The Traditional Four Steps Transportation Modeling Using Simplified Transport Network: A Case Study of Dhaka City, Bangladesh

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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, modal split and traffic assignments. This paper describes the process of the traditional four steps transportation modeling system using a simplified transport network in the context of Dhaka City, Bangladesh.

Keywords: Travel forecast, travel demand modeling, four steps transportation modeling, trip generation, trip distribution, modal split and traffic assignments.

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1. INTRODUCTION

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 [1].

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 [2]:

   a) Travel demand forecasting models for implementing the four-step urban planning process
   b) 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 [1].

The objectives of this paper are to learn about the Urban Transport Modeling System, to gain a better understanding of the behavior of the traffic condition of Dhaka metropolitan area on the zonal basis and to prepare the Network Assignment through the Transport Modeling System.

2. STUDY AREA PROFILE

The 79 wards (the smallest electoral unit) of Dhaka City Corporation area have been selected as the study area for this paper (Figure 1). Then these 76 wards are divided into 10 zones known as TAZ (Traffic Analysis Zone).
Figure 1: Dhaka City Corporation (study area)

Source: Dhaka City Corporation, 2010
3. METHODOLOGY OF THE RESEARCH

The traditional four step transportation modeling system has been taken to achieve the objectives. This is a macro-level working procedure [3]. The following four steps to be performed in the next stage:

3.1. TRIP GENERATION

Trip generation is the first step in the conventional four-step transportation planning process, widely used for forecasting travel demands. It predicts the number of trips originating in or destined for a particular traffic analysis zone [4].

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 [1]. 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 (2011) is determined (base year 2001). To do this at first existing trip production and attraction parameters are calculated using growth rates after 10 years (Table 1). These growth rates have been assumed on country aspect [5 and 6]. Now using Table 1, tables 2 and 3 have been generated. For details calculation please go through Appendix A-D (Supplementary File).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>4.50%</td>
</tr>
<tr>
<td>Income Level</td>
<td>10%</td>
</tr>
<tr>
<td>Land Price</td>
<td>25%</td>
</tr>
<tr>
<td>Employment</td>
<td>2.50%</td>
</tr>
</tbody>
</table>

Table 1: Growth rates of different variables after 10 years
Table 2: Population and average zonal income after 10 years for production

<table>
<thead>
<tr>
<th>Zone</th>
<th>Existing</th>
<th>After 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Population ($X_1$)</td>
<td>Average Zonal Income ($X_2$)</td>
</tr>
<tr>
<td>Zone 1</td>
<td>116939</td>
<td>1931</td>
</tr>
<tr>
<td>Zone 2</td>
<td>473490</td>
<td>2133</td>
</tr>
<tr>
<td>Zone 3</td>
<td>376925</td>
<td>1980</td>
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<tr>
<td>Zone 4</td>
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<td>Zone 6</td>
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<td>3753</td>
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<td>525673</td>
<td>3164</td>
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<td>5280</td>
</tr>
<tr>
<td>Zone 10</td>
<td>193302</td>
<td>4735</td>
</tr>
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</table>

Table 3: Employment and land price after 10 years for attraction

<table>
<thead>
<tr>
<th>Zone</th>
<th>Existing</th>
<th>After 10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Employment ($X_1$)</td>
<td>Land Price (*Lakh taka/Katha) ($X_2$)</td>
</tr>
<tr>
<td>Zone 1</td>
<td>51200</td>
<td>9.5</td>
</tr>
<tr>
<td>Zone 2</td>
<td>207202</td>
<td>20.0</td>
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<td>Zone 3</td>
<td>153789</td>
<td>16.2</td>
</tr>
<tr>
<td>Zone 4</td>
<td>200848</td>
<td>15.8</td>
</tr>
<tr>
<td>Zone 5</td>
<td>177655</td>
<td>21.9</td>
</tr>
<tr>
<td>Zone 6</td>
<td>105783</td>
<td>12.7</td>
</tr>
<tr>
<td>Zone 7</td>
<td>165183</td>
<td>8.2</td>
</tr>
<tr>
<td>Zone 8</td>
<td>201377</td>
<td>6.5</td>
</tr>
<tr>
<td>Zone 9</td>
<td>128368</td>
<td>18.4</td>
</tr>
<tr>
<td>Zone 10</td>
<td>34699</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*1 Lakh = 100000 Bangladesh Taka (BDT) and 1 Katha = 720 ft² of land

Calculation Process: Population after 10 years = Existing population ($1 + 0.045)^{10}$

Here, Growth Rate = 4.5% = 0.045; Projected Year = 10

Thus using similar formulas forecasted values for the other trip production and attraction parameters are calculated. From the calculated parameters for trip production and trip attraction after 10 years, two regression equations are found. 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. Finally the following two regression equations are found:
Regression Equation for Trip Production:

\[ Y_{production} = 49018.116 + 1.7966X_1 - 15.73X_2 \]

Where, \( a_0 = 49018.116 \)

\( a_1 = 1.7966 \) and \( a_2 = -15.73 \)

Regression Equation for Trip Attraction:

\[ Y_{attraction} = -204124.3952 + 3.6887X_1 + 22843.12X_2 \]

Where, \( b_0 = 204124.3952 \)

\( b_1 = 3.6887 \) and \( b_2 = 22843.12 \)

Using these regression equations now forecasted trips, for both trip production and attraction after 10 years, are calculated (Table 4).

<table>
<thead>
<tr>
<th>Zone</th>
<th>Production</th>
<th>Attraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trips/person/day</td>
<td>Trips/person/day</td>
</tr>
<tr>
<td>Zone 1</td>
<td>296505</td>
<td>598526</td>
</tr>
<tr>
<td>Zone 2</td>
<td>1283072</td>
<td>1961928</td>
</tr>
<tr>
<td>Zone 3</td>
<td>1019880</td>
<td>1483197</td>
</tr>
<tr>
<td>Zone 4</td>
<td>1109603</td>
<td>1677424</td>
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<tr>
<td>Zone 5</td>
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<td>1934899</td>
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<tr>
<td>Zone 6</td>
<td>688446</td>
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<td>Zone 7</td>
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<td>Zone 8</td>
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<td>1131867</td>
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<tr>
<td>Zone 9</td>
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<td>1491721</td>
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<tr>
<td>Zone 10</td>
<td>395176</td>
<td>492962</td>
</tr>
</tbody>
</table>

Calculation Process [4]:

Trip Production = \( a_0 + (a_1 \times \text{Forecasted Population}) + (a_2 \times \text{Forecasted Income}) \)

Trip Attraction = \( b_0 + (b_1 \times \text{Forecasted Employment}) + (b_2 \times \text{Forecasted Land Price}) \)

Here ends trip generation step after forecasting future productions/origin and attractions/destination. For details calculation please go through Appendix E-G (Supplementary File).
3.2. TRIP DISTRIBUTION

Trip distribution is the second component 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]. Trip distribution step is going to be started by introducing an origin-destination matrix for all the 10 zones (Table 5).

Table 5: Origin-Destination (OD) matrix

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
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<th>Zone 6</th>
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<tbody>
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</tbody>
</table>

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:

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

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

This process generates Table 6.
### Table 6: Adjusted origin-destination matrix

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
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<tr>
<td>Adjusted ΣD</td>
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<td>821143</td>
<td>1082209</td>
<td>357632</td>
<td>9344420</td>
</tr>
</tbody>
</table>

### 3.2.1. 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 [3].

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 [1].

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 [2].

Now a cost matrix is assumed (in terms of time), this table 7 is assumed by predicting the zone to zone travel cost.
Table 7: Cost matrix table \((C_{ij})\) in terms of time

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
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<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>Zone 2</td>
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<td>8</td>
<td>12</td>
<td>15</td>
<td>20</td>
<td>17</td>
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<td>15</td>
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</tr>
</tbody>
</table>

Using the following formula impedance factor is calculated (Table 8):

\[ \text{Impedance factor} = e^{-\beta C_{ij}} \]

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

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

Table 8: Impedance factor values

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>0.4493</td>
<td>0.3679</td>
<td>0.1353</td>
<td>0.2231</td>
<td>0.0821</td>
<td>0.1108</td>
<td>0.0608</td>
<td>0.0498</td>
<td>0.08208</td>
<td>0.030197</td>
</tr>
<tr>
<td>Zone 2</td>
<td>0.3679</td>
<td>0.4493</td>
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<td>0.449329</td>
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</tbody>
</table>

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 \(\frac{\text{Total Trip}}{\text{Total Impedance Factor}}=422354\)

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

Trip of any zone = \(\frac{\text{Total Trip}}{\text{Total Impedance Factor}}\) * Impedance factor for this particular zone

Finally trip distribution from one to different zones is found (Table 9).
Table 9: Trip distribution after 10 years for different zones

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
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<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
<th>ΣO</th>
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<tbody>
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<td>1072535</td>
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</tbody>
</table>

Now from Table 6 and Table 9, it is found that there are huge differences in the trip productions and 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 of Supplementary File). After using this program the adjusted trips from different zones are found. This is the final origin-destination matrix for trip distribution among different zones after 10 years (Table 10).

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

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
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</table>

3.3. MODAL SPLIT

Mode choice analysis is the third step in the conventional four-step transportation planning model. 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].
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. 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 [3].

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 [4].

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 [4].

Once disutility 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 disutility. 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 [2].

In this step the matrix for travel time and travel cost is given to calculate the utilities for three modes- Car, Bus and Rickshaw (Appendix- I of Supplementary File).
Moreover utility functions for these three modes are also assumed. The utility functions are as follows [7]:

\[
U_{Car} = -0.060054 \times TT - 0.043648 \times TC
\]

\[
U_{Bus} = 0.945505 - 0.060054 \times TT - 0.043648 \times TC
\]

\[
U_{Rickshaw} = 1.23213 - 0.060054 \times TT - 0.043648 \times TC
\]

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 in Table 11-13.

![Table 11: Utility matrix for car](image)

<table>
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<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
</tr>
</thead>
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<td>-5.7299</td>
<td>-4.7750</td>
<td>-6.6849</td>
</tr>
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</table>

![Table 12: Utility matrix for bus](image)

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<th>Zone 3</th>
<th>Zone 4</th>
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<th>Zone 8</th>
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</table>
Table 13: Utility matrix for rickshaw

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<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
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Now using the tables 11-13, the probability of different modes (Table 14-16) are calculated by using the formulas below [7]:

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

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

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

Table 14: Probability matrix for car

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
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Table 15: Probability matrix for bus

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<th>Zone 5</th>
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<th>Zone 8</th>
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Table 16: Probability matrix for rickshaw

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</table>

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 equation:

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

Finally the tables 17-19 for modal share for the three vehicles are found. This is the final output of modal choice step (tables 17-19). Here we get how many trips are made between one to another zone by different modes of vehicles.

Table 17: Modal share matrix for car

<table>
<thead>
<tr>
<th>O-D</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
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Table 18: Modal share matrix for bus

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<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
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<th>Zone 10</th>
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Table 19: Modal share matrix for rickshaw

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3.4. TRIP ASSIGNMENT

Trip assignment, traffic assignment or route choice concerns the selection of routes (alternative paths) between origins and destinations in transportation networks. It is the fourth step in the conventional transportation planning model. 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 [1].

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 [4]. 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 [2]. 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 [3].
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 [1]:

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

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.

\[
\frac{a_1}{a_2} = \frac{0.060054}{0.043684} = 1.37
\]

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 2).

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

\[
GTT = \left( \frac{a_2}{a_1} \right) \times TC + TT
\]

Now using the Dijkstra’s Method (Appendix-J) the shortest distance in terms of GTC from 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.
**Figure 2:** Generalized Travel Cost (GTC) for car, bus and rickshaw
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. For this 15% flow in peak hours total trips per link according to their shortest path is calculated for all the modes (Appendix-L).

Table 20 shows the flow of traffic from one node to another for different modes of traffic at peak hours:

Table 20: Total trips in each link for different modes at peak hour

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Occupancy of a vehicle refers to how many people occupy that vehicle in an average [1]. 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 [8]. Using these values of occupancy the no. of Car, Bus and Rickshaw that flow in the peak period in different links is calculated (Table 21).

Calculation Process:

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

Total No of vehicles = Flow of that vehicle / Occupancy of that vehicle or mode
Traffic assignment results (Figure 3) 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.

Thus the whole transportation modeling process is performed step by step, which is discussed elaborately in this paper while taking necessary data for the 10 zones of Dhaka City Corporation for study purpose.
Figure 3: Total number of vehicles in each link
4. 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 use 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.
REFERENCES


ACKNOWLEDGEMENT

It is a great pleasure to acknowledge my gratitude to Mr. Mamun Muntasir Rahman, Md. Aftabuzzaman, and Mr. Suman Kumar Mitra from the Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET), Bangladesh for their careful supervision and thoughtful suggestions.
# APPENDIX- A

**WARD WISE POPULATION OF DIFFERENT ZONES**

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**APPENDIX-B**

**AVERAGE ZONAL INCOME (TAKA/PERSOM/MONTH)**

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

**Calculation Process**

\[
\text{Income/ household} = \frac{\text{Lower} \times 6000 + \text{Middle} \times 30000 + \text{Higher} \times 60000}{\text{Total population}}
\]

\[
\text{Income/ person} = \frac{\text{Income/ household}}{5.5}
\]
# APPENDIX - C

## WARD WISE LAND PRICE OF DIFFERENT ZONES

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## APPENDIX- D

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**Calculation Process**

Employment (without household) = Employment (with household) - Household Work
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Assumed: Trip Rate

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<th>Trip Rate</th>
<th>Lower Family</th>
<th>Medium family</th>
<th>Higher family</th>
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<td></td>
<td>10.4</td>
<td>9.35</td>
<td>7.5</td>
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</table>

**Process of Calculation**

\[
\text{Trips/person/day for Lower Population} = \frac{\text{Lower population} \times \text{Lower family trip rate}}{5.5}
\]

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

<table>
<thead>
<tr>
<th>Zone</th>
<th>No of Employment</th>
<th>Trip Rate (for Employment)</th>
<th>Total trips/person/day</th>
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<td>977103</td>
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<td>Zone 10</td>
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<td>190845</td>
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</table>

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

<table>
<thead>
<tr>
<th>Regression Statistics</th>
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<tbody>
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<tr>
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<tr>
<td>Adjusted R Square</td>
<td>0.998791542</td>
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<tr>
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<td>Observations</td>
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#### ANOVA

<table>
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<th>MS</th>
<th>F</th>
<th>Significance F</th>
</tr>
</thead>
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<tr>
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<td>2.71347E+11</td>
<td>3720.252421</td>
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<tr>
<td>Residual</td>
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<td>510564891.5</td>
<td>72937841.64</td>
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<td>Total</td>
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<td>5.43205E+11</td>
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#### Coefficients

<table>
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<tr>
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<th>t Stat</th>
<th>P-value</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
<th>Lower 95.0%</th>
<th>Upper 95.0%</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>49018.11644</td>
<td>10910.1033</td>
<td>4.492910394</td>
<td>0.002822212</td>
<td>23219.82173</td>
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<tr>
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<tr>
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<td>2.177317697</td>
<td>-7.22462619</td>
<td>0.000173703</td>
<td>-20.87884469</td>
<td>10.58176823</td>
<td>20.87884469</td>
</tr>
</tbody>
</table>

\[ Y_{\text{production}} = 49018.116 + 1.7966X_1 - 15.73X_2 \]
SUMMARY OUTPUT OF REGRESSION EQUATION FOR TRIP ATTRACTION

Regression Statistics

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

ANOVA

<table>
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<tr>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Significance F</th>
</tr>
</thead>
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<td>Residual</td>
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<tr>
<td>Total</td>
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</table>

Coefficients

<table>
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<tr>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat</th>
<th>P-value</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
<th>Lower 95.0%</th>
<th>Upper 95.0%</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>-204124.3952</td>
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<td>Employment</td>
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</tr>
<tr>
<td>Price(Lakh/Katha)</td>
<td>22843.12069</td>
<td>10018.0195</td>
<td>2.280203257</td>
<td>0.056619299</td>
<td>-845.7311646</td>
<td>46531.97255</td>
<td>845.7311646</td>
</tr>
</tbody>
</table>

Y_{attraction} = -204124.3952 + 3.6887X_1 + 22843.12X_2
APPENDIX- H
PROGRAM FOR READJUSTING INTER-ZONAL TRIP DISTRIBUTION

#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 d[n];
    float t[n][n]={{189776.0555, 155375.4928, 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, 57159.4495, 46798.1991, 17216.0953},
                    {94240.0002, 94240.0002, 57159.4495, 189776.0555, 127210.6943, 94240.0002, 57159.4495, 46798.1991, 127210.6943, 77157.1863},
                    {31369.7710, 57159.4495, 155375.4928, 127210.6943, 189776.0555, 155375.4928, 94240.0002, 57159.4495, 46798.1991, 77157.1863},
                    {77157.1863, 127210.6943, 94240.0002, 155375.4928, 155375.4928, 127210.6943, 94240.0002, 57159.4495, 46798.1991, 127210.6943},
                    {25683.3962, 34668.9586, 94240.0002, 57159.4495, 94240.0002, 171716.4761, 189776.0555, 155375.4928, 57159.4495},
                    {189776.0555, 21027.7863, 34668.9586, 127210.6943, 189776.0555, 155375.4928, 127210.6943, 94240.0002, 57159.4495, 127210.6943},
                    {140589.5598, 31369.7710, 34668.9586, 46798.1991, 77157.1863, 127210.6943, 189776.0555, 57159.4495, 189776.0555, 171716.4761},
                    {155375.4928, 140589.5598, 759231.74, 769671.16, 821143.18, 1082208.75, 357632.20}};
    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++) {
        for (j=0; j<n; j++) {
            oc[i]=0;
            for (k=0; k<n; k++) {
                oc[i]=oc[i]+t[i][j]*b[j];
            }
            a[i]=o[i]/oc[i];
            printf("%.4f",a[i]);
            printf("\n");
        }
        for (j=0; j<n; j++) {
            for (k=0; k<n; k++) {
                t[i][j]=t[i][j]+a[i];
            }
        }
    }
}
for (i=0; i<n; i++) {
    for (j=0; j<n; j++) {
        printf("%.2f\t",t[i][j]);
        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];
        oc[i]=oc[i]+t[i][j];
        diff[j]=o[j]-oc[j];
        dif[j]=di[j];
    }
    di[j]=abs(diff[j]);
    printf("%.2f\t",diff[j]);
    printf("%.4f\t",dif[j]);
    printf("%d",di[j]);
    printf("\n");
}
printf("\n");
for (i=0; i<n; i++) {
    for (j=0; j<n; j++) {
        printf("%.2f\t",t[i][j]);
        printf("\n");
    }
}
**OUTPUT OF THE PROGRAM**

<p>| | | | |</p>
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### Travel Time matrix for different types of modes of traffic from one zone to another zone

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<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
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<tr>
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<td>48</td>
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<td>72</td>
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<tr>
<td>Bus</td>
<td>36</td>
<td>50</td>
<td>60</td>
<td>64</td>
<td>36</td>
<td>56</td>
<td>48</td>
<td>60</td>
<td>72</td>
</tr>
<tr>
<td>Rickshaw</td>
<td>34</td>
<td>46</td>
<td>52</td>
<td>56</td>
<td>34</td>
<td>56</td>
<td>48</td>
<td>60</td>
<td>72</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
</tr>
</thead>
<tbody>
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<td>27.5</td>
<td>30</td>
<td>15.5</td>
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<td>27.5</td>
<td>30</td>
<td>37.5</td>
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<tr>
<td>Bus</td>
<td>22.5</td>
<td>30</td>
<td>32</td>
<td>34</td>
<td>22.5</td>
<td>30</td>
<td>32</td>
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### Generalized Travel Cost (GTC) matrix for different types of modes of traffic from one zone to another zone

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<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
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<tbody>
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<td>22</td>
<td>12</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Bus</td>
<td>16</td>
<td>22</td>
<td>24</td>
<td>26</td>
<td>16</td>
<td>22</td>
<td>24</td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td>Rickshaw</td>
<td>13.5</td>
<td>19.5</td>
<td>21.5</td>
<td>23.5</td>
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### Necessary Tables for Modal Choice and Network Assignment

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<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
<th>Zone 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
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### Appendix - I

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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, i, 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)
    {
        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");
        }
    }
}
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

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Give the starting node

1

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 node

2

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

Give the next starting node 3
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 node 4
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 node 5
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 node 6
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 node 7
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 node 8
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 node 9
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 node 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

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
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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
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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
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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
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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
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Shortest path from 8 to node 3: 8 6 3
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Shortest path from 9 to node 6: 9 6
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Shortest path from 9 to node 10: 9 10
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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 - I
TOTAL TRIPS IN EACH LINK FOR DIFFERENT MODES AT PEAK HOUR

(For Car)

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<td>698 124 62 53 129 18 2383 94 927 2511 190 182 173 156 559 141</td>
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(For Bus at Peak Hours)

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## Flows (15% of the total flow)

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