AAiT
Addis Ababa Institute of Technology
Addis Ababa University

SCHOOL OF CIVIL AND ENVIROMENTAL ENGINEERING

Transport Engineering
CENG 3201

Chapter 2
Transportation Planning and Modeling

Tamru T.

2012 EC (2019/20GC)
1st Sem

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.

Introduction Cont…

- 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.

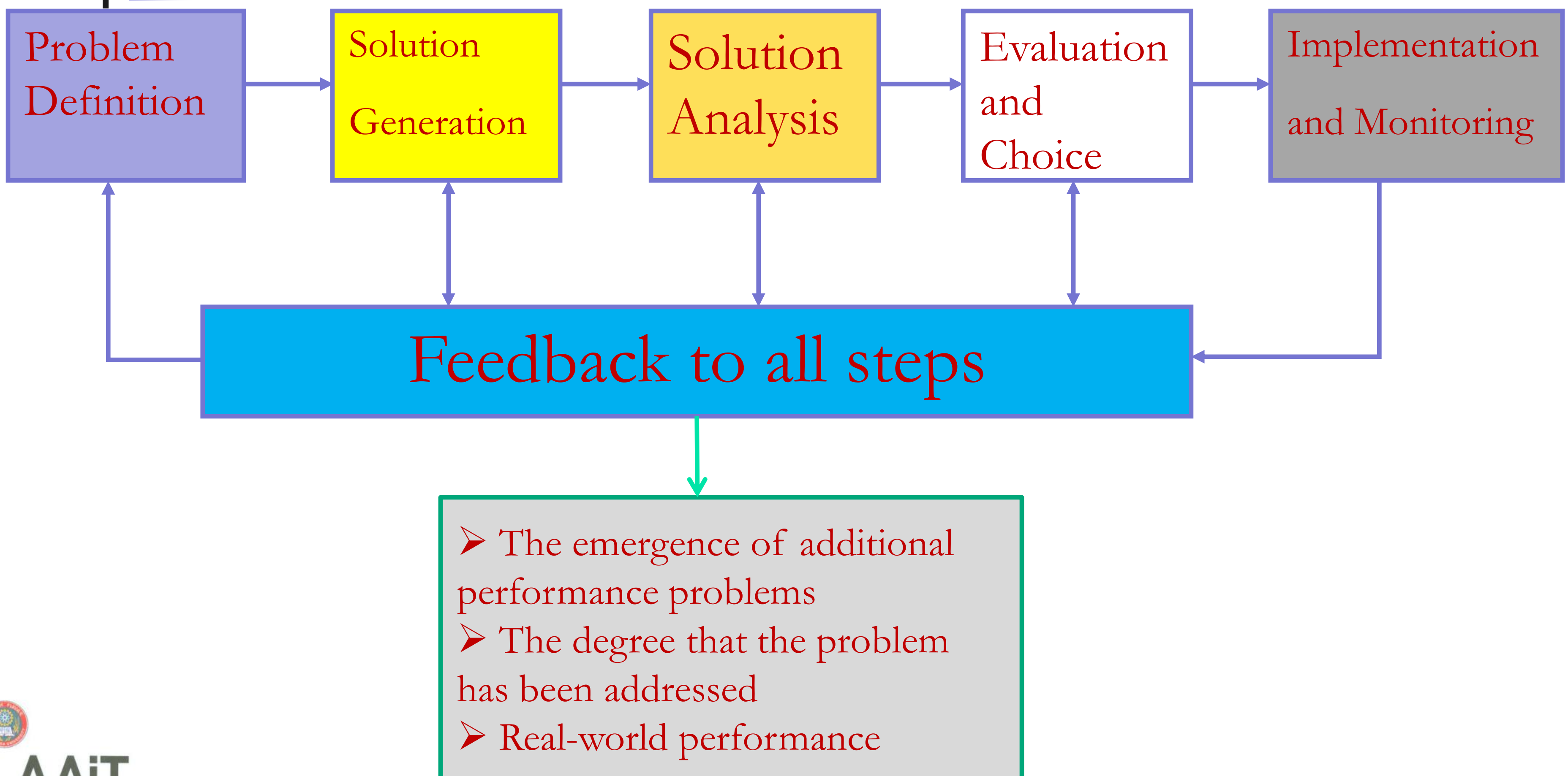
Introduction Cont…

- ## 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

Transportation Planning Process



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.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Transport Policy Cont…

- 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.

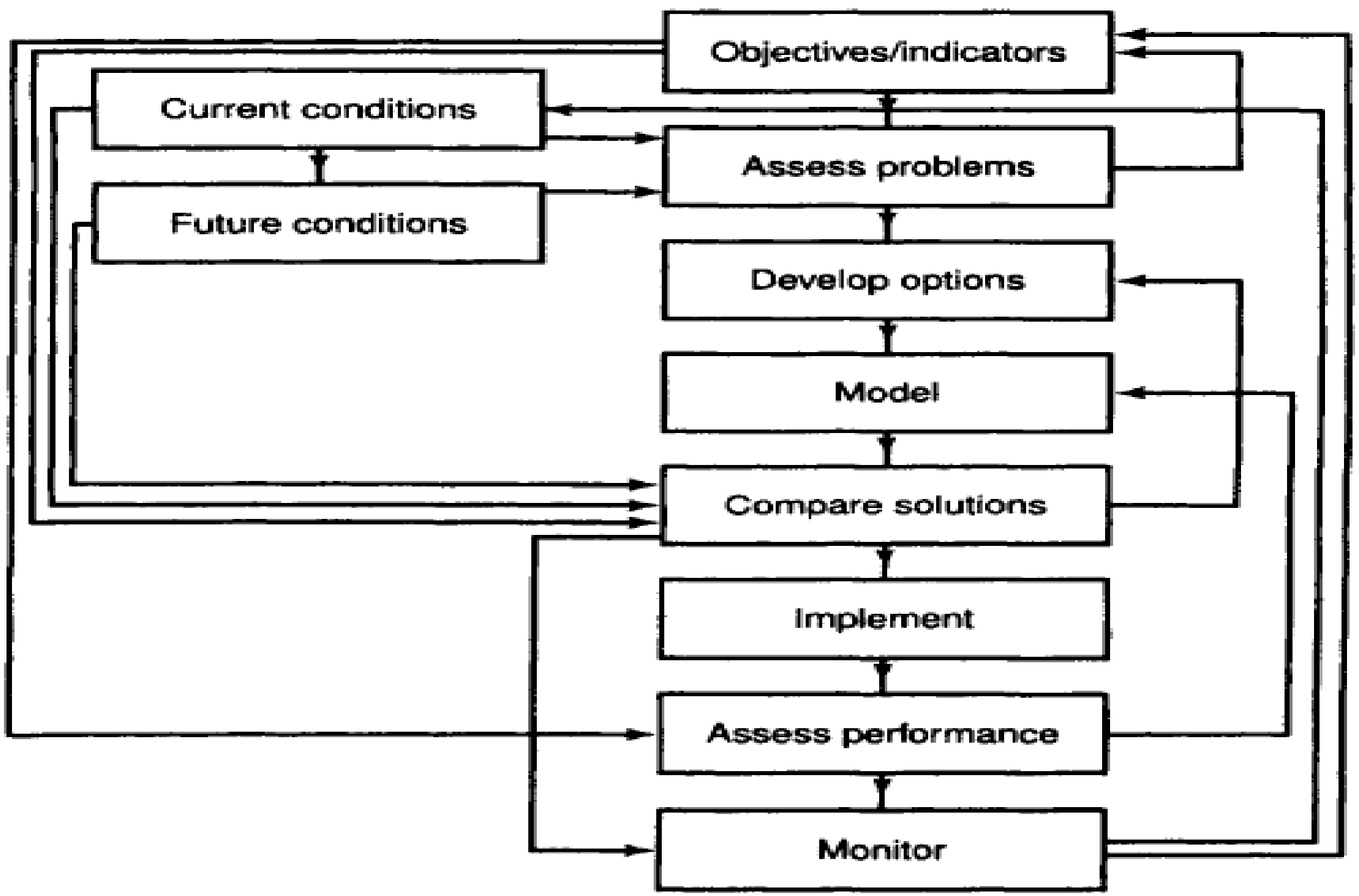
AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Transport Policy Cont…

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

Transport Policy Cont…

1. Objective-led strategy formulation



AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Transport Policy Cont…

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.

AAiT
Addis Ababa Institute of Technology
አዲስ አበባ ቴክኖሎጂ ኢንስቲትዩት
Addis Ababa University
አዲስ አበባ ዩኒቨርሲቲ

Transport Policy Cont…

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 can be achieved, and problems overcome.

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

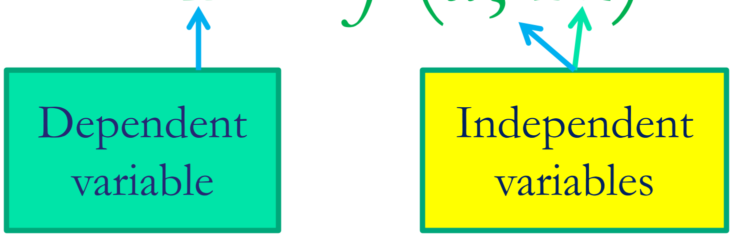
Transport Modeling

- **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.

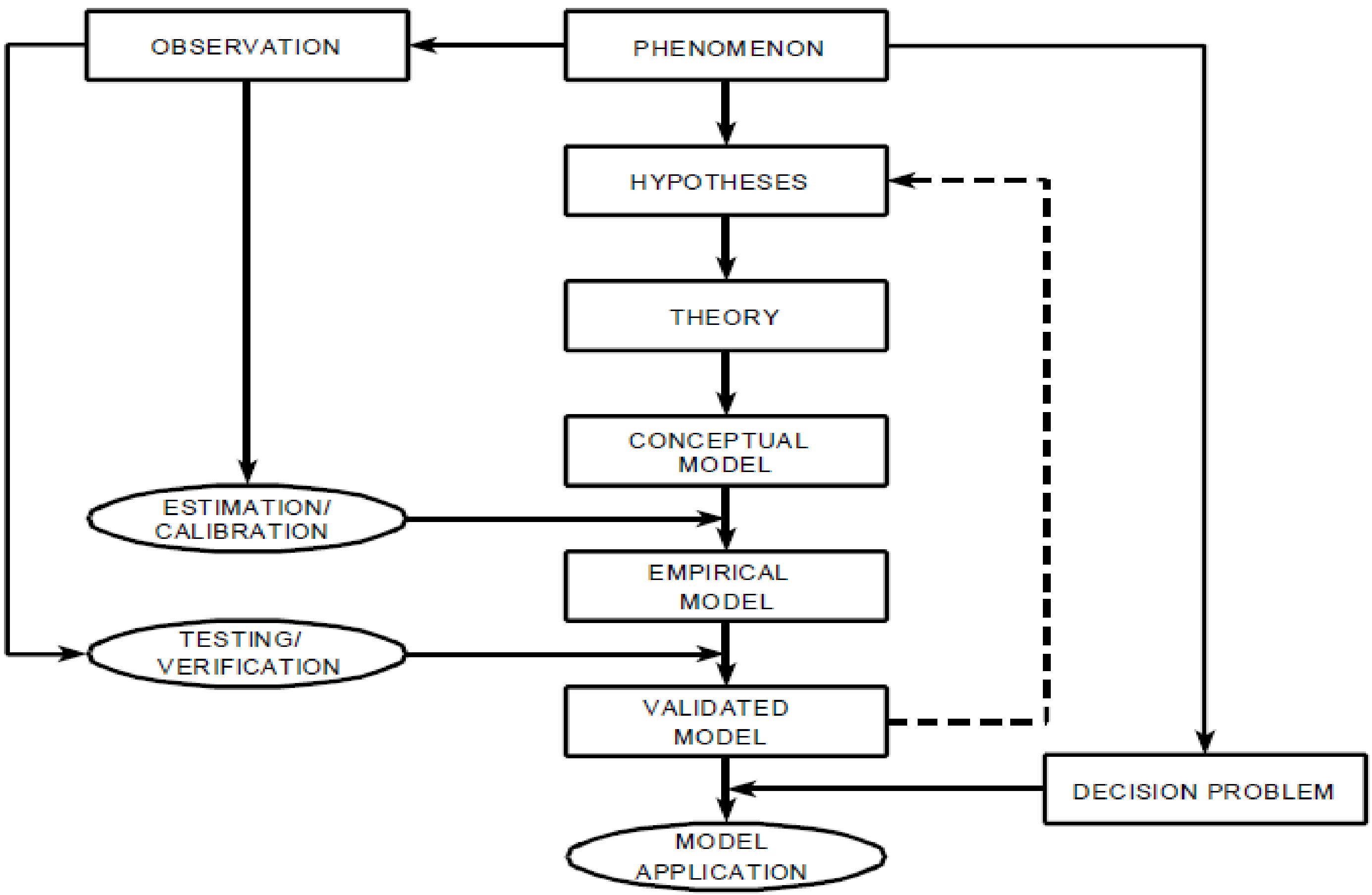
Transport Modeling Cont…

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

$$Y = f\,(a, X)$$



Transport Modeling Cont…



Model formulation process

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

Transport Modeling

- **Prerequisite for transport modeling**
  - Fundamental characteristics of transport problems,
  - Basic terms & Definitions (Ref. Lec. Note pp 10-13)
  - 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.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

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…

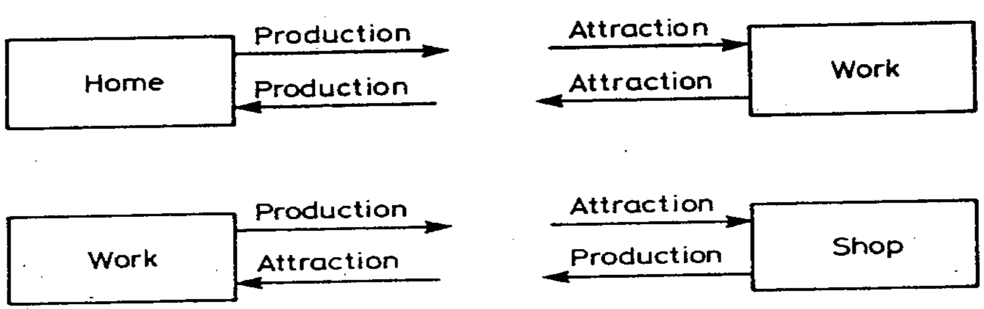
- **The Four step model**

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

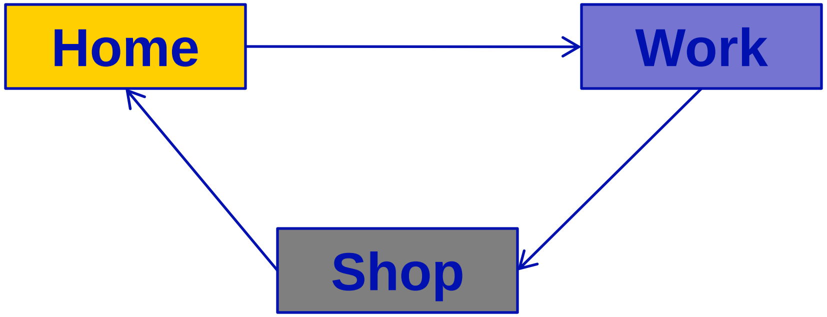
- **Journey:-** is a one-way movement from a point of origin to a point of destination.
- **Home-Based (HB) Trip:-** one where the home of the trip maker is either the origin or the destination of the journey.
- **Non-Home- Based Trip:-** one where neither end of the trip is the home of the traveler.
- **Trip Production:-** is the home end of an HB trip or the origin of an NHB trip.
- **Trip Attraction:-**is the non-home end of an HB trip or the destination of an NHB trip.



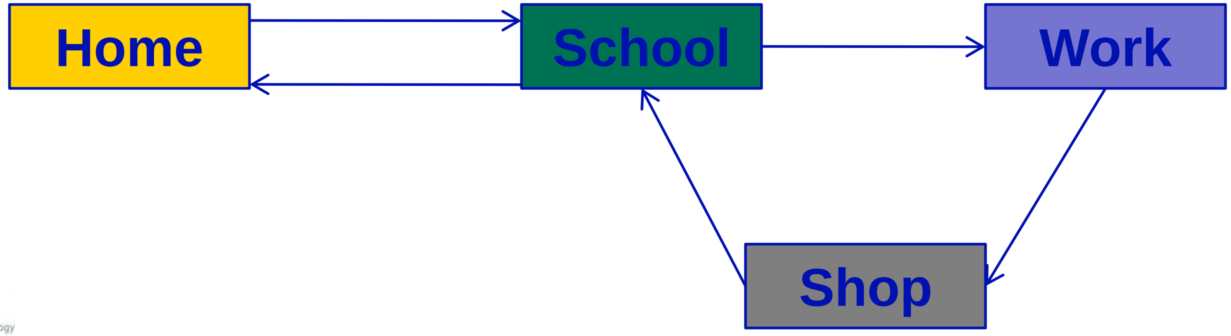
Example 1 (quiz)

Determine the total trip generated for each case below.

i



ii



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.

Trip Generation Cont…

- **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

Income, Car ownership, Household structure, Family size → HH Trip Generation Studies

Value of land, Residential density → Zonal Trip Generation Studies

Accessibility → Rarely Used for Trip Generation Studies

Addis Ababa Institute of Technology
Addis Ababa University

Trip Generation Cont…

- **Classifications of trips**

By trip Purpose:- In the case HB trips

- Trip to work
- Trip to School or Collage
- Shopping trips
- Social and recreational and
- Other trips

By time of Day

- Peak Period
- Off-Peak Period

By Person type

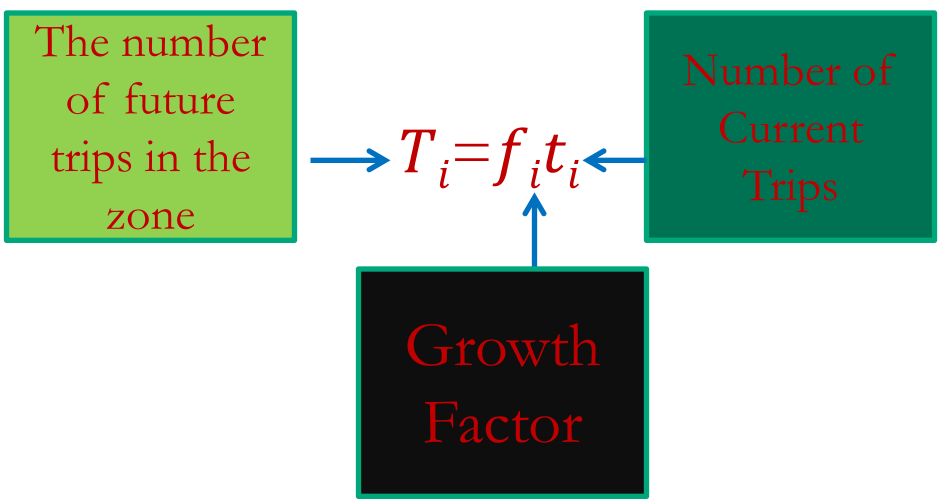
- Income Level
- Car Ownership
- Household size and Structure

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 house hold 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



Growth factor Modeling Cont…

The growth factor f_i depends on

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

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

, d= design year

c=current year

- **Merits= simple and easy to understand,**

Demerit= Over-estimated number of trips

Addis Ababa Institute of Technology
Addis Ababa University

Example 2

Consider a Zone with 250 households with one 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.

Future situation 500 households with one car.

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:-

xi are explanatory variables such as income, car ownership, population etc. and

Ti is generated trip.

ai are parameters determined through calibration process.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Regression analysis model Cont…

Two types of regression models are commonly used.

- Zonal-Based Multiple Regression
- Household-Based Regression

Balancing trip generation

- Prior to proceeding to Trip Distribution step, it is important to ensure that the production and attractions within the study area are equal.
- Productions are generally considered to be more accurate.
- Attraction are balanced proportionality to match productions within each zone.

- Sample example…

Example 3

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.

	Household size(x)			
	1	2	3	4
Trips	1	2	4	6
per	2	4	5	7
day(y)	2	3	3	4
	5	9	12	17

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Example 3-1

A mixed use traffic analysis zone has 10000 households (HH), 20,000 m2 of office space (OS) and 500 commercial center units (CU). Trips produced (Yp) and Trip attracted (Ya) in area can be estimated using a regression model below.

$$Y_p = 1.7HH$$
$$Y_a = 0.8OS + 2CU$$

a) Calculate the total trips produced and attracted in the zone.

b) Forecast the total trips produced and attracted in the zone 5 years from now if there is a 2% annual household population decrease and 5% office space increase.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Ex. 4 (Class Exercise)

Table 1 Presents the data collected in a house hold (HH) survey

Table 1

Type	Household size	Annual Income €,000	No. of non-workers	No. workers departing in the peak hour
1	3	25	2	1
2	4	50	2	2
3	5	60	3	2
4	3	70	2	1

The total number of household types is given in Table 2.

Table 2

Household type	No. of households
1	100
2	250
3	300
4	75

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Class Exe. Con.

The following linear regression model estimates the number of social/recreation trips.

$$y_1 = 0.08 + 0.01x_1 + 0.009x_2 + 0.02x_3$$

Where:
y_1 = coefficient for the number of household peak hour social/recreation trips
x_1 = Household annual income
x_2 = Household size
x_3 = Number of non-working household members

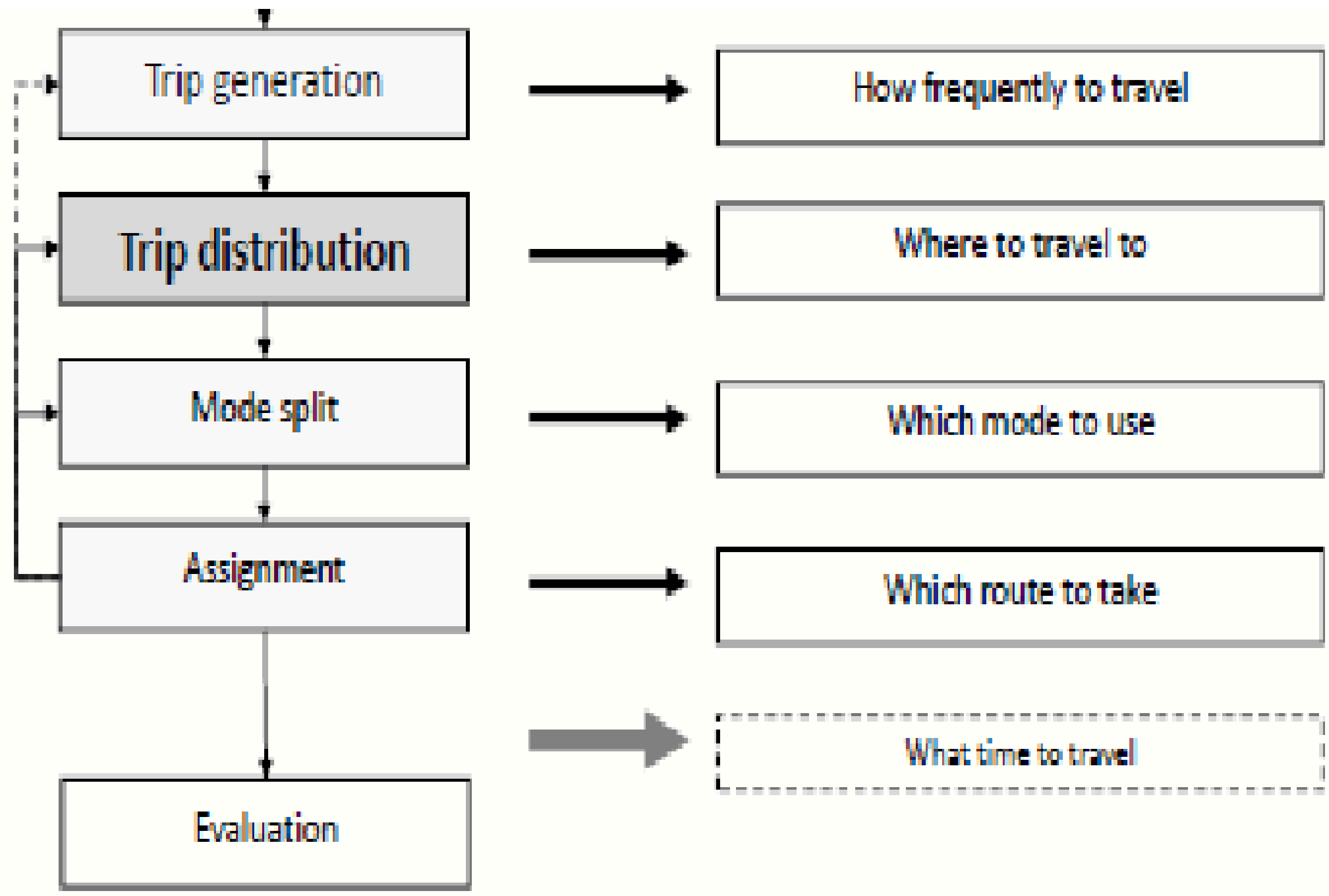
The following linear regression model estimates the number of retail trips.

$$y_2 = 0.5 + 0.01x_1 + 0.004x_2 + 0.01x_3$$

Where:
y_2 = coefficient for the number of household peak hour retail trips
x_1 = Household annual income
x_2 = Household size
x_3 = Number of non-working household members

Using the data above calculate the total number of peak hour work-based trips, retail and social/recreation trips.

Trip Distribution



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

Trip Distribution Cont…

		Destinations (1 to j)						
		1	2	3	4	...	j	Tot
Origins (1 to i)	1	T_{11}	T_{12}	T_{13}	T_{14}		T_{1j}	$\mathbf{O_1}$
	2	T_{21}	T_{22}	T_{23}	T_{24}		T_{2j}	$\mathbf{O_2}$
	3	T_{31}	T_{32}	T_{33}	T_{34}		T_{3j}	$\mathbf{O_3}$
	4	T_{41}	T_{42}	T_{43}	T_{44}		T_{4j}	$\mathbf{O_4}$
	....							
	i	T_{i1}	T_{i2}	T_{i3}	T_{i4}		T_{ij}	$\mathbf{O_i}$
	Tot	$\mathbf{D_1}$	$\mathbf{D_2}$	$\mathbf{D_3}$	$\mathbf{D_4}$		$\mathbf{D_j}$	

Productions (O_1 … O_i)

Attractions (D_1 … D_j)

Trip Distribution Cont…

Zones	1	2	$\dots$	j	$\dots$	n	O_i
1	T_{11}	T_{12}	$\dots$	T_{1j}	$\dots$	T_{1n}	O_1
2	T_{21}	T_{22}	$\dots$	T_{2j}	$\dots$	T_{2n}	O_2
$\vdots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\vdots$
	T_{i1}	T_{i2}	$\dots$	T_{ij}	$\dots$	T_{in}	O_i
$\vdots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\vdots$
n	T_{ni}	T_{n2}	$\dots$	T_{nj}	$\dots$	T_{nn}	O_n
D_j	D_1	D_2	$\dots$	D_j	$\dots$	D_n	T

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

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

- *Tij* is the number of trips between origin *i* and destination *j*.
- *Oi* is the total number of trips originating in zone *i* and
- *Dj* 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*

The Growth Factor Methods Cont…

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:- τ is the uniform growth factor,

t_{ij} is the previous total number of trips and

T_{ij} is the expected total number of trips.

AAiT
Addis Ababa Institute of Technology
አዲስ አበባ ቴክኖሎጂ ኢንስቲትዩት
Addis Ababa University
አዲስ አበባ ዩኒቨርሲቲ

The Growth Factor Methods Cont…

Year t	1	2
1	T_{11}^{t}	T_{12}^{t}
2	T_{21}^{t}	T_{22}^{t}

Year t	1	2
1	$T_{11}^{\hat{t}}$	$T_{12}^{\hat{t}}$
2	$T_{21}^{\hat{t}}$	$T_{22}^{\hat{t}}$

$$T_{ij}^{\hat{t}} = T_{ij}^{t} * Exp^{\hat{t}t}$$

- $T_{ij}^{\hat{t}}$ → trips from i to j in year $\hat{t}$
- T_{ij}^{t} → trips from i to j in year t
- $Exp^{\hat{t}t}$ → growth factor applied to all zone pairs (based on past trends, official forecasts)

Example 5

Given the base-year initial matrix below, estimate the forecast year matrix if the total trips would increase to 34.

	X	Y	Z	sum
X	1	2	4	7
Y	3	2	3	8
Z	4	2	2	8
sum	8	6	9	23

The Growth Factor Methods Cont…

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 τi and destination-specific τj growth factors respectively.

$T_{ij} = \tau_j t_{ij}$ for origin-specific factors

$T_{ij} = \tau_i t_{ij}$ for destination-specific factors

The Growth Factor Methods Cont…

Case 1: Origin constrained growth factor is used when estimation of growth in origin is more reliable than that in destination

$$Exp_i^{\hat{t}t} = \frac{O_i^{\hat{t}}}{O_i^{t}}, \forall i$$

Case 2: Destination constrained growth factor is used when estimation of growth in destination is more reliable than that in origin

$$Exp_j^{\hat{t}t} = \frac{D_j^{\hat{t}}}{D_j^{t}}, \forall j$$

The Growth Factor Methods Cont…

Case 3: Average zonal growth factor is used when estimations of growth in origin and destination are equally reliable

$$Exp_{ij}^{\hat{t}t} = \frac{\frac{O_i^t}{O_i^t} + \frac{D_j^t}{D_j^t}}{2}, \forall i, j$$

Example 6

Given the base-year initial matrix below, estimate the forecast year matrix if $\Sigma Ox=14$, $\Sigma Oy=8$, $\Sigma Oz=12$, $\Sigma Dx=16$, $\Sigma Dy=9$, $\Sigma Dz=9$.

Use singly constrained (origin) and average zone growth factor

	X	Y	Z	sum
X	1	2	4	7
Y	3	2	3	8
Z	4	2	2	8
sum	8	6	9	23

Class Exercise

		To					
		W	X	Y	Z	Total	Forecast
From	W	5	100	200	150	455	520
	X	150	40	160	190	540	630
	Y	210	130	30	320	690	520
	Z	270	50	65	18	403	560
	Total	635	320	455	678	2088	
	Forecast	560	460	580	630		

Use uniform growth, singly constrained (origin also Destination) and average zone growth factor, estimate forecasted O-D matrix

The Growth Factor Methods Cont…

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.

$$T_{ij} = t_{ij}\tau_i\tau_j A_i B_j$$

$$T_{ij} = t_{ij}a_i b_j$$

Addis Ababa Institute of Technology
Addis Ababa University

Doubly Constrained Growth Factor

Furness Method

Furness suggests updating the initial matrix by

- adjusting alternatively both the constraints to origins and destinations, until convergence is reached.
- This technique is iterative since the solution for ai depends on bj, and vice versa.

Doubly Constrained Growth Cont…

The procedure is:

- Set $bj = 1$
- With $bj = 1$, solve for ai to satisfy trip generation constraint ($\Sigma Tij = Oij$).
- With ai, solve for bj to satisfy trip attraction constraint ($\Sigma Tij = Dji$).
- Update matrix and check for errors.
- Repeat steps 2 and 3 till convergence.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Example 7

- ***Given the base-year initial matrix below, estimate the forecast year matrix using the Furness method if $\Sigma Ox=14$, $\Sigma Oy=8$, $\Sigma Oz=12$, $\Sigma Dx=16$, $\Sigma Dy=9$, $\Sigma Dz=9$.***

Stop the iteration when the origin and destination growth factors a and b are between 0.95 and 1.05.

	X	Y	Z	sum
X	1	2	4	7
Y	3	2	3	8
Z	4	2	2	8
sum	8	6	9	23

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

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.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Class Exercise

		To					
		1	2	3	4	Total	Forecast
From	1	5	50	100	200	355	400
	2	50	5	100	300	455	460
	3	50	100	5	100	255	400
	4	100	200	250	20	570	702
	Total	205	355	455	620	1635	
	Forecast	260	400	500	802		

Use, Doubly constrained estimate forecasted O-D matrix (stop iteration if ai and bj b/n 0.95 &1.05)

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.

- $Tij = \alpha OiDjf(cij)$

Where: α is the proportionality factor and

f(cij) is a generalized function of the travel costs with one or more parameters for calibration.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

The Gravity model Cont…

The need to satisfy the constraints (ΣTij=Oi and ΣTij=Dj) requires replacing the single proportionality factor α by two sets of balancing factors Ai and Bj as in the Furness model, yielding:

$$Tij = A_i B_j O_i D_j f(c_{ij})$$

$$A_i = 1 \Big/ \sum_j B_j D_j f(c_{ij}) \qquad B_j = 1 \Big/ \sum_i A_i O_i f(c_{ij})$$

The deterrence function f(cij) is the essence of the gravity model.

$f(c_{ij})=\exp(-\beta c_{ij})$………Exponential

$f(c_{ij})=c_{ij}^{-n}$ ……………Power

$f(c_{ij})=\mathrm{m}/ c_{ij}$ ……………Reciprocal

m , n and β have to be calibrated against base year & assume to stay constant in the forecast year

Example 8-1

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(cij) is defined as $f(c_{ij})=1/c_{ij}^2$ The cost matrix is as shown below , develop O-D matrix to meet the target use singly constrained.

		Zone			
		1	2	3	Sum
Zone	1				98
	2				106
	3				122
Sum		102	118	106	

Cost matrix

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

Exercise

Consider the cost matrix shown below together with the total trip matrix and attempt to estimate the O-D matrix of the gravity model .

$$f(c_{ij}) = \exp(-\beta c_{ij}) \,, \beta = 0.1$$

Cost matrix

Trip productions and trip attractions

	1	2	3	4	O_i
1	3	11	18	22	400
2	12	3	13	19	460
3	15.5	13	5	7	400
4	24	18	8	5	702
D_j	260	400	500	802	*1962*

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

The Gravity model Other approach

Singly constrained gravity model.

This is the most widely used trip distribution model which states that the number of trips between two zones is directly proportional to the number of trip attraction generated by the zone of destination and inversely proportional to a function of time of travel between the two zones.

The Gravity model
Other approach

Mathematically, the gravity model is expressed as

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum A_j F_{ij} K_{ij}} \right]$$

Where

T_{ij} = *number of trips that are produced in zone i and attracted to zone j*

P_i = *the total number of trips produced in zone i*

A_j = *number of trips attracted to zone j*

F_{ij} = *a value which has an inverse function of travel time*

K_{ij} = *socioeconomic adjustment factor for interchange ij*

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

The Gravity model
Other approach

Hence, calculate the adjusted attraction factor according to the following formula

$$A_{jk} = \frac{A_j}{C_{j(k-1)}} A_{j(k-1)}$$

Where

A_{jk} = *adjusted attraction factor for attraction zone (column) j, iteration k*
A_{jk} = *Aj when k=1*
C_{jk} = *actual attraction (column) total for zone j, iteration k*
A_j = *desired attraction total for attraction zone (column) j*
j = attraction zone number, j=1, 2, 3…..n
n = number of zones
k = iteration number, k=1, 2, 3….n

m= number of iteration

Example 8-2

For study area consisting of three zones, the number of production, attraction, and average travel times between each zone is given as shown in the following tables. Compute the intra zonal trips (Zone to zone trips). Assume k_{ij}=1 for all.

Table 1: Total no. of Trip production and Attraction in each zone.

Zone	1	2	3	Total
Trip production	140	330	280	750
Trip attraction	300	270	180	750

Table 2: Travel time between zones (min)

Zones	1	2	3
1	5	2	3
2	2	6	6
3	3	6	5

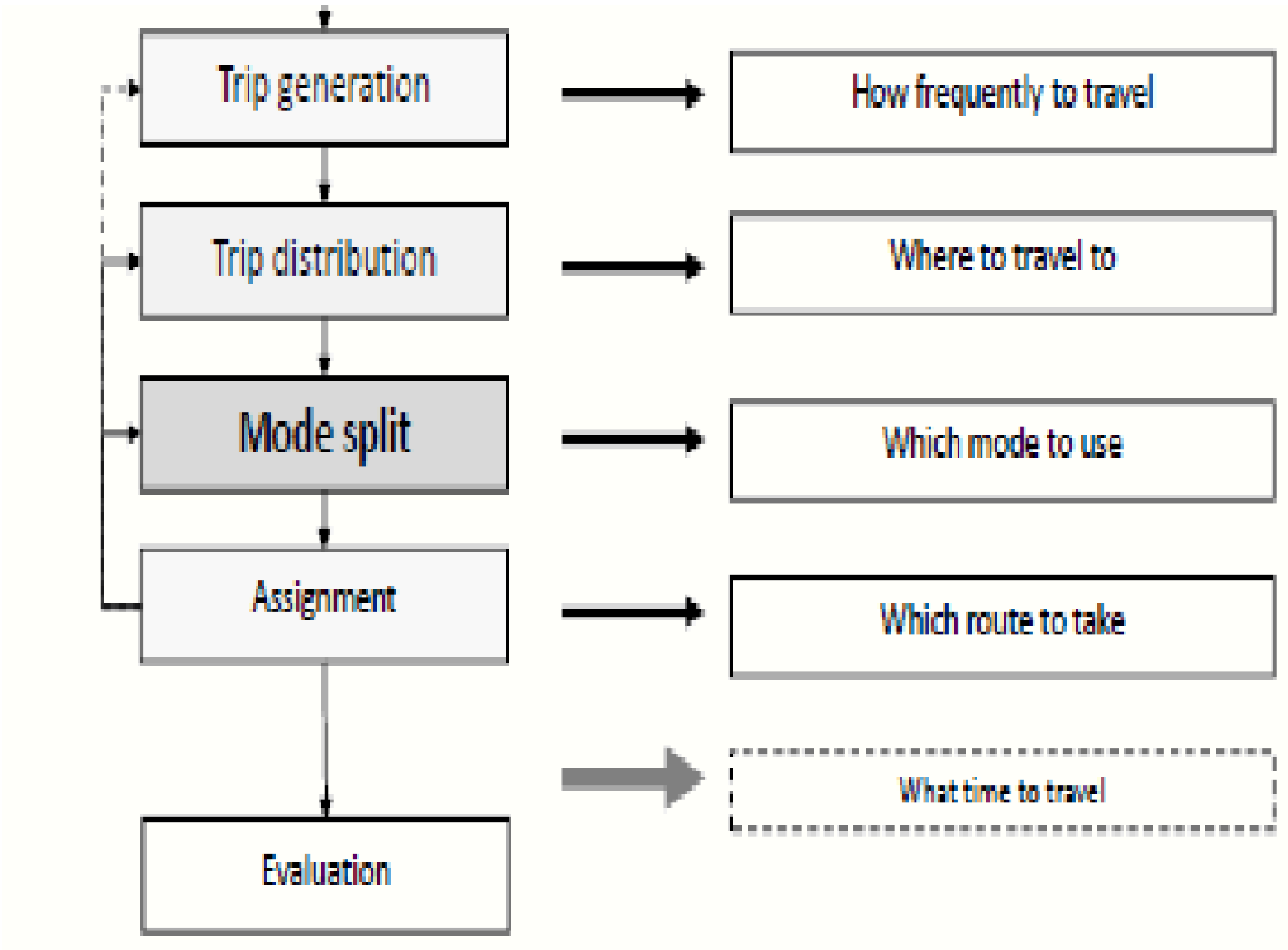
Table 3: F values vs travel time

Time(min)	F
1	82
2	52
3	50
4	41
5	39
6	26
7	20
8	13

QUESTIONS?

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Modal Choice



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

In most countries, mode choice modeling is of great political importance to improve the public transport system and to make the car drivers switch to public transport.

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:

$$C_{ij} = a_1 t_{ij}^v + a_2 t_{ij}^w + a_3 t_{ij}^t + a_4 t_{ij}^n + a_1 \delta^n + a_5 F_{ij}$$

where

t_{ij}^v is the in-vehicle travel time between i and j,
t_{ij}^w is the walking time to and from stops (stations),
t_{ij}^t is the waiting time at stops,
t_{ij}^n is the interchange time,
δ^n is an intrinsic 'penalty' or resistance to interchange, measured in time units (typically 2 to 5 minutes),
F_{ij} is fare charged to travel between i and j
a_1 to a_5 are coefficients associated to the elements of cost above.

AAi
Addis Ababa Institute of Technology
Addis Ababa University

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:

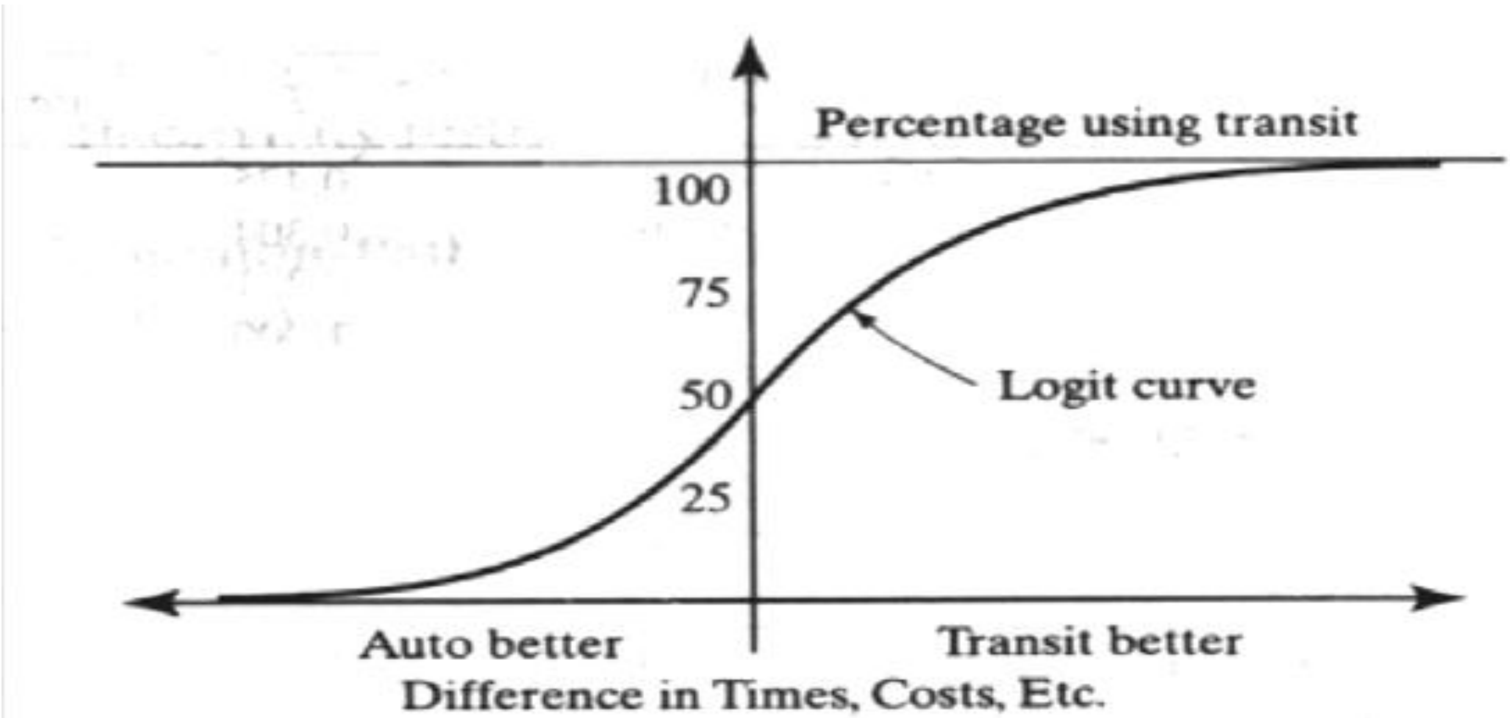
$$c_{ij} = a_1 t_{ij}^{v} + a_2 t_{ij}^{w} + a_3 t_{ij}^{t} + a_4 t_{nij} + a_5 F_{ij} + a_6 \phi_j + \delta$$

$$P_{ij}^{1} = \frac{T_{ij}^{1}}{T_{ij}} = \frac{\exp\left(-\beta C_{ij}^{1}\right)}{\sum_k \exp\left(-\beta C_{ij}^{k}\right)}$$

where P_{ij}^{1} is the proportion of trips travelling from i to j via mode 1. C_{ij}^{1} is the generalized cost of mode 1 and β is a calibrated parameter.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Modal Choice Cont…



S-shaped logit mode choice curve

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

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. Use β=0.7

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

Table 1: Trip characteristics

		t_{ij}^{w}	t_{ij}^{t}	f_{ij}	ϕ_j
car	20	-	18	4	1
bus	30	5	3	9	1
a_i	0.03	0.04	0.06	0.1	0.1

Modal Choice Cont…

Utility function

- If two modes, auto (A) and transit (T) with utility function $\mathbf{U_A}$ and $\mathbf{U_T}$ are being considered, the probability of selecting the auto mode A can be written as

$$P(A) = \frac{e^{U_A}}{e^{U_A} + e^{U_T}}$$

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Example 10

Assume there are 1000 trips being made between zones A and B, and that there are three mode available to make this trip. The utility of the individual modes, all people making the trip is defined as

$U_{auto} = 1 - 0.1TT - 0.05\ TC$

$U_{bus} = -0.1TT - 0.05\ TC$

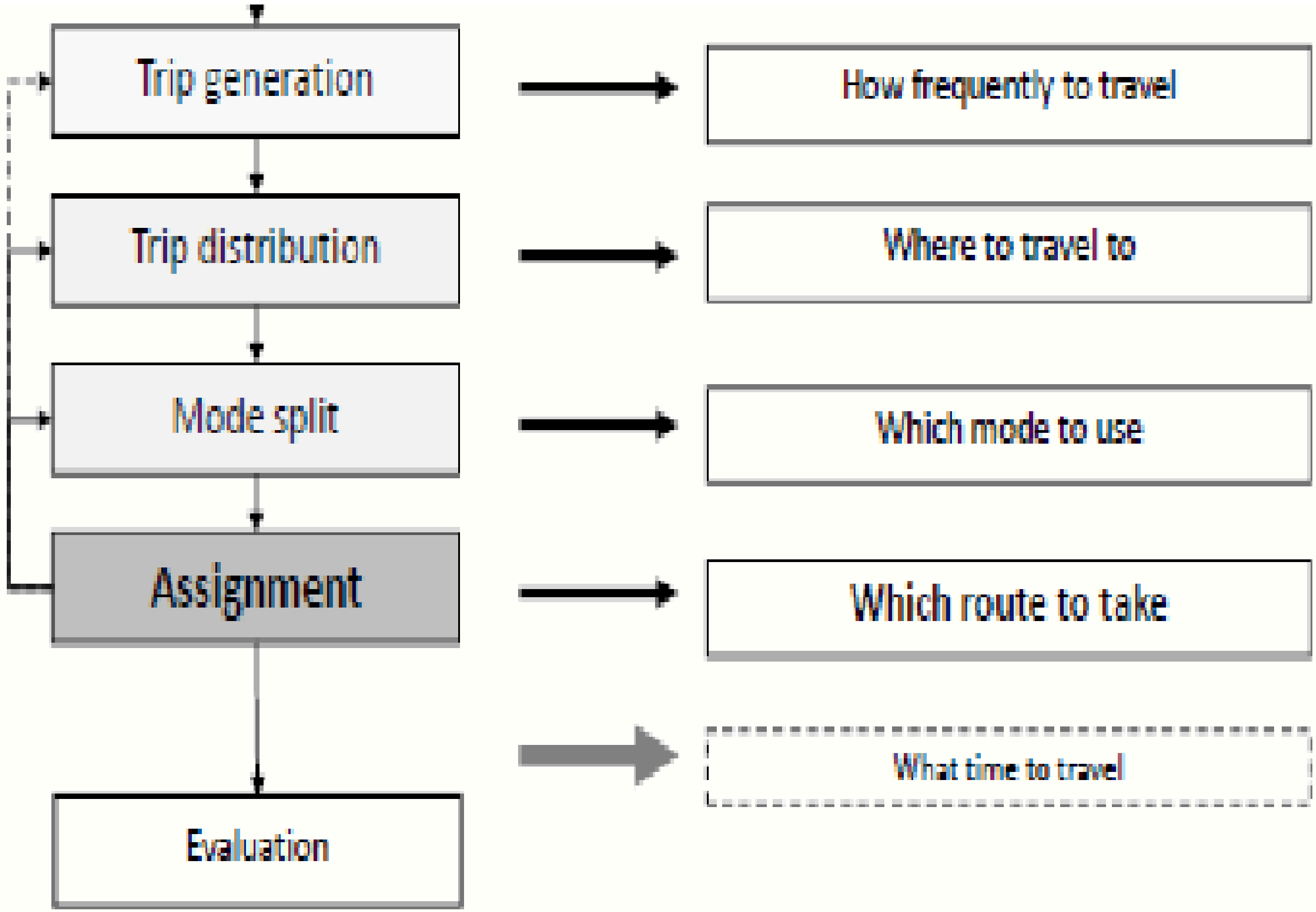
$U_{walk} = -0.05 - 0.01\ TT$

TC=Travel Cost (birr) and TT=Travel Time (min)

Predict how many people would be using each of the modes if: TT_{auto}=5min, TT_{bus}=15min, TT_{walk}= 20min, TC_{auto}=2birr, and TC_{bus}=1birr .

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Trip Assignment



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.

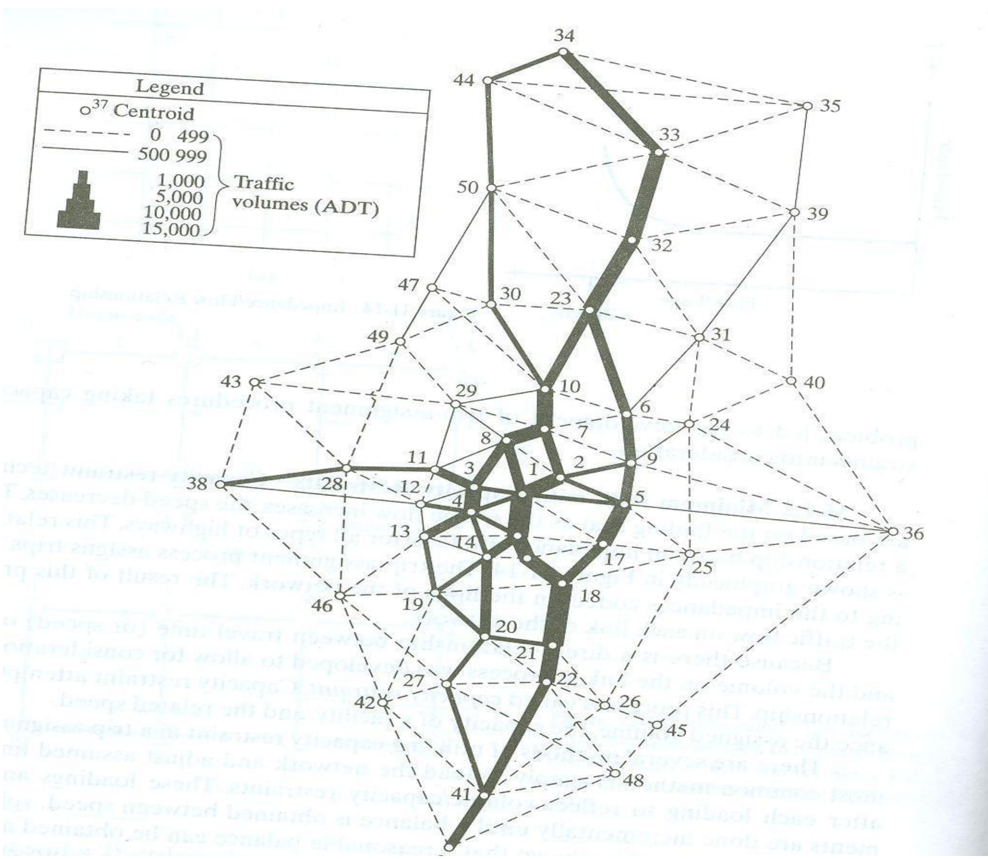
Trip Assignment Cont…

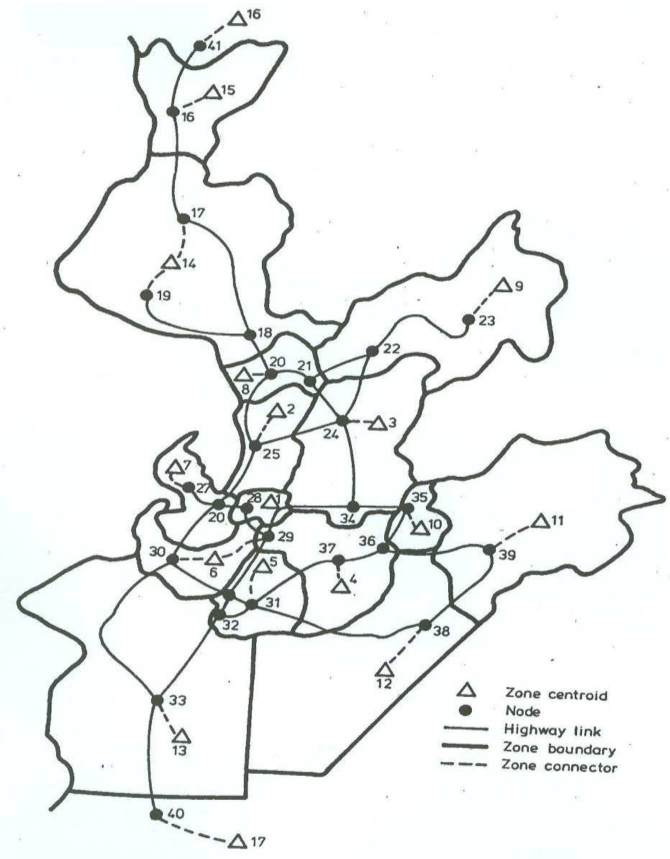
Necessary input for the assignment:

- 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.

AAiT

Trip Assignment Cont ….





Trip Assignment Cont…

There are two broad assignment models:

- *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.
    - The all-or-nothing (AON) assignment
- *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.
    - User equilibrium assignment (UE), system optimum assignment (SO)

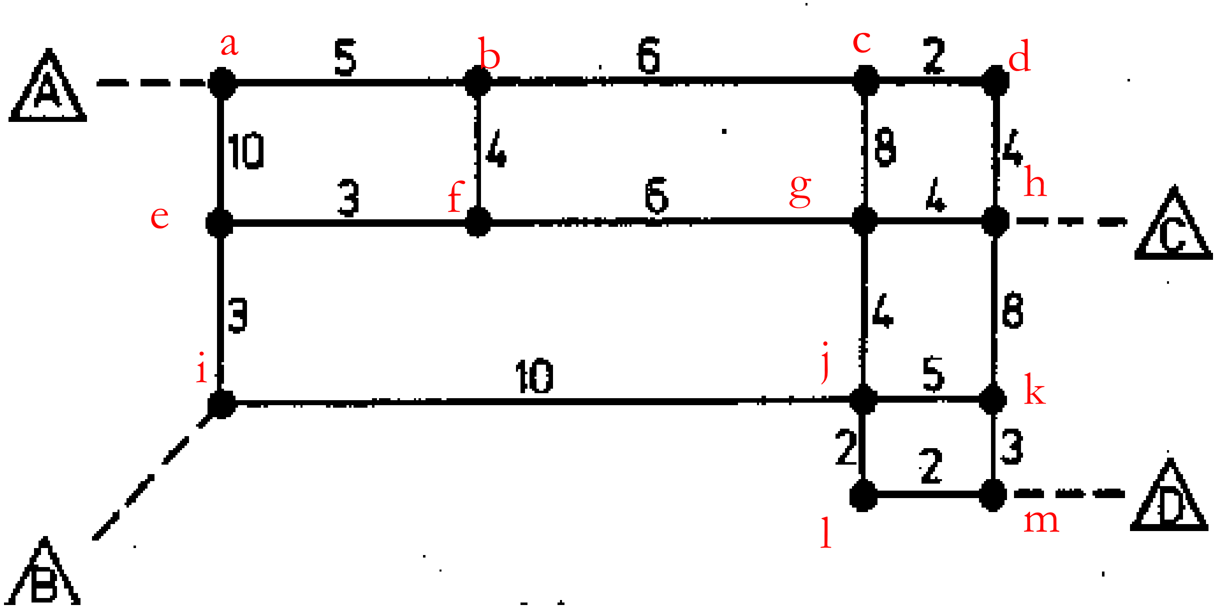
Trip Assignment Cont…

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.

Example 11

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.

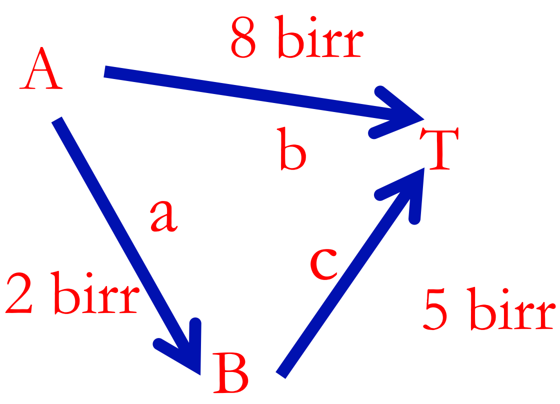


Trip matrix:

A-C = 400
A-D = 200
B-C = 300
B-D = 100`

Quiz 2

Assign Using AON assignment find out the flow on links a, b, & c.

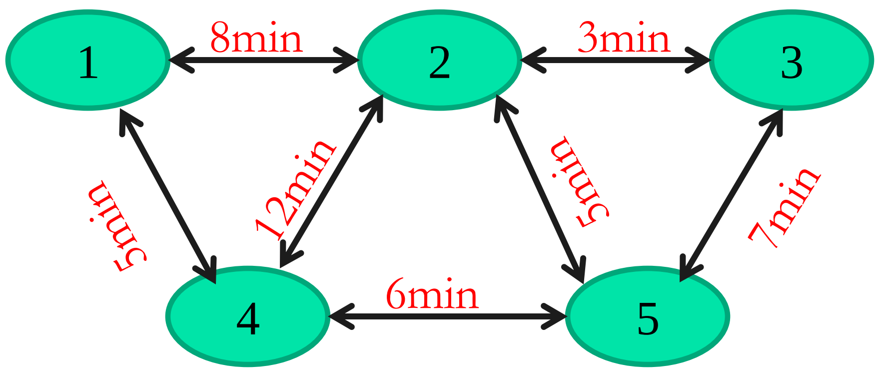


	T
A	500
B	900

Exercise

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.

Zone	1	2	3	4	5
1	-	100	100	200	150
2	400	-	200	500	500
3	200	100	-	100	150
4	200	150	300	-	400
5	200	100	50	350	-



Trip Assignment Cont…

User Equilibrium Assignment

- Based on War drop'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.

$$f_k(c_k - u) = 0 : \forall k \qquad c_k - u >= 0 : \forall k$$

where f_k is the flow on path k , c_k is the travel cost on path , 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 $f_k = 0$.

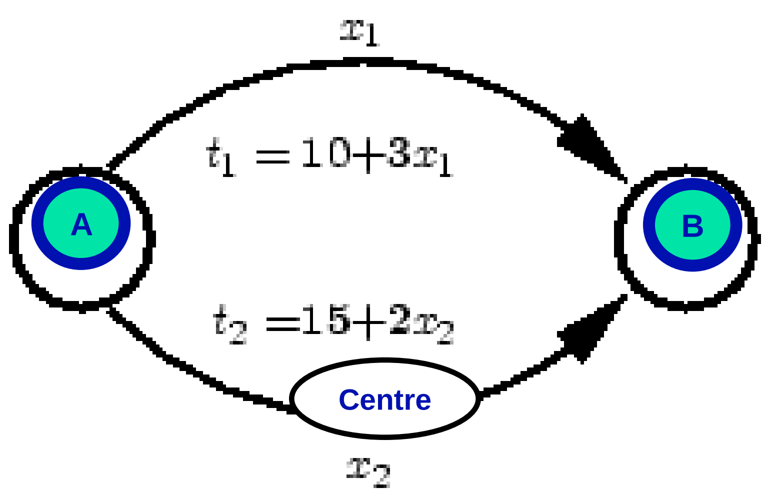
Trip Assignment Cont…

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.

Example 12

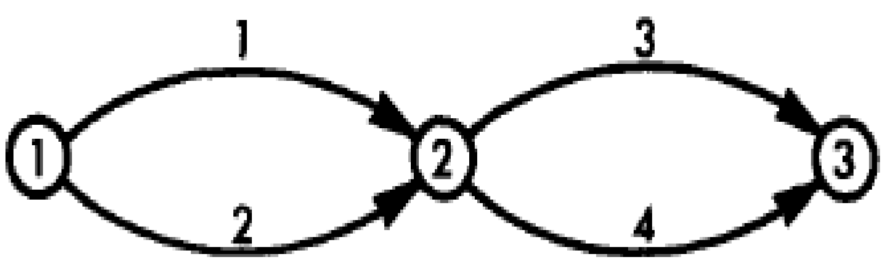
Let us suppose a case where travel time is not a function of flow as shown in other words it is constant as shown in the figure below for q_{12} = 1000vhl



Exercise

Find the system-optimizing flow pattern for the network shown in the figure below. Compare this flow pattern to the UE flow pattern and comment on the difference. The link performance functions are given below and the total trip between node 1 and 3 is 4 units.

$$t_1 = 2 + x_1^2$$
$$t_2 = 3 + x_2$$
$$t_3 = 1 + 3x_3^2$$
$$t_4 = 2 + 4x_4$$



Trip Assignment Cont…

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…

The indicator is often used to measure how close a solution is to Wardrop's equilibrium:

$$\delta = \frac{\sum_{ijr} T_{ijr}(C_{ijr} - C^*_{ij})}{\sum_{ij} T_{ij} C^*_{ij}}$$

Convergence criteria

Where

(Cijr – Cij*) excess cost between i & j relative to the minimum (Cij*)

Trip Assignment Cont…

Incremental Loading

- Parts of the matrix are assigned in each iteration. E.g.: 4 iterations: 40%, 30%, 20% or 10%, alternatively 25% at each iteration
- Does not necessarily converge to Wardrop's equilibrium !!
- Suffers from the limitation that once a flow has been assigned to a link it is not removed and loaded onto another one
  - *In other words, if one of the initial iterations assigns too much flow on a link for Wardrop's equilibrium to be met, then the algorithm will not converge to the correct solution.*

Trip Assignment Cont…

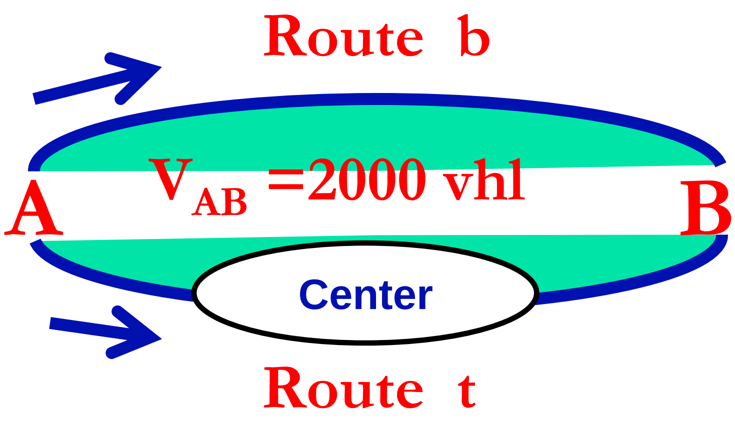
Incremental Loading

1. Select initial set of link costs (free flow/warm start)
   - set all flows to 0
   - partition trip matrix
2. build set of minimum cost trees for all origins
3. load first (next) matrix segment using AON
4. calculate new set of link costs
5. whole matrix assigned?
   - if yes, END
   - if no, go to (3)

Example 13

$T_t = 10 + 0.025V$

$T_b = 15 + 0.005V$



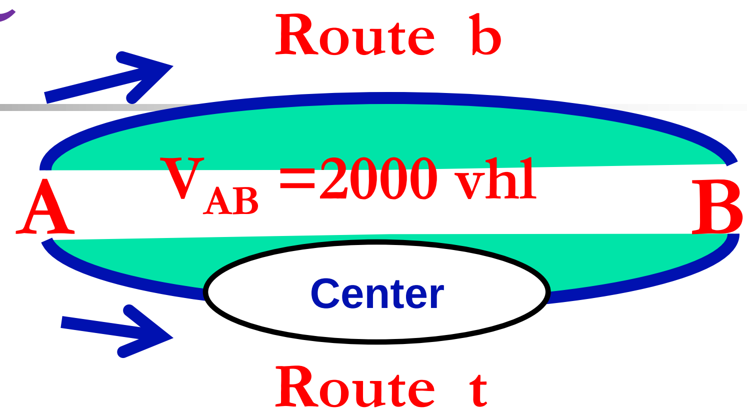
Assign the trips in each route by Incremental loading.

Use 4 iterations (Assign 25% of trips at each)

Class Exercise

$T_t = 10 + 0.025V$

$T_b = 15 + 0.005V$



Assign the trips in each route,
Use 4 iterations (Assign 40%, 30%, 20% &10% respectively), Does the solution converge to the equilibrium solution?

Trip Assignment Cont…

Successive Average

1. Select initial set of link costs (free flow/warm start)
   - get set of link costs (most likely free flow)
   - set all link volumes to 0,
   - set iteration number (n = 0)
2. Set n = n + 1
3. Update the minimum cost trees
4. All-or-nothing assignment, F_a^n
5. Update the link flows

$$V_a^n = \frac{n-1}{n} \cdot V_a^{n-1} + \frac{1}{n} \cdot F_a^n$$

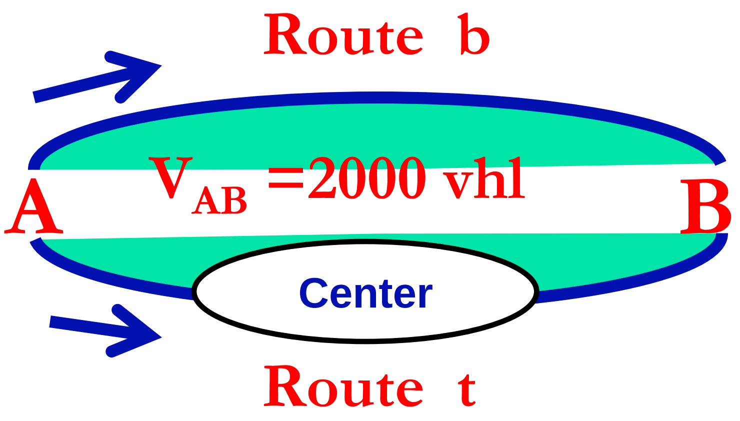
1. Update link costs given Van
2. Check for convergence; if no convergence then goes to step 2.

AAiT

Example 14

$T_t = 10 + 0.025V$

$T_b = 15 + 0.005V$



Assign the trips in each route by successive averages.

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.

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

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-makers may wish to look at a broader range of criteria than economic efficiency.

Impact Assessment

Categories of impacts	Method of assessment
Monetized impacts:	➢ Cost Benefit Analysis ➢ Net present value
Non-monetized impacts:	The significance of impacts is assessed by combining the value of the asset and the magnitude of the impacts. Significance can range from four pluses to four minuses + + + + - - - -

AAiT

Evaluation and Economic 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

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.

$$NPV = \sum_{i=1}^{t} \left[\frac{R_i - C_i}{(1+r)^i} \right]$$

AAiT

Addis Ababa Institute of Technology

Addis Ababa University

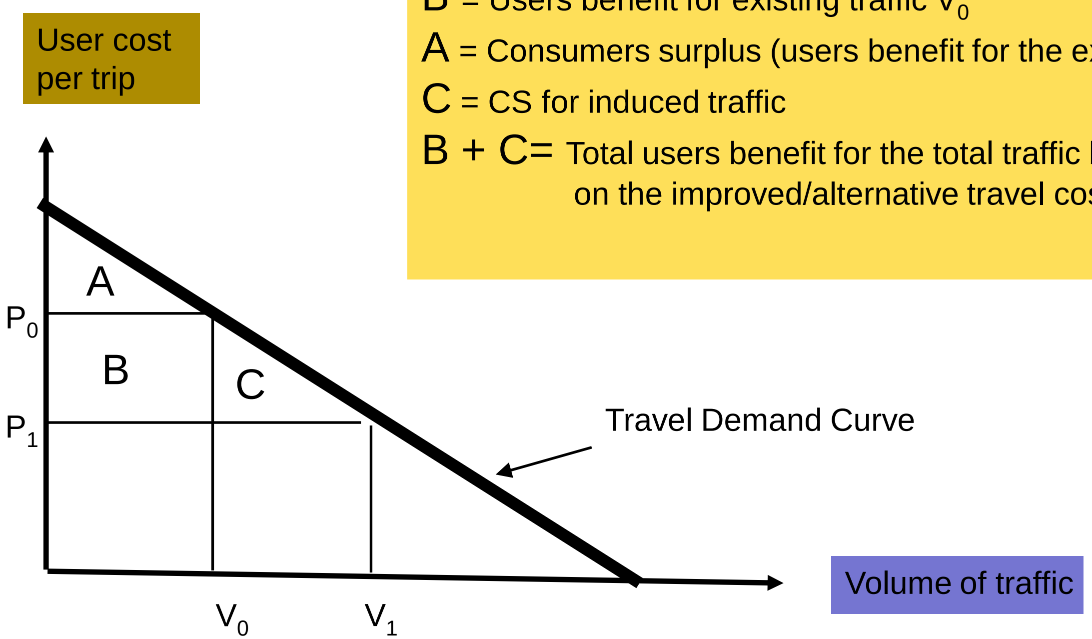
Consumers Surplus (Users Benefit)

B = Users benefit for existing traffic V_0

A = Consumers surplus (users benefit for the existing facility) for V_0

C = CS for induced traffic

B + C= Total users benefit for the total traffic based on the improved/alternative travel cost P1



Cost-Benefit Analysis Cont…

- **Net Present Value** = Benefit – Cost

  (NPV) = B- C

- Benefit Cost Ratio = Benefit / Cost

  (BCR)= 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),

$$\sum_{1=1}^{n} \frac{1}{(1+r)^n} = \frac{(1+r)^n - 1}{r(1+r)^n}$$

Cost-Benefit Analysis Cont…

- Internal Rate of Return (IROR)
  - ✓ Make the net present value at the given rate should be zero.
  - ✓ Calculate the rate (i) and compare with the given rate. (r)

Determine i, (P/A-i-n) from $NPV_i=0$

If r<i accept if not , don't accept

AAiT
Addis Ababa Institute of Technology
Addis Ababa University

Cost-Benefit Analysis Cont…

- Equivalent Uniform Annual Value (EUAV)
  - ✓ Calculate the total sum of the benefits and the initial investment of the project which is multiply by (A/P-i-n).

$$(A/P\text{-}i\text{-}n) = \frac{r(1+r)^{n}}{(1+r)^{n-1}}$$

  - ✓ If The result is (+ve) accept otherwise not.

Example 15

Alter.	construction cost	Annual saving in accident	Annual travel trip benefit	Annual opperating saving	Annual add. Maintenance cost
I	185,000.00	5,000.00	3,000.00	500.00	1,500.00
II	220,000.00	5,000.00	6,500.00	500.00	2,500.00
III	310,000.00	7,000.00	6,000.00	2,800.00	3,000.00

Econonic life = 50yrs

Discount rate= 5%

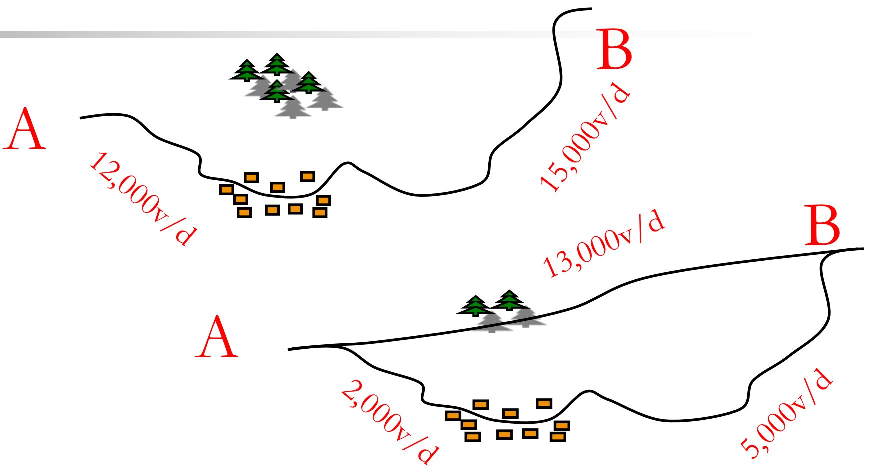
All are equal rate in every year

All costs are in Birr

Rank the given alternatives by using

- NPV
- B/C
- IROR
- EUAV

Class Exercise



- 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.

Determine the user benefit.

By using (NPV, B/C,EUA and IRR your analysis should this new road be built or not?

AAiT

QUESTIONS?