



TRANSPORTATION ENGINEERING AND PLANNING (110 401367) SPRING 2019-2020

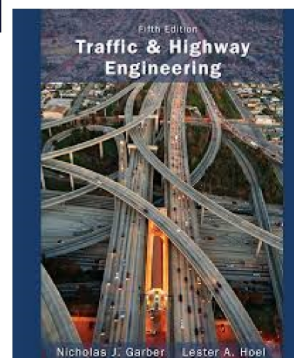
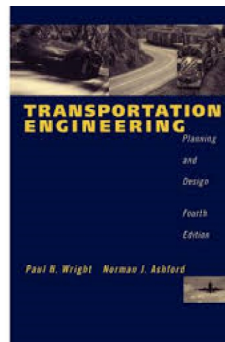
Lecture. No. 1 Introduction of Transportation Systems

Dr. Hamza Alkuime

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Textbook

- Paul H. Wright, Norman J. Ashford and Robert J. Stammer, **Transportation Engineering Planning and Design**, Fourth Edition, John Wiley and Sons, 1998
- Nicholas Garber and Lester Hoel, **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015



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Major Topics To Be Covered



Topics	No. of Weeks	Contact hours*
1. Introduction to transportation systems	1/3	1
2. Transportation planning	1	3
3. Demand forecasting using 4 steps modeling	4	12
4. Engineering economy in transportation	3	9
5. Evaluation of transportation alternatives	2	6
6. Urban mass transit systems	3 2/3	11
7. Airports	1	3
Total	15	45

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Grading Plan



- 1st Exam (25 Points)
- 2nd Exam (25 Points)
- Quizzes, Homework's and/or Participation (10 Points)
- Final exam (40 Points)

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General Notes



- The maximum allowed number of absentees from the course is **Four** classes.

–Exceeding these limits will lead to prevention from attending the final exam.

- Beware of **Plagiarism**: copying and handing in for credit someone else's work. Any plagiarism case will result in an automatic '**F**' for the course.

- **No MAKE-UP EXAMS**

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Class Rules



- No side talks, try to minimize distractions and feel free to discuss any matters with all of us. Everyone gets to be involved
- No use of e-devices (phones, Tablets, laptops, etc. (unless permitted)
- It is recommended to bring the course Textbook to access design charts, tables, equations, etc.
- Never handle the work of others
- Cheating will only get you into serious trouble

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Topic 1 : Introduction of Transportation Systems



References

- Paul H. Wright, Norman J. Ashford and Robert J. Stammer, **Transportation Engineering Planning and Design**, Fourth Edition, John Wiley and Sons, 1998
 ➤ [Chapter 1 : Introduction](#)
- Dušan Teodorović and Milan Janić , **Transportation Engineering: Theory, Practice and Modeling**,, 2017
 ➤ [Chapter 1 : Introduction](#)
- Animesh Das and Partha Chakroborty, **Principles of Transportation Engineering**, 6th edition, 2012
 ➤ [Chapter 1 : Introduction](#)

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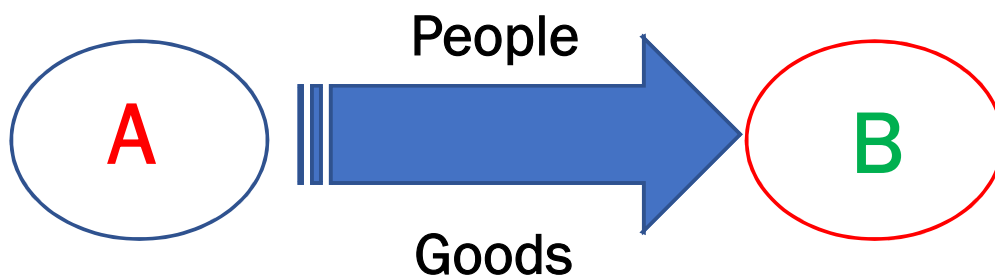
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Topic 1 : Introduction of Transportation Systems



Definition of Transportation

- The movement of people and goods from one location to another.



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Topic 1 : Introduction of Transportation Systems



Roles of Transportation in Society:

■ Economically

- Availability of goods and services
- Expansion of trade

■ Socially

- Affects employment opportunities

■ Environmentally

- Its pollution affects the air, water & land qualities which are dangerous to human, animal & plant lives.

■ Politically

- Increase the ability of the country to defend itself

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Topic 1 : Introduction of Transportation Systems



Transportation Engineering

- Transportation Engineering is a branch of the engineering that deals with planning, design, construction, operation, and management of *various transportation systems and their components*, to achieve a safe, efficient, convenient and economical movement of passengers and goods.

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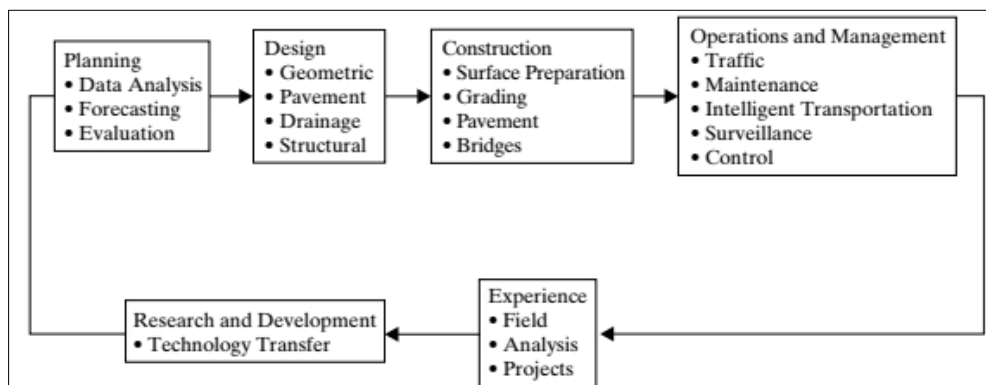
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Topic 1 : Introduction of Transportation Systems



Transportation Engineer

- The professional who is concerned with the planning, design, construction, operations, and management of a transportation system



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Topic 1 : Introduction of Transportation Systems



Transportation System

a facility consisting of the means and equipment necessary for the movement of passengers or/and goods

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Topic 1 : Introduction of Transportation Systems



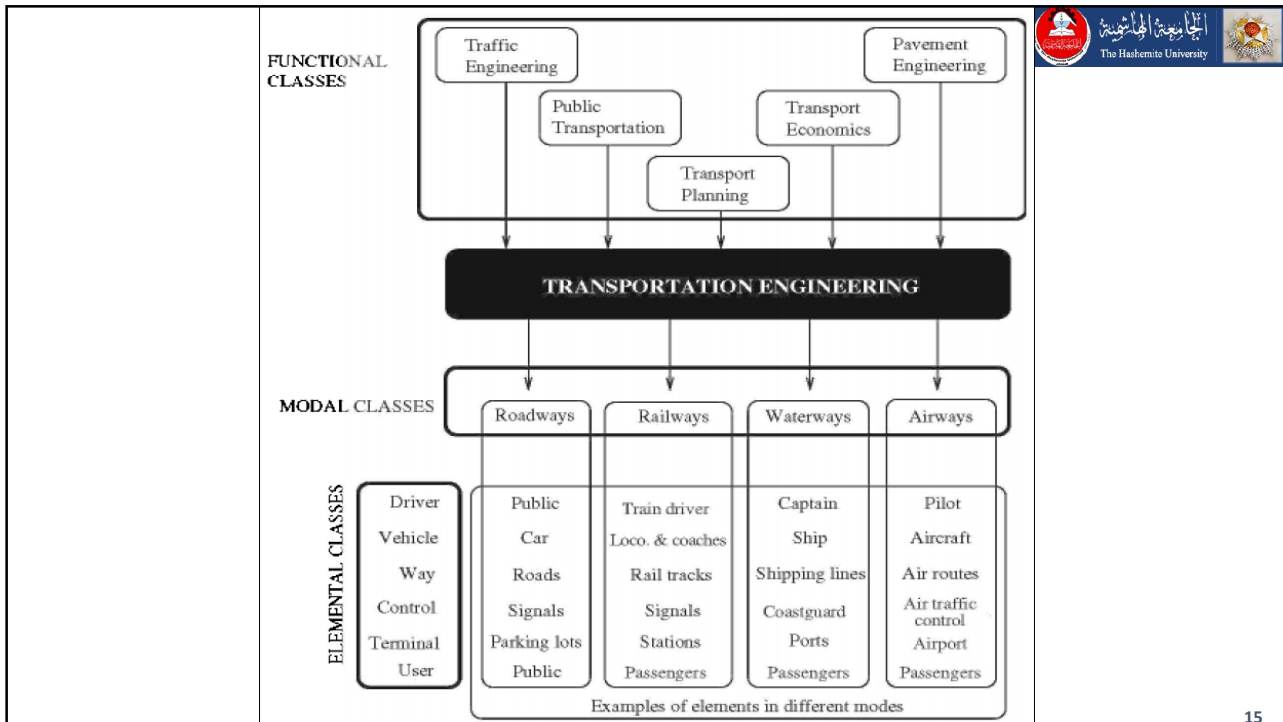
Classification of transportation studies

■ Transportation engineering can be classified according to :

- *Modal (mode of travel) classification*
- *Element classification*
- *Functional classification*

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Topic 1 : Introduction of Transportation Systems

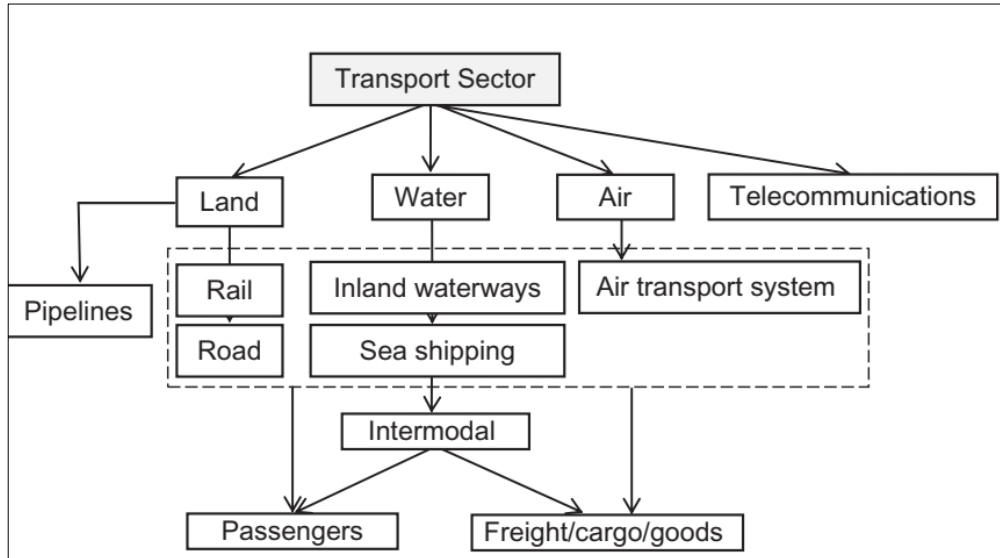
Modal classification

- Classification of transportation system based on mode of travel including
 - Walking, Car, Bus, Train, Ship, and Aircraft .etc
- Or it can be grouped to classes of modes which use a particular **"surface"** including
 - Land
 - Water
 - Air
 - Pipeline
 - Telecommunication

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Topic 1 : Introduction of Transportation Systems

Modal classification

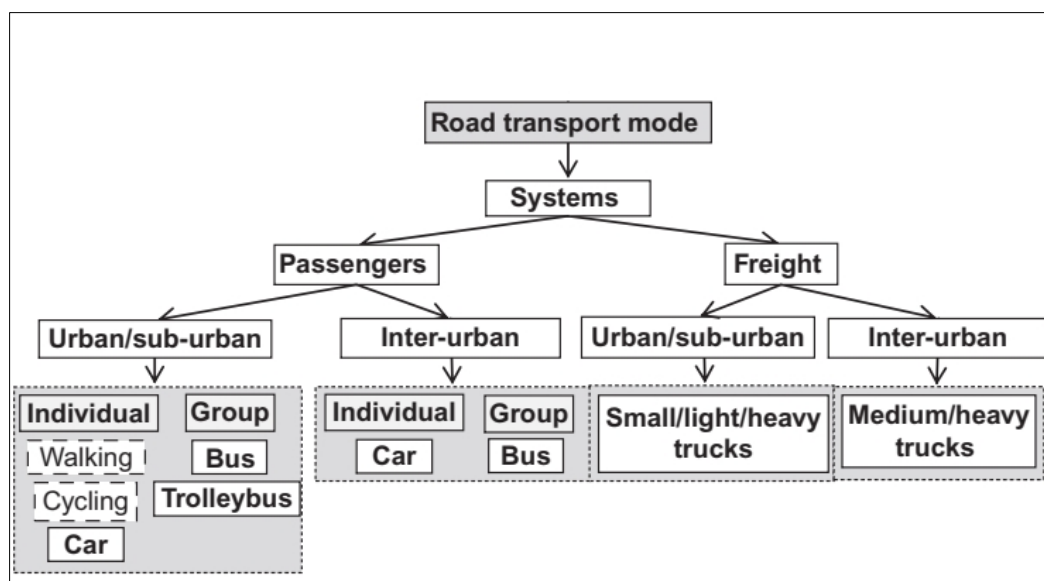


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Topic 1 : Introduction of Transportation Systems

Modal classification



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Topic 1 : Introduction of Transportation Systems



Trolleybus

- Trolley is an electric bus that draws power from dual overhead wires



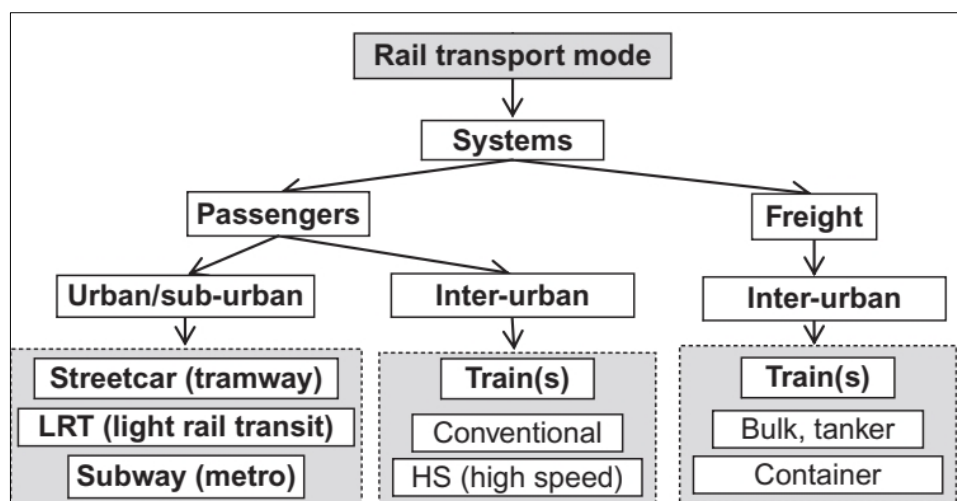
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Modal classification



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Tramway



High speed train



Bulk train

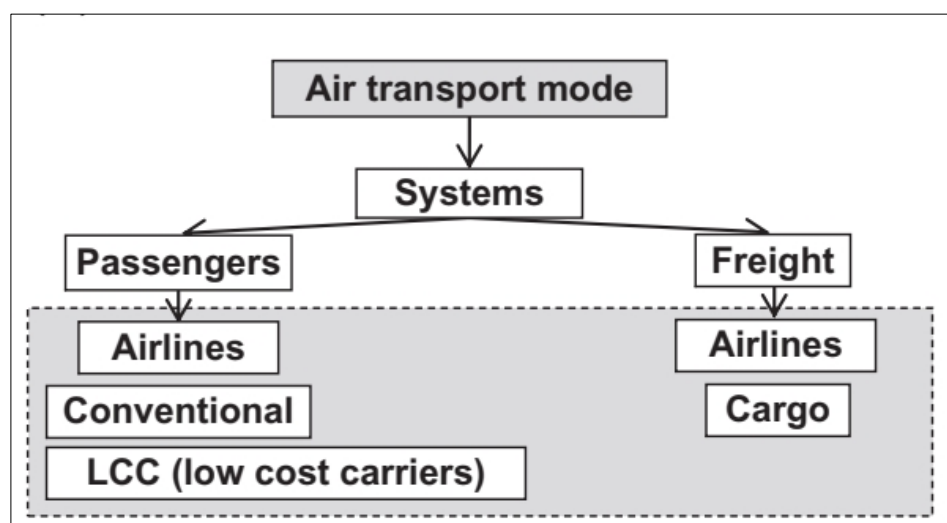
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Modal classification

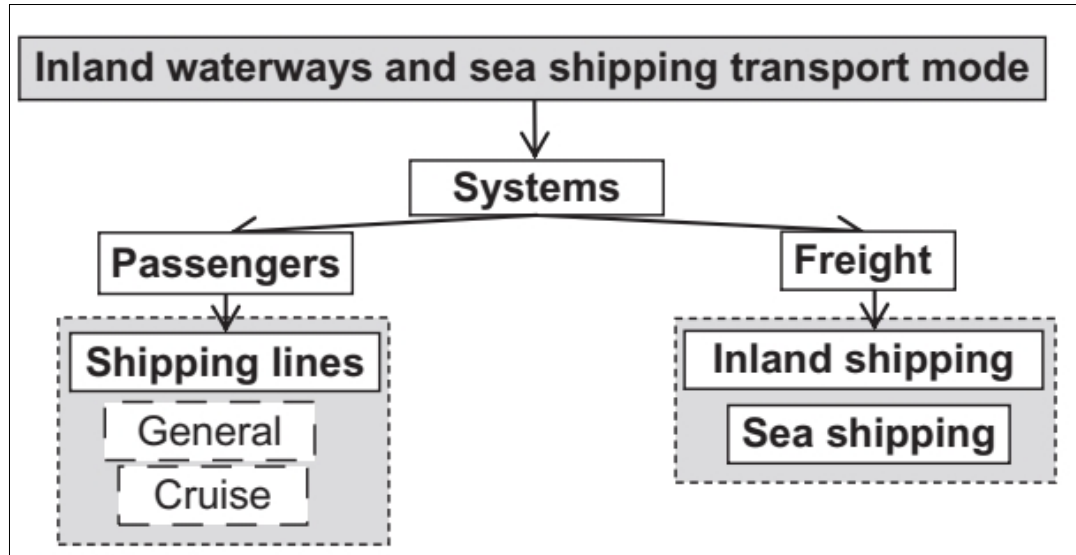


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Topic 1 : Introduction of Transportation Systems

Modal classification



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Topic 1 : Introduction of Transportation Systems



Inland shipping



Sea shipping



Cruise

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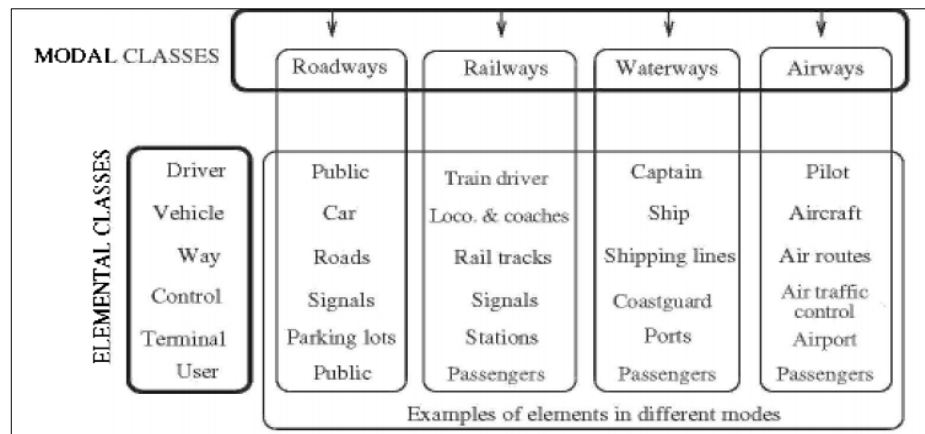
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Topic 1 : Introduction of Transportation Systems



Element classification

- Classification in terms of the basic elements which constitute any mode of transport



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Topic 1 : Introduction of Transportation Systems



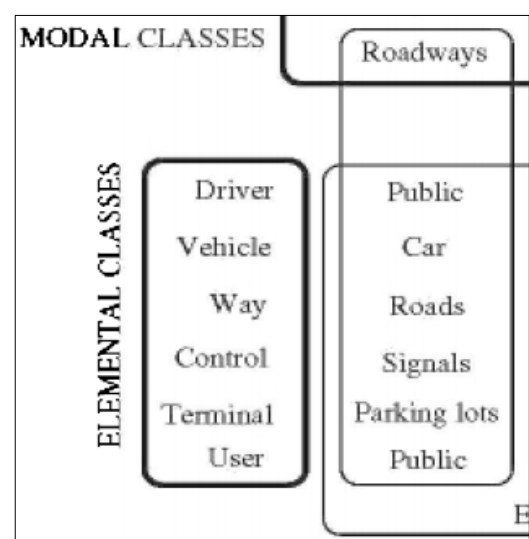
Element classification

1. Driver

- The person control the vehicle used in the selected mode of transportation

2. Vehicle

- The vehicle which are used in transportation



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Topic 1 : Introduction of Transportation Systems



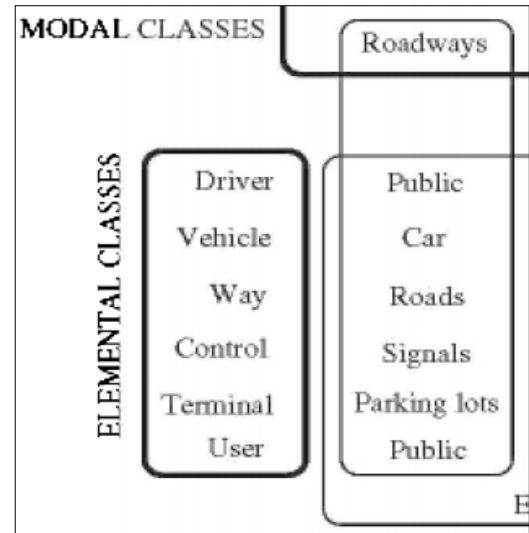
Element classification

3. Travel way

- A specified path which is either constructed or charted

4. Control

- System levels controls which are imposed on the movement of the vehicles



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Topic 1 : Introduction of Transportation Systems



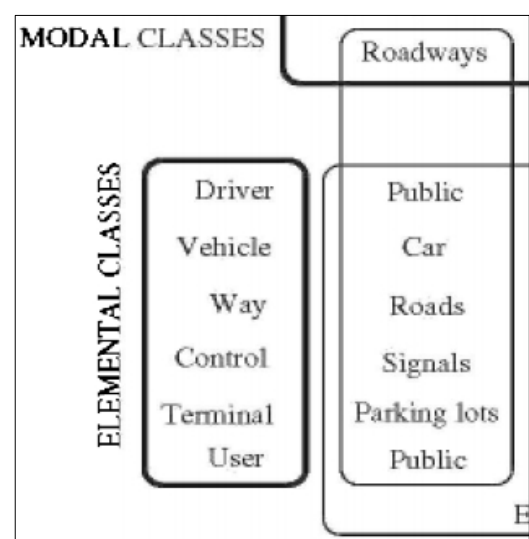
Element classification

3. Terminal

- A location where a vehicle of a mode stop for various reasons

4. User

- Public at large for passenger transport
- Organization for goods transport



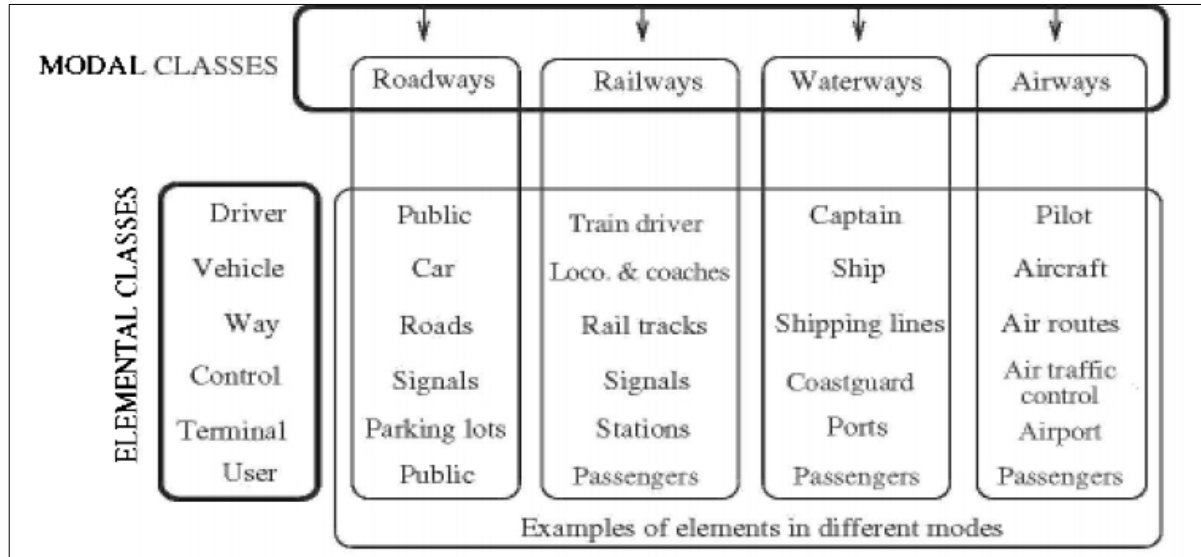
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Topic 1 : Introduction of Transportation Systems



Element classification



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Topic 1 : Introduction of Transportation Systems



Functional classification

Functionally, the transportation engineering can be divided into :

1. Traffic engineering

- Deals with *analysis, design, and operation of transportation facilities* used by different modes of transportation

2. Pavement engineering

- Deals with *structural analysis and design of the way* used by different modes of transportation

3. Public transportation

- Deals with *analysis, design, and operation of public transportation facilities*

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Topic 1 : Introduction of Transportation Systems



Functional classification

4. Transport planning

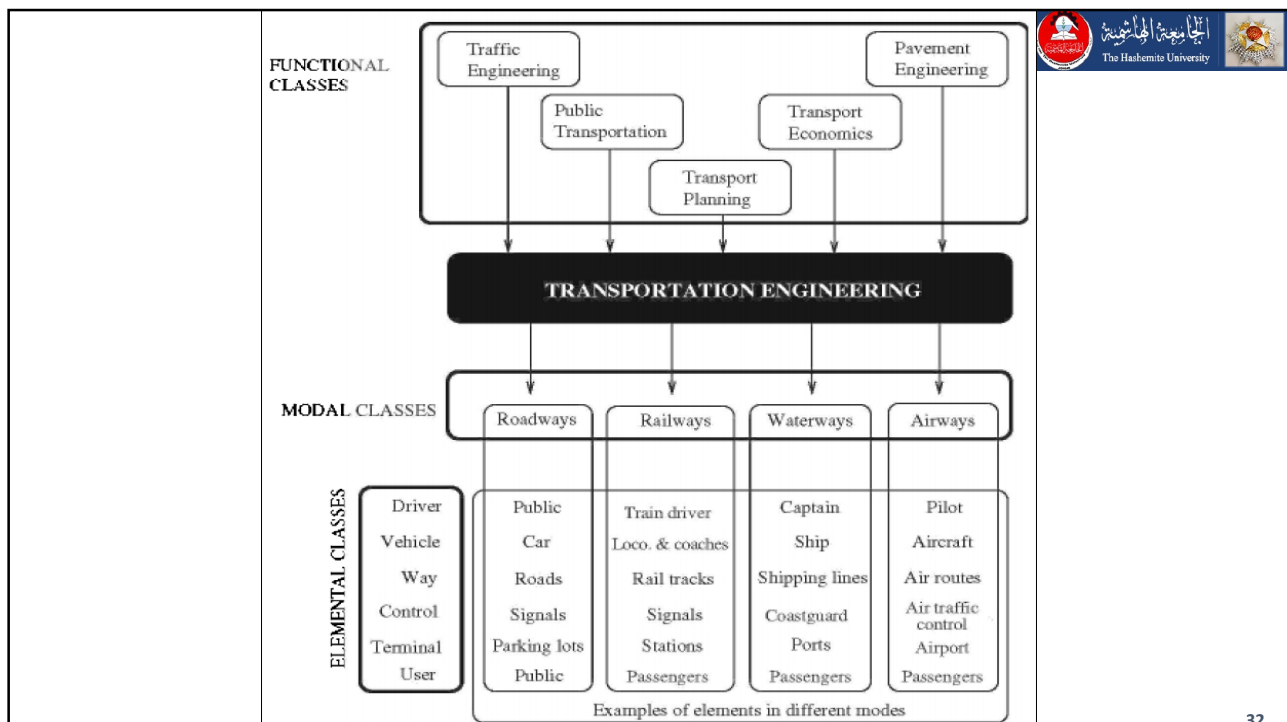
- Deals with **planning transportation facilities** with will be able to **meet the present and the future needs** in a **sustainable manner**

5. Transport economics

- Deals with **various economic costs and benefits** of **building and operating different transportation facilities**

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References



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- <https://www.urban-transport-magazine.com/en/sydney-more-light-rail-to-come/>
- <http://www.railsystem.net/light-rail-transit/>
- <https://www.google.com/url?sa=i&source=imgres&cd=&ved=2ahUKEwj3dHd5aPnAhUEKuWKHWW4D28Qjhx6BAGBEAI&url=https%3A%2F%2Fasia.nikkei.com%2Fbusiness%2Fbusiness-deals%2Fmalaysia-high-speed-rail-cancellation-a-blow-to-japan-s-shinkansen-exports&psig=AOvVaw05wlzLCRNGISKm7VfZHEX-&ust=1580214996124263>
- <https://www.shutterstock.com/image-photo/rail-cargo-train-bulk-focus-564761236>

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References



- <https://www.swzmaritime.nl/news/2018/11/06/study-says-inland-shipping-should-start-hydrogen-demonstration-projects/>
- <http://lahargroup.com/sea-freight.html>

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TRANSPORTATION ENGINEERING AND PLANNING (110 401367)

SPRING 2019-2020

Dr. Hamza Alkuime

January 29, 2020

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Topic 2 : Transportation planning

References

- Nicholas Garber and Lester Hoel , **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015

➤ [Chapter 11 : The Transportation planning process](#)



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Definition of transportation planning

- It is a methodological **process** of **preparing physical facilities and services of modes** for transportation needs
- It is **not intended** to **furnish a decision** or to **give a single result that must be followed**, although it can do so in relatively simple situations.
- It is intended to provide the **appropriate information** to those who will be affected and those responsible for deciding whether the transportation project should go forward.



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Transportation planning is needed because of



- Increased demand of new facilities and services
- Huge investments in transportation projects
- Land use development
- Many alternatives exist for any transportation project

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Basic elements of transportation planning



The transportation planning process comprises seven basic elements,

1. Situation definition
2. Problem definition
3. Search for solutions
4. Analysis of performance
5. Evaluation of alternatives
6. Choice of project
7. Specification and construction

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Basic elements of transportation planning



The elements are :

- Interrelated
- Not necessarily carried out sequentially.
- The information acquired in one phase of the process may be helpful in some earlier or later phase, so there is a continuity of effort that should eventually result in a decision

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Basic elements of transportation planning



1. Situation Definition

Involves **all of the activities** required to understand **the situation** that gave rise to the perceived need for a transportation improvement

- ❖ The present system is **analyzed**, and its **characteristics are described**
- ❖ **Information** about the surrounding **area**, its **people**, and their **travel habits** may be obtained.
- ❖ **Previous reports** and studies that may be relevant to the present situation are reviewed

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Basic elements of transportation planning



2. Problem Definition:

- To **describe** the problem in terms of the **objectives** to be accomplished by the project
- To **translate** those objectives into **criteria** that that can be used to quantify the extent to which a proposed transportation project will achieve the stated objective (measures of effectiveness).
- Identified the characteristics of an acceptable system
 - ❖ Constraints placed on the project (e.g. physical limitation [presence of other structures])
 - ❖ Design standards (e.g., bridge width, clearances)

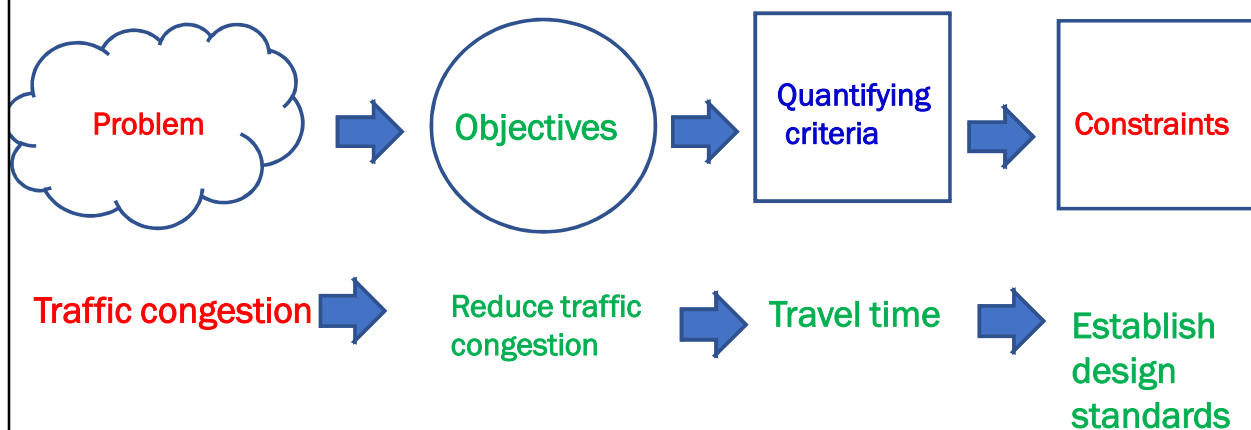
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Basic elements of transportation planning



2. Problem Definition:



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Basic elements of transportation planning



3. Search for Solutions (Idea-generating phase)

- **Consideration** is given to a variety of ideas, designs, locations, and system configurations that might provide solutions to the problem

- **Includes**

- *Preliminary feasibility studies*, which might narrow the range of choices to those that appear most promising.
- Some data gathering, field testing, and cost estimating may be necessary at this stage to determine the practicality and financial feasibility of the alternatives being proposed

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Basic elements of transportation planning



4. Analysis of Performance:

- To estimate performance of proposed alternatives **under present and future conditions**.
- Determination of the **investment cost** of building the transportation project, as well as **annual costs** for **maintenance and operation**.
- Involves the **use of mathematical models** for estimating travel demand.
- Determine use of the system (such as **trip length**, **travel by time of day**, and **vehicle occupancy**)
- **Environmental effects** are estimated

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Basic elements of transportation planning



3. Search for solutions (Idea-generating phase)

- *Consideration is given to a variety of ideas, designs, locations, and system configurations that might provide solutions to the problem*
- *Includes preliminary feasibility studies, which might narrow the range of choices to those that appear most promising.*
- *Some data gathering, field testing, and cost estimating may be necessary at this stage to determine the practicality and financial feasibility of the alternatives being proposed*

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Basic elements of transportation planning



5. Evaluation of Alternatives:

- **How well each alternative will achieve the objectives of the project as defined by the criteria.**
 - *Performance data produced in the analysis phase are used to compute the benefits and costs that will result if the project is selected.*

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Basic elements of transportation planning



6. Choice of Project:

- It is made after considering all the factors involved.
- Whether the factors were a single criterion such as cost (select the lower cost)
- In more complex projects other factors might be considered, selection is based on how the results are perceived by those involved in decision-making

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Basic elements of transportation planning



7. Specifications and construction

- Detailed design phase in which each of the components of the facility is specified.
- This involves its physical location, geometric dimensions, and structural configuration.

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Basic elements of transportation planning



Summary

Situation definition	Inventory transportation facilities, Measure travel patterns, Review prior studies
Problem definition	Define objectives (e.g., Reduce travel time), Establish criteria (e.g., Average delay time), Define constraints, Establish design standards
Search for solutions	Consider options (e.g., locations and types, structure needs, environmental considerations)
Analysis of performance	For each option, determine cost, traffic flow, impacts
Evaluation of alternatives	Determine values for the criteria set for evaluation (e.g., benefits vs. cost, cost-effectiveness, etc)
Choice of project	Consider factors involved (e.g., goal attainability, political judgment, environmental impact, etc.)
Specification and construction	Once an alternative is chosen, design necessary elements of the facility and create construction plans

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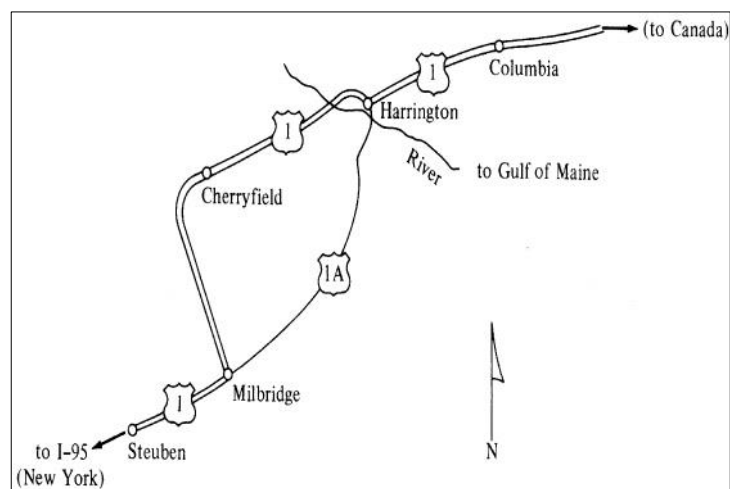
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Basic elements of transportation planning



Example : Planning the relocation of a rural road

- This example is based on a study completed by the engineering firm, Edwards and Kelsey



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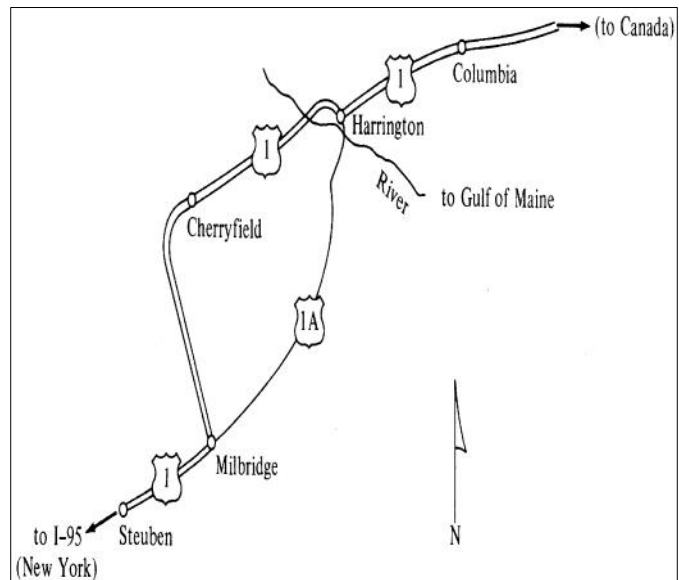
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 1- Situation definition

- The project is a proposed relocation or reconstruction of 3.3 miles of U.S. 1A located in the coastal town of Harrington, Maine.
- The town of Harrington has 553 residents, of whom 420 live within the study area and 350 live in the town center



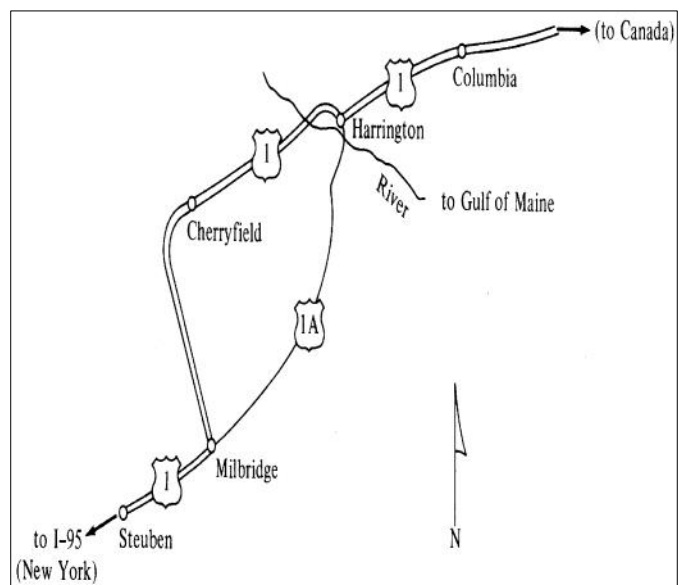
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 1- Situation definition

- The town of Harrington has 553 residents, of whom 420 live within the study area and 350 live in the town center
- Most of the town's industry consists of agriculture or fishing, so a realignment of the road that damages the environment would also affect the town's livelihood



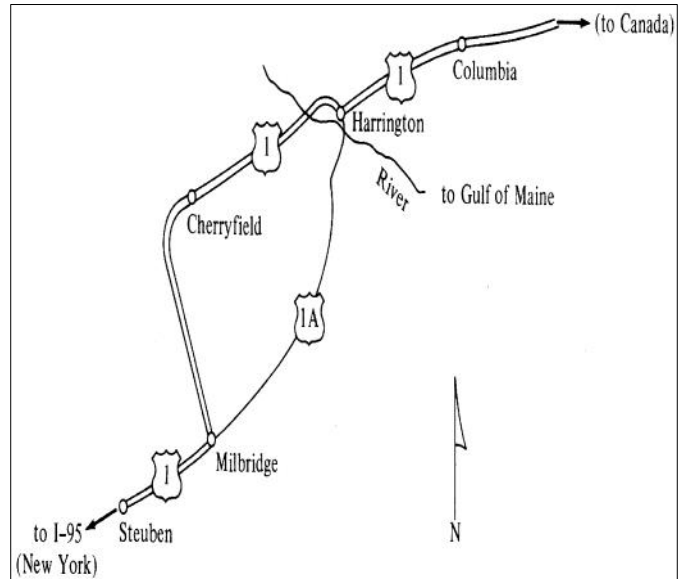
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 1- Situation definition

- Most of the town's industry consists of agriculture or fishing, so a realignment of the road that damages the environment would also affect the town's livelihood
- The average daily traffic is 2620 vehicles/day, of which 69 percent represent through traffic and 31 percent represent local traffic



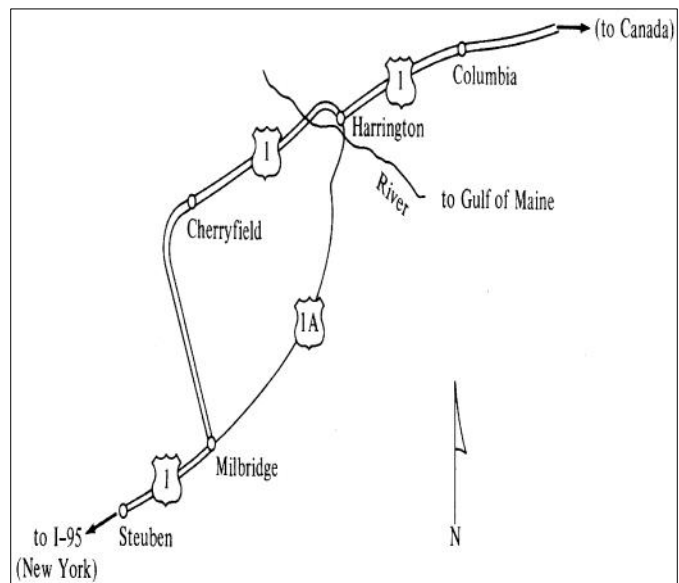
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 2- Problem definition

- Problems
 - High accident rate on 1A route
 - Low level of service for through traffic
- Objective
 - Reduce the high accident rate on this road
 - Improve the level of service for through traffic by increasing the average speed on the relocated highway.



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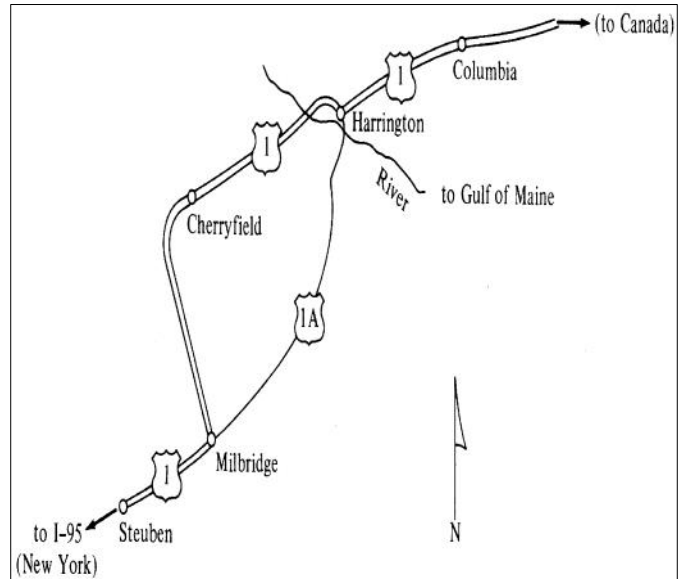
Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 2- Problem definition

■ Measures of effectiveness

- Accident rate
- Travel time
- Construction cost
- changes in noise levels and air quality
- Number of businesses and residences that would be displaced



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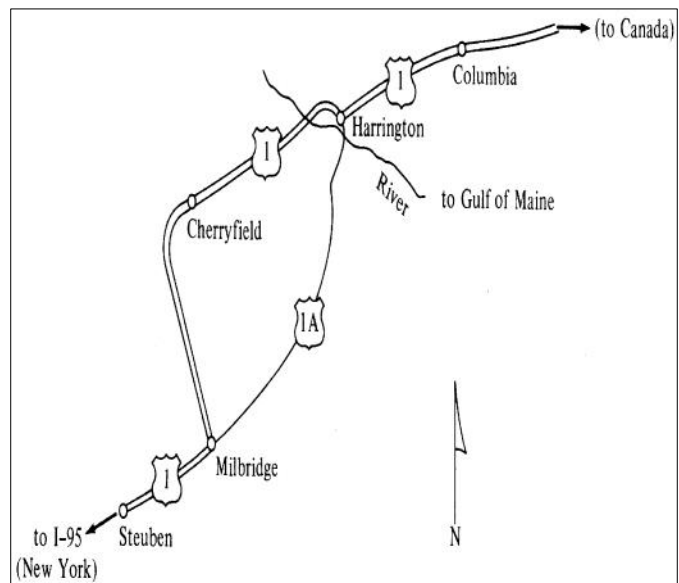
Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 2- Problem definition

■ Measures of effectiveness

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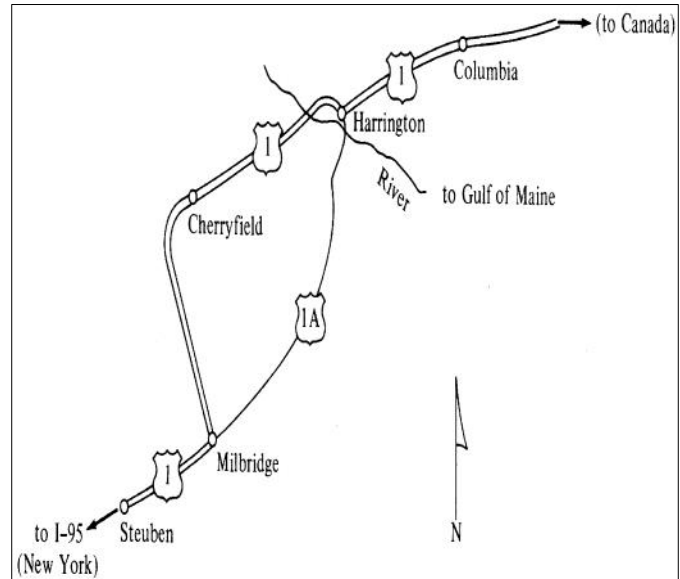
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 3- Search for solutions

- **Four alternative routes were identified**

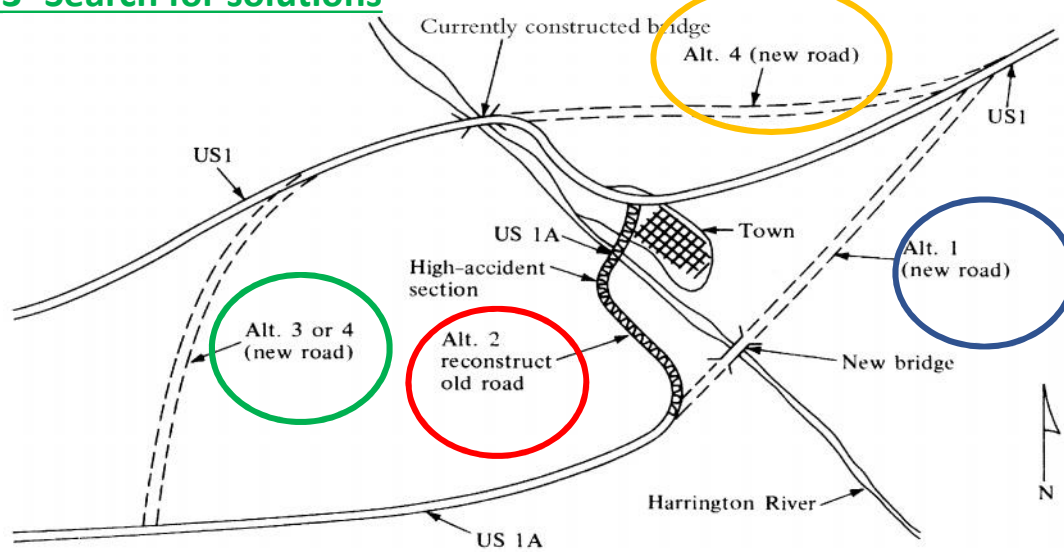


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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 3- Search for solutions



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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 4- Analysis of performance

Criteria	Alternatives				
	0	1	2	3	4
Speed (mi/h)	25	55	30	30	55
Distance (mi)	3.7	3.2	3.8	3.8	3.7
Travel time (min)	8.9	3.5	7.6	7.6	4.0
Accident factor (Relative to statewide average)	4	1.2	3.5	2.5	0.6
Construction cost (\$ million)	0	1.50	1.58	1.18	1.54
Residences displaced	0	0	7	3	0
City traffic					
Present	2620	1400	2620	2520	1250
Future (20 years)	4350	2325	4350	4180	2075
Air quality ($\mu\text{g}/\text{m}^3$ CO)	825	306	825	536	386
Noise (dBA)	73	70	73	73	70
Tax loss	None	Slight	High	Moderate	Slight
Trees removed (acres)	None	Slight	Slight	25	28
Runoff	None	Some	Some	Much	Much

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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 4- Analysis of performance

Table 11.2 Ranking of Alternatives

Criterion/Alternative	Alternatives				
	0	1	2	3	4
Travel time	4	1	3	3	2
Accident factor	5	2	4	3	1
Cost	1	3	5	2	4
Residences displaced	1	1	3	2	1
Air quality	4	1	4	3	2
Noise	2	1	2	2	1
Tax loss	1	2	4	3	2
Trees removed	1	2	2	3	4
Runoff	1	2	2	3	3

Note: 1 = highest; 5 = lowest

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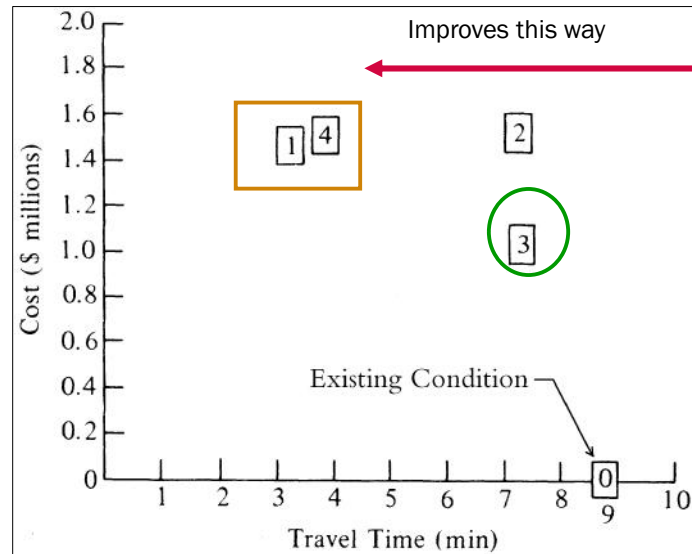
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Basic elements of transportation planning

Example : Planning the relocation of a rural road

Step 5 – Evaluation of alternatives

■ Travel time



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Topic 2 : Transportation planning

Example : Planning the relocation of a rural road

Step 6 – Choice of project

Step 7- Specification and construction

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TRANSPORTATION ENGINEERING AND PLANNING (110 401367) SPRING 2019-2020

Lecture. No. 3 Highway Classification

Dr. Hamza Alkuime

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Major Topics To Be Covered



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Topic 2 : Transportation planning



References

- Nicholas Garber and Lester Hoel , **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015
 - [Chapter 15: Geometric Design of Highway Facilities](#)
- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, **Highway Engineering: Planning, Design, and Operations**, 2016, Elsevier
 - [Chapter 15: Geometric Design of Highway Facilities](#)
- Federal Highway Administration (FHWA), **Highway Functional Classification Concepts, Criteria and Procedures**, 2013, (https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/)

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Highway Classification



Highways are **classified** according to :

- Their **location**.
- Their **respective functions** in terms of the **character of the service** they are providing.

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Highway Classification

Location classification



- Highways and streets are classified depending on the area in which they are located to :

- *Urban roads :*

- ❖ All highway facilities within urban areas.

- *Rural roads*

- ❖ The highway facilities outside urban areas

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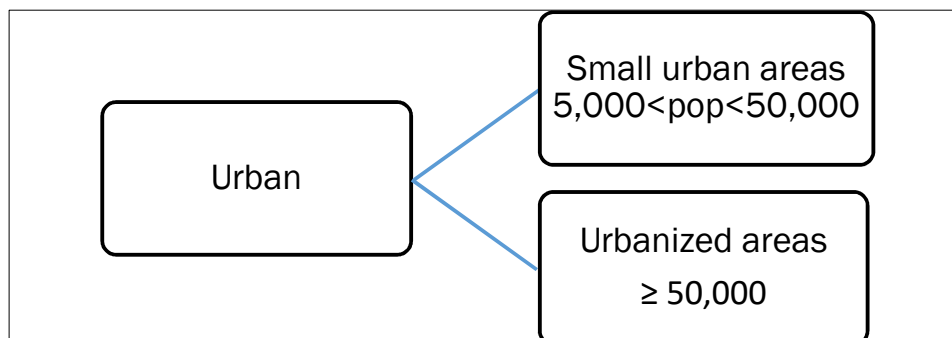
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Definition of Urban and Rural Areas

Urban areas



- Places within boundaries set by the responsible agencies/officials within the country having a **population of $\geq 5,000$**



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Definition of Urban and Rural Areas



Urban areas

Greater Tokyo Area, Japan, the world's **most populated urban area**, with about 38 million inhabitants



https://en.wikipedia.org/wiki/File:Ginza_area_at_dusk_from_Tokyo_Tower.jpg

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Definition of Urban and Rural Areas



Rural Areas:

- Those areas outside the boundaries of urban areas



<https://enacademic.com/dic.nsf/enwiki/11583337>

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Highway Location Classification

Urban and Rural

Urban and rural **functional systems** are classified **separately** since they have **different characteristics** with regards to:

- *Density and types of land use*
- *Density of street and highway networks*
- *Nature and travel patterns*

Highway Location Classification



Urban interstate



Rural two-lane highway

Highway Function Classification



- The **concept** of functional classification defines the role that a **particular roadway segment** plays in **serving this flow of traffic** through the network.
- Roadways are **assigned to one of several possible functional classifications** within a hierarchy **according to the character of travel service each roadway provides**.
- **Planners and engineers** use this hierarchy of roadways to **properly channel transportation movements** through a highway network **efficiently and cost effectively**

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Highway Function Classification



- Roadways serve two primary travel needs: **access to/egress** from specific locations and **travel mobility**
- While these two functions lie at opposite ends of the continuum of roadway function, **most roads provide some combination of each**

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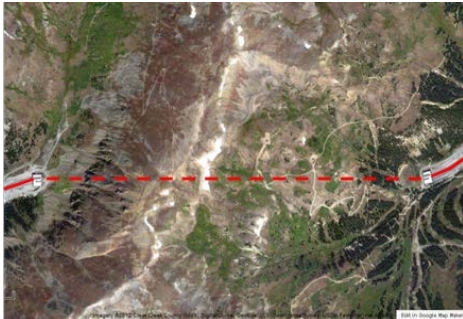
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Highway Functional Classification

Roads mobility and accessibility



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Aerial View of the Eisenhower (and Johnson) Tunnels along I-70, west of Denver, CO

There is no location that is immediately “**accessible**” to the roadway, thus the road roadway **entirely provides** “**mobility**”



View from Inside the Eisenhower Tunnel

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Highway Functional Classification

Roads mobility and accessibility



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The roadway **entirely provides** “**accessibility**” and offers almost nothing in terms of mobility

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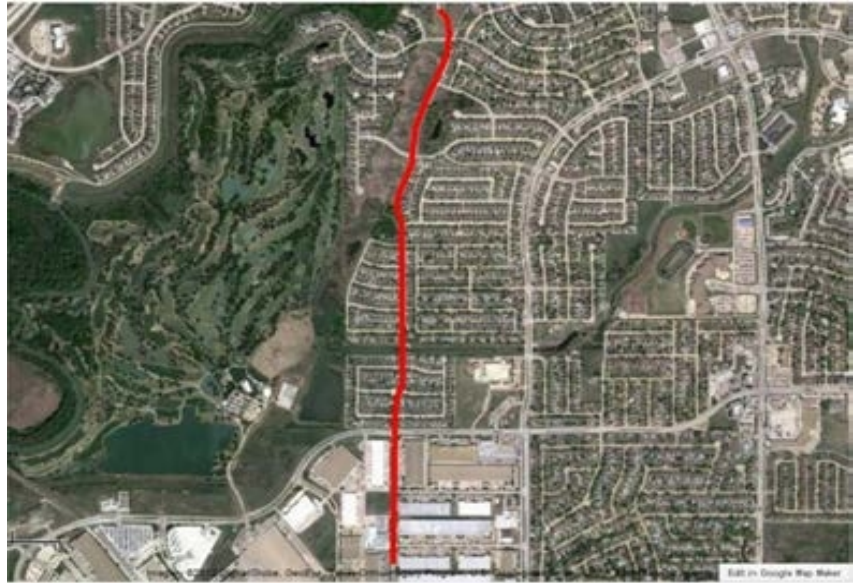
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Highway Functional Classification

Roads mobility and accessibility



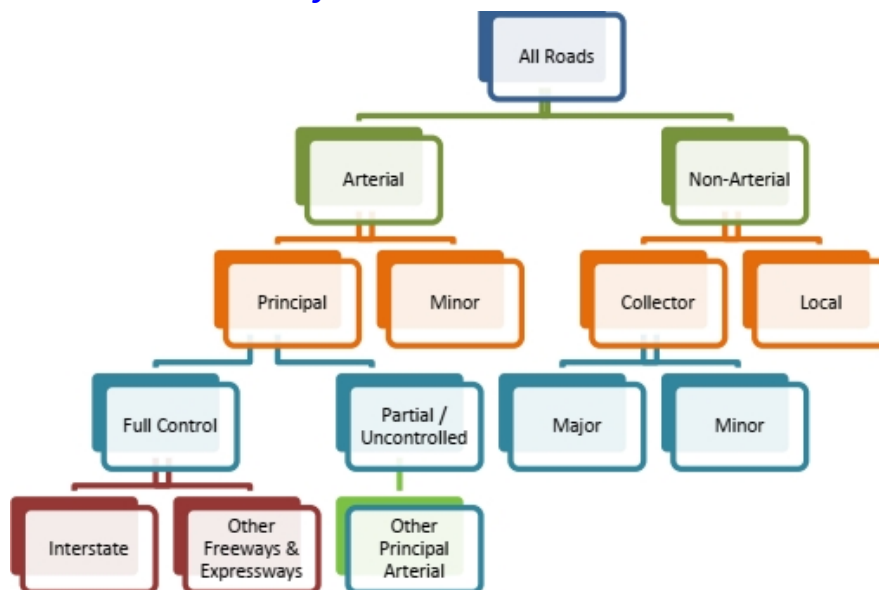
This roadway serves **both** **mobility needs** (the residents that live along the side streets that intersect **and land access needs** (there are both residential and commercial properties located along the roadway)



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Highway Functional Classification

Federal Functional Classification Decision Tree



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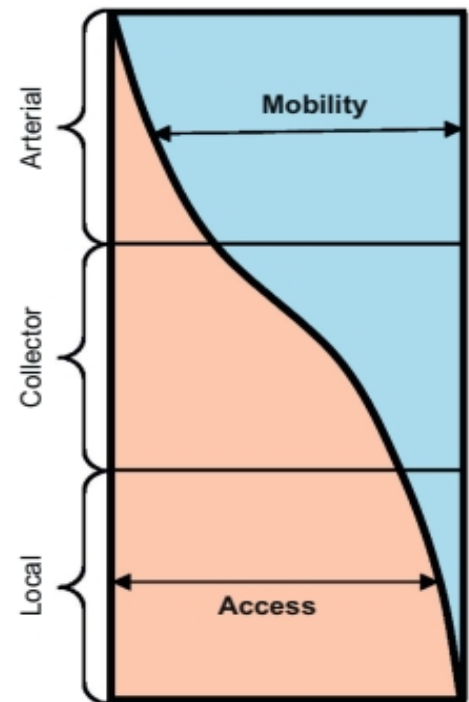
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Highway Functional Classification

Arterials

■ Roadways that provide a **high level of mobility**

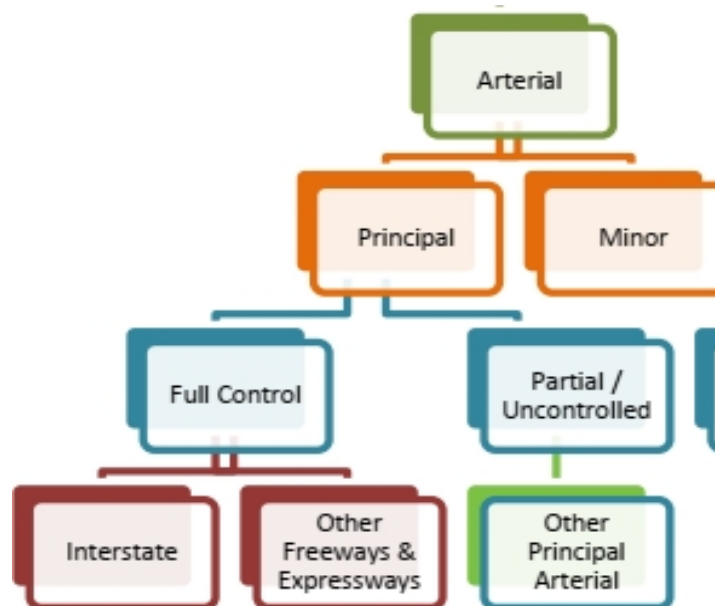
- emphasis on *providing high-speed, uninterrupted flow*
- *Long-distance trips are most practical on arterials*



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Highway Functional Classification

Arterials



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Highway Functional Classification

Arterials

Interstate

- The highest classification of Arterials
- Designed and constructed with mobility and long-distance travel in mind
- Provided a superior network of limited access, divided highways offering high levels of mobility while linking the major urban areas of the United States

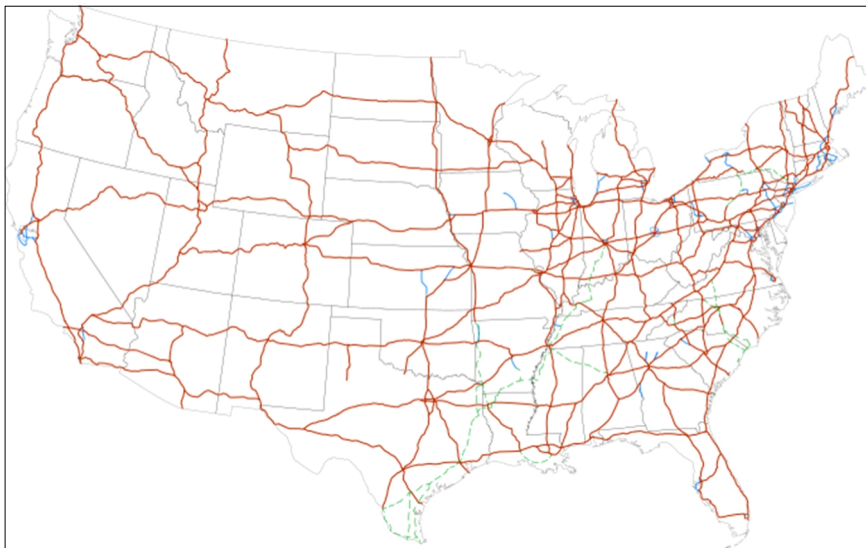


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Highway Functional Classification

Map of the present Interstate Highway System in the United States



https://en.wikipedia.org/wiki/Interstate_Highway_System

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Highway Functional Classification

Arterials

Other Freeways & Expressways

- Roadways have **directional travel lanes** are **usually separated by some type of physical barrier**, and **their access and egress points are limited to on- and off-ramp locations** or a very limited number of at-grade intersections
- Like Interstates, these roadways are designed and constructed to **maximize their mobility function**, and abutting land uses are not directly served by them

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Highway Functional Classification

Arterials

Other Freeways & Expressways



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Highway Functional Classification

Arterials

Other Principal Arterials

- These roadways serve major centers of metropolitan areas, provide a high degree of mobility and can also provide mobility through rural areas



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Highway Functional Classification

Arterials

Minor

- Provide service for trips of moderate length
- Serve geographic areas that are smaller than their higher arterial counterparts
- Offer connectivity to the higher arterial system.

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Highway Functional Classification

Arterials



Urban arterial



Suburban interstate
(Freeway)

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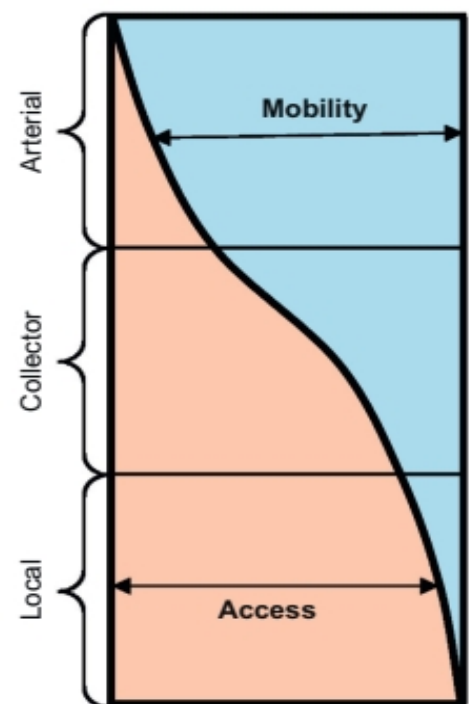
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Highway Functional Classification

Roads mobility and accessibility

■ Locals

- Roadways provide *a high level of accessibility*
- Provide *direct connectivity to businesses, residences, and other land uses*



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Highway Functional Classification

Local Streets



Local street

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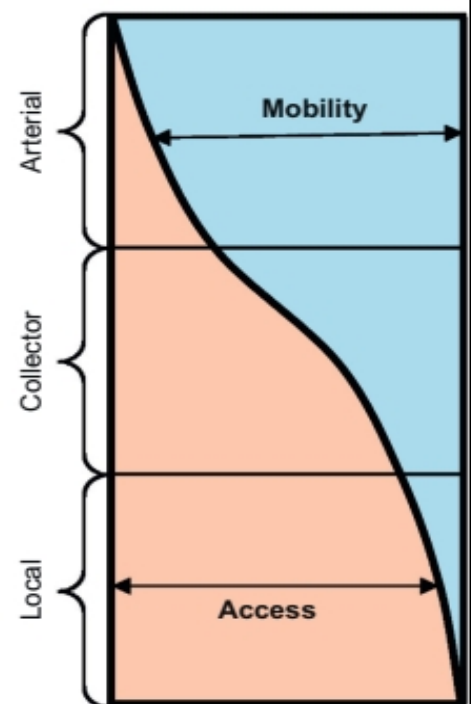
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Highway Functional Classification

Roads mobility and accessibility

■ Collector

- Roadways a more *balanced* blend of *mobility and access*
- Collectors *facilitate travel between local roads and arterials* by collecting traffic and distributing it to local roads or to higher mobility arterials



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Highway Classification

Collector



Collector roadway

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Highway Functional Classification

Collectors



■ Collectors are broken down into two categories:

➤ Major Collectors

➤ Minor Collectors

- The determination of whether a given Collector is a Major or a Minor collector is frequently one of the biggest challenges in functionally classifying a roadway network

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Highway Functional Classification

Collectors

■ Generally, **Major Collector** routes are :

- longer in length
- have lower connecting
- have lower driveway densities
- have higher speed limits
- spaced at greater intervals
- have higher annual average traffic volumes
- may have more travel lanes



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Highway Functional Classification

Relationship between Functional Classification and Travel Characteristics

National Classification	Distance Served (and Length of Route)	Access Points	Speed Limit	Distance between Routes	Usage (AADT and DVMT)	Significance	Number of Travel Lanes
Arterial	Longest	Few	Highest	Longest	Highest	Statewide	More
Collector	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Local	Shortest	Many	Lowest	Shortest	Lowest	Local	Few

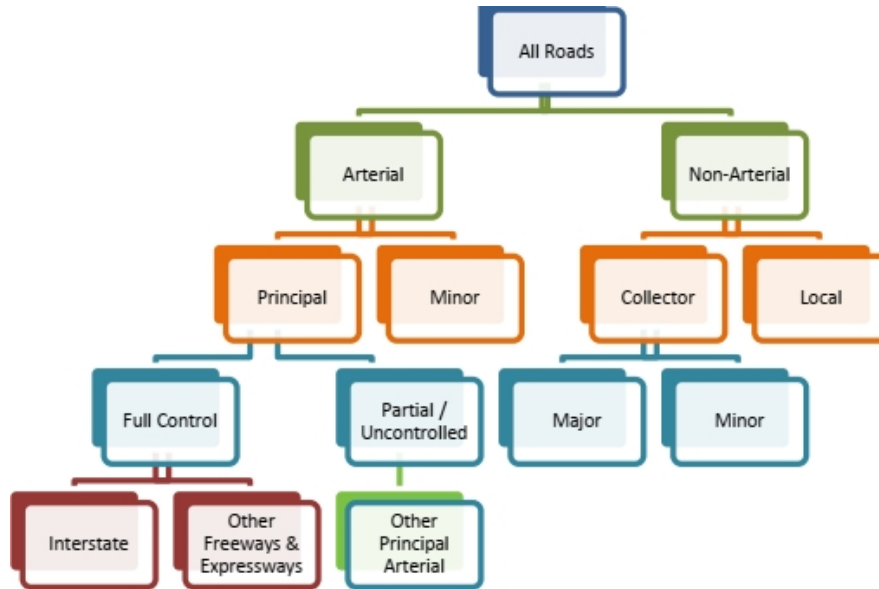


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Highway Functional Classification

Federal Functional Classification Decision Tree



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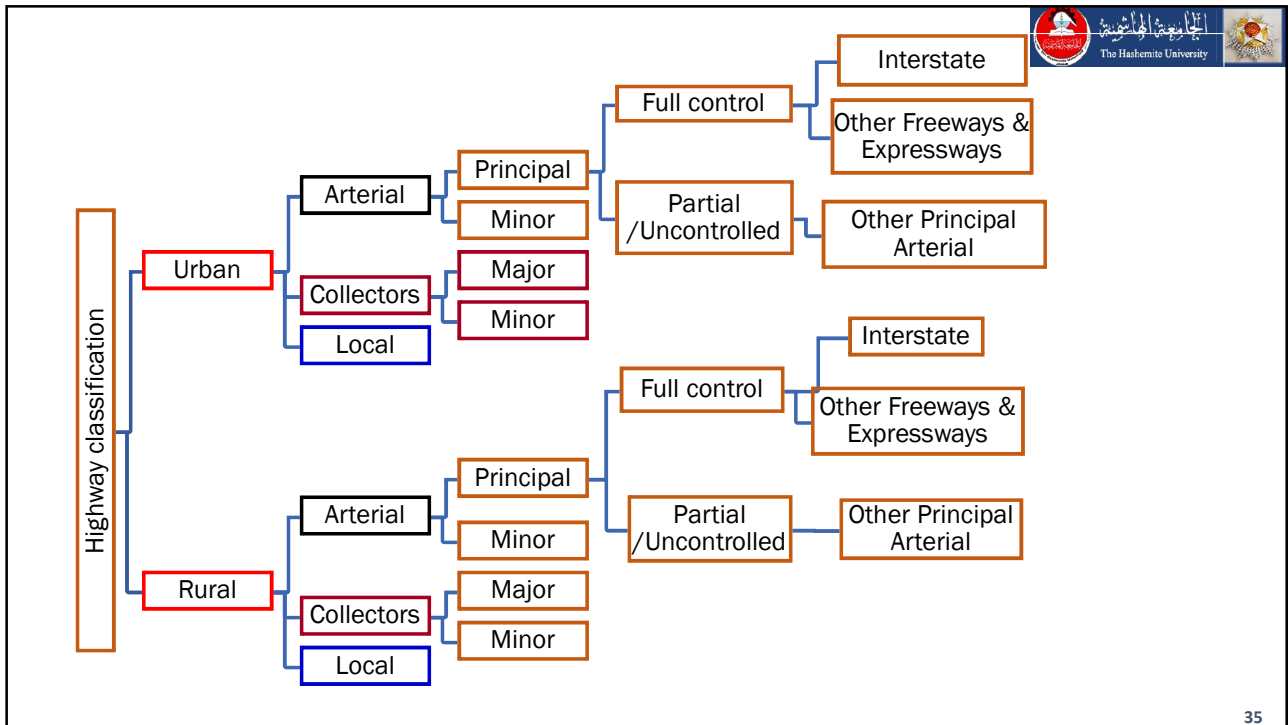
Highway Classification

In general,

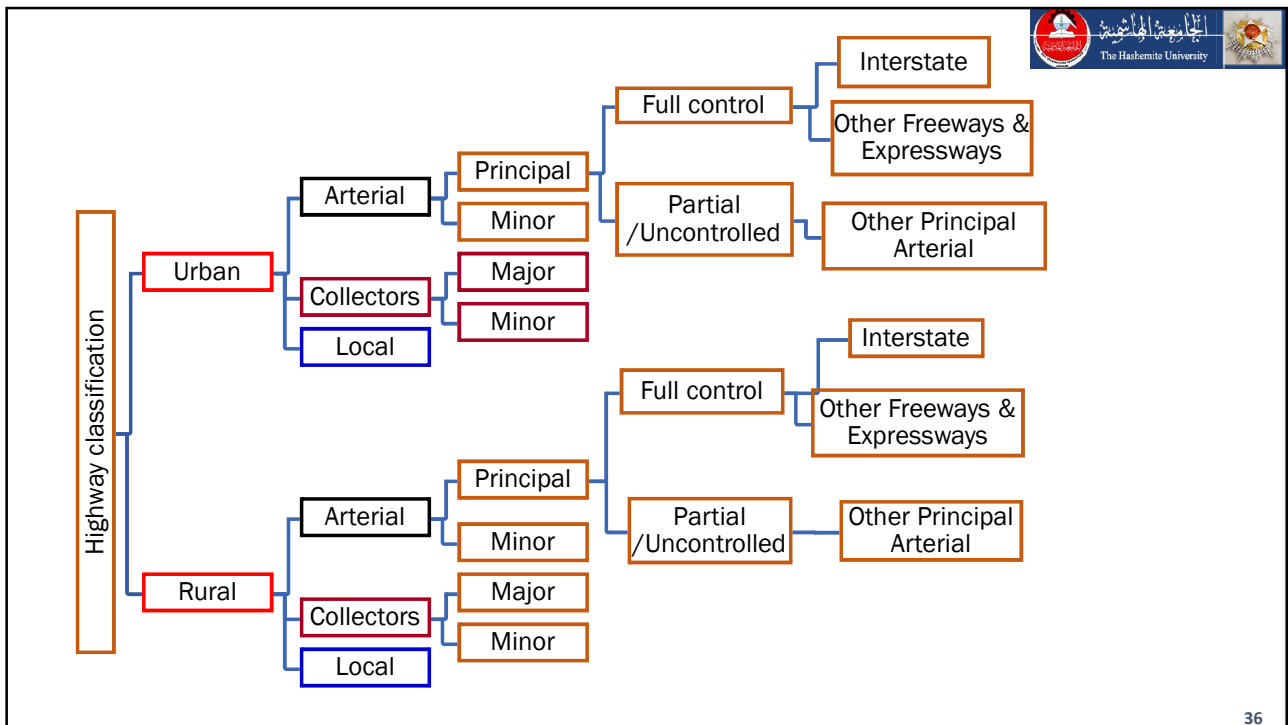
- In urban areas
 - there are relatively *more arterials*
- In rural areas
 - there are *more collectors*

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Highway Classification



Characteristics of Urban and Rural Principle Arterials

Urban	Rural
• Serve major activity centers, highest traffic volume corridors and longest trip demands • Carry high proportion of total urban travel on minimum of mileage • Interconnect and provide continuity for major rural corridors to accommodate trips entering and leaving urban area and movements through the urban area • Serve demand for intra-area travel between the central business district and outlying residential areas	• Serve corridor movements having trip length and travel density characteristics indicative of substantial statewide or interstate travel • Connect all or nearly all Urbanized Areas and a large majority of Urban Clusters with 25,000 and over population • Provide an integrated network of continuous routes without stub connections (dead ends)

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Highway Classification



Characteristics of Urban and Rural Minor Arterials

Urban	Rural
• Interconnect and augment the higher-level Arterials • Serve trips of moderate length at a somewhat lower level of travel mobility than Principal Arterials • Distribute traffic to smaller geographic areas than those served by higher-level Arterials • Provide more land access than Principal Arterials without penetrating identifiable neighborhoods • Provide urban connections for Rural Collectors	• Link cities and larger towns (and other major destinations such as resorts capable of attracting travel over long distances) and form an integrated network providing interstate and inter-county service • Be spaced at intervals, consistent with population density, so that all developed areas within the State are within a reasonable distance of an Arterial roadway • Provide service to corridors with trip lengths and travel density greater than those served by Rural Collectors and Local Roads and with relatively high travel speeds and minimum interference to through movement

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Highway Classification



Characteristics of Major Collectors (Urban and Rural)

MAJOR COLLECTORS	
Urban	Rural
• Serve both land access and traffic circulation in <u>higher</u> density residential, and commercial/industrial areas • Penetrate residential neighborhoods, often for <u>significant</u> distances • Distribute and channel trips between Local Roads and Arterials, usually over a distance of <u>greater than</u> three-quarters of a mile • Operating characteristics include higher speeds and more signalized intersections	• Provide service to any county seat not on an Arterial route, to the larger towns not directly served by the higher systems and to other traffic generators of equivalent intra-county importance such as consolidated schools, shipping points, county parks and important mining and agricultural areas • Link these places with nearby larger towns and cities or with Arterial routes • Serve the most important intra-county travel corridors

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Highway Classification



Characteristics of Minor Collectors (Urban and Rural)

MINOR COLLECTORS	
Urban	Rural
• Serve both land access and traffic circulation in lower density residential and commercial/industrial areas • Penetrate residential neighborhoods, often only for a <u>short</u> distance • Distribute and channel trips between Local Roads and Arterials, usually over a distance of <u>less than</u> three-quarters of a mile • Operating characteristics include lower speeds and fewer signalized intersections	• Be spaced at intervals, consistent with population density, to collect traffic from Local Roads and bring all developed areas within reasonable distance of a Collector • Provide service to smaller communities not served by a higher class facility • Link locally important traffic generators with their rural hinterlands

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40

Highway Classification

Characteristics of Urban and Rural Local Roads



Urban	Rural
• Provide direct access to adjacent land • Provide access to higher systems • Carry no through traffic movement • Constitute the mileage not classified as part of the Arterial and Collector systems	• Serve primarily to provide access to adjacent land • Provide service to travel over short distances as compared to higher classification categories • Constitute the mileage not classified as part of the Arterial and Collector systems

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Highway Classification

Urban Principal Arterial System



Urban interstate

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Final Considerations



- In many instances, **assigning a functional classification** to a roadway **is straightforward**, especially for Interstates and Locals
- However, there is **flexibility** when deciding between adjacent classifications
- For example
 - Deciding whether a given roadway acts as a Minor Arterial or Major Collector can be subject to debate.
 - Deciding between a Major Collector and Minor Collector assignment can be even more challenging
- To **assist transportation planners** responsible for determining the **functional classification of roadways**
 - Table 3-5 illustrates the range of lane width, shoulder width, AADTs, divided/undivided status, access control and access points per mile by functional classification categories.

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Final Considerations



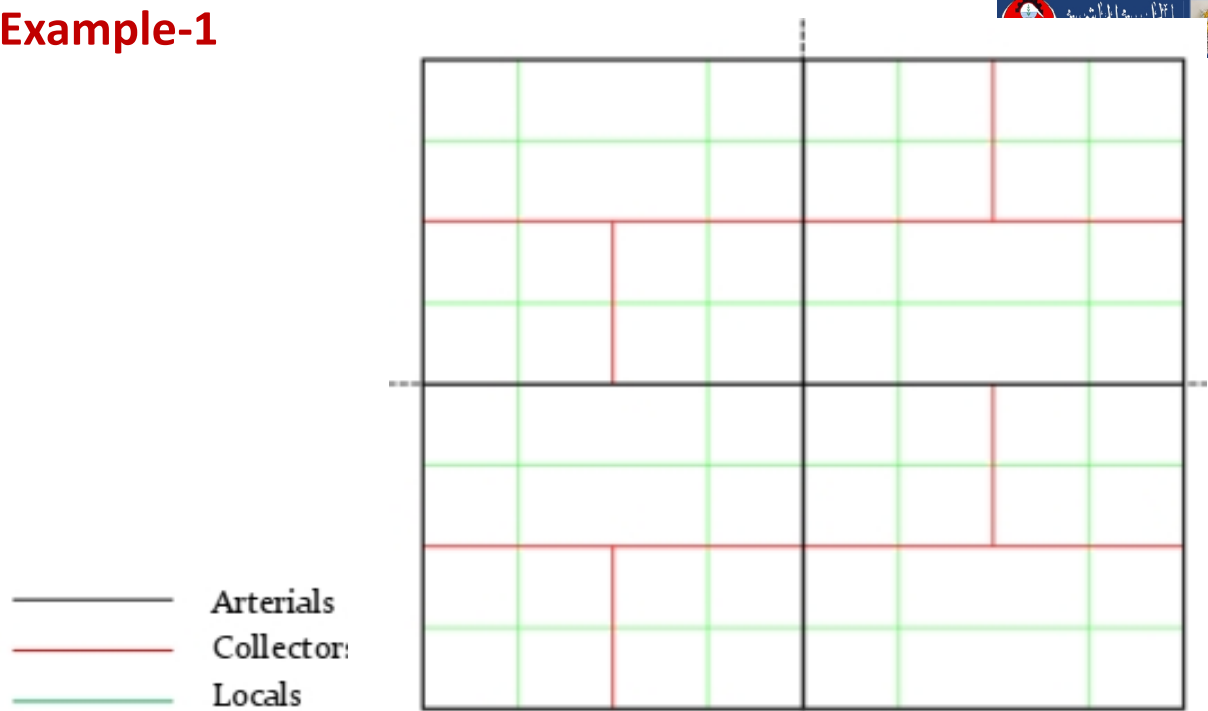
- To **assist transportation planners** responsible for determining the **functional classification of roadways**
 - Table 3-5 illustrates the range of lane width, shoulder width, AADTs, divided/undivided status, access control and access points per mile by functional classification categories.

	Arterials		
	Interstate	Other Freeways & Expressway	Other Principal Arterial
Typical Characteristics			
Lane Width	12 feet	11 - 12 feet	11 - 12 feet
Inside Shoulder Width	4 feet - 12 feet	0 feet - 6 feet	0 feet
Outside Shoulder Width	10 feet - 12 feet	8 feet - 12 feet	8 feet - 12 feet
AADT ¹ (Rural)	12,000 - 34,000	4,000 - 18,500 ²	2,000 - 8,500 ²
AADT ¹ (Urban)	35,000 - 129,000	13,000 - 55,000 ²	7,000 - 27,000 ²
Divided/Undivided	Divided	Undivided/Divided	Undivided/Divided
Access	Fully Controlled	Partially/Fully Controlled	Partially/Uncontrolled

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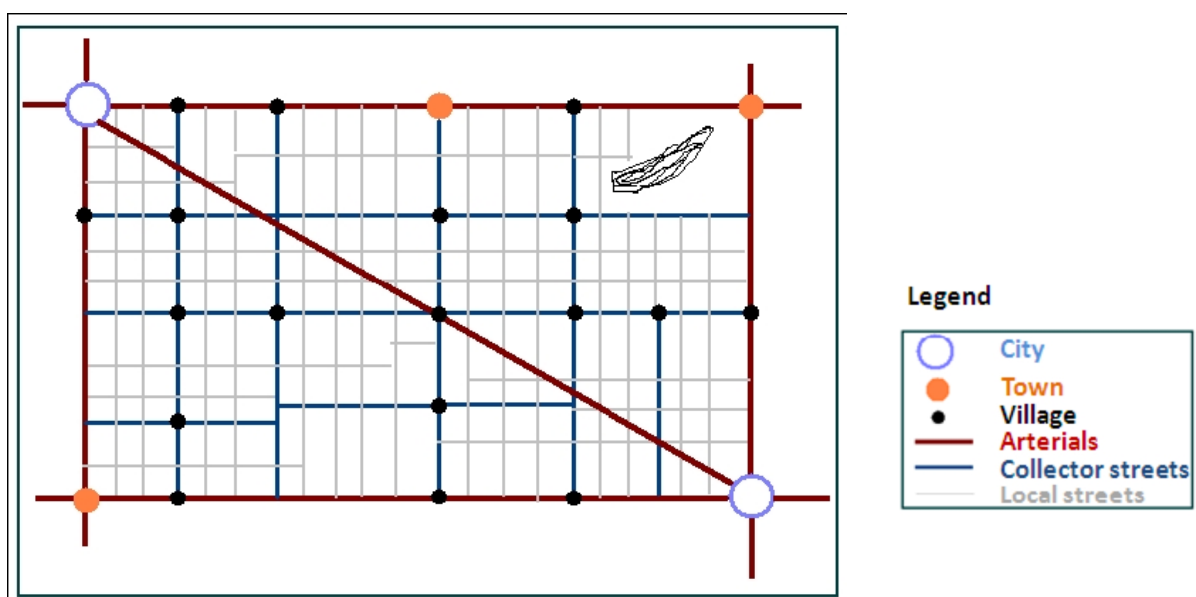
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Example-1



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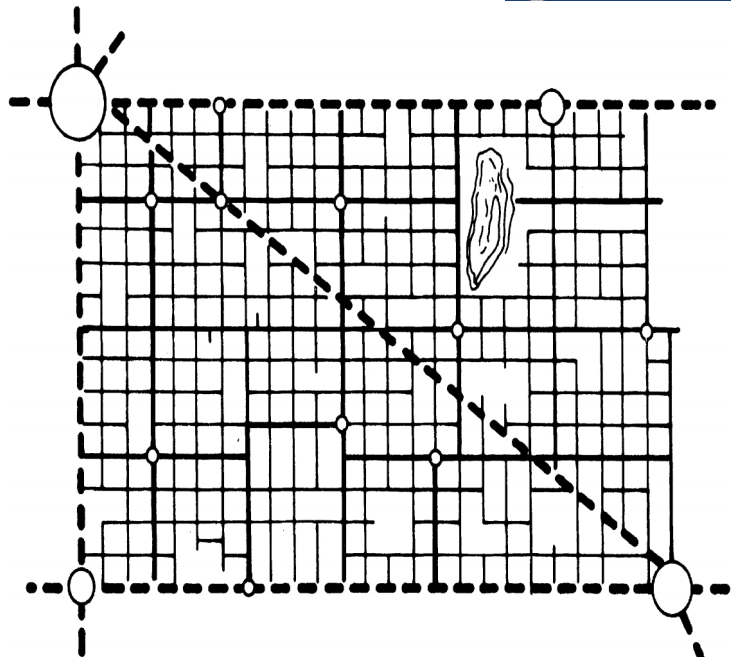
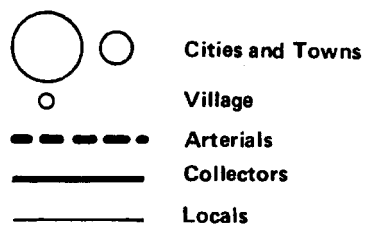
Example-2



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Example-3

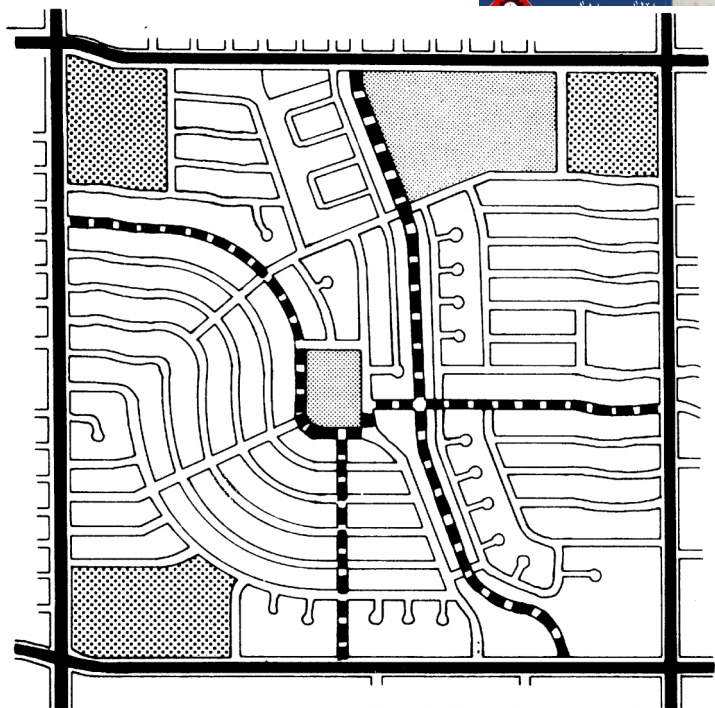
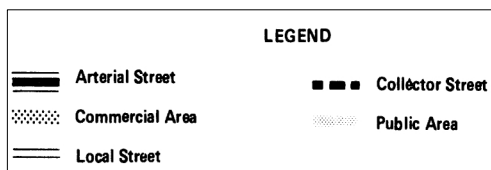
Schematic Illustration of a Functionally Classified Rural Highway Network



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Example-4

Schematic Illustration of the Functional Classes for a Suburban Road Network



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Table 3-5: VMT and Mileage Guidelines by Functional Classifications - Arterials

	Arterials			
	Interstate	Other Freeways & Expressway	Other Principal Arterial	Minor Arterial
Typical Characteristics				
Lane Width	12 feet	11 - 12 feet	11 - 12 feet	10 feet - 12 feet
Inside Shoulder Width	4 feet - 12 feet	0 feet - 6 feet	0 feet	0 feet
Outside Shoulder Width	10 feet - 12 feet	8 feet - 12 feet	8 feet - 12 feet	4 feet - 8 feet
AADT ¹ (Rural)	12,000 - 34,000	4,000 - 18,500 ²	2,000 - 8,500 ²	1,500 - 6,000
AADT ¹ (Urban)	35,000 - 129,000	13,000 - 55,000 ²	7,000 - 27,000 ²	3,000 - 14,000
Divided/Undivided	Divided	Undivided/Divided	Undivided/Divided	Undivided
Access	Fully Controlled	Partially/Fully Controlled	Partially/Uncontrolled	Uncontrolled
Mileage/VMT Extent (Percentage Ranges)¹				
Rural System				
Mileage Extent for Rural States ²	1% - 3%	0% - 2%	2% - 6%	2% - 6%
Mileage Extent for Urban States	1% - 2%	0% - 2%	2% - 5%	3% - 7%
Mileage Extent for All States	1% - 2%	0% - 2%	2% - 6%	3% - 7%
VMT Extent for Rural States ²	18% - 38%	0% - 7%	15% - 31%	9% - 20%
VMT Extent for Urban States	18% - 34%	0% - 8%	12% - 29%	12% - 19%
VMT Extent for All States	20% - 38%	0% - 8%	14% - 30%	11% - 20%
Urban System				
Mileage Extent for Rural States ²	1% - 3%	0% - 2%	4% - 9%	7% - 14%
Mileage Extent for Urban States	1% - 2%	0% - 2%	4% - 5%	7% - 12%
Mileage Extent for All States	1% - 3%	0% - 2%	4% - 5%	7% - 14%
VMT Extent for Rural States ²	17% - 31%	0% - 12%	16% - 33%	14% - 27%
VMT Extent for Urban States	17% - 30%	3% - 18%	17% - 29%	15% - 22%
VMT Extent for All States	17% - 31%	0% - 17%	16% - 31%	14% - 25%
Qualitative Description (Urban)	- Serve major activity centers, highest traffic volume corridors, and longest trip demands - Carry high proportion of total urban travel on minimum of mileage - Interconnect and provide continuity for major rural corridors to accommodate trips entering and leaving urban area and movements through the urban area - Serve demand for intra-area travel between the central business district and outlying residential areas			- Interconnect with and augment the principal arterials - Serve trips of moderate length at a somewhat lower level of travel mobility than principal arterials - Distribute traffic to smaller geographic areas than those served by principal arterials - Provide more land access than principal arterials without penetrating identifiable neighborhoods - Provide urban connections for rural collectors
Qualitative Description (Rural)	- Serve corridor movements having trip length and travel density characteristics indicative of substantial statewide or interstate travel - Serve all or nearly all urbanized areas and a large majority of urban clusters areas with 25,000 and over population - Provide an integrated network of continuous routes without stub connections (dead ends)			- Link cities and larger towns (and other major destinations such as resorts capable of attracting travel over long distances) and form an integrated network providing interstate and inter-county service - Spaced at intervals, consistent with population density, so that all developed areas within the State are within a reasonable distance of an arterial roadway - Provide service to corridors with trip lengths and travel density greater than those served by rural collectors and local roads and with relatively high travel speeds and minimum interference to through movement

1- Ranges in this table are derived from 2011 HPMS data.

2- For this table, Rural States are defined as those with a maximum of 75 percent of their population in urban centers.

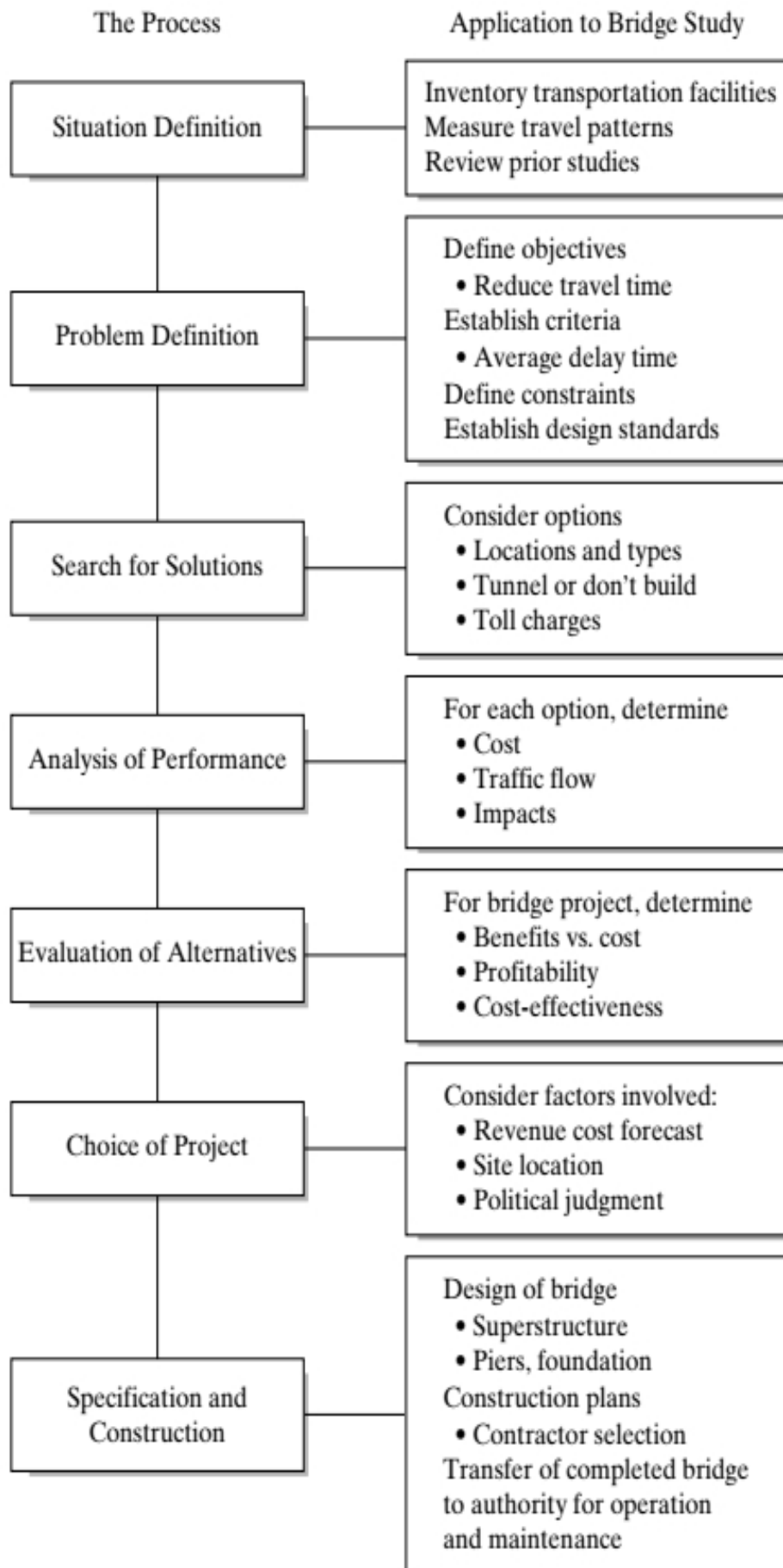
Table 3-6: VMT and Mileage Guidelines by Functional Classifications – Collectors and Locals

	Collectors		Local
	Major Collector ²	Minor Collector ²	
Typical Characteristics			
Lane Width	10 feet - 12 feet	10 - 11 feet	8 feet - 10 feet
Inside Shoulder Width	0 feet	0 feet	0 feet
Outside Shoulder Width	1 feet - 6 feet	1 feet - 4 feet	0 feet - 2 feet
AADT ¹ (Rural)	300 - 2,600	150 - 1,110	15 - 400
AADT ¹ (Urban)	1,100 - 6,300 ²		80 - 700
Divided/Undivided	Undivided	Undivided	Undivided
Access	Uncontrolled	Uncontrolled	Uncontrolled
Mileage/VMT Extent (Percentage Ranges)¹			
Rural System			
Mileage Extent for Rural States ³	8% - 19%	3% - 15%	62% - 74%
Mileage Extent for Urban States	10% - 17%	5% - 13%	66% - 74%
Mileage Extent for All States	9% - 19%	4% - 15%	64% - 75%
VMT Extent for Rural States ³	10% - 23%	1% - 8%	8% - 23%
VMT Extent for Urban States	12% - 24%	3% - 10%	7% - 20%
VMT Extent for All States	12% - 23%	2% - 9%	8% - 23%
Urban System			
Mileage Extent for Rural States ³	3% - 16%	3% - 16% ²	62% - 74%
Mileage Extent for Urban States	7% - 13%	7% - 13% ²	67% - 76%
Mileage Extent for All States	7% - 15%	7% - 15% ²	63% - 75%
VMT Extent for Rural States ³	2% - 13%	2% - 12% ²	9% - 25%
VMT Extent for Urban States	7% - 13%	7% - 13% ²	6% - 24%
VMT Extent for All States	5% - 13%	5% - 13% ²	6% - 25%
Qualitative Description (Urban)	• Serve both land access and traffic circulation in higher density residential, and commercial/industrial areas • Penetrate residential neighborhoods, often for significant distances • Distribute and channel trips between local streets and arterials, usually over a distance of greater than three-quarters of a mile	• Serve both land access and traffic circulation in lower density residential, and commercial/industrial areas • Penetrate residential neighborhoods, often only for a short distance • Distribute and channel trips between local streets and arterials, usually over a distance of less than three-quarters of a mile	• Provide direct access to adjacent land • Provide access to higher systems • Carry no through traffic movement
Qualitative Description (Rural)	• Provide service to any county seat not on an arterial route, to the larger towns not directly served by the higher systems, and to other traffic generators of equivalent intra-county importance such as consolidated schools, shipping points, county parks, important mining and agricultural areas • Link these places with nearby larger towns and cities or with arterial routes • Serve the most important intra-county travel corridors	• Be spaced at intervals, consistent with population density, to collect traffic from local roads and bring all developed areas within reasonable distance of a minor collector • Provide service to smaller communities not served by a higher class facility • Link locally important traffic generators with their rural hinterlands	• Serve primarily to provide access to adjacent land • Provide service to travel over short distances as compared to higher classification categories • Constitute the mileage not classified as part of the arterial and collectors systems

1- Ranges in this table are derived from 2011 HPMS data.

2- Information for Urban Major and Minor Collectors is approximate, based on a small number of States reporting.

3- For this table, Rural States are defined as those with a maximum of 75 percent of their population in urban centers.





TRANSPORTATION ENGINEERING AND PLANNING (110 401367) SPRING 2019-2020

Lecture. No. 4 Urban Transportation Planning

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning

References

- Nicholas Garber and Lester Hoel , ***Traffic & Highway Engineering***, 5th Edition.. Cengage Learning, 2015

➤ *Chapter 11 : The Transportation planning process*

❖ *Section 11.3*



2

2

Review

Definition of transportation planning

- It is a methodological **process** of **preparing physical facilities and services of modes** for transportation needs
- It is **not intended** to furnish a decision or to give a **single result that must be followed**, although it can do so in relatively simple situations.
- It is intended to provide the **appropriate information** to those who will be affected and those responsible for deciding whether the transportation project should go forward.



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Urban Transportation Planning

- **Involves** the **evaluation and selection** of highway or transit facilities to **serve present and future land uses**.
- For example,
 - *Construction of a new shopping center, airport, or convention center will require additional transportation services.*
 - *New residential development, office space, and industrial parks will generate additional traffic, requiring the creation or expansion of roads and transit services.*
- **Concerned** with two separate time horizons
 - 1. Short-term
 - 2. Long-term



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Urban Transportation Planning



1. Short-term

- To select projects that can be implemented within a **1- 3 year period**
- These projects are designed to provide **better management of existing facilities** by making them as efficient as possible.
- Involve programs such as
 - *Traffic signal timing to improve flow*
 - *Car and van pooling to reduce congestion*
 - *Park-and-ride fringe parking lots to increase transit ridership and Transit improvements.*

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Urban Transportation Planning



2. Long-term

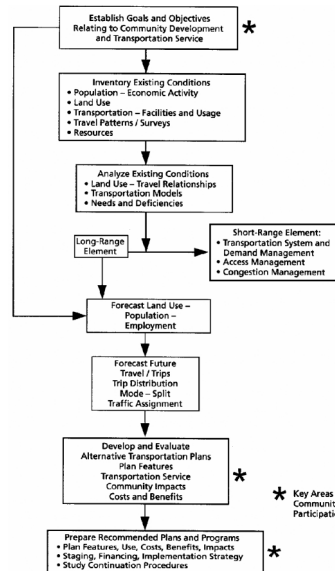
- Identifies the projects to be constructed **over a 20-year period**.
- Involve programs such as
 - *Adding new highway elements*
 - *Additional bus lines or freeway lanes*
 - *Additional Rapid transit systems and extensions*
 - *Access roads airports or shopping malls*

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Urban Transportation Planning

Comprehensive urban area transportation planning process



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Review

Definition of transportation planning

The transportation planning process comprises seven basic elements,

1. Situation definition
2. Problem definition
3. Search for solutions
4. Analysis of performance
5. Evaluation of alternatives
6. Choice of project
7. Specification and construction



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Urban Transportation Planning



Comprehensive urban area transportation planning process

1. Inventory of Existing Travel and Facilities
2. Establishment of Goals and Objectives
3. Generation of Alternatives
4. Estimation of Project Cost and Travel Demand
5. Evaluation of Alternatives

9

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Urban Transportation Planning



Inventory of Existing Travel and Facilities

- This is the **data-gathering activity** in which urban travel characteristics are described for each defined geographic unit or traffic zone within the study area
- Inventories and surveys are made to determine :
 - *Traffic volumes and land uses*
 - *Origins and destinations of travelers*
 - *Population*
 - *Employment*
 - *Economic activity*

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Urban Transportation Planning

Inventory of Existing Travel and Facilities



- Inventories are made of existing transportation facilities, both highway and transit.

- *Capacity, speed, travel time, and traffic volume are determined*

- The information gathered is summarized by geographic areas called traffic analysis zones (TAZ)

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Urban Transportation Planning

2. Establishment of Goals and Objectives



- A statement of **goals, objectives, and standards** is prepared that identifies
 - *deficiencies in the existing system*
 - *Desired improvement*
 - *what is to be achieved by the transportation improvements*

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Urban Transportation Planning

3. Generation of Alternatives

- In this phase, the **alternatives** to be analyzed **will be identified**



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Urban Transportation Planning

Estimation of Project Cost and Travel Demand

This activity involves two separate tasks:

- Planning-Level Cost Estimation
 - *Determination of project cost*
 - *Straightforward process*
- Planning-Level Demand Estimation
 - Estimation of the **amount of traffic expected** in the future
 - Requiring the **use of mathematical models and computer**



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Estimation of Project Cost and Travel Demand



Planning-Level Cost Estimation

- Project cost estimation at the planning stage may be hampered either because
 - *The project has not yet been well-defined*
 - *A significant amount of time has passed since the project's cost was estimated*

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Estimation of Project Cost and Travel Demand



Planning-Level Demand Estimation

- **Future travel** is determined by forecasting **future land use** in terms of the **economic activity and population** that the land use in each TAZ will produce
- With the land-use forecasting in terms of
 - *Number of jobs, residents, auto ownership and income*

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Estimation of Project Cost and Travel Demand



Planning-Level Demand Estimation

- The traffic that this land use will add to the highway and transit facility can be determined using the **four-step process**
- The urban traffic forecasting process involves
 - *Tip generation*
 - *Trip distribution*
 - *Modal split*
 - *Network assignment*
- The travel forecasting process is used to estimate the traffic volumes on each link of the system

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Urban Transportation Planning



5. Evaluation of Alternatives

- It can be **complex** in practice because of the **conflicting objectives and diverse groups** that will be affected
- For example
 - *Traveling public (user)*
 - ❖ Improve speed, safety, and comfort
 - *The highway or transit agencies (operator)*
 - ❖ Minimize cost
 - *Non-traveling public (community)*
 - ❖ preserve its lifestyle and improve or minimize environmental impacts

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Urban Transportation Planning

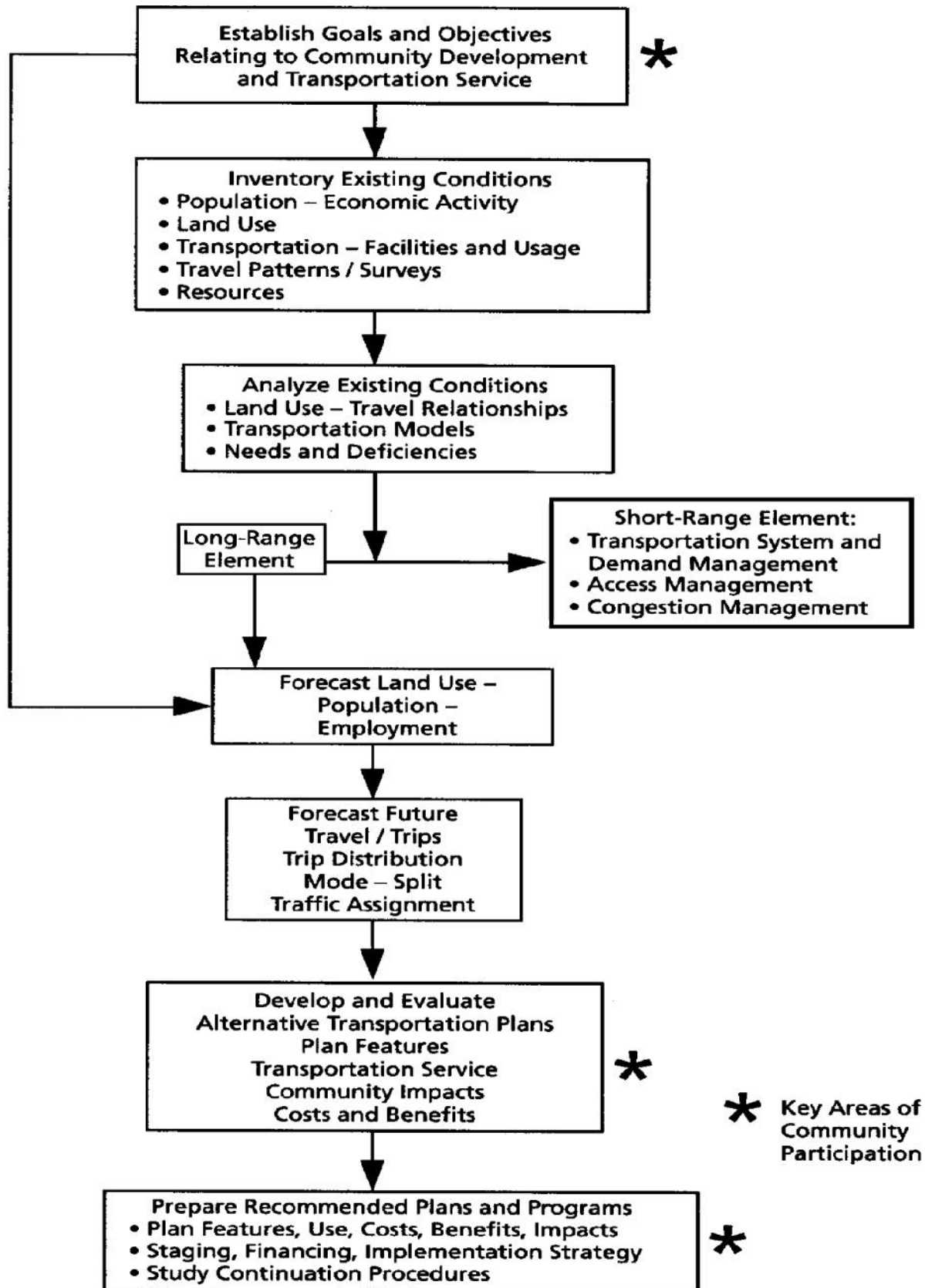


6. Choice of Project

- Selection of a project will be based on a process that will ultimately involve **elected officials and the public**
- It may involve
 - *A public referendum*
 - *A vote by a state legislature*

Comprehensive Urban Area Transportation Planning Process

(Nicholas Garber and Lester Hoel ,Traffic & Highway Engineering, 5th Edition.. Cengage Learning, 2015





**TRANSPORTATION ENGINEERING
AND PLANNING
(110 401367)
SPRING 2019-2020**

Lecture. No. 5
**Urban transportation
forecasting process**

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Topic 2 : Transportation planning

References

- Nicholas Garber and Lester Hoel , ***Traffic & Highway Engineering***, 5th Edition.. Cengage Learning, 2015

➤ *Chapter 11 : The Transportation planning process*

❖ *Section 11.4*



2

2

Review

transportation planning process

The transportation planning process comprises seven basic elements,

1. Situation definition
2. Problem definition
3. Search for solutions
4. Analysis of performance
5. Evaluation of alternatives
6. Choice of project
7. Specification and construction



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Comprehensive urban area transportation planning process

1. Inventory of Existing Travel and Facilities
2. Establishment of Goals and Objectives
3. Generation of Alternatives
4. Estimation of Project Cost and Travel Demand
5. Evaluation of Alternatives



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Urban Transportation Planning

Estimation of Project Cost and Travel Demand



This activity involves two separate tasks:

■ Planning-Level Cost Estimation

- *Determination of project cost*
- *Straightforward process*

■ Planning-Level Demand Estimation

- *Estimation of the amount of traffic expected in the future*
- *Requiring the use of mathematical models and computer*

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Estimation of Project Cost and Travel Demand

Planning-Level Demand Estimation



- The **traffic** that this land use will add to the highway and transit facility can be determined using the **four-step process**
- The urban traffic forecasting process involves
 - *Trip generation*
 - *Trip distribution*
 - *Modal split*
 - *Network assignment*
- The travel forecasting process is used to estimate the traffic volume volumes on each link of the system

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Urban transportation forecasting process



- It is carried out to **analyze the performance of various alternative**
- There are four basic elements and related tasks in the process
 1. *Data collection (or inventories),*
 2. *Analysis of existing conditions and calibration of forecasting techniques*
 3. *Forecast of future travel demand,*
 4. *Analysis of the results*

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Urban transportation forecasting process



The process involves :

1. Defining the Study Area
2. Data Collection
3. Population and Economic Data
4. Transportation Inventories
5. Information Systems
6. Travel Surveys
7. Calibration

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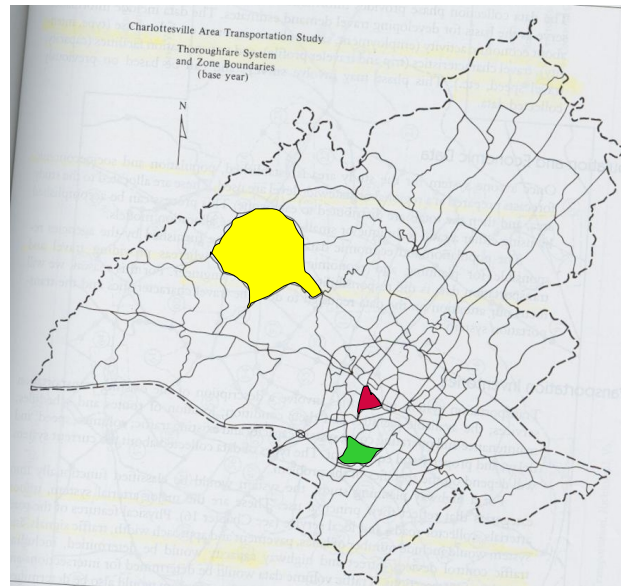
Urban transportation forecasting process

Defining the Study Area

- It is usually necessary to **delineate the study area boundaries** and to **further subdivide** the area into **traffic analysis zones (TAZ)** for **data tabulation**

Defining the Study Area

Traffic Analysis Zones (TAZ)



Defining the Study Area

Traffic Analysis Zones (TAZ)



The selection of these zones is based on the following criteria:

1. Socioeconomic characteristics should be homogeneous.
2. Intrazonal trips should be **minimized**.
3. Physical, political, and historical boundaries should be utilized where possible
4. Zones should not be created within other zones.

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Defining the Study Area

Traffic Analysis Zones (TAZ)



5. The zone system should generate and **attract approximately equal** trips, households, population, or area.

For example, labor force and employment should be similar.

6. Zones should use census tract boundaries where possible.
7. The total number of zones **should not be so large** as to overwhelm computer resources

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Defining the Study Area

Traffic Analysis Zones (TAZ)



- It may be necessary to exercise some judgment in determining the total number of zones
- Agencies may provide some guidance for achieving these seven criteria
 - *An average of 1,000 people/zone for smaller areas*
 - *A ratio of between 0.9 and 1.1 for productions to attractions*
 - *No more than 10,000 trips should be generated for a given zone*
 - *A ratio of labor force to employment must be at least 0.80*

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Urban transportation forecasting process



The process involves :

1. Defining the Study Area
2. **Data Collection**
3. Population and Economic Data
4. Transportation Inventories
5. Information Systems
6. Travel Surveys
7. Calibration

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Urban transportation forecasting process



Data Collection

- Provides information about the city and its people that will serve as the basis for developing travel demand estimates
- This phase may involve surveys and can be based on previously collected data.
- The data include Information about
 - *Economic activity (employment, sales volume, income, etc.)*
 - *land use (type, intensity)*
 - *Travel characteristics (trip and traveler profile)*
 - *Transportation facilities (capacity, travel speed, etc.).*

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Urban transportation forecasting process



3. Population and Economic Data

- Once a zone system for the study area is established, population and socioeconomic forecasts prepared at a regional or statewide level are used.
- The population and economic data **usually** will be furnished by the **agencies responsible for planning and economic development**

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Urban transportation forecasting process



4. Transportation Inventories

■ Involve a description of the existing transportation services

- *The available facilities and their condition*
- *location of routes and schedules;*
- *Maintenance and operating costs*
- *System capacity*
- *Existing traffic; volumes, speed ,and delay;*

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Urban transportation forecasting process



4. Transportation Inventories

■ The types of data collected about the current system will depend on the specifics of the problem

■ For a **highway planning study**,

- *The system would be classified functionally into categories that reflect their principal use. (e.g.,arterial system)*

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4. Transportation Inventories



Highway planning study

For highway planning, the collected data includes :

- Physical features of the road system
 - *number of lanes, pavement and approach width, traffic signals, and traffic-control devices.*
- Street and highway capacity would be determined
 - *capacity of intersections*
- Traffic volume data would be determined for intersections and highway links.
- Travel times along the arterial highway system would also be determined

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Urban transportation forecasting process



Highway planning study

- The process involves **developing a computerized network** of the existing street and highway system is produced
- The network consists of a series of
 - *links*
 - *Nodes*
 - *Centroids*
 - *External stations*

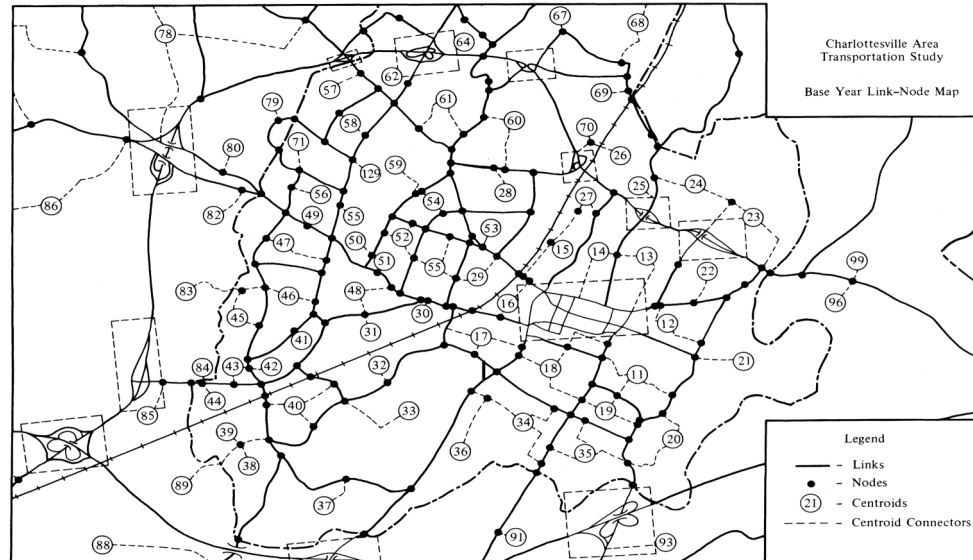
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Urban transportation forecasting process

Highway planning study

A computerized network of the existing street and highway system



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Urban transportation forecasting process

Highway planning study

■ links

➤ a portion of the highway system that can be described by its **capacity, lane width, and speed**

■ Nodes

➤ The **end point of a link** and represents an intersection or location where a link changes direction, capacity, width, or speed

■ Centroids

➤ The location within a zone where **trips are considered to begin and end**

■ External stations

➤ are those roadways where traffic is likely to enter or exit the study area

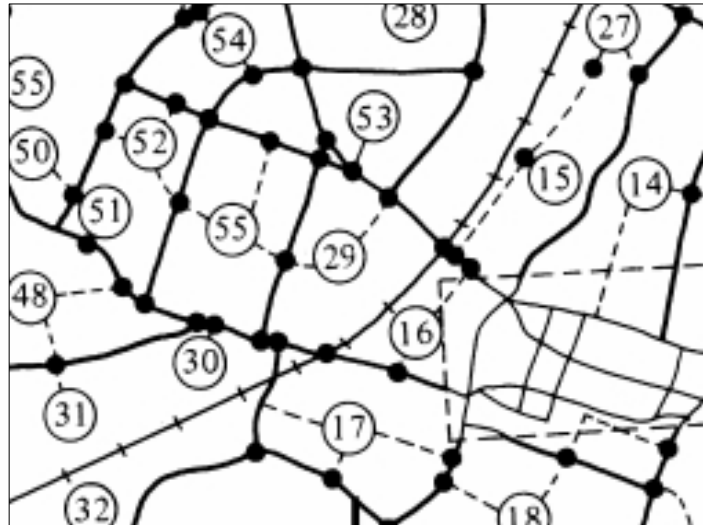
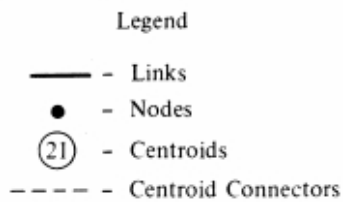
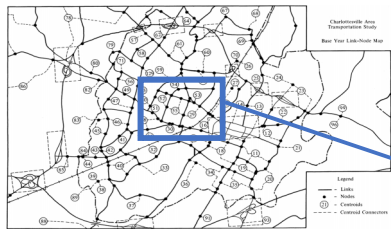
➤ It established at the study area boundary

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Urban transportation forecasting process

Highway planning study

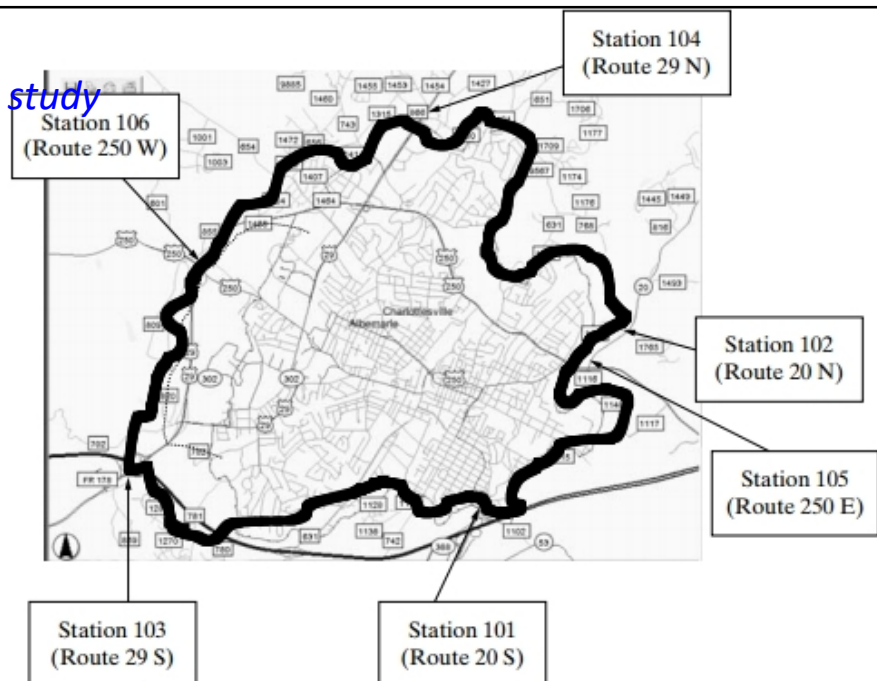


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Urban transport

Highway planning study



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Urban transportation forecasting process



5. Information Systems

- Almost all network data are organized within some type of Geographic Information System (GIS)
- A GIS is a spatially-oriented database management processing system containing location and attribute information for manmade and natural features and supporting related queries with these features

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Urban transportation forecasting process



5. Information Systems



<http://www.ammancitygis.gov.jo/>

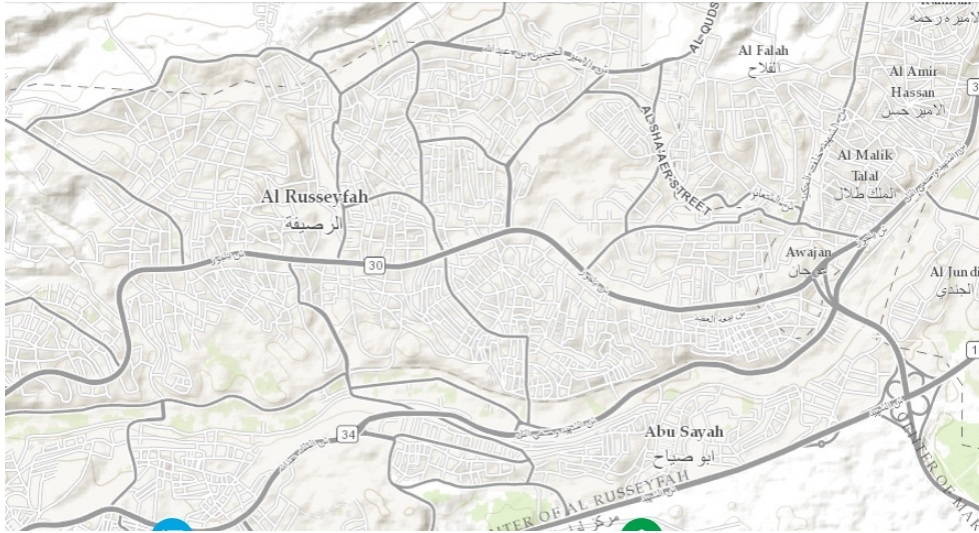
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Urban transportation forecasting process



5. Information Systems



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Urban transportation forecasting process



6. Travel Surveys

- Conducted to establish a complete understanding of the travel patterns within the study area
- For example, the **origin-destination (O-D) survey** is used to to understand why people travel and where they wish to go, for For single projects (such as a highway project)

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Urban transportation forecasting process



6. Travel Surveys

The O-D survey data may include

- where the trip begins and ends,
- the purpose of the trip,
- the time of day
- and the vehicle involved (auto or transit
- about the person making the trip
 - age, sex, income, vehicle owner,

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Urban transportation forecasting process



7. Calibration

- Concerned with establishing mathematical relationships that can be used to estimate future travel demand
- Analysis of the data will reveal the effect on travel demand of factors such as land use, socioeconomic characteristics, or transportation system factor

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7. Calibration

Example

Example 11.3 Estimating Trips per Day Using Multiple Regression

A multiple regression analysis shows the following relationship for the number of trips per household.

$$T = 0.82 + 1.3P + 2.1A$$

where

T = number of trips per household per day

P = number of persons per household

A = number of autos per household

If a particular TAZ contains 250 households with an average of 4 persons and 2 autos for each household, determine the average number of trips per day in that zone.

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7. Calibration

Solution

Solution:

Step 1. Calculate the number of trips per household.

$$\begin{aligned} T &= 0.82 + 1.3P + 2.1A \\ &= 0.82 + (1.3 \times 4) + (2.1 \times 2) \\ &= 10.22 \text{ trips/household/day} \end{aligned}$$

Step 2. Determine the number of trips in the entire zone.

$$\text{Total trips in TAZ} = 250 (10.22) = 2,555 \text{ trips/day}$$

Other mathematical formulas establish the relationships for trip length, percentage of trips by auto or transit, or the particular travel route selected.

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Urban transportation forecasting process



Summary

- Step 1. Population and economic analysis
- Step 2. Land use analysis determines where the activities will be located.
- Step 3. Trip generation determines how many trips each activity will produce or attract

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Urban transportation forecasting process



Summary

- Step 4. Trip distribution determines the origin or destination of trips that are generated at a given activity
- Step 5. Modal split determines which mode of transportation will be used to make the trip
- Step 6. Traffic assignment determines which route on the transportation network will be used when making the trip where each user seeks to minimize their travel time on the network.

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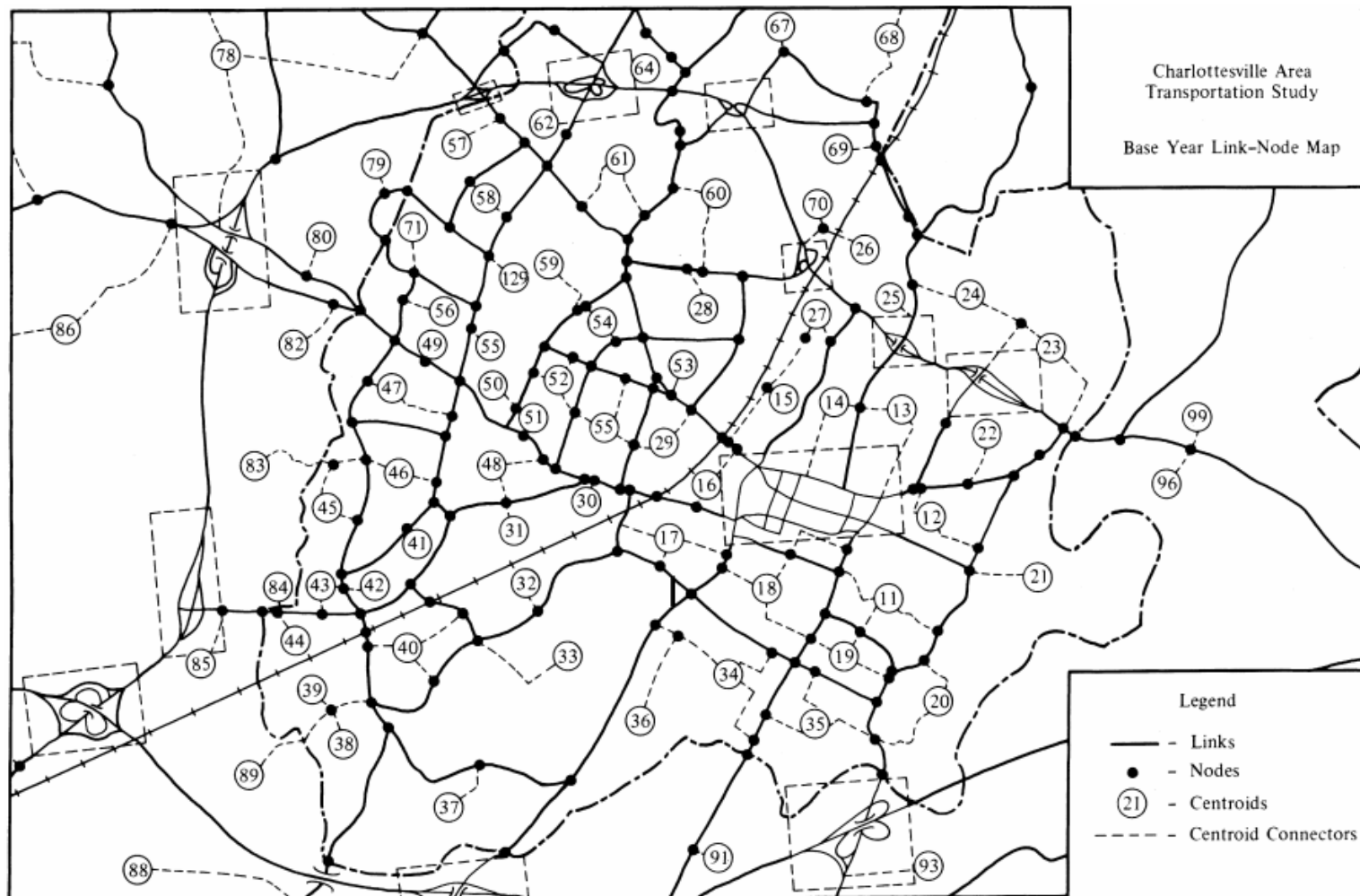
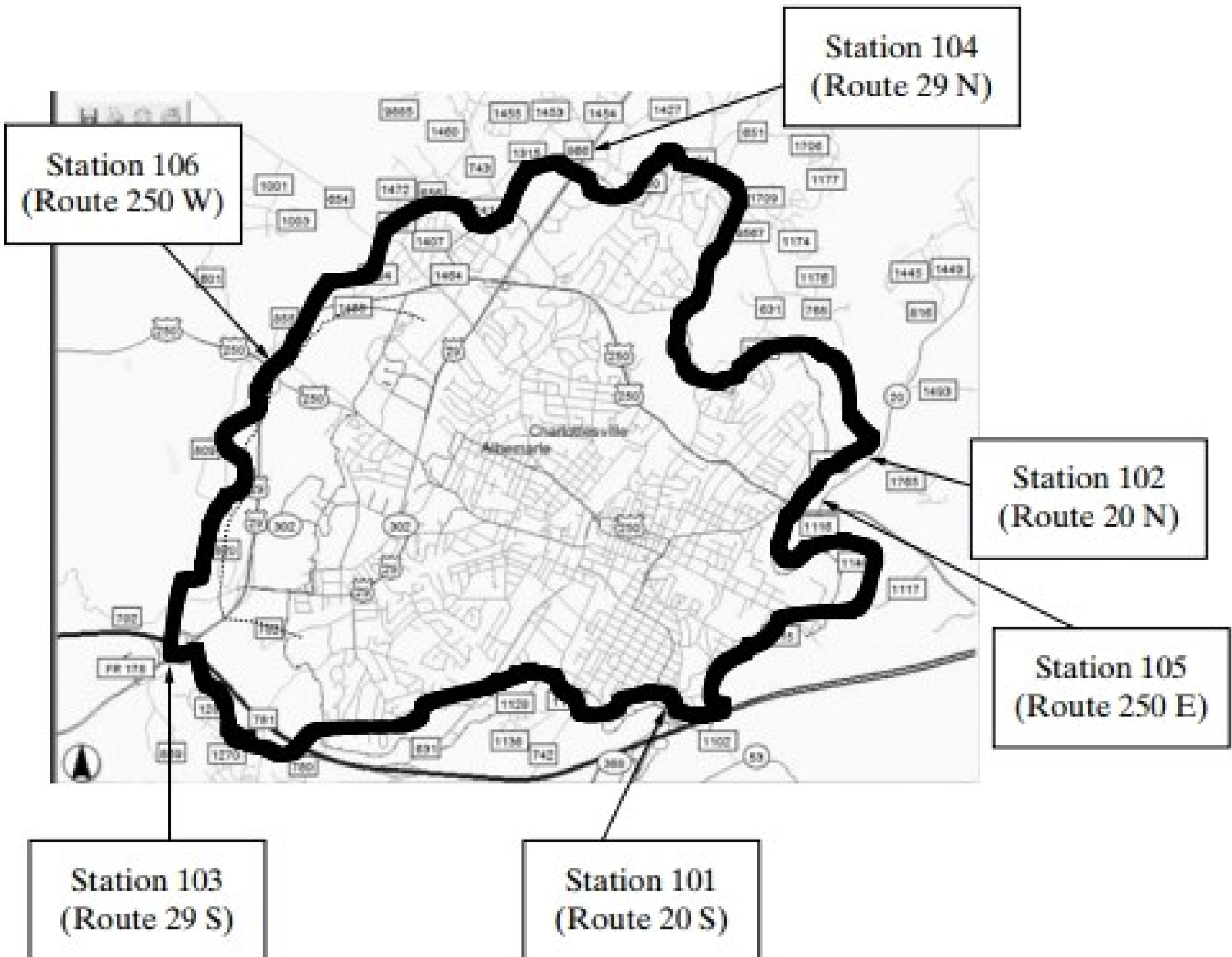


Figure 11.10 Link-Node Map for Highway System

SOURCE: Virginia Department of Transportation.





TRANSPORTATION ENGINEERING AND PLANNING (110 401367) SPRING 2019-2020

Lecture. No. 6 Travel demand forecasting

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning

References

- Nicholas Garber and Lester Hoel , **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015
 - Chapter 12 : Forecasting Travel Demand
 - ❖ Section 11.4
- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, **Highway Engineering: Planning, Design, and Operations**, 2016, Elsevier
 - Chapter 2.2: Planning concepts and Four-step process overview



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2

Topic 2 : Transportation planning



References

- Nicholas Garber and Lester Hoel , **Principles of Highway engineering and traffic analysis**, 5th Edition, 2012
 - [Chapter 8 : Travel Demand and traffic forecasting](#)
- Partha chakroborty and Animesh Das, **Principles of transportation engineering**, 2012,
 - [Chapter 9: Transportation demand analysis](#)
- Dušan Teodorović and Milan Janić, **Transportation engineering theory, practice and modeling** , 2017,
 - [Chapter 8: Transportation demand analysis](#)

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Review



Planning-Level Demand Estimation

- The traffic that this land use will add to the highway and transit facility can be determined using the **four-step process**
- The urban traffic forecasting process involves
 - *Tip generation*
 - *Trip distribution*
 - *Modal split*
 - *Network assignment*
- The travel forecasting process is used to estimate the traffic volume volumes on each link of the system

4

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Review

Defining the Study Area



- It is usually necessary to **delineate the study area boundaries** and to **further subdivide** the area into **traffic analysis zones (TAZ)** for **data tabulation**

5

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Review



The process involves :

1. Defining the Study Area
2. Data Collection
3. Population and Economic Data
4. Transportation Inventories
5. Information Systems
6. Travel Surveys
7. Calibration

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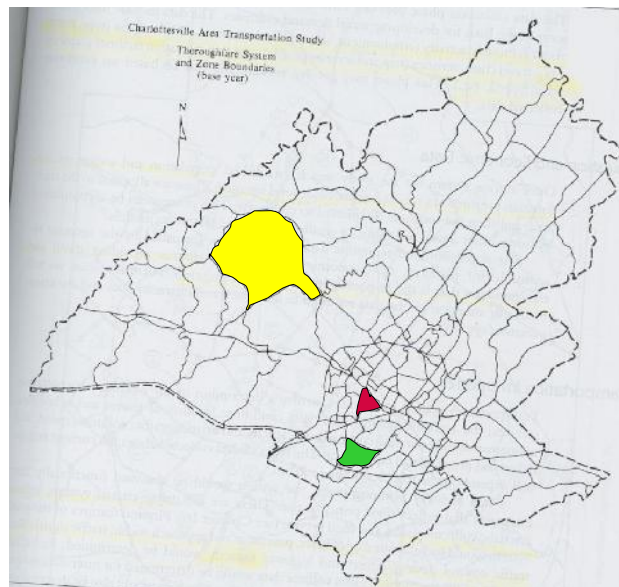
Review

Highway planning study

- The process involves **developing a computerized network** of the existing street and highway system is produced
- The network consists of a series of
 - *links*
 - *Nodes*
 - *Centroids*
 - *External stations*

Review

Traffic Analysis Zones (TAZ)



Review

Highway planning study

■ Links

➤ a portion of the highway system that can be described by its **capacity, lane width, and speed**

■ Nodes

➤ The **end point of a link** and represents an intersection or location where a link changes direction, capacity, width, or speed

■ Centroids

➤ The location within a zone where **trips are considered to begin and end**

■ External stations

➤ are those roadways where traffic is likely to enter or exit the study area

➤ It established at the study area boundary

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Travel demand

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Planning definitions and terms



■ Capacity

➤ A transportation facility's ability to accommodate a moving stream of people or vehicles in a given time period

■ Land use

➤ Refers to the manner in which portions of land or the structures on them are used (or designated for use in a plan), such as commercial, residential, retail, industrial, etc

■ Mode:

➤ A specific form of transportation, such as automobile, subway, bus, rail, air, bicycle, or foot.

■ Performance measures:

➤ Indicators of how well the transportation system is performing with regard to such measures as average speed, reliability of travel, and accident rates. Used as feedback in the decision-making process

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Nature and analysis of transportation demand



■ Transportation demand is a derived demand

– That is, a person **generally** demand to be transported not because he/she just wants to move, but because he/she wants to achieve some other purpose such as reaching school, university, or office.

■ Travel demand is **primarily generated** by the **populations** need to work, socialize, stud, etc.

– Therefore, it is not surprising that **two of the major aspects** in travel demand analysis **are land use and trip-purpose**

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Nature and analysis of transportation demand



Land use

- Land use refers to the manner in which portions of land or the structures on them are used (or designated for use in a plan), such as commercial, residential, retail, industrial, etc
- Land use affects the transportation demand through generation and distribution of trips

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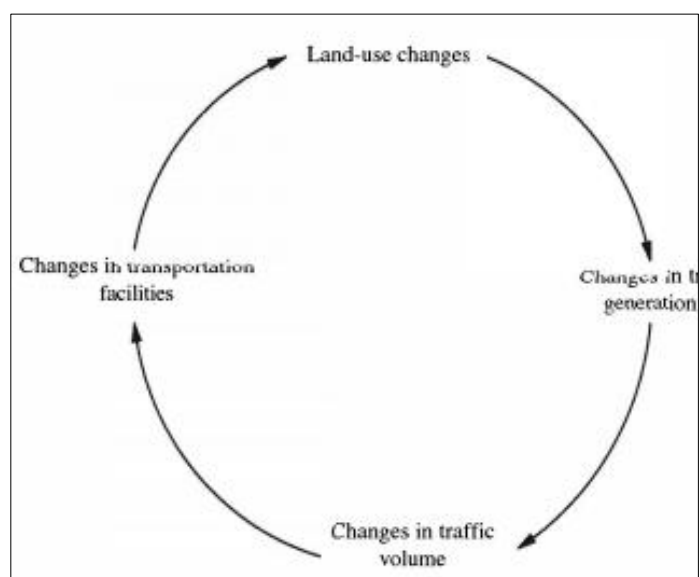
Nature and analysis of transportation demand



Relationship between land-use and transportation demand

- It is not necessarily a one-way effect but rather a part of a cycle

➤ *In this cycle in which land-use changes the transportation needs which in turn change land-use*



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Nature and analysis of transportation demand



Definition of a trip

■ Trip

- Is an out-way **movement** from **a point of origin to a point of destination**.
- The basic quantity in travel demand
- It **materializes** after the trip-maker makes certain decisions

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Nature and analysis of transportation demand



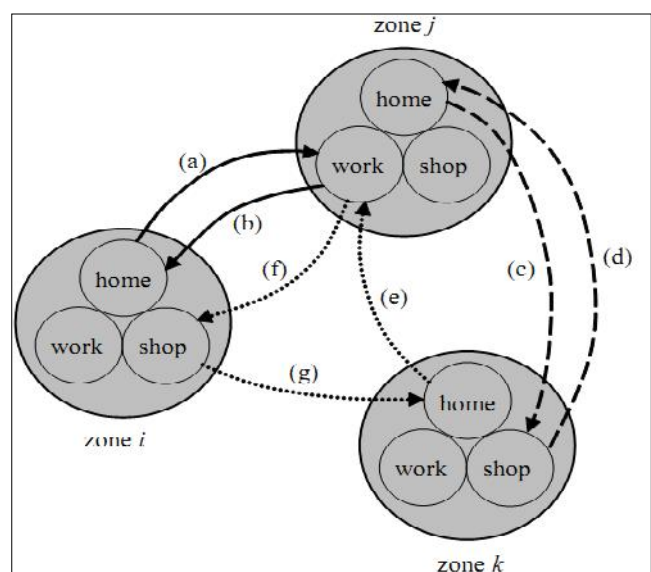
Trip-purpose

■ Home-based trips

- If either **origin** or **destination** of a trip is the **home of the trip maker**

■ Non home-based trips

- Any trip that is **not** a **home-based trip**



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Nature and analysis of transportation demand



Trip-purpose

■ Home-based work (HBW)

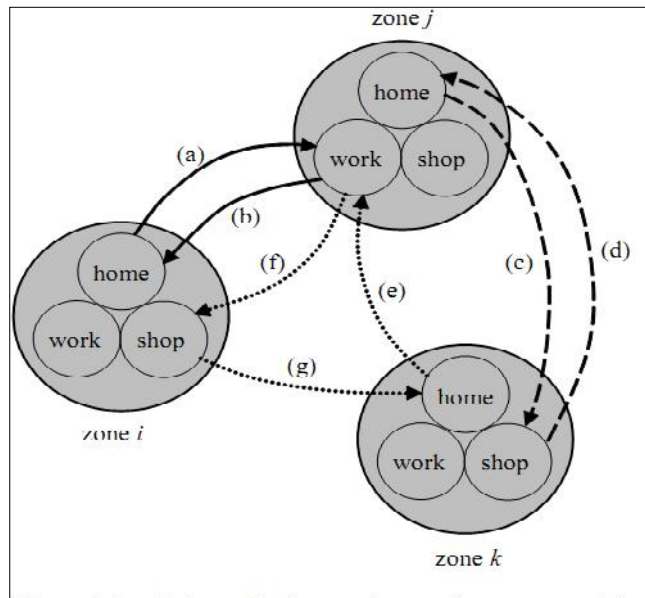
- If the trip is **between** the **home** and **the work** of the trip maker

■ Home-based other (HBO)

- If the trip is between the home and destination except the work of the trip maker

■ Non-home based (NHB)

- Any trip is not HBW or HBO



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Nature and analysis of transportation demand



Trip types

■ Trip production

- All the trips of home based
- The origin of the non home-based trips

■ Trip attraction

- Trips do not classify as trip production

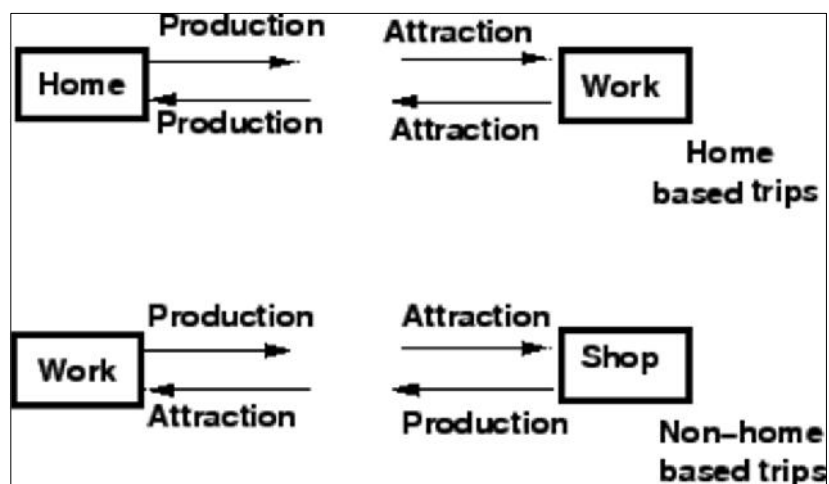


Image source: https://www.civil.iitb.ac.in/~vmtom/1100_LnTse/203_InTse/plain/

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Nature and analysis of transportation demand



Trip-purpose

■ Travel demand behaviors changes with the trip-purpose

- *Work trips*
- *Recreation trips*
- *Shopping trips*

■ The analysis of travel demand is done separately for different trip-purposes

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Nature and analysis of transportation demand



Trip-purpose

■ Work trips

- *Limited number of decisions are available*
- *A person does not necessarily decide every time whether to go to work or not*
- *Generally fixed location and time*
- *The choice of rout and mode of travel are not daily decisions*

■ Recreation trips

- *A large number of decisions are available*
- *To go or not*
- *Where, when, and how to go*

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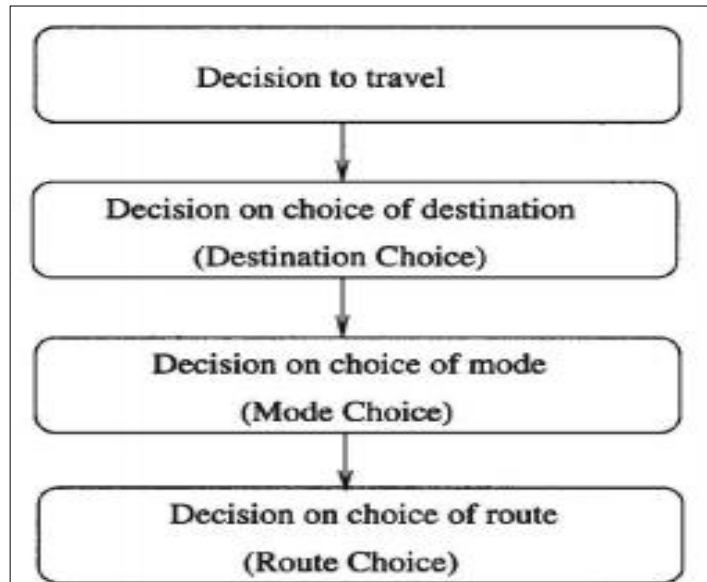
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Trip-maker travel decisions



■ This decisions can be broadly classified into:

- *The decision to travel*
- *The decision on the choice of destination*
- *The decision on the choice of mode*
- *The decision on the choice of route*



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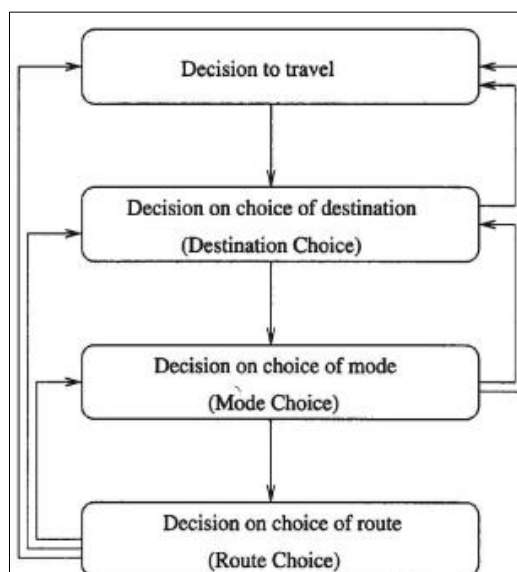
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Trip-maker travel decisions



Assumptions of non-sequential decision making

Usually the sequential demand analysis is used to determine the travel demands, **even** though this assumption may be debatable



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Travel demand forecasting

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Forecasting travel demand

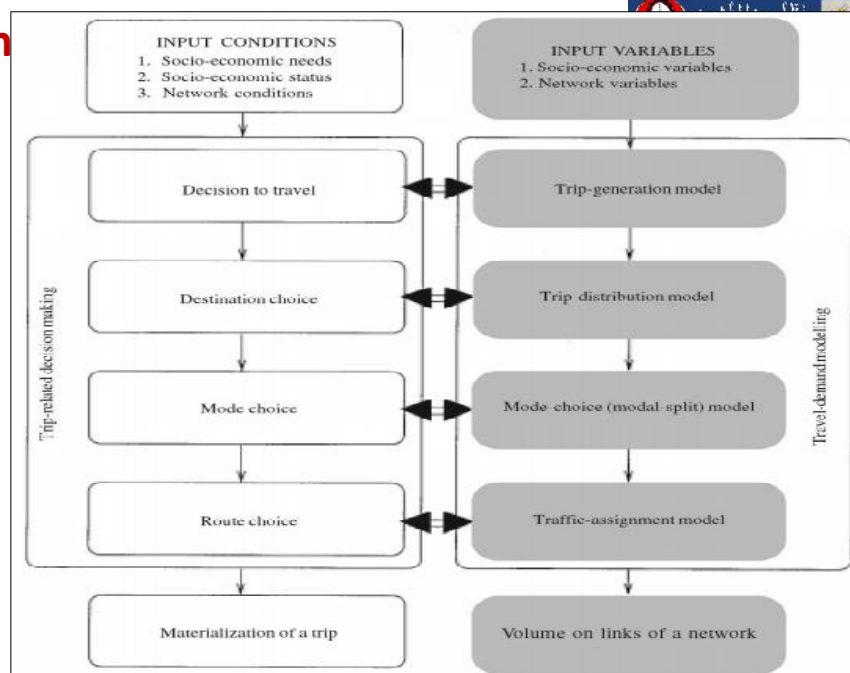
Travel demand definition

- It is the number of persons or vehicles per unit time that can be expected to travel on a given segment of a transportation system under a set of given land-use, socioeconomic, and environmental conditions

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Sequential demand analysis



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Sequential demand analysis



The analysis procedure

1. The entire study area is divided into various zones based on land-use
2. The total number of trips generated in the zone are estimated using trip generation models
3. The output of the trip-generation models are used to determine the number of trips between all zone pairs using the trip-distribution models
4. The relative shares of the generated trips for the different modes are estimated using the mode-choice models
5. The traffic-assignment models are used to estimate the volume on each link of the network

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TRANSPORTATION ENGINEERING AND PLANNING (110 401367) SPRING 2019-2020

Lecture. No. 7 Trip generation

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning



References

- Nicholas Garber and Lester Hoel , **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015
 - Chapter 12 : Forecasting Travel Demand
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- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, **Highway Engineering: Planning, Design, and Operations**, 2016, Elsevier
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2

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Topic 2 : Transportation planning



References

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- Dušan Teodorović and Milan Janić, **Transportation engineering theory, practice and modeling** , 2017,
 - [Chapter 8: Transportation demand analysis](#)

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Review



Planning-Level Demand Estimation

- The traffic that this land use will add to the highway and transit facility can be determined using the **four-step process**
- The urban traffic forecasting process involves
 - Trip generation (How many trips)
 - Trip distribution (From where to where)
 - Modal split (On what mode)
 - Network assignment (On what route)

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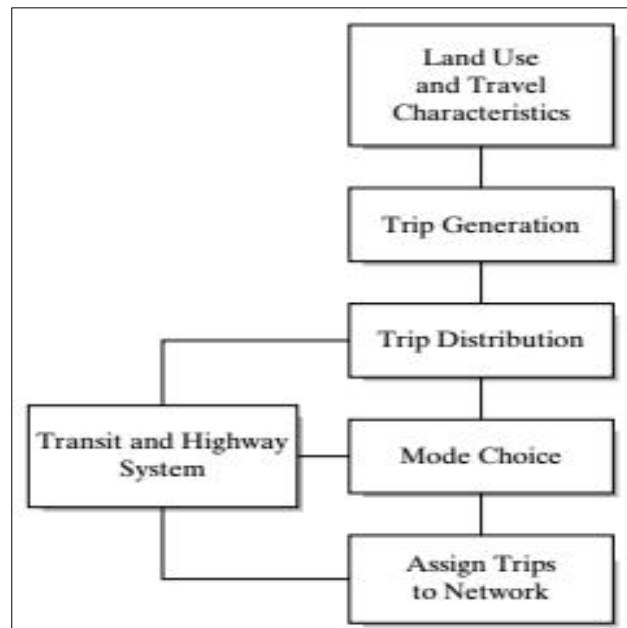
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Review

Travel Forecasting Process

■ Four-step process"

- Trip generation
 - ❖ How many trips
- Trip distribution
 - ❖ From where to where
- Modal choice
 - ❖ On what mode
- Traffic assignment
 - ❖ On what route



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1. Trip generation

- Trip generation estimates the number of trips generated for a given land use, based on prior data of traffic generators in the same land use category
 - The *number of trips* are typically a *function of the type* of *land use*, as well as its size .
- Trip generation is **the first and most important** analysis step in travel forecasting, for both **short- and long-term planning analyses**.

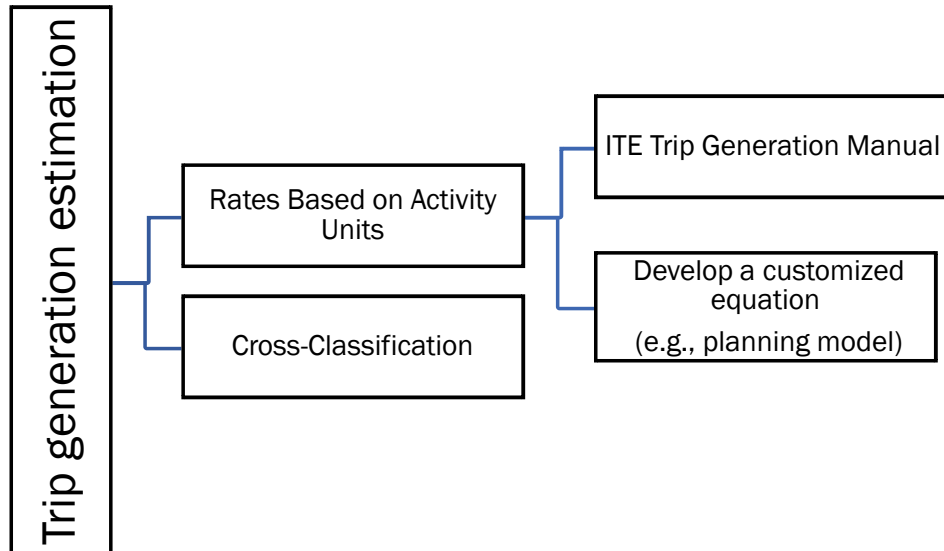
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Trip generation



The **main methods** for estimating generated trips



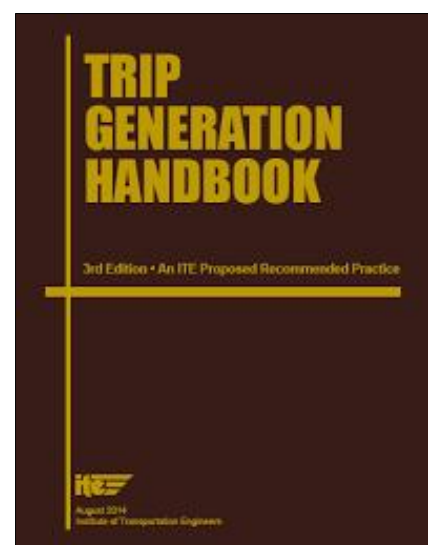
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Trip generation



Rates based on activity units

- **Rate:** it refers to the **number of trips per day per activity center**.
- **Trip generation rates and characteristics in the United States are collected and distributed in the ITE Trip Generation Manual**
 - *It contains data for a total of **172 land use types**, based on a sample of more than 5500 sites across the United States*
 - *The ITE manual applies to **single land use**, homogeneous sites or zones and covers significantly more than 100 land uses*



8

ITE Trip generation manual

Land use types

Common land use types featured in the manual include:

■ Port and terminal

- 6 land uses, including water ports, airports, transit stations, etc.

■ Industrial

- 9 land uses, including general light and heavy industrial, manufacturing, warehousing, etc.

■ Residential

- 19 land uses, including single-family homes, various types of apartments, senior living, mobile home parks, etc.

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ITE Trip generation manual

Land use types

■ Recreational

- 35 land uses, including various parks, fitness facilities, movie theaters, racetracks, etc.

■ Institutional

- 17 land uses, including schools, churches, military facilities, museums, libraries, etc.

■ Medical

- 4 land uses—hospital, nursing home, clinic, and animal hospital

■ Office

- 11 land uses, including general office, medical offices, government offices, post office, etc.

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ITE Trip generation manual

Land use types

■ Retail

- 43 land uses, including various supply stores, convenience stores, supermarkets, sporting goods stores, apparel stores, pet stores, etc.

■ Services

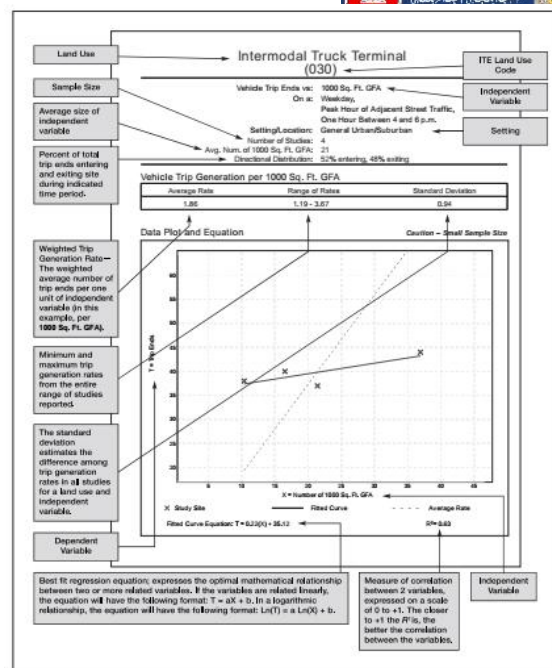
- 24 land uses, including restaurants, fast food, coffee shops, gas stations, banks, etc.

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ITE Trip generation manual

Sample Data Page in Trip Generation Manual

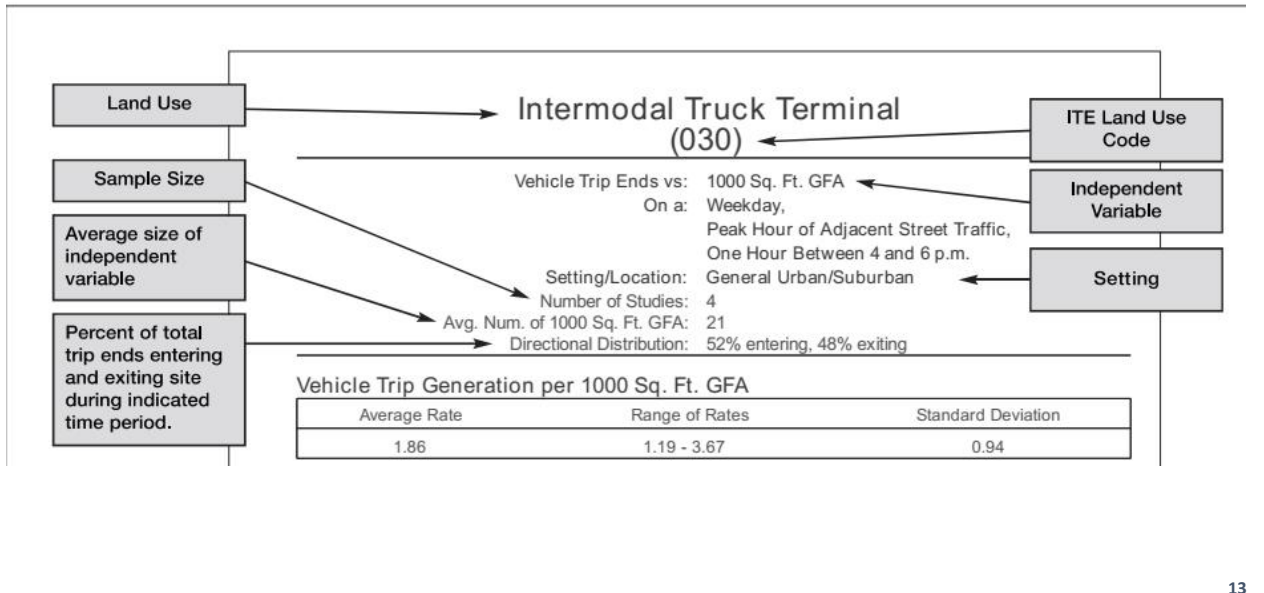


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ITE Trip generation manual

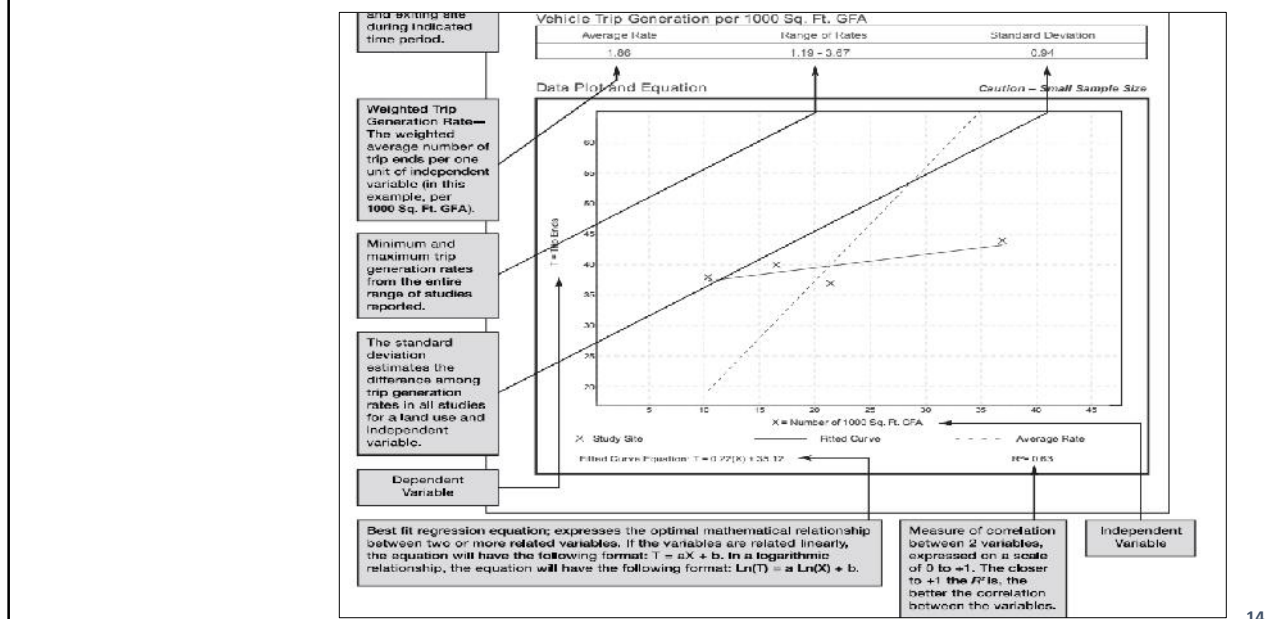
Sample Data Page in Trip Generation Manual



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ITE Trip generation manual

Sample Data Page in Trip Generation Manual



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ITE Trip generation manual

Generated trips estimation process

■ The process including:

1. *Choosing land use*
2. *Choosing analysis period*
3. *Choosing independent variable*



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ITE Trip generation manual

Generated trips estimation process

The general guidelines for use of the ITE manual are as follows:

1. Use equation first

- **if the model statistical fit defined through the R^2 is greater than 0.75.**

2. Use average rate,

- **If standard deviation is less than 1.1 times the average rate.**



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ITE Trip generation manual

Example-1

Estimate the number of trips (T) entering and exiting a university with 20,000 student ?



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ITE Trip generation manual

Example-1 Solution

1. Check the regression model

❖ $R^2=0.95 > 0.75$, thus use the model

2. Use the regression model

❖ $T = 1.38 (x) + 2108.83$

- T =Vehicle Trip Ends
- X =No. of students

❖ $T = 1.38 (20,000) + 2108.83$

❖ $T = 29,708.83$



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ITE Trip generation manual

Example-1 Solution



4. Directional Distribution: 50% entering, 50% exiting

- % of entering trips
 - ❖ $0.5 * 29708 = 14,854$
- % of exiting trips
 - ❖ $0.5 * 29708 = 14,854$

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ITE Trip generation manual

Example-2



A 500-acre site is being developed to support **400 single-family detached houses** and a swimming pool with a clubhouse.

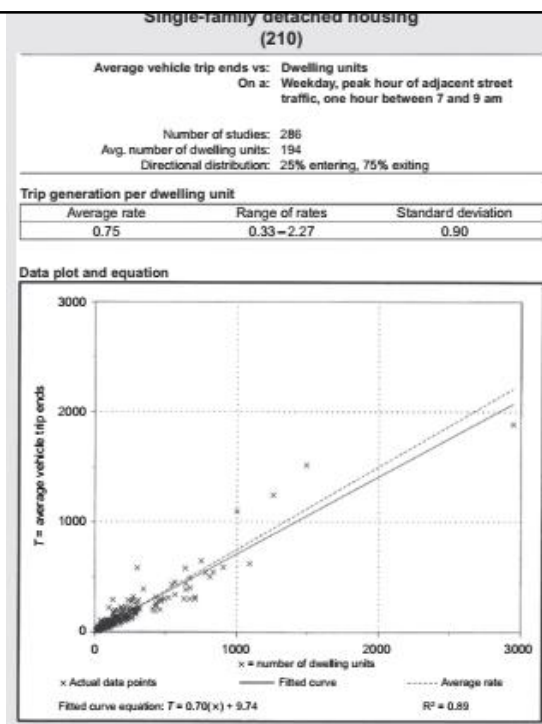
Estimate the **number of trips (T) exiting** the subdivision during **a typical am peak hour**.

20

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ITE Trip generation manual

Example-2



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ITE Trip generation manual

Example-2



Solution

1. Note that our site with 400 units is within the range of units for the study sites, with the bulk of the study sites having less than 1000 units.
2. $R^2 = 0.89$. Because this is >0.75 , we can use the fitted curve equation to solve for the answer versus looking at the average rate.
3. $T = 0.70 (X) + 9.74$, where X is the number of dwelling units.

$$T = 0.70 (400) + 9.74$$

$$T = 290 \text{ total trips}$$

Now, $T_{\text{exit}} = 0.75 (290) = 218$ trips exiting during the am peak hour.
The 0.75 comes from the chart in that 75% are exiting and 25% are entering during the am peak hour.

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ITE Trip generation manual

Example -3

You have been hired to conduct a TIA for a new fast-food restaurant with a drive-through window. Which of the following statements represents the best choice for estimating the number of trips into and out of the restaurant during the am peak?

- Can't estimate the trips because there is no equation.
- Can't estimate the trips because the standard deviation is too high.
- Can use the average rate because the standard deviation is in acceptable limits.
- Can use the average rate but should add a factor of safety to it.

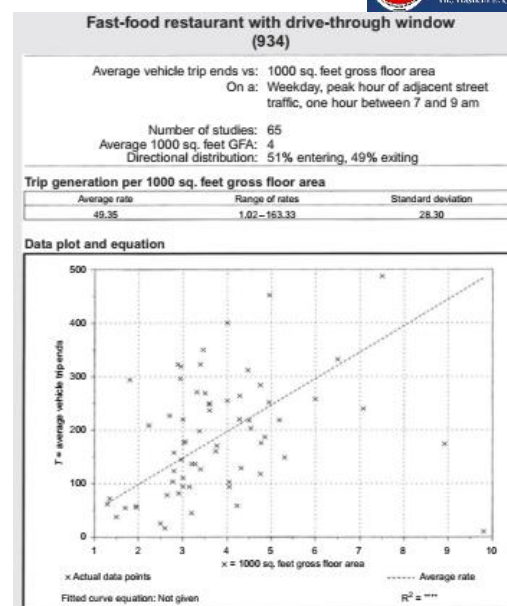
23

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ITE Trip generation manual

Example -3

Rate: it refers to the number of trips per day per activity center.



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ITE Trip generation manual



Example -3

As no equation is given for this land use code, it clearly is not an option for estimating trips. The scatter of the data further supports why the development of an equation was not appropriate for this example.

The land use code does contain an average rate of 49.35 trips per 1000 ft of gross floor area, and the standard deviation of the estimate is 28.30 trips. As this is less than 1.1 times the average, it is acceptable to use the average rate. The correct answer is (c).

25

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ITE Trip generation manual



Example -4

- A **commercial center** in the downtown contains several retail establishments and light industries. **Employed** at the center are **220 retail and 650 non-retail workers**. Determine the number of **trips per day attracted** to this zone.

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ITE Trip generation manual

Example -4



Rate: it refers to the number of trips per day per employee type (retail and nonretail)

Table 12.7 Trip Generation Rates by Trip Purpose and Employee Category

	Attractions per Household	Attractions per Nonretail Employee	Attractions per Downtown Retail Employee	Attractions per Other Retail Employee
HBW	—	1.7	1.7	1.7
HBO	1.0	2.0	5.0	10.0
NHB	1.0	1.0	3.0	5.0

Estimated trips is function with employee type (retail and nonretail)

ITE Trip generation manual

Example -4



Employed at the center are 650 non-retail and 220 retail and workers.

Table 12.7	Trip Purpose and Employee Category	
	Attractions per Nonretail Employee	Attractions per Downtown Retail Employee
HBW	1.7	1.7
HBO	2.0	5.0
NHB	1.0	3.0

Estimated HBW trips

$$(650 \times 1.7) + (220 \times 1.7) = 1479 \quad / \text{day}$$

ITE Trip generation manual



Example -4

Employed at the center are 650 non-retail and 220 retail and workers.

	Attractions per Nonretail Employee	Attractions per Downtown Retail Employee
HBW	1.7	1.7
HBO	2.0	5.0
NHB	1.0	3.0

Estimated HBO trips

$$(650 \times 2) + (220 \times 5) = 2400 \quad /day$$

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ITE Trip generation manual



Example -4

Employed at the center are 650 non-retail and 220 retail and workers.

	Attractions per Nonretail Employee	Attractions per Downtown Retail Employee
HBW	1.7	1.7
HBO	2.0	5.0
NHB	1.0	3.0

Estimated NHB trips

$$(650 \times 1) + (220 \times 3) = 1310 \quad /day$$

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ITE Trip generation manual

Example -4

Estimated Total trips

$$\text{HBW: } (220 \times 1.7) + (650 \times 1.7) = 1479$$

$$\text{HBO: } (220 \times 5.0) + (650 \times 2.0) = 2400$$

$$\text{NHB: } (220 \times 3.0) + (650 \times 1.0) = 1310$$

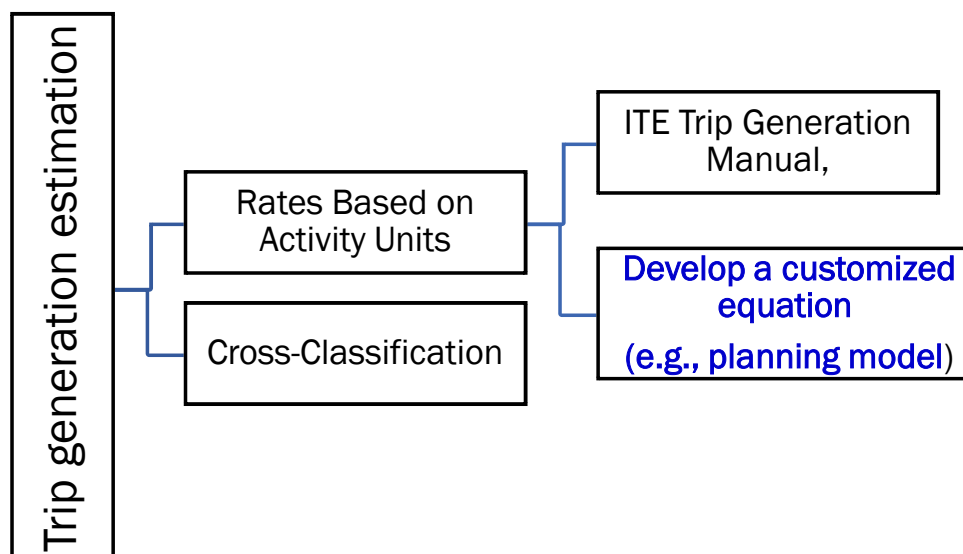
$$\text{Total} = 5189 \text{ trips/day}$$

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Trip generation

The [main methods](#) for estimating generated trips



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32

Develop a customized equation (e.g., planning model)



Case studies in Jordan

- Alkuime, H, 2015. ***Trip Attraction Model For Universities In Jordan.*** Master of Science in Civil Engineering in Transportation, Jordan University of Science and Technology
- Abu-Ameerh, S. 2007. ***Trip attraction model for hospitals in Amman.*** Master of Science in Civil Engineering in Transportation. Jordan University, Jordan.
- Al-Jabari, O. 2009. ***Trip Attraction Model For Fast Food Restaurants In Amman,*** Master of Science in Civil Engineering in Transportation, Jordan University, Jordan
- Al-Nawaiseh, H 2010. ***Trip Attraction Model For Private Schools In Amman,*** Master of Science in Civil Engineering in Transportation, Jordan University, Jordan

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Develop a customized equation (e.g., planning model)



Trip Attraction Model For Universities In Jordan

Regression models were developed to predict vehicles trips within the day or peak hours, based on different characteristics of universities such as:

1. Number of students.
2. Number of administrative staff.
3. Number of academic staff.
4. Gross floor area of universities.
5. Number of studying rooms and labs.
6. Number of courses
7. Number of lectures

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Develop a customized equation (e.g., planning model)



Trip Attraction Model For Universities In Jordan

University Name	Type	Province
Jordan University of Science & Tech. (JUST)	Public	Irbid
Al al-Bayt University (AABU)	Public	Al-Mafraq
Jadara University	Private	Irbid
Irbid National University	Private	Irbid
Philadelphia Private University	Private	Amman
Zarqa University (ZU)	Private	Zarqa
Jarash University	Private	Jarash
Ajloun National Private Univ.	private	Ajloun

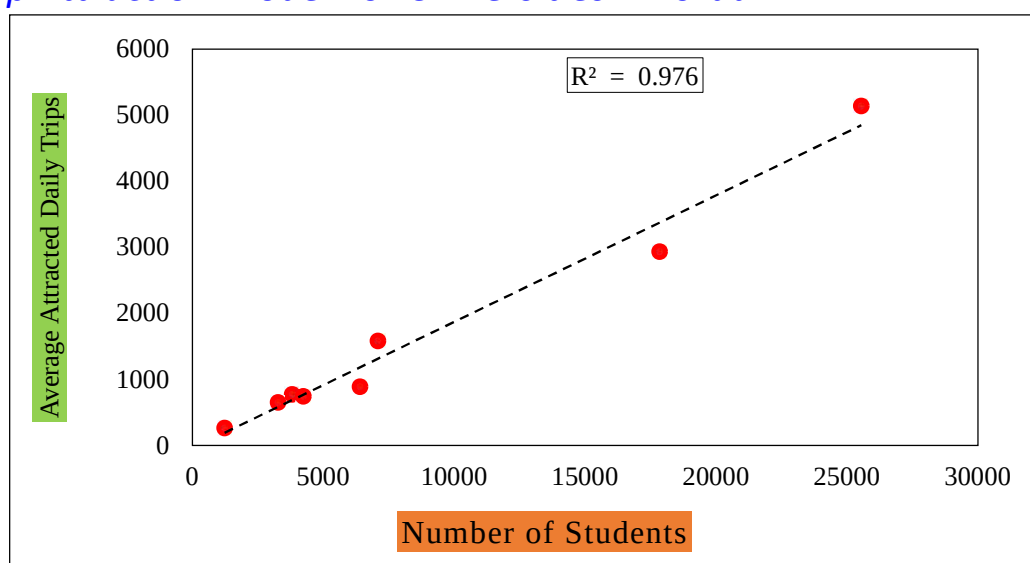
35

35

Develop a customized equation (e.g., planning model)



Trip Attraction Model For Universities In Jordan



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Develop a customized equation (e.g., planning model)



Trip Attraction Model For Universities In Jordan

Developed models	R ²
$LN(V_{TD}) = 0.472 + 0.297 * LN(GFA) + 0.3256 * LN(NS) + 0.360 * LN(NL)$	0.968
$LN(V_{AD}) = -0.205 + 0.296 * LN(GFA) + 0.325 * LN(NS) + 0.36 * LN(NL)$	0.967
$LN(V_{TH}) = -2.643 + 0.985 * LN(NS)$	0.985
$LN(V_{AH}) = -2.380 + 0.926 * LN(NS)$	0.976

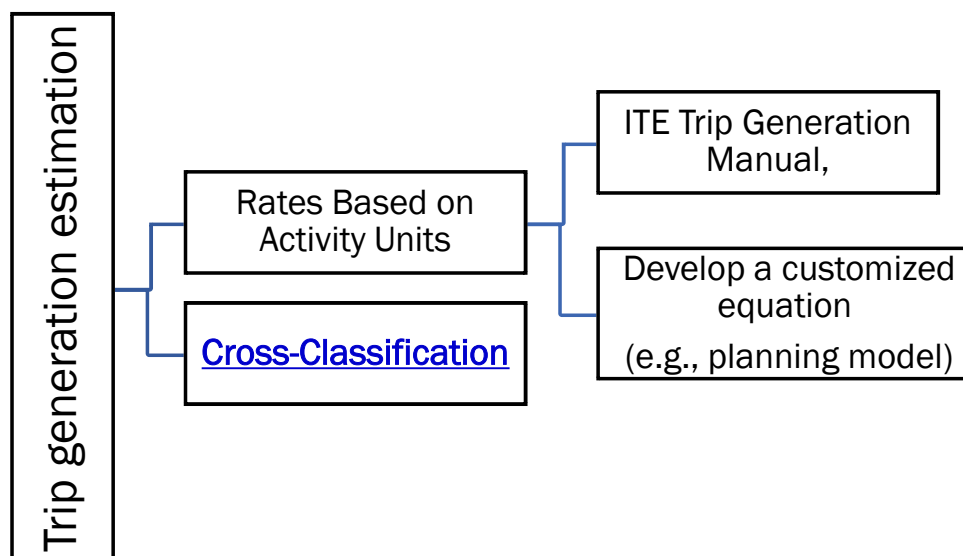
37

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Trip generation



The **main methods** for estimating generated trips



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Cross – Classification



- Cross-Classification: a technique developed by FHWA to **determine the number of trips that begin or end at the home**

➤ Home based trips

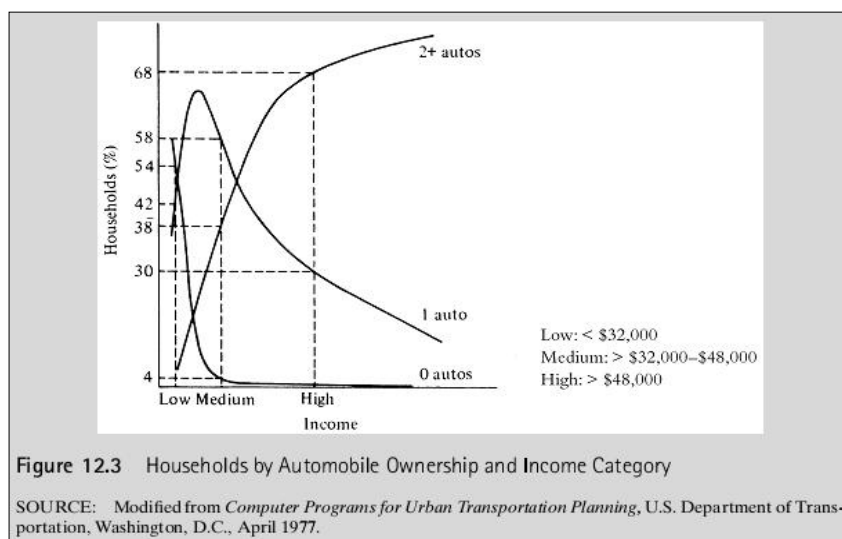
- The two variables most commonly used are **average income** and **auto ownership**.

➤ *Other variables that could be considered are **household size and stage** in the household life cycle*

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Cross – Classification



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Cross – Classification

Example - 5 : Developing Trip Generation Curves from Household Data

A travel survey produced the data shown in Table 12.1. **Twenty households** were interviewed

Based on the data provided, develop a set of curves showing the number of trips per household versus income and auto Ownership?

Table 12.1 Survey Data Showing Trips per Household, Income, and Auto Ownership

Household Number	Trips Produced per Household	Household Income (\$1000s)	Autos per Household
1	2	16	0
2	4	24	0
3	10	68	2
4	5	44	0
5	5	18	1
6	15	68	3
7	7	38	1
8	4	36	0
9	6	28	1
10	13	76	3
11	8	72	1
12	6	32	1
13	9	28	2
14	11	44	2
15	10	44	2
16	11	52	2
17	12	60	2
18	8	44	1
19	8	52	1
20	6	28	1

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Cross – Classification

Example - 5 : Developing Trip Generation Curves from Household Data

Step 1 : Produce a matrix that shows the number and percentage of households as a function of auto ownership and income grouping

Table 12.2 Number and Percent of Household in Each Income Category versus Car Ownership

Income (\$1000s)	Autos Owned			Total
	0	1	2+	
24	2(67)	1(33)	0(0)	3(100)
24–36	1(25)	3(50)	1(25)	5(100)
36–48	1(20)	2(40)	2(40)	5(100)
48–60	—	1(33)	2(67)	3(100)
>60	—	1(25)	3(75)	4(100)
Total	4	8	8	20

Note: Values in parentheses are percent of automobiles owned at each income range.

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Cross – Classification



Example - 5 : Developing Trip Generation Curves from Household Data

Step 2 : Produce a matrix shows Average Trips per Household versus Income and Car Ownership

Table 12.3 Average Trips per Household versus Income and Car Ownership

Income (\$1000s)	Autos Owned		
	0	1	2+
≤24	3	5	—
24–36	4	6	9
36–48	5	7.5	10.5
48–60	—	8.5	11.5
>60	—	8.5	12.7

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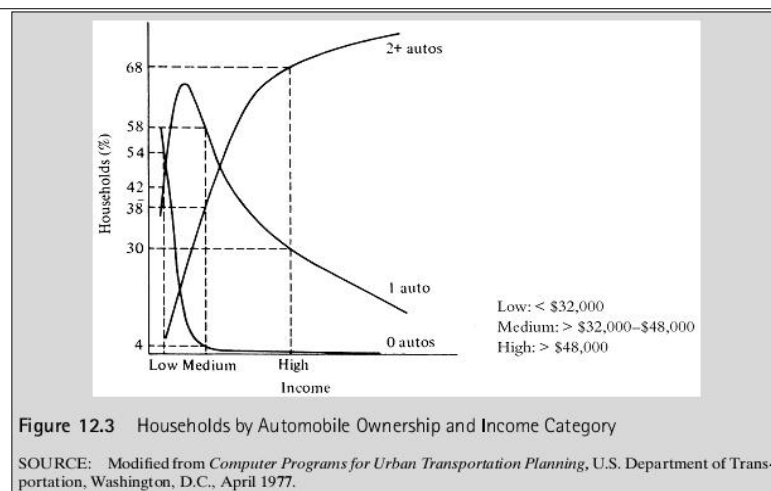
43

Cross – Classification



Example - 5 : Developing Trip Generation Curves from Household Data

Step 2: Plot Average Trips per Household versus Income and Car Ownership

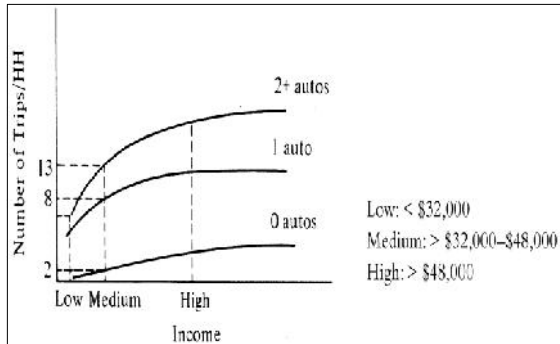


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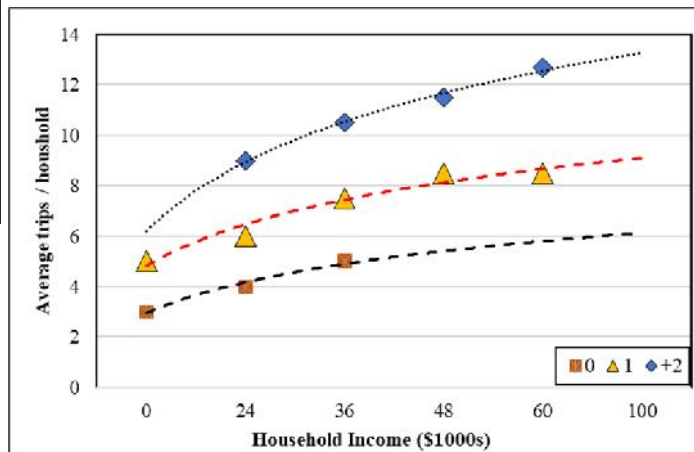
44

Cross – Classification

Example - 5 : Developing Trip Generation Curves from Household Data



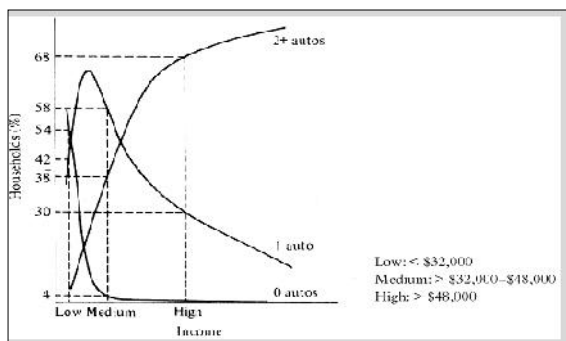
SOURCE: Modified from *Computer Programs for Urban Transportation Planning*, U.S. Department of Transportation, Washington, D.C., April 1977



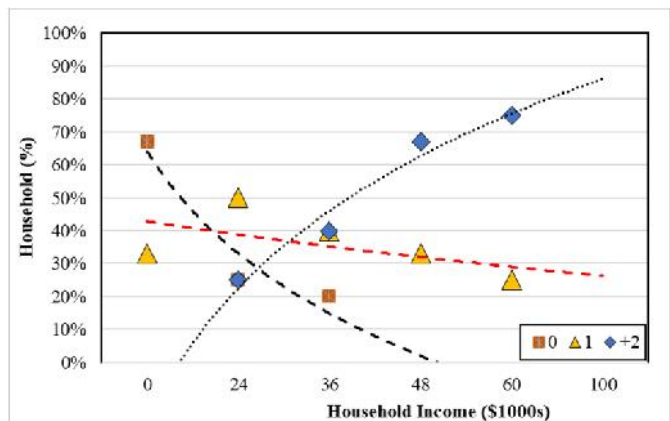
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Cross – Classification

Example - 5 : Developing Trip Generation Curves from Household Data



SOURCE: Modified from *Computer Programs for Urban Transportation Planning*, U.S. Department of Transportation, Washington, D.C., April 1977



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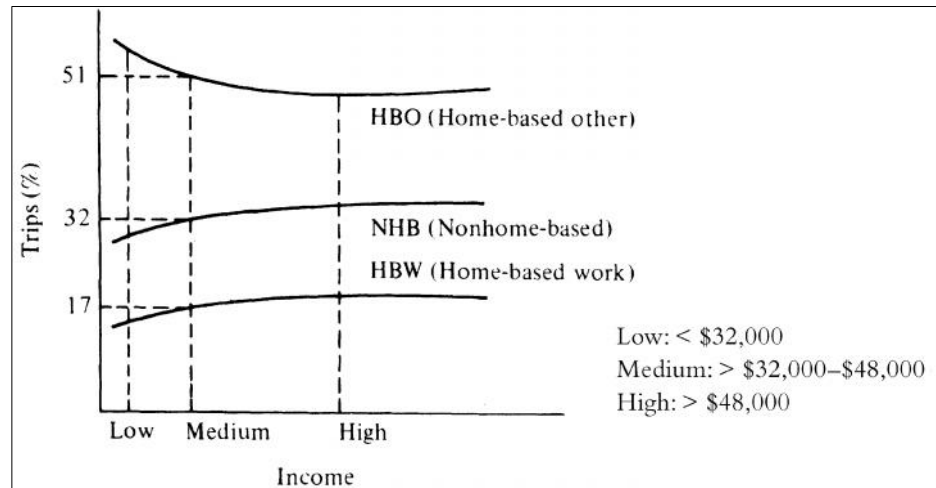
Cross – Classification



Example - 5 : Developing Trip Generation Curves from Household Data

Addition work (Step 3): Determine the percentage of trips by each trip purpose for each income category

* Data is not given in the example



Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Consider a zone that is located in a suburban area of a city. The population and income data for the zone are as follows.

- Number of dwelling units: **60**
- Average income per dwelling unit: **\$44,000**

Determine the **number of trips per day** generated in this zone for each trip purpose, assuming that the characteristics depicted in **Figures 12.2 through 12.5** apply in this situation.

Cross – Classification

Example -6 : Computing Trips Generated in a Suburban Zone

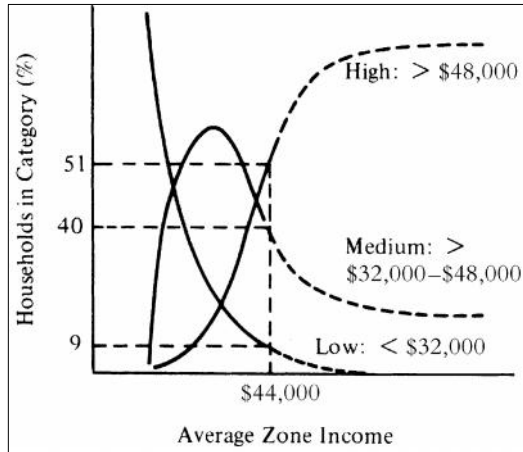


Figure 12.2

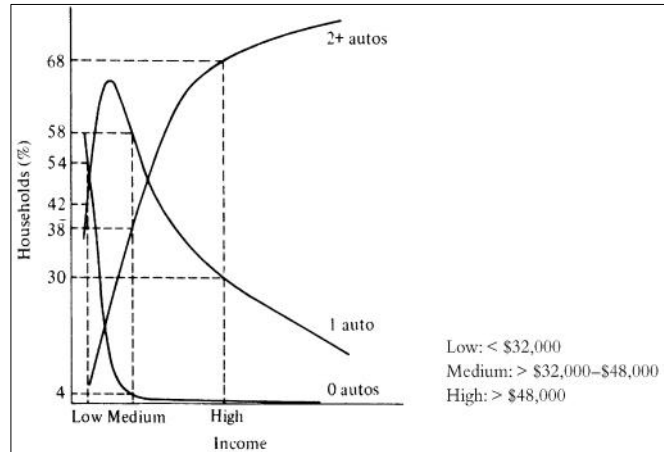


Figure 12.3

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Cross – Classification

Example -6 : Computing Trips Generated in a Suburban Zone

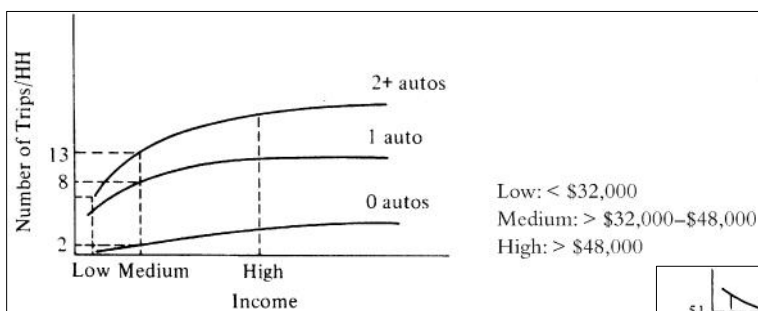
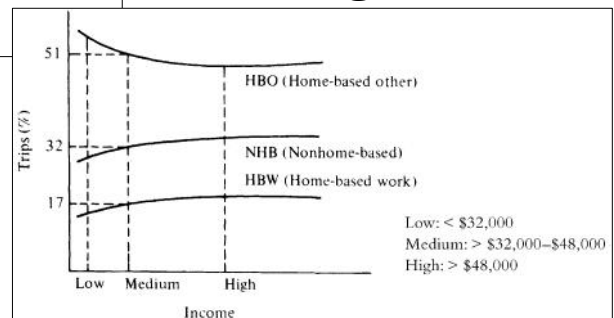


Figure 12.4

Figure 12.5



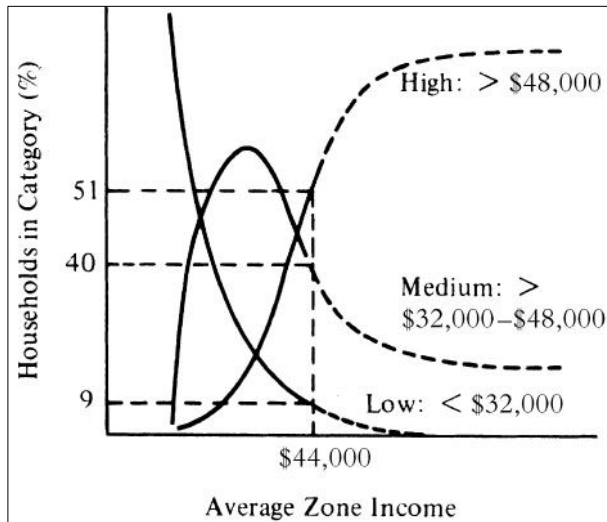
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Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 1 : Determine the percentage of households in each economic category



Income (\$)	Households (%)
Low (under 32,000)	9
Medium (32,000–48,000)	40
High (over 48,000)	51

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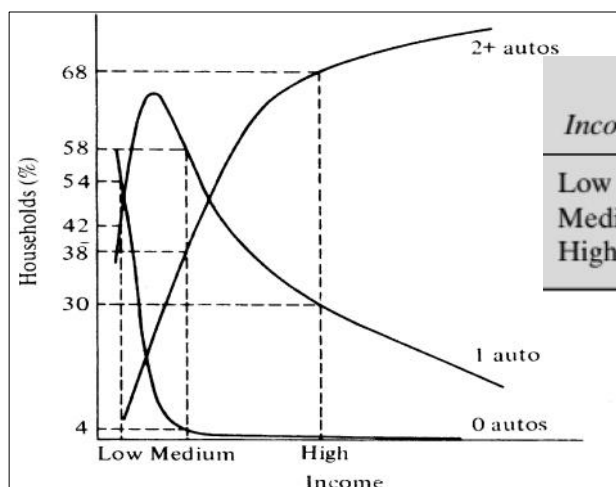
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Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 2 : Determine the number of trips per household per day for each income–auto ownership category.



Income	Autos/Household		
	0	1	2+
Low	54	42	4
Medium	4	58	38
High	2	30	68

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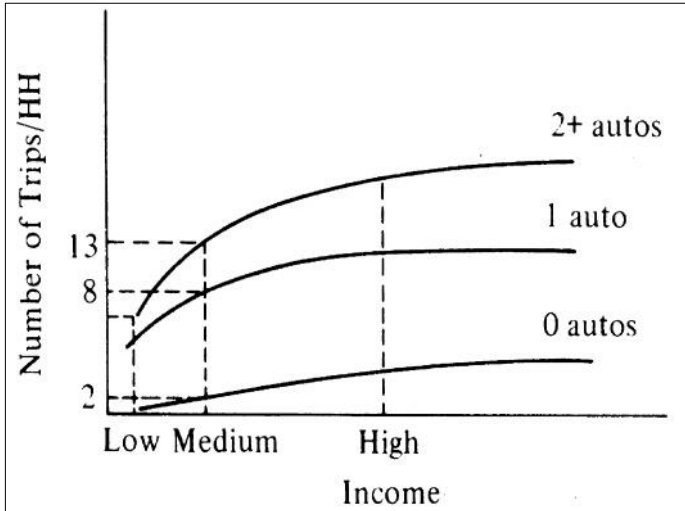
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Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 3: Determine the number of trips per household per day for each income–auto ownership category



Income	Autos/Household		
	0	1	2+
Low	1	6	7
Medium	2	8	13
High	3	11	15

58% of medium-income families own one auto per household.

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53

Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 4: Calculate the total number of trips per day generated in the zone

$$P_{gh} = HH \times I_g \times A_{gh} \times (P_H)_{gh}$$

$$P_T = \sum_g \sum_h P_{gh}$$

HH = number of households in the zone

I_g = percentage of households (decimal) in zone with income level g (low, medium, or high)

A_{gh} = percentage of households (decimal) in income level g with h autos per household ($h = 0, 1, \text{ or } 2+$)

P_{gh} = number of trips per day generated in the zone by householders with income level g and auto ownership h

$(P_H)_{gh}$ = number of trips per day produced in a household at income level g and auto ownership h

P_T = total number of trips generated in the zone

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Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 4: Calculate the total number of trips per day generated in the zone

Table 12.6 Number of Trips per Day Generated by Sixty Households

	<i>Income, Auto Ownership</i>	<i>Total Trips by Income Group</i>
$60 \times 0.09 \times 0.54 \times 1 = 3$ trips	L, 0+	
$60 \times 0.09 \times 0.42 \times 6 = 14$ trips	L, 1+	
$60 \times 0.09 \times 0.04 \times 7 = 2$ trips	L, 2+	19
$60 \times 0.40 \times 0.04 \times 2 = 2$ trips	M, 0+	
$60 \times 0.40 \times 0.58 \times 8 = 111$ trips	M, 1+	
$60 \times 0.40 \times 0.38 \times 13 = 119$ trips	M, 2+	232
$60 \times 0.51 \times 0.02 \times 3 = 2$ trips	H, 0+	
$60 \times 0.51 \times 0.30 \times 11 = 101$ trips	H, 1+	
$60 \times 0.51 \times 0.68 \times 15 = 312$ trips	H, 2+	415
Total = 666 trips		666

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55

Cross – Classification



Example -6 : Computing Trips Generated in a Suburban Zone

Step 5 : Determine the percentage of trips by trip purpose

Step 5. Determine the percentage of trips by trip purpose. As a final step, we can calculate the number of trips that are HBW, HBO, and NHB. If these percentages are 17, 51, and 32, respectively (see Figure 12.5), for the medium-income category, then the number of trips from the zone for the three trip purposes are $232 \times 0.17 = 40$ HBW, $232 \times 0.51 = 118$ HBO, and $232 \times 0.32 = 74$ NHB. (Similar calculations would be made for other income groups.) The final result, which is left for the reader to verify, is obtained by using the following percentages: low income at 15, 55, and 30, and high income at 18, 48, and 34. These yield 118 HBW, 327 HBO, and 221 NHB trips.

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Trip types

■ Trip production

- All the trips of home based
- The origin of the non home-based trips

■ Trip attraction

- Trips do not classify as trip production

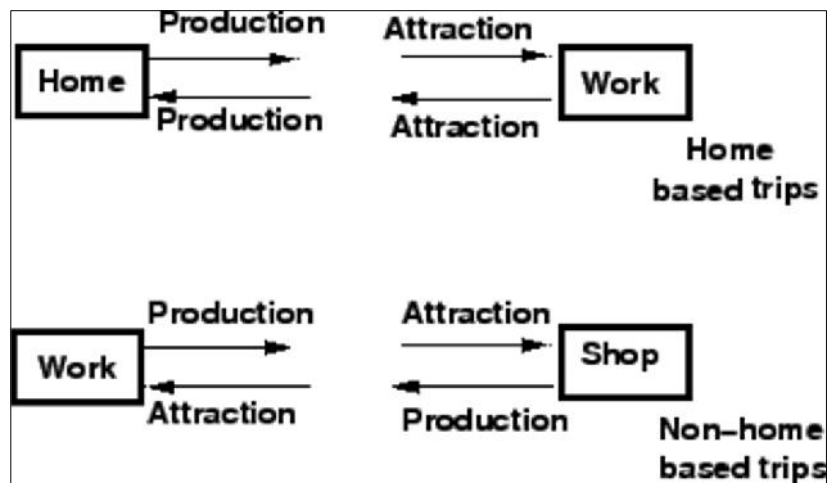


Image source: https://www.civil.iitb.ac.in/~vmtom/1100_LnTse/203_LnTse/plain/

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Trip generation

■ Attracted (T_a) trips

- T_a is function with *land use*

■ Produced (T_p) trips?

- T_p is function with population, income, household size, number of household size, vehicle owned

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Trip generation



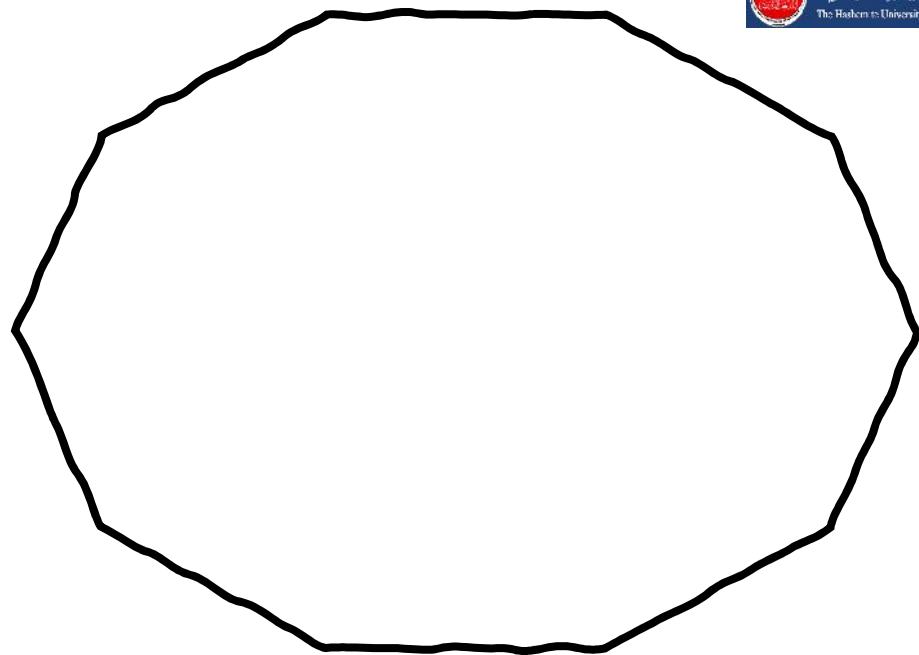
TRIP PURPOSE	MODEL TYPE	INDEPENDENT VARIABLES	REGRESSION	R ²
TO HOME	PRODUCED	POPULATION	$P = 0.514X_1 - 9.717$	0.745
	ATTRACTED	WORKERS PER ZONE & STUDENTS PER ZONE	$A = 0.812X_8 + 0.943X_{13} - 84.621$	0.983
TO WORK	PRODUCED	NO. OF HOUSEHOLDS	$P = 1.368X_2 - 225.047$	0.868
	ATTRACTED	WORKERS PER ZONE	$A = 0.8698X_6 - 192.25$	0.987
TO SCHOOL	PRODUCED	NO. OF HOUSEHOLDS	$P = 0.9851X_2 + 43.649$	0.737
	ATTRACTED	STUDENTS PER ZONE	$A = 0.8355X_{13} + 41.39$	0.972

Aloc, D. S. & Amar, J. A. N. A. C. Trip Generation Modeling of Lipa City Trip Generation Modelling of Lipa City. (2014). doi:10.13140/2.1.2171.7126

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Example

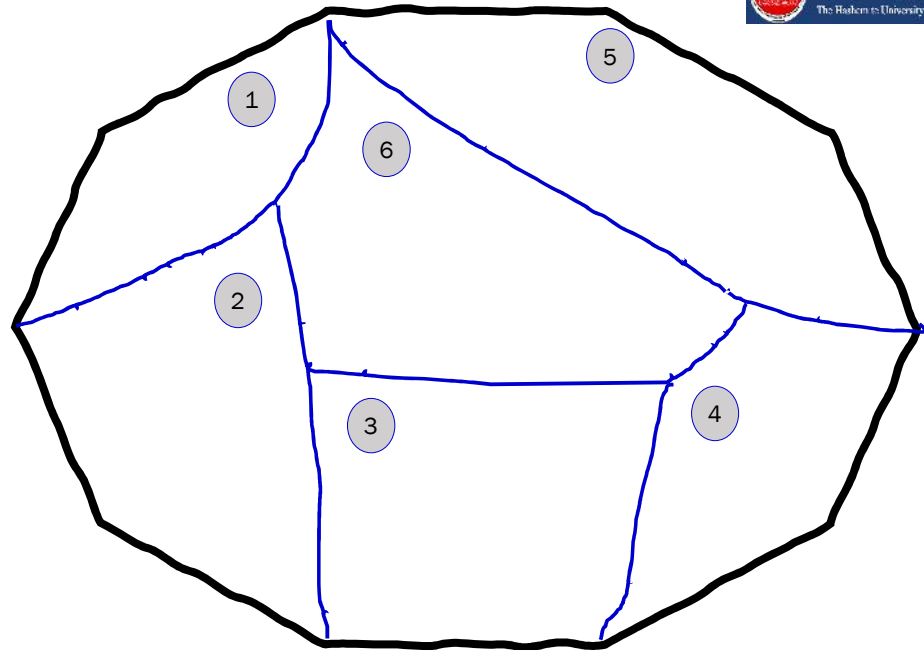


Study area

60

60

Example



Zoning

61

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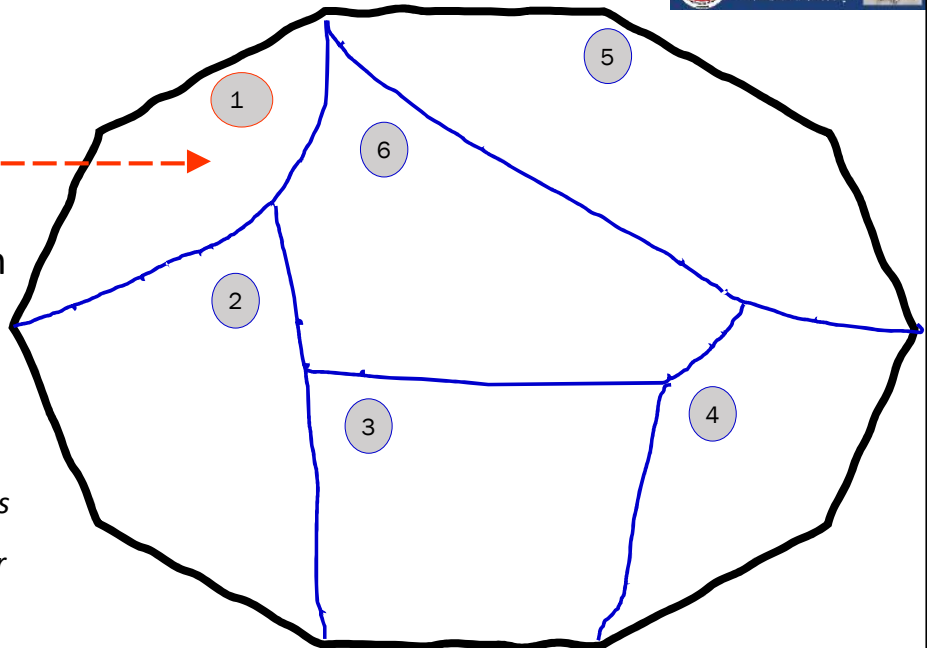
Example



Attracted trips

The land use within
Zone 1 are

- 120 office space
- 500 factory
- 50 educational seats
- 100 shopping center



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Example



How many trips are attracted (T_a) and produced to a zone 1?

Land use (By survey)	Number of units (By survey)	Trip rates (manual)	Attracted (T_a) trips (column 2 X column 3)
office space	120	1.18	472
factory	500	0.43	64.5
educational seats	50	1.2	108
shopping center	100	2.1	630
Total attracted trips (T_a)			626

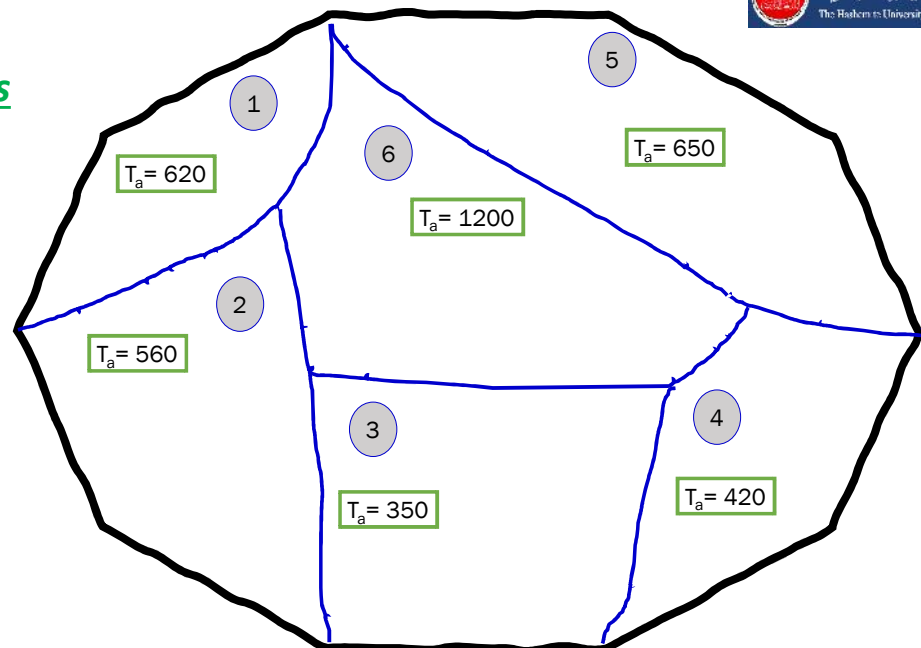
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Example



Attracted trips



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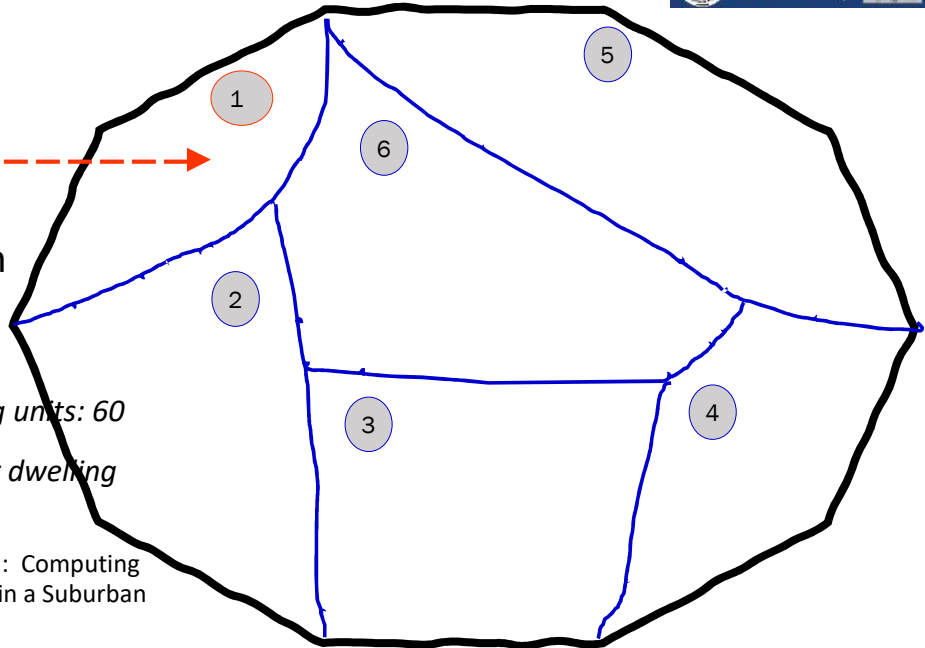
Example

Produced Trips

The land use within

Zone 1 are

- Number of dwelling units: 60
- Average income per dwelling unit: \$44,000
- ❖ See example - 6 : Computing Trips Generated in a Suburban Zone

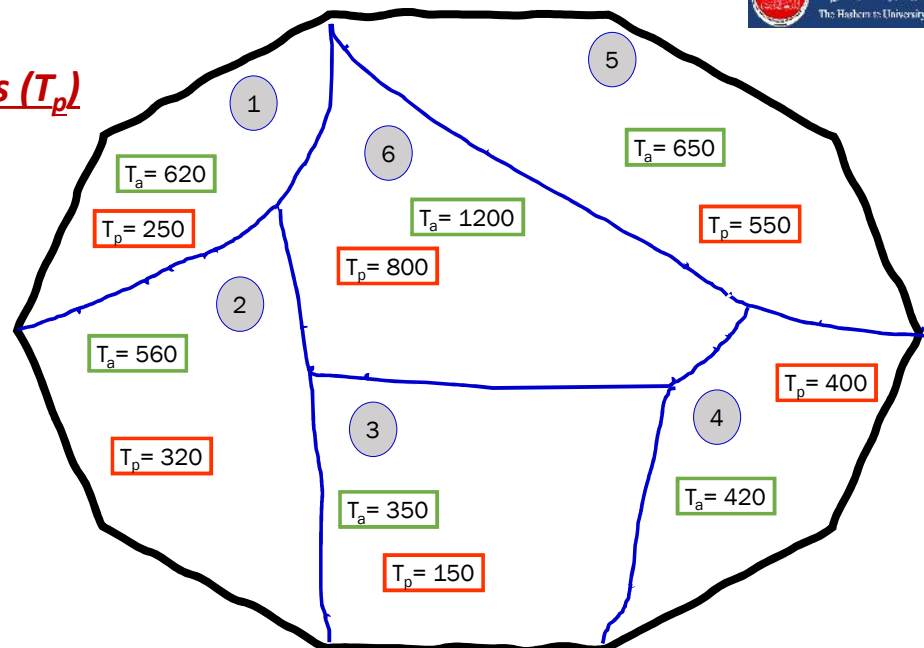


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Example

Produced trips (T_p)



66

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Balancing Trip Productions and Attraction



الجامعة الهاشمية
The Hashemite University



- A likely result of the trip generation process is that the number of **trip productions** may not be equal to the number of **trip attractions**
- **Trip productions**, which are based on census data, are considered to be more accurate than **trip attractions**
 - Trip attractions are usually modified so that they are equal to trip productions

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Balancing Trip Productions and Attraction



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Example - 6 : Balancing the Home-based trips

- The trip generation process between zone 1 through zone 3 has produced

➤ 600 HBW productions trips

➤ 800 HBW attraction trips

Zone	Unbalanced HBW Trips	
	Productions	Attractions
1	100	240
2	200	400
3	300	160
Total	600	800

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Balancing Trip Productions and Attraction

Example - 6 : Balancing the Home-based trips

■
$$= \frac{\text{Attractions}}{\text{Productions}}$$

➤
$$= \frac{240}{300} = 0.75$$

Zone	Unbalanced HBW Trips	
	Productions	Attractions
1	100	240
2	200	400
3	300	160
Total	600	800

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Balancing Trip Productions and Attraction

Example - 6 : Balancing the Home-based trips

■
$$= \frac{\text{Attractions}}{\text{Productions}} \times \text{Productions}$$

Table 12.8a Balancing Home-Based Work Trips				
Zone	Unbalanced HBW Trips		Balanced HBW Trips	
	Productions	Attractions	Productions	Attractions
1	100	240	100	180
2	200	400	200	300
3	300	160	300	120
Total	600	800	600	600

$$=(240 \times 0.75) = 180$$

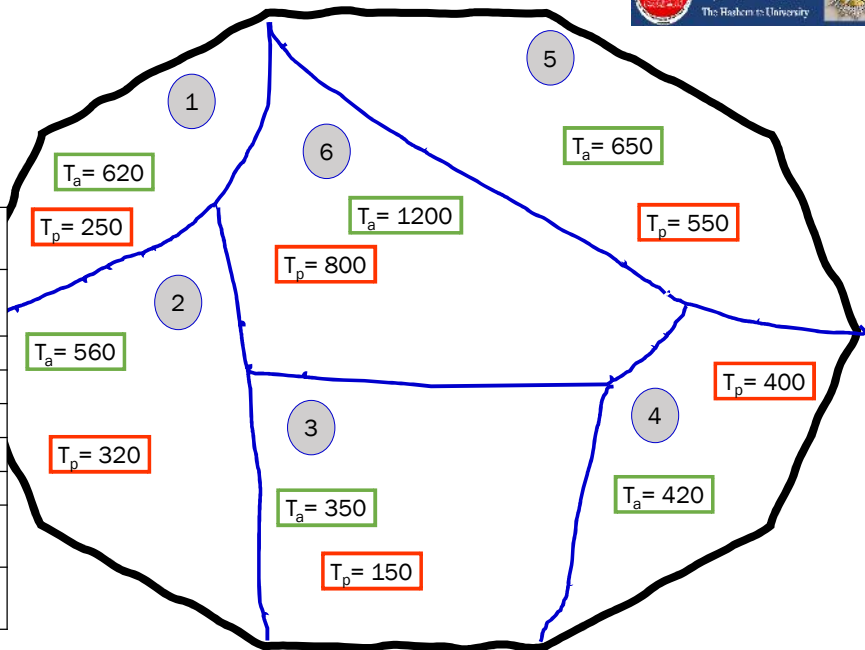
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Example

Unbalanced Trip Productions and Attractions

Zone ID	Unbalanced trips	
	Production	Attraction
1	250	620
2	320	560
3	150	350
4	400	420
5	550	650
6	800	1200
Total trips	2470	3800



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Example

Balancing Trip Productions and Attractions

■ = —————

➤ = ————— = 0.65

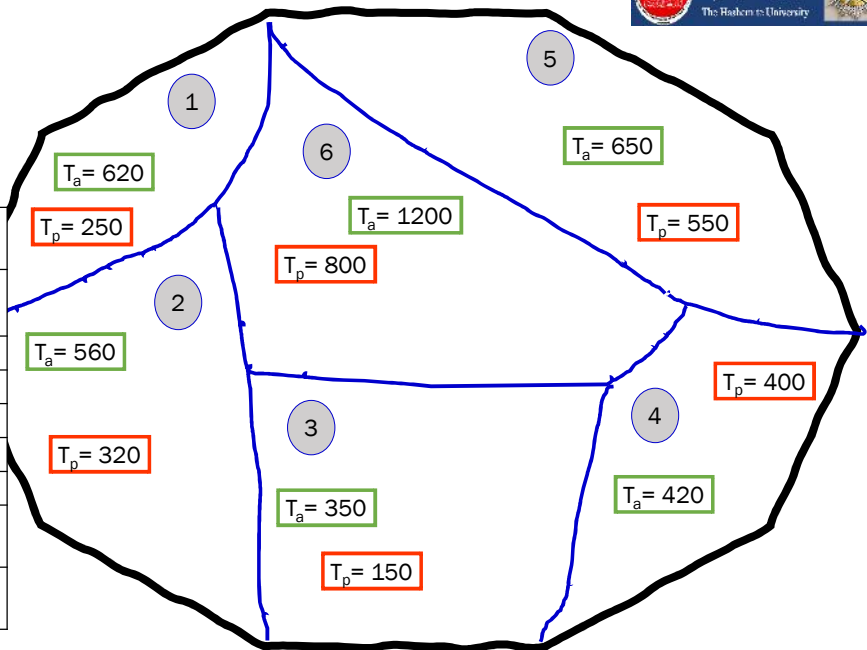
Zone ID	Unbalanced trips		Balanced trips	
	Production	Attraction	Production	Attraction
1	250	620	250	403
2	320	560	320	364
3	150	350	150	228
4	400	420	400	273
5	550	650	550	423
6	800	1200	800	780
Total trip	2470	3800	2470	2470

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Example

Balanced Trip Productions and Attractions

Zone ID	Balanced trips	
	Production	Attraction
1	250	403
2	320	364
3	150	228
4	400	273
5	550	423
6	800	780
Total trips	2470	2470





**TRANSPORTATION ENGINEERING
AND PLANNING
(110401367)
SPRING 2019-2020**

**Lecture. No. 8
Trip Distribution**

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning

References



- Nicholas Garber and Lester Hoel , **Traffic & Highway Engineering**, 5th Edition.. Cengage Learning, 2015

➤ Chapter 12 : Forecasting Travel Demand

❖ Section 11.4

- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, **Highway Engineering: Planning, Design, and Operations**, 2016, Elsevier

➤ Chapter 2.2: Planning concepts and Four-step process overview

2

2

Topic 2 : Transportation planning



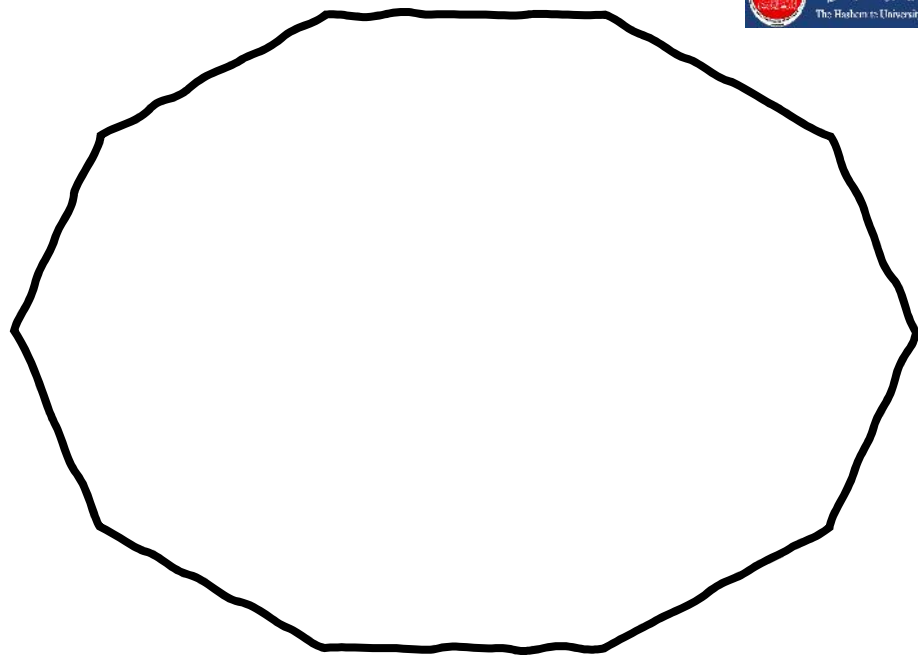
References

- Nicholas Garber and Lester Hoel , **Principles of Highway engineering and traffic analysis**, 5th Edition, 2012
 - [Chapter 8 : Travel Demand and traffic forecasting](#)
- Partha chakroborty and Animesh Das, **Principles of transportation engineering**, 2012,
 - [Chapter 9: Transportation demand analysis](#)
- Dušan Teodorović and Milan Janić, **Transportation engineering theory, practice and modeling** , 2017,
 - [Chapter 8: Transportation demand analysis](#)

3

3

Example

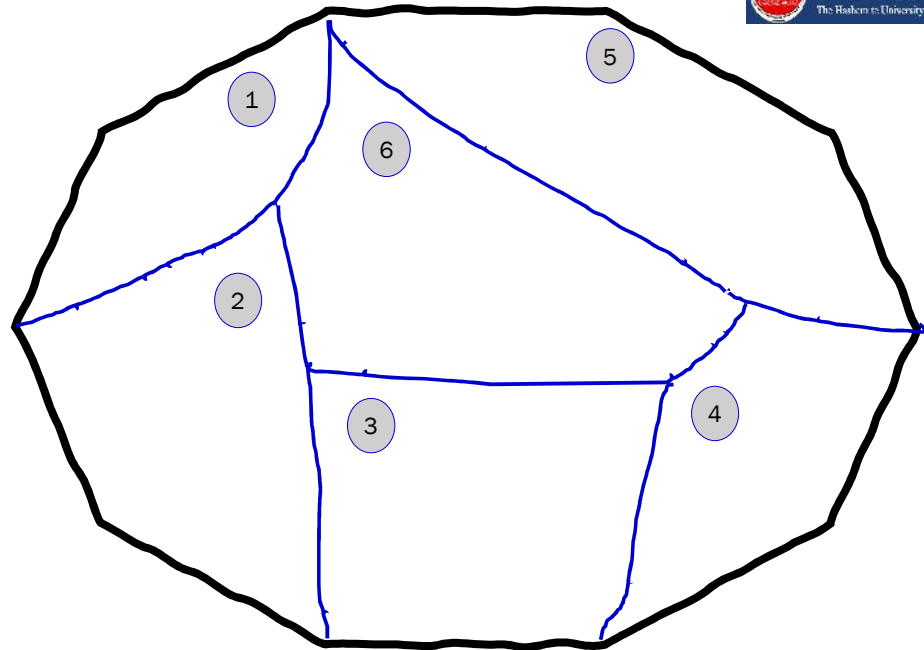


Study area

4

4

Example



Zoning

5

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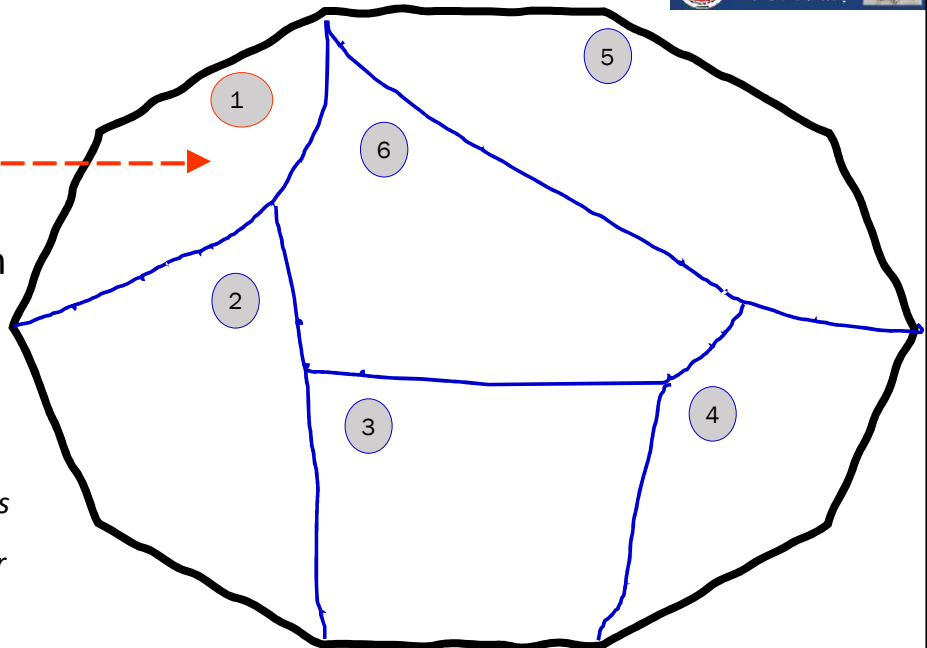
Example



Attracted trips

The land use within
Zone 1 are

- 120 office space
- 500 factory
- 50 educational seats
- 100 shopping center



6

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Example



How many trips are attracted (T_a) and produced to a zone 1?

Land use (By survey)	Number of units (By survey)	Trip rates (manual)	Attracted (T_a) trips (column 2 X column 3)
office space	120	1.18	472
factory	500	0.43	64.5
educational seats	50	1.2	108
shopping center	100	2.1	630
Total attracted trips (T_a)			626

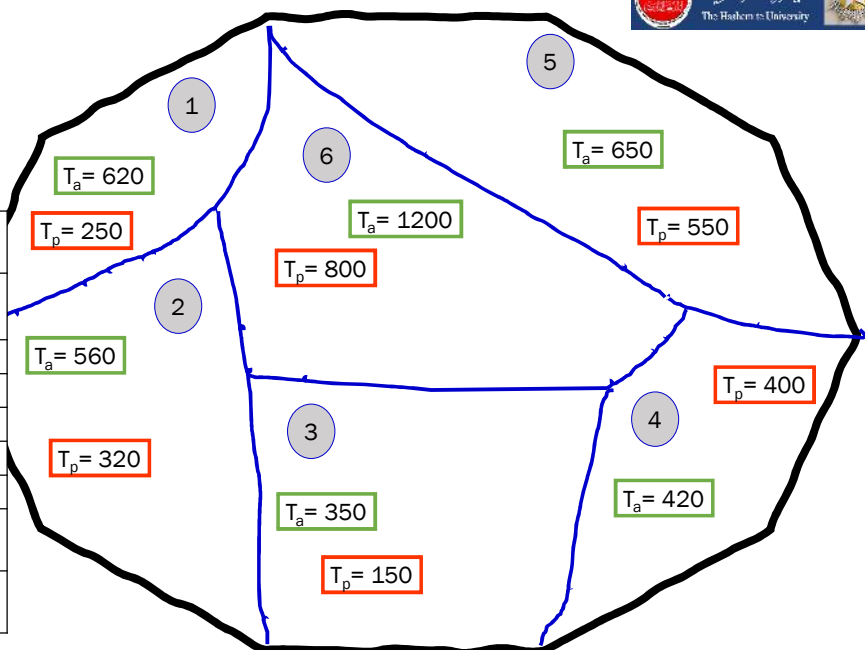
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Example



Balanced Trip Productions and Attractions

Zone ID	Balanced trips	
	Production	Attraction
1	250	403
2	320	364
3	150	228
4	400	273
5	550	423
6	800	780
Total trips	2470	2470



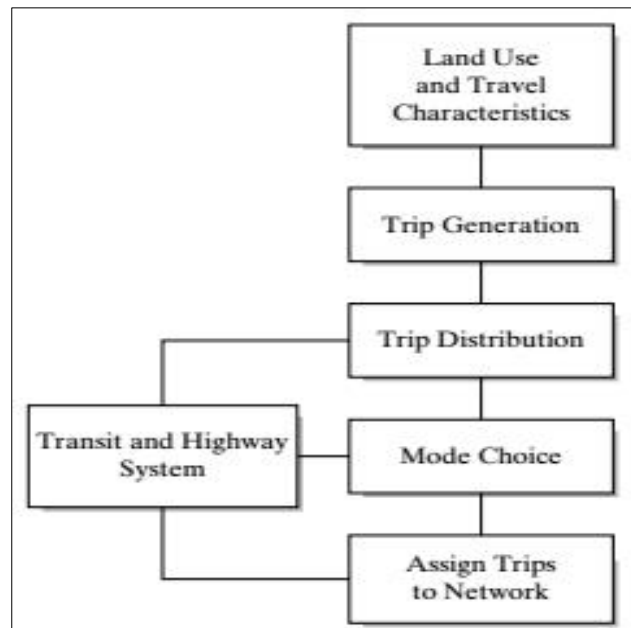
8

Review

Travel Forecasting Process

■ Four-step process"

- *Trip generation*
 - ❖ How many trips
- *Trip distribution*
 - ❖ From where to where
- *Modal choice*
 - ❖ On what mode
- *Traffic assignment*
 - ❖ On what route



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Trip distribution

■ is a process by which the **trips generated in one zone** are allocated to other zones in the study area.

■ These trips may be

- *Internal-internal*
 - ❖ within the study area
- *Internal-external*
 - ❖ between the study area and areas outside the study area

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Trip distribution



■ Goal

- *Where the trips are traveling*
- *What affect the destination*
 - ❖ Time, distance, speed

■ Inputs

- *Trip generated within the study area and zones*

■ Output

- *Origin- destination matrix*

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Trip distribution

Origin- destination matrix



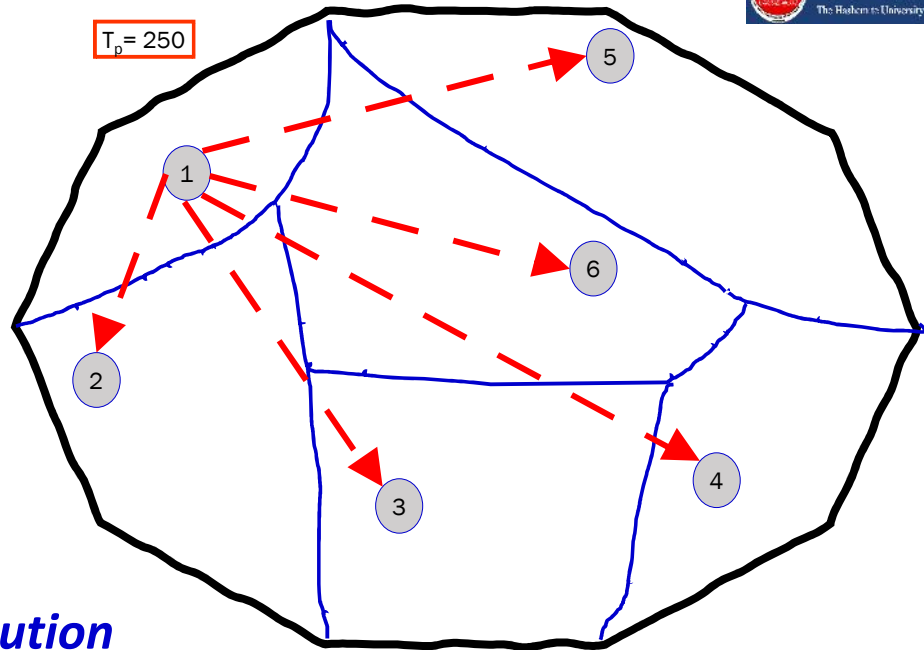
Origins	Destinations				$\sum_j T_{ij}$
	1	2	...	n	
1					P1
2		?			P2
...					...
m					Pm
$\sum_i T_{ij}$	A1	A2	...	An	

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Example

$$T_p = 250$$



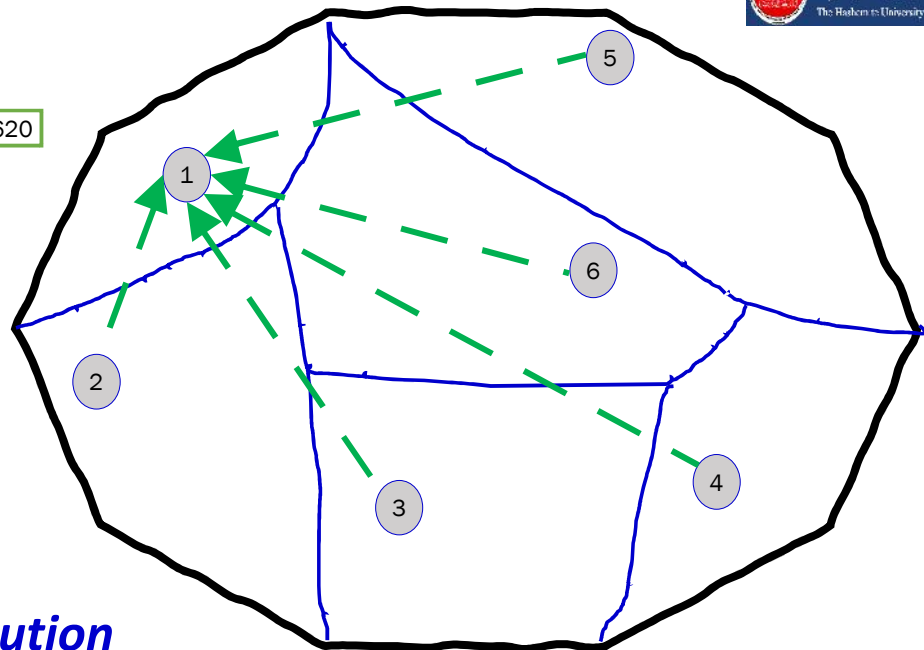
Trip distribution

13

13

Example

$$T_a = 620$$



Trip distribution

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Trip distribution

Methods

■ Gravity model

➤ *Preferred to be used because*

- ❖ Simple and accurate
- ❖ Uses the attributes of the transportation system and land-use characteristics
- ❖ Has been calibrated extensively for many urban areas

■ Growth factor models

■ Intervening opportunities



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Gravity Model

Definition

■ The number of trips between two zones is

➤ directly proportional to the *number of trip attractions* generated by the zone of destination

➤ inversely proportional to a *function of time of travel* between the two zones



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Gravity Model

Mathematically

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right]$$

i is origin zone number
j is destination zone
n is total number of zones

- T_{ij} = number of trips that are produced in **zone i** and attracted to **zone j**
- P_i = total number of trips produced in **zone i**
- A_j = number of trips attracted to **zone j**
 - The sum of P_i for all zones must equal the sum of A_j for all zone
- F_{ij} = a value which is an inverse function of travel time
- K_{ij} = socioeconomic adjustment factor for interchange ij

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Gravity Model

Mathematically

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right]$$

i is origin zone number
j is destination zone
n is total number of zones

- T_{ij} = number of trips that are produced in **zone i** and attracted to **zone j**
 - Determined from trip generation step
- P_i = total number of trips produced in **zone i**
- A_j = number of trips attracted to **zone j**
 - The sum of P_i for all zones must equal the sum of A_j for all zone
- F_{ij} = a value which is an inverse function of travel time
- K_{ij} = socioeconomic adjustment factor for interchange ij

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Gravity Model

Mathematically

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right]$$



i is origin zone number
j is destination zone
n is total number of zones

- P_i = total number of trips produced in **zone i**
 - Determined from trip generation step
- A_j = number of trips attracted to **zone j**
 - Determined from trip generation step
- The **sum of P_i** for **all zones** must equal the **sum of A_j** for all zone
- F_{ij} = a value which is an inverse function of travel time
 - Determined by a calibrating process

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Gravity Model

Mathematically



- F_{ij} = a value which is an inverse function of travel time
 - Determined by a calibrating process
- K_{ij} = socioeconomic adjustment factor for interchange ij
 - Determined by a calibrating process

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Gravity Model

Calibrating process

■ After each distribution process is completed,

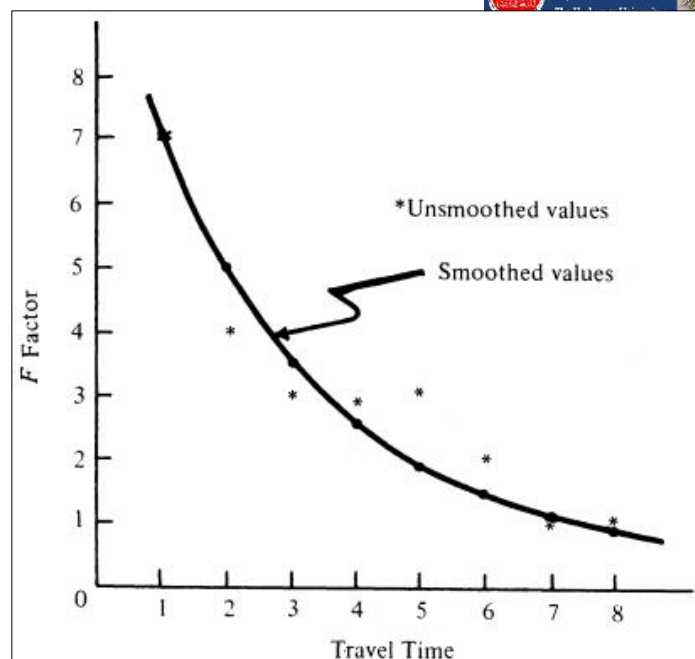
- The percentage of trips in each trip length category produced by the gravity model is **compared** with the percentage of trips recorded in the O-D survey.
- If the percentages **do not agree**, then
 - ❖ The F_{ij} factors that were used in the distribution process are adjusted
 - ❖ Another gravity model trip distribution is performed.
 - ❖ The calibration process is continued until the trip length percentages are in agreement

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Trip distribution

F values for calibration



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Trip distribution

F values for calibration

K-factors are applied to the gravity model as a fraction. If there is a deficiency of trips between TAZs and the condition cannot be corrected using calibrated friction factors, a K-factor greater than 1.0 would be applied, making the zone more attractive. If the zonal interchange has too many trips, a K-factor less than 1.0 would be applied. To prohibit trips, a zero is used.



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Trip distribution

Example -1 (Example 12.4)

- a study area consisting of **three zone**
- Trip Productions and Attractions for a Three-Zone Study Area
 - *Determined from trip generation step) are provided in Table 12.9*
- Average travel times between each zone
 - *Determined (Table 12.10)*
- Determine the **number of zone-to-zone trips** through **two iterations**.



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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -1: Trip Productions and Attractions for a Three-Zone Study Area

Zone	Balanced Trip	
	Production(P_i)	Attraction (A_j)
1	140	300
2	330	270
3	280	180
<u>Total</u>	<u>750</u>	<u>750</u>

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -2: Average travel times between each zone

Average travel time			
Zone	Zone		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>1</u>	5	2	3
<u>2</u>	2	6	6
<u>3</u>	3	6	5

Orange cells are internal-internal

green cell are internal-external

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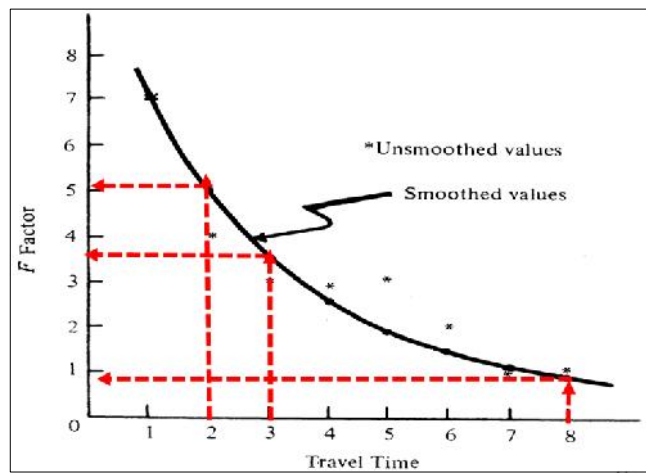
Example -1 (Example 12.4)



Use of Calibrated F Values and Iteration

- **Step -3:** Determination of F factors based on travel time (Calibration process)

Note that the book use another chart to determine the f factors for the example



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Example -1 (Example 12.4)



Use of Calibrated F Values and Iteration

- **Step -3:** Determination of F factors based on travel time (Calibration process)

Travel time (Min)	1	2	3	4	5	6	7	8
f factor	82	52	50	41	39	26	20	13

Note that the book use another chart to determine the f factors for the example

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -4: Determine f factor between zones

Travel time (Min)	1	2	3	4	5	6	7	8
f factor	82	52	50	41	39	26	20	13

Average travel time			
Zone	Zone		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>1</u>	5	2	3
<u>2</u>	2	6	6
<u>3</u>	3	6	5

F factor (F _{ij})			
Zone	Zone		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>1</u>	39	52	50
<u>2</u>	52	26	26
<u>3</u>	50	26	39

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F factor (F _{ij})			
Zone (i)	Zone (j)		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>1</u>	39	52	50
<u>2</u>	52	26	26
<u>3</u>	50	26	39

Zone	Balanced Trip	
	Production(P _i)	Attraction (A _j)
1	<u>140</u>	<u>300</u>
2	330	270
3	280	180
Total	<u>750</u>	<u>750</u>

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right]$$

i is origin zone number
j is destination zone number
n is total number of zones

<u>K_{ij} = 1</u> for all zones			
Zone	Zone		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>1</u>	1	1	1
<u>2</u>	1	1	1
<u>3</u>	1	1	1

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Solve

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right] \quad K_{ij} = 1 \text{ for all zones}$$

$$T_{1-1} = 140 \times \frac{300 \times 39}{(300 \times 39) + (270 \times 52) + (180 \times 50)} = 47$$

$$T_{1-2} = 140 \times \frac{270 \times 52}{(300 \times 39) + (270 \times 52) + (180 \times 50)} = 57$$

$$T_{1-3} = 140 \times \frac{180 \times 50}{(300 \times 39) + (270 \times 52) + (180 \times 50)} = 36$$

$$P_1 = 140$$

Make similar calculations for zones 2 and 3.

$T_{2-1} = 188$	$T_{2-2} = 85$	$T_{2-3} = 57$	$P_2 = 330$
$T_{3-1} = 144$	$T_{3-2} = 68$	$T_{3-3} = 68$	$P_3 = 280$

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Solve

Zone (i)	Zone (j)		
	1	2	3
1	39	52	50
2	52	26	26
3	50	26	39

Zone	Production (P_j)	Attraction (A_j)
1	140	300
2	330	270
3	280	180
Total	750	750

i and j are zones number
 n is total number of zones

$$T_{ij} = P_i \left[\frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}} \right]$$

$K_{ij} = 1$ for all zones

Zone	Zone		
	1	2	3
1	1	1	1
2	1	1	1
3	1	1	1

T_{2-3} $i=2, j=3, n=3$

$$T_{2-3} = P_2 \left[\frac{A_3 \times F_{23} \times K_{23}}{\sum_{j=1}^n A_j \times F_{2j} \times K_{2j}} \right]$$

$$= 330 \times \left[\frac{180 \times 26 \times 1}{300 \times 52 \times 1 + 270 \times 26 \times 1 + 180 \times 26 \times 1} \right]$$

$$= 330 \times \frac{4680}{2730}$$

$$= 56.5 \approx 57$$

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$$T_{2-3} \quad \text{Zone } i=2, j=3, n=3$$

$$T_{2-3} = P_2 \left[\frac{A_3 \times F_{23} \times k_{23}}{\sum_{j=1}^n A_j \times F_{2j} \times k_{2j}} \right]$$

$$\rightarrow A_1 \times F_{21} \times k_{21} + A_2 \times F_{22} \times k_{22} + A_3 \times F_{23} \times k_{23}$$

$$\rightarrow T_{2-3} = P_2 \left[\frac{A_3 \times F_{23} \times k_{23}}{A_1 \times F_{21} \times k_{21} + A_2 \times F_{22} \times k_{22} + A_3 \times F_{23} \times k_{23}} \right]$$

$$= 330 \left[\frac{180 \times 26 \times 1}{300 \times 52 \times 1 + 270 \times 26 \times 1 + 180 \times 26 \times 1} \right]$$

$$= 330 \times \frac{4680}{2730}$$

$$= 56.5 \approx 57$$

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Solve

Table 12.12 Zone-to-Zone Trips: First Iteration, Singly Constrained

Zone	1	2	3	Computed P	Given P
1	47	57	36	140	140
2	188	85	57	330	330
3	<u>144</u>	<u>68</u>	<u>68</u>	<u>280</u>	<u>280</u>
Computed A	379	210	161	750	750
Given A	300	270	180	750	

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Example -1 (Example 12.4)



Use of Calibrated F Values and Iteration

■ Step -6: Adjusted attraction trip factors

$$A_{jk} = \frac{A_j}{C_{j(k-1)}} A_{j(k-1)} \quad (12.4)$$

where

A_{jk} = adjusted attraction factor for attraction zone (column) j , iteration k

$A_{jk} = A_j$ 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, $j = 1, 2, \dots, n$

n = number of zones

k = iteration number, $k = 1, 2, \dots, m$

m = number of iterations

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Example -1 (Example 12.4)



Use of Calibrated F Values and Iteration

■ Step -6: Adjusted attraction trip factors

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

$$\text{Zone 1: } A_{12} = 300 \times \frac{300}{379} = 237$$

$$\text{Zone 2: } A_{22} = 270 \times \frac{270}{210} = 347$$

$$\text{Zone 3: } A_{32} = 180 \times \frac{180}{161} = 201$$

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Adjusted attraction trip factors

Table 12.13 Zone-to-Zone Trips: Second Iteration, Doubly Constrained

Zone	1	2	3	Computed P	Given P
1	34	68	38	140	140
2	153	112	65	330	330
3	116	88	76	280	280
Computed A	303	268	179	750	750
Given A	300	270	180	750	

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Use the adjusted factors (iteration No.2)

Apply the gravity model (Eq. 12.3) for all iterations to calculate zonal trip interchanges using the adjusted attraction factors obtained from the preceding iteration. In practice, the gravity model becomes

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

where T_{ijk} is the trip interchange between i and j for iteration k , and $A_{jk} = A_j$ when $k = 1$. Subscript j goes through one complete cycle every time k changes, and i goes through one complete cycle every time j changes. This formula is enclosed in parentheses and subscripted to indicate that the complete process is performed for each trip purpose.

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Example -1 (Example 12.4)

Use of Calibrated F Values and Iteration

■ Step -5: Use the adjusted factors (iteration No.2)

Perform a second iteration using the adjusted attraction values.

$$T_{1-1} = 140 \times \frac{237 \times 39}{(237 \times 39) + (347 \times 52) + (201 \times 50)} = 34$$

$$T_{1-2} = 140 \times \frac{347 \times 52}{(237 \times 39) + (347 \times 52) + (201 \times 50)} = 68$$

$$T_{1-3} = 140 \times \frac{201 \times 50}{(237 \times 39) + (347 \times 52) + (201 \times 50)} = 37$$

$$P_1 = 140$$

Make similar calculations for zones 2 and 3.

$$T_{2-1} = 153 \quad T_{2-2} = 112 \quad T_{2-3} = 65 \quad P_2 = 330$$

$$T_{3-1} = 116 \quad T_{3-2} = 88 \quad T_{3-3} = 76 \quad P_3 = 280$$

The results are summarized in Table 12.13. Note that, in each case, the sum of the attractions is now much closer to the given value. The process will be continued until there is a reasonable agreement (within 5%) between the A that is estimated using the gravity model and the values that are furnished in the trip generation phase.

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Example -2 (Example 12.5)

Selecting Singly or Doubly Constrained Gravity Model Results

Example 12.5 Selecting Singly or Doubly Constrained Gravity Model Results

A three-zone system with 900 home-based shopping productions is shown in Table 12.14. Zones 1 and 2 each generate 400 productions, while zone 3 generates 100 productions. Each zone contains a shopping mall with 300 attractions. The shopping mall in zone 1 can be easily reached due to the parking availability and transit service. Thus, F_{11} , F_{21} , and $F_{31} = 1.0$. Parking costs at the shopping mall in zone 2 are moderate with some transit service. Thus, F_{12} , F_{22} , and $F_{32} = 0.5$. Parking costs at the mall in zone 3 is high and transit service is unavailable. Thus, F_{13} , F_{23} , and $F_{33} = 0.2$.

Application of the singly constrained gravity model yields the results shown in Table 12.15 and application of the doubly constrained gravity model yields the results shown in Table 12.16.

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

- A three-zone system with 900 home-based shopping productions
 - Zones 1 and 2 each generate 400 productions, while zone 3 generates 100 productions
- Each zone contains a shopping mall with 300 attractions

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

- F factors
 - The shopping mall in zone 1 can be easily reached due to the parking availability and transit service.
 - ❖ Thus, F_{11} , F_{21} , and $F_{31} = 1.0$
 - Parking costs at the shopping mall in zone 2 are moderate with some transit service.
 - ❖ Thus, F_{12} , F_{22} , and $F_{32} = 0.5$
 - Parking costs at the mall in zone 3 is high and transit service is unavailable.
 - ❖ Thus, F_{13} , F_{23} , and $F_{33} = 0.2$

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

Table 12.14 Home-Based Shopping Productions and Attractions

Zone	Productions	Attractions
1	400	300
2	400	300
3	100	300
Total	900	900

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

Table 12.15 Zone-to-Zone Trips: Singly Constrained Gravity Model

Zone	1	2	3	Computed P	Given P
1	235	118	47	400	400
2	235	118	47	400	400
3	<u>59</u>	<u>29</u>	<u>12</u>	<u>100</u>	<u>100</u>
Computed A	529	265	106	900	900
Given A	300	300	300	900	

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

Table 12.16 Zone-to-Zone Trips: Doubly Constrained Gravity Model

Zone	1	2	3	Computed P	Given P
1	133	133	133	400	400
2	133	133	133	400	400
3	<u>33</u>	<u>33</u>	<u>33</u>	<u>100</u>	<u>100</u>
Computed A	300	300	300	900	900
Given A	300	300	300	900	

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Example -2 (Example 12.5)



Selecting Singly or Doubly Constrained Gravity Model Results

Which of the results shown for the singly constrained gravity model and for the doubly constrained gravity model are more likely to be the most accurate?

Solution: Table 12.15 is more likely to be accurate if engineering judgment suggests the occurrence of travel impedances and thus the friction factors are more accurate than trip attractions. Table 12.16 is more likely to be accurate if the attractions are more accurate than the friction factors.

In practice, these judgments must be made based on the quality of the data set. For example, if local land-use data had been recently used to develop trip attraction rates whereas friction factors had been borrowed from another area, then the selection of the doubly constrained gravity model results in Table 12.16 is recommended.

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Growth Factor Models



- This model is used when the available data is only
 - The origins and destinations between each zone for the current or base year
 - The trip generation values for each zone for the future year
- These models are used primarily to **distribute trips between zones in the study area and zones in cities external** to the study area.
- cannot be used to **forecast traffic between zones where no traffic currently exists**.
- the only measure of travel friction is the **amount of current travel**.
- **cannot reflect changes in travel time** between zones, as does the gravity mod

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Growth Factor Models



- These models are used **primarily** to distribute trips **between zones in the study area** and **zones in cities external to the study area**.
- This model is used when the available data is only
 - The origins and destinations between each zone for the current or base year
 - The trip generation values for each zone for the future year

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Growth Factor Models



- Cannot be used to forecast traffic between zones where no traffic currently exists.
- The only measure of travel friction is the amount of current travel.
- **Cannot reflect changes in travel time** between zones, as does the gravity model
- The most popular growth factor model is the Fratar method

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Growth Factor Models



Fratar method

- is a mathematical formula that proportions future trip generation estimates to each zone as a function of
 - *The product of the current trips between the two zones T_{ij}*
 - *The growth factor of the attracting zone G_j*

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Growth Factor Models

Fratar method

- T_{ij} = number of trips estimated from **zone i** to **zone j**
- t_{ij} = present trip generation in **zone i**
- G_i = growth factor of **zone i**
- G_j = growth factor of **zone j**
- G_x = growth factor of **zone x**
- $T_i = t_i G_i$ = future trip generation in **zone i**
- t_{ix} = number of trips between **zone i** and **other zones x**
- t_{ij} = present trips between **zone i** and **zone j**

$$T_{ij} = (t_i G_i) \frac{t_{ij} G_j}{\sum_x t_{ix} G_x}$$

i is origin zone number
j is destination zone number

x are all zones in the study area
except the origin zone i

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Example 12.6

Forecasting Trips Using the Fratar Model

Example 12.6 Forecasting Trips Using the Fratar Model

A study area consists of four zones (A, B, C, and D). An O-D survey indicates that the number of trips between each zone is as shown in Table 12.17. Planning estimates for the area indicate that in five years the number of trips in each zone will increase by the growth factor shown in Table 12.18 on page 612 and that trip generation will be increased to the amounts shown in the last column of the table.

Determine the number of trips between each zone for future conditions.

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Example 12.6



Forecasting Trips Using the Fratar Model

- A study area consists of four zones (A, B, C, and D).
- An O-D survey indicates that the number of trips between each zone is as shown in Table 12.17.
- Planning estimates for the area indicate that in five years the number of trips in each zone will increase by the growth factor shown in Table 12.18 on page 612
- That trip generation will be increased to the amounts shown in the last column of the table 12.18
- Determine the number of trips between each zone for future conditions.

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Example 12.6



Forecasting Trips Using the Fratar Model

■ Present Trips between Zone

Table 12.17 Present Trips between Zones

Zone	A	B	C	D
A	—	400	100	100
B	400	—	300	—
C	100	300	—	300
D	100	—	300	—
Total	600	700	700	400

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Example 12.6

Forecasting Trips Using the Fratar Model

■ Present Trip Generation and Growth Factors

Table 12.18 Present Trip Generation and Growth Factors

Zone	Present Trip Generation (trips/day)	Growth Factor	Trip Generation in Five Years
A	600	1.2	720
B	700	1.1	770
C	700	1.4	980
D	400	1.3	520

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Present Trip between zone i and zone j (t_{ij})

Zone (i)	Zone (j)			
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
<u>A</u>	-	400	100	100
<u>B</u>	400	-	300	-
<u>C</u>	100	300	-	300
<u>D</u>	100	-	300	-
Total	600	700	700	400

$$T_{ij} = (t_i G_i) \frac{t_{ij} G_j}{\sum_x t_{ix} G_x}$$

Present Trip Generation and Growth Factors

Zone	Present Trip Generation (Trips/ day) (T_i)	Growth factor (G_j)	Trip Generation in Five Years (= column 2 X column 3)
<u>A</u>	600	1.2	720
<u>B</u>	700	1.1	770
<u>C</u>	700	1.4	980
<u>D</u>	400	1.3	520

= 1.2*600)

i is origin zone number
j is destination zone number

x are all zones in the study area except the origin zone i

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Example 12.6

Forecasting Trips Using the Fratar Model

Solution: Using the Fratar formula (Eq. 12.5), calculate the number of trips between zones A and B, A and C, A and D, and so forth. Note that two values are obtained for each zone pair (that is, T_{AB} and T_{BA}). These values are averaged, yielding a value for $T_{AB} = (T_{AB} + T_{BA})/2$.

The calculations are as follows.

$$T_{ij} = (t_i G_i) \frac{t_{ij} G_j}{\sum_x t_{ix} G_x}$$

$$T_{AB} = 600 \times 1.2 \frac{400 \times 1.1}{(400 \times 1.1) + (100 \times 1.4) + (100 \times 1.3)} = 446$$

$$T_{BA} = 700 \times 1.1 \frac{400 \times 1.2}{(400 \times 1.2) + (300 \times 1.4)} = 411$$

$$\bar{T}_{AB} = \frac{T_{AB} + T_{BA}}{2} = \frac{446 + 411}{2} = 428$$

Similar calculations yield

$$\bar{T}_{AC} = 141 \quad \bar{T}_{AD} = 124 \quad \bar{T}_{BC} = 372 \quad \bar{T}_{CD} = 430$$

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⇒ Find the trips between Zone A and Zone B
step

① Trips from Zone A to Zone B

$\dot{i}$ = origin Zone $\Rightarrow \dot{i} = A$

$\dot{j}$ = Destination Zone $\Rightarrow \dot{j} = B$

x = All Zones except the origin Zone $\Rightarrow x = B, C, \text{ and } D$

$$\Rightarrow T_{\dot{i}\dot{j}} = t_{\dot{i}\dot{j}} G_{\dot{j}} \times \frac{t_{\dot{i}x} G_x}{\sum_x t_{\dot{i}x} G_x}$$

$$\rightarrow T_{AB} = (t_A G_A) \times \frac{t_{AB} G_B}{\sum_{x=B} t_{Ax} G_x}$$

$$L = t_{AB} G_B + t_{AC} G_C + t_{AD} G_D$$

$$\begin{array}{ccc} \underbrace{\quad}_{\dot{c}=A} & \underbrace{\quad}_{\dot{c}=A} & \underbrace{\quad}_{\dot{c}=A} \\ \underbrace{\quad}_{x=B} & \underbrace{\quad}_{x=C} & \underbrace{\quad}_{x=D} \end{array}$$

$$T_{AB} = \dots$$

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$$\rightarrow T_{AB} = (E_A G_A) \times \frac{E_{AB} G_B}{\sum_{X=B}^{X=D} E_{AX} G_X}$$

$$L = E_{AB} G_B + E_{AC} G_C + E_{AD} G_D$$

$\begin{matrix} \underbrace{\quad}_{i=A} & \underbrace{\quad}_{i=A} & \underbrace{\quad}_{i=A} \\ \underbrace{\quad}_{x=B} & \underbrace{\quad}_{x=C} & \underbrace{\quad}_{x=D} \end{matrix}$

$$T_{AB} = E_A G_A \times \frac{E_{AB} G_B}{E_{AB} G_B + E_{AC} G_C + E_{AD} G_D}$$

$$= (600 \times 1.2) \times \frac{(400)(1.1)}{(400 \times 1.1 + 100 \times 1.4 + 100 \times 1.3)} = 446$$

$$\Rightarrow \boxed{T_{AB} = 446}$$

step

② Trips from Zone B to Zone A

$\dot{C}$ = origin Zone $\rightarrow \dot{C} = B$

$\dot{U}$ = Destination Zone $\rightarrow \dot{U} = A$

X = All Zones except the origin zone $\rightarrow X = A, C, \text{ and } D$

$$\rightarrow T_{BA} = E_B G_B \times \frac{E_{BA} G_A}{\sum_{X=A}^{X=D} E_{BX} G_X}$$

$$L = E_{BA} G_A + E_{BC} G_C + E_{BD} G_D$$

$\begin{matrix} \underbrace{\quad}_{i=B} & \underbrace{\quad}_{i=B} & \underbrace{\quad}_{i=B} \\ \underbrace{\quad}_{x=A} & \underbrace{\quad}_{x=C} & \underbrace{\quad}_{x=D} \end{matrix}$

$$\begin{aligned}
 \rightarrow T_{BA} &= \cancel{t_B} G_B + \frac{t_{BA} G_A}{\sum_{n=A}^{n=D} t_{Bn} G_n} \\
 &\quad \rightarrow \underbrace{t_{BA} G_A}_{i=B, n=A} + \underbrace{t_{BC} G_C}_{i=A, n=C} + \underbrace{t_{BD} G_D}_{i=B, n=D} \\
 T_{BA} &= t_B G_B + \frac{t_{BA} G_A}{t_{BA} G_A + t_{BC} G_C + t_{BD} G_D} \\
 &= (700 \times 1.1) \times \frac{400 \times 1.2}{400 \times 1.2 + (300 \times 1.4) + (\cancel{0} \times \cancel{1.3})} \\
 &= (700 \times 1.1) \times \frac{400 \times 1.2}{400 \times 1.2 + 300 \times 1.4} = 416 \\
 &\quad \Rightarrow T_{BA} = 416
 \end{aligned}$$

Step ③ Average trips between Zone A and Zone B ($\bar{T}_{AB}$)

$$\begin{aligned}
 \bar{T}_{AB} &= \frac{T_{AB} + T_{BA}}{2} = \frac{416 + 441}{2} = 428 \\
 &\quad \Rightarrow \bar{T}_{AB} = 428
 \end{aligned}$$

Example 12.6

Forecasting Trips Using the Fratar Model



The results of the preceding calculations have produced the first estimate (or iteration) of future trip distribution and are shown in Table 12.19. The totals for each zone do not equal the values of future trip generation. For example, the trip

Table 12.19 First Estimate of Trips between Zones

Zone	A	B	C	D	Estimated Total Trip Generation	Actual Trip Generation
A	—	428	141	124	693	720
B	428	—	372	—	800	770
C	141	372	—	430	943	980
D	124	—	430	—	554	520
Totals	693	800	943	554		

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Example 12.6

Forecasting Trips Using the Fratar Model



generation in zone A is estimated as 693 trips, whereas the actual value is 720 trips. Similarly, the estimate for zone B is 800 trips, whereas the actual value is 770 trips.

Proceed with a second iteration in which the input data are the numbers of trips between zones as previously calculated. Also, new growth factors are computed as the ratio of the trip generation expected to occur in five years and the trip generation estimated in the preceding calculation. The values are given in Table 12.20.

The calculations for the second iteration are left to the reader to complete and the process can be repeated as many times as needed until the estimate and actual trip generation values are close in agreement.

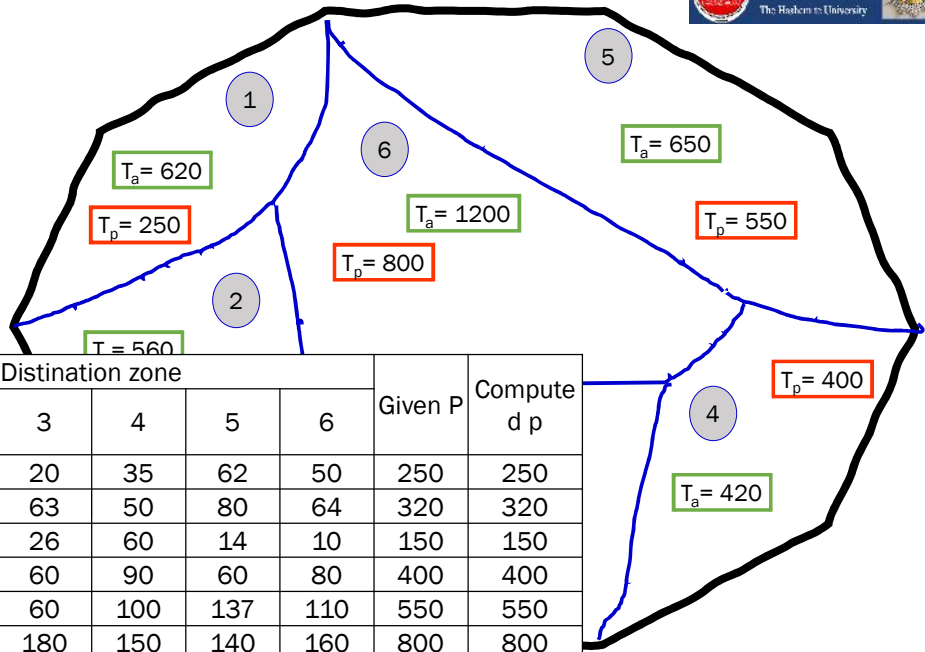
Table 12.20 Growth Factors for Second Iteration

Zone	Estimated Trip Generation	Actual Trip Generation	Growth Factor
A	693	720	1.04
B	800	770	0.96
C	943	980	1.04
D	554	520	0.94

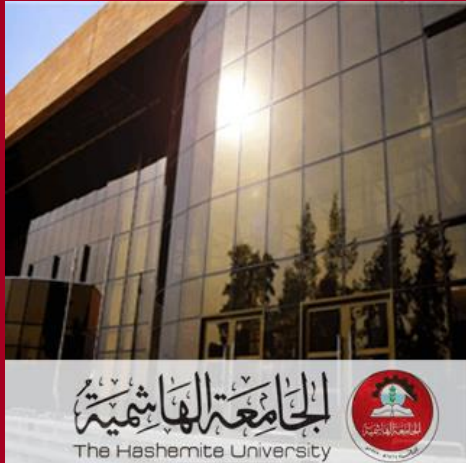
64

64

Example



Origin zone	Distination zone						Given P	Compute d p
	1	2	3	4	5	6		
1	63	20	20	35	62	50	250	250
2	41	22	63	50	80	64	320	320
3	18	22	26	60	14	10	150	150
4	40	70	60	90	60	80	400	400
5	63	80	60	100	137	110	550	550
6	90	80	180	150	140	160	800	800



**TRANSPORTATION ENGINEERING
AND PLANNING
(110401367)
SPRING 2019-2020**

**Lecture. No. 9
Model split**

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning



References

- Nicholas Garber and Lester Hoel , ***Traffic & Highway Engineering***, 5th Edition.. Cengage Learning, 2015

➤ *Chapter 12 : Forecasting Travel Demand*

❖ *Section 11.4*

- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, ***Highway Engineering: Planning, Design, and Operations***, 2016, Elsevier

➤ *Chapter 2.2: Planning concepts and Four-step process overview*

2

Topic 2 : Transportation planning



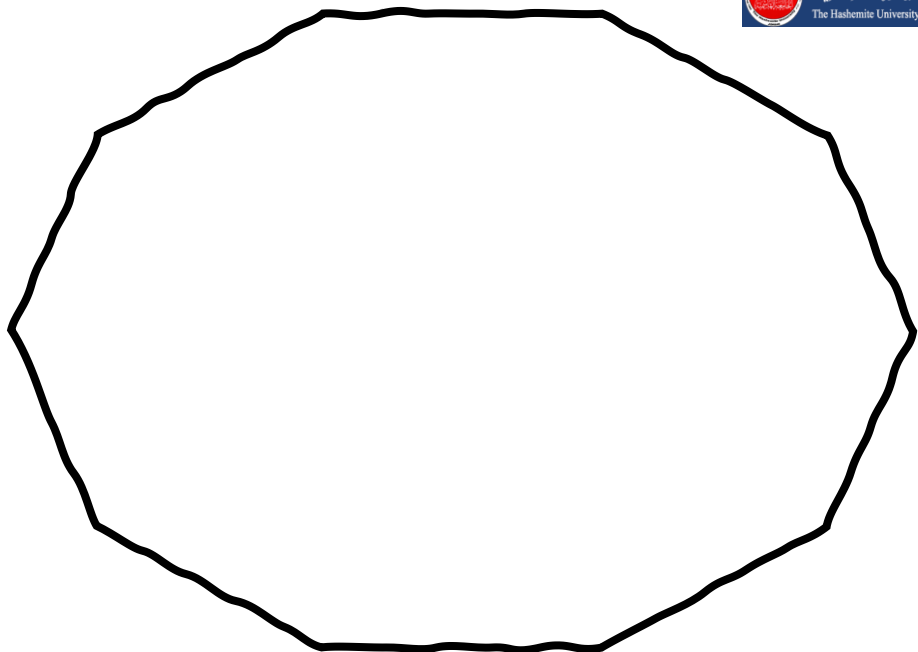
References

- Nicholas Garber and Lester Hoel , ***Principles of Highway engineering and traffic analysis***, 5th Edition, 2012
 - [*Chapter 8 : Travel Demand and traffic forecasting*](#)
- Partha chakroborty and Animesh Das, ***Principles of transportation engineering***, 2012,
 - [*Chapter 9: Transportation demand analysis*](#)
- Dušan Teodorović and Milan Janić, ***Transportation engineering theory, practice and modeling*** , 2017,
 - [*Chapter 8: Transportation demand analysis*](#)

3

3

Review

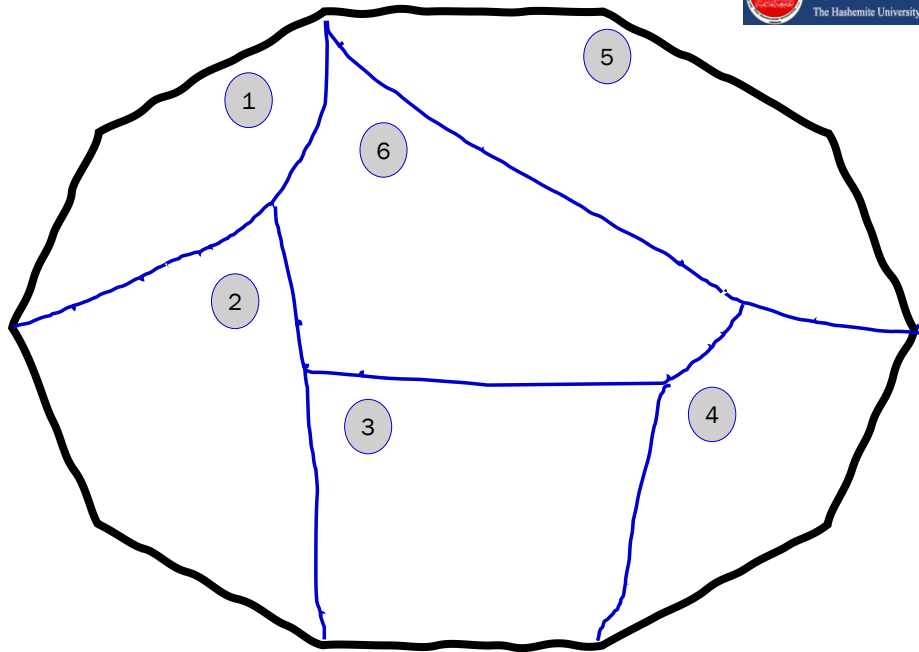


Study area

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Review



5

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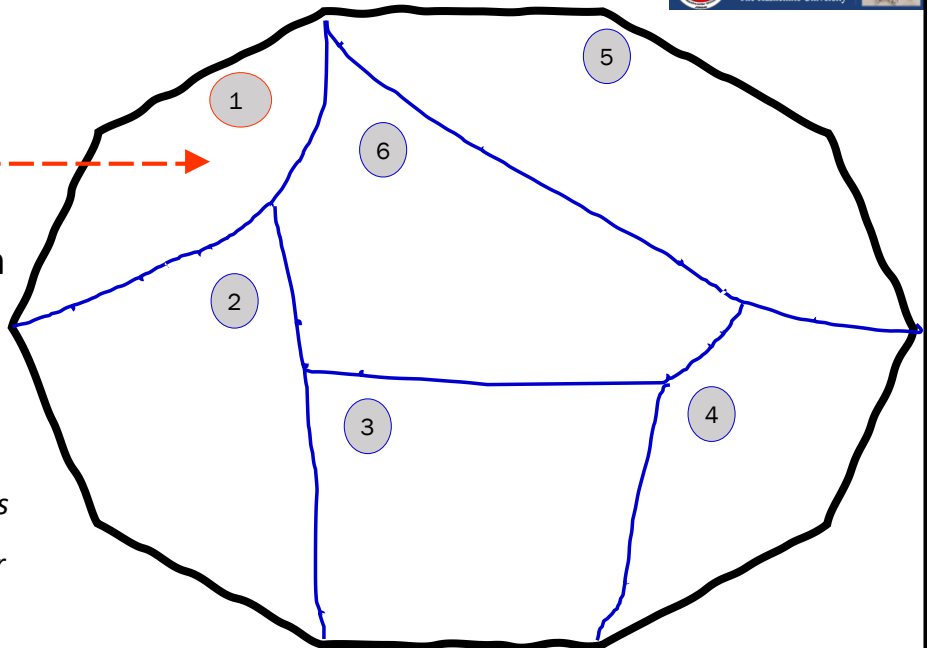
Zoning

Review

Attracted trips

The land use within
Zone 1 are

- 120 office space
- 500 factory
- 50 educational seats
- 100 shopping center



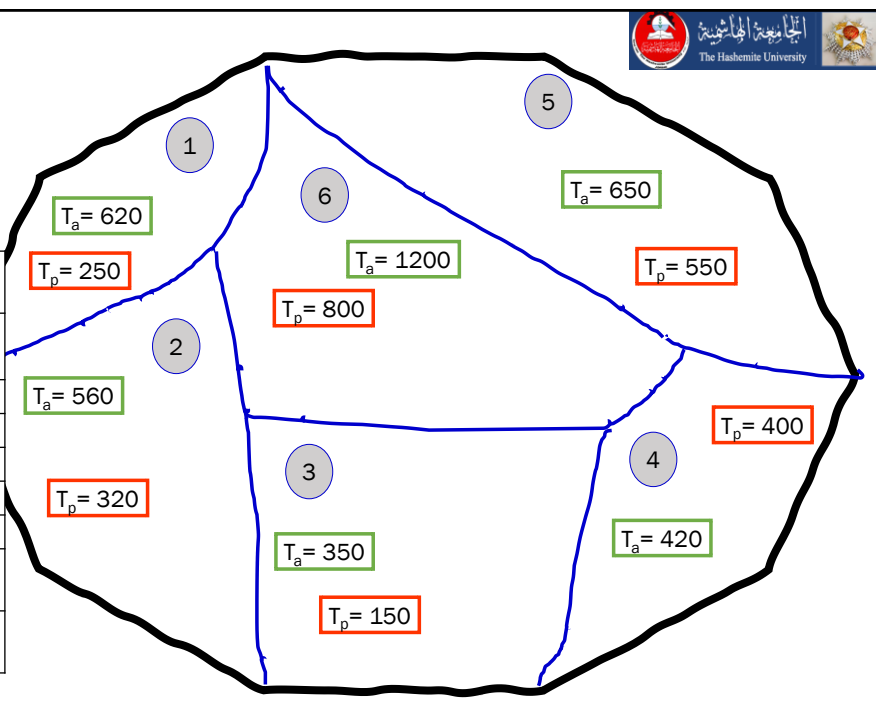
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Review

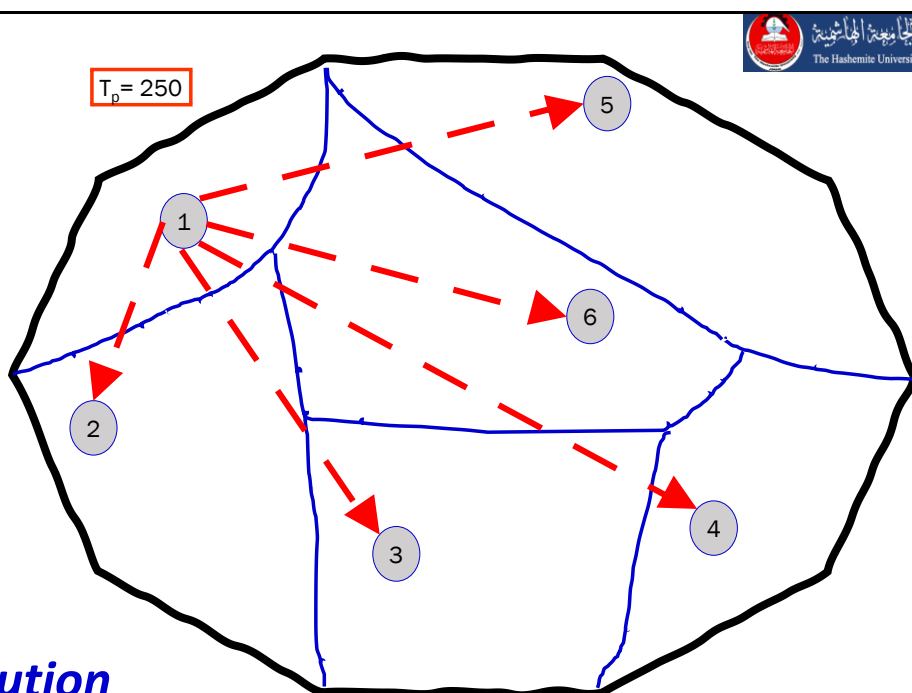
Balanced Trip Productions and Attractions

Zone ID	Balanced trips	
	Production	Attraction
1	250	403
2	320	364
3	150	228
4	400	273
5	550	423
6	800	780
Total trips	2470	2470



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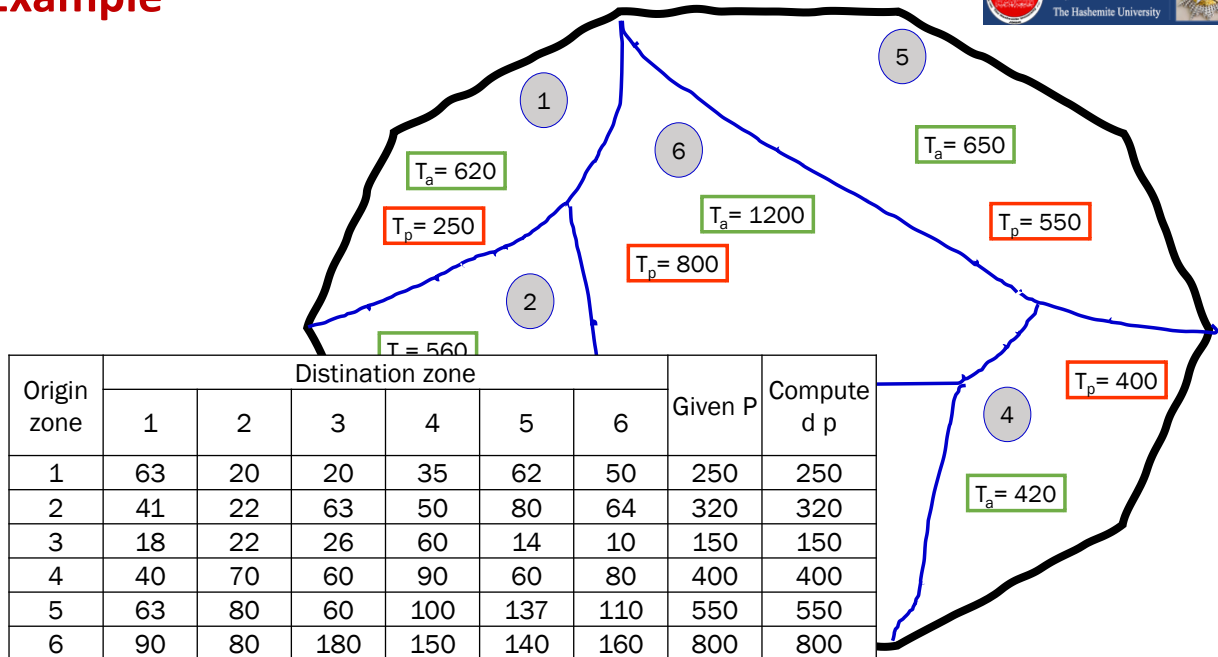
Example



Trip distribution

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Example



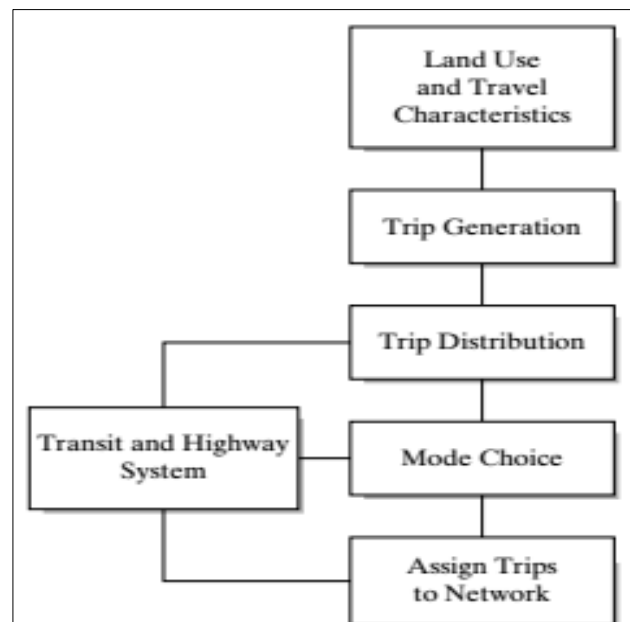
9

Review

Travel Forecasting Process

■ Four-step process"

- Trip generation
 - ❖ How many trips
- Trip distribution
 - ❖ From where to where
- Modal choice
 - ❖ On what mode
- Traffic assignment
 - ❖ On what route



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Model Split



Definition

- To determine the number (or %) of trips made between zones using each mode of travel

For the analysis, the following variables might be used:

- *Trip characteristics: length, time of day, purpose, ...etc.*
- *Trip maker characteristics: income, auto ownership, employment, ...etc.*
- *Transportation system characteristics: accessibility, parking, travel time, ...etc.*

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Model Split



■ Goal

- *What modes these trips are taking ?*
- *What influences the choice of mode ?*
 - ❖ Path that minimizes travel cost, time, distance, speed

■ Inputs

- *Origin- destination matrix*

■ Output

- *Mode wise Origin- destination matrix*

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Model Split

■ Goal

- *What modes these trips are taking ?*
- *What influences the choice of mode ?*
 - ❖ Path that minimizes travel cost, time, distance, speed

■ Inputs

- *Origin- destination matrix*

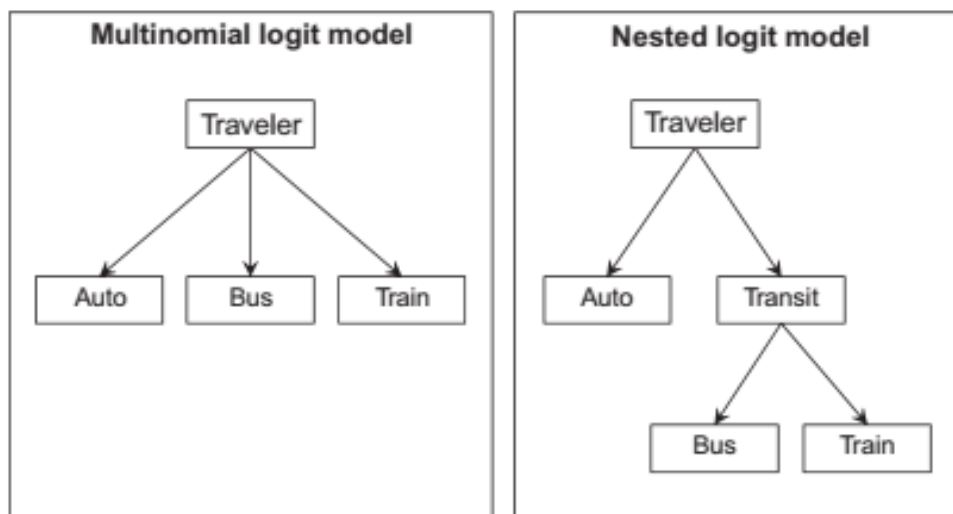
■ Output

- *Mode wise Origin- destination matrix*

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Model split



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Origin zone	<u>Generated trips</u>					
	Destination zone					
	1	2	3	4	5	6
1	63	20	20	35	62	50
2	41	22	63	50	80	64
3	18	22	26	60	14	10
4	40	70	60	90	60	80
5	63	80	60	100	137	110
6	90	80	180	150	140	160

mode choice 41%

↓

Origin zone	<u>Trips by Car (41% of trip generated)</u>					
	Distination zone					
	1	2	3	4	5	6
1	26	8	8	15	26	21
2	17	9	26	21	34	27
3	8	9	11	25	6	4
4	17	29	25	38	25	34
5	26	34	25	42	58	46
6	38	34	76	63	59	67

mode choice 58%

↓

Origin zone	<u>Trips by Bus (58% of trip generated)</u>					
	Distination zone					
	1	2	3	4	5	6
1	37	12	12	20	36	29
2	24	13	37	29	46	37
3	10	13	15	35	8	6
4	23	41	35	52	35	46
5	37	46	35	58	79	64
6	52	46	104	87	81	93

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Model Split

Types of Mode Choice Models

Depending on the level of detail required, three types of transit estimating procedures

1. **Direct Generation** of transit trips
2. **Trip End** models
3. **Trip Interchange Modal Split** models.

Model Split

Direct Generation of transit trips

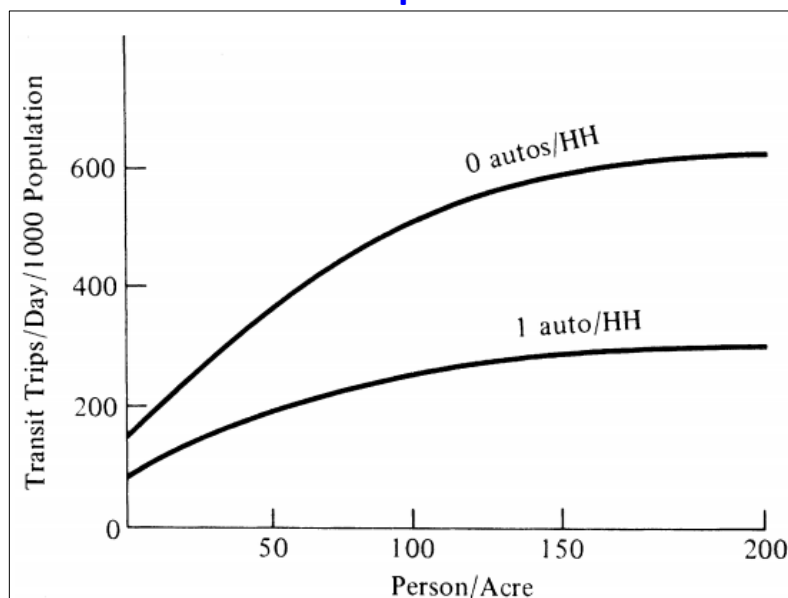
- Transit trips can be generated directly, by estimating either total person trips or auto driver trips.
 - This method assumes that the attributes of the system are not relevant.
 - Factors such as travel time, cost, and convenience are not considered.

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Model Split

Direct Generation of transit trips



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Example 12.7

Estimating Mode Choice by Direct Trip Generation

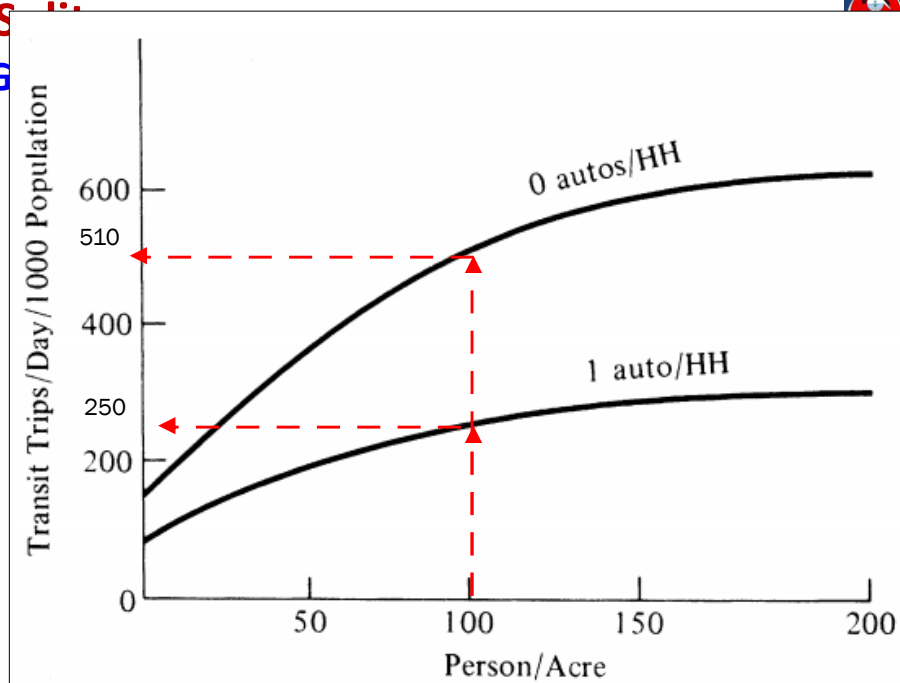
- Determine the number of transit trips per day in a zone which has **5000 people** living on **50 acres**. The auto ownership is **40% of zero autos** per household and **60% of one auto per household**

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Model S

Direct G



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Model Split

Types of Mode Choice Models

Solution: Calculate the number of persons per acre: $5000/50 = 100$. Then determine the number of transit trips per day per 1000 persons (from Figure 12.8) to calculate the total of all transit trips per day for the zone.

Zero autos / HH: 510 trips / day / 1000 population

One auto / HH: 250 trips / day / 1000 population

Total Transit Trips: $(0.40)(510)(5) + (0.60)(250)(5) =$
 $1020 + 750 = 1770$ transit trips per day

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Trip End Models

Definition

- To determine the % of total person or auto trips that will use a mode,
- Estimates are made **prior** to the trip distribution phase based on:
 - *land-use or socioeconomic characteristics of the zone.*
- This method does not incorporate the quality of service.

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Trip End Models

Procedures

1. Generate total person trip productions and attractions by trip purpose.

➤ *Determined from trip generation step*

2. Compute the urban travel factor (UTF)

$$\text{UTF} = \frac{1}{1000} \times \left(\frac{\text{Houdhold}}{\text{auto}} \right) \times \left(\frac{\text{Person}}{\text{mi}^2} \right)$$

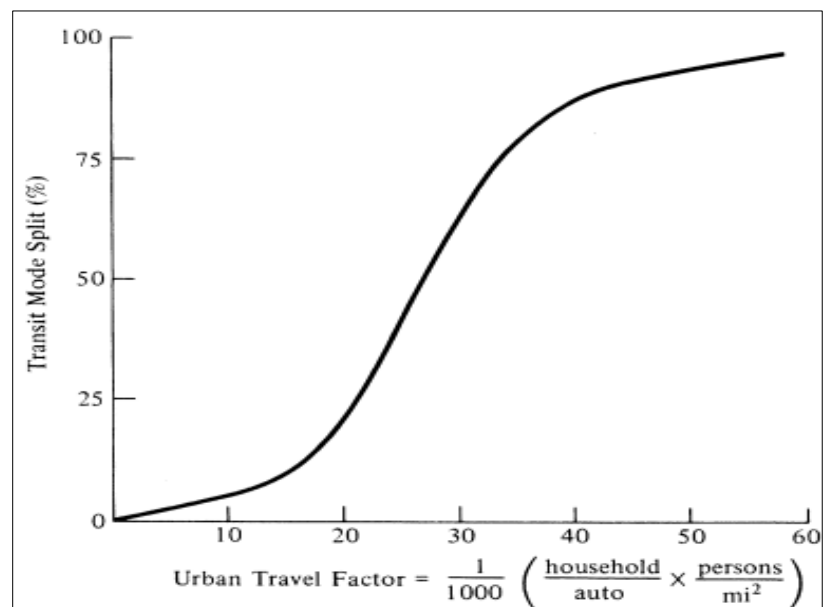
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Trip End Models

Procedures

3. Determine the **percentage of these trips by transit** using a mode choice curve.



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Trip End Models

Procedures

4. Apply auto occupancy factors.
5. Distribute transit and auto trips separately



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Trip End Models

Example 12.8 : Estimating Trip Productions by Transit

- The total number of productions in a zone is 10,000 trips/day.
- The number of households per auto is 1.80, and residential density is 15,000 persons/square mile.
- Determine the percent of residents who can be expected to use transit.



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Trip End Models



Example 12.8 : Estimating Trip Productions by Transit

Solution

Compute the urban travel factor (UTF)

$$\text{UTF} = \frac{1}{1000} \times \left(\frac{\text{Houdhold}}{\text{auto}} \right) \times \left(\frac{\text{Person}}{\text{mi}^2} \right)$$

$$\text{UTF} = \frac{1}{1000} \times (1.8) \times (15000) = \underline{27.0}$$

27

27

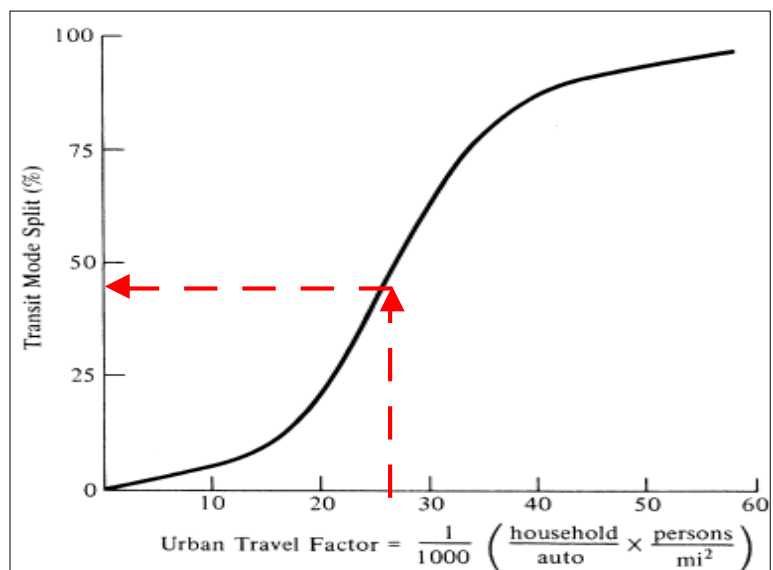
Trip End Models



Example 12.8 : Estimating Trip Productions by Transit

Solution

3. Transit mode split = 45%.



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Model Split



Trip Interchange Models

- In this method estimates are made **after** the trip distribution
- In this method, **system level-of-service variables** are considered, including:
 - Relative travel time,
 - Relative travel cost,
 - Economic status of the trip maker
 - Relative travel service.
- An example of this procedure is illustrated using the **QRS** method which takes **account of service parameters in estimating mode choice**.

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Trip Interchange Models



QRS method

- The QRS method is based on the following relationship

$$MS_a = \frac{I_{ijt}^{-b}}{I_{ija}^{-b} + I_{ija}^{-b}} \times 100 \text{ or } \frac{I_{ija}^b}{I_{ijt}^b + I_{ija}^b} \times 100$$
$$MS_t = (1 - MS_a) \times 100$$

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Trip Interchange Models

QRS method

$$MS_a = \frac{I_{ijt}^{-b}}{I_{ija}^{-b} + I_{ijt}^{-b}} \times 100 \text{ or } \frac{I_{ija}^b}{I_{ijt}^b + I_{ija}^b} \times 100$$

$$MS_t = (1 - MS_a) \times 100$$

- MS_t = proportion of trips between **zone i** and **zone j** using transit
- MS_a = proportion of trips between **zone i** and **zone j** using auto
- b = an exponent,
➤ *which depends on trip purpose*

i is origin zone number
j is destination zone number
t for transit mode
a for auto mode

Trip Interchange Models

QRS method

$$MS_a = \frac{I_{ijt}^{-b}}{I_{ija}^{-b} + I_{ijt}^{-b}} \times 100 \text{ or } \frac{I_{ija}^b}{I_{ijt}^b + I_{ija}^b} \times 100$$

$$MS_t = (1 - MS_a) \times 100$$

- I_{ijm} = a value referred to as the *impedance* of **travel of mode m**, between **zone i** and **zone j**

➤ *It is a measure of the total cost of the trip.*

- *Impedance (I) = (in vehicle time [mintue) + (2.5 x excess time [min]) + (3 x $\frac{\text{trip cost } [\text{\$}]}{\text{income earned/min}}$)*

Trip Interchange Models

QRS method

■ The impedance value

- *Determined for each zone pair*
- *Represents a measure of the expenditure required to make the trip by either auto or transit*

■ In-vehicle time

- *is time spent traveling in the vehicle*

■ Excess time

- *is time spent traveling but not in the vehicle, including waiting for the train or bus and walking to the station.*

■ Assume that the time worked per year is 120,000 min

$$MS_a = \frac{I_{ijt}^{-b}}{I_{ija}^{-b} + I_{ija}^{-b}} \times 100 \text{ or } \frac{I_{ija}^b}{I_{ijt}^b + I_{ija}^b} \times 100$$
$$MS_t = (1 - MS_a) \times 100$$

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QRS method

Data needed

■ Distance between zones by auto and transit

■ Transit fare

■ Out-of-pocket auto cos

■ Parking cost



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QRS method

Data needed

- Highway and transit speed
- exponent values, b
- median income,
- excess time,
 - *includes the time required to walk to a transit vehicle and time waiting or transferring.*
 - *Assume that the time worked per year is 120,000 min.*



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QRS method

Example 12.9 : Computing Mode Choice Using the QRS Model

- The data in table 12.21 have been developed for travel between a **suburban zone S** and a **downtown zone D**
- Determine the **percent of work** trips by **auto** and **transit**



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QRS method

Example 12.9 : Computing Mode Choice Using the QRS Model

- An exponent value of 2.0 is used for work travel.
- Median income is \$24,000 per year

Table 12.21 Travel Data Between Two Zones, S and D

	<i>Auto</i>	<i>Transit</i>
Distance	10 mi	8 mi
Cost per mile	\$0.15	\$0.10
Excess time	5 min	8 min
Parking cost	\$1.50 (or 0.75/trip)	—
Speed	30 mi/h	20 mi/h

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QRS method

Example 12.9 : Computing Mode Choice Using the QRS Model

Solution: Use Eq. 12.6.

$$MS_a = \frac{I_{ija}^b}{I_{ijt}^b + I_{ija}^b}$$

$$I_{SDa} = \left(\frac{10}{30} \times 60 \right) + (2.5 \times 5) + \left\{ \frac{3 \times [(1.50/2) + 0.15 \times 10]}{24,000/120,000} \right\}$$

$$= 20 + 12.5 + 33.75$$

$$= 66.25 \text{ equivalent min}$$

$$I_{SDt} = \left(\frac{8}{20} \times 60 \right) + (2.5 \times 8) + \left[\frac{3 \times (8 \times 0.10)}{24,000/120,000} \right] = 24 + 20 + 12$$

$$= 56 \text{ equivalent min}$$

$$MS_a = \frac{(56)^2}{(56)^2 + (66.25)^2} \times 100 = 41.6\%$$

$$MS_t = (1 - 0.416) \times 100 = 58.4\%$$

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QRS method

Example 12.9 : Computing Mode Choice Using the QRS Model

Thus, the mode choice of travel by transit between zones S and D is 68.4%, and by highway the value is 41.6%. These percentages are applied to the estimated trip distribution values to determine the number of trips by each mode. If for example, the number of work trips between zones S and D was computed to be 500, then the number by auto would be $500 \times 0.416 = 208$, and by transit, the number of trips would be $500 \times 0.584 = 292$.

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$\dot{O}$ = origin zone = Zone $S \Rightarrow \dot{O} = S$ $q \rightarrow$ Auto
 $\dot{D}$ = Destination zone $\Rightarrow$ Zone $D \Rightarrow \dot{D} = D$ $t \rightarrow$ transit

Step 1: Find the impedance terms for traveling by Auto (u) and transit (t).

① In-vehicle time

$$(1-1) \text{ by Auto} = \frac{\text{Distance travelled} \text{ [Feet (2.21)]}}{\text{Speed}}$$

$$\begin{aligned}
 &= \frac{10 \text{ mi}}{30 \frac{\text{mi}}{\text{hr}}} = 10 \text{ mi} \times \frac{1 \text{ hr}}{30 \text{ mi}} \times \frac{60 \text{ min}}{1 \text{ hr}} \\
 &= \frac{10 \times 60}{30} = 20 \text{ min.}
 \end{aligned}$$

$$\begin{aligned}
 (1-2) \text{ by transit} &= \frac{\text{Distance travelled}}{\text{speed}} = \frac{8 \text{ mi}}{20 \frac{\text{mi}}{\text{hr}}} = 8 \text{ mi} \times \frac{1 \text{ hr}}{20 \text{ mi}} \times \frac{60 \text{ min}}{1 \text{ hr}} \\
 &= \frac{8}{20} \times 60 = 24 \text{ min.}
 \end{aligned}$$

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② Excess time. [From Table 12.21]

↳ by Auto 5 min
by transit 8 min.

③ Trip cost [Table 12.21]

$$\text{by Auto} = 0.75 \$ + 0.15 \frac{\$}{\text{mi}} \times 10 \text{ mi} = 0.75 + 0.15 = 2.25 \$$$

$$\text{by transit} = 0.1 \frac{\$}{\text{mi}} \times 8 \text{ mi} = 0.8 \$$$

④ income earn/min

$$= \frac{24000}{120000 \text{ (assumed) (min)}} = \frac{24 \$}{120 \text{ min}} = 0.2 \$/\text{min.}$$

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⇒ Summary

	in-vehicle time (min)	Excess time (min)	Trip cost (\$)	income/min
by Auto	20	5	2.25	0.2
by transit	24	8	0.8	0.2

⇒ Step 2 Find the impedance for each mode

$$I_{cja} = I_{SDq} = \text{in-vehicle time} + 2.5 \text{ excess time} + 3 \times \frac{\text{trip cost}}{\text{income/min}}$$

by Auto

$$= 20 + 2.5 \times 5 + 3 \times \frac{2.25}{0.2} = 20 + 12.5 + 33.75 = 66.25 \text{ equivalent min}$$

$$I_{cjt} = I_{SDb} = \text{in-vehicle time} + 2.5 \text{ excess time} + 3 \times \frac{\text{trip cost}}{\text{income/min}}$$

by transit

$$= 24 + 2.5 \times 8 + 3 \times \frac{0.8}{0.2} = 24 + 20 + 12 = 56 \text{ equivalent min}$$

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$$\Rightarrow I_{SDA} = 66.25, I_{SDE} = 56, b = 2 \text{ [given]}$$

→ Step 3 Find M_{SA} and M_{SD}

$$\Rightarrow M_{SA} = \frac{I_{SDA}^b}{I_{SDE}^b + I_{SDA}^b} \times 100 = \frac{I_{SDA}^b}{I_{SDE}^b + I_{SDA}^b} \times 100 = \frac{(66.25)^2}{(56)^2 + (66.25)^2} = \frac{4389}{3736 + 4389} \times 100$$

$$\Rightarrow M_{SA} = 0.58 \times 100 = 58\%$$

$$\Rightarrow M_{SE} = 1 - M_{SA} = 1 - 0.58 = 41.6\%$$

$$\Rightarrow M_{SA} = 58.4\% \\ M_{SE} = 41.6\%$$

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Model Split

Logit Models

- An alternative approach used in transportation demand analysis is to consider the relative utility of each mode as a summation of each modal attribute.
- the choice of a mode is expressed as a probability distribution.

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Model Split

Logit Models

- If two modes, **auto (A)** and **transit (T)**, are being considered, the probability of selecting the auto mode A can be written as

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

Model Split

Logit Models

- U_x = **utility** of mode x
- n = number of attributes
- X_i = attribute value (time, cost, and so forth)
- a_i = coefficient value for attributes i (negative, since the values are disutility's)

$$U_x = \sum_{i=1}^n a_i X_i$$

Logit Models

The utility functions for auto and transit are as follows.

$$\begin{aligned}\text{Auto: } U_A &= -0.46 - 0.35T_1 - 0.08T_2 - 0.005C \\ \text{Transit: } U_T &= -0.07 - 0.05T_1 - 0.15T_2 - 0.005C\end{aligned}$$

where

T_1 = total travel time (minutes)
 T_2 = waiting time (minutes)
 C = cost (cents)

The travel characteristics between two zones are as follows:

	Auto	Transit
T_1	20	30
T_2	8	6
C	320	100

Solution: Use the logit model to determine the percent of travel in the zone by auto and transit.

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Model Split

Solution: Use the logit model to determine the percent of travel in the zone by auto and transit.

$$U_x = \sum_{i=1}^n a_i x_i$$

$$U_A = -0.46 - (0.35 \times 20) - (0.08 \times 8) - (0.005 \times 320) = -9.70$$

$$U_B = -0.07 - (0.35 \times 30) - (0.08 \times 6) - (0.005 \times 100) = -11.55$$

Using Eq.12.9 yields

$$P_A = \frac{e^{U_A}}{e^{U_A} + e^{U_T}} = \frac{e^{-9.70}}{e^{-9.7} + e^{-11.55}} = 0.86$$

$$P_T = \frac{e^{U_T}}{e^{U_A} + e^{U_T}} = \frac{e^{-11.55}}{e^{-9.7} + e^{-11.55}} = 0.14$$

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Example

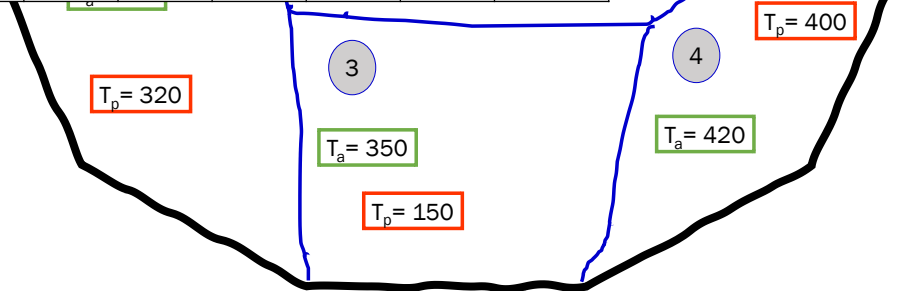
	Trip distribution							
Origin zone	Destination zone						Given P	Computed p
	1	2	3	4	5	6		
1	63	20	20	35	62	50	250	250
2	41	22	63	50	80	64	320	320
3	18	22	26	60	14	10	150	150
4	40	70	60	90	60	80	400	400
5	63	80	60	100	137	110	550	550
6	90	80	180	150	140	160	800	800



Model split

➤ 42 % by car

➤ 58% by bus



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Origin zone	<u>Generated trips</u>					
	Destination zone					
	1	2	3	4	5	6
1	63	20	20	35	62	50
2	41	22	63	50	80	64
3	18	22	26	60	14	10
4	40	70	60	90	60	80
5	63	80	60	100	137	110
6	90	80	180	150	140	160

mode choice 41%

mode choice 58%

Origin zone	<u>Trips by Car (41% of trip generated)</u>					
	Distination zone					
	1	2	3	4	5	6
1	26	8	8	15	26	21
2	17	9	26	21	34	27
3	8	9	11	25	6	4
4	17	29	25	38	25	34
5	26	34	25	42	58	46
6	38	34	76	63	59	67

Origin zone	<u>Trips by Bus (58% of trip generated)</u>					
	Distination zone					
	1	2	3	4	5	6
1	37	12	12	20	36	29
2	24	13	37	29	46	37
3	10	13	15	35	8	6
4	23	41	35	52	35	46
5	37	46	35	58	79	64
6	52	46	104	87	81	93

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**TRANSPORTATION ENGINEERING
AND PLANNING
(110401367)
SPRING 2019-2020**

**Lecture. No. 10
Traffic Assignment**

Dr. Hamza Alkuime

1

Topic 2 : Transportation planning

References

- Nicholas Garber and Lester Hoel , ***Traffic & Highway Engineering***, 5th Edition.. Cengage Learning, 2015
 - [Chapter 12 : Forecasting Travel Demand](#)
 - ❖ [Section 11.4](#)
- Daniel J Findley, Christopher Cunningham, Bastian J. Schroeder, Thomas H. Brown, ***Highway Engineering: Planning, Design, and Operations***, 2016, Elsevier
 - [Chapter 2.2: Planning concepts and Four-step process overview](#)



2

2

Topic 2 : Transportation planning



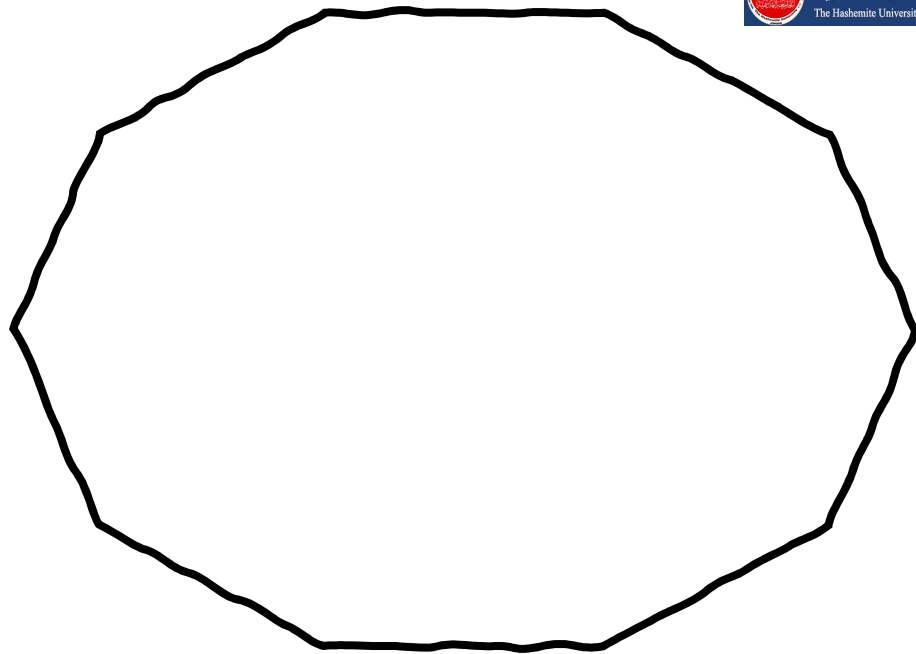
References

- Nicholas Garber and Lester Hoel , ***Principles of Highway engineering and traffic analysis***, 5th Edition, 2012
 - [*Chapter 8 : Travel Demand and traffic forecasting*](#)
- Partha chakroborty and Animesh Das, ***Principles of transportation engineering***, 2012,
 - [*Chapter 9: Transportation demand analysis*](#)
- Dušan Teodorović and Milan Janić, ***Transportation engineering theory, practice and modeling*** , 2017,
 - [*Chapter 8: Transportation demand analysis*](#)

3

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Review

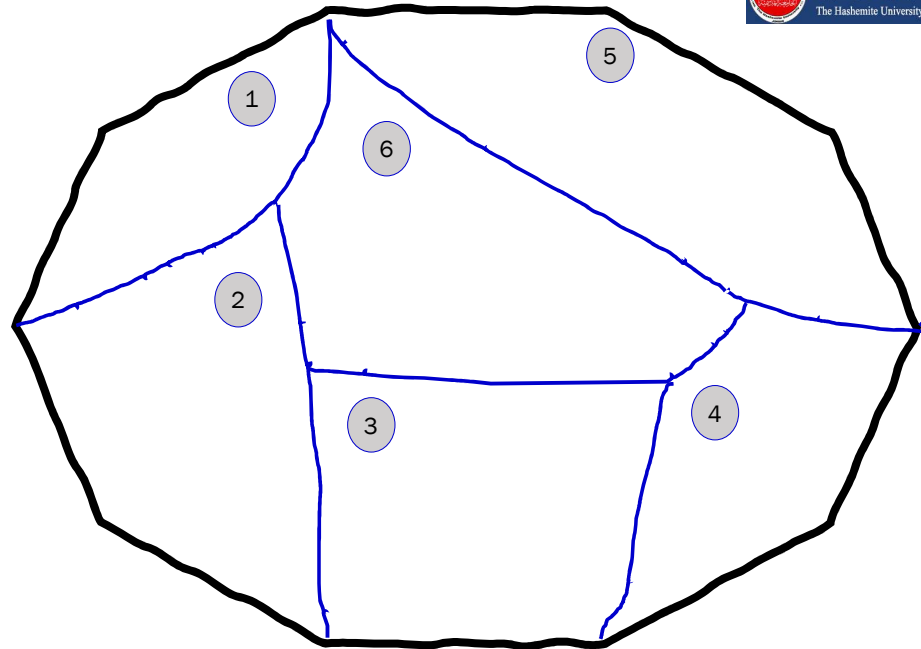


Study area

4

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Review



Zoning

5

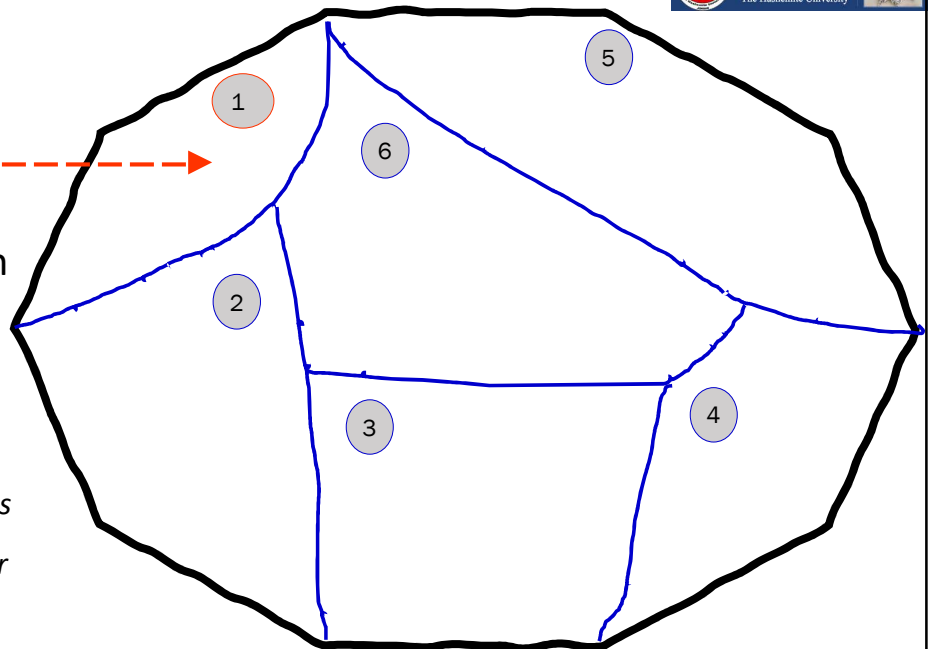
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Review

Attracted trips

The land use within
Zone 1 are

- 120 office space
- 500 factory
- 50 educational seats
- 100 shopping center



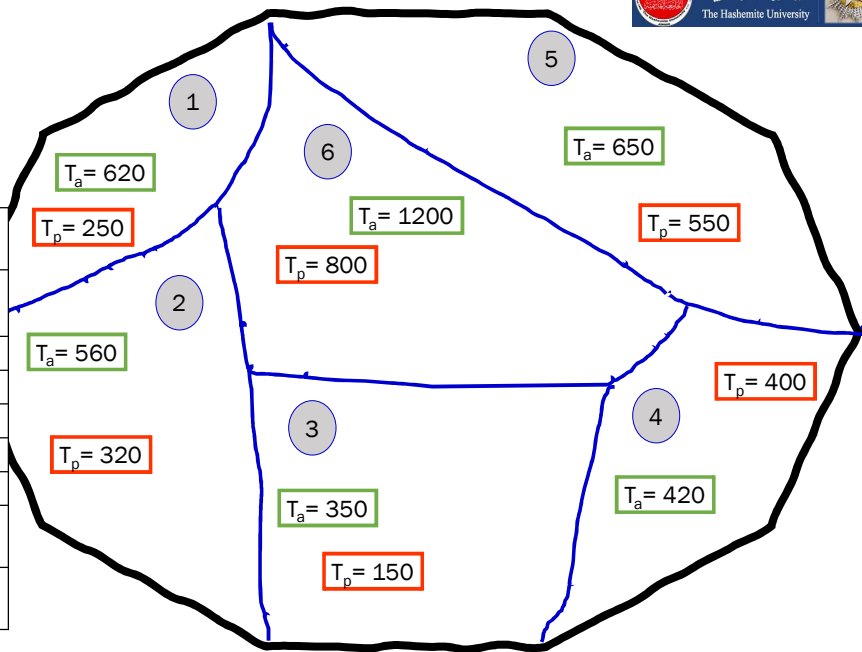
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Review

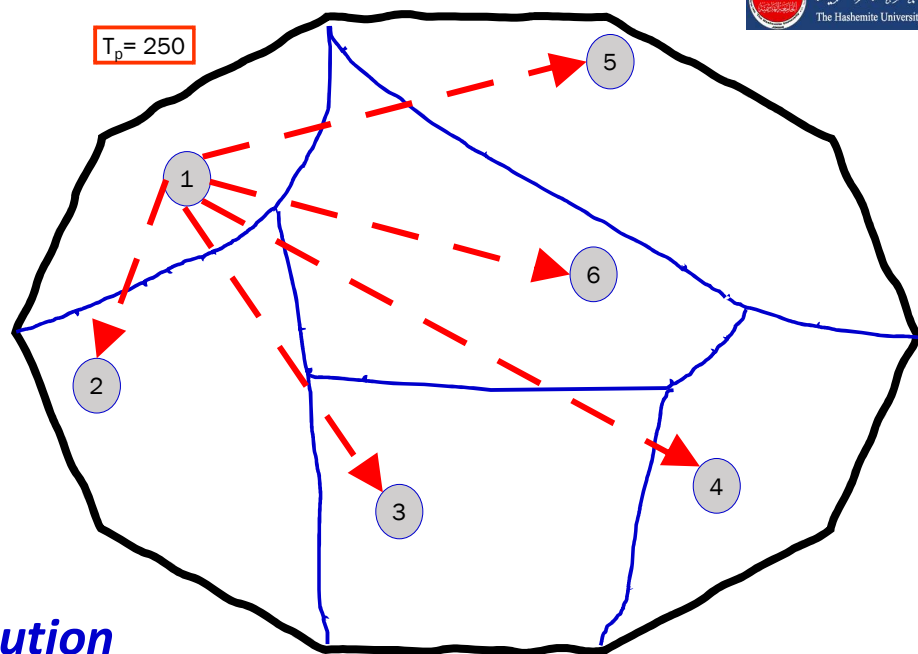
Balanced Trip Productions and Attractions

Zone ID	Balanced trips	
	Production	Attraction
1	250	403
2	320	364
3	150	228
4	400	273
5	550	423
6	800	780
Total trips	2470	2470



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Example



Trip distribution

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Example

	Trip distribution							
Origin zone	Destination zone						Given P	Computed p
	1	2	3	4	5	6		
1	63	20	20	35	62	50	250	250
2	41	22	63	50	80	64	320	320
3	18	22	26	60	14	10	150	150
4	40	70	60	90	60	80	400	400
5	63	80	60	100	137	110	550	550
6	90	80	180	150	140	160	800	800

$$T_a = 650$$

$$T_p = 550$$

$$T_p = 400$$

$$T_p = 320$$

$$T_a = 350$$

$$T_a = 420$$

$$T_p = 150$$

Model split

➤ 42 % by car

➤ 58% by bus

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Origin zone	Generated trips					
	Destination zone					
	1	2	3	4	5	6
1	63	20	20	35	62	50
2	41	22	63	50	80	64
3	18	22	26	60	14	10
4	40	70	60	90	60	80
5	63	80	60	100	137	110
6	90	80	180	150	140	160

mode choice 41%

mode choice 58%

Origin zone	Trips by Car (41% of trip generated)					
	Distination zone					
	1	2	3	4	5	6
1	26	8	8	15	26	21
2	17	9	26	21	34	27
3	8	9	11	25	6	4
4	17	29	25	38	25	34
5	26	34	25	42	58	46
6	38	34	76	63	59	67

Origin zone	Trips by Bus (58% of trip generated)					
	Distination zone					
	1	2	3	4	5	6
1	37	12	12	20	36	29
2	24	13	37	29	46	37
3	10	13	15	35	8	6
4	23	41	35	52	35	46
5	37	46	35	58	79	64
6	52	46	104	87	81	93

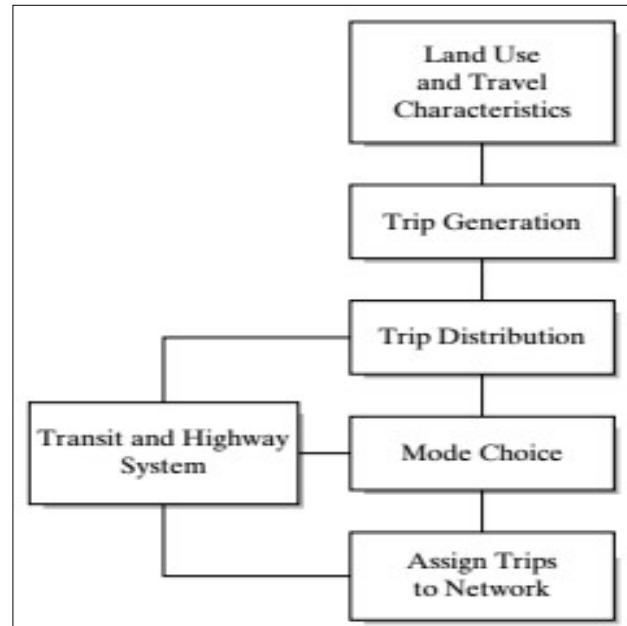
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Review

Travel Forecasting Process

■ Four-step process"

- Trip generation
 - ❖ How many trips
- Trip distribution
 - ❖ From where to where
- Modal choice
 - ❖ On what mode
- Traffic assignment
 - ❖ On what route



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Traffic assignment

■ Goal

- What path or route will a person choose ?
- What influences the choice of route?
 - ❖ Path that minimizes travel cost, time, distance, speed

■ Inputs

- Origin- destination matrix (trip table)

■ Output

- Path table

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Traffic assignment

Definition

■ Used to

- *determine the actual street and highway routes that will be used*
- *The number of automobiles and buses that can be expected on each highway segment*



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Traffic assignment

Definition

■ Used to

- *determine the actual street and highway routes that will be used*
- *The number of automobiles and buses that can be expected on each highway segment*



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Traffic assignment



Definition

- The TAZ's zones are interconnected by links,
 - which represent the physical characteristics of the road segments and facilities of the transportation network
- The traffic assignment step uses the characteristics of all links when determining which paths are most desirable for travelers, and therefore are expected to carry the highest traffic loads.
- A path is then represented through a series of links, each with its own set of attributes and characteristics
 - These attributes can include length, speed limit, travel time, capacity, functional classification, and a host of other variables used to describe the characteristics and expected performance of the link
- The link attributes are translated to the path through a process called skimming.

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Traffic assignment



Data needed

- number of trips that will be made from one zone to another (this information was determined in the trip distribution phase)
- Available highway or transit routes between zones
- How long it will take to travel on each route
- A decision rule (or algorithm) that explains how motorists or transit users select a route
- External trips that were not considered in the previous trip generation and distribution steps

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Traffic assignment

Approaches

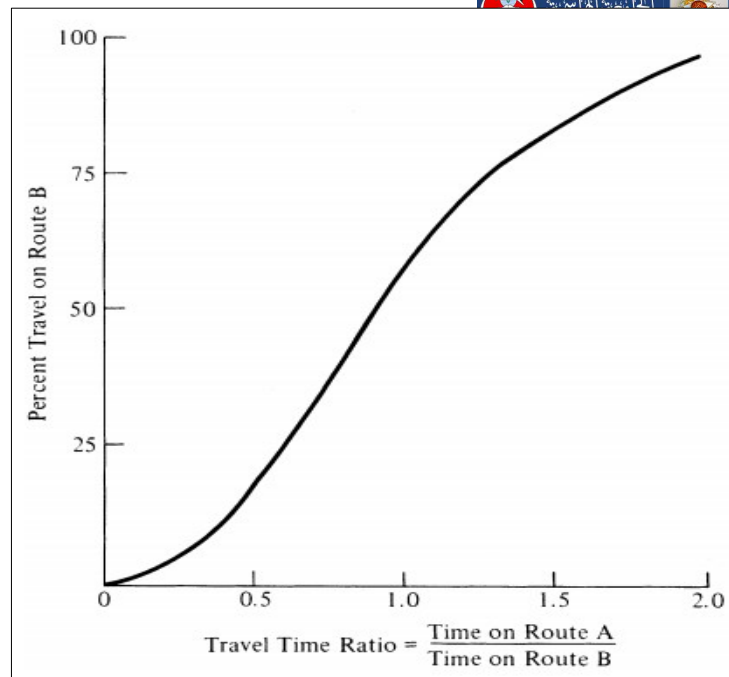
Three basic approaches can be used for traffic assignment purposes:

- Diversion curves
- Minimum time path (all-or-nothing) assignment
 - *commonly used*
 - *generally produces accurate results*
 - *adequately demonstrates the basic principles involved*
- Minimum time path with capacity restraint

Traffic assignment

Diversion curves

- Travel Time Ratio
versus Percentage
of Travel on Route
B



Traffic assignment



Minimum time path (all-or-nothing) assignment

- This method assigns all trips to those **links** that comprise the shortest time path between the **two zones**.
 - also other variables, such as lowest cost *can be used*
- It assumed that a motorist or transit user will select the quickest route between any O-D pair.
 - *The traveler will always select the route that represents minimum travel time.*

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Traffic assignment



skim tree

- The results can be depicted as a tree, referred to as a *skim tree*.
 - *All trips from that zone are assigned to links on the skim tree.*
 - *Each zone is represented by a node in the network which represents the entire area being examined.*
- The problem is finding the minimum-travel-time paths connecting each O-D pair for a given set of link travel time

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Traffic assignment

skim tree

- A path is then represented through a series of links, each with its own set of attributes and characteristics
 - These attributes can include length, speed limit, travel time, capacity, functional classification, and a host of other variables used to describe the characteristics and expected performance of the link
- The link attributes are translated to the path through a process called skimming.

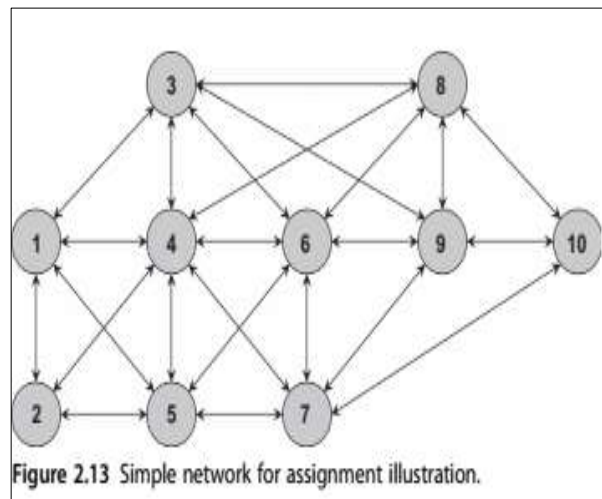
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Traffic assignment

skim tree

- If evaluating a trip with origin in zone 1 and destination in zone 4, the path is represented
 - $1 \rightarrow 4$
 - $1 \rightarrow 3 \rightarrow 4$
 - $1 \rightarrow 5 \rightarrow 4$
 - $1 \rightarrow 2 \rightarrow 4$
 - $1 \rightarrow 2 \rightarrow 5 \rightarrow 4$
- Therefore, the decision of which path drivers will take becomes a function of the attributes of each path, which, in turn, are estimated from the aggregated attributes of each link sequence



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Traffic assignment

skim tree

- Figure 2.14 amends the previous example by adding link **travel times (in minutes)** for each zone-to-zone connector

➤ it appears that link 1 → 4 is indeed the shortest travel time between zones 1 and 4 at 2 min

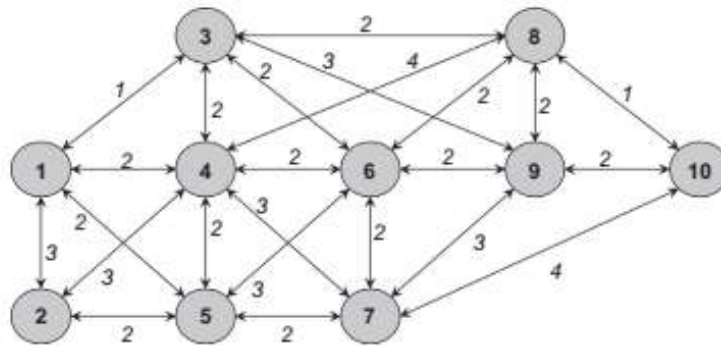


Figure 2.14 Simple assignment network with link travel times.

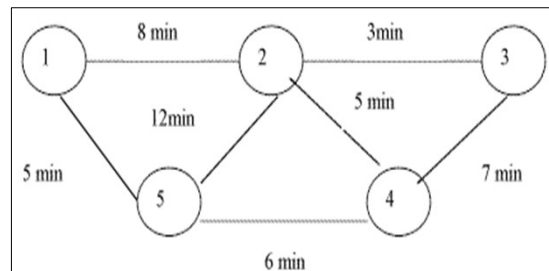
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Example -1

- Assign the vehicle trips shown in the O-D trip table to the network shown in Figure below using the all-or-nothing assignment technique.
- Make a list of the links in the network and indicate the volume assigned to each.
- Calculate the **total vehicle minutes of travel**.
- Show the minimum path and assign traffic for each of the five nodes.

From/to	Trips between Zones				
	1	2	3	4	5
1	-	100	100	200	150
2	400	-	200	100	500
3	200	100	-	100	150
4	250	150	300	-	400
5	200	100	50	350	-

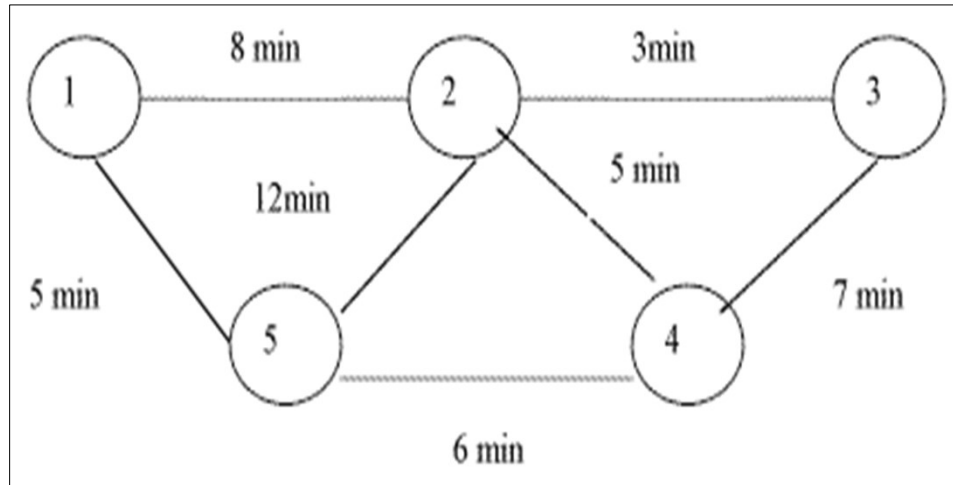


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Example -1

Travel time between zones



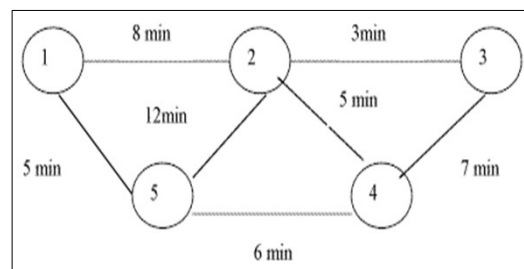
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Example -1

Step 1: Find the shortest paths between zones

Nodes		Shortest	Path	Cumulative Travel Time
From	To	Path	ID	(min)
1	2	1-2	1	8
	3	1-2,2-3	2	11
	4	1-5,5-4	3	11
	5	1-5	4	5
2	1	2-1	5	8
	3	2-3	6	3
	4	2-4	7	5
	5	2-4,4-5	8	11
3	1	3-2,2-1	9	11
	2	3-2	10	3
	4	3-4	11	7
	5	3-4,4-5	12	13
4	1	4-5,5-1	13	11
	2	4-2	14	5
	3	4-	15	7
	5	4-5	16	6
5	1	5-1	17	5
	2	5-4,4-2	18	11
	3	5-4,4-3	19	13
	4	5-4	20	6



shortest path = The path with minimum cumulative travel time

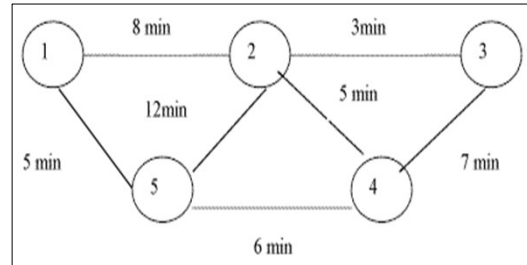
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Example -1

Step 2: Find total cumulative travel time for shortest paths between zones

Nodes		Shortest Path	Path ID	Cumulative Travel Time (min)
From	To			
1	2	1-2	1	8
	3	1-2,2-3	2	11
	4	1-5,5-4	3	11
	5	1-5	4	5
2	1	2-1	5	8
	3	2-3	6	3
	4	2-4	7	5
	5	2-4,4-5	8	11
3	1	3-2,2-1	9	11
	2	3-2	10	3
	4	3-4	11	7
	5	3-4,4-5	12	13
4	1	4-5,5-1	13	11
	2	4-2	14	5
	3	4-	15	7
	5	4-5	16	6
5	1	5-1	17	5
	2	5-4,4-2	18	11
	3	5-4,4-3	19	13
	4	5-4	20	6



shortest path = The path with minimum cumulative travel time

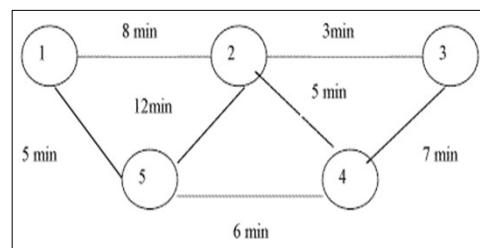
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Example -1

Step 3: Find traffic volumes (or estimated trips) for shortest paths between zones

Nodes		Shortest Path	Path ID	Cumulative Travel Time (min)	Traffic volume on shortest paths
From	To				
1	2	1-2	1	8	100
	3	1-2,2-3	2	11	100
	4	1-5,5-4	3	11	200
	5	1-5	4	5	150
2	1	2-1	5	8	400
	3	2-3	6	3	200
	4	2-4	7	5	100
	5	2-4,4-5	8	11	500
3	1	3-2,2-1	9	11	200
	2	3-2	10	3	100
	4	3-4	11	7	100
	5	3-4,4-5	12	13	150
4	1	4-5,5-1	13	11	250
	2	4-2	14	5	150
	3	4-	15	7	300
	5	4-5	16	6	400
5	1	5-1	17	5	200
	2	5-4,4-2	18	11	100
	3	5-4,4-3	19	13	50
	4	5-4	20	6	350



Trips between Zones					
From/to	1	2	3	4	5
1	-	100	100	200	150
2	400	-	200	100	500
3	200	100	-	100	150
4	250	150	300	-	400
5	200	100	50	350	-

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Example -1

Step 4: Find total trips (volume) on each link

Nodes		Shortest Path	Path ID	Estimated trips between zones
From	To			
1	2	1-2	1	100
	3	1-2,2-3	2	100
	4	1-5,5-4	3	200
	5	1-5	4	150
2	1	2-1	5	400
	3	2-3	6	200
	4	2-4	7	100
	5	2-4,4-5	8	500
3	1	3-2,2-1	9	200
	2	3-2	10	100
	4	3-4	11	100
	5	3-4,4-5	12	150
	4	5-4	20	350

Link	Used in Paths with ID	Cumulative trips on link
1-2	1 and 2	=100+100=200
2-1	5 and 9	=400+200=600

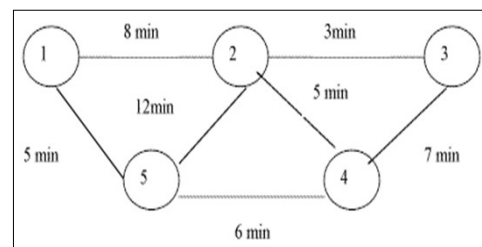
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Example -1

Step 4: Find total trips (volume) on each link

Selected Link	Used in Paths with ID	Cumulative trips on link	Link travel time (min) from
1-2	1, 2	=100+100=200	8
2-1	5, 9	=400+200=600	8
1-5	3, 4	=200+150=350	5
5-1	3	450	5
2-5	0	0	5
5-2	0	0	12
2-3	3,6	=200+200=400	3
3-2	9,10	300	3
2-4	7,8	600	5
4-2	14,18,	250	5
3-4	12,	250	7
4-3	19	350	7
4-5	8,12,13,16	1300	6
5-4	18,19,20	700	6



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Example -1

Step 5: Find total vehicle minutes of travel on each link

Link	Used in Paths with ID	Colmlative trips on link	Travel time (min [from figure])	Total vehicle minutes of travel (column 3 X column 4)
1-2	1, 2	200	8	1600
2-1	5, 9	600	8	4800
1-5	3, 4	350	5	1750
5-1	3	450	5	2250
2-5	0	0	12	0
5-2	0	0	12	0
2-3	3,6	300	3	900
3-2	9,10	300	3	900
2-4	7,8	600	5	3000
4-2	14,18,	250	5	1250
3-4	12,	250	7	1750
4-3	19	350	7	2450
4-5	8,12,13,16	1300	6	7800
5-4	18,19,20	700	6	4200
Total				32650

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Example -1

Step 6: Assign traffic for each of the five nodes

Link	Cumulative trips on link	Total vehicle minutes of travel (column 2 X column 3)
1-2	200	1600
2-1	600	4800
1-5	350	1750
5-1	450	2250
2-5	0	0
5-2	0	0
2-3	300	900
3-2	300	900
2-4	600	3000
4-2	250	1250
3-4	250	1750
4-3	350	2450
4-5	1300	7800
5-4	700	4200
Total		32650

Trips between Zones					
From/to	1	2	3	4	5
1	-	100	100	200	150
2	400	-	200	100	500
3	200	100	-	100	150
4	250	150	300	-	400
5	200	100	50	350	-

Node	Attracted trips	Volume Assigned
1	600+450	1050
2	200+300+250	750
3	300+350	650
4	600+250+700	1550
5	350+1300	1650

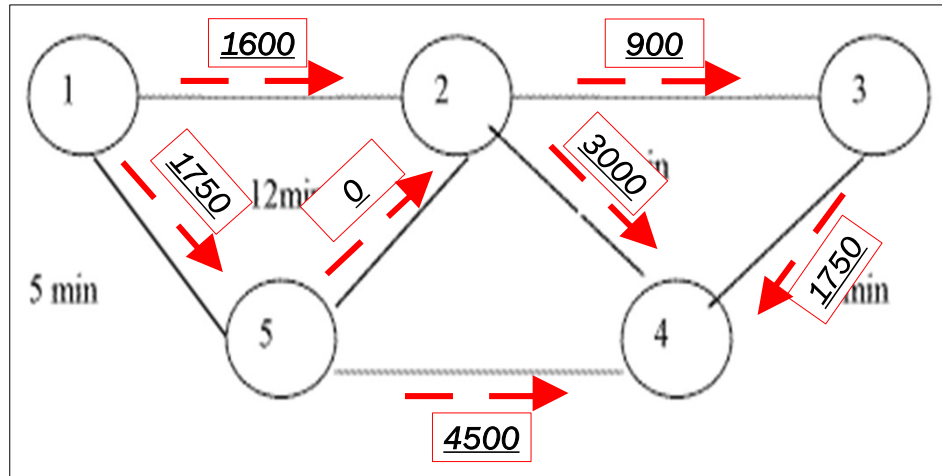
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Example -1

Step 6: Assign traffic for each of the five nodes

Link	Total vehicle minutes of travel (column 2 X column 3)
1-2	1600
2-1	4800
1-5	1750
5-1	2250
2-5	0
5-2	0
2-3	900
3-2	900
2-4	3000
4-2	1250
3-4	1750
4-3	2450
4-5	7800
5-4	4200
Total	32650



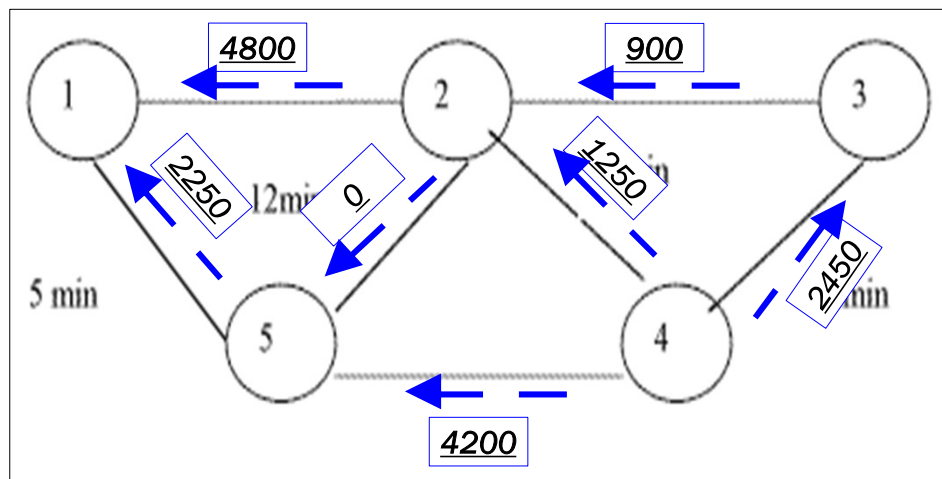
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Example -1

Step 6: Assign traffic for each of the five nodes

Link	Total vehicle minutes of travel (column 2 X column 3)
1-2	1600
2-1	4800
1-5	1750
5-1	2250
2-5	0
5-2	0
2-3	900
3-2	900
2-4	3000
4-2	1250
3-4	1750
4-3	2450
4-5	7800
5-4	4200
Total	32650



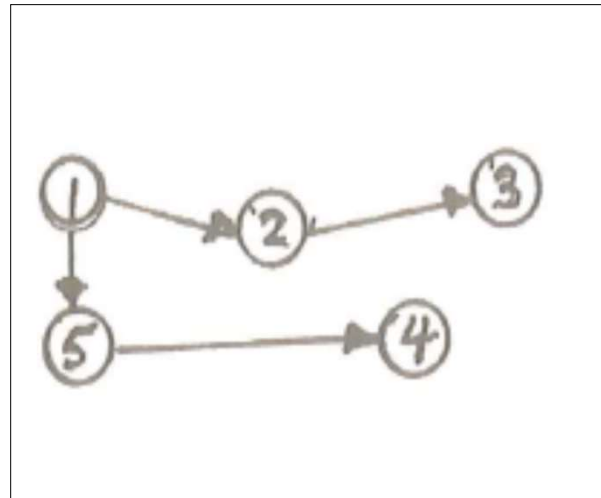
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Example -1

Step 7: Draw the minimum path (skim trees) at each node

Nodes		Shortest Path	Path ID
From	To		
<u>1</u>	2	1-2	1
	3	1-2,2-3	2
	4	1-5,5-4	3
	5	1-5	4



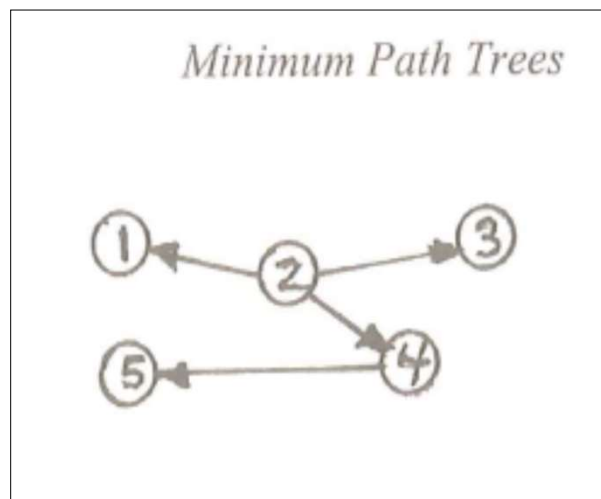
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Example -1

Step 7: Draw the minimum path (skim trees) at each node (cont.)

Nodes		Shortest Path	Path ID
From	To		
<u>2</u>	1	2-1	5
	3	2-3	6
	4	2-4	7
	5	2-4,4-5	8



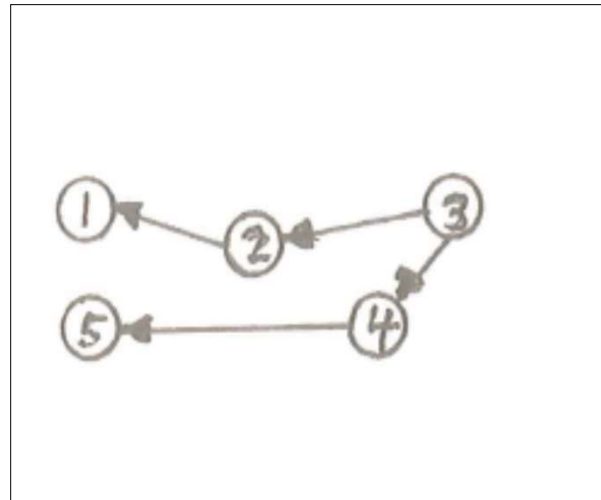
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Example -1

Step 7: Draw the minimum path (skim trees) at each node (cont.)

Nodes		Shortest Path	Path ID
From	To		
<u>3</u>	1	3-2,2-1	9
	2	3-2	10
	4	3-4	11
	5	3-4,4-5	12



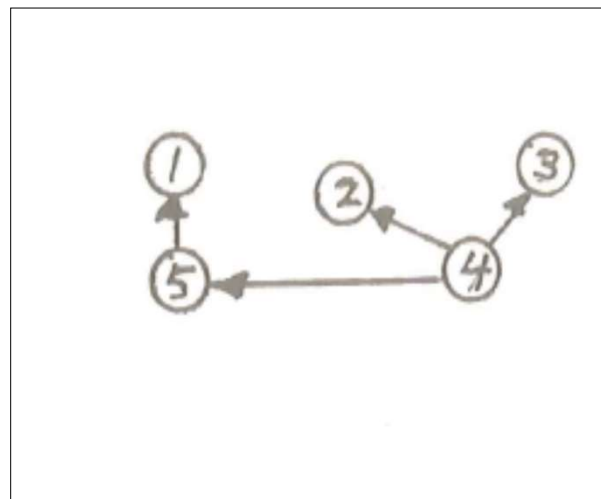
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Example -1

Step 7: Draw the minimum path (skim trees) at each node (cont.)

Nodes		Shortest Path	Path ID
From	To		
<u>4</u>	1	4-5,5-1	13
	2	4-2	14
	3	4-	15
	5	4-5	16



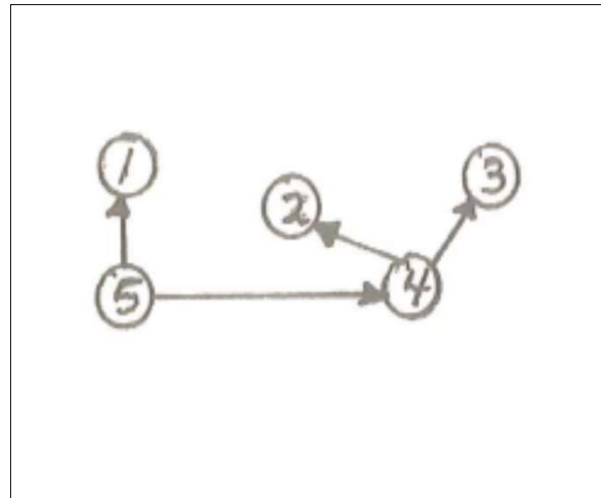
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Example -1

Step 7: Draw the minimum path (skim trees) at each node (cont.)

Nodes		Shortest Path	Path ID
From	To		
<u>5</u>	1	5-1	17
	2	5-4,4-2	18
	3	5-4,4-3	19
	4	5-4	20



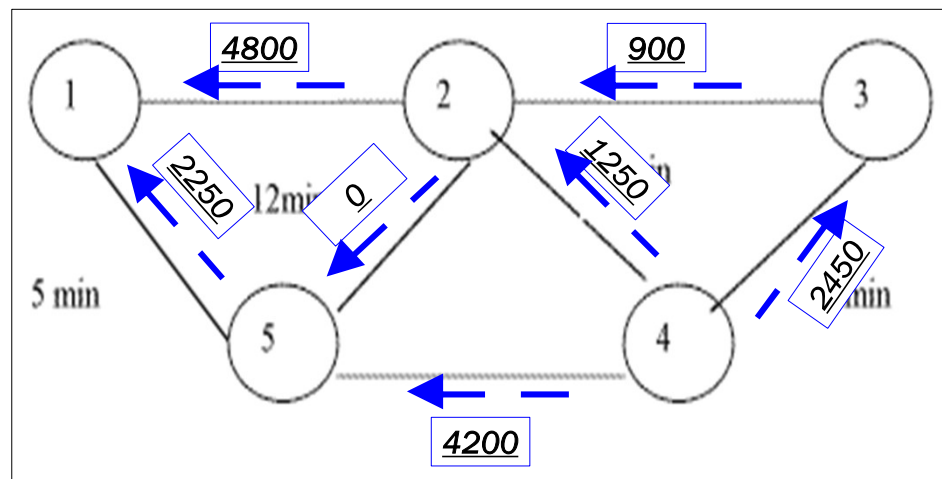
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Example -1

Step 6: Assign traffic for each of the five nodes

Link	Total vehicle minutes of travel (column 2 X column 3)
1-2	1600
2-1	4800
1-5	1750
5-1	2250
2-5	0
5-2	0
2-3	900
3-2	900
2-4	3000
4-2	1250
3-4	1750
4-3	2450
4-5	7800
5-4	4200
Total	32650



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What next

- The process of calculating the travel demand for an urban transportation system is now completed.
- The results of this work will be used to
 - Determine where improvements will be needed in the system
 - Make economic evaluations of project priority
 - Assist in the geometric and pavement design phases

