Urban Transportation planning Lecture Notes

(Visakha Institute of Engineering & Technology)

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Urban Transportation planning

Unit-1: Urban transportation Problem travel demand: Urban issues, Travel characteristics, Evolution of planning Process, Supply and demand --Systems approach. Travel demand: Trades, Overall planning process, Long term Vs Short term planning, Demand function, Independent Variables, Travel attributes, Assumptions in demand Estimation, Sequential and simultaneous Approaches, Aggregate and Disaggregate Techniques.

Unit-2: Data Collection and Inventories: Collection of data—Organization of surveys and Analysis, Study area, Zoning, Types of source of data, Road side Interviews, Home interview surveys, commercial vehicle surveys, Sampling Techniques, Expansion factors, Accuracy Checks, Use of secondary sources, economic data—Income—Population –Employment—vehicle ownership.

Unit-3: Trip generation and distribution: UTPS approach, Trip generation analysis: Zonal Models, Category Analysis, House hold models, Trip attraction models, Commercial trip rates.

Trip Distribution: Growth Factor Methods, Gravity Models, Opportunity Models, Time Function iteration models. Bypass Trips.

Unit-4: Mode choice and traffic assignment: Mode choice behavior, Competing Modes, Mode split curves, models and probabilistic approaches.

Traffic Assignment: Basic elements of Transport networks, coding, Route properties, path building criteria, skimming tree, All-or-Nothing assignment, capacity Restraint Techniques, Reallocation of assigned volumes, Equilibrium assignment, Diversion Curves.

Unit-5: Plan Preparation and Evaluation: Travel Forecasts to Evaluate Alternative Improvements, Impacts of New Development on Transportation Facilities. Master plans, Selection of corridor, Corridor Identification, Corridor deficiency analysis, Economic Impacts of transportation.

UNIT 1
Urban Transportation Problem Travel Demand:

Urban issues

- No Integration between Land use and Transport while preparing Urban Transport Plan.
- No Quantification of Community Impact for Transport Proposals
- No consideration of issues like Non-motorized Trips, Mobility for Weaker Section and Physically Handicapped,
- Non-consideration of equity issues
- Conventional techniques are used for developing Transport Model

Travel characteristics

(Travel characteristics-i.e. Trip and traveler profile)

There are certain special characteristics of travel demand that require recognition for planning and design purposes, and these are discussed below:

Spatial and Temporal Variations

The total magnitude of travel demand alone is not sufficient for detailed planning and management purposes. The spatial and temporal distributions of travel also are important items of information to be considered in determining supply strategies. The peaking of travel at certain time periods requires a level of transportation supply that is not needed at other times. However, due to the nature of supply which cannot be adjusted easily, large investments have to be made to provide roadway or transit service capacities to accommodate peak period travel, and this capacity is not utilized efficiently at other times. An imbalance in the directional distribution of travel also creates similar inefficiencies.

The spatial orientation of trips has important influence on supply requirements and costs. A few typical spatial distribution patterns of trips in urban areas are listed below:

- Travel along dense corridors, which are usually radial connecting suburbs to central business district (CBD).
- Diffused travel pattern caused by urban sprawl.
- Suburb to suburb or circumferential travel.
- Travel within large activity centers in CBD and suburbs.

Different modes of transportation may be needed to serve these different travel patterns. For example, fixed-route public transit service usually is efficient for concentrated travel along a dense corridor, but it is not ideally suited to serve a diffused travel pattern in a cost-effective manner.
Choice of domicile and work place, lifestyles and different travel needs of individuals and families make the comprehension of trip making characteristics of a large metro area very complex. These complexities may be illustrated through trips made by a typical suburban US household on a given weekday (Figure 1). Assume that this household has four members, including two kids who go to a grade school, and two cars. It can be seen that there are at least 11 trips made by this household at different times of day. Most of the trips are auto trips and

two trips are taken in the “walk” mode. Travel demand modeling attempts to capture such spatial and temporal variations in travel at an aggregate level, such as a zone, in which a number of households, businesses and offices exist.

Classification of Travel by Trip Purpose and Market Segments

In addition to the spatial and temporal characteristics of travel demand, there are several other aspects of travel demand which must be recognized. ‘Trip purposes’ such as work, shopping, and social-recreation; and trip maker’s characteristics such as income and car ownership, are important factors influencing the elasticity of demand reflecting its sensitivity with respect to travel time and cost. For example, ‘work’ trips may be more likely to use public transit for a given level of service than trips of other trip purposes.

For a metropolitan study, it is useful to classify travel according to spatial orientation and trip purpose as shown in Figure 2. The concept of “market segmentation” is applicable to the classification of travel based on trip purpose, trip makers’ characteristics, and spatial-temporal concentration. This concept is used in the field of ‘marketing’ for developing different types of consumer products targeted to match different tastes and preferences of potential users/buyers of these products. The concept of market segmentation is applicable to public transportation planning. A single type of transit service is not suitable for all transit market segments. For example, express buses may be needed for a commuter market segment. Taxicabs serve a different market segment. NCHRP Report 212 by Woodruff, et al. examined this subject in depth.

Evolution of planning Process

The planning process:

- Links transportation goals to the goals of land use, cultural preservation, social, economic, environmental, and quality of life for the area covered by the plan;
- Uses data to examine current transportation operations and identify future transportation needs;
- Helps planners and Tribal governments make well-informed decisions on how to spend money set aside for transportation projects;
- Involves Tribal communities, Federal government agencies, State and local governments, metropolitan and regional planning organizations, special interest groups, and others; and
- Results in workable strategies to achieve transportation investment goals over both the long term (20 years or more) and the short term (three to five years).

Supply and demand -Systems approach

The concept of demand and supply are fundamental to economic theory and is widely applied in the field to transport economics. In the area of travel demand and the associated supply of transport infrastructure, the notions of demand and supply could be applied. However, we must be aware of the fact that the transport demand is a *derived* demand, and not a need in itself. That is, people travel not for the sake of travel, but to practice in activities in different locations

The concept of equilibrium is central to the supply demand analysis. It is a normal practice to plot the supply and demand curve as a function of cost and the intersection is then plotted in the equilibrium point as shown below

The demand for travel T is a function of cost C is easy to conceive. The classical approach defines the supply function as giving the quantity T which would be produced, given a market price C. Since transport demand is a derived demand, and the benefit of transportation after on the nonmonetary terms (time in particular), the supply function takes the form in which C is the unit cost associated with meeting a demand T. Thus, the supply function encapsulates response of the transport system to a given level of demand. In other words, supply function will answer the question what will be the level of service of the system, if the estimated demand is loaded to the system. The most common supply function is the link travel time function which relates the link volume and travel time.

Travel demand:

- 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.
- Forecasts of travel demand are used to establish the vehicular volume on future or modified transportation system alternatives.

Trades Analysis

This approach to demand estimation is based on the extrapolation of past trends.

Travel Demand Forecasting:

Trends and Issues While there are other methods used to estimate travel demand in urban areas, travel demand forecasting and modeling remain important tools in the analysis of transportation plans, projects, and policies. Modeling results are useful to those making transportation decisions (and analysts assisting in the decision-making process) in system and facility design and operations and to those developing transportation policy. NCHRP Report 365 (Martin and McGuckin, 1998) provides a brief history of travel demand forecasting through its publication year of 1998; notably, the evolution of the use of models from the evaluation of long-range plans and major transportation investments to a variety of ongoing, everyday transportation planning analyses. Since the publication of NCHRP Report 365, several areas have experienced rapid advances in travel modeling:

- The four-step modeling process has seen a number of enhancements. These include the more widespread incorporation of time-of-day modeling into what had been a process for modeling entire average weekdays; common use of supplementary model steps, such as vehicle availability models; the inclusion of non-motorized travel in models; and enhancements to procedures for the four main model components (e.g., the use of logic destination choice models for trip distribution).

- Data collection techniques have advanced, particularly in the use of new technology such as global positioning systems (GPS) as well as improvements to procedures for performing household travel and transit rider surveys and traffic counts.
- A new generation of travel demand modeling software has been developed, which not only takes advantage of modern computing environments but also includes, to various degrees, integration with geographic information systems (GIS).
- There has been an increased use of integrated land use transportation models, in contrast to the use of static land use allocation models.
- Tour- and activity-based modeling has been introduced and implemented.
- Increasingly, travel demand models have been more directly integrated with traffic simulation models. Most travel demand modeling software vendors have developed traffic simulation packages.

Estimation of Travel Demand

In urban transportation planning process is to estimate the amount of traffic expected in the future. Future travel is determined by forecasting future land use in terms of the economic activity and population that the land use in each traffic analysis zones (TAZ) will produce.

With the land-use forecasts established in terms of number of jobs, residents, auto ownership, income, and so forth, the traffic that this land use will add to the highway and transit facility can be determined.

This is carried out in a four-step process that includes the determination of

1. The number of trips generation.
2. The origin and destination of trips/trip distribution.
3. The mode of transportation used by each trip /modal split(for example, auto, bus, rail),
4. The route taken by each trip/network assignment.

Overall planning process

- Transportation planning is the process of defining future policies, goals, investments, and designs to prepare for future needs to move people and goods to destinations.

- 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.

- Urban transportation planning involves the evaluation and selection of highway or transportation 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.

- Transportation planning is more than listing highway and transit projects. It requires developing strategies for operating, managing, maintaining, and financing the area's transportation system to achieve the community's long-term transportation goals.

- Urban transportation planning is concerned with two separate time horizons.
  1. The first is a short-term emphasis intended 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 improvement.
  2. The second time horizon 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.

Urban Transportation planning

As listed in the figure presented before, a brief outline related to various steps of planning is presented in the following paragraphs.

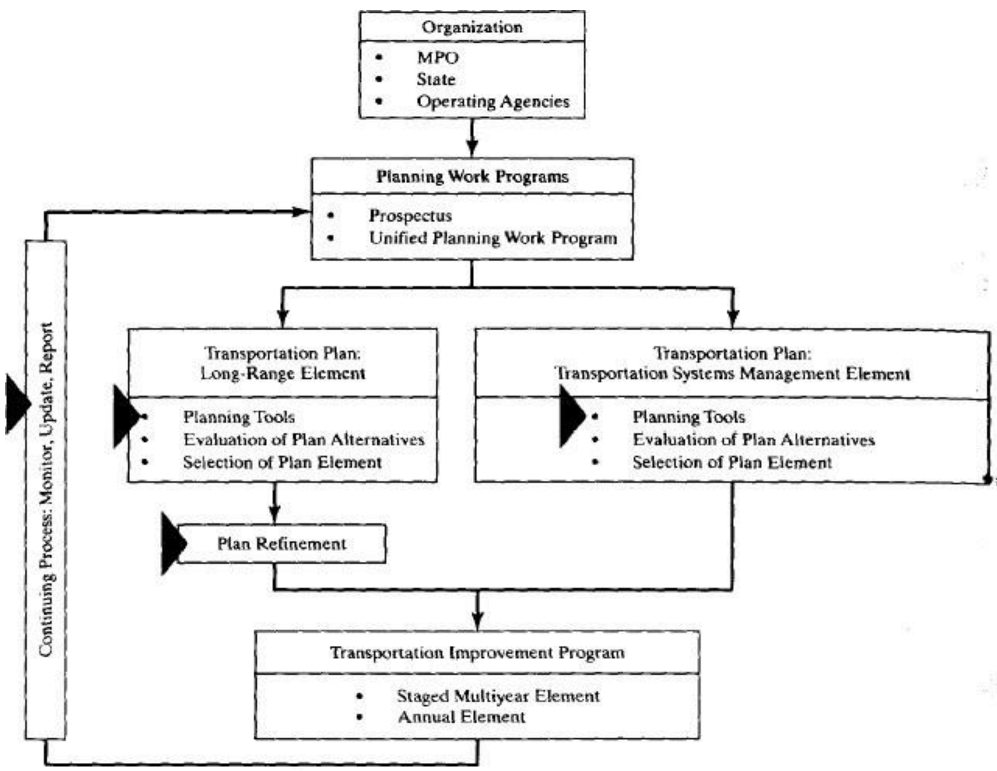


Figure 11-1 Urban Transportation Planning Process (FHWA/UMTA, 1977).

Organization

These are the organizations responsible for the planning and implementation of the plans in different areas.

– State Metropolitan Planning Organizations, like MSRDC, MMRDA, MAHADA, CIDCO etc.
– To look after the planning and making sure to achieve the goals and objectives reflecting current community values.

Prospectus

These organizations should prepare plans that are clear in vision and clearly indicate the responsibilities of different coordinating agencies so that there is no overlap of works and interference.

– Establishes a multiyear framework for the planning process.
– Defines planning procedures, important issues, responsibilities and elements of planning.

Unified planning work progress

– Describe all anticipated urban transportation and transportation-related planning activities
– Documents works to be performed

Transportation plan

The transportation plan includes planning at two levels:
a) Long-range plan
b) Transportation System management Plan

Long Range Element

Includes
– Provision of facilities, major changes in existing facilities and long-range policy actions.
– Identification of Planning tools for analysis of alternatives
– Evaluation of alternatives (Travel Demand Forecasting used as a planning tool for evaluation)
– Decision making for selecting most promising alternatives

Transportation System Management Element

Caters to short range transportation needs and makes the existing system efficient. Basic strategies to increase efficiency are:

– Efficient use of existing road space
– reducing vehicle use in congested areas
– improving transit service
– improving internal management efficiency

Long term Urban Transportation planning

- Long Term Strategy plan which examines the traffic implications of alternative land use options and recommends the best pattern of staging development
- Consider and evaluate different strategies for urban development to determine the optimal urban transport system with maximum benefits to the community at least investment
- To work out a rational balance between residential and work place so that journey to work trip is contained

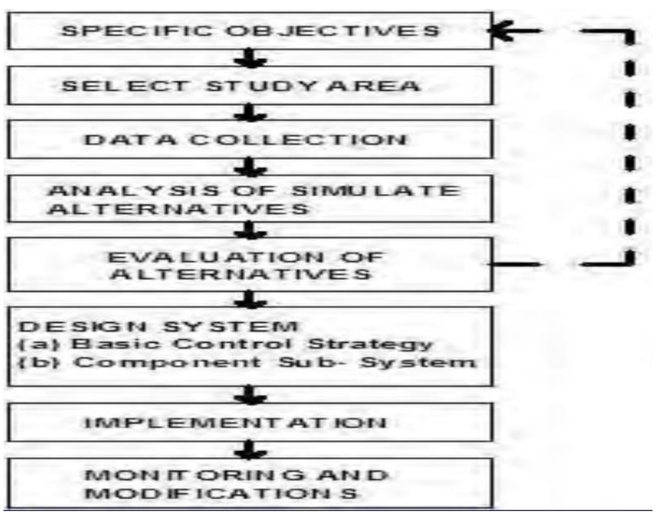
- To work out a financially feasible transport system that is compatible to environment and with preferences to the community where the option of Public Transport can also be examined and developed.

Short term Urban Transportation planning

Design and Implement Transport projects that becomes an integral parts of long term transport plan.

- Improve the existing situation by optimizing the transport system with least cost through development of TSM.
- Control the movement of people and goods on the urban transport network in safe and efficient manner.
- No. of measures adopted for preparation of Short Term Transport Plan
  Traffic Engineering Techniques
  Lorry Routes
  Traffic Restraint
  Parking Control
  Bus Priority
  Public Transport Pricing and Marketing
  Pedestrian Scheme

Steps in short term transportation planning



Demand function

- Necessary understand the where to invest in new facilities and what type of facilities to invest
- Two interrelated elements need to be considered
- Overall regional traffic growth/decline
- Potential traffic diversions
- Travel demand modeling aims to establish the spatial distribution of travel explicitly by means of an appropriate system of zones

Independent Variables

Travel attributes Travel attributes such as time, cost, frequency, and comfort

Value of Travel Attributes

The behavioral values of travel attributes can be calculated by using the estimated parameters shown in Table 2 and procedure described earlier. These values including their upper and lower limits calculated for 95% level of confidence are presented in Table 3. It is found that the average value of travel time savings for the population under study is Tk. 22.17 per hour. For 95% level of confidence, the upper and lower limits of VOT are Tk. 33.18 per hour and Tk. 8.68 per hour respectively. The VOT obtained in this study can be compared with the same obtained in DITS study that ranges between Tk. 3.60 to 17.70 per hour with an average of Tk. 7.02 per hour (DITS, 1993). The difference can be attributed to the characteristics of the population considered in the study. The present study deals with the people who use motorized vehicles for trip making rather than the whole population as dealt with in DITS study. For an average trip, the value of changing load factor by 1% is Tk. 0.365 (Tk. 0.041 per km) and the value of introducing air-condition in the vehicle is Tk. 8.11 (Tk. 0.91 per km).

Table 3. Value of Travel Attributes

Travel Attributes	Behavioural Value	Upper limit	Lower limit
Average Value of Time (Taka/hour)	22.17	33.18	8.68
Average Value of Changing Load Factor by 1% (Taka/km)	0.041	0.048	0.034
Average Value of Introducing Air-condition in the Vehicle (Taka/km)	0.91	1.14	0.72

Assumptions in demand Estimation

- The flow of persons per hour traveling from an origin to a destination ~demand! decreases in relation to increases in travel time and cost of that journey on the road network;
- The routes of travel selected from each origin to each destination have equal travel times and costs, and no unused route has a lower travel time and cost; and
- Route travel times and costs reflect total vehicle flows on the links of the road network, resulting from these origin-destination-route choices.

Sequential Approaches / Modal

The travel demand is modeled in sequential steps of trip generation, trip distribution, modal split and assignment.

Simultaneous Approaches / Modal

–If two or more steps in the sequential approach are combined then it results in a simultaneous model.

– Simultaneous demand models are also called as direct demand models – *Examples*

- Combined modal split and distribution model
- Intercity travel demand model

Aggregate Techniques/Modal

– The demand model that uses summaries of data is an aggregate model

– The traditional four stage urban travel demand model is an aggregate travel demand model as it uses zonal summaries or aggregate data

Disaggregate Techniques/Modal

– The demand model that uses the data on individual decision making unit as it is and explains the behavior of the decision making unit when confronted with alternatives is a disaggregate model

Unit 2
Data Collection and Inventories

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/transportation. Capacity, speed, travel time, and traffic volume are determined. The information gathered is summarized by geographic areas called traffic analysis zones (TAZ).

The size of the TAZ will depend on the nature of the transportation study, and it is important that the number of zones be adequate for the type of problem being investigated. Often, census tracts or census enumeration districts are used as traffic zones because population data are easily available by this geographic designation.

Collection of data

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.

This phase may involve surveys and can be based on previously collected data.

Overview

The four-stage modeling, an important tool for forecasting future demand and performance of a transportation system, was developed for evaluating large-scale infrastructure projects. Therefore, the four-stage modeling is less suitable for the management and control of existing software. Since these models are applied to large systems, they require information about travelers of the area influenced by the system. Here the data requirement is very high, and may take years for the data collection, data analysis, and model development. In addition, meticulous planning and systematic approach are needed for accurate data collection and processing.

There are three important aspects of data collection namely; **Survey design, Household data collection, and data analysis**.

Organization of surveys and Analysis

Survey design

Designing the data collection survey for the transportation projects is not easy. It requires considerable experience, skill, and a sound understanding of the study area. It is also important to know the purpose of the study and details of the modeling approaches, since data requirement is influenced by these. Further, many practical considerations like availability of time and money also has a strong bearing on the survey design.

In this section, we will discuss the basic information required from a data collection, defining the study area, dividing the area into zones, and transport network characteristics.

Information needed

Typical information required from the data collection can be grouped into four categories, enumerated as below.

1. ***Socio-economic data***: Information regarding the socio-economic characteristics of the study area. Important ones include income, vehicle ownership, family size, etc. This information is essential in building trip generation and modal split models.
2. ***Travel surveys***: Origin-destination travel survey at households and traffic data from cordon lines and screen lines (defined later). Former data include the number of trips made by each member of the household, the direction of travel, destination, the cost of the travel, etc. The latter include the traffic flow, speed, and travel time measurements. These data will be used primarily for the calibration of the models, especially the trip distribution models.

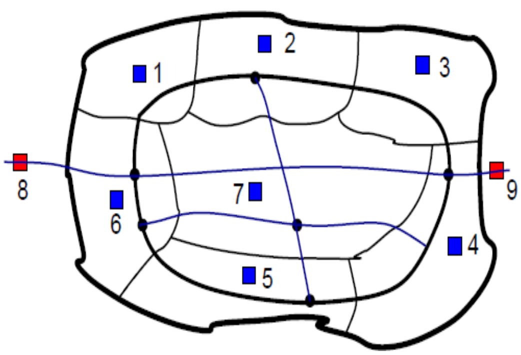


Figure 6:1: zoning of a study area

3. ***Land use inventory***: This includes data on the housing density at residential zones, establishments at commercial and industrial zones. This data is especially useful for trip generation models.
4. ***Network data***: This includes data on the transport network and existing inventories. Transport network data includes road network, traffic signals, junctions etc. The service inventories include data on public and private transport networks. These particulars are useful for the model calibration, especially for the assignment models.

Urban area

1. Population not less than 5,000.
2. Non-agricultural workers not less than 75% of the total workers.
3. Population density not less than 400 per sq. km.

Towns with population of 0.1 million and above are termed as cities.

Transportation Survey

The first stage in the formulation of a transportation plan is to collect data on all factors are Likely to influence travel pattern. The work involves a number of surveys so as to have:

1. An inventory of existing travel pattern.

2. An inventory of existing transports facilities.

3. An inventory of existing land use and economic activities.

Study area

Transportation planning can be at the national level, regional level or at the urban level. For planning at the urban level, the study area should embrace the whole conurbation containing the existing and potential continuously built-up areas of the city.

The imaginary line representing the boundary of the study area is termed as the 'external cordon'. The area inside the external cordon line determines the travel pattern to a large extent and as such is surveyed in great detail.

Selection of External Cordon Line

The selection of the external cordon line for urban transportation planning should be done carefully with due to consideration to the following factors:

1. The external cordon line should circumscribe all areas, which are already built up, and those areas, which are considered likely to be developed during the planning period.
2. The external cordon line should contain all areas of systematic daily life of the people oriented towards the city center and should in effect be the commuter shed.
3. The external cordon line should -be continuous and uniform in its courses so that movements cross it only once. The line should intersect roads where it is safe and convenient for carrying out traffic survey.
4. The external cordon line should be compatible with the previous studies of the areas studies planned for the future.

Zoning

The defined study area is sub-divided into smaller areas called zones or traffic zones.

- The purpose of such a subdivision is to facilitate the spatial quantification of land use and economic factors, which influence travel pattern. Subdivision into zones further helps in geographically associating the origins and destinations of travel.
- Zones within the study area are called internal zones and those outside the study area are called external zones.
- In large study projects, it is convenient to divide the study area into sectors, which are sub divided into zones. Zones can themselves be sub divided into sub- zones depending upon the type of land use.
- A convenient system of coding of the zones will be useful for the study. One such system is to divide the study area into 9 sectors. The central sector CBD is designated 0, and the remaining eight are designated from 1 to 8 in clockwise manner. The prefix 9 is reserved for the external zones. Each sector is subdivided into 10 zones bearing numbers from 0 to 9.

It would be helpful, if the following points are kept in view when dividing the area into Zones:

1. The zones should have a homogenous land use so as to reflect accurately the associated trip making behavior.
2. Anticipated change in land use should be considered when sub- dividing the study area into zones.
3. It would be advantages, if the subdivision follows closely that adopted by other bodies(e.g. census department) for data collection. This will facilitate correlation of data.
4. The zones should not too large to cause considerable errors in data. At the sometime, they should not be too small either to cause difficulty in handling and analyzing the data.As a general guide, a population of 1000-3000 may be the optimum for a small

area, and a population of 5000- 10000 may be the optimum for large urban areas. In residential areas, the zones may accommodate roughly 1000 households.

5. The zones should preferably have regular geometric form for easily determining the centroid, which represent the origin and destination of travel.
6. The sectors should represent the catchment of trips generated on a primary route.
7. Zones should be compatible with screen lines and cordon lines.
8. Zone boundaries should preferably be watersheds of trip making.
9. Natural or physical barriers such as canals, rivers, etc. can form convenient zone boundaries.
10. In addition to the external cordon lines, there may be a number of internal cordon lines arranged as concentric rings to check the accuracy of survey data.

Screen lines

Running through the study area are also established to check the accuracy of data collected from home- interview survey. Screen lines can be convenitally located along physical or natural barriers having a few crossing points. Examples of such barriers are river, railway lines, canals, etc.

Types of Movements

The basic movements for which survey data are required are:

1. Internal to internal.
2. External to internal.
3. Internal to external.
4. External to external.

For large urban areas, the internal to internal travel is heavy whereas for small areas having a small population (say less than 5000) the internal to internal travel is relatively less. Most details of internal to internal travel can be obtained by home interview survey.

The details of internal- external, external internal and external- external travels can be studied by cordon surveys.

Types of source of data

Data Collection:

The data can be collected:

1. At home.
2. During the trip end.
3. At the destination of the trip.

When collected at home, the data can be wide ranging and can over all the trips made during a given period. The data collected during the trip is necessary of limited scope since the procedure yields data only on the particular trip intercepted.

At the destination end, the direct interview types of surveys provide data on demand for parking facilities and or the trip ends at major traffic attraction centers such as factories, offices and commercial establishments.

The following are the surveys that are usually carried out:

1. Home- interview survey.
2. Commercial vehicles surveys.

3. Intermediate public transport surveys.
4. Public transport surveys.
5. Road –side – interview surveys.
6. Post- card- questioner surveys.
7. Registration- number surveys.
8. Tag- on- vehicle surveys.

The information to be collected from home-interview survey can be broadly classified in two Groups:

1. Household information.
2. Journey or trip data.

The household information needs to contain data with regard to:

a- Size of household.
b- Age of all the numbers of the households.
c- Sex.
d- Structure of households.
e- Employee.
f- Occupation.
g- Place of work.
h- No. of vehicles owned.
i- Household income.

Journey data will contain information all trips made during the previous 24hr. with regard to:

a. Origin and destination of trip.
b. Purpose of trip.
c. Modes of travel.
d. Time at start of trip.
e. Time at finish of trip.

Inventory of Transport Facilities

The inventory of existing transport facilities should be undertaken to identify the deficiencies in the present system and the extent to which they need to be improved. The inventory consists of:

- Inventory of streets forming the transport network. Link width length, no. of lanes. Nodes complete geometric of intersection.
- Traffic volume composition peak and off peak.
- Studies on travel time by different modes.
- Inventory of public transport buses.
- Inventory of rail transport facilities.
- Parking inventory
- Accident data.

Inventory of Land Use and economic Activities

1. Inventory of Land Use Since travel characteristics are closely related to the land use pattern, it is of utmost important that an accurate inventory of land-use be prepared. Data on intensity of usage of land for different purposes, such as residential, industrial,

commercial, recreational, open space, etc. in each of the traffic zones are to be collected from concerned departments/ organization.

2. Inventory of Economic Activities Aggregate data on demographic and socioeconomic activities should be collected other sources to include the following:
   - Population of the planning area and various zones.
   - Age, sex, and composition of the family.
   - Employment statistics.
   - Housing statistics.
   - Income.
   - Vehicle ownership.

Road side Interviews

These provide trips not registered in a household survey, especially external-internal trips. This involves asking questions to a sample of drivers and passengers of vehicles crossing a particular location. Unlike household survey, the respondent will be asked with few questions like origin, destination, and trip purpose. Other information like age, sex, and income can also be added, but it should be noted that at road-side, drivers will not be willing to spend much time for survey.

Home interview surveys

Home-interview survey is one of the most reliable type of surveys for collection of origin and destination data. The survey is essentially intended to yield data on the travel pattern of the residents of the household and the general characteristics of the household influencing trip making. The information on the travel pattern includes number of trips made, their origin and destination, purpose of trip, travel mode, time of departure from origin and time of arrival at destination and so on. The information on household characteristics includes type of dwelling unit, number of residents, age, sex, race, vehicle ownership, number of drivers, family income and so on. Based on these data it is possible to relate the amount of travel to household and zonal characteristics and develop equations for trip generation rates.

It is impractical and unnecessary to interview all the residents of the study area. Since travel patterns tend to be uniform in a particular zone. The size of the sample is usually determined on the basis of the population of the study area. And the standards given by the Bureau of Public Roads as shown in below table.

Table 9.1 Standards for Sampling Size for Home-interview survey

Population of Study Area	Sample Size
Under 50,000	1 in 5 households
50,000 – 150, 000	1 in 8 households
150,000 – 300,000	1 in 10 households
300,000 – 500,000	1 in 15 households
500,000 – 1,000,000	1 in 20 households
Over 1,000,000	1 in 25 households

Standard Practice now is instead to calculate the sample size which will achieve the desired precision for key indicators at the required level of confidence. One such equation is given by Traffic Appraisal manual.

$$n = p(1-p)N^3/[(E/1.96)^2(N-1)+p(1-p)N^2]$$

n = required number of households in an area of interest E =
accuracy level

P =Proportion of households in the area with attributes of interest.

The usual procedure is for an interviewer to call on a household on a scheduled data and to leave a copy of the home interview questionnaire. This questionnaire is broadly divided into :

a) General household characteristics – number of residents, vehicles owned, income, dwelling type.

b) Characteristics about family members – occupation, sex, age.

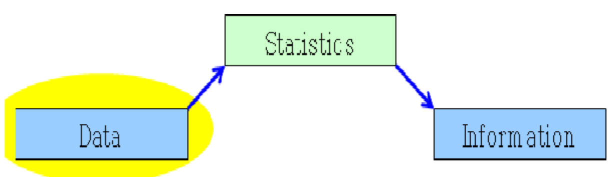
c) Individual travel information – trip origin and destination, purpose, land – use, travel time and transport mode.

Commercial vehicle surveys

A similarly styled survey of non-residential land uses could be designed to collect information on goods movements, but transport resources are rarely allocated to such an ambitious project. Instead, urban freight flows are usually measured indirectly from commercial vehicle survey.
Commercial vehicle surveys are conducted to obtain information on journeys made by all commercial vehicles based within the study area. The addresses of the vehicle operators are obtained and they are contacted. Forms are issued to drivers with a request that they record the particulars of all the trips they would make.

Sampling Techniques

Statistics is a tool for converting *data* into *information*:



- But where then does *data* come from? How is it gathered? How do we ensure its accurate? Is the data reliable? Is it representative of the population from which it was drawn? This chapter explores some of these issues.

Sampling Plans…

We will focus our attention on these three methods:

- Simple Random Sampling,
- Stratified Random Sampling, and
- Cluster Sampling

Simple Random Sampling…

A **simple random sample** is a sample selected in such a way that every possible sample of the same size is equally likely to be chosen.

Drawing three names from a hat containing all the names of the students in the class is an example of a simple random sample: any group of three names is as equally likely as picking any other group of three names.

- Random sample of 100 cokes bottles today at the coke plant.
- Random sample of 50 pine trees in a 1000 acre forest.
- Random sample of 5 deer in a national forest.

Stratified Random Sampling…

- A stratified random sample is obtained by separating the population into mutually exclusive sets, or strata, and then drawing simple random samples from each stratum.

Cluster Sampling…

- A cluster sample is a simple random sample of groups or clusters of elements (vs. a simple random sample of individual objects).
- This method is useful when it is difficult or costly to develop a complete list of the population members or when the population elements are widely dispersed geographically. Used more in the "old days".
- Cluster sampling may increase sampling error due to similarities among cluster members.

Sampling Errors..

Two major types of error can arise when a sample of observations is taken from a population:

- Sampling error refers to differences between the sample and the population that exist only because of the observations that happened to be selected for the sample. Random and we have no control over.

Non-Sampling Errors…

Non-sampling errors are more serious and are due to mistakes made in the acquisition of data or due to the sample observations being selected improperly. Most likely caused be poor planning, sloppy work, act of the Goddess of Statistics, etc.

1) Errors in data acquisition,
2) Non response errors and Selection bias.

Expansion factors

Sample expansion the second step in the data preparation is to amplify the survey data in order to represent the total population of the zone. This is done with the help of expansion factor which is defined as the ratio of the total number of household addressed in the population to that of the surveyed. A simple expansion factor Fi for the zone i could be of the following form.

$$F_i = \frac{a}{b-d}$$

where a is the total number of household in the original population list, b is the total number of addresses selected as the original sample, and d is the number of samples where no response was obtained.

Accuracy Checks

SURVEY DATA CHECKS: The data collected for transportation planning by any survey can be check out by following methods:

Accuracy Check

- Data accuracy is the foundation dimension of data quality.

- Accuracy
- Timeliness
- Relevance
- Completeness
- Understood by users
- Trusted by users etc.

Screen Line Checks

- Traffic counts taken at selected screen lines are useful for comparing model generated travel pattern with actual volumes of traffic crossing screen line and making adjustments.
- This check is useful for calibration and validation of model
- Check is carried out data collected by home interview survey
- It is line separating study area.

Consistency check

- Data constitutes summarizes the validity, accuracy, usability and integrity of related data applications.
- This confirming the data reliability.

Cordon line checks

- Cordon line is the boundary of study area
- The data collected from internal to external, external to internal and external to external
- Cordon line points can be use to compare the trips calculated and observed.
- This check is very useful for data adjustment for study area

Use of secondary sources

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. These are allocated to the study area, and then the totals are distributed to each zone. This process can be accomplished by using either a ratio technique or small-area land-use allocation models.

The population and economic data usually will be furnished by the agencies responsible for planning and economic development, whereas providing travel and transportation data is the responsibility of the traffic engineer. For this reason, the data required to describe travel characteristics and the transportation system are described as follows.

The transportation facility inventories provide the basis for establishing the networks that will be studied to determine present and future traffic flows. Data needs can include the following items:

• Public streets and highways

—Rights of way

—Roadway and shoulder widths

—Locations of curbed sections

—Locations of structures such as bridges, overpasses, underpasses, and major culverts

—Overhead structure clearances

—Railroad crossings

—Location of critical curves or grades

—Identification of routes by governmental unit having maintenance jurisdiction

—Functional classification

—Street lighting

• Land use and zoning controls

• Traffic generators

—Schools

—Parks

—Stadiums

—Shopping centers

—Office complexes

• Laws, ordinances, and regulations

• Traffic control devices

—Traffic signs

—Signals

—Pavement markings

• Transit system

—Routes by street

—Locations and lengths of stops and bus layover spaces

—Location of off-street terminals

—Change of mode facilities

• Parking facilities

• Traffic volumes

• Travel times

• Intersection and roadway capacities

In many instances, the data will already have been collected and are available in the files of city, county, or state offices. In other instances, some data may be more essential than others. A careful evaluation of the data needs should be undertaken prior to the study.

—Income—–Employment—vehicle ownership.

Socio-economic data: Information regarding the socio-economic characteristics of the study area. Important ones include income, vehicle ownership, family size, etc. This information is essential in building trip generation and modal split models.

Household characteristics This section includes a set of questions designed to obtain socioeconomic information about the household. Relevant questions are:number of members in the house, no.of employed people, number of unemployed people, age and sex of the members in the house etc., number of two-wheelers in the house, number of cycles, number of cars in the house etc., house ownership and family income.

Unit 3

Trip generation and distribution:

UTPS approach

The first phase of the transportation planning process deals with surveys, data collection and inventory. The next phase is the analysis of the data so collected and building models to describe the mathematical relationship that can be discerned in the trip-making behaviour. The analysis and model building phase starts with the step commonly known as Trip Generation.

Trip Generation:

Trip generation is a general term used in the transportation planning process to calculate the number of trip ends in a given area. The objective of the trip generation stage is to understand the reasons behind the trip making behaviour and to produce mathematical relationships to synthesize the trip-making pattern on the basis of observed trips, land-use data, transportation system characteristics, trip maker characteristics and household characteristics.

Trip Types:

Trips can be defined based on the nature of movement between the zones and across the cordon lines. They are also categorized based on the location of trip ends. Categorizations in use are:

- Intra-zonal trips
- Inter-zonal trips
- Through trips
- Home-based trips
- Non-home based trips

Intra-zonal, Inter-zonal and through trips are already defined while discussing transportation surveys. The first activity in travel-demand forecasting is to identify the various trip types important to a particular transport-planning study. The trip types studied in a particular area depend on the types of transport-planning issues to be resolved. The first level of trip classification used normally is a broad grouping into home-based and non-home-based trips.

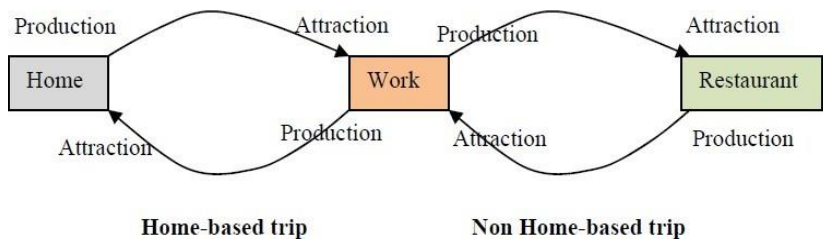
Home- based trips: Home-based trips are those trips having one end of the trip (either origin or destination) at the home of the persons making the trip.

Non-home-based trips: Non-home based trips are those trips having neither end at the home of the person making the trip. The trip ends are classified into productions and attractions.

Trip Production: A production is the home end of any trip that has one end at the home (i.e. of a homebase trip), or is the origin of a trip with neither end home based (i.e. of a non – home based trip).

Trip attraction models

: An attraction is the non-home end of a home-based trip, and is the destination of a trip with neither end home-based (i.e. of a non-home-based trip).



This points towards one aspect related to trips generated, i.e. the total number of trips produced in any area should be equal to the total number of trips attracted in that area. If trips produced are Pi in zone 'i' and trips attracted are Aj towards zone 'j', then

$$\sum_{i=1}^{N} P_i = \sum_{j=1}^{M} A_j \text{ and}$$

$$\text{Total number of trips} = T_{ij} = \sum_{i=1}^{N} P_i + \sum_{j=1}^{M} A_j$$

Trip purpose:

Trips are made with different purposes and a classification of trips by purpose is necessary. Trip classifications that have been used in the major transport-planning studies for home based trips are:

- Work
- Education
- Social
- Recreational and sports
- Shopping
- Others

Trip Mode:

Trip mode is the type of vehicle used by a person for traveling between an origin and destination.

Trip Time:

Trip time is the time taken while moving between a set of origin and destination.

Trip Length:

Trip length is the distance traveled between a set of origin and destination.

Factors influencing trip production

Households may be characterized in many ways, but a large number of trip-production studies have shown that the following variables are the most important characteristics with respect to the major trip types such as work and shopping trips:

1. The number of workers in a household, and
2. The household income or some proxy of income, such as the number of cars per household.

Various factors that create an effect on the production of the trips are discussed below:

Population and its characteristics: The size of the population in an area obviously has an effect on the total number of trips supposed to be produced from that area. This further can be looked at in terms of:

a. **Number of households in an area**: More are the households more will be the trips.
b. **Size and composition of the household**: Bigger is the size of the household, it is possible that more trips will be produced by that household. The composition defines the members of a household involved in different activities that necessitates travel. This may be related to work, education, shopping, recreation, etc and thus produces different types of trips from a single household.
c. **Population density**: This is one factor that is discussed in detail with respect to the use of different modes or travel. In general, if the density is more, more will be the trips from that area.

Household Income: Disposable household income will define the possibility of trip making by the members of a household.

Factors influencing attraction rates

1. Land use activities: Land use activities in an area define the type of the trips that will be attracted towards that area. If the area is homogeneous in nature then the trips made to that area will be of same nature but heterogeneous activities will attract different types of trips.

2. Employment opportunities: The employment potentiality of any area is defined by the type of activity undertaken in that area. The industrial, shopping unit or an office establishment directly governs the trip attraction rate.

3. Floor area allotted for the activities: Another factor to which the trip attraction rate can be related is the floor space in the premises of industries, shops and offices. This will allow the estimation of different trips which can be made to an area.

Factors affecting trip making patterns

1. Study Area characteristics: Certain characteristics of the study area affect the trip making pattern in that area. These characteristics are discussed below.

***a.* Location of an activity:** The distance of the activity zone from the household is an important determinant of the amount of travel that people might like to do if needed. The further the activity centre, the less the number of trips are likely to be to that activity.

***b.* Accessibility of an activity:** Accessibility to an activity is governed by the type of network facilities available in that area and the affordability of those facilities to the masses.

Commercial trip rates **Bypass Trips**

Trip generation analysis

Methods of trip generation

There are three main methods of generating trips from the study area. They are:

- Expansion factor method
- Least square regression analysis method
- Category analysis method

Expansion factor method

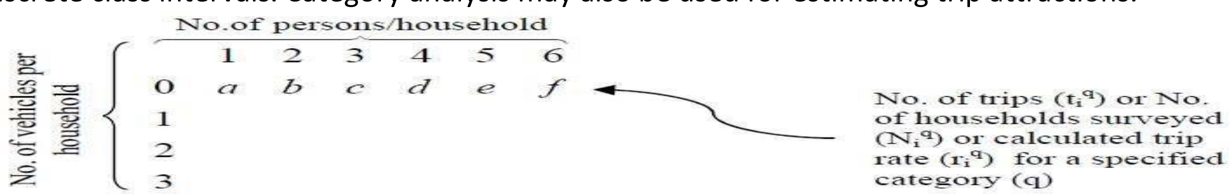
The expansion factor method uses past growth rates as a means of predicting future trips from the estimated present trips. Such correlations can be developed with:

- Growth of traffic
- Rise in population
- Agricultural and industrial production
- Total mileage of roads
- Fuel consumption estimates
- Per capita income
- National GDP, etc.

Due to fast changing scenario and the complexities involved in the estimation of future values, the use of this method is confined to short term forecasting in small urban or rural areas.

Category Analysis

Category Analysis or cross-classification technique is simply a technique for estimation of the trip production characteristics of households which have been sorted in a number of separate categories according to a set of properties that characterize the household. The method was developed by Wotton and Pick and has been used in some transportation studies in U.K. A multidimensional matrix defines the categories, each dimension in the matrix representing one independent variable. The independent variables themselves are classified into a definite number of discrete class intervals. Category analysis may also be used for estimating trip attractions.



Assumptions

The technique is based on the following assumptions:

(i) The household is the fundamental unit in the trip generation process, and most journeys begin or end in response to the requirements of the family.

(ii) The trips generated by the household depend upon the characteristics of that household and its location relative to its required facilities or activities.

(iii) Households with one set of characteristics generate different rates of trips from households with other set of characteristics.
(iv) Trip generation rates are stable over a time so long as factors external to the household are the same as when the trips were first measured.

Trip attraction

- Trip attraction rates can be made by analyzing the urban activities that attract trips.
- Trips are attracted to various locations, depending on the character of, location, and amount of activities taking place in a zone.
- Three tools are used for this end too, but obviously types of independent variables used are different.

Zonal Models

A Sample Zonal Attraction Model

The sample model estimate relative attractiveness by regressing factored values of sample trips (aggregated to the zone level) on relevant zonal characteristics. The choice of explanatory variables is constrained in a manner similar to trip productions models - model significance, policy sensitivity, and forecastability. These models are summarized in Box 1.

Box 1. Sample Estimated Zonal Trip Attraction Models

Example of Estimated Trip Attraction Models	
Zonal HBW Attractions =	1.45 * Total Employment
Zonal HBO Attractions =	9.00 * Retail Employment + 1.70 * Service Employment + 0.50 * Other Employment + 0.90 * Number of Households
Zonal NHB Attractions =	4.10 * Retail Employment + 1.20 * Service Employment + 0.50 * Other Employment + 0.50 * Number of Households
Source: Martin and McGuckin (1998), Table 8, pg. 28.	

Zonal Based Trip Generation Models

Zonal Based Models use zonal averages to estimate trip making.
One problem with this approach is that zonal averages may be deceptive depending on the distribution of a given parameter.
For example, two zones with the same average income could have very different income distribution and presumable different travel performances.
These models are referred to as **AGGREGATE** Models

House hold models

Household Based Trip Generation Models

Household Based Models use the household as the unit for estimating trip making.
The underlying assumption of household based models is the assumption that household with the same characteristics (for example, same number of adults and cars, and same income) tend to have the same travel tendencies

As we have discussed, this assumption might or might not be true depending on the characteristic of the land use in which the household is located

Based on this assumption average trip making is determined for each household category These models are called **DISAGGREGATE** Models

A Sample Household Trip Production Model

A category model was estimated for household trips by purpose from the trip data and demographic characteristics of the 200 sample households. Category variables are selected based on ability to significantly discriminate trip rates between categories, general policy sensitivity, and the availability of future data. Category models are less restrictive than regression models but require that the joint distribution of population variables be forecast. A variety of methods have been used with iterative proportional fitting perhaps the most direct. The role of activity system forecasts is clear, as is the need for quality forecasts of automobile ownership since this variable is typically most highly correlated with total trips per household. The resulting estimated trip rates are displayed in Table 4 (to simplify presentation, rates from Martin and McGuckin (1998) are utilized). Aggregation proceeds directly since the model is linear. Once the joint distribution of households is known for the base or forecast year, the cell counts are multiplied by the estimated trip rates to obtain the total number of trips per zone.

Trip Rate Analysis

Trip rate is estimated on characteristics of the trip generators with in the zone. Production rates are determined using the characteristics of the residential land uses and attraction rates using the characteristics of the nonresidential land uses

Trip Distribution

Introduction

Once estimate of the trips generated, i.e. produced from and attracted to the various zones, are made the next step is to determine the direction of travel of these trips. The number of trips produced in any zone of the study area has to be apportioned to the zones to which these trips are attracted. Say, there are pi trips produced from zone i by trip maker's category 'q' and aj is the number of trip ends attracted to zone j, then the number of trips between zone 'i' and zone 'j' (i.e. tq

i-j) would be estimated using trip distribution technique. This can be represented in a matrix form as given below:

$$\text{Productions (origin zones)} \overset{\text{Attractions (Destination zones)}}{\begin{bmatrix} & 1 & 2 & 3 & \cdots & n & \sum p_i \\ 1 & t_{11} & t_{12} & t_{13} & \cdots & t_{1n} & p_1 \\ 2 & t_{21} & t_{22} & t_{23} & & t_{2n} & p_2 \\ & & | & & \ddots & & | \\ & t_{n1} & t_{n2} & t_{n3} & \cdots & t_{nn} & p_n \\ \sum^{n} a_j & a_1 & a_2 & a_3 & \cdots & a_n & \end{bmatrix}}$$

The horizontal axis of the trip matrix shown represents the zones of attractions (i.e. destinations) and the vertical axis represents the zones of production (i.e. origin) numbered from 1 to n. The total of any individual row, i, represents the total number of trips produced in zone i (pi) and the total of any individual column, j, represents the number of trips attracted to zone j (aj). Therefore,

$$p_i^q = \Sigma_j t_{ij}^q$$

$$a_j^q = \Sigma_i t_{ij}^q$$

Based on the future land uses in the zones and the area, the future trips going to be produced or attracted from or to any zone are computed. These may be denoted as Pi and Aj respectively.

Methods of trip distribution

There are two categories of trip distribution methods, namely,

(i) Growth factor methods

(ii) Synthetic methods

Growth factor methods have been used in earlier studies and have yielded now to the more rational synthetic models. Both of these categories are further divided as follows:

Growth factor methods:

(i) Uniform factor method
(ii) Average factor method
(iii) Detroit Method
(iv) Fratar method
(v) Furness method
(vi) Time function iteration method

Synthetic methods:

(i) Gravity Model
(ii) Tanner Model
(iii) Intervening opportunities model
(iv) Competing opportunities model

Growth Factor Methods The growth factor methods are based on the assumption that the present travel patterns can be projected to the design year in the future by using expansion factors. This can be represented by the

general formula as given below:

Ti-j = ti-j x F

Where, Ti-j = number of trips from zone I to zone j in design year (future) ti-j = number of trips from zone I to zone j in observed base year F = growth factor

Uniform growth factor method

This is the oldest of the growth factor methods and considers the growth rate for the whole area. A single growth factor, F, for the entire study area is calculated by dividing the future estimated number of trip ends for the design year by the trip ends in the base year. The future trips between zone i and j, Ti-j, are then calculated by applying the uniform growth factor F to the base year trips between zones i and j, as,

Ti-j = ti-j x F

Let us take one example: An O-D trip matrix for three zones in an area is given below. The future trips produced and attracted from or towards these zones are 360, 1260 and 3120 respectively. It is required to distribute the future trips among these zones.

O \ D	1	2	3
1	60	100	200
2	100	20	300
3	200	300	20

Iteration-1:

O \ D	1	2	3	p_i	P_i
1	60	100	200	360	360
2	100	20	300	420	1260
3	200	300	20	520	3120
a_j	360	420	520	1300	
A_j	360	1260	3120		4740

Uniform growth factor F= 4740/1300 = 3.646

Multiplying the cells in the matrix by the uniform growth factor, the following matrix results:

O \ D	1	2	3	p_i^1	P_i^1
1	218	365	729	1312	360
2	365	73	1094	1532	1260
3	729	1094	73	1896	3120
a_j^1	1312	1532	1896	4740	
A_j^1	360	1260	3120		4740

Uniform growth factor (New) = 4740/4740 = 1.0 STOP

It can be noted that all the trips have been distributed among the zones. As the new growth factor is equal to 1.0, the iteration can be stopped here. But the total number of trips generated from each zone, as calculated, do not tally with the known future trip values for those zones. This is because of the assumption of a uniform growth rate for all the zones. The method, therefore, suffers from the following

disadvantages:

(i) The assumption of a uniform growth rate for the entire study is not correct, because each zone will have its own growth rate and the rate of growth of traffic movement between any two zones will be different.

(ii) The method under-estimates movements where present day development is limited and over-estimates movements where present day development is intensive.

(iii) If the present trip movement between any two zones is zero, the future trip movement also becomes zero as per this method. This may rarely be the case in reality.

Average growth factor method

In this method, an average growth factor between the two zones related to two trip ends is calculated based on the growth factors of the zones at both the ends of the trip. This factor thus represents theaverage growth associated both with the origin and the destination zones. The trip values in the given matrix are then multiplied with the computed growth factor values between the origin and destination

$$T_{i-j} = t_{i-j}\ x\left[\frac{F_j + F_i}{2}\right]$$

Where, T_{i-j} = future trips from zone i to zone j

ti-j= present trips from zone i to zone j

Fi = Pi/pi = growth factor related to trips produced from zone i Fj

= Aj/aj = growth factor for trips attracted to zone j

If after the iteration the trips produced or attracted (calculated) agrees with the trips produced or attracted (for future) for each zone, the process is stopped. But if it is not so, then new growth factors for each zone are computed and a new iteration is started. The process continues till the zonal growth factors come out to be either 1.0 or very near to 1.0.

Example: Let us take the previous example.

O \ D	1	2	3	p_i	P_i	$F_i=P_i/p_i$
1	60	100	200	360	360	1
2	100	20	300	420	1260	3
3	200	300	20	520	3120	6
a_j	360	420	520	1300		
A_j	360	1260	3120		4740	
$F_j = A_j/a_j$	1	3	6			

Computing trips between pairs of zones using formula given above:

$$T_{1-1} = \frac{1+1}{2} x\, 60 = 60$$

$$T_{1-2} = \frac{1+3}{2} x\, 100 = 200$$

$$T_{1-3} = \frac{1+6}{2} x\, 200 = 700$$

$$T_{2-1} = \frac{3+1}{2} x\, 100 = 200$$

$$T_{2-2} = \frac{3+3}{2} x\, 20 = 60$$

$$T_{2-3} = \frac{3+6}{2} x\, 300 = 1350$$

$$T_{3-1} = \frac{6+1}{2} x\, 200 = 700$$

$$T_{3-2} = \frac{6+3}{2} x\, 300 = 1350$$

$$T_{3-3} = \frac{6+6}{2} x\, 20 = 120$$

The new O-D trip matrix then becomes:

O \ D	1	2	3	p_i^1	P_i^1	$F_i^1=P_i^1/p_i^1$
1	60	200	700	960	360	0.375
2	200	60	1350	1610	1260	0.783
3	700	1350	120	2170	3120	1.438
a_j^1	960	1610	2170	4740		
A_j^1	360	1260	3120		4740	
$F_j^1 = A_j^1/a_j^1$	0.375	0.783	1.438			

As the growth factors of zones are not either 1.0 or near to 1.0, the next interaction starts till the desired accuracy is reached.

The average factor method has the same disadvantages of the uniform factor method. The multiplying factor has no real significance and is only a convenient tool to balance the movements. There is no explanation of the movement between zones and the factors causing the movement. It has the additional disadvantage that a large number of iterations are required. As in the case of the uniform factor method, if ti-j is zero, Ti-j also becomes zero. Because of these drawbacks the method is rarely used except for updating existing table and for quick results.

Detroit method

This method is the further improvement on average factor method and takes into account the growth factor for zones and average growth factor for the entire study area. The trips are computed as:

$$T_{i-j} = t_{i-j} \times \frac{F_i \times F_j}{F}$$

Where, $F_i = P_i / p_i$

$F_j = A_j / a_j$

$F = (P + A)/(p + a)$

Let us look at an example:

D / O	1	2	3	p_i	P_i	$F_i = P_i/p_i$
1	60	100	200	360	360	1
2	100	20	300	420	1260	3
3	200	300	20	520	3120	6
a_j	360	420	520	1300		
A_j	360	1260	3120		4740	
$F_j = A_j/a_j$	1	3	6			

Iteration-1:

$$T_{1-1} = 60 \times \frac{1 \times 1}{3.646} = 16$$

$$T_{1-2} = 100 \times \frac{1 \times 3}{3.646} = 82$$

$$T_{1-3} = 200 \times \frac{1 \times 6}{3.646} = 329$$

$$T_{2-2} = 20 \times \frac{3 \times 3}{3.646} = 494$$

$$T_{2-3} = 300 \times \frac{3 \times 6}{3.646} = 1481$$

$$T_{3-3} = 20 \times \frac{6 \times 6}{3.646} = 197$$

The trips for zone connectivity 2-1, 3-1 and 3-2 will remain same as the reverse flow. The new O-D trip matrix would be as given below:

D / O	1	2	3	p_i	P_i	$F_i=P_i/p_i$
1	16	82	329	427	360	0.84
2	82	494	1481	2057	1260	0.61
3	329	1481	197	2007	3120	1.55
a_j	427	2057	2007	4491		
A_j	360	1260	3120		4740	
$F_j = A_j/a_j$	0.84	0.61	1.55			

New growth factor for the whole study area F1 = 4740/4491 = 1.055

As the growth factors of zones are not either 1.0 or near to 1.0, the next interaction starts till the desired accuracy is reached.

Fratar method

According to this method, the total trips for each zone are distributed to the inter-zonal movements, as a first approximation, according to the relative attractiveness of each movement. This relative attractiveness is considered in the form of Locational factor (L). The trips distributed can be computed as follows:

$$T_{i-j} = t_{i-j} \times F_i \times F_j \times \left(\frac{L_i + L_j}{2} \right)$$

Where Fi =growth factor for zone 'i' Fj
=growth factor for zone 'j'

Li = Location factor for zone 'i' =

Lj = Location factor for zone j =

Now let us take another example to illustrate the actual procedure.

D / O	A	B	C	D	p_i	P_i	F_i
A	-	10	12	18	40	80	2.0
B	10	-	14	14	38	114	3.0
C	12	14	-	6	32	48	1.5
D	18	14	6	-	38	38	1.0
a_j	40	38	32	38	148		
A_j	80	114	48	38		280	
F_j	2.0	3.0	1.5	1.0			

Iteration-1:

$$L_A = \frac{40}{10\times3+12\times1.5+18\times1} = \frac{40}{66} = 0.606$$

$$L_B = \frac{38}{10\times2+14\times1.5+14\times1} = \frac{38}{55} = 0.690$$

$$L_C = \frac{32}{12\times2+14\times3+6\times1} = \frac{32}{72} = 0.444$$

$$L_D = \frac{38}{18\times2+14\times3+6\times1.5} = \frac{38}{87} = 0.437$$

$$T_{A-B} = 10\times2\times3\times\left[\frac{0.606+0.690}{2}\right] = 39$$

$$T_{A-C} = 12\times2\times1.5\times\left[\frac{0.606+0.444}{2}\right] = 19$$

$$T_{A-D} = 18\times2\times1\times\left[\frac{0.606+0.437}{2}\right] = 19$$

$$T_{B-C} = 14\times3\times1.5\times\left[\frac{0.690+0.444}{2}\right] = 36$$

$$T_{B-D} = 14\times3\times1.0\times\left[\frac{0.690+0.437}{2}\right] = 24$$

$$T_{C-D} = 6\times1.5\times1.0\times\left[\frac{0.444+.437}{2}\right] = 4$$

Now the new O-D trip matrix would be:

O \ D	A	B	C	D	p_i	P_i	F_i
A	-	39	19	19	77	80	1.04
B	39	-	36	24	99	114	1.15
C	19	36	-	4	59	48	0.81
D	19	24	4	-	47	38	0.808
a_j	77	99	59	47	282		
A_j	80	114	48	38		280	
F_j	2.0	3.0	1.5	1.0			

The process is repeated to obtain a second iteration using values of new growth factors and inter-zonal movements obtained from the first iteration till the growth factors for different production and attraction zones become equal to or nearly equal to 1.0.

The procedure is laborious except for simple problems, but can be conveniently tackled by a computer. It has the same drawbacks as observed in other growth factor methods. It is unable to forecast trips for those areas which were predominantly under-developed during the base year. It does not take into account the effect of changes in accessibility for various zones of the study area.

Furness method

The method requires the estimates of future traffic originating and terminating at each zone, thus yielding origin growth factor and destination growth factors for each zone. The traffic movements are made to agree alternately with the future traffic originating in each zone and the estimated future traffic terminating in each zone, until both these conditions are roughly satisfied. Thus,

$$T^1_{i-j} = t_{i-j} \times F^b_i$$

$$T^2_{i-j} = T^1_{i-j} \times F^1_j$$

$$T^3_{i-j} = T^2_{i-j} \times F^2_i$$

The following example would illustrate the method:

O \ D	1	2	3	4	p_i	P_i	F_i
1	8	3	16	15	42	147	3.5
2	6	9	8	5	28	42	1.5
3	10	8	3	8	29	32	1.1
4	2	4	7	12	25	30	1.2
a_j	26	24	34	40	124		
A_j	39	24	68	120		251	
F_j	1.5	1.0	2.0	3.0			

Iteration-1:

Scale down the O-D trip matrix using origin growth factors.

O \ D	1	2	3	4	p_i	P_i	F_i
1	28	11	56	52	147	147	1.00
2	9	13	12	8	42	42	1.00
3	11	9	3	9	32	32	1.00
4	2	5	8	15	30	30	1.00
a_j	50	38	79	84	251		
A_j	39	24	68	120		251	
F_j	0.78	0.63	0.86	1.43			

Time Function iteration models

This method assumes that the trip distance is influenced by the journey time and row and column totals are nothing but trip ends. The method starts with converting the given O-D trip matrix into a unity matrix and finding the growth factors for different production zones for the given future trips produced from these zones. The procedure after this remains the same as that of Furness method. Final trip matrix is then converted into travel time index matrix, which provides the effect of travel time between the zones. The method can be understood from the example taken below.

Example: The trip frequency observed in actual for the given O-D trip matrix is as below:

Travel time	Percent Trips	Travel time	Percent Trips
7 – 8	0	1 – 2	15
4 – 5	30	0 – 1	40
2 – 3	15		

O \ D	1	2	3	4	p_i	P_i
1	-	25	50	25	100	300
2	25	-	150	75	250	1000
3	50	150	-	200	400	800
4	25	75	200	-	300	300
a_j	100	250	400	300	1050	
A_j	300	1000	800	300		2400

Iteration-1: Unity matrix

O \ D	1	2	3	4	p_i	P_i	F_i
1	-	1	1	1	3	300	100
2	1	-	1	1	3	1000	333
3	1	1	-	1	3	800	267
4	1	1	1	-	3	300	100
a_j	3	3	3	3	12		
A_j	300	1000	800	300		2400	

Iteration-2 Scale trip matrix using production growth factors

O \ D	1	2	3	4	p_i	P_i	F_i
1	-	100	100	100	300	300	1.00
2	334	-	333	333	1000	1000	1.00
3	266	267	-	267	800	800	1.00
4	100	100	100	-	300	300	1.00
a_j	700	467	533	700	2400		
A_j	300	1000	800	300		2400	
F_j	0.43	2.14	1.50	0.43			

Iteration-3: Scale trip O-D matrix using attraction growth factors.

The procedure will continue till equilibrium is achieved. Now, the final O-D trip matrix is used to compute the travel time index matrix. This can be computed as follows:

Cell value of travel time index matrix = ti-j from original matrix / Ti-j from final matrix

Say, the travel time index matrix is:

D / O	1	2	3	4
1	-	1/7.36	1/1.84	1/1.08
2	1/7.2	-	1/4.12	1/2.44
3	1/1.84	1/4.21	-	2.2/1
4	1/1.12	1/2.45	2.22/1	-

The values obtained as such can be termed as friction factor or deterrent factor. This can be represented as:

Friction factor = *f* (1/Travel time)

This can help in identifying settlement pattern.

Trips computed for different travel times are as follows:

Travel time	Percent Trips	Travel time	Percent Trips
7 – 8	4.76	1 – 2	14.28
4 – 5	28.57	0 – 1	38.09
2 – 3	14.28		

The trip frequency data, observed and calculated, is presented as a frequency polygon. If the two data sets do not match then new O-D adjustment factors are calculated and further these are used to compute the final origin and destination trip values.

Gravity Models

The gravity model gets its name from the fact that it is conceptually based on Newton's law of gravitation. Accordingly it is heuristically derived for synthesizing trip interchanges. It states that the trip interchange between zone 'i' and zone 'j' is directly proportional to the product of the population of the two zones and is inversely proportional to a function of spatial separation of zones under consideration.

This can be represented by the relationship given as below:

$$T_{i-j} \propto P_i$$
$$\propto P_j$$
$$\propto \frac{1}{f(d_{i-j})}$$
$$T_{i-j} = K \frac{P_i P_j}{f(d_{ij})}$$

Where Ti-j = Trip interchanges between zones 'I' and 'j' Pi
= Population in zone 'i'

Pj = Population in zone 'j'

f(di-j) = Travel time factor function or friction factor, in terms of travel distance, travel time, travel cost, etc. This may take different functional forms. One such form is (di-j)α K =
A constant, usually independent of 'i' and 'j'

α = An exponential constant, whose value is usually found to lie between 1 and 3

This is known as unconstrained Gravity model. It shows following shortcomings:

a. If population is doubled, the trips produced will quadruple.

b. No constraint is taken in the analysis.

c. Aggregation of zone is considered but characteristics of the zone are not considered.
Modification was made to the above unconstrained Gravity Model by introducing the employment opportunities of the destination zone to make it synonymous with trip attractions. So the modified unconstrained Gravity Model is represented as:

$$T_{i-j} = K \frac{P_i A_j}{(d_{ij})^{\alpha}}$$

$$\text{Where } K = \frac{\sum_i p_i}{\sum_j \sum_i t_{i-j}} \text{ or } = \frac{\sum_j a_j}{\sum_i \sum_j t_{i-j}}$$

Further, the constrained gravity models were proposed so as to take into consideration the effect of production or attraction zones. Accordingly, these were termed as Production constrained Gravity model or attraction constrained gravity model. The formulation is given below:

Production Constrained Gravity Model:

$$t_{i-j} = A_i \times \frac{P_i P_j}{(d_{i-j})^{\alpha}}$$

$$\text{Where } A_i = \frac{1}{\sum_j p_j (d_{i-j})^{\alpha}}$$

Attraction Constrained Gravity Model:

$$t_{i-j} = B_j \times \frac{A_j A_i}{(d_{i-j})^{\alpha}}$$

$$\text{Where } B_j = \frac{1}{\sum_i a_i (d_{i-j})^{\alpha}}$$

Production – Attraction Constrained Gravity Model:

$$t_{i-j} = \frac{A_i B_j p_i a_j}{(d_{i-j})^{\alpha}}$$

$$\text{Where } p_i = \sum_j t_{i-j}; \quad a_j = \sum_i t_{i-j}$$

$$A_i = \frac{1}{\sum_j B_j a_j (d_{i-j})^{-\alpha}}; \qquad B_j = \frac{1}{\sum_i A_i p_i (d_{i-j})^{-\alpha}}$$

Calibration Process:

1. Assume values for B_j and α, say $B_j = 1.0$ and α = 2. Now calculate A_i.
2. Calculate B_j for calculated A_i values and α.
3. Re-iterate till the new A_i and B_j values are very near to the A_i and B_j values of previous iteration.
4. Use final values of A_i and B_j with value of α to compute $T_{i,p}$ and $T_{j,a}$.
5. Form an O-D trip matrix.

Limitation:

The limitation of procedure described is it requires that two criteria be satisfied by a base year calibration. These two criteria are: agreement between observed and simulated trip length constraint equation .A principal difficulty wit this calibration procedure is that the travel time factor function and associated trip length frequency distribution are assumed to be constant for each zone of a study area.

Opportunity Models

Opportunity model are based on the statistical theory of probability as the theoretical foundation. The concept has been pioneered by Schneider and developed by subsequent studies. The two well known models are:

(i) The intervening opportunities models ;
(ii) The competing opportunities model.

Intervening opportunities model

The basic hypothesis of the intervening opportunity model can be represented by the general formula as given below;

$$t_{ij} = k\frac{a_j}{v_j}$$

Where ti-j= predicted number of trips between zone i and zone j
aj = total number of trip attractions at the destination zone j
vj = Number of intervening opportunities met upto the destination zone j k = constant

It states that the number of trips from an origin zone to a destination zone is directly proportional to the number of opportunities at the destination zone and inversely proportional to the number of intervening opportunities. This is also known as ‘Stouffer Model’.

Schneider Modification

Modified hypothesis states that the probability that a trip will terminate in some destination point is equal to the product of the probability that the destination met is acceptable and the probability that an acceptable destination closer to the origin has not been found. This can be formulated for a small destination zone ‘dv’ as:

Pr(dv) = [1 – Pr(v)] . l. dv

Where Pr(dv) = probability that a trip will terminate when dv destination opportunities are considered

Pr(v) = Cumulative probability that a trip will terminate by the time ‘v’ possible destinations are considered

v = Cumulative total of the destinations already considered

l = a constant probability of a destination being accepted it is considered The integration of this will yield the following:

Pr(v) = [1 – ki . exp(-l.v)]

Where ki = a constant for zone ‘i’, which ensures that all the trips produced at zone ‘i’ are distributed

In the intervening opportunities model, it is assumed that the trip interchange between an origin and a destination zone is equal to the total trips emanating from the origin zone multiplied by the probability that each trip will find an acceptable terminal at the destination. It is further assumed that the probability that a destination will be acceptable is determined by two zonal characteristics, namely the size of the destination zone and the order in which it is encountered as trips proceed from the origin. The probability function in above may then be expressed as the difference between the probability that the trip origins at i will find a suitable terminal in one of the destinations, ordered by closeness to i, up to and including j, and the probability that they will find a suitable terminal in the destinations up to but excluding j. The following equation represents mathematically this concept as:

$$Pr_{(i-j)} = Pr(v + v_j) - Pr(v)$$

$$Pr_{(i-j)} = [1 - e^{-(v + v_j) . l}] - [1 - e^{-v . l}]$$

$$= [e^{-v . l} - e^{-(v + v_j) . l}]$$

The above expression is the probability as defined in the stochastic relationship T = P . B.

Therefore,

$$b_{ij} = [e^{-v . l} - e^{-(v + v_j) . l}]$$

Hence, the number of trips between different zones can be computed as:

$$T_{i-j} = P_i . [e^{-v . l} - e^{-(v + v_j) . l}]$$

The following example illustrates the application of the above method.

Unit 4
Mode choice and traffic assignment:

Mode choice

The choice of transport mode is probably one of the most important classic models in transport planning. This is because of the key role played by public transport in policy making. Public transport modes make use of road space more efficiently than private transport. Also they have more social benefits like if more people begin to use public transport, there will be less congestion on the roads and the accidents will be less. Again in public transport, we can travel with low cost. In addition, the fuel is used more efficiently. Main characteristics of public transport is that they will have some particular schedule, frequency etc.

On the other hand, private transport is highly flexible. It provides more comfortable and convenient travel. It has better accessibility also. The issue of mode choice, therefore, is probably the single most important element in transport planning and policy making. It affects the general efficiency with which we can travel in urban areas. It is important then to develop and use models which are sensitive to those travel attributes that influence individual choices of mode.

Mode choice behavior

Mode choice is a key aspect of travel demand modeling. The choice of travel mode is a complicated behavioral process and as such is a core focus in Travel Behavior

Factors influencing the choice of mode

The factors may be listed under three groups:

1. **Characteristics of the trip maker** : The following features are found to be important:
(a) car availability and/or ownership;
(b) possession of a driving license;
(c) household structure (young couple, couple with children, retired people etc.);
(d) income;
(e) decisions made elsewhere, for example the need to use a car at work, take children to school, etc;
(f) residential density.

2. **Characteristics of the journey**: Mode choice is strongly inuenced by:
(a) 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;
(b) Time of the day when the journey is undertaken.
(c) Late trips are more di_cult to accommodate by public transport.

3. **Characteristics of the transport facility**: There are two types of factors.One is quantitative and the other is qualitative. Quantitative factors are:
(a) relative travel time: in-vehicle, waiting and walking times by each mode;

(b) relative monetary costs (fares, fuel and direct costs);
(c) availability and cost of parking
Qualitative factors which are less easy to measure are:
(a) comfort and convenience
(b) reliability and regularity
(c) protection, security
A good mode choice should include the most important of these factors.

Types of modal split models

Trip-end modal split models

Traditionally, the objective of transportation planning was to forecast the growth in demand for car trips so that investment could be planned to meet the demand. When personal characteristics were thought to be the most important determinants of mode choice, attempts were made to apply modal-split models immediately after trip generation. Such a model is called trip-end modal split model. In this way different characteristics of the person could be preserved and used to estimate modal split. The modal split models of this time related the choice of mode only to features like income, residential density and car ownership.
The advantage is that these models could be very accurate in the short run, if public transport is available and there is little congestion. Limitation is that they are insensitive to policy decisions example: Improving public transport, restricting parking etc. would have no effect on modal split according to these trip-end models.

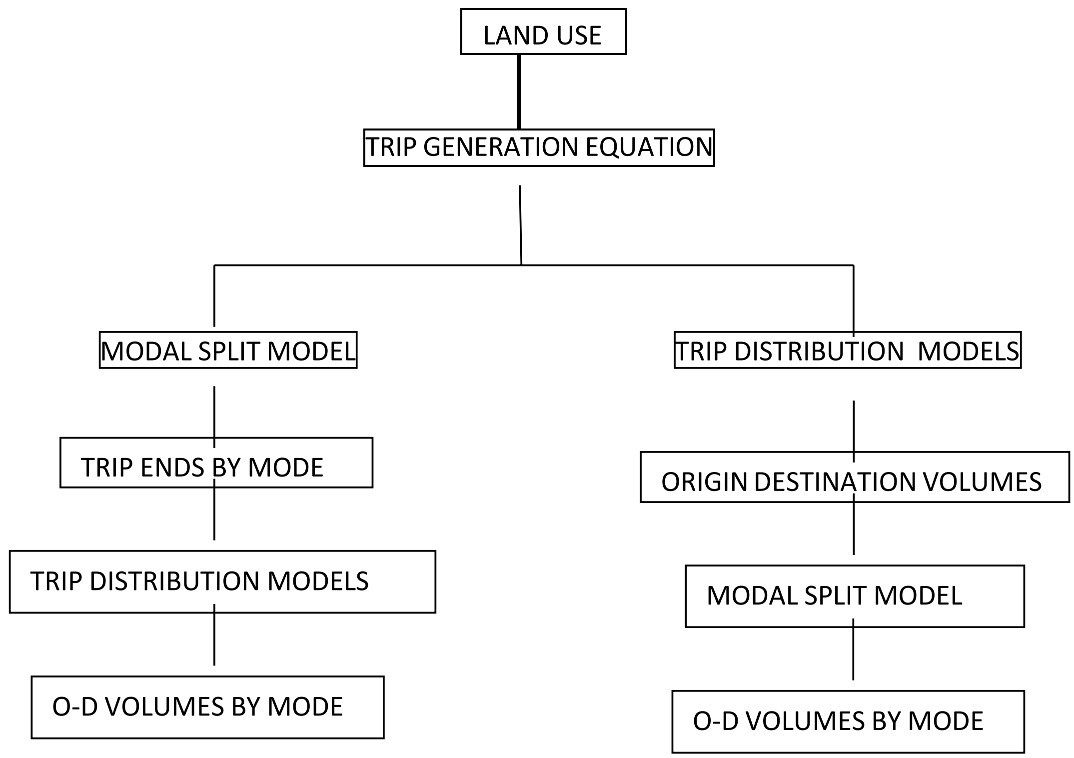
Trip-interchange modal split models

This is the post-distribution model; that is modal split is applied after the distribution stage. This has the advantage that it is possible to include the characteristics of the journey and that of the alternative modes available to undertake them. It is also possible to include policy decisions. This is beneficial for long term modeling.

Aggregate and disaggregate models

Mode choice could be aggregate if they are based on zonal and inter-zonal information. They can be called disaggregate if they are based on household or individual data.

Trip End Modal Split Model	Trip Interchange Modal Split Model
Performs modal split after trip generation	Performs modal split after trip distribution
Performed in medium and small sized cities	Performed for large urban areas
Assumes that modal patronage is relatively insensitive to the service characteristics of transport modes	Incorporates measures of relative service characteristics of competing modes
Determined based on socio-economic characteristics of trip maker	Determined based on socio-economic characteristics of trip maker
Emphasize on transit captives	Emphasize on choice transit riders
E.g. Southeastern Wisconsin Transportation Study	E.g. Toronto Model



Trip Assignment

Purpose of traffic assignment

The last phase of the four-step sequential transportation demand forecasting process is concerned with the trip maker's choice of path between pairs of zones by a travel mode. This results in vehicular flows on the multimodal transportation network. This step may be viewed as the equilibrium model between the demand for travel, estimated earlier in the process, and the supply of transportation in terms of the physical facilities. In the case of the various possible mass transit modes, it includes the frequency of service being provided. Incidentally, this conceptual framework of economic theory is applicable to earlier steps of the process as well and has been so treated by many researchers.

Traffic assignment is the stage in the transport planning process wherein the trip interchanges are allocated to different parts of the network forming the transportation system. In this stage:

- The route to be traveled is determined and
- The inter-zonal flows are assigned to the selected routes.
- The traffic assignment to the network has following applications:
- To determine the deficiencies in the existing transportation system by assigning the future trips to the existing system.
- To evaluate the effects of limited improvements and additions to the existing transportation system by assigning estimated future trips to the improved network.
- To develop construction priorities by assigning estimated future trips for intermediate years to the transportation system proposed for those years.

- To test alternative transportation system proposals by systematic and readily repeatable procedures.
- To provide design hour traffic volumes on highway and turning movements at junctions.Thus the assignment process is useful both to the transports planners and the highway facility designers, to the former because of the need to evaluate how the proposed transport system will work, and to the latter, for geometric design of individual links and intersections.

The advent the modern digital computers has facilitated the growth of assignment techniques, which involve computations too laborious for manual handling.

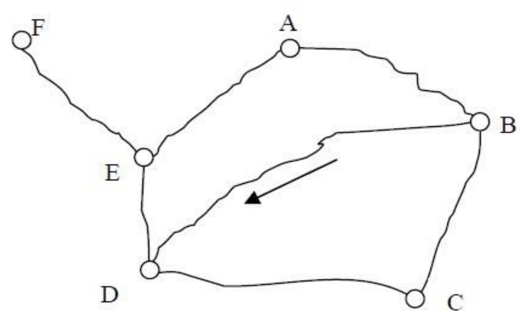
Transportation Networks

Transportation Network primarily consists of two elements:

- Links
- Nodes

Link is defined as connectivity between two nodes. The links may have traffic movements either in both the directions or in one direction only. Sometimes the links on which direction of travel is marked are also known as an Arc.

The nodes are the location in space which provides an opportunity to the vehicle to enter or leave a system or facilitate the movements in different directions. The node from which an arc is diverted is termed it's A-node and the node to which it is diverted is termed its B-node. A representative map of the network system is shown in the figure below.



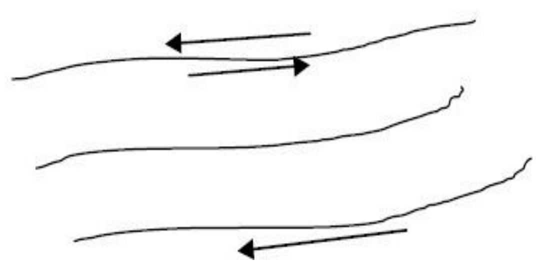
Links can be classified in two ways based on the direction of movement of traffic on that link. These are:

- Bidirectional / Undirected
- Unidirectional / Directed

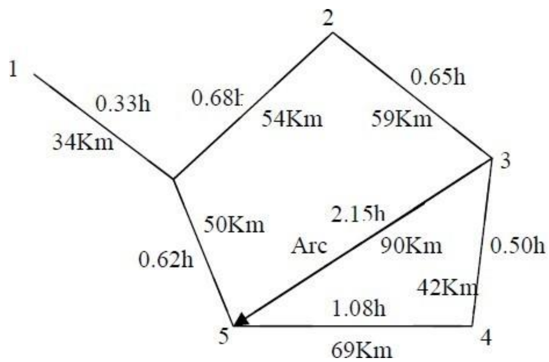
Generally, undirected link is assumed to have traffic moving in both the directions.

Representation of links in a network System:

- Bidirectional
- Undirected
- Unidirectional



The above network is represented in the form of links and nodes showing the direction of movement of the traffic along the links along with the travel attribute value written on the side of the link. The travel attribute values may be in terms of travel time, travel cost, travel distance, etc. usually numbers are used to specify the nodes in the network from the point of view of computational ease. One such network is represented in the figure below.



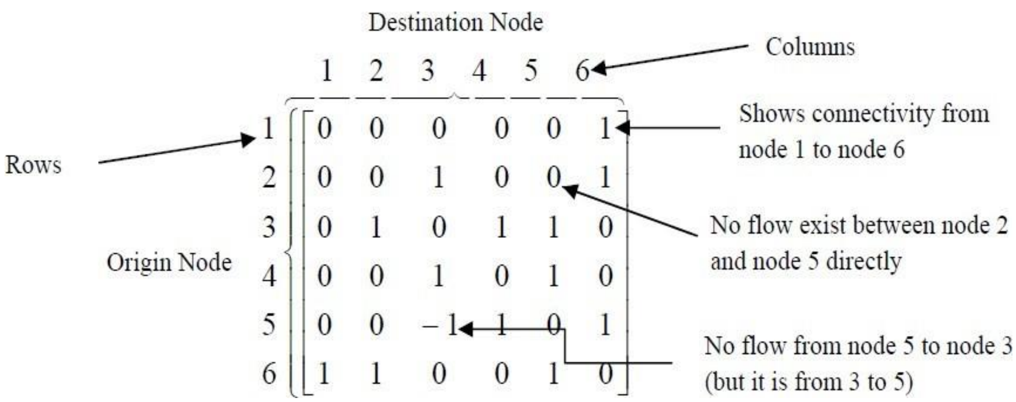
Network Representation:

Mostly, two types of matrices are used to represent a network for computational work and making computer programmes related to them. These are:

- Connection Matrix
- Node-Arc / Node-Link Incidence Matrix

Connection Matrix:

A connection matrix defines the connectivity between different nodes available in a transportation network. This helps in building a network in a systematic way. It has rows and columns. Rows define the originating nodes and columns define the destination nodes. The numbers 0, 1 and -1 denotes no flow along the link, flow along the link and reverse direction flow along the link, respectively. A connection matrix is shown in the figure below.



Node-Link Incidence Matrix

Node-link incidence matrix defines the connectivity from a node to different nodes of the network. This also uses numbers to represent the connectivity as done in the connection matrix. This is shown in the figure below.

Network Assignment Methods

The network assignment methods are basically single-path methods, which allocate trips on one preferred path between each origin and destination pair. This technique is executed based on three steps, in combination of what is listed initially as requirement. These are:

- A driver route selection criteria
- A tree building technique
- Method of allocating trip interchanges between these routes

Driver route-selection Criteria

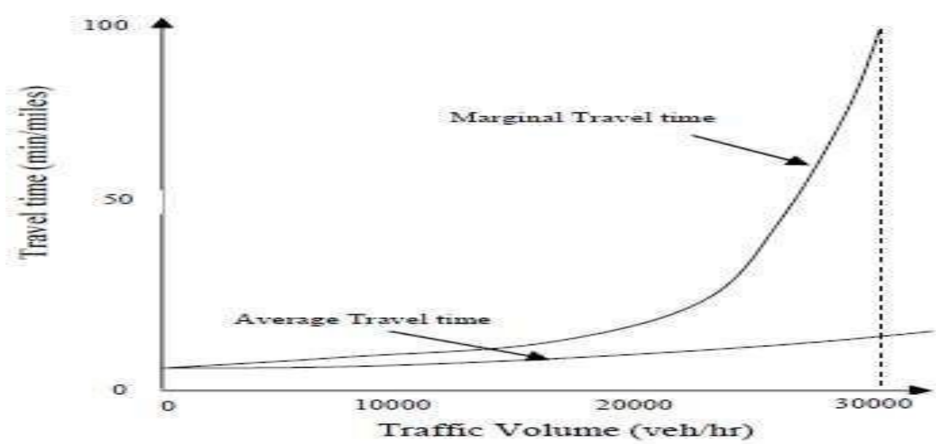
Driver's route-selection is based on Wardrop's principles. Wardrop has given two principles, as follows:

System Optimization criteria:

'The trip times on all the routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route'.

The system optimization is based on 'marginal cost concept' of economics.

Let us consider a link carrying traffic volume in vehicle/hr. As the traffic volume increases the travel time on the link also increases. This increase per unit volume becomes more after certain volume on the link. In terms of marginal travel time, the increase becomes exponential after certain value of traffic volume. As can be seen from the figure, the increase in average travel time per mile with increase in traffic volume from nil to 3000 veh/hr is from 5 min/mile to 15 min/mile, whereas, the increase in marginal travel time is from 5 min/mile to 105 min/mile during the same change in volume. It indicates that the entry of one vehicle at a flow of 3000 veh/hr increases the travel time effect by 90 min/mile (=105 – 15 min/mile).



User Optimization criteria:

'The average journey time of all motorists is a minimum which implies that the aggregate vehicle hours spent in traveling is a minimum.'

This criterion indicates towards the 'average cost concept' of economics. It means that every user tries to minimize the individual travel time. Therefore, the user will base their route choice decision on the average travel time relationship and will select the route according to the marginal travel time criteria. Reacting to marginal travel time criteria will minimize the total travel time of all the vehicles using the system.

Route Builiding Algorithm

Next step after finalization and coding of network is the computation of minimum travel path between the zones. This is already discussed in one of the previous lectures. Some of the techniques or algorithms used for finding the minimum travel path tree are:

1. Network analysis
2. Moore's tree building algorithm
3. Shortreed and Wilson's Modified tree-building algorithm
4. Dijkstra's algorithm
5. D'Esopo's algorithm

Route Builiding Algorithm:

Moore's Algorithm

For each origin centroid, a label is assigned to each node in the network of the following form:
Node 'j' label = [i, d(j)]
Where,
i = the node nearest to zone 'j' which is on the travel time path back to the origin
d(j) = the minimum travel time from node 'j' back to the origin centroid
Initially, each node is assigned a d(j) magnitude which is very large, say, 999, with the exception of the origin node where it is set to '0'. As the tree is built out from the origin, the following sum is formed for each node
Node: Node 'j' sum = [d(i) + l(i,j)]
Where,
d(i) = travel time from the origin to node 'i' which has just been connected to the origin
l(i.j) = travel time along the link which connects node 'j' to node 'i'
If the sum just formed is greater than the d(j) already recorded for node 'j', then the node is by-paased. If the sum is less than the d(j) existing, then the d(j) is replaced by the newly formed sum and 'i' is changed in the label to reflect the new connecting link for j back to the origin.
This process is continued until all nodes have been reached.

Shortreed and wilson's Method

(Moore's modified method / computationally efficient method)
The improved efficiency results from the manner in which the node labels are stored and updated. This algorithm uses three concepts which are known as the tree table, the link table and the list.

Tree Table: It shows the sequence of node that defines the minimum path from any particular centroid back to the origin centroid.

Link Table: It defines all the links in the network in terms of other nodes at either end or the travel time along the link.

List: A table in which all of the links emerging from a specified node are entered along the travel times or the links.

Steps for minimum path tree:

1. Initialize the tree table with all the total times equal to 999 with the exception of the origin node which is set equal to 0 and this activity is shown in table above.
2. Add to the list all nodes connected to the nodes just added to the tree table.
3. Test all entries in the list to determine if "Node to" + "Total time from origin" travel time is less than the "Total travel time" in the tree table and if so enter it in the tree table.
4. Return to 2 and repeat until the list is empty.

<u>Network coding:</u>

- Ideally the network should be the smallest possible, in terms of links and nodes, adequate for the purpose for which it is required.
- All redundant links and nodes should be removed beforehand. Dead end links apart from centroid and gateway connectors should be removed.

- For some purposes, especially if minimum path costs only are required, the use of spider network, in which groups of two or more links from the original network are combined into a single link representing minimum cost paths between their end nodes, may be appropriate, to reduce CPU time.
- Numbering the network nodes, including centroids, sequentially without gaps, as suggested saves time in the initialization process and uses less computers core storage
- It may be assumed that the real network nodes start at node number Ncent+1 and hence, at step 2(b)(ii), node k is entered into L and ensuring that paths do not pass through centroids or gateways en route to other nodes.
- It is possible to avoid completely the need for tests to prevent centroids and gateways from entering the loose ends table by separating their connector links from the real network links.

Route Choice Behaviour

The most fundamental element of any traffic assignment is to select a criterion which explains the choice by driver of one route between an origin-destination pair from among the number of potential paths available.

All-or-Nothing assignment

All or Nothing assignment technique allocates the entire volume interchanging between pairs of zones to the minimum path calculated on the basis of free-flow link impedances. This is the simplest technique and is based on the premise that the route followed by traffic is the one having the least travel resistance. The resistance itself can be measured in terms of travel time, distance, cost or a suitable combination of these parameters. The traffic flows are assigned to the minimum path tree. The assignment algorithm loads the matrix 'T' to the shortest path tree and produces flows VAB on links between node A and B. two basic variations of the algorithm are given as follows:

Pair to Pair method

This is simplest but not necessarily results in the most efficient one. The steps are: Initialize all VAB = 0, then for each pair (i, j):

1. Set B to destination 'j'
2. If (A, B) is the back link of B then increment VAB by Tij i.e. VAB = VAB + Tij
3. Set B to A
4. If A = i, terminate (and process the next pair), otherwise return to step-2.

Once-Through method (Cascade method)

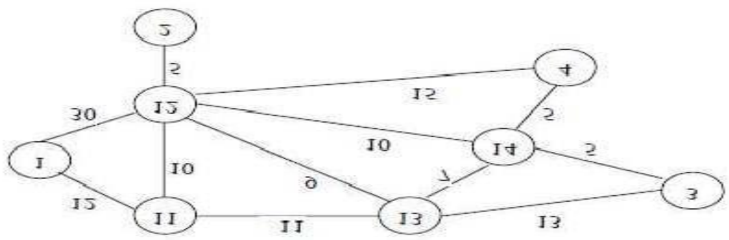
Allocates cumulative flows on minimum path trees using steps as follows:

1. Set all VA = 0 except for destination 'j' for which Vj = Tij.
2. Set B equal to the most distant node from 'i'.
3. Increment VA by VB: VA = VA + VB (where A is back node of B).
4. Increment VAB by VB: VAB = VAB + VB
5. Set B equal to next most distant node; if B=I then origin has been reached; begin processing the next origin; otherwise proceed with step-3.

Example

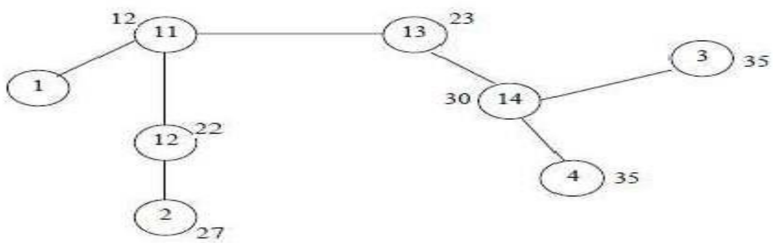
Assign traffic from origin node 1 to destination nodes 2, 3 and 4 as follows for the given network.

From Zone Centroid	To Zone Centroid	Traffic Volume (vehicles/hour)
1	2	2500
1	4	4000
1	3	3000



Solution:

Find Minimum travel path tree based on any method. Say, the minimum travel path tree from origin node 1 is as follows:



Link Table:

Link No.	Node (i)	Node (j)	Travel Time
1	1	11	12
2	1	12	30
3	11	12	10
4	11	13	11
5	12	2	5
6	12	4	15
7	12	13	9
8	12	14	10
9	13	3	13
10	13	14	7
11	14	3	5
12	14	4	5

Tree Table

Node (j)	Predecessor node (i)	Travel Time
1	0	0
2	12	27
3	14	35
4	14	35
11	1	12
12	11	22
13	11	23
14	13	30

N-Array Table

Position in order Of removal	Node
1	1
2	11
3	12
4	13
5	2
6	14
7	3
8	4

Working Table

Step	j	V_j	$i = p_i$	a	V_a	V_i
8	4	4000	14	12	4000	4000
7	3	3000	14	11	3000	7000
6	14	7000	13	10	7000	7000
5	2	2500	12	5	2500	2500
4	13	7000	11	4	7000	7000
3	12	2500	11	3	2500	9500
2	11	9500	1	1	9500	9500
1	1	9500	0			

Volume Array

Node	Volume (V_i)
1	0, 9500
2	0, 2500
3	0, 3000
4	0, 4000
11	0, 9500
12	0, 2500
13	0, 7000
14	0, 7000

Link	V_a	**Total link volume**
1	0, 9500	9500
2	0	0
3	0, 2500	2500
4	0, 7000	7000
5	0, 2500	2500
6	0	0
7	0	0
8	0	0
9	0	0
10	0, 7000	7000
11	0, 3000	3000
12	0, 4000	4000

Capacity Restraint Techniques

Capacity restraint assignment is a process in which the travel resistance of a link is increased according to a relation between the practical capacity of the link and the volumes assigned to the link. This technique has been developed to overcome the inherent weakness of all-or- nothing assignment technique which takes no account of the capacity of the system between a pair of zones. The capacity restraint system, on the other hand, clearly restrains the number of vehicles that can use any particular corridor and, in fact, the whole system, if the assigned volumes are beyond the capacity of the network, and redistributes the traffic to realistic alternative paths.

Because of the iterative nature of the calculations involved, the capacity restraint technique is carried out entirely by an electronic computer. The procedure is similar to the all-or-nothing assignment as far as the initial data input are concerned. The additional data that is fed is the capacity of each link. The best paths are determined in the same way as in all-or-thing technique by building the minimum path trees. Traffic is then assigned to the minimum path, either fully or in stages, and as the assigned volume on each link approaches the capacity of the link, the new set of travel time of the link is calculated. This results in a new network with a different minimum path tree, differing significantly from the earlier minimum path tree. As a consequence, assigning interzonal volumes to the new tree produces a new volume on each link. This iterative process is repeated until a satisfactory balance between volume and speed is achieved. Some of the methods of capacity restraint are given below.

Smock Method

In this method, the all-or-nothing assignment is first worked out. In an iterative procedure, the link travel ties are modified according to the function:

$$T_A = T_0 \times \exp\left(\frac{V}{C} - 1\right) \qquad \text{for } T_A \leq 5T_0$$

Where To = Original travel time or the travel time on a link when volume equals capacity

TA= adjusted travel time

V = assigned volume

C = computed link capacity

In the second iteration, the adjusted travel times TA are used to determine the minimum paths or trees. The resulting link volumes are averaged and these are again used to calculate the adjusted travel time for the next iteration.

WEYNE State Arterial method

This method is one of the earlier capacity restrained assignment methods. It is based on assigning traffic to various routes between an origin-destination pair such that the travel time on these routes are equal and any route between the origin-destination pair with zero flow will have a larger travel time. Various steps of this method are as follows;

1. Construct a minimum travel path tree for all origin zones based on travel time computed from average speeds on links, under typical flow conditions as existing.
2. Assign inter-zonal volumes to minimum travel path tree on A-O-N basis.
3. Compute the link travel times as (ith iteration)

$T_i = e^{(R_i - 1)} \times T_o$

Where, RI = Average assigned volume (from previous iteration) / capacity of the link

Average assigned volume = (Vi-1 + Vi-2)/2

To = original travel time on the link

4. Go to step 1 and repeat upto step 3 until equilibrium is reached i.e. Ti / Ti+1 ≈ 1.0 The limitations of this method are: variations in travel time are taken into consideration, and A-O-N assignment technique is used for assigning the volume to the network.

Multiple Route Assignment

All road users may not be able to judge the minimum path for themselves. It may also happen that all road users may not have the same criteria for judging the shortest route. These limitations of the all-or-nothing approach are recognized in the multiple route assignment technique. The method consists of assigning inter-zonal flow to a series of routes, the proportion of the total flow assigned to each being a function of the length of the route in relation to the shortest route. In an interesting approach suggested by Burell, it is assumed that a driver does not know the actual travel times, but that he associates with each link a supposed time. This supposed time is drawn from link time. The driver is then assumed to select the route which minimizes the sum of his supposed link times. Multiple route models have been found to yield more accurate assignment than all-or-nothing assignments

User Equilibrium assignment (UE)

The user equilibrium assignment is based on Wardrop's first principle, which states that no driver can unilaterally reduce his/her travel costs by shifting to another route. User Equilibrium (UE) conditions can be written for a given O-D pair as:

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

$$c_k - u >= 0 : \forall k$$

where **f** is the flow on path k, ck is the travel cost on path k, and u is the minimum cost. Equation labelqueue2 can have two states.

1. If ck - u = 0, from equation 10.1 f > 0. This means that all used paths will have same travel time.
2. If ck - u > 0, then from equation 10.1 f = 0.

This means that all unused paths will have travel time greater than the minimum cost path. where f is the flow on path k, ck is the travel cost on path k, and u is the minimum cost.

Assumptions in User Equilibrium Assignment

1. The user has perfect knowledge of the path cost.
2. Travel time on a given link is a function of the flow on that link only.
3. Travel time functions are positive and increasing.

The solution to the above equilibrium conditions given by the solution of an equivalent nonlinear mathematical

$$\text{Minimize} \quad Z = \sum_a \int_0^{x_a} t_a(x_a)dx,$$

$$\text{subject to} \quad \sum_k f_k^{rs} = q_{rs} \quad : \forall r, s$$

$$x_a = \sum_r \sum_s \sum_k \delta_{a,k}^{rs} f_k^{rs} \quad : \forall a$$

$$f_k^{rs} \geq 0 \quad : \forall \ k, r, s$$

$$x_a \geq 0 \quad : a \in A$$

Where k is the path, x_a equilibrium flows in link a, t_a travel time on link a, frs $_k$ flow on path k connecting

O-D pair r-s, q_{rs} trip rate between r and sand frs $_{a;k}$ is a definitional constraint and is given by

$$\delta^{r,s}_{a,k} = \begin{cases} 1 & \text{if link a belongs to path k,} \\ 0 & \text{otherwise} \end{cases}$$

The equations above are simply flow conservation equations and non negativity constraints, respectively. These constraints naturally hold the point that minimizes the objective function. These equations state user equilibrium principle .The path connecting O-D pair can be divided into two categories : those carrying the flow and those not carrying the flow on which the travel time is greater than (or equal to)the minimum O-D travel time. If the flow pattern satistices these equations no motorist can better o_ by unilaterally changing routes. All other routes have either equal or heavy travel times. The user equilibrium criteria is thus met for every O-D pair. The UE problem is convex because the link travel time functions are monotonically increasing function, and the link travel time a particular link is independent of the flow and other links of the networks. To solve such convex problem Frank Wolfe algorithm is useful.

Diversion Curves

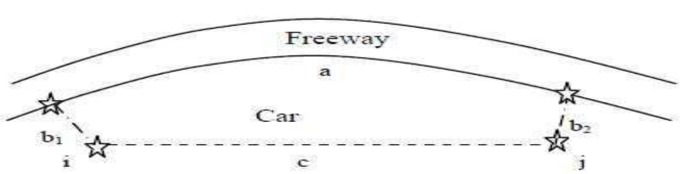
One of the frequently used assignment techniques in initial years was the development and use of diversion curves. These curves represent empirically derived relationships showing the proportion of traffic that is likely to be diverted on a new facility (by pass, new expressway, new arterial street etc.), once such a facility is constructed. The data collected on the pattern of travel in the past years serve to build up such curves. Diversion curves can be constructed using a variety of variables such as:

(i) Travel time saved
(ii) Distance saved
(iii) Travel time ratio
(iv) Distance ratio
(v) Travel time and distance saved
(vi) Distance and speed ratio
(vii) Travel cost ratio

Some of the diversion curve methods used in different parts of the world are discussed in the following paragraphs.

Indiana US method (Brown method)

It compares two paths between same set of origin and destination. One is travel by personal car and other is travel by transit. A person traveling by car has to cover distance equal to ‘c’, whereas, person who travels by transit has to walk to the transit stop from home (say b1) and then again walks from transit stop to the destination (say b2). The distance travel using transit is say ‘a’.



travels by transit has to walk to the transit stop from home (say b_1) and then again walks from transit stop to the destination (say b_2). The distance travel using transit is say 'a'.

Now, percent users using freeway will be given by

$$F = (F_1 + F_2) \times F_3 / 100$$

Where, F_1 = factor based on freeway distance (a)

$= 0$, when $a < 0.4$ miles

$= 2.8a^2 + 30.24a - 11.65$, when $0.4 < a \leq 5.4$ miles

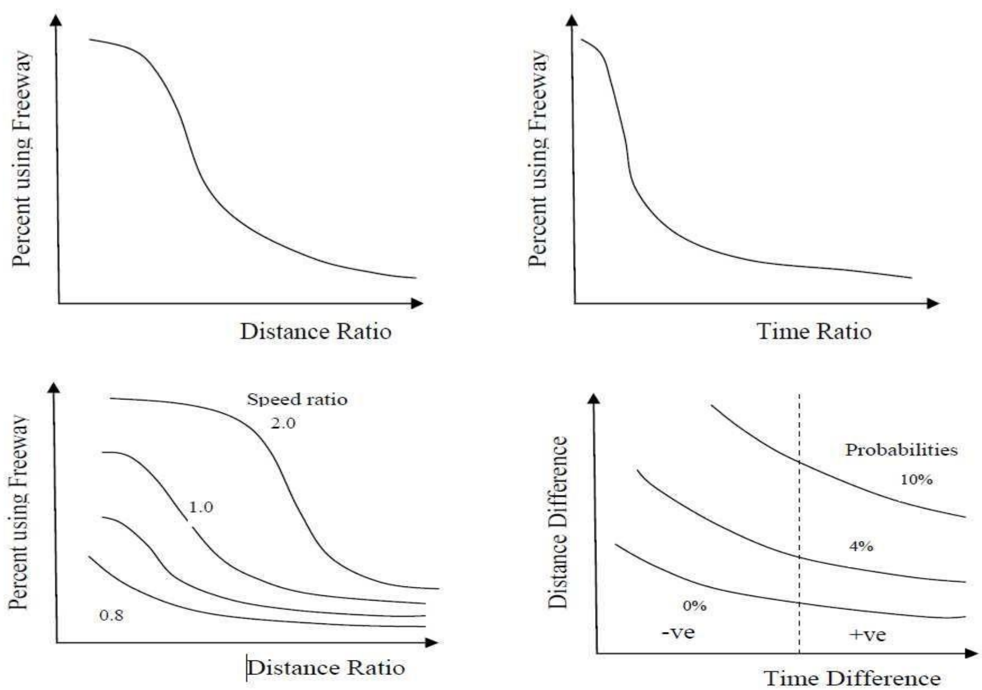
$= 70$, when $a > 5.4$ miles

F_2 = factor based upon access distance (b_1)

$= 33.3\, a/(a + b) - 3.3$, when $a < 0.4$ miles, and $0 \leq b \leq 9a$

F_3 = factor based upon excess distance i.e. $[(a + b) - c]$ (say $= v$)

$= 100 - 200(v/a)^2$, when $a < 0.4$ miles



Bureau of Public Roads method

A well-known example of diversion curves using travel time ratio to determine the traffic diverted to expressway is the Bureau of Public Roads Curve. The curve is "S" shaped. The following formula has been fitted to this type of curves:

$$P = \frac{100}{1 + t_R^6}$$

Where P = percentage of traffic diverted to new system

t_R = Travel time ratio

$$t_R = \frac{Time\ on\ new\ system}{Time\ on\ old\ system}$$

California Diversion Curve method

Another well known example using two variables, distance and travel time saved while moving on a motorway, is the California Diversion Curve.

The following formula has been developed to fit the above curves.

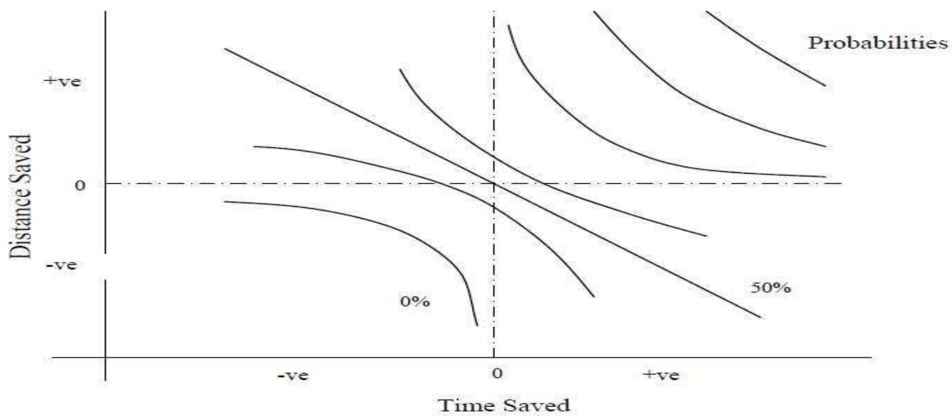
$$P = 50 + \frac{50(d + 0.5t)}{\left[(d - 0.5t)^2 + 4.5\right]^{0.5}}$$

Where P = percentage of vehicles moving on freeway

d = distance saved (in miles) on the freeway

t = time saved (in minutes) on the freeway

The diversion curve developed is shown in figure below.



Diversion curve assignments have the drawback that only two alternative routes for each pair of zones are considered. The technique is, therefore, eminently suitable for new bypasses, new motorways and such new facilities, but is of limited use in a complex urban network. Diversion curves reflect the travel resistance as measured by present day travel, but their use for future travel when the pattern can undergo radical changes is doubtful.

UNIT 5

Plan Preparation and Evaluation:

Travel Forecasts to Evaluate Alternative Improvements, Impacts of New Development on Transportation Facilities. Master plans, Selection of corridor, , Corridor deficiency analysis, Economic Impacts of transportation.

Corridor Identification

Initially, the study area was broadly defined to enable a regional assessment of alternative routes. The study area was bounded by US 287 on the west, WCR 23 on the east, Harmony Road/WCR 74 on the north, and Crossroads Boulevard/WCR 62 on the south. The study area is contained in both Larimer and Weld counties. While this broad study area was used to assess mobility and potential effects at a regional level, the study's logical termini were subsequently refined as described in Section 2.3 of this report.

SH 392 provides regional access to the towns of Windsor, Severance, and Timnath, and the cities of Loveland, Greeley, and Fort Collins. The SH 392 corridor crosses through both long-standing rural farming communities and emerging suburban development. Some of the features present in the study area include open spaces, trails, and golf courses. Commercial districts are developing not only along the SH 392 corridor, but also at the I-25/US 34 Interchange, and along Crossroads Boulevard. Other features of regional significance include the Cache La Poudre River (commonly referred to as the Poudre River), the Fort Collins-Loveland Municipal Airport, the Great Western Railway, the Union Pacific Railroad (UPRR), the Budweiser Events Center, and Fossil Creek Reservoir.

Regional Transportation Plan Vision

The NFRMPO has identified several highways as being "Regionally Significant Corridors" and SH 392 is one of them. The NFRMPO defines a Regionally Significant Corridor as, "A multimodal, regional system comprised of transportation corridors that connect communities by facilitating the movement of people, goods, information, and services" (NFRMPO, 2003). Three criteria are considered in the identification of regionally significant corridors: connectivity, functional classification, and trip length.

The *NFRMPO 2030 Transportation Plan* contains the following Corridor Vision for SH 392:

"The vision of the SH 392 Urban corridor is primarily to increase mobility as well as maintain system quality and improve safety. This corridor serves as a local facility, provides commuter access, and makes east-west connections within the south Fort

Collins, Windsor, Lucerne and Severance areas. SH 392 serves as Main Street through Windsor. Future travel modes to be planned for in the corridor include passenger vehicle, bus service, truck freight, and bicycle and pedestrian facilities. Transportation Demand Management (TDM) would likely be effective in this corridor. The transportation system

in the area serves towns, cities, and destinations within the corridor as well as destinations outside of the corridor. The communities along the corridor value high levels of mobility, transportation choices, connections to other areas, safety, and system preservation…Users of this corridor want to support the movement of commuters,

Current Planning Efforts

Local jurisdictions are conducting the following transportation planning efforts related to the SH 392 EOS.

- The NFRMPO is in the process of preparing the *NFRMPO 2035 Transportation Plan*. A draft plan is anticipated to be submitted to CDOT in 2007.

- Larimer County is actively coordinating with Fort Collins on the Growth Management Area (GMA) expansion and on the airport master planning efforts.

- Weld County is currently planning improvements to both WCR 7 and WCR 13.

- Fort Collins recently approved a proposal to expand the boundary of the City's GMA to include the Fossil Creek Cooperative Planning Area, an area generally located immediately west of I-25, both north and south of Carpenter Road. Once Larimer County and the City sign a revised Intergovernmental Agreement (IGA), the City will formally amend the City's Comprehensive Plan and the Structure Plan Map to depict the amended GMA boundary. In addition to approving the GMA boundary amendment, the City is pursuing annexation of the enclave and working with property owners (in particular, those with properties near the I-25 interchange) regarding the appropriate land uses on the current Structure Plan Map.

- Windsor is currently conducting a revitalization plan with a traffic and parking component. Current recommendations include diverting truck traffic around the downtown area, signalization of the Main Street/5th Street intersection, decreasing intown posted travel speed, examining a roundabout at the east entrance to downtown Windsor, and altering the on-street parking configuration to allow parallel parking.

- The Fort Collins/Loveland Municipal Airport updated their Master Plan in April 2006.

- On March 23, 2005, the Timnath Board of Trustees approved a resolution adopting the *North Area Comprehensive Plan Amendment* for the Town. This Plan provides the principles, goals, policies, and future land use plan. The intent of the Comprehensive Plan is to preserve and enhance the Town's identity, while still allowing for it to grow and flourish in a manner that is acceptable to its residents.

Project Purpose

A primary goal of this study was to identify ROW needs for future transportation improvements to meet travel demand in 2030. Based on the project need as described below, the project purpose was to identify the mobility needs in 2030 and develop solutions that meet this need. This study will guide future roadway improvement projects and ongoing development for the SH 392 corridor. The primary goal of the transportation improvement was to ensure that adequate provisions were made to the SH 392 corridor to meet regional transportation mobility needs for 2030 and beyond.

In addition to the primary purpose of the EOS, other factors were also considered. These include making provisions for transportation solutions that minimize effects to the natural, cultural, and social environment of the surrounding communities, that provide for the safe movement of people and goods, and that make full use of the EOS to identify other opportunities to address the needs of SH 392.

The EOS allowed CDOT to examine various alternatives for meeting those mobility needs on this major east-west connection between Loveland/Fort Collins and Windsor/Greeley. The study incorporated a context sensitive solutions approach to balance mobility needs with potential environmental and socio-economic effects.

The EOS served as a planning document that identified the ROW necessary for future transportation needs resulting in a recommended "footprint" characterized by each alignment.

This footprint may be used by local planning agencies and CDOT to preserve a roadway corridor for future improvement projects and guide ongoing development.

Two Stage Modal Split

Vandertol et al. have developed a simple two stage model which recognizes explicitly the existence of both captive and of choice transit riders. The model first identifies both the production and attraction trip ends of transit captives and choice transit riders separately. The ntwo groups of trip makers are then distributed from origin to destinations. The choice transit riders are then split between transit and car according to a choice modal split model, which reflects the relative characteristics of the trip by transit and the trip by car.

In most cities, the transit captive is severely restricted in the choice of both household and employment locations. Studies in a number of cities have shown that the trip ends of the transit captives tend to be clustered in zones that are well served by public transport. The challenge is to develop it to formulate a technique that uses information normally available in urban areas.

Zonal work trip productions disaggregated by the captive and the choice transit riders may be estimated from: $P_{iq} = h_i t_{pq}$

Where, P_{iq} = no of work trips produced in zone i by type q trip makers

h_i = the no of households in zone i

t_{pq} = work trip production rate for trip maker group q which is a function of economic status of a zone and the average no of employees per household.

The work trips attracted to each zone j by trip maker type q may be estimated from

$$a_{jq} = [p_{rcq}]\,[r_{ct}]\,[e_{tj}]$$

Where, a_{jq}= the no of work trips of type q trip maker attracted to zone j

$[p_{rcq}]$ = A row vector of the probability of the trip maker type q being in occupation in category type c.

$[r_{ct}]$ = A c*t matrix of the probabilities of an occupation category type c within an industry type t.

[etj] = a t*j matrix of the no of jobs within each industry type t in each zone j.

Linear Regression Analysis

Linear regression analysis is a well-known statistical technique for fitting mathematical relationships between dependent and independent variables. This technique has been exploited fruitfully in a number of transportation planning studies carried out so far and has become a very powerful tool in the hands of the transportation planner. In the case of trip generation equations, the dependent variables are the various measurable factors that influence trip generation. The general from of the equation obtained is :

$$Y_p = a + b_1X_1 + b_2X_2 + b_3X_3 ,.....+ b_n X_n$$

Where Y_p = number of trips for specified purpose p (dependent variable)

$X_1, X_2, X_3 \ldots\ldots X_n$ = independent variables relating to various trip influencing factors

$b_1, b_2, b_3 \ldots, b_n$ = multiplicative coefficients of the respective independent variables $X_1, X_2, X_3, \ldots X_n$ obtained by linear regression analysis, representing the relative influence of the variables on the trips generated

a = Disturbance term, which is a constant, and represent that portion of the value of Y_p not explained by the independent variables and is additive in nature

Multiple Regression Analysis

The majority of trip-generation studies performed have used multiple regression analysis to develop the prediction equations for the trips generated by various types of land use. Most of these regression equations have been developed using a stepwise regression analysis computer program. Stepwise regression –analysis programs allow the analyst to develop and test a large number of potential regression equations using various combinations and transformations of both the dependent and independent variables. The planner may then select the most appropriate prediction equation using certain statistical criteria. In formulating and testing various regression equations, the analyst must have a thorough understanding of the theoretical basis of the regression analysis.

Toronto Modal

Trip interchange modal split models allocate trips between public transport and private transport after trip distribution stage. The split between two modes is assumed to be a function of the following variables between each pair of zones:

1. Measures of system characteristics, like
- Relative Travel Time (RTT)
- Relative Travel Cost (RTC)
- Relative Travel Service (RTS)

2. Economic status of the Trip maker, like

a. Low-income group

b. Medium income group

c. High income group

Relative Travel Time

(RTT) by competing modes can be computed as:

$RTT=(x_1+ x_2+ x_3+ x_4+ x_5)/(x_6+ x_7+ x_8)$

This represents the door to door travel time to train to that of automobiles

X_1 = Time spent in transit vehicle

X_2 =Transfer time between transit vehicles

X_3 = Time spent in waiting for a transit vehicle

X_4 = Walking time to a transit vehicle

X_5 = Walking time from transit vehicle

X_6 = Auto driving time

X_7 = Parking delay at destination

X_8 = Walking time from parking place to destination

Relative Travel Cost (RTC) by competing modes is computed as:

$RTC=x_9/\{(x_{10}+ x_{11}+ x_{12}/2).1/x_{13}\}$

Where, X_9 =Transit Fare

X_{10} =Cost of gasoline

X_{11} =Cost of oil charge and lubrication

X_{12} =Parking Cost at destination

X_{13} = Average Car Occupancy

Relative Travel Service

(RTS) is computed as:

$RTS= (x_2+ x_3+ x_4+ x_5)/(x_7+ x_8)$

The application of Toronto model is in the forecasting of person trips.

The difference in the two methods lies in the method of introducing service characteristics in the model. It is introduced in terms of ratio of accessibility index (macroscopic way) in Southeastern Wisconsin method and directly as ratio of travel times, etc. in Toronto model.

Logit Analysis

The basic idea underlying modern approaches to travel demand modeling is that travel is the result of choices made by individuals or collective decision-making units such as households. Individuals choose which activities to do during the day and whether to travel to perform them, and, if so, at which locations to perform the activities, when to perform them, which modes to use, and which routes to take. Many of these choice situations are discrete, meaning the individual has to choose from a set of mutually exclusive and collectively exhaustive alternatives.

The mathematical transformation of logit model is as given below:

$P_i = exp(V_i)/\{exp(V_i) + exp(V_j)\}$

Where, V_i and V_j are measured utilities of options i and j respectively.

Binary Choice Logit Model

These are the simplest type of mode choice models. These models compare the travel choices between two modes. Say, c_{ij}^{m} is the generalized cost of travel between zone ‘i’ and zone ‘j’ using a mode ‘m’, then

If $c_{ij}^{2} - c_{j}^{1}$ = positive, then mode-1 would be chosen

If $c_{ij}^{2} - c_{j}^{1}$ = negative, then mode-2 would be chosen

If $c_{j}^{2} - c_{j}^{1}$ = zero, then both the modes have equal probability of being chosen

The probability of choosing mode for a trip between zones ‘i’ and ‘j’ is given by:

$$P_{ij}^{1} = \frac{T_{ij}^{1}}{\sum T_{ij}} = \frac{e^{-\alpha c_{ij}^{1}}}{e^{-\alpha c_{ij}^{1}} + e^{-\alpha c_{ij}^{2}}}$$

$$P_{ij}^{1} = \frac{e^{-\alpha c_{ij}^{2}}}{e^{-\alpha c_{ij}^{1}} + e^{-\alpha c_{ij}^{2}}} = 1 - P_{ij}^{1}$$

Multinomial Logit Model

This is the simplest and most practical discrete choice model. It can be generated assuming that the random residuals are distributed IID Gumbel such that,

$$P_{iq} = \frac{\exp(\beta V_{iq})}{\sum_{A_i \in A_q} \exp(\beta V_{jq})}$$

Where the utility functions usually have the linear in the parameters form and parameter β is related to the common standard deviation of the Gumbel variate by:

$\beta_2 = \pi_2/6\ \sigma_2$

Aggregate Model

Modal split models of 1960’s and early 1970’s in most cases were based on an ‘aggregate’ approach, which examined the mode choice of trip makers and their trips in groups based on similar socioeconomic and/or trip characteristics. These mode choice models usually involved two modes only - auto and transit. A detailed stratification scheme was used, and the share of each mode was determined for each stratified group of trips, which then was correlated with selected independent variables. The dependent variable was ‘percent transit’ applicable to a group of trips of similar characteristics made by similar trip makers. Commonly used independent variables include: the ratio of travel time by transit to that by automobile; the ratio of travel cost by transit to that by automobile; and the ratio of accessibility by transit to that by automobile. The relationship of the dependent variable, percent transit, with the independent variable, say ratio of travel times, commonly was expressed by a set of curves. These curves sometimes were referred to as modal diversion curves.

Disaggregate Behavioral Logit Models

During late 1970’s a new approach known as disaggregate behavioral method was developed and refined by a number of researchers. This approach recognized each individual’s choice of mode for each trip instead of combining the trips in homogeneous groups. The underlying premise of this modeling approach is that an individual trip maker’s choice of a mode of travel is based on the principle called ‘utility maximization’. Another premise is that the utility of using one mode of travel for a trip can be estimated using a mathematical function referred to as the ‘utility function’, which generates a numerical utility value/score based on several attributes of the mode (for the trip) as well as the characteristics of the trip maker.
Examples of a mode’s attributes for a trip include travel time and costs. The utilities of alternative modes also can be calculated in a similar manner. A trip maker chooses the mode from all alternatives that has the highest utility value for him/her.