CHAPTER ONE
1. TRANSPORT PLANNING

1.1. Introduction

Transport planning- is planning and realization of strategies to supply the requirement of transport services to meet the transport demand.

The formation of the nation's transportation system has been evolutionary, not the result of a grand plan. The system now in place is the product of many individual decisions to select projects for construction or improvement, such as bridges, highways, tunnels, harbors, railway stations, and airport runways.

The process for planning transportation systems should be a rational one that serves to furnish unbiased information about the effects that the proposed transportation project will have on the affected community and on users. For example, if noise or air pollution is a concern, the process will examine and estimate how much additional noise or air pollution will occur if the transportation facility is built.

The process must be flexible enough to be applicable to any transportation project or system, because the kinds of problems that transportation engineers work on will vary over time.

The transportation planning process 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. Rather, the process 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.

1.2. Basic Elements of Transportation Planning

The transportation planning elements basically comprises planning of transport systems/physical planning and financing.

Planning of Transport Systems/physical planning

- ✓ The preparation of a structural plan for the area of which the authority (metropolitan or local/regional) has jurisdiction
- ✓ The structural plan should contain land use policies and proposals for road and rail network and to related services; e.g. rail terminals, public transport interchange facilities, docks and airports

Financing

- ✓ Transport was traditionally regarded as public goods.
- ✓ Transport infrastructure cost paid by public authorities
- ✓ Financial structure is tough depending on the type of infrastructure and the administrative/political/geographical level in scope

Elements of Transportation Planning Process

The transportation planning process comprises seven basic elements, which are interrelated and 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. The elements in the process are:

- Situation definition
- Problem definition
- Search for solutions
- Analysis of performance
- Evaluation of alternatives
- Choice of project
- Specification and construction

A. Situation Definition

The first step in the planning process is *situation definition,* which involves all of the activities required to understand the situation that gave rise to the perceived need for a transportation improvement. In this phase, the basic factors that created the present situation are described, and the scope of the system to be studied is delineated. 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 and summarized.

B. Problem Definition

The purpose of this step is to describe the problem in terms of the objectives to be accomplished by the project and to translate those objectives into criteria that can be quantified. Objectives are statements of purpose, such as to reduce traffic congestion; to improve safety; to maximize net highway-user benefits; and to reduce noise. Criteria are the measures of effectiveness that can be used to quantify the extent to which a proposed transportation project will achieve the stated objectives. For example, the objective "to reduce traffic congestion" might use "travel time" as the measure of effectiveness.

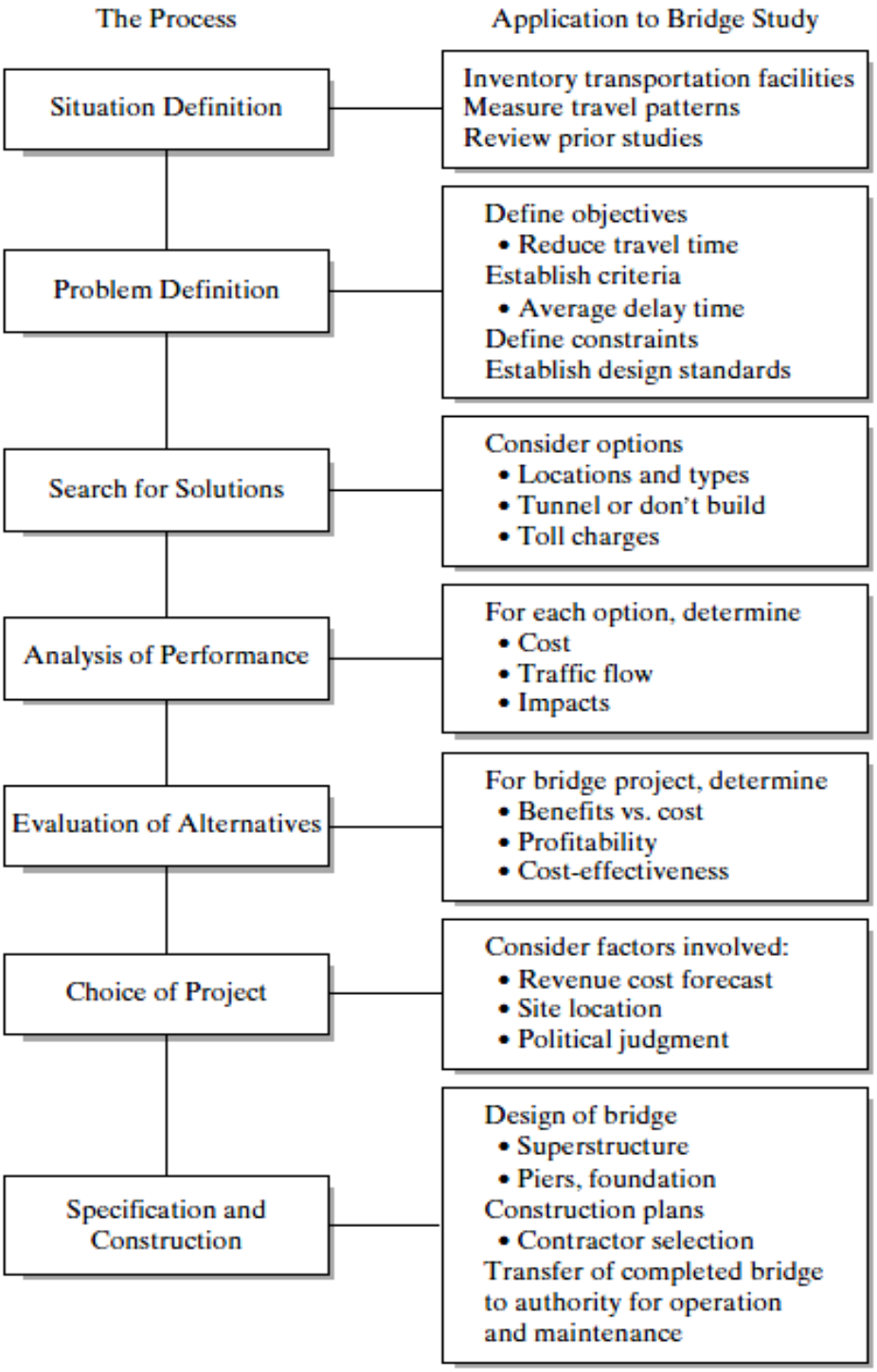


Figure 1.1: Basic Elements in the Transportation Planning Process Applied to Consider the Feasibility of a New Bridge

C. Search for Solutions

In this phase of the planning process, consideration is given to a variety of ideas, designs, locations, and system configurations that might provide solutions to the problem. This is the brainstorming stage, in which many options may be proposed for later testing and evaluation. Alternatives can be proposed by any group or organization.

The transportation engineer has a variety of options available in any particular situation, and any or all may be considered in this idea-generating phase. Among the options that might be used are different types of transportation technology or vehicles, various system or network arrangements, and different methods of operation. This phase also 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.

D. Analysis of Performance

The purpose of performance analysis is to estimate how each of the proposed alternatives would perform under present and future conditions. The criteria identified in the previous steps are calculated for each transportation option. Included in this step is a determination of the investment cost of building the transportation project, as well as annual costs for maintenance and operation. The number of persons or vehicles that will use the system is determined, and these results, expressed in vehicles or persons/hour, serve as the basis for project design. Other information about the use of the system (such as trip length, travel by time of day, and vehicle occupancy) are also determined and used in calculating user benefits for various criteria or measures of effectiveness. Environmental effects of the transportation project (such as noise and air pollution levels and acres of land required) are estimated. These nonuser impacts are calculated in situations where the transportation project could have significant impacts on the community or as required by law.

E. Evaluation of Alternatives

The purpose of the evaluation phase is to determine how well each alternative will achieve the objectives of the project as defined by the criteria. The performance data produced in the analysis phase are used to compute the benefits and costs that will result if the project is selected. In cases where the results cannot be reduced to a single monetary value, a weighted ranking for each alternative might be produced and compared with other proposed projects.

If the benefit-cost ratio result is positive, the evaluation of alternative sites requires additional comparison of factors, both for engineering and economic feasibility and for environmental impact.

F. Choice of Project

Project selection is made after considering all the factors involved. In a simple situation, for example, where the project has been authorized and is in the design phase, a single criterion (such as cost) might be used and the chosen project would be the one with the lowest cost. With a more complex project, however, many factors have to be considered, and selection is based on how the results are perceived by those involved in decision-making. If the project involves the community, it may be necessary to hold additional public hearings. A bond issue or referendum may be required. It is possible that none of the alternatives will meet the criteria or standards, and additional investigations will be necessary.

G. Specification and Construction

Once the transportation project has been selected, the project moves into a detailed design phase in which each of the components of the facility is specified. For a transportation facility, this involves its physical location, geometric dimensions, and structural configuration. Design plans are produced that can be used by contractors to estimate the cost of building the project. When a construction firm is selected, these plans will be the basis on which the project will be built.

Urban transport planning

Urban transportation planning involves the evaluation and selection of highway or transit facilities to serve present and future land uses. For example, the construction of a new shopping center, airport, or convention center will require additional transportation services. Also, new residential development, office space, and industrial parks will generate additional traffic, requiring the creation or expansion of roads and transit services.

Urban transportation planning is concerned with two separate time horizons.

The first is a short-term project emphasized to select projects that can be implemented within a one- to three-year period. These projects are designed to provide better management of existing facilities by making them as efficient as possible. Short-term projects 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.

The long-term project deals with the long-range transportation needs of an area and identifies the projects to be constructed over a 20-year period. Long-term projects involve programs such as adding new highway elements, additional bus lines or freeway lanes, rapid transit systems and extensions, or access roads to airports or shopping malls.

The urban transportation planning process can be carried out in terms of the procedures outlined previously and is usually described as follows.

a) 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, land uses, origins and destinations of travelers, population, employment, and economic activity. Inventories are made of existing transportation facilities, both highway and transit. Capacity, speed, travel time, and traffic volume are determined.

b) Establishment of Goals and Objectives

A statement of goals, objectives, and standards are prepared to identify deficiencies in the existing system, desired improvements, and what is to be achieved by the transportation improvements.

c) Generation of Alternatives

In this phase of the urban transportation planning process, the alternatives to be analyzed will be identified. The options available to the urban transportation planner include various technologies (LRT or BRT), network configurations of single line, two branches or geometric (radial or grid pattern),vehicles (singly driven buses or multicar trains), operating policies (10-minute headways at peak hours and 30-minute at off-peak hours), and organizational arrangements (private or public).

d) Estimation of Project Cost and Travel Demand

This activity in the urban transportation planning process involves two separate tasks. The first is to determine the project cost, and the second is to estimate the amount of traffic expected in the future. The estimation of facility cost is relatively straightforward, whereas the estimation of future traffic flows is a complex undertaking requiring the use of mathematical models and computers.

e) Evaluation of Alternatives

This phase of the process is similar in concept to what was described earlier but can be complex in practice because of the conflicting objectives and diverse groups that will be affected by an urban transportation project.

Among the groups that could be affected are the traveling public (user), the highway or transit agencies (operator), and the non-traveling public (community). Each of these groups will have different objectives and viewpoints concerning how well the system performs. The traveling public wants to improve speed, safety, and comfort; the

transportation agency wishes to minimize cost; and the community wants to preserve its lifestyle and improve or minimize environmental impacts.

f) Choice of Project

Selection of a project will be based on a process that will ultimately involve elected officials and the public. Quite often, funds to build an urban transportation project (such as a subway system) may involve a public referendum.

Evaluating transport alternatives

The objective of an evaluation is to furnish the appropriate information about the outcome of each alternative so that a selection can be made. The evaluation process should be viewed as an activity in which information relevant to the selection is available to the person or group who will make a decision. An essential input in the process is to know what information will be important in making a project selection.

Selecting and Measuring Evaluation Criteria

Criteria not only must be relevant to the problem but should also have other attributes. They should be easy to measure and sensitive to changes made in each alternative. Also, it is advisable to limit the number of criteria to those that will be most helpful in reaching a decision in order to keep the analysis manageable for both the engineer who is doing the work and the person(s) who will act on the result.

Criteria for Evaluating Transportation Alternatives are:

- Capital costs
  - ✓ Construction
  - ✓ Right of way
  - ✓ Vehicles
- Maintenance costs
- Facility operating costs
- Travel time
  - ✓ Total hours and cost of system travel

- ✓ Average door-to-door speed
- ✓ Distribution of door-to-door speeds

- Vehicle operating costs
- Safety
- Social and environmental costs
  - ✓ Noise
  - ✓ Visual quality
  - ✓ Community cohesion
  - ✓ Air and water quality

Evaluation Based on Economic Criteria

Economic evaluation methods require that each measure of effectiveness be converted into monetary units. The approach considers the total costs of each alternative, including user and facility costs, and then to select the project that has the lowest total cost. These include facility costs for construction, maintenance, and operation and user costs for travel time, accidents, and vehicle operations.

- The cost of a transportation facility improvement includes two components: first cost or capital cost (engineering design, right of way, and construction) and continuing costs (maintenance, operation, and administration).
- Three commonly used measures of user costs are included in a transportation project evaluation: costs for vehicle operation, travel time costs, and costs of accidents, as illustrated in Figure 3.2.

An economic evaluation of a transportation project is completed using most commonly one of the following methods: benefit-cost ratio (BCR), or internal rate of return (IRR).

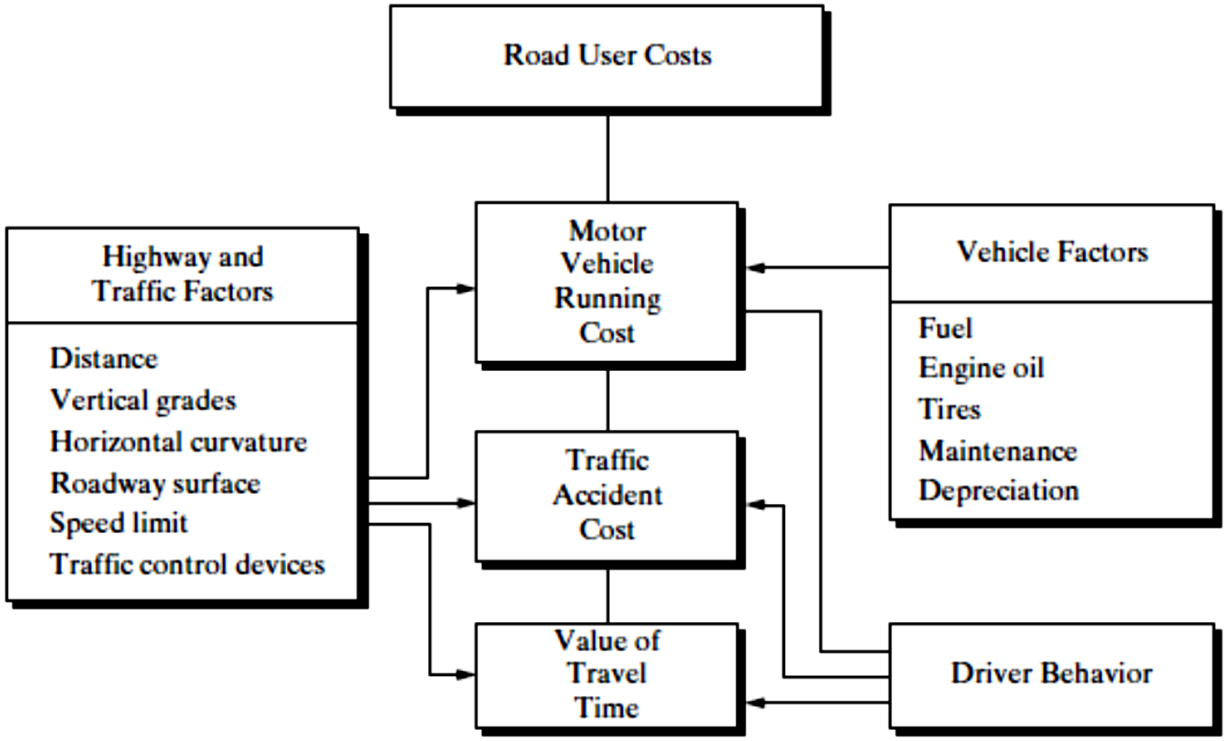


Figure 1.2: Road User Cost Factors

Evaluation Based on Multiple Criteria

This evaluation method seeks to include measurable criteria that are not translated just in monetary terms in addition to economic evaluation method.

Numerical ranking methods, one of multiple criteria method, require that each measure of effectiveness be translated to an equivalent score rather than monetary unit. In addition, cost-effectiveness methods require only that each measure of effectiveness be displayed in matrix form and it is the task of the analysts to develop relationships between various impacts and the costs involved.

1.3. Transport planning data collection

Data are an essential input to the effective planning and design of transport systems, either directly by describing the current state of the system, or indirectly by allowing the calibration of models which yield insights into the processes at work in the system or help to predict how the system is likely to perform in the future with and without policy intervention.

The data collection phase provides information about the city and its people that will serve as the basis for developing travel demand estimates. The data include information about economic activity (employment, sales volume, income, etc.), land use (type, intensity), travel characteristics (trip and traveler profile), and transportation facilities (capacity, travel speed, etc.).

Defining the data requirements

The requirement for information needs to be refined into a precise specification of data requirements in terms of the variable(s) to be studied and the hypotheses to be tested. Data is used to elaborate cause-effect relationships to be investigated

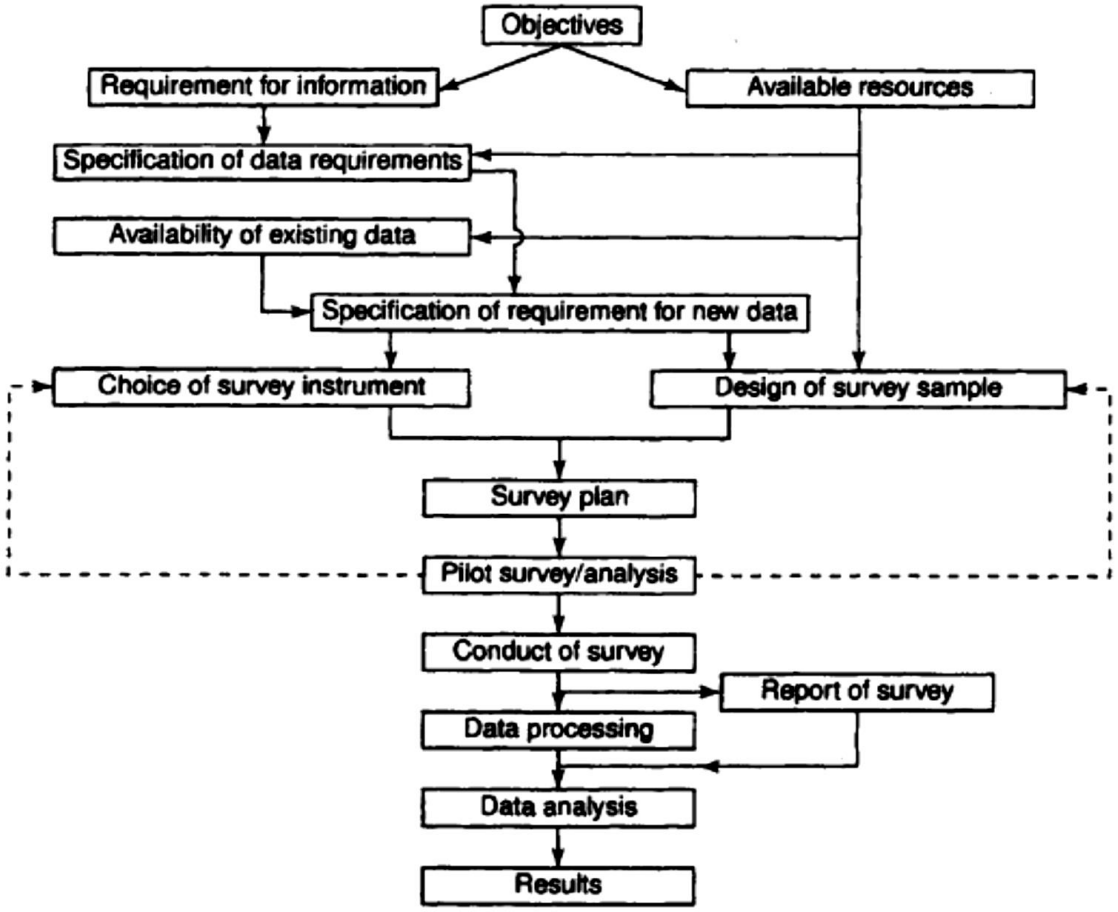


Figure 1.3: Stages in the design and conduct of a survey

1.3.1. Sources of transport planning data

There are two sources of data for transport planning; primary sources (direct surveying data) and secondary sources (existing data). The choice of data collection method depends on purpose of data & budget allocated.

a. Secondary sources (existing data)

Once the data requirements have been specified, it is important to consider whether they can be met by making use of existing data, thereby avoiding the need for a special survey. So, it is the first step in data collection. The three main sources of data are:

- Publication database
- previous local area surveys

- data produced as a by-product of control or management system
  E.g. vehicle flow past at toll point

Advantages

- saves lots of time & money
- when a survey is likely to cause disruption and annoyance to the travelling public
- it is important for political reasons to be seen to be conducting a survey

Problems/disadvantages

- (no) knowledge of how data was collected
- definitions & categories may be different
- different spatial aggregations
- disaggregation and cross classifications may not be available (privacy)
- access to raw data may be difficult/impractical (obsolete media, file formats, inadequate documentation)
- client may want new data to be collected

b. Primary sources (direct surveying data)

Assuming that, after careful consideration of all secondary sources of data, the need for further data collection is established, the next stage is to produce a detailed specification of this requirement. The specification must take account of the resources available since they may seriously constrain what can be achieved in terms of accuracy or coverage. The primary data can be collected in the following different methods.

- Observational surveys
- Household self-completion surveys
- Telephone interview surveys
- Road side interviews/Surveys
- Household personal interview surveys
- Group discussion surveys (focus group)
- In-depth interviews

Advantages

- The data may be accurate
- Can achieve up to date (current condition) data

Disadvantages

- It is time and money consuming
- The quality of data depends on personal
- The data may bias to the interest of data collector (specially at interviews)

1.3.2. Type of transport planning data

The types of transport planning data to be collected are:

a) Vehicular traffic flow data
b) Public transport user data
c) Pedestrian volume data
d) Cyclists and cycle facilities data
e) Spot speed data
f) Origin-Destination (OD)cordon data
g) Journey speed, travel time and delay data
h) Parking use data
i) Environmental impact data (noise and air pollution)

1.3.3. Data collection sampling methods

Data cannot be collected for the entire target population! The choice of sampling method will depend on the objectives of the survey and perhaps on the survey technique being employed.

Sampling methods

a) Random sampling: all samples have an equal chance of being selected
   - It is a theoretically attractive method
   - It is impractical for a “live” event

b) Systematic sampling: select every n^{th} unit
   - The concept is easily understood, even by inexperienced staff and is therefore widely applied in surveys of live events.
   - The method is random in as much as that until the first unit is selected
   - All units have equal probability of being chosen, but it is not truly random and may produce biased results if the sequence of units has any significance

c) Stratified sampling
   - It involves division of the population into groups on the basis of some characteristic and applying a different sampling rate in each group.
   - The method is usually applied when it is necessary to ensure adequate representation of a minority

d) Cluster sampling
   - It involves selecting groups of adjacent units (e.g. addresses on a street or a group of vehicles following one another in a traffic stream)
   - This technique usually results in increased survey efficiency

1.4. Introduction to Transport Modeling

Introduction

Models are simplified representations of reality which can be used to explore the consequences of particular policies or strategies. They are deliberately simplified in order to keep them manageable and to avoid extraneous detail while hopefully encapsulating the important (determining) features of the system of interest.

The reason for using models is that estimates can be made of likely outcomes more quickly and at lower cost and risk than would be possible through implementation and monitoring.

Models can be used in a variety of ways.

1) To predict future conditions in the absence of policy intervention-thus providing an assessment of the extent to which conditions will deteriorate, or ameliorate, and giving an indication of the conditions which are likely to prevail at some future date.
2) To predict future conditions on the assumption that each of a series of specified policies or designs is implemented- thus helping to establish the extent of any benefits which can be attributed to each one and thus in turn providing the basis for an appraisal of their relative costs and benefits.
3) To test the performance of a given policy intervention in each of a series of imagined futures- thus indicating its 'robustness' in the face of future uncertainty.
4) To produce very short-term forecasts as part of an on-line management or control system such as might be found in a sophisticated area traffic control system.

Models range in sophistication from simple equations encapsulating empirical relationships which can be worked out on the back of an envelope, on a calculator or in a spreadsheet, through to suites of computer programs each involving hundreds of lines of code to perform sophisticated mathematical functions or detailed simulations.

Models can be

- quantitative (with numbers) or qualitative (without)
- static (relating to states or conditions) or dynamic (relating to processes)
- causal (why something happens) or simply correlative
- aggregate or disaggregate
- transparent (to aid understanding or explanation) or a black box
- predictive (what will happen) or prescriptive (what should happen)
- empirical (based directly on data) or synthetic (based on a relationship derived from the data)

Advantages of Modeling

- ✓ help visualize and understand problems
- ✓ important part of decision-making processes
- ✓ facilitate the discussion of assumptions and are (can be), therefore, more transparent than mental models
- ✓ assist in the analysis of risk and uncertainty
- ✓ models can provide important inputs to the appraisal process

Disadvantages of Modeling

- ✓ can be opaque
- ✓ could alienate planning processes
- ✓ often require a good deal of expensive data
- ✓ May influence problem definition

Purpose of a model

- ✓ to help understand how the system works
- ✓ to help explain or communicate how the system works

- ✓ to help predict usage and performance of the system in various possible future circumstances
- ✓ to help design or manage facilities and services
- ✓ to help evaluate possible investment options

The choice of method of modelling depends on: the purpose of the exercise, the level of detail and accuracy required and the resources available.

Transport Modeling

Transport model is a simplified mathematical representation of a small part of the real world, aiming at describing and explaining travel behavior and visualizing the amount and patterns of transport.

The bases of mathematical model are the data for **land use** and **transport system**, together with an **understanding of human behavior.**

Development and short history of transport model

- ➢ 1960 – 1975: The first complete model in use; USA and Europe
  - ▪ Driving force
    - ✓ The increased traffic volume
    - ✓ Theoretical development
    - ✓ The computer (important prerequisites)
  - ▪ Focus
    - ✓ Traffic growth/forecasts; How large roads do we need?
- ➢ 1975 – 1985: models got a bad reputation in many countries, focuses were on traffic safety and environmental conditions- but still research in universities - theoretical development

- 1985 – 1995: Revival of models—focus on getting traffic data to calculate safety and env'tal effects of different projects /traffic plans

Uses in today transport model

- Providing traffic data for the future; thus understanding of the challenges (problems) to come; such as
  - ✓ Traffic Congestion and delay
  - ✓ Traffic accident
  - ✓ Env'tal condition (air pollution and noise)
  - ✓ Parking difficulties
  - ✓ Future transport costs for people and for business/industry
  - ✓ Accessibility and mobility, etc.
- Analyzing the effect of alternative traffic plans/projects
- Providing traffic data for "Cost-Benefit-Analysis"
- Providing traffic data for calculating the development of traffic accidents and environmental conditions

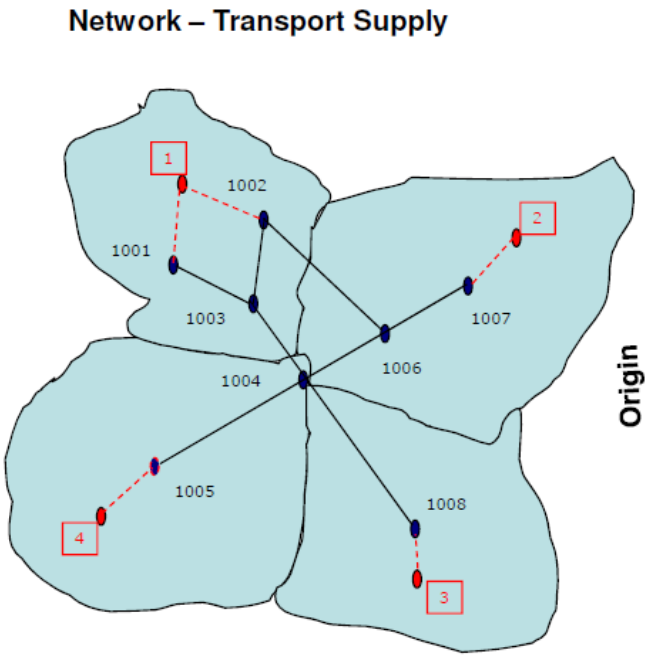
Networks and Zones in Transport Modelling

In principle greater accuracy in transport modelling could be achieved using these systems.

Definition

Networks

- ✓ It is graphical representations of the transport system.
- ✓ It usually represented as a set of zones and links.
- ✓ It encompasses large enough area to study all significant impacts and influences.



Matrix – Travel Demand

Destination

Origin	1	2	3	4	T
1	-	3	2	7	12
2	7	-	8	16	31
3	5	2	-	12	19
4	4	4	4	-	12
T	16	9	14	35	74

Figure 1.4: Networks of travel

Zones

- ✓ It is reduction of the trip matrix into manageable proportions.
- ✓ Size of zones: compromise between accuracy and economy.
- ✓ Boundaries chosen to reflect
  - zones for which data is available, e.g. enumeration districts or political units
  - zones used in previous studies
- ✓ It distinguishes between "internal zones" in the study area bounded by external cordon and "external zones" covering the rest of the world.

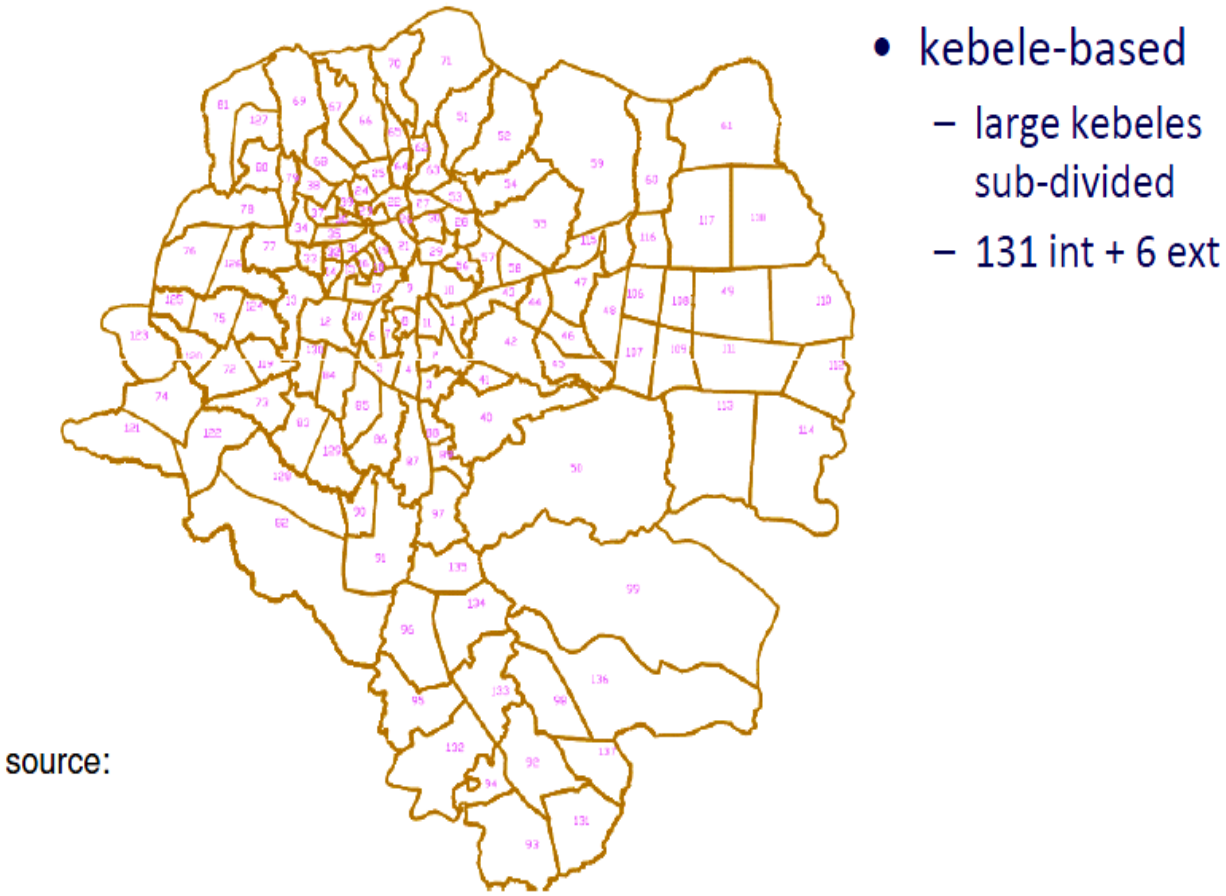


Figure1.5: Ideal Zones of Addis Ababa

An ideal Zone is

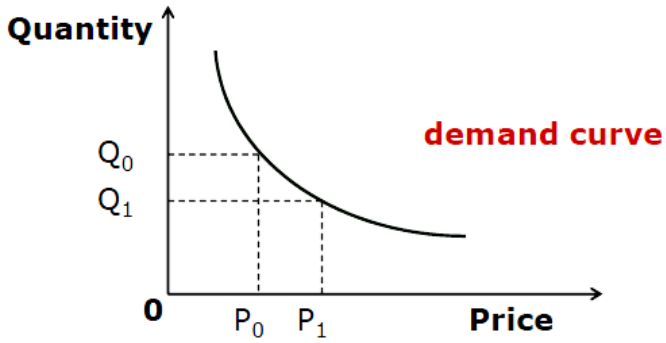
- Consistent with land use and population characteristics
- Divided by distinct barriers to movement (e.g. rivers)
- Centered around points of access to transport facilities (e.g. stations)
- Roughly equal size
- "Hierarchical Zoning Systems"

Demand for Transport

Travel demand is expressed as 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.

Demand for transport is a base for transport model

Demand is the amount of a product or service desired at a particular price in a given time period. This is shown graphically in a demand curve or numerically in a demand schedule.



Price	Quantity
100	3000
90	3150
80	3350
70	3600
60	3900

Figure 1.6: Demand curve

Demand for transport (Qi) is typically taken to be a function of:

- ✓ The price of the service (Pi)
- ✓ The price of other services (Pn)
- ✓ The quality of the service (e.g. journey time, service frequency, rolling stock quality) (Si)
- ✓ The quality of other services (Sn)
- ✓ Income (Y)

Qi = f (Pi, Pn, Si, Sn, Y)

What makes transport different from other products?

- Transport is a derived demand (not basic need?)
- Transport as a whole is a normal good ($\Delta Q > 0$) but some public transport modes may be inferior goods ($\Delta Q < 0$)
- Demand varies by:
  - ✓ Socio-economic characteristics of passengers

- ✓ Journey purpose
- ✓ Time of day/day of week/time of year

Four Stage Model (FSM)

What is the four-stage model?

The four-stage model (FSM) is the primary tool for forecasting demand and performance of a transportation system, typically defined at a regional or sub-regional scale.

The FSM must be suitably policy sensitive to allow for the comparison of alternative interventions to influence future demand and performance. The models system was developed for evaluating large-scale infrastructure projects, not for subtle and complex policies involving the management and control of existing infrastructure or the introduction of policies that directly influence travel behavior. For example, the construction of a LRT network compared to a car pool scheme.

Application of travel forecasting models is a continuous process. The period required for data collection, model estimation, and subsequent forecasting exercises may take years during which time the activity and transportation systems change, as do policies of interest, often requiring new data collection efforts and new modeling effort.

The components of four stage model in transport modeling are:

1. **Trip Generation** (production and attraction): models calculate the number of trips generated by (Oi-origin) and attracted to (Dj-destination) each zone in the study area
2. **Trip Distribution**: models calculate the trip pattern connecting trip productions and attractions
3. **Mode Choice**: models distribute trips from one origin (zone) to a destination to the different modes of transport

4. **Traffic Assignment**: car trips are distributed to the road network and public transport trips distributed to the public transport network

The inputs for these models include zones and networks, base year travel data and future planning data.

Some definitions in common use

- "journey" – complete excursion (out and back)
- "trip" or "journey leg" – a one-way journey
- "origin" - place where the trip started
- "destination" - place where the trip ended
- "home-based trip" – trip having origin or destination at the trip-maker's home
- HBW: Home-based work
- HBO: Home-based other
- "Non-Home-Based" - all other trips (NHB)
- **mode** – means of transport used for the trip or trip stage
- **main mode** – a multimode‟ trip is normally the one used for the longest distance
- **trip purpose** - with respect to the destination, e.g. work, business trip, leisure, shopping, education
- **O-D matrix** - matrix of trips from particular origins to particular destinations

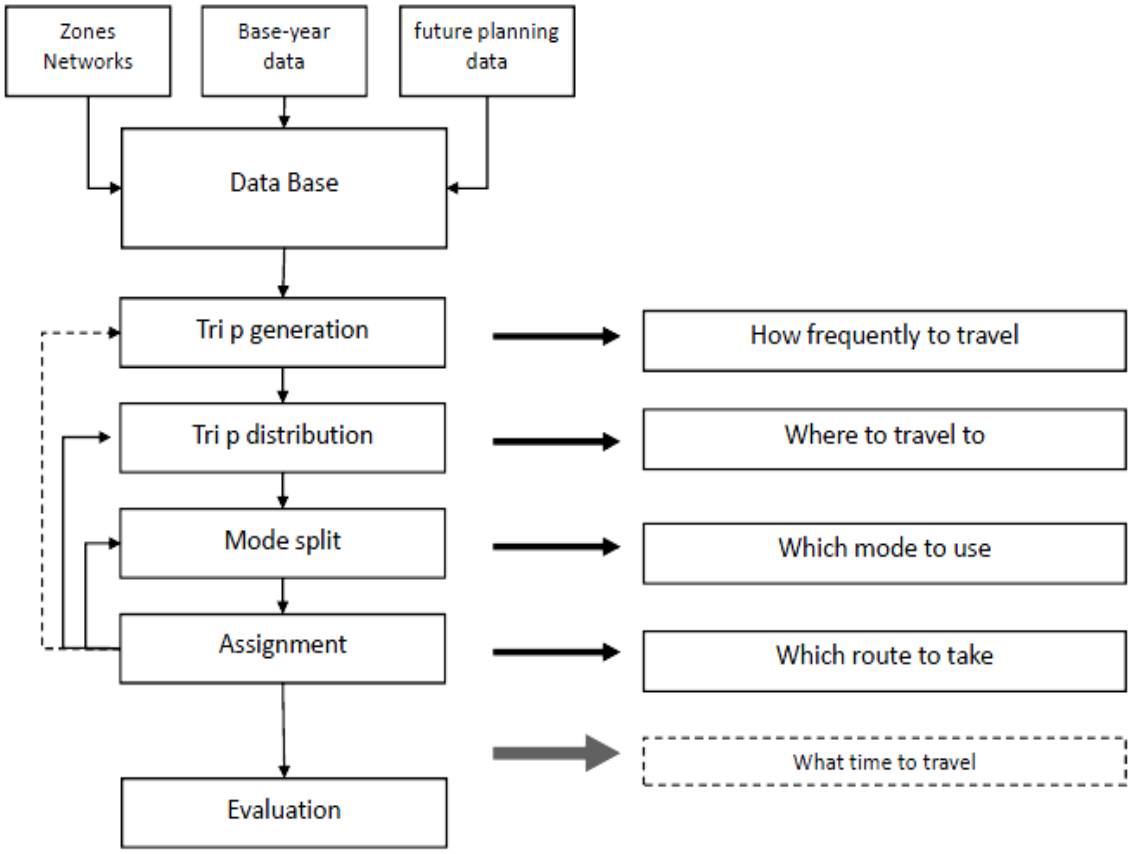


Figure 1.7: Four stage model

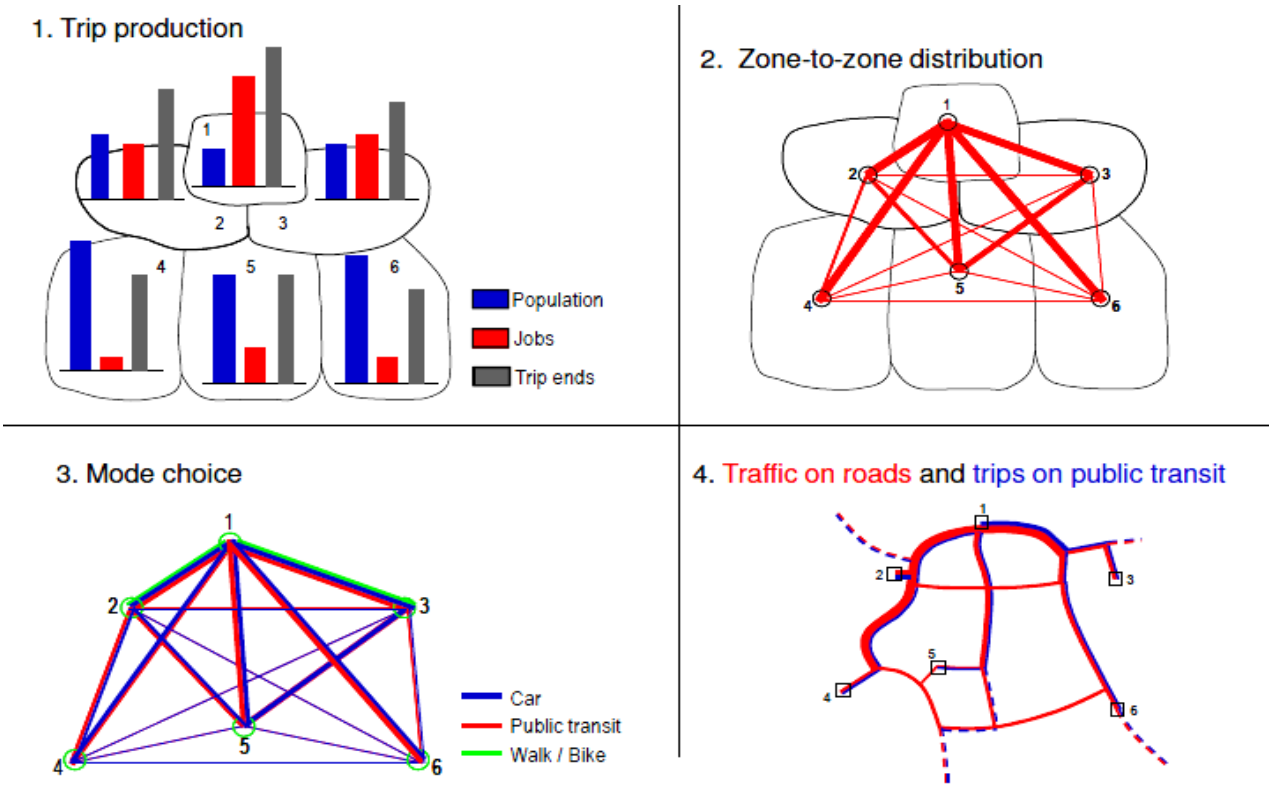


Figure 1.8: FSM in a nutshell

1.4.1 Trip Generation

Trip generation is the process of determining the number of trips that will begin or end in each traffic analysis zone within a study area. Since the trips are determined without regard to destination, they are referred to as *trip ends.* Each trip has two ends, and these are described in terms of trip purpose, or whether the trips are either produced by a traffic zone or attracted to a traffic zone. For example, a home-to-work trip would be considered to have a trip end produced in the home zone and attracted to the work zone.

Trip generation analysis has two functions: (1) to develop a relationship between trip end production or attraction and land use and (2) to use the relationship to estimate the number of trips generated at some future date under a new set of land use conditions.

Trip purpose

It has been found in practice that better trip generation models can be obtained if trips by different purposes are identified and modeled separately. In the case of HB trips, five categories have been usually employed:

- Trips to work;
- Trips to school or colleges (education trips);
- Social trips;
- Recreational trips; and
- Other trips.

The first two trips are usually called compulsory (mandatory) trips and all the others are called discretionary (optional) trips. The latter category encompasses all trips made for less routine purposes, such as health, bureaucracy (need to obtain a passport or a certificate) and trips made as an accompanying person. NHB trips are normally not separated because they only amount to 15 - 20% of all trips.

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

Productions

Attractions

Figure 1.9: Trip production matrix

Factors affecting trip production

- At the HH level, the following are used in several studies
  - ✓ **Income** – the higher the income the higher is the trip generation rate
  - ✓ **Car ownership** – car owning household will generate more trips than a non-car owning household and also the more cars there are in the household, the more the number of trips generated.
  - ✓ Household structure (number of employed persons)
  - ✓ Family size – the bigger the family, the more trips there are likely to be generated.
- At an individual level, the following can be added to the above
  - ✓ age
  - ✓ gender
  - ✓ employments condition

Factors affecting trip attraction

- Roofed space available for industrial, commercial and other services
- Zonal employment, categorized in different groups (especially public attractive and non-public attractive employment)
- Shopping center
- schools, universities
- entertainment (theaters, cinemas, sport arenas etc.)

Growth Factor Modelling

Since the early 1950's several techniques have been proposed to model trip generation. From the range of techniques available to do trip generations include:

- ✓ expansion factors
- ✓ category analysis
- ✓ regression analysis
- ✓ discrete choice models

The common and easiest method of modelling trip generation is expansion factor (growth factor) method. The only problem of this method is the estimation of growth factor, G_i, the rest is trivial.

If we already know trip rates for a given period, they can be adjusted for future periods using an expansion or growth factor

$$\hat{O}_i = O_i \cdot G_i$$

where,

$\hat{O}_i$ is trip origins in the future (design) period

O_i is trip origins in the current period (available)

G_i is the expansion (growth) factor

The expansion factor method has advantages in that it is very simple but:

- ✓ It requires good base year data for all zones and reliable expansion factors
- ✓ It is generally not sensitive to causal or policy changes.

The expansion factor can be a function of population, car ownership, income etc.

$$G_i = \frac{f(P_i^d . I_i^d . C_i^d)}{f(P_i^c . I_i^c . C_i^c)}$$

Where: P – population, I – income and C – car ownership

Index, d = design year and C = current year

Example: The current and future zone population conditions on a route x-y are given as:

- Current condition,
  - 250 household without car
  - 250 household with one car
  - 50 household with two cars
- Future condition

- 600 household with one car

- If the trip production rate are 2.5, 6 and 10 for non-car owner, one car owner and 2 car owners respectively; calculate the growth factor and the future trip (assume a trip rate is constant)

Solution:

- Trip production in Current condition,

  O_i = 250*2.5 + 250*6 + 50*10 = 2625 trips/day

- Growth factor, $G_i = \frac{f(C_i^d)}{f(.C_i^c)}$

  G_i= 600/250 = 2.4

- Future trip, $\hat{O}$ =O_i* 2.4 = 2625*2.4 = 6300 trips/day

1.4.2 Trip Distribution

Trip Generations and attractions provide an idea of level of trip of trip making in the study area whereas Trip Distribution – provide a better idea on the pattern of trip making, from where to where do trips take place.

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 within the study area (internal – internal) or between the study area and areas outside the study area (internal – external).

For example, if the trip generation analysis results in an estimate of 200 HBW trips in zone 10, then the trip distribution analysis would determine how many of these trips would be made between zone 10 and all the other internal zones.

In addition, the trip distribution process considers internal-external trips (or vice versa) where one end of the trip is within the study area and the other end is outside the study area.

Methods

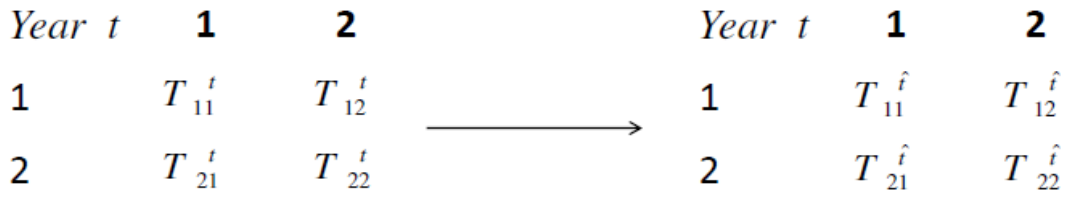
- Two Types of Estimation
  - Updating an existing O-D matrix, i.e. initial Tij's are known, future Oi and Dj may be known as well
    - ✓ sampling fraction to gross up sample surveys
    - ✓ growth factor with singly constrained solution
    - ✓ growth factor with doubly constrained solution (e.g. the Furness method)
    - ✓ using traffic flow count data
  - Creating an O-D matrix from zonal origins or destinations, i.e. Oi and Dj are known but initial Tij's are unknown
    - ✓ gravity model

Expansion factor methods

Trip distribution can be computed when the only data available are the origins and destinations between each zone for the current or base year and the trip generation values for each zone for the future year. Growth factor models are used primarily to distribute trips between zones in the study area and zones in cities external to the study area. Since they rely upon an existing O-D matrix, they cannot be used to forecast traffic between zones where no traffic currently exists. Further, the only measure of travel friction is the amount of current travel. Thus, the growth factor method cannot reflect changes in travel time between zones, as does the gravity model.

- Make use of the patterns that exist in an old matrix for the study area
- Are simple and easy to understand
- Can use a 'Uniform Growth Factor' or different 'Zone Growth Factors'
- Rely very heavily on patterns in the old matrix so not suitable for very long-term planning

- Take no account of changing costs, policies etc. unless reflected by the growth factors
- Suffer from empty cell problem, i.e. if a cell is empty (Tij = 0), growth factor methods cannot do anything to the empty cell



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

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

Example: Given the base year initial matrix below, estimate the forecast year matrix if the total trips would increase to 340.

T_{ij}	x	Y	Z	sum
X	10	23	20	53
Y	30	11	26	67
Z	17	24	9	50
sum	57	58	55	**170**

Gravity models

The most widely used and documented trip distribution model is the *gravity model,* which states that the number of trips between two zones is directly proportional to the number of trip attractions generated by the zone of destination and inversely proportional to a function of time of travel between the two zones.

- most popular method from the so-called synthetic distribution methods which use rules based on observed data for trip distribution
- especially useful when there is no reliable prior matrix

Origins

Newton's Law of Gravity

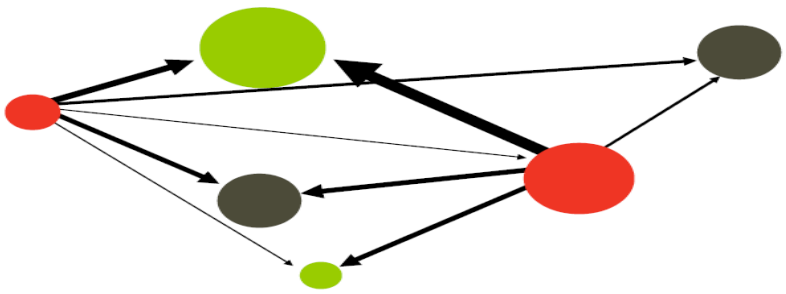
'Any particle of matter in the universe attracts any other with a force varying directly as the product of the masses and inversely as the square of the distance between them': Isaac Newton

$$F = G\frac{m_1 m_2}{r^2}$$



Figure 3.9: Newton's law of gravity

- Production and Attraction



- O-D Matrix, Production and Attraction

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

Productions

Attractions

A mathematical model developed and used to forecast the passenger traffic on the railroad line he was responsible for

$$T_{ij} = \frac{k \cdot P_i \cdot A_j}{d_{ij}^2}$$

- d_{ij} = distance
- P_i, A_j = population around the stations

1.4.3 Mode Choice (Modal Split)

Mode choice is that aspect of the demand analysis process that determines the number (or percentage) of trips between zones that are made by private mode (automobile) and by public transport mode (transit).

The selection of one mode or another is a complex process that depends on factors such as the traveler's income, the availability of transit service or auto ownership, and the relative advantages of each mode in terms of travel time, cost, comfort, convenience, and safety. Mode choice models attempt to replicate the relevant characteristics of the traveler, the transportation system, and the trip itself, such that a realistic estimate of the number of trips by each mode for each zonal pair is obtained.

Mode choice models

- ✓ sometimes developed as a separate (stand-alone) component of the four-stage model
- ✓ sometimes combined with distribution models
- ✓ sometimes defined to estimate main mode split (private versus public) with sub-mode split determined in the public transport assignment

- Mode choice models can be calibrated to disaggregate, semi-aggregate or aggregate data
  - ✓ Disaggregate models (second – generation model) are calibrated are based on observed choices made at the level of the individual traveler.
  - ✓ Semi-aggregate and aggregate models are calibrated to aggregate market share data either based on observed relations for groups of travelers or on average relations at a zonal level.
  - ✓ Disaggregate models are more likely to be estimated for a specific purpose, whereas aggregate models are more likely to use behavioral parameters transferred from elsewhere.

- Disaggregate models have their foundations in discrete choice analysis:
  - ✓ Branch of behavioral studies which use mathematical models to explain, forecast and evaluate decision makers' choices.
- The key features of the methodology are
  - ✓ Focus on the decision-maker
  - ✓ A discrete dependent variable (0-1, yes-no)

Disaggregate methods pros and cons

- **Pros**
  - ✓ Behaviorally oriented analysis of choice
  - ✓ Variation in data/avoids averaging
  - ✓ Segmentation analysis
  - ✓ Analysis of relative values
- **Cons**
  - ✓ May need large samples
  - ✓ Can be correlation/little variation problems
  - ✓ Forecasting problems (data, perceptions, habit)
  - ✓ Can become complex

The decision-maker

- In discrete choice models the unit of observation is the choice make by the decision-maker
- Decision-maker can be
  - ✓ an individual
  - ✓ a household

- ✓ a company or
- ✓ a government

- In the context of mode choice models
  - ✓ it is usually assumed that the decision-maker is the individual
  - ✓ the decision-maker is faced with a choice between available modes (each described in terms of its attributes)

Factors Influencing the Choice of Mode

The factors influencing mode choice may be classified into three groups:

1. Characteristics of the trip maker. The following features are generally believed to be important:
   - car availability and/or ownership;
   - possession of a driving licence;
   - household structure (young couple, couple with children, retired, singles, etc.),
   - income;
   - decisions made elsewhere, for example the need to use a car at work, take children to school, etc;
   - residential density.
2. Characteristics of the journey. Mode choice is strongly influenced by:
   - The trip purpose; for example, the journey to work is normally easier to undertake by public transport than other journeys because of its regularity and the adjustment possible in the long run;
   - Time of the day when the journey is undertaken. Late trips are more difficult to accommodate by public transport.
3. Characteristics of the transport facility. These can be divided into two categories. Firstly, quantitative factors such as:
   - relative travel time: in-vehicle, waiting and walking times by each mode;
   - relative monetary costs (fares, fuel and direct costs);
   - availability and cost of parking.

   Secondly, qualitative factors which are less easy to measure, such as:
   - comfort and convenience;
   - reliability and regularity;
   - protection, security.

Concept of Utility

In general, discrete choice model postulate that:

"The *probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option*."

To represent the attractiveness of the alternatives the *concept of utility* (which is a convenient theoretical construct, tautologically defined as what the individual seeks to

maximize) is used. Utility function measures the degree of satisfaction that people derive from their choices; and disutility function: represents generalized costs of each choice.

Generalized Cost

- $V = a_1T_{iv} + a_2T_{at} + a_3T_{wt} + a_4T_{in} + a_5F + a_6$

- Where:
  V = generalised cost of travel
  T_{iv} = in-vehicle time
  T_{at} = access time
  T_{wt} = waiting time
  T_{in} = interchange time
  F = fare
  a_1 = value of time
  a_2 = the value of access time
  a_3 = value of wait time
  a_4 = value of interchange time
  a_5 = 1
  a_6 = a mode specific constant

Generalized time

- $V = a_1T_{iv} + a_2T_{at} + a_3T_{wt} + a_4T_{in} + a_5F + a_6$

- Where:
  V = generalised time of travel
  T_{iv} = in-vehicle time
  T_{at} = access time
  T_{wt} = waiting time
  T_{in} = interchange time
  F = fare
  a_1 = 1
  a_2 = the value of access time relative to in-vehicle time
  a_3 = value of wait time relative to in-vehicle time
  a_4 = value of interchange time relative to in-vehicle time
  a_5 = value of money, in terms of rail time (1/VOT)
  a_6 = a mode specific constant

The Logit Model

The Logit model is the most commonly used discrete choice model in determining the probability of individual choosing one of different alternatives.

The Logit Model

model form: $$P_i = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

P_i= Probability of an individual choosing alternative i
U_i=Utility function of mode i
N=set of modal alternatives
e = base of natural logarithm

where $U_i = f(X_{i,k})$

$$U_i = a_0 + a_1\{travel\ time\} + a_2\{wait\ time\} + a_3\{cost\}$$

Utility Maximization - Most common decision rule adopted. Assumes that individuals trade-off one attribute against another and that the attractiveness of a choice-alternative can be reduced to a single index known as utility (U)

Utility can be viewed as the negative of generalized cost but it is important to note that it has no 'tangible' scale (i.e. it is not in time or money units)

- **Decision rules – how utility maximization is choices made?**
- If just two alternatives described solely in terms of time (T) and cost (C), and a linear-additive utility function with weights (coefficients) $\alpha_T$and α_C are provided
- α_T or α_C could vary between alternatives or be the same
- Coefficients of U are estimated to generate probabilities in the Logit model that best fit the actual choices in the data on which the model is estimated.

- To account for the variables which cannot be observed or measured, we introduce an error term for each alternative (e_i)

$$U_i = V_i + e_i$$
$$U_i = \alpha_T T_i + \alpha_C C_i + ASC_i + e_i$$

  - V_i is representative or deterministic utility
  - e_i is random utility

- Utility coefficients may be negative/positive
  - ✓ "bad" (e.g. time and cost) have negative coefficients
  - ✓ "good" (e.g. frequency) have positive coefficient

Example on Logit model

Utility functions for auto and transit is given as:

$$U = a_k - 0.35t_1 - 0.08t_2 - 0.005c$$

Where:

- ✓ a_k= mode specific variable (error consideration)
- ✓ t_1 = total travel time (minutes)
- ✓ t_2 = waiting time (minutes)
- ✓ c = cost (cents)

Travel characteristics between two zones:

Variable	Auto	Transit
a_k	-0.46	-0.07
t_1	20	30
t_2	8	6
c	320	100

Determine the probability of selection of auto and transit.

Solution

U_{auto} = -0.46 – 0.35(20) – 0.08(8) – 0.005(320) = **-9.70**

$U_{transit}$ = -0.07 – 0.35(30) – 0.08(6) – 0.005(100) = **-11.55**

Logit Model:

$$p(auto) = \frac{e^{Ua}}{e^{Ua} + e^{Ut}} = \frac{e^{-9.70}}{e^{-9.70} + e^{-11.55}} = \mathbf{0.86}$$

$$p(transit) = \frac{e^{Ut}}{e^{Ua} + e^{Ut}} = \frac{e^{-11.55}}{e^{-9.70} + e^{-11.55}} = \mathbf{0.14}$$

1.4.4 Traffic Assignment

Traffic Assignment is the final step in the traditional four stage model process. Assignment deals with the supply side of transport modeling and the equilibrium between demand and supply.

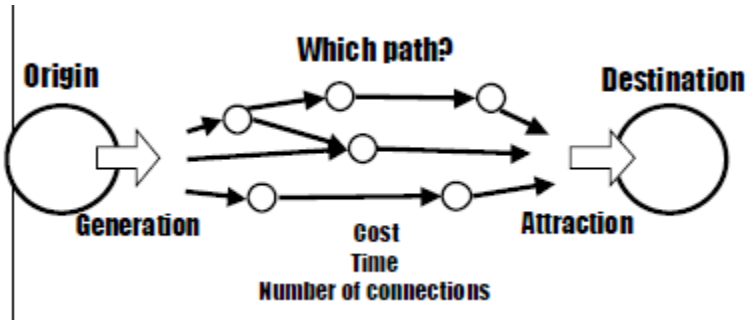
Supply: is made up of network (links) and the costs of travelling on those links

Demand: is indicated by the number of O-D pairs and mode for a given level of service.

- Trip assignment is trip maker's choice of path between origin and destination
  - ✓ Public Transport (PT): passengers' choice of lines (or line sequences) and transfer stops
  - ✓ Auto: drivers' choice of route

Vehicle trips from one zone to another are assigned to specific travel routes between zones. This assignment is done on the basis of minimum generalized cost of travel between each i & j pair of zones. This generalized cost as defined earlier is a linear

combination of the link journey time and the link distance + fixed costs such as parking or tolls.



- The application of traffic assignment may be
  - ✓ strategic multimodal studies
  - ✓ separate highway/PT studies
  - ✓ New routing, new road investments, urban traffic control improvements, etc.

Primary Requirements to model trip assignment to:

- Develop good aggregate network measures
- Estimate zone to zone travel cost for a given level of demand
- Obtain reasonable link flows to identify heavily congested links
- Identify routes used between O-D pairs
- Analyze which O-D pairs use a particular route

To carry out a trip assignment, the following data are required: (1) number of trips that will be made from one zone to another (this information was determined in the trip distribution phase), (2) available highway or transit routes between zones, (3) how long it will take to travel on each route, (4) a decision rule (or algorithm) that explains how motorists or transit users select a route, and (5) external trips that were not considered in the previous trip generation and distribution steps.

Basic Inputs to develop trip assignments are:

- Trip matrix estimating demand
- Person trips will have to be converted to vehicle trips
- Route selection rules

Considerations in route choices are:

- Assume a rational traveler who choose the least cost route
- Factors include journey time, distance, monetary, congestion and queues, type of road, scenery, road works, reliability of travel time and habit
  - ✓ It is difficult to include all of these factors in a generalized cost expression
  - ✓ The most common methods include time and monetary costs – in most programs the user can allocate weights to travel time and distance to try to represent drivers' perceptions of these factors
  - ✓ Time is more important in urban areas.
- Car ownership
- Time of the day: morning peak, afternoon peak and off – peak

Basic Approaches in Trip Assignment

Three basic approaches can be used for traffic assignment purposes: (1) diversion curves, (2) minimum time path (all-or-nothing) assignment, and (3) minimum time path with capacity restraint.

- Each method identifies a set of attractive routes and stores it in a data structure called a tree
- Suitable proportions of the trip matrix are assigned to routes in the tree
- The search for convergence to Wardrops equilibrium is then conducted

All or Nothing Assignment Method

It is also called Shortest Path Method – assumes that travelers want to use the minimum impedance route between two points.

This method is selected because it is commonly used, generally produces accurate results, and adequately demonstrates the basic principles involved. The *minimum time path* method assigns all trips to those links that comprise the shortest time path between the two zones.

The minimum path assignment is based on the theory that a motorist or transit user will select the quickest route between any O-D pair without regard to congestion caused by other vehicles. In other words, the traveler will always select the route that represents minimum travel time. Thus, to determine which route that will be, it is necessary to find the shortest route from the zone of origin to all other destination zones. 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.

Assumptions

- link costs are fixed i.e. no congestion
- all drivers think alike
- every driver from i to j chooses the same route
- all drivers are assigned to that route and none to others

These assumptions are reasonable in sparse and uncongested networks with few alternative routes. In addition, this approach really gives a desire line i.e. what drivers would do if all choices were available to them and if congestion was not an influence.

Example: The following figure represents travel times on the links connecting six zonal centroids. Determine the minimum path from each zone to each other zone using the all-or-nothing trip assignment method.

