Chapter II
Transportation Planning and Modeling

Tewodros N.
www.tnigatu.wordpress.com
tedy nihe@gmail.com
Lecture Overview

- **Transportation Planning**
  - Introduction
  - Transportation Planning Process
  - Transportation Policy
  - The transport policy formulation process

- **Transportation Modeling**
  - Modeling principles
  - Transport Modeling
  - Prerequisite for transport modeling
  - The Four step model

- **Evaluation and Economic Appraisal of transport projects**
  - Valuing Transport Costs and Benefits
  - Cost-Benefit Analysis: the Appraisal Process
Introduction

➢ Transportation Planning

Help to create

➢ High quality transportation facilities and services
➢ Reasonable cost
➢ Minimal environmental impact
➢ Enhance economic activity.

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Transportation Planning

A process that develops information to help make decisions on the future development and management of transportation systems.

Focused on developing long range (15-30 years) transportation plans.

Balance supply with future travel demand.
Introduction Cont…

➢ Transportation Planning

Addresses Problems

➢ Travel demand alternatives for congestion reduction
➢ Land use/transportation coordination
➢ Fuel reduction measures
➢ Air quality measures
➢ Safety measures
➢ Economic development/redevelopment activity

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Transportation Planning Process

Problem Definition -> Solution Generation -> Solution Analysis -> Evaluation and Choice -> Implementation and Monitoring

Feedback to all steps

- The emergence of additional performance problems
- The degree that the problem has been addressed
- Real-world performance

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Transport Policy

Transportation Policy

Is a guiding principle (plan of action) that influences how the transport system should behave to achieve desired outcomes and avoid transport problems.

Include

- Road expansion plans,
- Transit system priorities,
- Fuel tax,
- Emission limits etc.
Objectives:- is a statement of a desired end-state.

Objectives in transport policy can be categorized

- **Statements of Vision:** Broad indications of the type of area which politicians or the public wish to see.
- **Higher level objectives:** referred to as aims or goals, identify attributes of transport system, or its side effects, which can be improved as a means of realizing the vision.
- **Quantified objectives:** provide a clear basis for assessing performance of the strategy, but they do require careful definition if the specified thresholds are to be realistic.
- **Solution-specific ‘objectives’:** specifying solutions within the objectives and may lead to an overall strategy which is less appropriate to the area’s needs.
Transport Policy Cont...

- The transport policy formulation process
  1. Objective-led strategy formulation
  2. Problem oriented approach
1. Objective-led strategy formulation
1. Objective-led strategy formulation

- Offers a logical basis for proposing solutions, and also for assessing any proposals offered by others.
- Ensures that the appraisal of alternatives is conducted in a logical, consistent, and comprehensive way against the full set of objectives.
- Assessing the performance of the implemented measures improves the ability to judge the potential of similar measures elsewhere, and to predict their impact.
- Regular monitoring provides a means of checking not just on the scale of current problems, but also, through attitude surveys, on the perception of those problems.
2. Problem oriented approach

➢ Start by defining types of problems
➢ Starts at the second box in the Objective-led strategy formulation flow chart
➢ Merit = Being easily understood
➢ Demerit = Dependent on developing a full list of potential problems at the outset.
Transport Policy Cont...

Policy Instruments/Measures

The means by which the objectives described above can be achieved, and problems overcome.

- Infrastructures
- Management
- Information
- Pricing
- Land use
- Attitudinal and behavioral measures
Transport Modeling

- **Modeling principles**
  - Models are a simplified representation of a part of reality.
  - Is only realistic from a particular perspective.
  - During their formulation, calibration and use, planners can also learn much about the behavior and internal workings of the system under scrutiny.
  - Their function is to give insight into complex interrelationships in the real world and to enable statements about what (most probably) will happen if changes occur or put in that (part of) reality.
Transport Modeling Cont...

- **Transport models**
- Study of the behavior of individuals in making decisions regarding the provision and use of transport.
- Are abstract mathematical models

\[ Y = f(a, X) \]

- Dependent variable
- Independent variables

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Transport Modeling Cont...

Model formulation process

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Transport Modeling Cont...

- purposes of mathematical models

- To gain a more structural analysis of the complex transport system
- To find out which factors play an important role, and how sensitive the transport system is to changes in the different factors
- To analyze the effect of alternative traffic projects and contribute towards their economic appraisal
- To help transport planners make reliable predictions and forecasts of future changes in usage of traffic facilities for sake of facility design, control and operation.
- To enable quantified calculations of expected effects in the transportation system when changes (policy measures or interventions) are put in the system
- To find design parameters that lead to an optimal performance of the modeled system

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Transport Modeling

➢ Prerequisite for transport modeling
➢ Basic terminologies,
➢ Fundamental characteristics of transport problems,
➢ Gather the necessary data and
➢ Understand basic regression analysis
Transport Modeling Cont...

- Fundamental characteristics of transport problems
  - Transport services come with side effects
  - The demand for transport is derived; it is not an end by itself.
  - Transport demand takes place over space.
  - Both transport demand and supply have very strong dynamic elements.
  - Transport is a service and not a good.
  - The transport system requires fixed assets and the mobile units.
  - Transport infrastructure is lumpy
  - Transport investment has an important political role.
  - The demand for transport services is highly qualitative and differentiated.
Transport Modeling Cont...

- Data requirements
- Socio-economic data
- Travel surveys
- Network data
- Land use inventory
Transport Modeling Cont...

- Data required for modeling is primarily collected through surveys;
  - Household survey
  - External cordon and Intercept surveys
  - Travel Diary
  - O-D survey
  - Questionnaire
  - In-house and Roadside Interviews
Transport Modeling Cont...

- Mathematical background
- Multiple regression analysis
- Elementary statistics
Transport Modeling Cont...

➢ The Four step model

Aims to establish the spatial distribution of travel explicitly by means of an appropriate system of zones.

➢ Trip generation:- forecasts the number of trips that will be made.

➢ Trip distribution:- determines where the trips will go.

➢ Mode usage:- how the trips will be divided among the available modes of travel.

➢ Trip assignment:- predicts the routes that the trips will take, resulting in traffic forecasts for the highway system and rider-ship forecasts for the transit system.
Trip Generation

Define the magnitude of total daily travel in the model system, at the household and zonal level, for various trip purposes (activities).

Aims at predicting the total number of trips produced in the zone and attracted by it respectively for each TAZ of the study area.

It has two basic functions:

➢ To develop a relationship between trip production or attraction and land use, and

➢ To use the relationship developed to estimate the number of trips generated at some future date under a new set of land-use conditions.
Factors which have considerable impact on the trip producing capacity of a TAZ are:

- Income
- Car ownership
- Household structure
- Family size
- Value of land
- Residential density
- Accessibility

HH Trip Generation Studies

Zonal Trip Generation Studies

Rarely Used for Trip Generation Studies

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Trip Generation Cont...

- Classifications of trips

By trip Purpose: In the case HB trips
- Trip to work
- Trip to School or College
- Shopping trips
- Social and recreational and
- Other trips

By time of Day
- Peak Period
- Off-Peak Period

By Person type
- Income Level
- Car Ownership
- Household size and Structure
Trip Generation Cont...

- Trip generation models
  - Growth factor,
  - Regression,
  - Discrete choice and
  - Category classification.
Growth factor Modeling

- Tries to predict the number of trips produced or attracted by a household or a zone as a linear function of explanatory variables.

- What Trips to be Considered

- What is the minimum age to be included in the analysis

\[ T_i = f_i t_i \]

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The growth factor $f_i$ depends on

- Population (P) of the zone,
- Average household Income (I),
- Average vehicle ownership (V).

$$f_i = \frac{f(P_i^d, I_i^d, V_i^d)}{f(P_i^c, I_i^c, V_i^c)}$$

- Merits = simple and easy to understand,
- Demerit = Over-estimated number of trips
Example 1

Consider a Zone with 250 households with car and 250 households without car. Assuming we Know the average trip generation rates of each group:

- Car-owning households produce: 6.0 trips/day
- Non-Car-owning households produce: 2.5 trips/day
Regression analysis model

- Used to establish a statistical relationship between the number of trips produced and the characteristics of the individuals, the zone, and the transportation network.

\[ T_i = a_0 + a_1 x_1 + a_2 x_2 + \ldots a_i x_i \ldots + a_k x_k \]  

where:-

- \( x_i \) are explanatory variables such as income, car ownership, population etc. and
- \( T_i \) is generated trip.
- \( a_i \) are parameters determined through calibration process.
Example 2

Let the trip rate of a zone is explained by the household size done from the field survey. It was found that the household size are 1, 2, 3 and 4. The trip rates of the corresponding household is as shown in the table below. Fit a linear equation relating trip rate and household size.

<table>
<thead>
<tr>
<th>Household size(x)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trips per day(y)</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>12</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

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Regression analysis model Cont…

Two types of regression models are commonly used.

- Zonal-Based Multiple Regression
- Household-Based Regression
Trip Distribution

➢ Provides the planner with the numbers of trip productions and trip attraction that each zone will have.

➢ Determine where the trips produced in each zone will go—how they will be divided among all other zones in the study area.

➢ Produce O-D matrix that shows the number of trips originated in the study zone and where these trips are destined to.

➢ The main diagonal corresponds to Intra-Zonal Trips

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Trip Distribution Cont…

<table>
<thead>
<tr>
<th>Zones</th>
<th>1</th>
<th>2</th>
<th>...</th>
<th>j</th>
<th>...</th>
<th>n</th>
<th>$O_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$T_{11}$</td>
<td>$T_{12}$</td>
<td>...</td>
<td>$T_{1j}$</td>
<td>...</td>
<td>$T_{1n}$</td>
<td>$O_1$</td>
</tr>
<tr>
<td>2</td>
<td>$T_{21}$</td>
<td>$T_{22}$</td>
<td>...</td>
<td>$T_{2j}$</td>
<td>...</td>
<td>$T_{2n}$</td>
<td>$O_2$</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$T_{i1}$</td>
<td>$T_{i2}$</td>
<td>...</td>
<td>$T_{ij}$</td>
<td>...</td>
<td>$T_{in}$</td>
<td>$O_i$</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$T_{ni}$</td>
<td>$T_{n2}$</td>
<td>...</td>
<td>$T_{nj}$</td>
<td>...</td>
<td>$T_{nn}$</td>
<td>$O_n$</td>
<td></td>
</tr>
<tr>
<td>$D_j$</td>
<td>$D_1$</td>
<td>$D_2$</td>
<td>...</td>
<td>$D_j$</td>
<td>...</td>
<td>$D_n$</td>
<td>$T$</td>
</tr>
</tbody>
</table>

Where $D_j = \Sigma_i T_{ij}$,

$O_i = \Sigma_j T_{ij}$, and $T = \Sigma_{ij} T_{ij}$.

- $T_{ij}$ is the number of trips between origin $i$ and destination $j$.
- $O_i$ is the total number of trips originating in zone $i$ and
- $D_j$ is the total number of trips attracted to zone $j$. 
Trip Distribution Cont...

- Two basic categories of aggregate trip distribution methods predominate in urban transportation planning are:
  - The Growth Factor methods
  - The Gravity Model
The Growth Factor Methods

- Involve scaling an existing matrix (called base matrix) by applying multiplicative factors (often derived from predicted productions and/or attractions) to matrix cells.

- The base year matrix contains an estimate of the trips being made in the base year.
  - Uniform Growth Factor
  - Singly Constrained Growth-Factor
  - Doubly Constrained Growth Factor
Uniform Growth Factor

- A uniform growth rate can be applied if the only information available is about a general growth rate for the whole study area.

\[ T_{ij} = \tau t_{ij} \]

Where:
- \( \tau \) is the uniform growth factor,
- \( t_{ij} \) is the previous total number of trips and
- \( T_{ij} \) is the expected total number of trips.
Example 3

Consider the simple four-by-four base year matrix shown below. Determine the trip matrix if the growth in traffic in the study area is expected to be of 20% in the next three years.

\[
\begin{array}{cccc|c}
 & 1 & 2 & 3 & 4 \ 
1 & 5 & 50 & 100 & 200 \ 
2 & 50 & 5 & 100 & 300 \ 
3 & 50 & 100 & 5 & 100 \ 
4 & 100 & 200 & 250 & 20 \ 
\hline
\sum_i & 205 & 355 & 455 & 620 \ 
\frac{\sum_j}{i} & 355 & 455 & 255 & 570 \ 
\hline
\end{array}
\]

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Singly Constrained Growth-Factor

➢ If information is available on the expected growth of either trips originating or trips attracted to each zone, it will result in origin-specific $\tau_i$ and destination-specific $\tau_j$ growth factors respectively.

$$T_{ij} = \tau_j t_{ij} \quad \text{for origin-specific factors}$$
$$T_{ij} = \tau_i t_{ij} \quad \text{for destination-specific factors}$$
Example 4

Consider the following trip matrix with growth predicted for origins.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>∑</th>
<th>Target O_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>355</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>455</td>
<td>460</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>100</td>
<td>5</td>
<td>100</td>
<td>255</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>200</td>
<td>250</td>
<td>20</td>
<td>570</td>
<td>702</td>
</tr>
<tr>
<td>∑ i</td>
<td>205</td>
<td>355</td>
<td>455</td>
<td>620</td>
<td>1635</td>
<td>1962</td>
</tr>
</tbody>
</table>

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Doubly Constrained Growth Factor

- When information is available on the growth in the number of trips originating and terminating in each zone, we know that there will be different growth rates for trips in and out of each zone and consequently having two sets of growth factors for each zone.

- Iterative methods are proposed to obtain an estimated trip matrix which satisfies both sets of trip-end constraints, or the two sets of growth factors.

\[
T_{ij} = t_{ij} \tau_i \tau_j A_i B_j
\]

\[
T_{ij} = t_{ij} a_i b_j
\]
Doubly Constrained Growth Factor

The procedure is:

- Set \( b_j = 1 \)
- With \( b_j = 1 \), solve for \( a_i \) to satisfy trip generation constraint \( (\Sigma T_{ij} = O_{ij}) \).
- With \( a_i \), solve for \( b_j \) to satisfy trip attraction constraint \( (\Sigma T_{ij} = D_{ji}) \).
- Update matrix and check for errors.
- Repeat steps 2 and 3 till convergence.
Example 5

Determine the trip matrix of

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>( \sum_j )</th>
<th>Target ( O_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>355</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>5</td>
<td>100</td>
<td>300</td>
<td>455</td>
<td>460</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>100</td>
<td>5</td>
<td>100</td>
<td>255</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>200</td>
<td>250</td>
<td>20</td>
<td>570</td>
<td>702</td>
</tr>
<tr>
<td>( \sum_i )</td>
<td>205</td>
<td>355</td>
<td>455</td>
<td>620</td>
<td>1635</td>
<td></td>
</tr>
</tbody>
</table>

Target \( D_j \)

| 260 | 400 | 500 | 802 | 1962 |
Solution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>[\sum_{i} ]</th>
<th>Target [O_{i}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.25</td>
<td>44.12</td>
<td>98.24</td>
<td>254.25</td>
<td>401.85</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>45.30</td>
<td>3.81</td>
<td>84.78</td>
<td>329.11</td>
<td>462.99</td>
<td>460</td>
</tr>
<tr>
<td>3</td>
<td>77.04</td>
<td>129.50</td>
<td>7.21</td>
<td>186.58</td>
<td>400.34</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>132.41</td>
<td>222.57</td>
<td>309.77</td>
<td>32.07</td>
<td>696.82</td>
<td>702</td>
</tr>
<tr>
<td>[\sum_{i} ]</td>
<td>260.00</td>
<td>400.00</td>
<td>500.00</td>
<td>802.00</td>
<td>1962</td>
<td></td>
</tr>
</tbody>
</table>

Target
\[D_{j}\]

<table>
<thead>
<tr>
<th></th>
<th>260</th>
<th>400</th>
<th>500</th>
<th>802</th>
<th>1962</th>
</tr>
</thead>
</table>

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Example 6
Growth Factor Cont…

The advantages of Growth Factor method are:

✓ Simple to understand.
✓ Preserve observed trip pattern.
✓ Useful in short term-planning.

The limitations are:

○ Depends heavily on the observed trip pattern.
○ It cannot explain unobserved trips.
○ Do not consider changes in travel cost.
○ Not suitable for policy studies like introduction of a mode.

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The Gravity model

The number of trips between two zones is directly related to activities in the two zones, and inversely related to the separation between the zones as a function of the generalized cost.

\[ T_{ij} = \alpha O_{ij} D_{ij} f(c_{ij}) \]

Where: \( \alpha \) is the proportionality factor and
\( f(c_{ij}) \) is a generalized function of the travel costs with one or more parameters for calibration.
The Gravity model Cont…

The need to satisfy the constraints (\(\sum T_{ij}=O_{ij}\) and \(\sum T_{ij}=D_{ji}\)) requires replacing the single proportionality factor \(\alpha\) by two sets of balancing factors \(A_i\) and \(B_j\) as in the Furness model, yielding:

\[
T_{ij} = A_i B_j O_i D_j f(c_{ij})
\]

The deterrence function \(f(c_{ij})\) is the essence of the gravity model.

\[
\begin{align*}
f(c_{ij}) &= \exp(-\beta c_{ij}) \\
f(c_{ij}) &= c_{ij}^{-n} \\
f(c_{ij}) &= \sum_m F^m \delta_{ij}^m
\end{align*}
\]
Example 7

The productions from zone 1, 2 and 3 are 98, 106, 122 and attractions to zone 1, 2 and 3 are 102, 118, 106. The function $f(c_{ij})$ is defined as $f(c_{ij}) = \frac{1}{c_{ij}^2}$ The cost matrix is as shown below

$$
\begin{bmatrix}
1.0 & 1.2 & 1.8 \\
1.2 & 1.0 & 1.5 \\
1.8 & 1.5 & 1.0 \\
\end{bmatrix}
$$

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Example 8

Consider the cost matrix shown below together with the total trip matrix from example 4 and attempt to estimate the parameters $a_i b_j$ of the gravity model of the type $T_{ij} = a_i b_j \exp(-\beta c_{ij})$.

<table>
<thead>
<tr>
<th>Cost matrix (minutes)</th>
<th>Target $O_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>15.5</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>$D_j$</td>
<td>260</td>
</tr>
<tr>
<td>Target</td>
<td></td>
</tr>
</tbody>
</table>

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Modal Choice

In this phase of travel-demand forecasting, we analyze people’s decisions regarding mode of travel; auto, bus, train, and so on.

Mode choice models can also be done on both aggregate (Zonal) and disaggregate (Household or individual) levels.

Three broad categories of factors are considered in mode usage:

- The characteristics of the trip maker
- The characteristics of the trip
- The characteristics of the transportation system

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Modal Choice Cont…

Types of modal split models

- **Trip-end modal split models**
  - Apply modal-split models immediately after trip generation.
  - Different characteristics of the person could be preserved and used to estimate modal split.
  - Relate the choice of mode only to features like income, residential density and car ownership.
  - Advantage very accurate in the short run, if public transport is available and there is little congestion.
  - Limitation is that they are insensitive to policy decisions
Modal Choice Cont…

Types of modal split models

- **Trip-interchange modal split models**
  - Distribution model; that is modal split is applied after the distribution stage.
  - Advantage that it is possible to include the characteristics of the journey and that of the alternative modes available to undertake them.
  - Possible to include policy decisions.
  - Beneficial for long term modeling.
Modal Choice Cont...

**Logit models**

- Is choice model that assumes an individual maximizes utility in choosing between available alternatives.

- The functional form of the logit model for k number of alternative modes is:

\[
c_{ij} = a_1 t_{ij}^v + a_2 t_{ij}^w + a_3 t_{ij}^t + a_4 t_{nij} + a_5 F_{ij} + a_6 \phi_j + \delta
\]

\[
P_{ij}^1 = \frac{T_{ij}^1}{T_{ij}} = \frac{\exp \left( -\beta c_{ij}^1 \right)}{\sum_k \exp \left( -\beta c_{ij}^k \right)}
\]
Modal Choice Cont...

S-shaped logit mode choice curve

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Example 9

Let the number of trips from zone to zone is 5000, and two modes are available which has the characteristics given in Table 1. Compute the trips made by mode bus, and the fare that is collected from the mode bus. If the fare of the bus is reduced to 6, then find the fare collected.

Table 1: Trip characteristics

<table>
<thead>
<tr>
<th></th>
<th>$t_{ij}$</th>
<th>$t_{ij}$</th>
<th>$f_{ij}$</th>
<th>$\phi_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>car</td>
<td>20</td>
<td>-</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>bus</td>
<td>30</td>
<td>5</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>car</td>
<td>0.03</td>
<td>0.04</td>
<td>0.06</td>
<td>0.1</td>
</tr>
</tbody>
</table>

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Trip Assignment

➢ Traffic analysis in which inter-zonal trips are assigned to the network.

➢ Involves computing one or more optimal (usually shortest) routes between each origin and destination and distributing travel demand over these routes.

➢ The sum of all trips along these routes over all OD pairs results in a traffic load on all links and nodes.
Trip Assignment Cont...

Necessary input for the assignment:

- An OD table of trips between the zones, usually all trip purposes combined;
- A (computer) representation of the network;
- Characteristics of the network elements (links and nodes);
- A route choice model.
There are two broad assignment models:

1. **Minimum path assignment:** Assume that the capacity and travel cost of the links is unaffected by the volume of traffic and all the traffic will choose to travel on the shortest path.

2. **The all-or-nothing (AON) assignment**

3. **The congested assignment:** Address the fact that the travel time and cost on a link increases as the volume of traffic on the link increases.

4. **User equilibrium assignment (UE), system optimum assignment (SO)**
Trip Assignment Cont…

*All-or-Nothing Assignment*

- All traffic between an O-D pair is assigned to just one path (usually the shortest path) connecting the origin and destination.
- Unrealistic in that only one path between every O-D pair is utilized even if there is another path with the same or nearly the same travel time.
- Travel time is taken as a fixed input and does not vary depending on the congestion on a link.
- May be reasonable in sparse and uncongested networks where there are few alternative routes and they have a large difference in travel cost.
- Used to identify the desired path.

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Example 10

Assign the vehicle trip shown in the following O-D trip to the network using all or nothing assignment technique to summarize your result. List all of the network and their corresponding traffic volume after loading.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>100</td>
<td>100</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>-</td>
<td>200</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
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<td>200</td>
<td>100</td>
<td>-</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>150</td>
<td>300</td>
<td>-</td>
<td>400</td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>100</td>
<td>50</td>
<td>350</td>
<td>-</td>
</tr>
</tbody>
</table>
Trip Assignment Cont...

User Equilibrium Assignment

- Based on Wardrop's first principle
  “Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip maker can reduce his path costs by switching routes.”

- In the congested network, all the used routes between an O-D pair have equal and minimum costs while all unused routes have greater or equal costs.

\[ f_k (c_k - u) = 0 : \forall k \quad c_k - u \geq 0 : \forall k \]

where \( f_k \) is the flow on path \( k \), \( c_k \) is the travel cost on path \( k \), and \( u \) is the minimum cost.

- Equation labelqueue2 can have two states.
- If \( c_k - u = 0 \), from equation 1 \( f_k \geq 0 \). This means that all used paths will have same travel time.
- If \( c_k - u \geq 0 \), then from equation 1 \( f_k = 0 \).
Trip Assignment Cont…

User Equilibrium Assignment

➢ The user equilibrium assignment assumes that:
  ➢ The user has perfect knowledge of the path cost.
  ➢ Travel time on a given link is a function of the flow on that link only.
  ➢ Travel time functions are positive and increasing.

\[
\text{Minimize}\, Z = \sum_a \int_0^{x_a} t_a(x_a) \, dx, \quad f_{kr}^s \geq 0 : \forall \, k, r, s \\
\text{subject to}\, \sum_k f_{kr}^s = q_{rs} : \forall r, s \\
x_a \geq 0 : a \in A \\
x_a = \sum_r \sum_s \sum_k \delta_{a,k}^r f_{kr}^s : \forall a \\
\delta_{a,k}^r = \begin{cases} 
1 & \text{if link } a \text{ belongs to path } k, \\
0 & \text{otherwise}
\end{cases}
\]

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Example 11

Let us suppose a case where travel time is not a function of flow as shown in other words it is constant as shown in the figure below for $q_{12} = 12$

\[ t_1 = 10 + 3x_1 \]
\[ t_2 = 15 + 2x_2 \]
System Optimum Assignment (SO)

- Based on Wardrop's second principle
  Under social equilibrium conditions, traffic should be arranged in congested networks in such a way that the average (or total) travel cost is minimized.
- Congestion is minimized when drivers are told which routes to use.
- Is not a behaviorally realistic model
Trip Assignment Cont…

Direct output of the assignment computation:

- **The routes** (consecutive series of adjacent links and nodes);
- **The route characteristics** (travel times, distances, costs);
- **Route loads**: the number of trips per route;
- **Link and node loads**: the number of trips per unit time (flow) on each link and each turn at junctions.
Evaluation and Economic Appraisal of transport projects

- **Appraisal** forecasting the effect it will have on policy indicators and weighing them up to decide whether overall the proposal is beneficial.

- **Economic efficiency** projects could be found and undertaken which would make everyone better off, those projects would serve to promote economic efficiency.

- If the benefits measured in money terms exceed the costs; the most efficient project is that for which the difference is greatest.

- Some other indicators cannot be expressed in money
  - The difficulty of finding satisfactory methodologies for valuing some benefits and costs in money terms
  - Decision-takers may wish to look at a broader range of criteria than economic efficiency.

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Evaluation and Economic Appraisal of transport projects Cont…

- Transport project expenditures can be readily valued using monitory terms and maintenance can be computed using the market price of the nation. Operating cost usually takes the form:

\[ G = M + \gamma T \]

- Costs of transport projects - pain and grief resulting from accidents, environmental effects - do not have a market price.
Evaluation and Economic Appraisal of transport projects Cont...

**Accidents**
- Damage to property and vehicles,
- Health service, ambulance and police costs, and
- Loss of production due to victims being unable to work
- Difficult is to place a money value on the pain, grief and suffering caused by death or injury in an accident.

**Environmental**
- Property demolition,
- Noise nuisance,
- Visual intrusion and air pollution.
- Consumption of scarce and non-renewable resources such as oil.

**Benefits**
- Reduction of congestion and travel time,
- Provision of accessibility,
- Enhancement of environment
Evaluation and Economic Appraisal of transport projects Cont…

Benefits

✓ Reduction of congestion and travel time,
✓ Provision of accessibility,
✓ Enhancement of environment

$$\Delta G = G_i - G_f$$

➢ Where \(\Delta G\) is the saving in operating cost, \(G_i\) is the initial cost before the project and \(G_f\) is the current cost after the construction of the project.

➢ The total saving in operating cost is given by

$$\sum_{m} \sum_{l} 0.5(G_i - G_f)(Q_i - Q_f)$$

➢ Where \(Q_i\) and \(Q_f\) are the initial and final volume of traffic, \(m\) is the mode and \(l\) is the link.
Cost-Benefit Analysis

➢ Mainly involves financial and social appraisal of the projects.

➢ Financial Appraisal:- measuring all the effects of the project on the cash flow of the agent undertaking it.

➢ Social Appraisal:- measure the benefits and costs whoever receives them and whatever form they take.

➢ In order to undertake an appraisal, it is necessary to identify:
  • The base case (i.e. what will happen without the project)
  • The option (what will happen with it)
Cost-Benefit Analysis Cont…

financial appraisal

➢ Cash flow are then 'discounted' back to the present to find its Net Present Value (NPV) in financial terms.

➢ The NPV is simply the difference between the sum of the discounted costs and the discounted benefits.

\[ NPV = \sum_{i=1}^{t} \left[ \frac{R_i - C_i}{(1 + r)^i} \right] \]
Cost-Benefit Analysis Cont...

- If a number of projects are competing for scarce resources, a simple value for money index can then be derived by dividing the net present value of the benefits minus costs of the project by the net present value of the financial requirement, and then ranking the projects in order of this indicator.

- Multi-criteria approaches require three stages:
  1. Definition of a set of objectives, which may for instance relate to accessibility, the environment, safety, economy and equity.
  2. Measurement of the extent to which each project contributes towards the desired objective.
  3. Weighting of the measures in order to aggregate them and produce a ranking of projects.
Cost-Benefit Analysis Cont...

- **Net Present Value** = Benefit − Cost
  
  \( (NPV) = B - C \)

- **Benefit Cost Ratio** = Benefit / Cost
  
  \( (BCR) = \frac{B}{C} \)

- **Net Present Value** = Benefit − Cost
  
  \[
  NPV = -I_0 + \frac{b_1}{(1+r)} + \frac{b_2}{(1+r)^2} + \frac{b_3}{(1+r)^3} + \ldots + \frac{b_n}{(1+r)^n}
  \]

  OR

  \[
  NPV = -I_0 + \sum_{t=1}^{n} \frac{b_t}{(1+r)^t}
  \]

- **Note:** for identical annual benefit \( b_t = b \) (throughout the analysis period),

  \[
  \Sigma b_t/ (1+r)^n = b \left[\frac{(1-(1/(1+r))^{n+1})}{(1-(1/(1+r))})\right]
  \]
Cost-Benefit Analysis Cont...

- Benefit / Cost ratio = Benefits / Costs
  \[ B / C = \frac{\Delta B}{I + \Delta M} \]

- Net Benefit / Cost ratio = (Benefits – Costs) / Costs
  \[ NB / C = \frac{\Delta B - (I + \Delta M)}{I + \Delta M} \]

- For a project to be economically viable, either of the following condition must be satisfied:
  \[ NPV = -I_0 + \sum_{t=1}^{n} \frac{b_t}{(1+r)^t} \geq 0 \quad \text{OR} \quad B / C = \frac{\Delta B}{I + \Delta M} \geq 1.0 \quad \text{OR} \quad NB / C = \frac{\Delta B - (I + \Delta M)}{I + \Delta M} \geq 0 \]
Example 12

- What are the costs and benefits of this project? Should this new road be built?

- Existing situation
  - Length (A-B) = 25Km
  - Travel Time (A-B) = 30min

- Planned situation
  - Length (A-B) = 17Km
  - Travel Time (A-B) = 15min

- Induced traffic A-B: 3,000 Veh/day
- Saving for Existing Traffic (10,000Veh/day): 8Km and 15min
- Assume Value of time = 5birr/hr
- Assume driving cost = 0.05 birr/km
- Analysis Period = 25 years
- Discount rate = 8%
- Cost of building is 95million birr.

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Thank You!

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