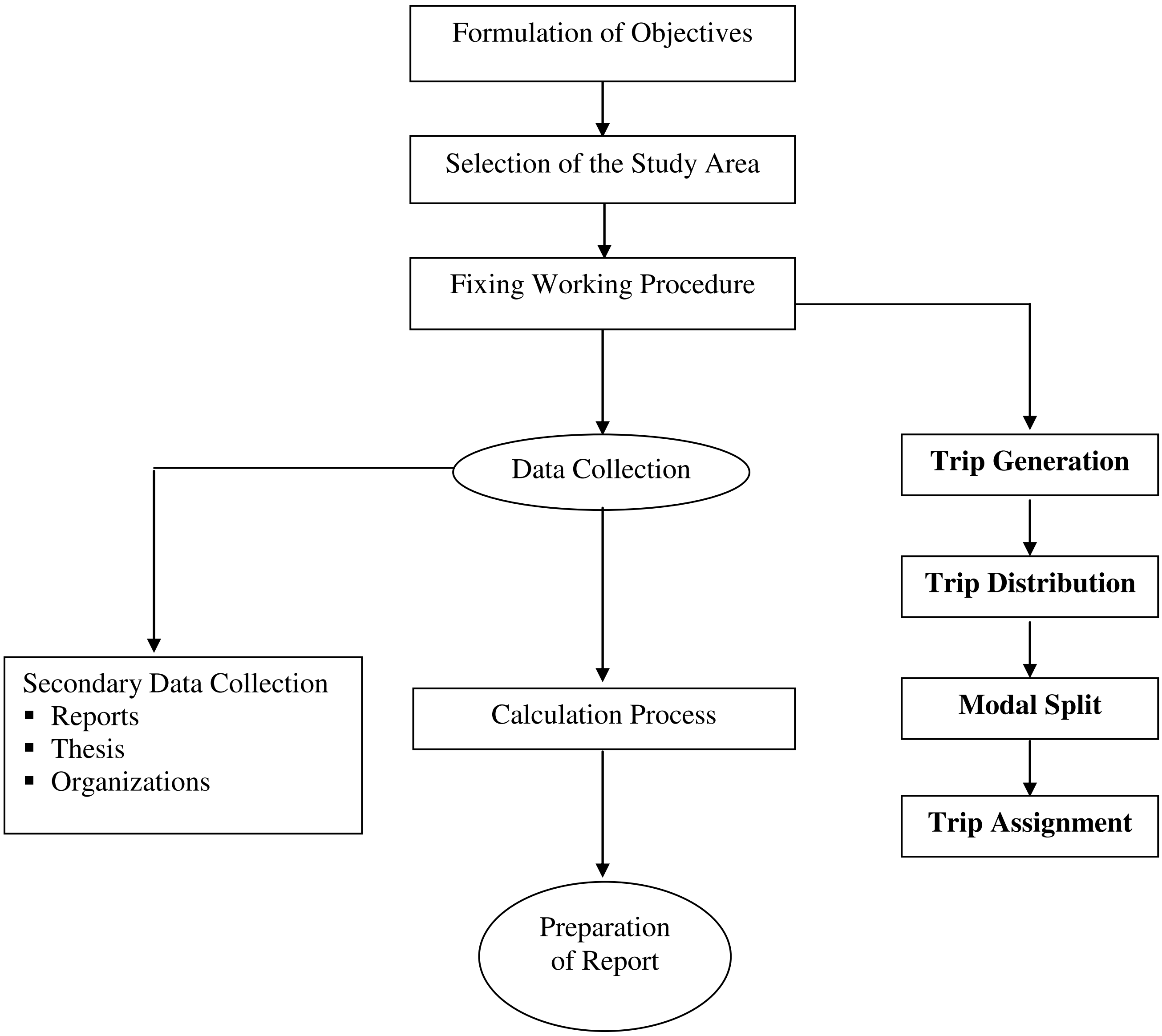


Figure 1.1: Flow Chart of Methodology

1.4 LIMITATIONS OF THE RESEARCH

The main limitation of this research was to collect necessary data. We cannot find the recent data on population, employment and income. Therefore, we have to use the previous census data for calculation. Moreover, some values related to calculations are given by the course instructors which are not quite accurate rather they are assumed from studying various reports published from different institutions related to transportation planning and management.

CHAPTER 02

THEORETICAL FRAMEWORK

2.1 TRANSPORT NETWORKS

- Defined in terms of nodes and links.
- In highway network, nodes are junctions; links are sections of road between junctions.
- In rail network, nodes are railway stations, links are sections of railway track.

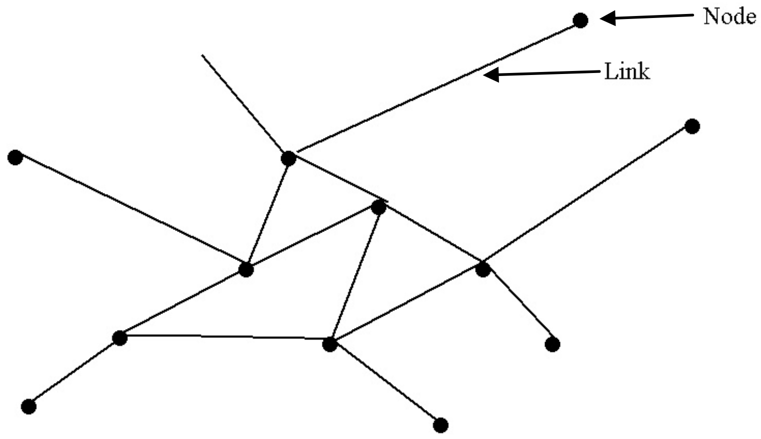


Figure 2.1: Transport Network

2.2 TRAFFIC/TRAVEL ANALYSIS ZONES (TAZ)

Travel simulations require that an urban area be represented as a series of small geographic areas called traffic or travel analysis zones (TAZ). Zones are characterized by their population, employment and other factors and are the places where trips begin (trip producers) or end (trip attractors). The boundaries of these zones should, whenever feasible, coincide with census tract boundaries and with jurisdictional boundaries. The zones should also be small enough so that there are a large number of inter zonal trips being made in the study area. Intrazonal trips should not be more than 10 to 15 percent of the total trips being made in each zone. (Figure 2.2 illustrates the concept of the zonal system that is basic to any transportation planning effort).

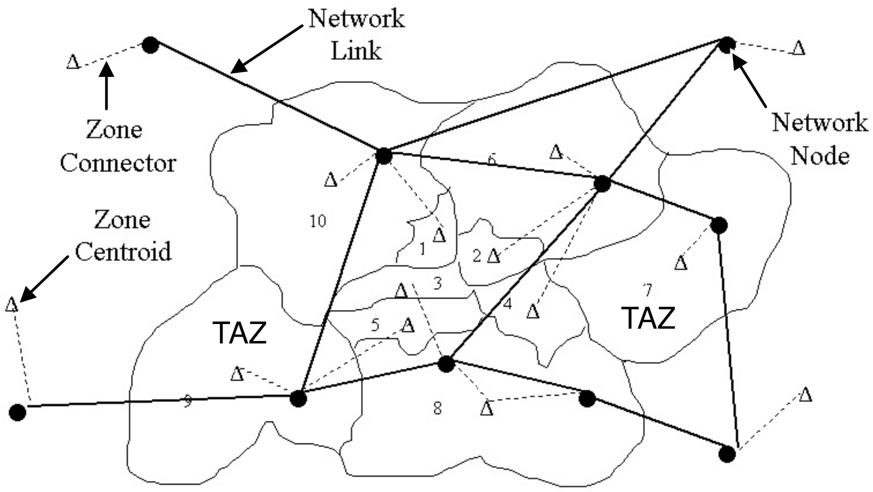


Figure 2.2: Traffic Analysis Zone (TAZ)

2.3 TRANSPORTATION MODELING

Transportation planning uses the term 'models' extensively. This term is used to refer to a series of mathematical equations that are used to represent how choices are made when people travel. Travel demand occurs as a result of thousands of individual travelers making individual decisions on how, where and when to travel.

Transportation planning is a complex process that involves a basic sequence of steps. Several can take place at once and it is not unusual to repeat some of the steps several times. Travel demand models are used in the forecasting step of the process as the means to predict how well alternative plans perform in meeting goals.

Models are used in a sequence of steps to answer a series of questions about future travel patterns. The basic questions asked and the modeling steps they involve are as follows:

1. What will our community look like in the future?

- a) How many people will there be? (Population forecasts)
- b) What will they be doing? (Economic forecasts)
- c) Where will activities take place? (Land use pattern)

2. What are the travel patterns in the future?

- a) How many trips will be made? (Trip generation)
- b) Where will the trips be? (Trip distribution)
- c) What modes will be used? (Mode split)
- d) What routes will be used? (Traffic assignment)

2.3.1 TRIP GENERATION

The first step in travel forecasting is trip generation. In this step information from land use, population and economic forecasts are used to estimate how many person trips will be made to and from each zone.

A **trip** is a one-way person movement by a mechanized mode of transport, having two trip ends, an origin (the start of the trip) and a destination (the end of the trip). Trips are usually divided into home-based and non-home-based.

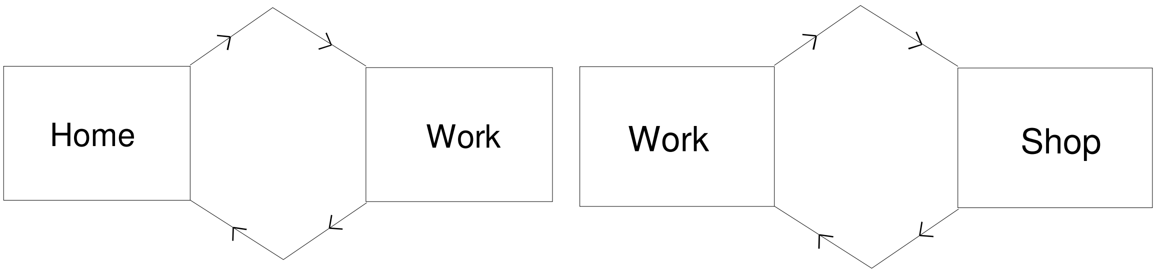


Figure 2.3: Home-based and Non-home-based Trips

Trip ends may be classified either as origins and destinations, or as productions and attractions. The terms production and attraction are not defined in terms of the directions of trips but in terms of the land use associated with each trip end.

A **trip production** is defined as a trip end connected with a residential land use in a zone, and a **trip attraction** is defined as a trip end connected to a non-residential land use in a zone.

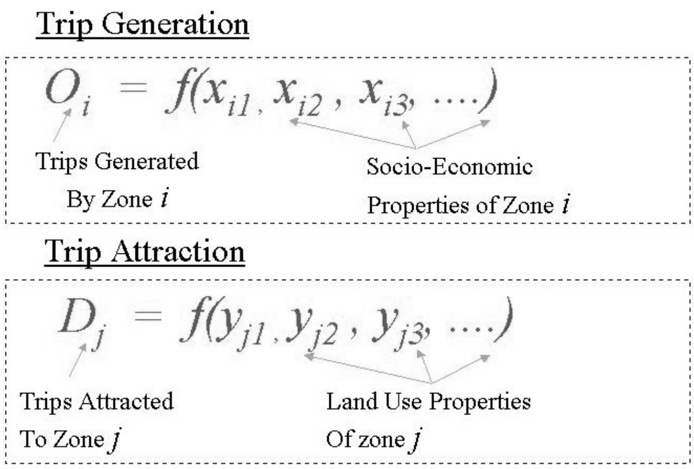


Figure 2.4: Classic Trip Generation

For **Trip Production** the explanatory variables are:

- Population (In the form of Male/Female/Age Distribution/Household size etc.)
- Residential Density
- Car Ownership
- Household Income/Individual person Income
- Accessibility
- Distance from CBD

For **Trip Attraction** the explanatory variables are:

- Employment
- Commercial or Industrial activities/ Land Use
- Number of shopping malls
- Land price

There are methods of developing trip generation model. These are:

1. Expansion Factor Method
2. Category Analysis or Cross Classification Method and
3. Multiple Regression Analysis Method

1. Expansion Factor Method is mentioned primarily to emphasize that its use is now generally out-dated in relation to trip generation in fast changing complex urban areas. Methods of this nature, which simply place reliance upon past growth rates as a means of predicting future trips, should be confined to short-term forecasting in rural areas.

2. Category Analysis Method has been developed which considers the household as the fundamental analysis unit. Category Analysis has some appeal as a method of predicting trip generation or trip attraction. One obvious reason for this is that it is intuitively appealing to categorize households in a given zone, both now and future and associates each with an expected trip making behaviour. More important is the fact that its usage cuts down very considerably on the amount of current home interview data which will be gathered and analyzed.

3. Multiple Regression Analysis Method is probably that which has been used in the majority of transport demand studies. The extensive use of the 'best fit' least square method, which involves developing a linear equation of the form:

$$Y = a_0 + a_1 X_1 + a_2 X_2 + \ldots\ldots\ldots\ldots\ldots a_n X_n$$

Where,

Y= Total Trip Production or Attraction,

$X_1, X_2, \ldots\ldots\ldots\ldots\ldots X_n$ = Explanatory Variables ,

a_0 = Intercept &

$a_1, a_2, \ldots\ldots\ldots\ldots a_n$ = Coefficients of explanatory variables

The following four guidelines are helpful in deciding which explanatory variables to include in a model. The selected explanatory variables

- must be linearly related to the dependent variable
- must be highly correlated with the independent variable
- must not be highly correlated between themselves
- must lend them selves to relatively easy projection

The relationships expressed by the Y-equations remain stable; the future numbers of zonal trips are estimated by substituting appropriate future estimates of the explanatory variables.

Multiple linear regression analysis method is of two types:

(i) Aggregated or Zonal least-square regression, where each traffic zone is treated as one observation.

(ii) Disaggregate or Household least-square regression, where each household is treated as an observation.

The purpose of the Trip Generation modeling process is to identify those which are meaningful determinants of trip making behavior and express their effects in a mathematical way so that they can be used with confidence as a predictive tool.

2.3.2 TRIP DISTRIBUTION

Trip generation only finds the number of trips that begin or end at a particular zone. These trip ends are linked together to form an origin-destination pattern of trips through the process of trip distribution. Trip distribution is used to represent the process of destination choice.

Generations	Attractions 1	2	3	...j	...z	$\sum_j T_{ij}$	
1	T_{11}	T_{12}	T_{13}	$...T_{1j}$	$...T_{1z}$	O_1	
2	T_{21}	T_{22}	T_{23}	$...T_{2j}$	$...T_{2z}$	O_2	
3	T_{31}	T_{32}	T_{33}	$...T_{3j}$	$...T_{3z}$	O_3	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	
i	T_{i1}	T_{i2}	T_{i3}	$...T_{ij}$	$...T_{iz}$	O_i	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	
z	T_{z1}	T_{z2}	T_{z3}	$...T_{zj}$	$...T_{zz}$	O_z	$\sum_j T_{ij} = O_i$
$\sum T_{ij}$	D_1	D_2	D_3	$...D_j$	$...D_z$	$\sum_{ij} T_{ij} = T$	$\sum_i T_{ij} = D_j$

Where: T_{ij} = Trips from origin i to destination j.

Figure 2.5: General form of the two dimensional trip matrix

Trip Distribution is the procedure utilize to distribute generated and attracted trips from each zones to any other zones. There are two types of trip distribution methods. The methods are:

1. Growth Factor Methods and

2. Synthetic Methods

Four different types of growth factor methods have been developed. These are:

a. Uniform Factor method

b. Average Factor method

c. Fratar method

d. Furness method

a) Uniform Factor Method involves the determination of a single growth factor for the entire survey area: all interzonal trips are then multiplied by the factor in order to get the future interzonal flow. The expansion factor used is the ration of the total number of future trip ends to the existing total.

This can be represented by the following formula:

$$T_{i\text{-}j} = t_{i-j} \times E$$

Where, $T_{i\text{-}j}$ = Design year number of trips from zone i to zone j

$t_{i\text{-}j}$ = Observed based year number of trips from zone i to zone j

E = Growth factor

b) Average Factor Method represents an attempt to take into account the fact that rates of development in zones are normally different from the rate for the urban area as a whole and this can be expected to be reflected in different interzonal trip growth rates. Thus it utilizes a different growth factor for each interzonal movement: this is composed of the average of the growths expected at each pair of origin and destination zones. This can be represented by the following formula:

Where; $T_{i\text{-}j} = t_{i-j} \times \left[\dfrac{E_j + E_i}{2}\right]$

$T_{i\text{-}j}$ = Future trips from zone i to zone j

$t_{i\text{-}j}$ = Present trips from zone i to zone j

$E_i = \dfrac{P_i}{p_i}$ = Generated trips growth factor for zone i

$E_j = \dfrac{A_j}{a_j}$ = Attracted trip growth factor for jone j

P_i = Future generated trips for zone i

p_i = Present generated trips for zone i

A_j = Future attracted trips for zone j

a_j = Present attracted trips for zone j

c) Fratar Method of successive approximations is perhaps the most widely known iterative process. More complicated than the average factor method, it gives more rational answers. The formula can be shown as:

$$T_{i\text{-}j} = t_{i-j} \times \frac{P_i}{p_i} \times \frac{A_j}{a_j} \times \frac{\sum^{k} t_{i-k}}{\sum^{k}\left[\dfrac{A_k}{a_k}\right] \times t_{i-k}}$$

Where; $T_{i\text{-}j}$ = Future trips from zone i to zone j

$t_{i\text{-}j}$ = Present trips from zone i to zone j

P_i = Future generated trips for zone i

p_i = Present generated trips for zone i

A_j = Future attracted trips for zone j

a_j = Present attracted trips for zone j

k=total number of zones

d) Furness Method is also iterative in nature. For this the estimates of future traffic originating and terminating at each zone are required, thus yielding origin growth factors and destination growth factors for each zone. The traffic movements are made to agree alternatively with the future traffic originating in each zone and the estimated the future terminating in each zone, until both these conditions are roughly satisfied.

Three different types of Synthetic method have been developed. These are:

i) Gravity Model

ii) Tanner Model and

iii) Opportunity Model

i) The Gravity Model To date, the most widely used trip distribution model has been the so-called "gravity model." As the name implies, this model adapts the gravitational concept, as advanced by Newton in 1686, to the problem of distributing traffic throughout an urban area. The gravity model has been the most widely used formula mainly because it is simple in concept and because it has been well documented.

In essence, the gravity model says that trip interchange between zones is directly proportional to the relative attraction of each of the zones and inversely proportional to some function of the spatial separation between zones. This function of spatial separation adjusts the relative attraction of each zone for the ability, desire, or necessity of the trip maker to overcome the spatial separation involved. Mathematically, the gravity model is stated as follows:

$$T_{ij} = \frac{kP_i A_j}{d_{ij}^c}$$

Where,

$$T_{ij} = \text{Trip between zone i to Zone j}$$
$$P_i = \text{Trip generated in zone i}$$
$$A_j = \text{Trip attracted in zone j}$$
$$d_{ij} = \text{Distance between zone i to zone j (in terms of time, cost etc)}$$
$$k = \text{Constant usually independent to i}$$
$$c = \text{Exponential constant}$$

The general form of the gravity model which is derived can be shown as:

$$T_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_{i=1}^{n} A_j F_{ij} K_{ij}}$$

Where,

$$T_{ij} = \text{Trip between jone i to zone j}$$
$$F_{ij} = \frac{1}{C_{ij}} = \text{Friction or travel time factor}$$
$$K_{ij} = \text{Set of interzonal socio - economic adjustment factor}$$

Calibration of the Gravity Model

Calibration is the process of determining the travel time factor which expresses the area wide effect of spatial separation on trip interchange between zones and the factor which is the specific zone to zone adjustment factor to account for the social and economic factors influencing the travel pattern. Computer programme are available to facilitate the calibration process, which is otherwise very complex.

ii) Tanner Model suggests that the inverse of the n^{th} power in the gravity model cannot give valid estimates at both very small & very large distances. So a new formula is given by Tanner in the following form:

$$t_{1\text{-}2} = \frac{mP_1 P_2 e_{1-2}^{-\lambda d}}{d_{1-2}} \left[\frac{1}{C_1} + \frac{1}{C_2} \right]$$

Where,

t_{1-2} = number of journey per day between the two places 1 and 2

m = a constant

P_1 and P_2 = populations, or other measures of size of the two places

d_{1-2} = distance between places 1 and 2

C_1 and C_2 = constants, one for each place, C_1 being defined by :

$$C_1 = \sum_j P_j e^{-di-j}$$

Where the summation is over all places j

iii) Opportunity Model which is derived on the basis of probability theory assumes that as trips which are generated in zone i move away from that zone, they incur increasing opportunities for their purposes to be satisfied at any zone j, & therefore there is an increasing probability function that they will not proceed beyond zone j.

Two forms of opportunity model have been developed, the **Intervening Opportunity Model** and the **Competing Opportunity Model**.

The basic Intervening model is expressed as:

$$T_{ij} = G_i \left[e^{-LD} - e^{-L(D+D_j)} \right]$$

Where,

T_{ij} = future number of trips from zone i to zone j

G_i = total number of trips generated in jone i

D = total number of destination opportunities closer in time to zone i than are those in zone j

D_j = number of destination opportunities in zone j

L = probability that any given destination opportuinty will be selected.

In the competing opportunity model, the adjusted probability of a trip ending in a zone is the product of two independent probabilities. A form of this model is given below:

$$T_{i\text{-}j} = \frac{P_j \dfrac{A_i}{\sum_j A_j}}{\sum \left[\dfrac{A_j}{\sum_j A_j} \right]}$$; Where

Pj = Future generated trips for zone j

T_{ij} = future number of trips from zone i to zone j

A_j = Trip attracted in zone j

2.3.3 Modal Split/Modal Choice

Mode choice is one of the most critical parts of the travel demand modeling process. It is the step where trips between a given origin and destination are split into trips using transit, trips by car pool or as automobile passengers and trips by automobile drivers. There are some factors that influence the choice of mode. They are:

1. Characteristics of the Trips
- **a.** Trip Purpose
- **b.** Trip Length

2. Household characteristics
- **a**. Income
- **b.** Car Ownership
- **c.** Family size

3. Zonal Characteristics
- **a.** Residential density
- **b.** Concentration of Workers
- **c.** Distance from CBD

4. Network characteristics
- **a.** Accessibility ratio (Public vs. Private)
- **b.** Travel time ratio
- **c.** Travel cost ratio

Depending on their positions in the demand forecasting sequence, modal choice models are classified as **pre-distribution modal split** and **post-distribution modal split**. As their name implies, for the former one the modal split is considered prior to trip distribution stage. The later one is vice-versa.

There are two methods of Mode choice modeling. They are:

1. Aggregate Model
- **a.** Simplified Diversion Curve
- **b.** Stratified Diversion Curve

2. Disaggregated Model

i) Discrete Choice Model

ii) The Multinomial Logit Model

iii) Nested Model

a) Simplified Diversion Curve The Graph below shows the general form of the simplified diversion curve. As the cost increases the probability of choosing modes decreases.

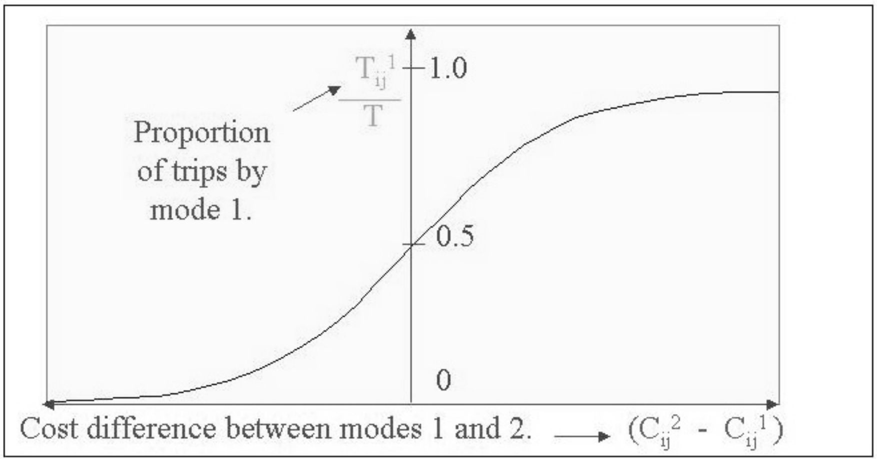


Figure 2.6: Simplified Diversion Curve

i) Discrete Choice Model described by the utility of using any mode measures the degree of satisfaction that people derived from their choices. A disutility function represents the generalized cost that is associated with each choice. The magnitude of either depends on the characteristics of each choice & on the characteristics of individual making that choice. In order to specify a utility function it is necessary to select the relevant variables.

The Utility function is typically expressed as the linear weighted sum of the independent variables or their transformation. In the equation form it can be shown as:

$$U = a_0 + a_1 X_1 + a_2 X_2 + \dots\dots\dots\dots\dots\dots + a_n X_n$$

Where;

U =Utility

$X_1, X_2, \dots\dots\dots, X_n$=Attributes

$a_0, a_1, \dots\dots\dots, a_n$= Constants

This utility function can be formulated as Mode-specific Model and Attribute-specific Model. In the Mode-specific model for different mode there will be different explanatory variables, the slope & intercept. This can be shown by using the following equations:

$$U_1 = a_0 + a_1 X_1 + a_2 X_2$$

$$U_2 = b_0 + b_1 X_3 + b_2 X_4$$

$$U_3 = c_0 + c_1 X_5 + c_2 X_6$$

In the Attribute-specific model the explanatory variables will be the same with their slope but not equaling the intercept. This can be shown by using the following equations:

$$U_1 = a_0 + a_1 X_1 + a_2 X_2$$

$$U_2 = b_0 + a_1 X_1 + a_2 X_2$$

$$U_3 = c_0 + a_1 X_1 + a_2 X_2$$

ii) The Multinomial Logit Model calculates the proportion of trips that will select a specific mode K according to the following relationship:

$$P(K) = \frac{e^{U_K}}{\sum_X e^{U_X}}$$

Where;

P(K) = the probability of choosing a mode K

U_K= Utility of mode K

U_X= Utility of mode X

We have to consider the change in the modal share if any new mode is introduced into the system. The effects of adding a new mode can be utilized. Modal share also changes with the policy change in the total transportation system. The major weakness is that we need huge amount of data.

2.3.4 TRIP/NETWORK ASSIGNMENT

Trip assignment models are based on minimum time algorithms that identify the minimum time paths through networks. It is the most time consuming and data intensive step in the process and is done differently for highway trips and transit trips.

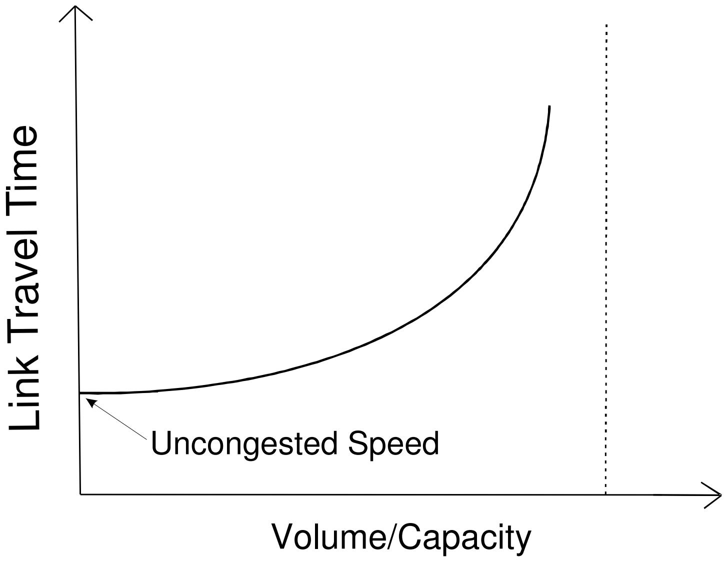


Figure 2.7: Graphical representation of link performance

In this figure the time associated with travel on a link in the network is related in a nonlinear way with the amount of traffic on that link. In practical terms this relationship means that as a roadway becomes congested, it will take a longer time to travel the link distance and thus the model will assign fewer vehicles to that link.

The techniques of network assignment are:

a) All-or-Nothing Assignment

b) Capacity Restrained Assignment &

c) Stochastic Equilibrium Assignment

a) All-or-Nothing Assignment

This assignment procedure estimates the shortest time path between each zonal pair in the system based on uncongested speeds and assigns all of the volume making these trips to the shortest path. Therefore if there are 1,000 trips going from zone i to zone j and the shortest path consists of a route defined by a set of links, all 1,000 trips would be assigned to each link. Clearly, such an assignment ignores the effect congestion has on an individual's choice of route.

b) Capacity Restraint Assignment

More common today for roadway assignments is the "capacity-restrained" assignment, a strategy which assigns traffic in steps. One option in this approach is "proportional" assignment, which allocates a portion of the trips between every origin-destination zone pair to the network at each step. An alternative is the "incremental" assignment, which allocates all of the trips between a subset of zone pairs at each step. In either case the travel times between all zone pairs are recalculated after each assignment step, considering the traffic already assigned, to adjust the speeds on all network links. The revised speeds on all links are determined by a speed-volume function that indicates the maximum speed likely for a particular volume/capacity ratio.

c) Stochastic Equilibrium Assignment

It assumes that several routes between an origin and destination might be perceived by travelers as having equaled times or otherwise be equally attractive to the traveler. As a result these routes might be equally used by the travelers. In this case route choice probabilities are calculated often using a similar concept of the logit model formulation presented above and then used to estimate from a probabilistic perspective the number of trips that will take different routes.

The four-step modeling process described above has been the mainstay of transportation planning for the past 50 years. New, computer-based models are being developed that simulate the individual vehicle or traveler in very fine detail. These so-called micro simulation models are based on underlying assumptions or algorithms and individual's behaviour. So instead of predicting the aggregate movement of traffic flows, micro simulation models predict the paths and behavior of hundreds and thousands of individual trips. These models are in the early stages of development, but it is likely that over the next decade, micro simulation models will become important tools in analyzing transportation demand.

CHAPTER 03

DATA COLLECTION PROCEDURE

Transportation planning is a complex process that involves a basic sequence of steps. Several can take place at once and it is not unusual to repeat some of the steps several times. Travel demand models are used in the forecasting step of the process as the means to predict how well alternative plans perform in meeting goals. Data collection is one of the basic steps in the transportation planning process.

3.1 DATA COLLECTION: Data must be compiled about the present status of the transportation system and its use. This could include traffic data, transit rider ship statistics, census information and interviews of households about their travel patterns. Data are also gathered on land use, development trends, environmental factors, and financial resources. This will assist in problem definition and in developing methods to forecast future travel patterns. Good data are essential to the planning process. Without good data, the results of the planning process have little real meaning and can lead to the wrong projects selected and a wrong direction for the region.

In this research project two explanatory variables have been taken for both trip production (Population and income) and trip attraction (Employment and land price). The procedure of how the data is collected or calculated is described in later part of this research.

3.2 POPULATION: The number of population of different zones is directly collected from the statistical book of Bangladesh Population Census-1991 (Appendix- A) for production.

Table 3.1: Population of Different Zones

Zone	Population
Zone 1	116939
Zone 2	473490
Zone 3	376925
Zone 4	451756
Zone 5	484981
Zone 6	284057
Zone 7	467491
Zone 8	525673
Zone 9	325121
Zone 10	193302

Source: Reference 5

3.3 AVERAGE ZONAL INCOME (TAKA/PERSON/MONTH): Another explanatory variable for production has been taken as income per person. As this data is not found directly from any source it is calculated. The whole calculation process of how average zonal income is found is shown in Appendix- B. From there we have found the table 3.1. Here some vales like percentage of lower, middle and higher income people of different zones and the income of them are assumed from the reports of Dhaka Transport Co-Ordination Board (DTCB) [Ref: 7] and Dhaka Urban Transport Project (DUTP) [Ref: 8].

**Taka = Bangladesh Taka (BDT) = unit of money in Bangladesh.

Table 3.2: Average Zonal Income

Zone	Average Zonal Income (taka/person/month)
Zone 1	1931
Zone 2	2133
Zone 3	1980
Zone 4	4898
Zone 5	4920
Zone 6	3753
Zone 7	3202
Zone 8	3164
Zone 9	5280
Zone 10	4735

Source: Appendix- B

3.4 AVERAGE ZONAL LAND PRICE (LAKH PER KATHA): This attraction parameter data is collected from an unpublished thesis report (Appendix- C). *** [1 Lakh=100000 BDT]

Table 3.3: Average Zonal Land Price (in lakh taka per katha)

Zone	Land Price (In Lakh taka per Katha)
Zone 1	9.5
Zone 2	20.0
Zone 3	16.2
Zone 4	15.8
Zone 5	21.9
Zone 6	12.7
Zone 7	8.2
Zone 8	6.5
Zone 9	18.4
Zone 10	9.0

Source: Reference 6

3.5 AVERAGE ZONAL EMPLOYMENT: This is another parameter or variable for trip attraction. This data is got also from the statistical book of Bangladesh Population Census-1991. The necessary calculation is shown in Appendix- D.

Table 3.4: Average Zonal Employment

Zone	No. of Employment
Zone 1	51200
Zone 2	207202
Zone 3	153789
Zone 4	200848
Zone 5	177655
Zone 6	105783
Zone 7	165183
Zone 8	201377
Zone 9	128368
Zone 10	34699

Source: Reference 5

3.6 TOTAL TRIPS/PERSON/DAY FOR PRODUCTION: The procedure for calculating total trips/person/day for production in existing situation is shown in Appendix- E. And the necessary data and values are assumed from the reports of DTCB (Ref: 7) and DUTP (Ref: 8).

Table 3.5: Total trips/person/day for Production

Zone	Trips/person/day
Zone 1	216709
Zone 2	873051
Zone 3	697517
Zone 4	776774
Zone 5	832492
Zone 6	502936
Zone 7	840124
Zone 8	945303
Zone 9	552647
Zone 10	333569

Source: Appendix- E

3.7 TOTAL TRIPS/PERSON/DAY FOR ATTRACTION: This data is calculated by multiplying trip rate for employment with no. of employments which is shown in Appendix- F. Trip rates for employment is assumed from the DTCB (Ref: 7) report.

Table 3.6: Total trips/person/day for Attraction

Zone	Trips/person/day
Zone 1	179200
Zone 2	932409
Zone 3	538262
Zone 4	1205088
Zone 5	977103
Zone 6	528915
Zone 7	578141
Zone 8	604131
Zone 9	641840
Zone 10	190845

Source: Appendix- F

Table 3.7: Existing Situation of Trip Production and Trip Attraction

Existing						
Production				Attraction		
TAZ	Total trips/person/day	Population (X_1)	Average Zonal Income (X_2)	Total trips/person/day	Employment (X_1)	Land Price (Lakh/Katha) (X_2)
Zone 1	216709	116939	1931	179200	51200	9.5
Zone 2	873051	473490	2133	932409	207202	20.0
Zone 3	697517	376925	1980	538262	153789	16.2
Zone 4	776774	451756	4898	1205088	200848	15.8
Zone 5	832492	484981	4920	977103	177655	21.9
Zone 6	502936	284057	3753	528915	105783	12.7
Zone 7	840124	467491	3202	578141	165183	8.2
Zone 8	945303	525673	3164	604131	201377	6.5
Zone 9	552647	325121	5280	641840	128368	18.4
Zone 10	333569	193302	4735	190845	34699	9.0

Data from existing travel is used to make forecasts of future travel using travel demand models. This requires forecasts of future land use and economic conditions as well as understanding of how people make travel choices. Forecasting requires large amounts of data and is done under many assumptions. The basic assumptions and procedures used for travel demand forecasting are set out in chapter 04.

CHAPTER 04

TRIP GENERATION

The first step in travel forecasting is trip generation. In this step information from land use, population and economic forecasts are used to estimate how many person trips will be made to and from each zone. This is done separately by trip purpose. Trip purposes that can be used include: home based work trips (work trips that begin or end at home), home based shopping trips, home based other trips, school trips, non-home based trips (trips that neither begin nor end at home), truck trips and taxi trips.

Trip generation uses trip rates that are averages for large segment of the study area. Trip productions are based on household characteristics such as the number of people in the household and the number of vehicles available. For example, a household with four people and two vehicles may be assumed to produce 3.00 work trips per day. Trips per household are then expanded to trips per zone. Trip attractions are typically based on the level of employment in a zone. For example a zone could be assumed to attract 1.32 home based work trips for every person employed in that zone. Trip generation is used to calculate person trips.

Here in this stage, trip production and trip attraction after 10 years is determined. To do this the following procedure is followed:

At first existing trip production and attraction parameters are calculated using the following growth rates after 10 years. These growth rates are assumed.

Table 4.1: Growth rates of different variables after 10 years

Variable	Growth Rate
Population	4.50%
Income Level	10%
Land Price	25%
Employment	2.50%

Now using the above growth rates we have found the tables 4.2 and 4.3 below:

Table 4.2: Population and average zonal income after 10 years for production

Zone	Existing		After 10 Years	
	Population (X_1)	Average Zonal Income (X_2)	Population (X_1)	Average Zonal Income (X_2)
Zone 1	116939	1931	**181603**	**5008**
Zone 2	473490	2133	**735315**	**5532**
Zone 3	376925	1980	**585353**	**5136**
Zone 4	451756	4898	**701563**	**12705**
Zone 5	484981	4920	**753161**	**12761**
Zone 6	284057	3753	**441132**	**9734**
Zone 7	467491	3202	**725999**	**8305**
Zone 8	525673	3164	**816354**	**8206**
Zone 9	325121	5280	**504903**	**13695**
Zone 10	193302	4735	**300192**	**12280**

Table 4.3: Employment and land price after 10 years for attraction

Zone	Existing		After 10 Years	
	Employment (X_1)	Land Price (Lakh taka/Katha) (X_2)	Employment (X_1)	Land Price (Lakh/Katha) (X_2)
Zone 1	51200	9.5	**65540**	**25**
Zone 2	207202	20.0	**265236**	**52**
Zone 3	153789	16.2	**196863**	**42**
Zone 4	200848	15.8	**257102**	**41**
Zone 5	177655	21.9	**227413**	**57**
Zone 6	105783	12.7	**135411**	**33**
Zone 7	165183	8.2	**211448**	**21**
Zone 8	201377	6.5	**257780**	**17**
Zone 9	128368	18.4	**164322**	**48**
Zone 10	34699	9.0	**44418**	**23**

Calculation Process

$$\text{Population after 10 years} = \text{Existing population}(1+0.045)^{\wedge}10$$

Here, Growth rate= 4.5%= 0.045

Projected year=10

Thus using similar formulas forecasted values for the other trip production & attraction parameters are calculated.

From the calculated parameters for trip production & trip attraction after 10 years, two regression equations are found from Microsoft Excel Data Analysis portion using Regression formula. Here X-inputs for production are considered as population and income after 10 years and Y- input is considered as existing trips. This is also done for attraction parameters too. And finally the following two regression equations are found. (Appendix- G).

Regression Equation for Trip Production

$Y_{production}$= 49018.116+1.7966×X_1-15.73×X_2

Where, a_0 =49018.116

a_1 =1.7966

a_2 =-15.73

Regression Equation for Trip Attraction

$Y_{attraction}$=-204124.3952+3.6887X_1+22843.12X_2

Where, b_0 =204124.3952

b_1 =3.6887

b_2 =22843.12

Using these regression equations now forecasted trips, for both trip production and attraction after 10 years, are calculated. And the table is shown below.

Table 4.4: Forecasted trips for production and attraction after 10 years

	After 10 years	
Zone	**Production**	**Attraction**
	Trips/person/day	**Trips/person/day**
Zone 1	296505	598526
Zone 2	1283072	1961928
Zone 3	1019880	1483197
Zone 4	1109603	1677424
Zone 5	1201413	1934899
Zone 6	688446	1046528
Zone 7	1222716	1060918
Zone 8	1386605	1131867
Zone 9	740705	1491721
Zone 10	395176	492962

Calculation Process

Trip Production= a_0 + (a_1 ×Forecasted Population) + (a_2 ×Forecasted Income)

Trip Attraction= b_0 + (b_1 ×Forecasted Employment) + (b_2 ×Forecasted Land Price)

Here ends trip generation step after forecasting future productions/origin and attractions/destination.

CHAPTER 05

TRIP DISTRIBUTION

Trip generation only finds the number of trips that begin or end at a particular zone. These trip ends are linked together to form an origin-destination pattern of trips through the process of trip distribution. Trip distribution is used to represent the process of destination choice, i.e. "I need to go shopping but where should I go to meet my shopping needs?" Trip distribution leads to a large increase in the amount of data which needs to be dealt with. Origin-destination tables are very large.

The most commonly used procedure for trip distribution is the 'gravity model'. The gravity model takes the trips produced at one zone and distributes to other zones based on the size of the other zones (as measured by their trip attractions) and on the basis of the distance to other zones. A zone with a large number of trip attractions will receive a greater number of distributed trips than one with a small number of trip attractions. Distance to possible destinations is the other factor used in the gravity model. The number of trips to a given destination decreases with the distance to the destination (it is inversely proportional). The distance effect is found through a calibration process which tries to lead to a distribution of trips from the model similar to that found from field data.

'Distance' can be measured several ways. The simplest way this is done is to use auto travel times between zones as the measurement of distance. Other ways might be to use a combination of auto travel time and cost as the measurement of distance. Still another way is to use a combination of transit and auto times and costs (composite cost). This method involves using multiplying auto travel times and costs by a percentage and transit time/cost another percentage to get a composite time and cost of both modes. Because of calculation procedures, the model must be iterated a number of times in order to balance the trip numbers to match the trip productions and attractions found in trip generation.

Now trip distribution step is going to be started by introducing an origin-destination matrix for all the 10 zones.

Table 5.1: Origin- Destination Matrix

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	∑O
Zone 1											**296505**
Zone 2											**1283072**
Zone 3											**1019880**
Zone 4											**1109603**
Zone 5											**1201413**
Zone 6											**688446**
Zone 7											**1222716**
Zone 8											**1386605**
Zone 9											**740705**
Zone 10											**395176**
∑D	**598526**	**1961928**	**1483197**	**1677424**	**1934899**	**1046528**	**1060918**	**1131867**	**1491721**	**492962**	

Here,

Total Trip Production=9344120 and

Total Trip Attraction=12879969 which is greater than trip productions.

But total trip attraction/ destinations must be equal to total trip productions. As trip production is considered to be exact. For this reason the trip attraction for different zones is multiplied by an adjustment factor. The factor can be stated as follows:

$$\text{Adjustment Factor} = \frac{\text{Total Production}}{\text{Total Attraction}} = 0.73$$

$$\text{Adjusted trip attraction} = \frac{\text{Total Production}}{\text{Total Attraction}} \times \text{Trip attraction of any zone}$$

From the above process table 5.2 is found.

Table 5.2: Adjusted Origin- Destination Matrix

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	∑O
Zone 1											**296505**
Zone 2											**1283072**
Zone 3											**1019880**
Zone 4											**1109603**
Zone 5											**1201413**
Zone 6											**688446**
Zone 7											**1222716**
Zone 8											**1386605**
Zone 9											**740705**
Zone 10											**395176**
Adjusted ∑D	**434217**	**1423334**	**1076025**	**1216932**	**1403725**	**759232**	**769671**	**821143**	**1082209**	**357632**	**9344120**

Transport Network Link Impedance or resistance to flow

The difficulty of moving from one node to another in a network is the link impedance. Impedance in electrical terms means total resistance and for transport the meaning is the same.

For modeling 'Link Impedance' can be expressed as distance but travel time or apparent costs are usually better measures. Arbitrary units that are functions of impedance factors may be more convenient than actual measurable quantities for modeling purposes. Such factors can be determined by calibration of some distribution function such as a Gravity Model with a known distribution pattern obtained from an origin - destination survey.

It is essential to the modeling process to obtain the best practical measure of impedance. This is usually done by testing model output against historical information for the same situation. The measures of impedance which give the closest match are used. The measures may be different for different transport activities.

Now a cost matrix is assumed (in terms of time), this table is assumed by predicting the zone to zone travel cost.

Table 5.3: Cost Matrix table (C_{ij}) in terms of time

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	8	10	20	15	25	22	28	30	25	35
Zone 2	10	8	12	15	20	17	25	26	22	32
Zone 3	20	12	8	20	12	12	15	25	23	30
Zone 4	15	15	20	8	12	15	20	22	12	20
Zone 5	26	20	10	12	8	10	15	17	15	22
Zone 6	22	17	12	15	10	8	9	12	10	20
Zone 7	28	25	15	20	15	9	8	10	11	17
Zone 8	30	26	25	22	17	12	10	8	9	15
Zone 9	25	22	23	12	15	10	11	9	8	18
Zone 10	15	32	30	20	22	20	17	15	18	8

Using the following formula impedance factor is calculated:

Impedance factor $= e^{-\beta C_{ij}}$

Where, Dispersion parameter measuring sensitivity to cost, $\beta = 0.1$ (assumed)

C_{ij} = General cost of travel between zone i to zone j

Table 5.4: Impedance factor table

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	0.4493	0.3679	0.1353	0.2231	0.0821	0.1108	0.0608	0.0498	0.08208	0.030197
Zone 2	0.3679	0.4493	0.3012	0.2231	0.1353	0.18268	0.0821	0.0743	0.1108	0.040762
Zone 3	0.1353	0.3012	0.4493	0.1353	0.3012	0.30119	0.2231	0.0821	0.10026	0.049787
Zone 4	0.2231	0.2231	0.1353	0.4493	0.3012	0.22313	0.1353	0.1108	0.30119	0.135335
Zone 5	0.0743	0.1353	0.3679	0.3012	0.4493	0.36788	0.2231	0.1827	0.22313	0.110803
Zone 6	0.1108	0.1827	0.3012	0.2231	0.3679	0.44933	0.4066	0.3012	0.36788	0.135335
Zone 7	0.0608	0.0821	0.2231	0.1353	0.2231	0.40657	0.4493	0.3679	0.33287	0.182684
Zone 8	0.0498	0.0743	0.0821	0.1108	0.1827	0.30119	0.3679	0.4493	0.40657	0.22313
Zone 9	0.0821	0.1108	0.1003	0.3012	0.2231	0.36788	0.3329	0.4066	0.44933	0.165299
Zone 10	0.2231	0.0408	0.0498	0.1353	0.1108	0.13534	0.1827	0.2231	0.1653	0.449329

Now, $\sum \text{Impedance Factor}$ =**22.1239** and
Total Trip**=9344120**

Another factor is calculated for the distribution of trips among the zones.

That factor is $= \dfrac{\text{Total Trip}}{\text{Total Impedance Factor}}$ =422354

Now trip for each zone to different zones using the following formula is calculated.

Trip of any zone $= \dfrac{\text{Total Trip}}{\text{Total Impedance Factor}}$ * Impedance factor for this particular zone

Finally trip distribution from one to different zones is found.

Table 5.5: Trip distribution after 10 years for different zones

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	∑O
Zone 1	189776	155375	57159	94240	34669	46798	25683	21028	34669	12754	**672152**
Zone 2	155375	189776	127211	94240	57159	77157	34669	31370	46798	17216	**830972**
Zone 3	57159	127211	189776	57159	127211	127211	94240	34669	42345	21028	**878009**
Zone 4	94240	94240	57159	189776	127211	94240	57159	46798	127211	57159	**945194**
Zone 5	31370	57159	155375	127211	189776	155375	94240	77157	94240	46798	**1028702**
Zone 6	46798	77157	127211	94240	155375	189776	171716	127211	155375	57159	**1202020**
Zone 7	25683	34669	94240	57159	94240	171716	189776	155375	140590	77157	**1040607**
Zone 8	21028	31370	34669	46798	77157	127211	155375	189776	171716	94240	**949341**
Zone 9	34669	46798	42345	127211	94240	155375	140590	171716	189776	69815	**1072535**
Zone 10	94240	17216	21028	57159	46798	57159	77157	94240	69815	189776	**724589**
∑D	**750339**	**830972**	**906173**	**945194**	**1003837**	**1202020**	**1040607**	**949341**	**1072535**	**643103**	**9344120**

Now from Table 5.2 and Table 5.5 it is seen that there are huge differences in the trip productions & trip attractions than what it should be. Although it is found that total trips are same but there are differences in the total production and attraction into different zones. It means the inter-zonal distribution is not correct. For this purpose iteration by using a program of Microsoft Visual C++, to solve the problem is held (Appendix- H). After using the program the adjusted trips from different zones are shown in the following table. Which is same as what it should be?

Table 5.6: Adjusted trip distribution after 10 years for different zones

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	∑O
Zone 1	49251	109183	26394	50265	19145	11568	7322	6909	13570	2898	**296505**
Zone 2	137694	455381	200587	171643	107787	65126	33751	35195	62548	13359	**1283071**
Zone 3	39434	237636	232956	81046	186750	83591	71422	30281	44060	12703	**1019879**
Zone 4	66794	180858	72083	276441	191856	63619	44504	41992	135982	35474	**1109603**
Zone 5	22702	112002	200063	189201	292234	107095	74918	70689	102856	29654	**1201413**
Zone 6	17691	78975	85563	73216	124981	68329	71308	60880	88583	18920	**688446**
Zone 7	21604	78964	141049	98817	168684	137577	175364	165465	178361	56831	**1222716**
Zone 8	22401	90486	65713	102460	174901	129074	181828	255945	275890	87907	**1386606**
Zone 9	16399	59940	35640	123672	94857	70003	73055	102833	135389	28917	**740705**
Zone 10	40248	19909	15979	50171	42529	23251	36199	50954	44969	70969	**395176**
∑D	**434217**	**1423334**	**1076025**	**1216932**	**1403725**	**759232**	**769671**	**821143**	**1082209**	**357632**	**9344120**

This is the final origin-destination matrix for trip distribution among different zones after 10 years. In the next chapter the step modal split is discussed.

CHAPTER 06

MODAL SPLIT

Mode choice is one of the most critical parts of the travel demand modeling process. It is the step where trips between a given origin and destination are split into trips using transit, trips by car pool or as automobile passengers and trips by automobile drivers. Calculations are conducted that compare the attractiveness of travel by different modes to determine their relative usage. All proposals to improve public transit or to change the ease of using the automobile are passed through the mode split/auto occupancy process as part of their assessment and evaluation.

A utility function measures the degree of satisfaction that people derive from their choices and a disutility function represents the generalized cost that is associated with each choice.

The most commonly used process for mode split is to use the 'Logit' model. This involves a comparison of the "disutility" or "utility" of travel between two points for the different modes that are available. Disutility is a term used to represent a combination of the travel time, cost and convenience of a mode between an origin and a destination. It is found by placing multipliers (weights) on these factors and adding them together.

Disutility calculations may contain a "mode bias factor" which is used to represent other characteristics or travel modes which may influence the choice of mode (such as a difference in privacy and comfort between transit and automobiles). The mode bias factor is used as a constant in the analysis and is found by attempt to fit the model to actual travel behavior data. Generally, the disutility equations do not recognize differences within travel modes. For example, a bus system and a rail system with the same time and cost characteristics will have the same disutility values. There are no special factors that allow for the difference in attractiveness of alternative technologies.

Once disutilities are known for the various mode choices between an origin and a destination, the trips are split among various modes based on the relative differences between disutilities. The logit equation is used in this step. A large advantage in disutility will mean a high percentage for that mode. Mode splits are calculated to match splits found from actual traveler data. Sometimes a fixed percentage is used for the minimum transit use (percent captive users) to represent travelers who have no automobile available or are unable to use an automobile for their trip.

In this step the matrix for travel time and travel cost is given to calculate the utilities for three modes of Car, Bus and Rickshaw (Appendix- I).

Moreover utility functions for these three modes are also assumed. The utility functions are as follows:

$$U_{Car} = -0.060054\,TT - 0.043648\,TC$$

$$U_{Bus} = 0.945505 - 0.060054\,TT - 0.043648\,TC$$

$$U_{Rickshaw} = 1.23213 - 0.060054\,TT - 0.043648\,TC$$

Where, TT=Travel Time from one Zone to other zone

TC=Travel cost from one Zone to other zone

The utilities are calculated for different modes of traffic using the matrices shown in the Appendix-I and their respective utility functions. Utility matrix tables for different modes of traffic are shown below:

Table 6.1: Utility matrix table for Car

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	-1.5280	-1.9100	-3.8200	-2.8650	-4.7750	-4.2020	-5.3479	-5.7299	-4.7750	-6.6849
Zone 2	-1.9100	-1.5280	-2.2920	-2.8650	-3.8200	-3.2470	-4.7750	-4.9659	-4.2020	-6.1119
Zone 3	-3.8200	-2.2920	-1.5280	-3.8200	-2.2920	-2.2920	-2.8650	-4.7750	-4.3930	-5.7299
Zone 4	-2.8650	-2.8650	-3.8200	-1.5280	-2.2920	-2.8650	-3.8200	-4.2020	-2.2920	-3.8200
Zone 5	-4.9659	-3.8200	-1.9100	-2.2920	-1.5280	-1.9100	-2.8650	-3.2470	-2.8650	-4.2020
Zone 6	-4.2020	-3.2470	-2.2920	-2.8650	-1.9100	-1.5280	-1.7190	-2.2920	-1.9100	-3.8200
Zone 7	-5.3479	-4.7750	-2.8650	-3.8200	-2.8650	-1.7190	-1.5280	-1.9100	-2.1010	-3.2470
Zone 8	-5.7299	-4.9659	-4.7750	-4.2020	-3.2470	-2.2920	-1.9100	-1.5280	-1.7190	-2.8650
Zone 9	-4.7750	-4.2020	-4.3930	-2.2920	-2.8650	-1.9100	-2.1010	-1.7190	-1.5280	-3.4380
Zone 10	-2.8650	-6.1119	-5.7299	-3.8200	-4.2020	-3.8200	-3.2470	-2.8650	-3.4380	-1.5280

Table 6.2: Utility matrix table for Bus

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	-0.1246	-0.3921	-1.7298	-1.0610	-2.3986	-1.9973	-2.7999	-3.0674	-2.3986	-3.7363
Zone 2	-0.3921	-0.1246	-0.6597	-1.0610	-1.7298	-1.3285	-2.3986	-2.5324	-1.9973	-3.3350
Zone 3	-1.7298	-0.6597	-0.1246	-1.7298	-0.6597	-0.6597	-1.0610	-2.3986	-2.1311	-3.0674
Zone 4	-1.0610	-1.0610	-1.7298	-0.1246	-0.6597	-1.0610	-1.7298	-1.9973	-0.6597	-1.7298
Zone 5	-2.5324	-1.7298	-0.3921	-0.6597	-0.1246	-0.3921	-1.0610	-1.3285	-1.0610	-1.9973
Zone 6	-1.9973	-1.3285	-0.6597	-1.0610	-0.3921	-0.1246	-0.2584	-0.6597	-0.3921	-1.7298
Zone 7	-2.7999	-2.3986	-1.0610	-1.7298	-1.0610	-0.2584	-0.1246	-0.3921	-0.5259	-1.3285
Zone 8	-3.0674	-2.5324	-2.3986	-1.9973	-1.3285	-0.6597	-0.3921	-0.1246	-0.2584	-1.0610
Zone 9	-2.3986	-1.9973	-2.1311	-0.6597	-1.0610	-0.3921	-0.5259	-0.2584	-0.1246	-1.4623
Zone 10	-1.0610	-3.3350	-3.0674	-1.7298	-1.9973	-1.7298	-1.3285	-1.0610	-1.4623	-0.1246

Table 6.3: Utility matrix table for Rickshaw

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	-0.2529	-0.6242	-2.4806	-1.5524	-3.4087	-2.8518	-3.9656	-4.3369	-3.4087	-5.2651
Zone 2	-0.6242	-0.2529	-0.9955	-1.5524	-2.4806	-1.9236	-3.4087	-3.5944	-2.8518	-4.7082
Zone 3	-2.4806	-0.9955	-0.2529	-2.4806	-0.9955	-0.9955	-1.5524	-3.4087	-3.0375	-4.3369
Zone 4	-1.5524	-1.5524	-2.4806	-0.2529	-0.9955	-1.5524	-2.4806	-2.8518	-0.9955	-2.4806
Zone 5	-3.5944	-2.4806	-0.6242	-0.9955	-0.2529	-0.6242	-1.5524	-1.9236	-1.5524	-2.8518
Zone 6	-2.8518	-1.9236	-0.9955	-1.5524	-0.6242	-0.2529	-0.4386	-0.9955	-0.6242	-2.4806
Zone 7	-3.9656	-3.4087	-1.5524	-2.4806	-1.5524	-0.4386	-0.2529	-0.6242	-0.8098	-1.9236
Zone 8	-4.3369	-3.5944	-3.4087	-2.8518	-1.9236	-0.9955	-0.6242	-0.2529	-0.4386	-1.5524
Zone 9	-3.4087	-2.8518	-3.0375	-0.9955	-1.5524	-0.6242	-0.8098	-0.4386	-0.2529	-2.1093
Zone 10	-1.5524	-4.7082	-4.3369	-2.4806	-2.8518	-2.4806	-1.9236	-1.5524	-2.1093	-0.2529

Now using those above tables the probability of different modes are calculated by using the formulas below:

$$\text{Probability}_{\text{Car}} = \frac{e^{U_{\text{Car}}}}{e^{U_{\text{Car}}} + e^{U_{\text{Bus}}} + e^{U_{\text{Rickshaw}}}}$$

$$\text{Probability}_{\text{Bus}} = \frac{e^{U_{\text{Bus}}}}{e^{U_{\text{Car}}} + e^{U_{\text{Bus}}} + e^{U_{\text{Rickshaw}}}}$$

$$\text{Probability}_{\text{Rickshaw}} = \frac{e^{U_{\text{Rickshaw}}}}{e^{U_{\text{Car}}} + e^{U_{\text{Bus}}} + e^{U_{\text{Rickshaw}}}}$$

Table 6.4: Probability matrix table for Car

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	0.1156	0.1089	0.0775	0.0927	0.0638	0.0718	0.0563	0.0517	0.0638	0.0413
Zone 2	0.1089	0.1156	0.1023	0.0927	0.0775	0.0865	0.0638	0.0612	0.0718	0.0473
Zone 3	0.0775	0.1023	0.1156	0.0775	0.1023	0.1023	0.0927	0.0638	0.0691	0.0517
Zone 4	0.0927	0.0927	0.0775	0.1156	0.1023	0.0927	0.0775	0.0718	0.1023	0.0775
Zone 5	0.0612	0.0775	0.1089	0.1023	0.1156	0.1089	0.0927	0.0865	0.0927	0.0718
Zone 6	0.0718	0.0865	0.1023	0.0927	0.1089	0.1156	0.1123	0.1023	0.1089	0.0775
Zone 7	0.0563	0.0638	0.0927	0.0775	0.0927	0.1123	0.1156	0.1089	0.1056	0.0865
Zone 8	0.0517	0.0612	0.0638	0.0718	0.0865	0.1023	0.1089	0.1156	0.1123	0.0927
Zone 9	0.0638	0.0718	0.0691	0.1023	0.0927	0.1089	0.1056	0.1123	0.1156	0.0834
Zone 10	0.0927	0.0473	0.0517	0.0775	0.0718	0.0775	0.0865	0.0927	0.0834	0.1156

Table 6.5: Probability matrix table for Bus

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	0.4705	0.4970	0.6267	0.5629	0.6863	0.6511	0.7195	0.7403	0.6863	0.7879
Zone 2	0.4970	0.4705	0.5235	0.5629	0.6267	0.5888	0.6863	0.6976	0.6511	0.7602
Zone 3	0.6267	0.5235	0.4705	0.6267	0.5235	0.5235	0.5629	0.6863	0.6631	0.7403
Zone 4	0.5629	0.5629	0.6267	0.4705	0.5235	0.5629	0.6267	0.6511	0.5235	0.6267
Zone 5	0.6976	0.6267	0.4970	0.5235	0.4705	0.4970	0.5629	0.5888	0.5629	0.6511
Zone 6	0.6511	0.5888	0.5235	0.5629	0.4970	0.4705	0.4837	0.5235	0.4970	0.6267
Zone 7	0.7195	0.6863	0.5629	0.6267	0.5629	0.4837	0.4705	0.4970	0.5103	0.5888
Zone 8	0.7403	0.6976	0.6863	0.6511	0.5888	0.5235	0.4970	0.4705	0.4837	0.5629
Zone 9	0.6863	0.6511	0.6631	0.5235	0.5629	0.4970	0.5103	0.4837	0.4705	0.6016
Zone 10	0.5629	0.7602	0.7403	0.6267	0.6511	0.6267	0.5888	0.5629	0.6016	0.4705

Table 6.6: Probability matrix table for Rickshaw

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	0.4138	0.3941	0.2958	0.3444	0.2499	0.2771	0.2243	0.2080	0.2499	0.1708
Zone 2	0.3941	0.4138	0.3742	0.3444	0.2958	0.3247	0.2499	0.2412	0.2771	0.1925
Zone 3	0.2958	0.3742	0.4138	0.2958	0.3742	0.3742	0.3444	0.2499	0.2679	0.2080
Zone 4	0.3444	0.3444	0.2958	0.4138	0.3742	0.3444	0.2958	0.2771	0.3742	0.2958
Zone 5	0.2412	0.2958	0.3941	0.3742	0.4138	0.3941	0.3444	0.3247	0.3444	0.2771
Zone 6	0.2771	0.3247	0.3742	0.3444	0.3941	0.4138	0.4040	0.3742	0.3941	0.2958
Zone 7	0.2243	0.2499	0.3444	0.2958	0.3444	0.4040	0.4138	0.3941	0.3841	0.3247
Zone 8	0.2080	0.2412	0.2499	0.2771	0.3247	0.3742	0.3941	0.4138	0.4040	0.3444
Zone 9	0.2499	0.2771	0.2679	0.3742	0.3444	0.3941	0.3841	0.4040	0.4138	0.3150
Zone 10	0.3444	0.1925	0.2080	0.2958	0.2771	0.2958	0.3247	0.3444	0.3150	0.4138

Now modal share is calculated by multiplying the trip making from one zone to other zone (from trip distribution) with the probability. This is calculated by the following equation:

$$\text{Modal Share for any Mode} = \text{Trip}_{i-j} \times \text{Probability}_{i-j}$$

And finally we got the tables for modal share for the three vehicles, which are shown below:

Table 6.7: Modal Share matrix table for Car

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	5695	11894	2046	4659	1221	831	412	357	865	120
Zone 2	15000	52659	20526	15908	8354	5631	2152	2154	4492	632
Zone 3	3056	24318	26938	6281	19111	8554	6620	1930	3043	656
Zone 4	6191	16762	5587	31967	19633	5896	3449	3016	13915	2749
Zone 5	1389	8680	21794	19361	33793	11666	6943	6112	9533	2130
Zone 6	1270	6828	8756	6786	13615	7901	8006	6230	9650	1466
Zone 7	1216	5034	13073	7658	15634	15447	20279	18025	18838	4913
Zone 8	1157	5537	4189	7358	15122	13208	19807	29597	30976	8147
Zone 9	1045	4305	2461	12656	8791	7626	7716	11546	15656	2412
Zone 10	3730	942	825	3888	3054	1802	3130	4722	3751	8207

Table 6.8: Modal Share matrix table for Bus

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	23173	54264	16541	28296	13140	7532	5268	5115	9313	2284
Zone 2	68434	214263	105006	96624	67550	38348	23163	24552	40727	10155
Zone 3	24713	124401	109609	50791	97762	43759	40206	20782	29215	9404
Zone 4	37601	101811	45174	130069	100435	35813	27890	27342	71186	22231
Zone 5	15836	70191	99431	99045	137500	53226	42174	41623	57901	19309
Zone 6	11519	46502	44791	41216	62116	32150	34495	31870	44026	11857
Zone 7	15543	54194	79401	61928	94958	66552	82511	82236	91009	33463
Zone 8	16584	63122	45100	66715	102985	67569	90368	120426	133461	49486
Zone 9	11255	39029	23631	64741	53399	34791	37277	49745	63703	17396
Zone 10	22657	15134	11829	31442	27692	14571	21315	28684	27053	33392

Table 6.9: Modal Share matrix table for Rickshaw

O-D	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	20382	43025	7807	17310	4785	3205	1642	1437	3392	495
Zone 2	54261	188458	75054	59111	31884	21148	8436	8489	17329	2572
Zone 3	11665	88917	96409	23974	69877	31278	24597	7568	11802	2642
Zone 4	23003	62284	21323	114405	71787	21909	13165	11634	50881	10493
Zone 5	5476	33131	78838	70794	120940	42203	25800	22954	35422	8216
Zone 6	4901	25645	32015	25214	49251	28278	28807	22780	34908	5597
Zone 7	4845	19736	48575	29231	58092	55578	72574	65204	68513	18454
Zone 8	4660	21826	16424	28387	56795	48296	71653	105922	111454	30274
Zone 9	4099	16607	9547	46275	32667	27586	28062	41543	56031	9109
Zone 10	13861	3833	3324	14841	11783	6878	11755	17548	14165	29370

This is the final output of modal choice step. Here we get how many trips are made between one to another zone by different modes of vehicles. In the next chapter discussion on trip assignment is described.

CHAPTER 07

TRIP ASSIGNMENT

Once trips have been split into highway and transit trips, the specific path that they use to travel from their origin to their destination must be found. These trips are then assigned to that path in the step called traffic assignment. Traffic assignment is the most time consuming and data intensive step in the process and is done differently for highway trips and transit trips.

The process first involves the calculation of the shortest path from each origin to all destinations (usually the minimum time path is used). Trips for each O-D pair are then assigned to the links in the minimum path and the trips are added up for each link. The assigned trip volume is then compared to the capacity of the link to see if it is congested. If a link is congested the speed on the link needs to be reduced to result in a longer travel time on that link. Changes in travel times mean that the shortest path may change. Hence the whole process is repeated several times (iterated) until there are equilibrium between travel demand and travel supply. Trips on congested links will be shifted to uncontested links until this equilibrium, condition occurs. Traffic assignment is the most complex calculation in the travel modeling sequence and there are a variety of ways in which it is done to keep computer time to a minimum.

At first a network is assumed and then we calculate the Generalized Travel Cost (GTC) factor for each mode. The procedure for calculating GTC is shown below:

$$GTC = TC + \left(\frac{a_1}{a_2}\right) \times TT$$

Where, TC=Travel Cost

TT=Travel time

a_1 =Co-efficient of the Travel Time factor

a_2 = Co-efficient of the Travel Cost factor

The values a_1 & a_2 come from the utility functions mentioned earlier in the Modal Choice step.

$$\left(\frac{a_1}{a_2}\right) = \frac{0.060054}{0.043684} = 1.37$$

Now using the GTC table (Appendix- I), the calculated values of GTC for different modes are put into the different links of the assumed network.

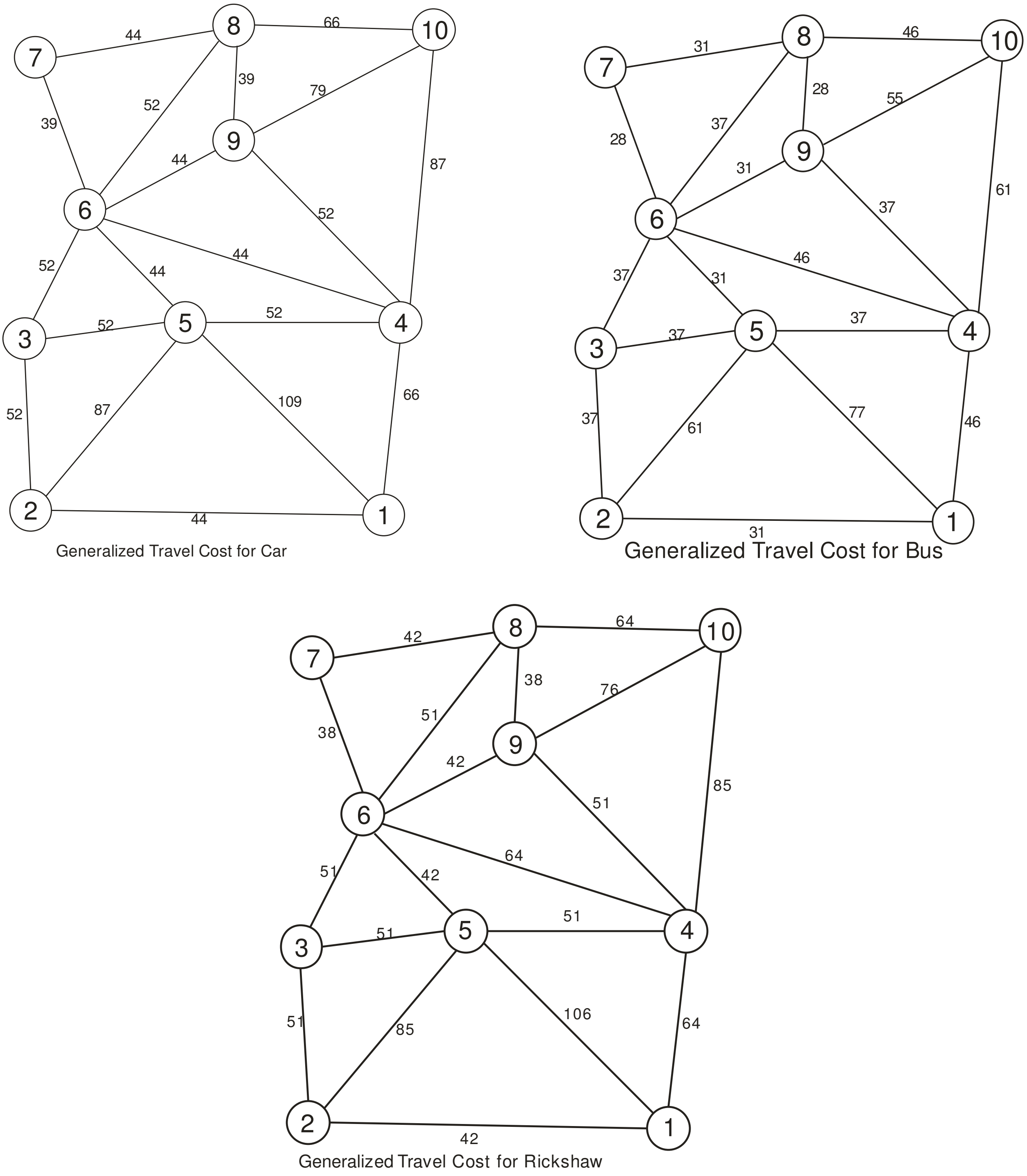


Figure 7.1: Generalized Travel Cost (GTC) for Car, Bus and Rickshaw

Thus Generalized Travel Time (GTT) can also be measured from the equation below:

$$\mathbf{GTT = (a_2/a_1) * TC + TT}$$

Now using the Dijkstra's Method (Appendix- J) the shortest distance in terms of GTC from any one node to the other node for different modes (Appendix- K) is calculated. Here All-or-nothing Assignment for calculating the traffic flow for different modes from one node to other node is considered.

In highly congested areas, particularly in large urban areas, the finite amount of physical highway capacity results in the spreading of the peak periods. While it is not possible for a roadway to carry an hourly volume of traffic that is greater than its theoretical maximum capacity, the highway assignment algorithms commonly used can produce traffic volumes on roadways that exceed the capacity. In these cases, the volume of traffic assigned during the peak periods must be constrained and change as the capacity of the highway system is reached.

Traffic assignment is typically done for peak hour travel while forecasts of trips are done on a daily basis. A ratio of peak hour travel to daily travel is needed to convert daily trips to peak hour travel (for example it may be assumed that ten percent of travel occurs in the peak hour).

In this report it is assumed that 15% of travel occurs in the peak hour. And for this 15% flow in peak hours total trips per link according to their shortest path is calculated for the all thee modes (Appendix- L).

The following table shows the flow of traffic from one node to another for different modes of traffic at peak hours:

Table 7.1: Total Trips in each Link for Different Modes at Peak Hour

Link	Flow for Car	Flow for Bus	Flow for Rickshaw
1-2	9922	58160	36689
1-4	8400	59513	31602
1-5	390	4347	1539
2-3	12891	90059	48406
2-5	2550	20664	9754
3-5	7428	44648	28915
3-6	12912	101680	49056
4-5	8395	51375	31186
4-6	4120	31011	15619
4-9	6046	40844	22618
4-10	2581	22639	9916
5-6	13094	76268	48485
6-7	15650	95531	58061
6-8	8869	66801	33541
6-9	10296	62068	38163
7-8	8030	39704	29273
8-9	9308	50442	34081
8-10	3843	27096	14473
9-10	923	6668	3492

Occupancy of a vehicle refers to how many people occupy that vehicle in an average.

Occupancy for Car, Bus and Rickshaw has been assumed as from DUTP report for car is 1.85, for bus it is 28.5 and for Rickshaw it is 1.63. Using these values of occupancy the no. of Car, Bus and Rickshaw that flow in the peak period in different links is calculated and that is shown in Table 7.2.

Calculation Process

The total number of vehicles for a particular mode can be calculated from the formula below:

Total No of vehicles= Flow of that vehicle / Occupancy of that vehicle or mode

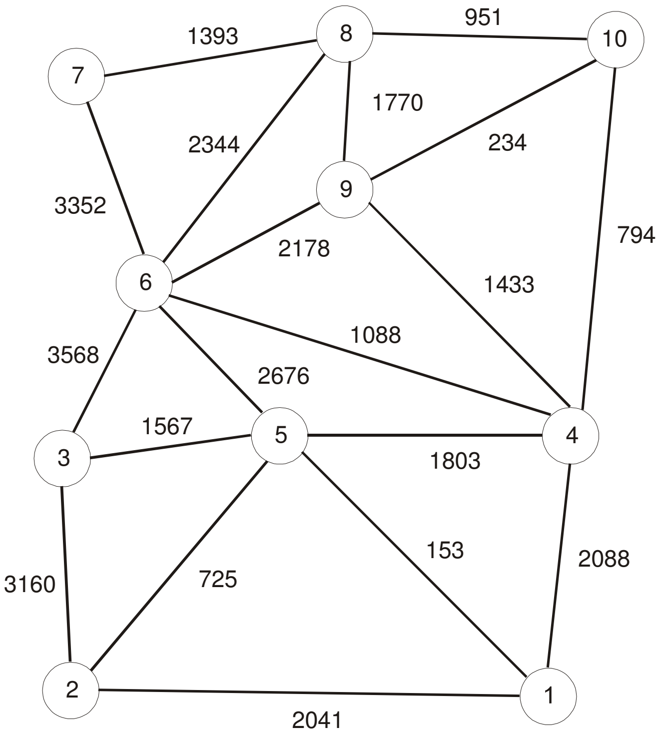
Table 7.2: Total number of modes in each link at peak hours***

Link	Bus			Car			Rickshaw		
	Flow	Occupancy	Number	Flow	Occupancy	Number	Flow	Occupancy	Number
1-2	58160	28.5	2041	9922	1.85	5364	36689	1.63	22509
1-4	59513	28.5	2088	8400	1.85	4541	31602	1.63	19388
1-5	4347	28.5	153	390	1.85	211	1539	1.63	944
2-3	90059	28.5	3160	12891	1.85	6968	48406	1.63	29697
2-5	20664	28.5	725	2550	1.85	1378	9754	1.63	5984
3-5	44648	28.5	1567	7428	1.85	4015	28915	1.63	17739
3-6	101680	28.5	3568	12912	1.85	6979	49056	1.63	30096
4-5	51375	28.5	1803	8395	1.85	4538	31186	1.63	19133
4-6	31011	28.5	1088	4120	1.85	2227	15619	1.63	9582
4-9	40844	28.5	1433	6046	1.85	3268	22618	1.63	13876
4-10	22639	28.5	794	2581	1.85	1395	9916	1.63	6083
5-6	76268	28.5	2676	13094	1.85	7078	48485	1.63	29745
6-7	95531	28.5	3352	15650	1.85	8460	58061	1.63	35620
6-8	66801	28.5	2344	8869	1.85	4794	33541	1.63	20577
6-9	62068	28.5	2178	10296	1.85	5566	38163	1.63	23413
7-8	39704	28.5	1393	8030	1.85	4341	29273	1.63	17959
8-9	50442	28.5	1770	9308	1.85	5031	34081	1.63	20908
8-10	27096	28.5	951	3843	1.85	2077	14473	1.63	8879
9-10	6668	28.5	234	923	1.85	499	3492	1.63	2142

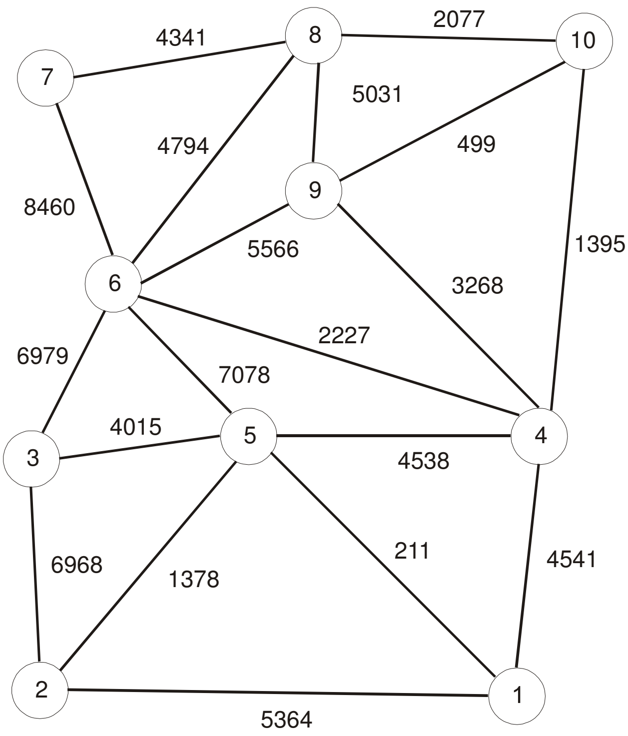
*** Please go to page 42, to see the graphical representation (Figure 7.2) of Table 7.2.

Traffic assignment results (Table 7.2) indicate the amount of travel to be expected on each link in the network at some future date with a given transportation system. Levels of congestion travel times, speed of travel and vehicle miles of travel are direct outputs from the modeling process. Link traffic volumes are also used to determine other effects of travel for plan evaluation. Some of the key effects are accidents, and estimates of air pollution emissions. Each of these effects needs to be estimated through further calculations. Typically these are done by applying accident or emission rates by highway type and by speed. Assumptions need to be made of the speed characteristics of travel for non-peak hours of the day and for variation in travel by time of the year.

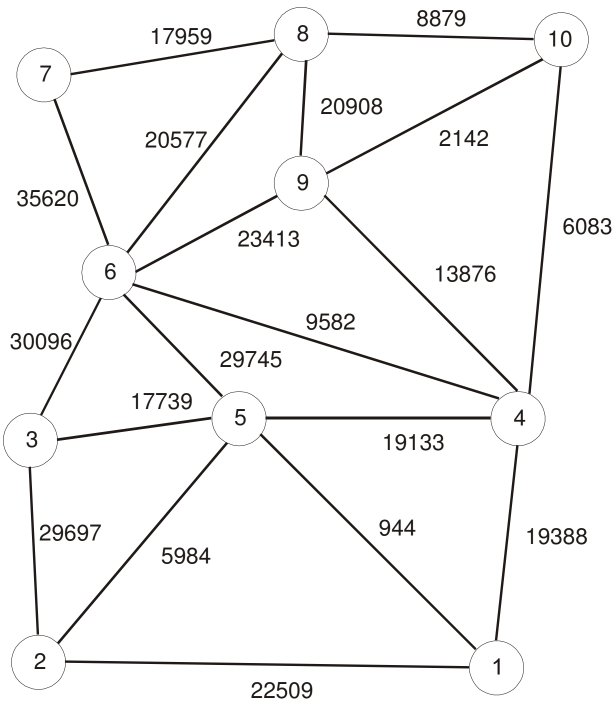
This is how the whole transportation modeling process is performed step by step, which is discussed elaborately in this scientific research paper, while taking necessary data for the 10 zones of Dhaka City Corporation for study purpose.



Total no of Bus in each link



Total no of Car in each link



Total no of Rickshaw in each link

Figure 7.2: Total Number of Vehicles in each Link

CHAPTER 08

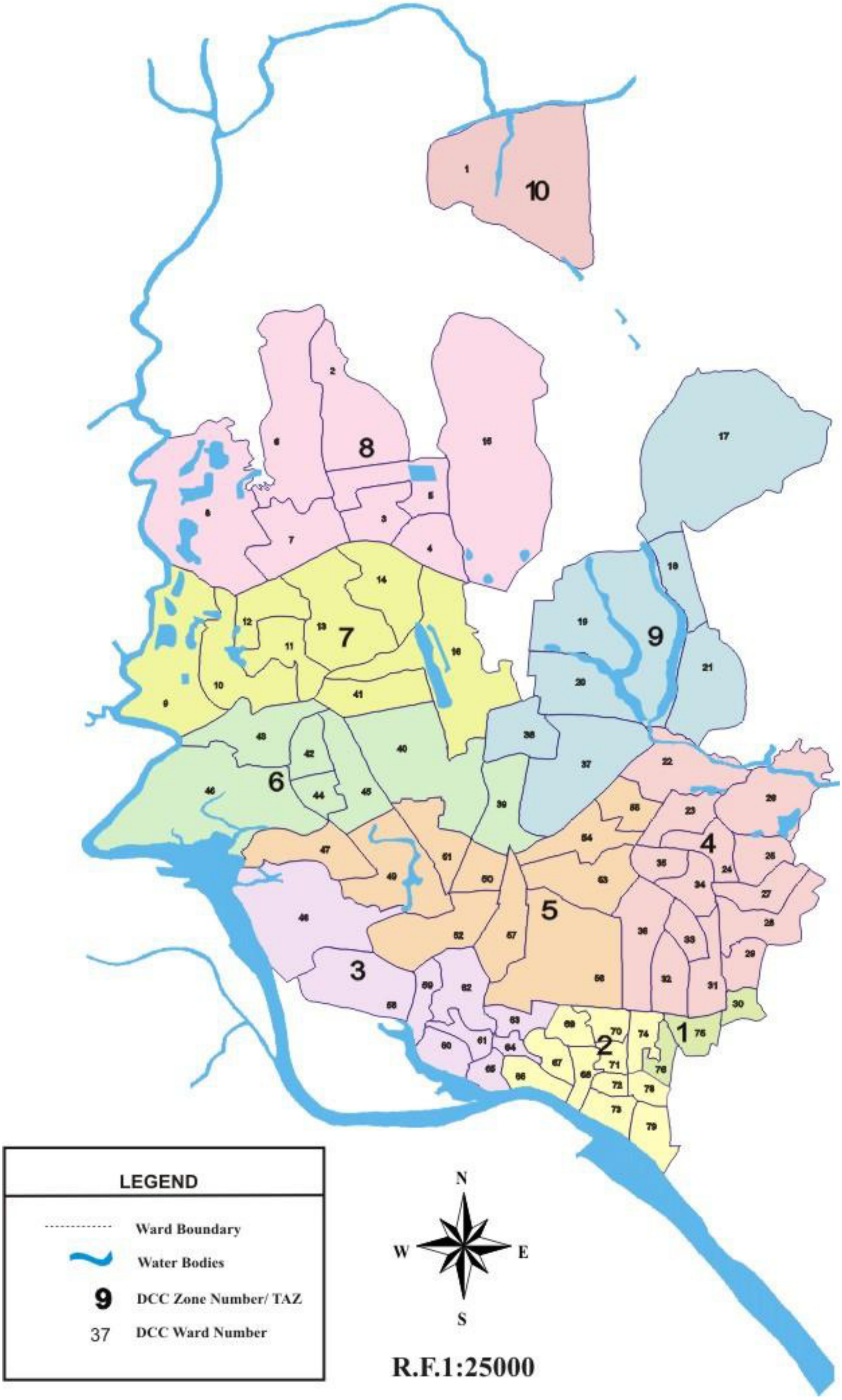
RECOMMENDATIONS AND CONCLUSION

Transportation models are being called upon to provide forecasts for a complex set of problems that in some cases can go beyond their capabilities and original purpose. Travel demand management, employer based trip reduction programs, pedestrian and bicycle programs and land use polices may not be handled well in the process. Transportation travel forecasting models uses packaged computer programs which have limitations on how easily they can be changed. In some cases the models can be modified to accommodate additional factors or procedures while in other cases major modifications are needed or new software is required.

All models are based on data about travel patterns and behavior. If this data is out-of-date, incomplete or inaccurate the results will be poor no matter how good the models are. One of the most effective ways of improving model accuracy and value is to have a good basis of recent data to use to calibrate the models and to provide for checks of their accuracy.

Models need to demonstrate that they provide an accurate picture of current travel before they should be used to forecast future travel. Better data, improved representation of bicycle and pedestrian travel, better auto occupancy models, better time of day factors, use more trip purposes, better representation of access, incorporate costs into trip distribution, add land use feedback, add intersection delays- are some important points which should be considered and included in the traditional transport modeling system to make it much more convenient and realistic.

Map 01: Dhaka City Corporation



Source: Dhaka City Corporation

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APPENDIX- A

WARD WISE POPULATION OF DIFFERENT ZONES

Zone	Ward No	Population	Zone	Ward No	Population
1	30	25201	**5**	52	37624
	75	62368		53	62425
	76	29370		54	36857
2	66	45619		55	55482
	67	34501		56	70501
	68	54044		57	48815
	69	71291	**6**	39	35285
	70	56072		40	36294
	71	52302		42	21125
	72	46514		43	29137
	73	44282		44	40746
	74	68865		45	21963
3	48	41843		46	31837
	58	50228		47	67670
	59	26025	**7**	9	74491
	60	71276		10	93565
	61	35672		11	49010
	62	50810		12	76107
	63	26366		13	56267
	64	38880		14	45443
	65	35825		16	45201
4	22	42725		41	27407
	23	43652	**8**	2	90349
	24	32328		3	109457
	25	33863		4	53564
	26	20221		5	47930
	27	18061		6	52038
	28	43727		7	69434
	29	24165		8	72422
	31	30213		15	30479
	32	55888	**9**	17	84525
	33	35382		18	20353
	34	26945		19	53337
	35	22992		20	43314
	36	21594		21	59884
5	49	41502		37	39710
	50	46070		38	23998
	51	85705	**10**	1	193302

APPENDIX- B
AVERAGE ZONAL INCOME (TAKA/PERSON/MONTH)

Zone	% of Population			Total Population	No of Population			Income Per household	Income per person
	Lower	Medium	Higher		Lower	Medium	Higher		
Zone 1	82	17	1	116939	95890	19880	1169	10620	**1931**
Zone 2	78	20.5	1.5	473490	369322	97065	7102	11730	**2133**
Zone 3	81.5	17	1.5	376925	307194	64077	5654	10890	**1980**
Zone 4	19	76	5	451756	85834	343335	22588	26940	**4898**
Zone 5	21	72	7	484981	101846	349186	33949	27060	**4920**
Zone 6	44	52	4	284057	124985	147710	11362	20640	**3753**
Zone 7	53.5	45	1.5	467491	250108	210371	7012	17610	**3202**
Zone 8	55	43	2	525673	289120	226039	10513	17400	**3164**
Zone 9	14	78	8	325121	45517	253594	26010	29040	**5280**
Zone 10	24	70	6	193302	46392	135311	11598	26040	**4735**

Here, Average Population; Lower= 47.2%, Middle= 49.05% and Higher= 3.75%
Average monthly income per person (in taka), Lower= 6000, Middle=30000 and higher= 60000
Average persons per household= 5.5

Calculation Process

$$\text{No of population} = \frac{\text{\% of population} * \text{total population}}{100}$$

$$\text{Income/ household} = \frac{\text{Lower} * 6000 + \text{Middle} * 30000 + \text{Higher} * 60000}{\text{Total population}}$$

$$\text{Income/ person} = \text{Income/ household} / 5.5$$

APPENDIX- C
WARD WISE LAND PRICE OF DIFFERENT ZONES

Zone	Ward No	Land Price (In Lakh taka Per Katha)	Zone	Ward No	Land Price (In Lakh taka Per Katha)
1	30	10.5	5	52	17.5
	75	14		53	27.5
	76	12		54	22.5
2	66	27.5		55	17.5
	67	27.5		56	22.5
	68	27.5		57	17.5
	69	17.5	6	39	20
	70	22.5		40	13
	71	25		42	10
	72	16		43	5.5
	73	15		44	10
	74	14		45	20
3	48	6.5		46	11.5
	58	11		47	11.5
	59	11.5	7	9	4
	60	11.5		10	7
	61	17.5		11	7.5
	62	21.5		12	11
	63	27.5		13	6
	64	27.5		14	11
	65	11.5		16	7.5
4	22	11		41	11.5
	23	12.5	8	2	9
	24	13.5		3	6.5
	25	7		4	6
	26	6.5		5	6
	27	8		6	6
	28	9		7	8
	29	8.5		8	5
	31	32.5		15	5.5
	32	31	9	17	12.25
	33	20		18	35
	34	21.5		19	19
	35	17		20	21
	36	22.5		21	9
5	49	37.5		37	15
	50	17.5		38	17.5
	51	17.5	10	1	9

APPENDIX- D
WARD WISE EMPLOYMENT OF DIFFERENT ZONES

Zone	Ward No	Employment (With Household)	Household Work	Employment (Without Household)
1	30	17153	3598	13555
	75	37043	13211	23832
	76	19763	5950	13813
2	66	37114	11307	25807
	67	21240	6081	15159
	68	38900	7924	30976
	69	42037	14726	27311
	70	31563	11026	20537
	71	32898	7365	25533
	72	28349	9309	19040
	73	25751	7442	18309
	74	38544	14014	24530
3	48	24627	8273	16354
	58	28551	10776	17775
	59	14259	5312	8947
	60	39500	12546	26954
	61	21943	5474	16469
	62	34216	9282	24934
	63	16859	3450	13409
	64	18920	5397	13523
	65	22105	6681	15424
4	22	24767	9195	15572
	23	26135	8971	17164
	24	19014	7189	11825
	25	18472	6142	12330
	26	12761	3644	9117
	27	11994	3631	8363
	28	25666	8044	17622
	29	17771	2921	14850
	31	18589	4529	14060
	32	35665	11974	23691
	33	21455	5830	15625
	34	19102	4379	14723
	35	16089	4431	11658
	36	17232	2984	14248
	49	22467	7564	14903
5	50	26047	8850	17197

	51	49145	14030	35115
	52	23318	5896	17422
	53	32860	11799	21061
	54	20586	6450	14136
	55	29441	12227	17214
	56	37500	14916	22584
	57	27704	9681	18023
	39	20926	6475	14451
	40	21338	7314	14024
6	42	12751	4286	8465
	43	16637	6392	10245
	44	27457	8553	18904
	45	11780	4383	7397
	46	18223	6996	11227
	47	35394	14324	21070
	9	40997	14372	26625
	10	50773	19802	30971
7	11	27443	9055	18388
	12	41549	14213	27336
	13	31286	13001	18285
	14	25461	9103	16358
	16	24637	7986	16651
	41	17136	6567	10569
	2	49346	18213	31133
	3	68210	27155	41055
8	4	31710	10780	20930
	5	26758	9920	16838
	6	30923	10736	20187
	7	41578	13004	28574
	8	40815	14802	26013
	15	20639	3992	16647
	17	48091	17045	31046
	18	13106	5049	8057
9	19	32526	11518	21008
	20	28221	6974	21247
	21	32446	12347	20099
	37	25894	8177	17717
	38	14377	5183	9194
10	1	56793	22094	34699

Calculation Process

Employment (without household) = Employment (with household) - Household Work

APPENDIX- E

CALCULATION OF TOTAL TRIPS/PERSON/DAY FOR PRODUCTION

Zone	Population			Trips/person/day			Total trips/person/day
	Lower	Medium	Higher	Lower	Medium	Higher	
Zone 1	95890	19880	1169	181319	33795	1595	**216709**
Zone 2	369322	97065	7102	698355	165011	9685	**873051**
Zone 3	307194	64077	5654	580876	108931	7710	**697517**
Zone 4	85834	343335	22588	162304	583669	30802	**776774**
Zone 5	101846	349186	33949	192582	593617	46294	**832492**
Zone 6	124985	147710	11362	236335	251106	15494	**502936**
Zone 7	250108	210371	7012	472931	357631	9562	**840124**
Zone 8	289120	226039	10513	546700	384267	14337	**945303**
Zone 9	45517	253594	26010	86068	431110	35468	**552647**
Zone 10	46392	135311	11598	87724	230029	15816	**333569**

Assumed:

Trip Rate	Lower Family	Medium family	Higher family
	10.4	9.35	7.5

Process of Calculation

$$\text{Trips/person/day for Lower Population} = \frac{\text{Lower population} * \text{Lower family trip rate}}{5.5}$$

Here, Average persons per household= 5.5

$$\text{Total trips/person/day} = (\text{Lower} + \text{Middle} + \text{Higher})\ \text{trips/person/day}$$

APPENDIX- F

CALCULATION OF TOTAL TRIPS/PERSON/DAY FOR ATTRACTION

Zone	No of Employment	Trip Rate (for Employment)	Total trips/person/day
Zone 1	51200	3.5	**179200**
Zone 2	207202	4.5	**932409**
Zone 3	153789	3.5	**538262**
Zone 4	200848	6	**1205088**
Zone 5	177655	5.5	**977103**
Zone 6	105783	5	**528915**
Zone 7	165183	3.5	**578141**
Zone 8	201377	3	**604131**
Zone 9	128368	5	**641840**
Zone 10	34699	5.5	**190845**

Process of Calculation

Here, Trip Rate for Employment is assumed.

Total trips/person/day for production = No. of Employment * Trip Rate for Employment

APPENDIX- G

SUMMARY OUTPUT OF REGRESSION EQUATION FOR TRIP PRODUCTION

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999529933
R Square	0.999060088
Adjusted R Square	0.998791542
Standard Error	8540.365428
Observations	10

ANOVA

	df	SS	MS	F	Significance F
Regression	2	5.42694E+11	2.71347E+11	3720.252421	2.54569E-11
Residual	7	510564891.5	72937841.64		
Total	9	5.43205E+11			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	**49018.11664**	10910.10333	4.492910394	0.002822212	23219.82173	74816.41155	23219.82173	74816.41155
Population	**1.796654515**	0.020829541	86.2551168	7.41328E-12	1.747400477	1.845908554	1.747400477	1.845908554
Average Zonal income	**-15.73030646**	2.177317697	-7.22462619	0.000173703	-20.87884469	-10.58176823	-20.87884469	-10.58176823

$$\mathbf{Y_{production} = 49018.116 + 1.7966X_1 - 15.73X_2}$$

SUMMARY OUTPUT OF REGRESSION EQUATION FOR TRIP ATTRACTION

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.914147622
R Square	0.835665876
Adjusted R Square	0.788713269
Standard Error	150146.9581
Observations	10

ANOVA

	df	SS	MS	F	Significance F
Regression	2	8.02483E+11	4.01242E+11	17.79807193	0.001799066
Residual	7	1.57809E+11	22544109023		
Total	9	9.60292E+11			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	**-204124.3952**	153934.5827	-1.326046374	0.226454737	-568121.8424	159873.0521	-568121.8424	159873.0521
Employment	**3.688785302**	0.877037019	4.205963059	0.004005774	1.614922298	5.762648305	1.614922298	5.762648305
Price(Lakh/Katha)	**22843.12069**	10018.0195	2.280203257	0.056619299	-845.7311646	46531.97255	-845.7311646	46531.97255

$$\mathbf{Y_{attraction}=-204124.3952+3.6887X_1+22843.12X_2}$$

APPENDIX- H
PROGRAM FOR READJUSTING INTER-ZONAL TRIP DISTRIBUTION

PROGRAM

```
#include<stdio.h>
#define n 10
void main() {
int i, j;
float a[n];
float b[n]={1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000};
float oc[n];
float dc[n];
float diff[n];
int dif[n];
int di[n];
float t[n][n]={189776.0555,	155375.4928, 57159.4495, 94240.0002, 34668.9586, 46798.1991,
25683.3962, 21027.7863, 34668.9586, 12753.9971,
155375.4928, 189776.0555, 127210.6943, 94240.0002, 57159.4495, 77157.1863, 34668.9586,	31369.7710,
	46798.1991,	17216.0953,
57159.4495,	127210.6943, 189776.0555, 57159.4495, 127210.6943, 127210.6943, 94240.0002,
	34668.9586,	42344.7617,	21027.7863,
94240.0002,	94240.0002,	57159.4495,	189776.0555, 127210.6943, 94240.0002, 57159.4495,
	46798.1991,	127210.6943, 57159.4495,
31369.7710,	57159.4495,	155375.4928, 127210.6943, 189776.0555, 155375.4928, 94240.0002,
	77157.1863,	94240.0002,	46798.1991,
46798.1991,	77157.1863,	127210.6943, 94240.0002, 155375.4928, 189776.0555, 171716.4761,
	127210.6943, 155375.4928, 57159.4495,
25683.3962,	34668.9586,	94240.0002,	57159.4495,	94240.0002,	171716.4761,
189776.0555, 155375.4928,	140589.5598, 77157.1863,
21027.7863,	31369.7710,	34668.9586,	46798.1991, 77157.1863,	127210.6943, 155375.4928,
189776.0555,	171716.4761, 94240.0002,
34668.9586,	46798.1991,	42344.7617,	127210.6943, 94240.0002, 155375.4928, 140589.5598,
171716.4761,	189776.0555, 69814.7092,
94240.0002,	17216.0953,	21027.7863,	57159.4495,	46798.1991,	57159.4495,
	77157.1863, 94240.0002,	69814.7092,	189776.0555
};
float o[n]={296505.25, 1283071.57, 1019880.17, 1109602.95, 1201412.68, 688445.92, 1222715.53,
1386604.88, 740705.07, 395175.82};
float d[n]={434217.04,1423333.76,1076025.19,1216932.14,
	1403724.70,759231.74,769671.16,821143.18,1082208.75,357632.20};
again:
for (i=0; i<n; i++) {
	oc[i]=0;
			for (j=0; j<n; j++) {
			oc[i]=oc[i]+t[i][j]*b[j];}
		a[i]=o[i]/oc[i];
		printf("%.2f\t",oc[i]);
	  printf("%.4f\t",a[i]);
		printf("\n");
}
for (j=0; j<n; j++) {
	for (i=0; i<n; i++) {
			t[i][j]=t[i][j]*a[i];}
```

```
}
printf("\n");

for (i=0; i<n; i++) {
for (j=0; j<n; j++) {
                        printf("%.2f\t",t[i][j]);
                        printf("\t");}
            printf("\n");
}
printf("\n");

for (j=0; j<n; j++) {
        dc[j]=0;
            for (i=0; i<n; i++) {
                        dc[j]=dc[j]+t[i][j];}

            b[j]=d[j]/dc[j];

            printf("%.2f\t",dc[j]);
          printf("%.4f\t",b[j]);
            printf("\n");
}

for (i=0; i<n; i++) {
   for (j=0; j<n; j++) {
            t[i][j]=t[i][j]*b[j];}
}

printf("\n");
for (i=0; i<n; i++) {
        oc[i]=0;
            for (j=0; j<n; j++) {
                        oc[i]=oc[i]+t[i][j];}

diff[i]=o[i]-oc[i];
dif[i]=diff[i
];
di[i]=abs(dif[i]);
        printf("%.2f\t",oc[i]);
        printf("%.4f\t",diff[i]);
        printf("%d",dif[i]);
        printf("%d",di[i]);

printf("\n");
}
if (di[0]>1 || di[1]>1 || di[2]>1 || di[3]>1 || di[4]>1 || di[5]>1|| di[6]>1|| di[7]>1|| di[8]>1|| di[9]>1) goto again;
printf("\n");

for (i=0; i<n; i++) {
            for (j=0; j<n; j++) {
                        printf("%.2f\t",t[i][j]);
                        printf("\t");}
            printf("\n");}
}
```

OUTPUT OF THE PROGRAM

```
49252.13        109186.22       26394.76        50266.57
        19145.82        11568.05        7322.35
6909.05     13570.04        2898.33
137697.61       455393.94       200592.05       171648.3
1       107790.77       65128.02        33751.99
    35196.27        62550.39        13359.72

39435.53        237643.03       232963.03       81049.05
        186755.27       83593.16        71424.88
    30281.80        44061.17        12703.16

66795.81        180863.59       72085.54        276449.5
6       191861.34       63620.49        44505.81
    41993.75        135986.14       35474.87

22701.92        112005.97       200069.09       189206.2
0       292241.91       107098.02       74920.63
    70691.81        102859.28       29655.09

17691.10        78977.68        85564.91        73218.63
        124985.08       68330.56        71310.38
    60882.29        88586.06        18920.50

21604.89        78966.41        141052.61       98820.74
        168688.14       137581.27       175370.19
    165471.59       178365.03       56832.23

22401.28        90488.32        65715.27        102463.4
1       174906.28       129077.52       181834.66
    255954.14       275897.78       87909.01

16399.83        59941.77        35640.54        123675.2
1       94860.06        70004.95        73057.75
    102837.62       135393.20       28917.73

40248.87        19909.25        15979.32        50172.64
        42530.18        23251.68        36200.09
                    50955.98        44969.95        70970.62
```

APPENDIX- I

NECESSARY TABLES FOR MODAL CHOICE AND NETWORK ASSIGNMENT

Travel Time matrix for different types of modes of traffic from one zone to another zone

O-D	Zone 1			Zone 2			Zone 3			Zone 4			Zone 5			Zone 6			Zone 7			Zone 8			Zone 9			Zone 10		
	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw
Zone 1	8	12	16	10	15	20	20	30	40	15	22.5	30	25	37.5	50	22	33	44	28	42	56	30	45	60	25	37.5	50	35	52.5	70
Zone 2	10	15	20	8	12	16	12	18	24	15	22.5	30	20	30	40	17	25.5	34	25	37.5	50	26	39	52	22	33	44	32	48	64
Zone 3	20	30	40	12	18	24	8	12	16	20	30	40	12	18	24	12	18	24	15	22.5	30	25	37.5	50	23	34.5	46	30	45	60
Zone 4	15	22.5	30	15	22.5	30	20	30	40	8	12	16	12	18	24	15	22.5	30	20	30	40	22	33	44	12	18	24	20	30	40
Zone 5	26	39	52	20	30	40	12	18	24	12	18	24	8	12	16	10	15	20	15	22.5	30	17	25.5	34	15	22.5	30	22	33	44
Zone 6	22	33	44	17	25.5	34	12	18	24	15	22.5	30	10	15	20	8	12	16	9	13.5	18	12	18	24	10	15	20	20	30	40
Zone 7	28	42	56	25	37.5	50	15	22.5	30	20	30	40	15	22.5	30	9	13.5	18	8	12	16	10	15	20	11	16.5	22	17	25.5	34
Zone 8	30	45	60	26	39	52	25	37.5	50	22	33	44	17	25.5	34	12	18	24	10	15	20	8	12	16	9	13.5	18	15	22.5	30
Zone 9	25	37.5	50	22	33	44	23	34.5	46	12	18	24	15	22.5	30	10	15	20	11	16.5	22	9	13.5	18	8	12	16	18	27	36
Zone 10	15	22.5	30	32	48	64	30	45	60	20	30	40	22	33	44	20	30	40	17	25.5	34	15	22.5	30	18	27	36	8	12	16

Travel Cost matrix for different types of modes of traffic from one zone to another zone

O-D	Zone 1			Zone 2			Zone 3			Zone 4			Zone 5			Zone 6			Zone 7			Zone 8			Zone 9			Zone 10		
	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw
Zone 1	24	8	12	30	10	15	60	20	30	45	15	22.5	75	25	37.5	66	22	33	84	28	42	90	30	45	75	25	37.5	105	35	52.5
Zone 2	30	10	15	24	8	12	36	12	18	45	15	22.5	60	20	30	51	17	25.5	75	25	37.5	78	26	39	66	22	33	96	32	48
Zone 3	60	20	30	36	12	18	24	8	12	60	20	30	36	12	18	36	12	18	45	15	22.5	75	25	37.5	69	23	34.5	90	30	45
Zone 4	45	15	22.5	45	15	22.5	60	20	30	24	8	12	36	12	18	45	15	22.5	60	20	30	66	22	33	36	12	18	60	20	30
Zone 5	78	26	39	60	20	30	36	12	18	36	12	18	24	8	12	30	10	15	45	15	22.5	51	17	25.5	45	15	22.5	66	22	33
Zone 6	66	22	33	51	17	25.5	36	12	18	45	15	22.5	30	10	15	24	8	12	27	9	13.5	36	12	18	30	10	15	60	20	30
Zone 7	84	28	42	75	25	37.5	45	15	22.5	60	20	30	45	15	22.5	27	9	13.5	24	8	12	30	10	15	33	11	16.5	51	17	25.5
Zone 8	90	30	45	78	26	39	75	25	37.5	66	22	33	51	17	25.5	36	12	18	30	10	15	24	8	12	27	9	13.5	45	15	22.5
Zone 9	75	25	37.5	66	22	33	69	23	34.5	36	12	18	45	15	22.5	30	10	15	33	11	16.5	27	9	13.5	24	8	12	54	18	27
Zone 10	45	15	22.5	96	32	48	90	30	45	60	20	30	66	22	33	60	20	30	51	17	25.5	45	15	22.5	54	18	27	24	8	12

Generalized Travel Cost (GTC) matrix for different types of modes of traffic from one zone to another zone

O-D	Zone 1			Zone 2			Zone 3			Zone 4			Zone 5			Zone 6			Zone 7			Zone 8			Zone 9			Zone 10		
	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw	Car	Bus	Rickshaw
Zone 1	35	24	34	44	31	42	87	61	85	66	46	64	109	77	106	96	67	93	122	86	119	131	92	127	109	77	106	153	107	149
Zone 2	44	31	42	35	24	34	52	37	51	66	46	64	87	61	85	74	52	72	109	77	106	114	80	110	96	67	93	140	98	136
Zone 3	87	61	85	52	37	51	35	24	34	87	61	85	52	37	51	52	37	51	66	46	64	109	77	106	101	70	98	131	92	127
Zone 4	66	46	64	66	46	64	87	61	85	35	24	34	52	37	51	66	46	64	87	61	85	96	67	93	52	37	51	87	61	85
Zone 5	114	80	110	87	61	85	52	37	51	52	37	51	35	24	34	44	31	42	66	46	64	74	52	72	66	46	64	96	67	93
Zone 6	96	67	93	74	52	72	52	37	51	66	46	64	44	31	42	35	24	34	39	28	38	52	37	51	44	31	42	87	61	85
Zone 7	122	86	119	109	77	106	66	46	64	87	61	85	66	46	64	39	28	38	35	24	34	44	31	42	48	34	47	74	52	72
Zone 8	131	92	127	114	80	110	109	77	106	96	67	93	74	52	72	52	37	51	44	31	42	35	24	34	39	28	38	66	46	64
Zone 9	109	77	106	96	67	93	101	70	98	52	37	51	66	46	64	44	31	42	48	34	47	39	28	38	35	24	34	79	55	76
Zone 10	66	46	64	140	98	136	131	92	127	87	61	85	96	67	93	87	61	85	74	52	72	66	46	64	79	55	76	35	24	34

APPENDIX- J
DIJKSTRA'S METHOD FOR FINDING SHORTEST PATH

PROGRAM

```
#INCLUDE<STDIO.H>
//#INCLUDE<CONIO.H>
#DEFINE MAX 10
INT PARENT[MAX];
VOID SHOW(INT P)
{
	IF(PARENT[P]!=-1)
		SHOW(PARENT[P]);
	PRINTF("%D ", P+1);
}
VOID MAIN()
{
	//CLRSCR();
	INT I,J,K,V,ADJAN[MAX][MAX],DIST[MAX],N,S[MAX];
	INT START, END, EDGECOST;
	PRINTF("GIVE THE NUMBER OF NODES:");
	SCANF("%D", &N);
	//PRINTF("GIVE THE NUMBER OF EDGES:");
	//SCANF("%D", &N);

	FOR(I=0;I<N;I++)
	FOR (J=0;J<N;J++)
	{
		IF(I==J) ADJAN[I][J]=0;
		ELSE ADJAN[I][J]=32000;
	}

	FOR (I=0;I<N;I++)
	PARENT[I]=-1;
	PRINTF("GIVE THE START, END AND EDGE COST\N");
	SCANF("%D%D%D", &START, &END, &EDGECOST);
	WHILE(START!=0 && END!=0)
	{
		ADJAN[START-1][END-1]=EDGECOST;
		ADJAN[END-1][START-1]=EDGECOST;
		SCANF("%D%D%D", &START, &END, &EDGECOST);
	}
	FOR(I=0;I<N;I++)
	{
		FOR(J=0;J<N;J++)
		{
			PRINTF("%D ", ADJAN[I][J]);
		}
		PRINTF("\N");
	}

	PRINTF("GIVE THE STARTING NODE");
	SCANF("%D", &V);
	WHILE (V!=0)
	{
```

```
		V--;
		FOR(I=0;I<N;I++)
		{
			S[I]=0;
			DIST[I]=ADJAN[V][I];
			IF(DIST[I]<32000)
				PARENT[I]=V;
		}
		S[V]=1;
		DIST[V]=0;
		PARENT[V]=-1;

		INT NUM, U,W,MIN;
		FOR(NUM=2;NUM<=N-1;NUM++)
		{
			MIN=32000;
			FOR(I=0;I<N;I++)
			{
				IF(DIST[I]<MIN && S[I]==0)
				{
					MIN=DIST[I];
					U=I;
				}
			}

			S[U]=1;
			FOR (W=0;W<N;W++)
			{
				IF(S[W]==0 && ADJAN[U][W]<32000)
				{
					IF(DIST[W]>DIST[U]+ADJAN[U][W])
					{
						DIST[W]=DIST[U]+ADJAN[U][W];
						PARENT[W]=U;
					}
				}
			}

		}

		//OUTPUT
		//PRINTF("GIVE THE NODE WHOSE SHORTEST PATH IS REQUIRED:");
		INT TARGET;
		//SCANF("%D",&TARGET);
		FOR(TARGET=1;TARGET<=N;TARGET++)
		{
			PRINTF("SHORTEST PATH FROM %D TO NODE %D:  ",V+1,TARGET);
			SHOW(TARGET-1);
			PRINTF("\N");
		}
		//GETCH();
		PRINTF("GIVE THE NEXT STARTING NODE");
	SCANF("%D", &V);

		}
	}
```

APPENDIX- K
SHORTEST PATHS OF DIFFERENT LINKS

OUTPUT FOR CAR

Give the number of nodes: 10
Give the start, end and edge cost
1 2 44
1 5 109
1 4 66
2 3 52
2 5 87
3 6 52
3 5 52
4 5 52
4 6 66
4 9 52
4 10 87
5 6 44
6 7 39
6 8 52
6 9 44
7 8 44
8 9 39
8 10 66
9 10 79
0 0 0
0 44 32000 66 109 32000 32000 32000 32000 32000
44 0 52 32000 87 32000 32000 32000 32000 32000
32000 52 0 32000 52 52 32000 32000 32000 32000
66 32000 32000 0 52 66 32000 32000 52 87
109 87 52 52 0 44 32000 32000 32000 32000
32000 32000 52 66 44 0 39 52 44 32000
32000 32000 32000 32000 32000 39 0 44 32000 32000
32000 32000 32000 32000 32000 52 44 0 39 66
32000 32000 32000 52 32000 44 32000 39 0 79
32000 32000 32000 87 32000 32000 32000 66 79 0

Give the starting node1
Shortest path from 1 to node 1: 1
Shortest path from 1 to node 2: 1 2
Shortest path from 1 to node 3: 1 2 3
Shortest path from 1 to node 4: 1 4
Shortest path from 1 to node 5: 1 5
Shortest path from 1 to node 6: 1 4 6
Shortest path from 1 to node 7: 1 4 6 7
Shortest path from 1 to node 8: 1 4 9 8
Shortest path from 1 to node 9: 1 4 9
Shortest path from 1 to node 10: 1 4 10

Give the next starting node2
Shortest path from 2 to node 1: 2 1
Shortest path from 2 to node 2: 2
Shortest path from 2 to node 3: 2 3

Shortest path from 2 to node 4: 2 1 4
Shortest path from 2 to node 5: 2 5
Shortest path from 2 to node 6: 2 3 6
Shortest path from 2 to node 7: 2 3 6 7
Shortest path from 2 to node 8: 2 3 6 8
Shotest path from 2 to node 9: 2 3 6 9
Shortest path from 2 to node 10: 2 1 4 10

Give the next starting node3
Shortest path from 3 to node 1: 3 2 1
Shortest path from 3 to node 2: 3 2
Shortest path from 3 to node 3: 3
Shortest path from 3 to node 4: 3 5 4
Shortest path from 3 to node 5: 3 5
Shortest path from 3 to node 6: 3 6
Shortest path from 3 to node 7: 3 6 7
Shortest path from 3 to node 8: 3 6 8
Shortest path from 3 to node 9: 3 6 9
Shortest path from 3 to node 10: 3 6 8 10

Give the next starting node4
Shortest path from 4 to node 1: 4 1
Shortest path from 4 to node 2: 4 1 2
Shortest path from 4 to node 3: 4 5 3
Shortest path from 4 to node 4: 4
Shortest path from 4 to node 5: 4 5
Shortest path from 4 to node 6: 4 6
Shortest path from 4 to node 7: 4 6 7
Shortest path from 4 to node 8: 4 9 8
Shortest path from 4 to node 9: 4 9
Shortest path from 4 to node 10: 4 10

Give the next starting node5
Shortest path from 5 to node 1: 5 1
Shortest path from 5 to node 2: 5 2
Shortest path from 5 to node 3: 5 3
Shortest path from 5 to node 4: 5 4
Shortest path from 5 to node 5: 5
Shortest path from 5 to node 6: 5 6
Shortest path from 5 to node 7: 5 6 7
Shortest path from 5 to node 8: 5 6 8
Shortest path from 5 to node 9: 5 6 9
Shortest path from 5 to node 10: 5 4 10

Give the next starting node6
Shortest path from 6 to node 1: 6 4 1
Shortest path from 6 to node 2: 6 3 2
Shortest path from 6 to node 3: 6 3
Shortest path from 6 to node 4: 6 4
Shortest path from 6 to node 5: 6 5
Shortest path from 6 to node 6: 6
Shortest path from 6 to node 7: 6 7
Shortest path from 6 to node 8: 6 8
Shortest path from 6 to node 9: 6 9
Shortest path from 6 to node 10: 6 8 10

Give the next starting node7
Shortest path from 7 to node 1: 7 6 4 1
Shortest path from 7 to node 2: 7 6 3 2
Shortest path from 7 to node 3: 7 6 3
Shortest path from 7 to node 4: 7 6 4
Shortest path from 7 to node 5: 7 6 5
Shortest path from 7 to node 6: 7 6
Shortest path from 7 to node 7: 7
Shortest path from 7 to node 8: 7 8
Shortest path from 7 to node 9: 7 6 9
Shortest path from 7 to node 10: 7 8 10

Give the next starting node8
Shortest path from 8 to node 1: 8 9 4 1
Shortest path from 8 to node 2: 8 6 3 2
Shortest path from 8 to node 3: 8 6 3
Shortest path from 8 to node 4: 8 9 4
Shortest path from 8 to node 5: 8 6 5
Shortest path from 8 to node 6: 8 6
Shortest path from 8 to node 7: 8 7
Shortest path from 8 to node 8: 8
Shortest path from 8 to node 9: 8 9
Shortest path from 8 to node 10: 8 10

Give the next starting node9
Shortest path from 9 to node 1: 9 4 1
Shortest path from 9 to node 2: 9 6 3 2
Shortest path from 9 to node 3: 9 6 3
Shortest path from 9 to node 4: 9 4
Shortest path from 9 to node 5: 9 6 5
Shortest path from 9 to node 6: 9 6
Shortest path from 9 to node 7: 9 8 7
Shortest path from 9 to node 8: 9 8
Shortest path from 9 to node 9: 9
Shortest path from 9 to node 10: 9 10

Give the next starting node10
Shortest path from 10 to node 1: 10 4 1
Shortest path from 10 to node 2: 10 4 1 2
Shortest path from 10 to node 3: 10 8 6 3
Shortest path from 10 to node 4: 10 4
Shortest path from 10 to node 5: 10 4 5
Shortest path from 10 to node 6: 10 8 6
Shortest path from 10 to node 7: 10 8 7
Shortest path from 10 to node 8: 10 8
Shortest path from 10 to node 9: 10 9
Shortest path from 10 to node 10: 10

Give the next starting node

SHORTEST PATH FOR BUS

Shortest path from 1 to node 1: 1
Shortest path from 1 to node 2: 1 2
Shortest path from 1 to node 3: 1 2 3
Shortest path from 1 to node 4: 1 4
Shortest path from 1 to node 5: 1 5
Shortest path from 1 to node 6: 1 4 6
Shortest path from 1 to node 7: 1 4 6 7
Shortest path from 1 to node 8: 1 4 9 8
Shortest path from 1 to node 9: 1 4 9
Shortest path from 1 to node 10: 1 4 10
Shortest path from 2 to node 1: 2 1
Shortest path from 2 to node 2: 2
Shortest path from 2 to node 3: 2 3
Shortest path from 2 to node 4: 2 1 4
Shortest path from 2 to node 5: 2 5
Shortest path from 2 to node 6: 2 3 6
Shortest path from 2 to node 7: 2 3 6 7
Shortest path from 2 to node 8: 2 3 6 8
Shortest path from 2 to node 9: 2 3 6 9
Shortest path from 2 to node 10: 2 1 4 10
Shortest path from 3 to node 1: 3 2 1
Shortest path from 3 to node 2: 3 2
Shortest path from 3 to node 3: 3
Shortest path from 3 to node 4: 3 5 4
Shortest path from 3 to node 5: 3 5
Shortest path from 3 to node 6: 3 6
Shortest path from 3 to node 7: 3 6 7
Shortest path from 3 to node 8: 3 6 8
Shortest path from 3 to node 9: 3 6 9
Shortest path from 3 to node 10: 3 6 8 10
Shortest path from 4 to node 1: 4 1
Shortest path from 4 to node 2: 4 1 2
Shortest path from 4 to node 3: 4 5 3
Shortest path from 4 to node 4: 4
Shortest path from 4 to node 5: 4 5
Shortest path from 4 to node 6: 4 6
Shortest path from 4 to node 7: 4 6 7
Shortest path from 4 to node 8: 4 9 8
Shortest path from 4 to node 9: 4 9
Shortest path from 4 to node 10: 4 10
Shortest path from 5 to node 1: 5 1
Shortest path from 5 to node 2: 5 2
Shortest path from 5 to node 3: 5 3
Shortest path from 5 to node 4: 5 4
Shortest path from 5 to node 5: 5
Shortest path from 5 to node 6: 5 6
Shortest path from 5 to node 7: 5 6 7
Shortest path from 5 to node 8: 5 6 8
Shortest path from 5 to node 9: 5 6 9
Shortest path from 5 to node 10: 5 4 10

Shortest path from 6 to node 1: 6 4 1
Shortest path from 6 to node 2: 6 3 2
Shortest path from 6 to node 3: 6 3
Shortest path from 6 to node 4: 6 4
Shortest path from 6 to node 5: 6 5
Shortest path from 6 to node 6: 6
Shortest path from 6 to node 7: 6 7
Shortest path from 6 to node 8: 6 8
Shortest path from 6 to node 9: 6 9
Shortest path from 6 to node 10: 6 8 10
Shortest path from 7 to node 1: 7 6 4 1
Shortest path from 7 to node 2: 7 6 3 2
Shortest path from 7 to node 3: 7 6 3
Shortest path from 7 to node 4: 7 6 4
Shortest path from 7 to node 5: 7 6 5
Shortest path from 7 to node 6: 7 6
Shortest path from 7 to node 7: 7
Shortest path from 7 to node 8: 7 8
Shortest path from 7 to node 9: 7 6 9
Shortest path from 7 to node 10: 7 8 10
Shortest path from 8 to node 1: 8 9 4 1
Shortest path from 8 to node 2: 8 6 3 2
Shortest path from 8 to node 3: 8 6 3
Shortest path from 8 to node 4: 8 9 4
Shortest path from 8 to node 5: 8 6 5
Shortest path from 8 to node 6: 8 6
Shortest path from 8 to node 7: 8 7
Shortest path from 8 to node 8: 8
Shortest path from 8 to node 9: 8 9
Shortest path from 8 to node 10: 8 10
Shortest path from 9 to node 1: 9 4 1
Shortest path from 9 to node 2: 9 6 3 2
Shortest path from 9 to node 3: 9 6 3
Shortest path from 9 to node 4: 9 4
Shortest path from 9 to node 5: 9 6 5
Shortest path from 9 to node 6: 9 6
Shortest path from 9 to node 7: 9 8 7
Shortest path from 9 to node 8: 9 8
Shortest path from 9 to node 9: 9
Shortest path from 9 to node 10: 9 10
Shortest path from 10 to node 1: 10 4 1
Shortest path from 10 to node 2: 10 4 1 2
Shortest path from 10 to node 3: 10 8 6 3
Shortest path from 10 to node 4: 10 4
Shortest path from 10 to node 5: 10 4 5
Shortest path from 10 to node 6: 10 8 6
Shortest path from 10 to node 7: 10 8 7
Shortest path from 10 to node 8: 10 8
Shortest path from 10 to node 9: 10 9
Shortest path from 10 to node 10: 10

SHORTEST PATH FOR RICKSHAW

Shortest path from 1 to node 1: 1
Shortest path from 1 to node 2: 1 2
Shortest path from 1 to node 3: 1 2 3
Shortest path from 1 to node 4: 1 4
Shortest path from 1 to node 5: 1 5
Shortest path from 1 to node 6: 1 4 6
Shortest path from 1 to node 7: 1 4 6 7
Shortest path from 1 to node 8: 1 4 9 8
Shortest path from 1 to node 9: 1 4 9
Shortest path from 1 to node 10: 1 4 10
Shortest path from 2 to node 1: 2 1
Shortest path from 2 to node 2: 2
Shortest path from 2 to node 3: 2 3
Shortest path from 2 to node 4: 2 1 4
Shortest path from 2 to node 5: 2 5
Shortest path from 2 to node 6: 2 3 6
Shortest path from 2 to node 7: 2 3 6 7
Shortest path from 2 to node 8: 2 3 6 8
Shortest path from 2 to node 9: 2 3 6 9
Shortest path from 2 to node 10: 2 1 4 10
Shortest path from 3 to node 1: 3 2 1
Shortest path from 3 to node 2: 3 2
Shortest path from 3 to node 3: 3
Shortest path from 3 to node 4: 3 5 4
Shortest path from 3 to node 5: 3 5
Shortest path from 3 to node 6: 3 6
Shortest path from 3 to node 7: 3 6 7
Shortest path from 3 to node 8: 3 6 8
Shortest path from 3 to node 9: 3 6 9
Shortest path from 3 to node 10: 3 6 8 10
Shortest path from 4 to node 1: 4 1
Shortest path from 4 to node 2: 4 1 2
Shortest path from 4 to node 3: 4 5 3
Shortest path from 4 to node 4: 4
Shortest path from 4 to node 5: 4 5
Shortest path from 4 to node 6: 4 6
Shortest path from 4 to node 7: 4 6 7
Shortest path from 4 to node 8: 4 9 8
Shortest path from 4 to node 9: 4 9
Shortest path from 4 to node 10: 4 10
Shortest path from 5 to node 1: 5 1
Shortest path from 5 to node 2: 5 2
Shortest path from 5 to node 3: 5 3
Shortest path from 5 to node 4: 5 4
Shortest path from 5 to node 5: 5
Shortest path from 5 to node 6: 5 6
Shortest path from 5 to node 7: 5 6 7
Shortest path from 5 to node 8: 5 6 8
Shortest path from 5 to node 9: 5 6 9
Shortest path from 5 to node 10: 5 4 10

Shortest path from 6 to node 1: 6 4 1
Shortest path from 6 to node 2: 6 3 2
Shortest path from 6 to node 3: 6 3
Shortest path from 6 to node 4: 6 4
Shortest path from 6 to node 5: 6 5
Shortest path from 6 to node 6: 6
Shortest path from 6 to node 7: 6 7
Shortest path from 6 to node 8: 6 8
Shortest path from 6 to node 9: 6 9
Shortest path from 6 to node 10: 6 8 10
Shortest path from 7 to node 1: 7 6 4 1
Shortest path from 7 to node 2: 7 6 3 2
Shortest path from 7 to node 3: 7 6 3
Shortest path from 7 to node 4: 7 6 4
Shortest path from 7 to node 5: 7 6 5
Shortest path from 7 to node 6: 7 6
Shortest path from 7 to node 7: 7
Shortest path from 7 to node 8: 7 8
Shortest path from 7 to node 9: 7 6 9
Shortest path from 7 to node 10: 7 8 10
Shortest path from 8 to node 1: 8 9 4 1
Shortest path from 8 to node 2: 8 6 3 2
Shortest path from 8 to node 3: 8 6 3
Shortest path from 8 to node 4: 8 9 4
Shortest path from 8 to node 5: 8 6 5
Shortest path from 8 to node 6: 8 6
Shortest path from 8 to node 7: 8 7
Shortest path from 8 to node 8: 8
Shortest path from 8 to node 9: 8 9
Shortest path from 8 to node 10: 8 10
Shortest path from 9 to node 1: 9 4 1
Shortest path from 9 to node 2: 9 6 3 2
Shortest path from 9 to node 3: 9 6 3
Shortest path from 9 to node 4: 9 4
Shortest path from 9 to node 5: 9 6 5
Shortest path from 9 to node 6: 9 6
Shortest path from 9 to node 7: 9 8 7
Shortest path from 9 to node 8: 9 8
Shortest path from 9 to node 9: 9
Shortest path from 9 to node 10: 9 10
Shortest path from 10 to node 1: 10 4 1
Shortest path from 10 to node 2: 10 4 1 2
Shortest path from 10 to node 3: 10 8 6 3
Shortest path from 10 to node 4: 10 4
Shortest path from 10 to node 5: 10 4 5
Shortest path from 10 to node 6: 10 8 6
Shortest path from 10 to node 7: 10 8 7
Shortest path from 10 to node 8: 10 8
Shortest path from 10 to node 9: 10 9
Shortest path from 10 to node 10: 10

APPENDIX- L

TOTAL TRIPS IN EACH LINK FOR DIFFERENT MODES AT PEAK HOUR

(For Car at Peak Hours)

Link	**Flows (15% of the total flow)**																		**Total**
1-2	1782	306	2248	2383	94	458	2511	141											**8140**
1-4	698	124	62	53	129	18	2383	94	927	2511	190	182	173	156	559	141			**8400**
1-5	183	208																	**390**
2-3	306	3075	843	322	322	672	458	3643	1022	753	828	644							**12891**
2-5	1251	1299																	**2550**
3-5	940	2863	836	2788															**7428**
3-6	843	322	322	672	1282	991	289	455	98	1022	1312	753	1958	828	627	644	368	123	**12912**
4-5	940	836	2942	2901	319	457													**8395**
4-6	124	62	883	516	190	1016	182	1146											**4120**
4-9	53	129	451	2085	173	1101	156	1896											**6046**
4-10	18	94	412	319	559	141	582	457											**2581**
5-6	1748	1040	915	1428	2040	2342	2264	1317											**13094**
6-7	62	322	991	516	1040	1200	182	753	1958	1146	2342	2315	2823						**15650**
6-8	322	289	98	915	933	220	828	627	2264	1979	123	270							**8869**
6-9	672	455	1428	1446	2823	644	368	1317	1143										**10296**
7-8	2701	736	2968	1156	469														**8030**
8-9	53	451	173	1101	4642	1156	1730												**9308**
8-10	98	220	736	1220	123	270	469	707											**3843**
9-10	361	562																	**923**

(For Bus at Peak Hours)

Link	Flows (15% of the total flow)																		Total
1-2	8141	2482	10266	14496	1524	3708	15274	2270											**58160**
1-4	4245	1130	790	767	1397	343	14496	1524	5641	15274	1728	2332	2488	1689	3399	2270			**59513**
1-5	1971	2376																	**4347**
2-3	2482	15753	5753	3475	3683	6110	3708	18663	6976	8130	9470	5855							**90059**
2-5	10134	10530																	**20664**
3-5	7620	14666	6777	15585															**44648**
3-6	5753	3475	3683	6110	6565	6032	3118	4383	1411	6976	6720	8130	11912	9470	6766	5855	3545	1775	**101680**
4-5	7620	6777	15067	14859	2897	4154													**51375**
4-6	1130	790	5373	4184	1728	6183	2332	9291											**31011**
4-9	767	1397	4102	10679	2488	10009	1689	9712											**40844**
4-10	343	1524	3335	2897	3399	2270	4717	4154											**22639**
5-6	7985	6327	6244	8687	9318	14246	15450	8011											**76268**
6-7	790	3475	6032	4184	6327	5175	2332	8130	11912	9291	14246	9984	13653						**95531**
6-8	3683	3118	1411	6244	4781	1779	9470	6766	15450	10137	1775	2186							**66801**
6-9	6110	4383	8687	6605	13653	5855	3545	8011	5219										**62068**
7-8	12337	5020	13557	5592	3198														**39704**
8-9	767	4102	2488	10009	20021	5592	7463												**50442**
8-10	1411	1779	5020	7424	1775	2186	3198	4303											**27096**
9-10	2610	4059																	**6668**

(For Rickshaw at Peak Hours)

Link	Flows (15% of the total flow)																		Total
1-2	6455	1171	8140	8868	386	1750	9344	575											**36689**
1-4	2597	481	246	216	509	74	8868	386	3451	9344	735	727	699	615	2079	575			**31602**
1-5	718	822																	**1539**
2-3	1171	11260	3173	1266	1274	2600	1750	13339	3847	2961	3274	2491							**48406**
2-5	4783	4970																	**9754**
3-5	3597	10483	3199	11637															**28915**
3-6	3173	1266	1274	2600	4692	3690	1135	1771	396	3847	4803	2961	7287	3274	2464	2491	1432	499	**49056**
4-5	3597	3199	10770	10621	1233	1768													**31186**
4-6	481	246	3287	1975	735	3783	727	4385											**15619**
4-9	216	509	1745	7633	699	4259	615	6942											**22618**
4-10	74	386	1574	1233	2079	575	2226	1768											**9916**
5-6	6331	3871	3444	5314	7389	8715	8521	4901											**48485**
6-7	246	1266	3690	1975	3871	4321	727	2961	7287	4385	8715	8338	10278						**58061**
6-8	1274	1135	396	3444	3417	840	3274	2464	8521	7245	499	1032							**33541**
6-9	2600	1771	5314	5237	10278	2491	1432	4901	4138										**38163**
7-8	9782	2769	10749	4210	1763														**29273**
8-9	216	1745	699	4259	16720	4210	6232												**34081**
8-10	396	840	2769	4542	499	1032	1763	2633											**14473**
9-10	1367	2125																	**3492**