||Jai Sri Gurudev||

Sri AdichunchanagiriShikshana Trust(R)

SJB Institute of Technology

(Affiliated to VTU, Accredited by NAAC with 'A' Grade, Approved by AICTE- New Delhi, Accredited by NBA)

No. 67, BGS Health & Education City, Dr.Vishnuvardhana Road, Kengeri, Bangalore-560060.

Department of Civil Engineering

VII SEMESTER – B. E

Academic Year 2021 –22

NOTES

Subject Name: Urban Transportation Planning

Subject Code: 18CV745

Staff In-charge:

Nisarga P

Assistant Professor

Syllabus

Course Title: **URBAN TRANSPORT PLANNING** **Course code:** **18CV745**

Module: I	**Teaching Hours**
Urban transport planning: Urbanization, urban class groups, transportation problems and identification, impacts of transportation, urban transport system planning process, modeling techniques in planning. Urban mass transportation systems: urban transit problems, travel demand, types of transit systems, public, private, para-transit transport, mass and rapid transit systems, BRTS and Metro rails, capacity, merits and comparison of systems, coordination, types of coordination.	8
Blooms Taxonomy: L1 – Remembering, L2 – Understanding, L3 – Applying	

Module: II	**Teaching Hours**
Data Collection and Inventories: Collection of data – Organisation of surveys and Analysis, Study Area, Zoning, Types and Sources 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 Owner Ship	8
Blooms Taxonomy: L1 – Remembering, L2 – Understanding, L3 – Applying	

Module: III	**Teaching Hours**
Trip Generation & Distribution: UTPS Approach, Trip Generation Analysis: Zonal Models, Category Analysis, Household Models, Trip Attraction models, Commercial Trip Rates; Trip Distribution by Growth Factor Methods. Problems on above	8
Blooms Taxonomy: L3 – Applying, L4 – Analysing	

Module: IV	**Teaching Hours**
Trip Distribution: Gravity Models, Opportunity Models, Time Function Iteration Models. Travel demand modeling: gravity model, opportunity models, Desire line diagram. Modal split analysis. Problems on above	8
Blooms Taxonomy: L2 – Understanding, L3 – Applying, L4 – Analysing, L5:	

Module: V	**Teaching Hours**
Traffic Assignment: Diversion Curves; 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. Introduction to land use planning models, land use and transportation interaction.	8
Blooms Taxonomy: L2 – Understanding, L3 – Applying, L4 – Analysing, L5:	

MODULE 1

URBAN TRANSPORT PLANNING

Urbanization:

- Urbanization and industrialization are two of the most important features of modern civilization.
- Urbanization provides the necessary infrastructure for trade, commerce and industry
- It also provides better living standards in terms of educational facilities, health care, recreation and several intellectual pursuits.
- Urbanization attracts the surplus labour force from the rural areas and utilizes it in running the various services which are vital to the existence of town.
- The United Nations estimates shows that 47% of the world population line in urban areas. India Is still one of the countries having a low degree of urbanisation essentially a rural oriented country but the urban population has been growing at a fast rate.
- With the growth of cities, need for more residential buildings and office accommodation become necessary. The residences begin to pushed outwards from city centres, increasing the separation between the places of work and residence.
- The existing transport net-work which was adequate for the needs, become overloaded and turns out to be incapable of handling the newly created transport demand and thus demand for the better transport facilities.
- The unplanned growth of city lead to either congestion in the city centre or to urban spawl. Both of these situations bring in extreme pressure on the transport capacity.

Difficulties in Urban Traffic Condition

The report by Buchanan deals with the nature of the present difficulties being faced by towns. Though the report is fairly old, relevance even today is unquestionable.

- The most serious effect of increasing urbanization and accelerated traffic cause the severe congestion on the streets. The condition results in concentrated demand both in time and space.
- The very advantage claimed for motor vehicle viz. its ability to provide a door to door service seems to be difficult to obtain. It is not possible to stop the vehicle and get down at one’s own will.
- Parking at a safe place is almost an impossibility in some areas of the city

- Loading and unloading of goods by commercial vehicles is hampered by too many restrictions.
- Congestion results in delays and time losses.
- Driver stresses are caused by frustration and delays.
- An inevitable result of growth of traffic results in increased road traffic, which take a great toll of human life every year.
- The deterioration due to traffic has been causing serious concern.
  a) The noise in the streets and adjoining areas has been growing up to intolerable levels
  b) The exhaust from the vehicles pollutes the atmosphere with fumes and smell
  c) Vibration of buildings and adjacent structures and visual intrusion are some of the other ill-effects.

Impacts of Transportation

Some of the major environmental impact of transport development are:

1. *Energy consumption in transport and environment pollution:*

- Transportation requires energy mainly for vehicle operation and to some extent for manufacturing of vehicles. The energy consumption in transport is main cause of pollution.
- There is a significant difference in fuel efficiencies between various modes of transport Eg: Consumption of energy in car is more among urban transport modes. Though there is significant improvement in the fuel efficiency of automobiles, the energy consumption will continue to increase in spite of fuel efficiency measures.

2. *Air Pollution*

Pollution of the atmosphere by fumes and smoke emitted by the motor vehicles makes the urban street extremely unpleasant. With further growth of vehicle population, the problem is bound to assume serious proportions.

The major source of the pollutants in the exhaust gas emitted by the internal combustion engine. The following are the major components of the exhaust gas:

- Corbon di-oxide (CO_2): It is the most important contributor to climatic change.
- Corbon monoxide (CO): This is the poisonous gas caused as a result of incomplete combustion. Small doses of CO present in air due to rad traffic may not be a medical danger, but can cause major effects.
- Oxides of nitrogen and lead compounds: The concentration of nitrogen oxides due to road traffic being small, there presence does not appear danger to health but the effect of long-

term exposure might cause anxiety. Increase in concentration of lead compounds also affects the well-being of the society.

- Carbon particles (Smoke): Smoke contains minute particles of carbon and though by itself is not a health hazard, it may prove dangerous in combination with other compounds.

3. *Noise Pollution:*

Another impact of transport system is the noise pollution. The sources of noise from road vehicles are many and varied including,

a) Noise generated from various parts of the vehicles like engine, exhaust, breaks, horns, chassis, loads in the vehicle, door slamming etc.

- Motor vehicles and scooters are generally nosier than passenger cars
- Commercial trucks are a main source of noise as they carry heavy loads
- Old and improper maintenance of vehicles generates more noise

b) Noise contributed by the interaction between vehicle and road surface:

- Smooth surface generally produces less noise than rough surface
- Grooved cement concrete has been practically found to be a source of annoying noise

c) Noise dependent on the speed, flow, density of traffic:

- AS the traffic volume increases, the noise level inevitably raises
- Higher speed also known to cause higher noise level
- Noise level increases during acceleration

4. *Visual intrusion and degrading the aesthetics:*

- In urban areas, the motor vehicles have been competing for space for movement and it appears that buildings seem to raise from the plinth of cars.
- The tranquillity and openness of parks and squares has been occupied and spoiled.
- To attract the attention of the motorist numerous signs, signals and bill board have sprung up all along streets, spoiling the beauty of the surrounding land, historical landmarks and architectural master pieces.
- Service stations, garages and petrol filling stations have spread up along the road and added their mite to the degradation of the general scene.

5. *Severance and land consumption:*

Severance is the general term denoting the psychological, cultural and physical disturbance caused by a traffic facility on the neighbourhood, land, society and life cycle.

- Highway and streets consume an enormous amount of land and requires compulsory acquisition of land which can cause disruption to way of life among community.
- The amount of land acquired by streets and highways is so large that it has created problems of rehabilitation and relocation.
- Precious land uses such as forestry, agriculture, housing and nature reserves may be displaced.

TRANSPORT SYSTEM PLANNING

Transport planning is s science that seeks to study the problems thar arises in providing transportation facilities in an urban, regional or national setting and to prepare a systematic basis for planning such facilities.

Interdependence of the Land use and Traffic

Transportation planning was done through measurement of traffic using streets, identifying those sections were present traffic has exceeded the capacity and undertaking improvement measures to relieve congestion and bottle necks in the smooth traffic flow. This simplest approach failed to deal with complex transport problems and only provided short term solutions. This approach is eventually abounded.

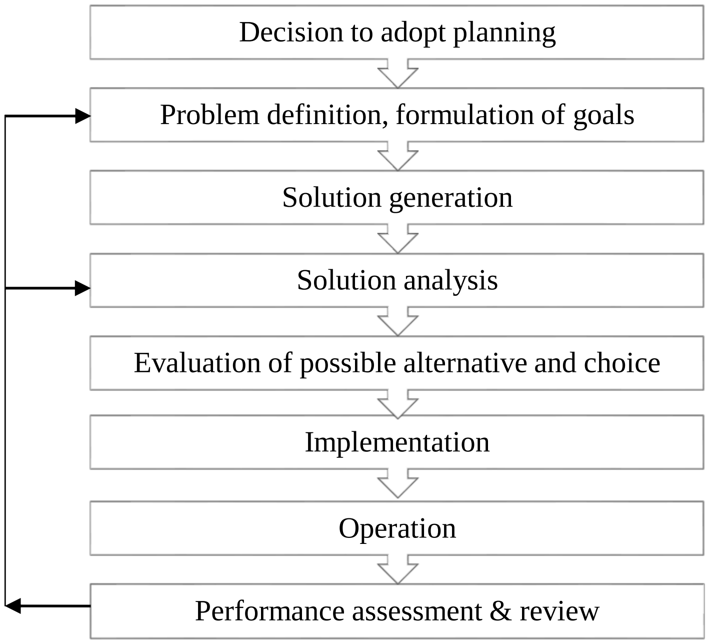
1. In 1954, **Mitchell and Rapkin** made a statement that '*Urban transport was a function of land use*'. It paved the way for a new line of thinking in urban transportation and land use planning.

Mitchell and Rapkin observed the various kind of activities based on the land called land use – "generated'' different amount and kinds odf traffic. They concluded that measures such as provision and improvement of physical channel of movement and regulation and control of traffic were effective in dealing with urban traffic. But the most basic level of action for a long run solution of traffic problem is the planning, guidance and control of land use pattern.

2. **Buchannan** has also emphasised the inter-relationship between traffic and buildings in town. He states that 'In towns, traffic takes place because of buildings in fact all movements in town have an origin and destination in building'. The pattern traced by traffic is thus closely related to the manner in which buildings are arranged.

System Approach to Transport Planning

The process involved in the system approach in transport planning is represented in figure below:



- The transport planning starts with the decision to adopt planning as a tool for achieving certain desired goals and objectives.
- After goals and objectives are defined, solutions are generated taking due consideration of problems, constraints, potential and forecasting. These solutions are evaluated after analysis.
- The best amongst is chosen for implementation.
- After implementation, the system is studied in operation and its performance assessed. Based on this assessment it may be necessary to go back to certain stages of planning and repeat the sequence.

Stages in Transport Planning

Transport planning can be broken down into five stages:

1. Survey and analysis of existing condition
2. Forecast, analysis of future condition and plan synthesis
3. Evaluation
4. Programme adoption and implementation
5. Continuing study

1. Survey and analysis of existing condition:

The survey and inventory start with definition of survey area and division of area into smaller units called zones to study the pattern of movement. Some of the goals are formed to meet some of the aspects line:

a) Minimum disruption of environment
b) Minimum demolition of general environment
c) A high benefit/cost ratio
d) Operational feasibility
e) To improve safety of travel

The inventory of existing travel pattern includes:

- Collection of data on origin and destination of journey, traffic volume on various links in the existing network
- Collection of data on movement of goods vehicles and public transport buses
- Collection of data on movement by rail transit
- Parking characteristics (supply, usage, duration and method of charging

The inventory of existing transport facilities includes:

- Studies on travel time by different modes
- Inventory of public transport buses, their speeds, schedules, capacity, terminals, passenger carried etc.
- Parking inventory, accident data etc.

The inventory of land use and economic activities consists of:

- Information on land use type (residential, commercial, recreational etc)
- Population statistics, household structure including family income, car ownership, family size, gender etc
- Employment pattern

2. *Forecast, Analysis of future condition and Plan synthesis:*

- Transport plans are long-run in scope and involve planning 20 to 25 years ahead. It therefore be become necessary to do prediction of travel pattern and needs for the future year.
- Forecasting future economic activity for the study year is an important and difficult phase in the in the transport planning process. Future land-use pattern also needs to be predicted.
- Economic activity can be predicted by extending past trends in the various parameters representing economic activity
- Population forecast can be done by studies of past trend. More detailed studies of birth, death and migration data help
- Estimation of future employment pattern follow from prediction of economic activity.
- Future car ownership is an important parameter that influence future travel and mode choice
- The predicted growth in land use pattern such as residential, industrial, commercial, recreational and open spaces can be determined by formulating suitable land use allocation models.

Eg: Knowing the expected rate of GNP (Gross National Product), expected traffic growth T can be calculated as:

$$\log T = A_0 + A_1 \log (GNP)$$

Where, A_0 = regression constant

A_1 = regression co-efficient/ elasticity co-efficient

3. *Evaluation:*

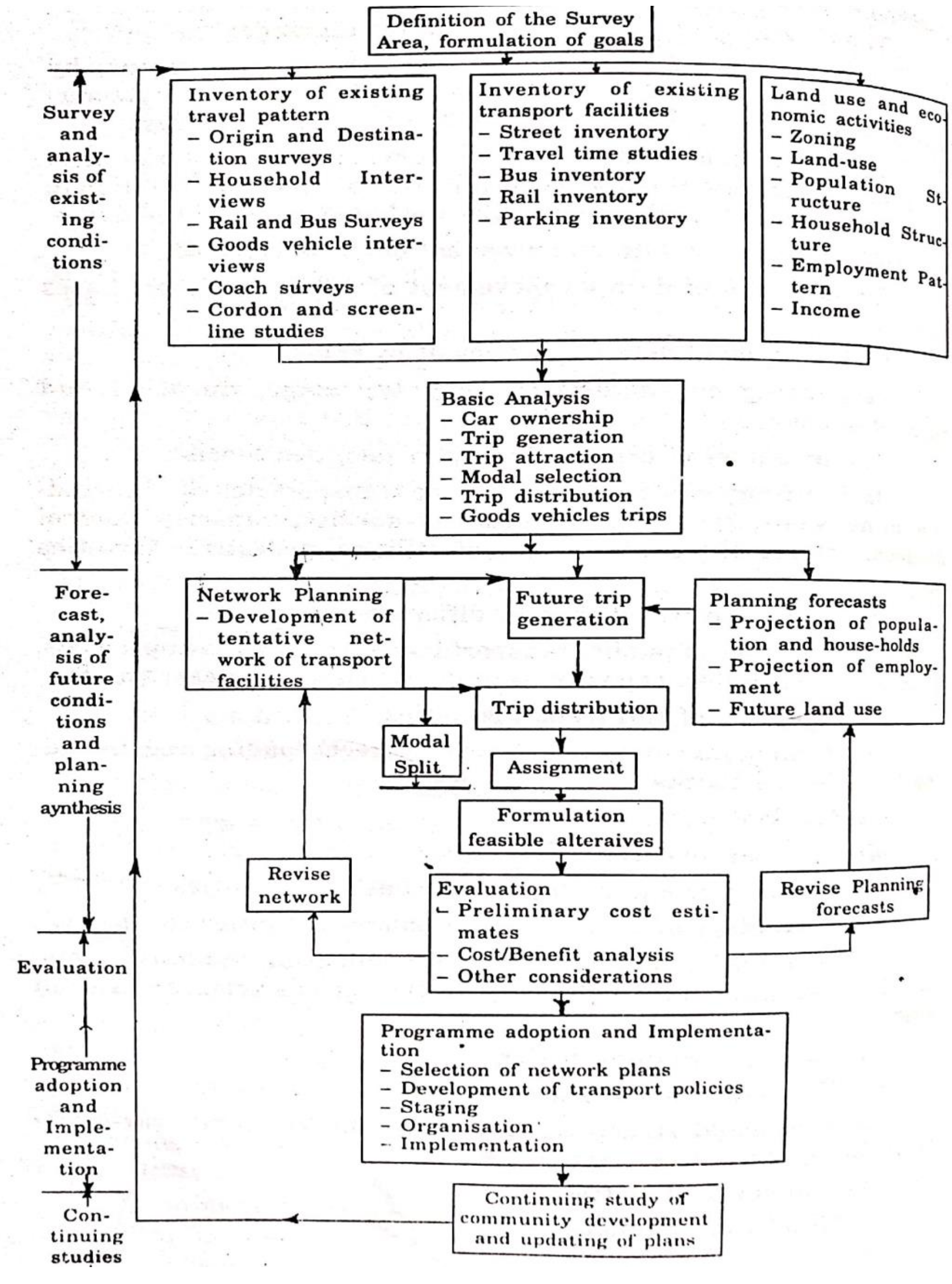
- In an urban system, a number of alternative transport plans are feasible for a given set of goals and policies. In order to select the best from these, it is necessary to evaluate each of alternatives as to how it fulfils the desired objectives
- At this stage, it may be necessary to revise the plans and go back to initial stage of design to evolve further alternatives.

4. *Programme adoption and Implementation:*

- The best alternative emerging from the evaluation study is selected for adoption and implementation.
- The stages in which the project is to be implemented are decided with the consideration of financial resources.

5. *Continuing study:*

- Transport planning is a dynamic and complex process, there cannot be any finality about the plan. The urban system and the people inhibiting it are not deterministic and are governed by random behaviour. Technology and preferences of people may change. Plans and policies which are relevant today may not remain so in future. This underlines the need for a continuous review and updating of the plan
- Periodic survey should be carried out on the trends in travel pattern, journey times and other relevant factors and the plan readjusted, if need to be.



Transportation Planning Models

The process of travel demand forecasting consists of four stage model

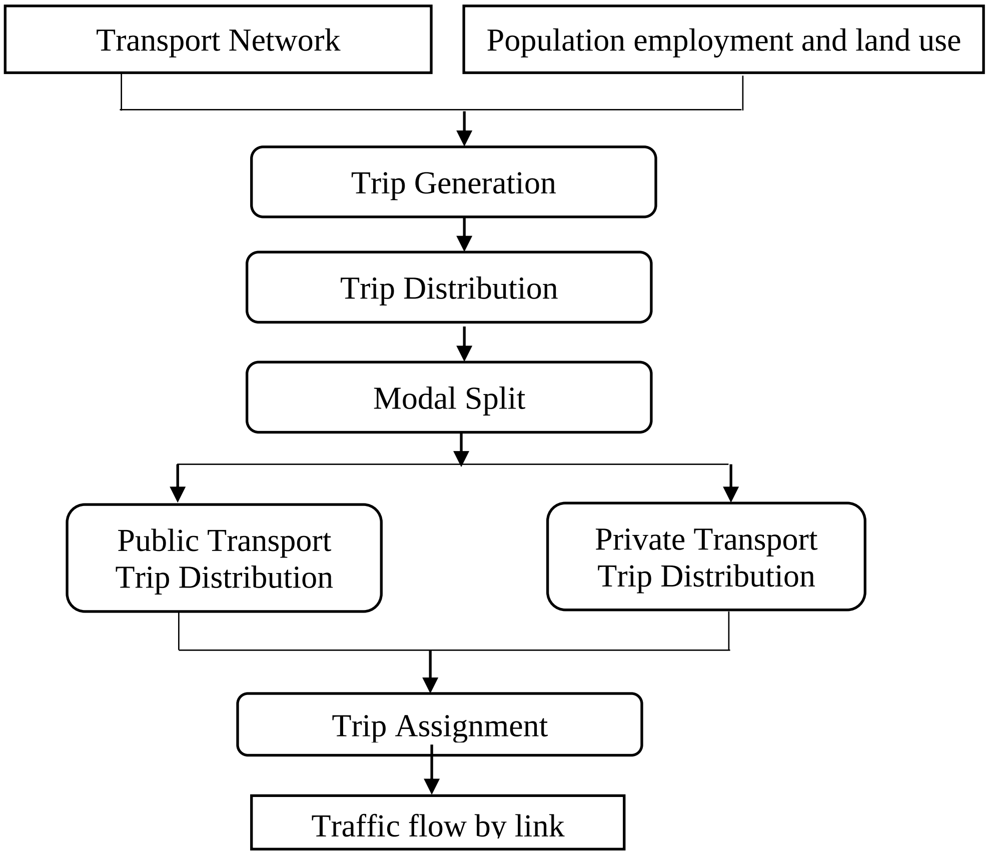


Fig: Stages in Transport Modelling

1. Trip Generation:

Trip generation is the first stage of transportation demand models. It is a general term used in the transportation planning process to cover the number of trip ends in the given area. Trip generation is classified into production and attraction.

Production (Origin): Number of trip end originated in zone i

Attraction(Destination): Number of trip end attracted to zone j

There are basically two tools for trip generation analysis:

a) Multiple linear regression analysis
b) Category analysis

2. Trip Distribution:

The decision to travel for a given purpose called trip generation. The decision to choose destination from origin is directional distribution and forms the second stage of travel demand modelling.

Trip distribution is determined by the number of trip ends originated in zone-i to number of trips attracted to zone-j, which can be understand by matrix between zones. The matrix is called origin-destination (O&D) matrix.

The trip generation models include:

a) Growth factor models
    - Uniform growth factor
    - Average growth factor
    - Fratar method
    - Furness method
b) Synthetic modes
    - Gravity model
    - Opportunity model

3. Modal Split:

The third stage in travel demand modelling is modal split. Modal split is determined by number of trips of people process by the different mode of travel. In other words, modal split is used to C two or more mode categories like public transport riders and personal/private riders.

Modal split methods include:

a) Probit Model
b) Logit Model

4. Trip Assignment:

Trip assignment is fourth and final phase of the four-stage modelling. Travelers will choose the route which will take minimum travel time, minimum travel distance dependent on the traffic volume on the road. The following are commonly used traffic assignment models.

1. All or nothing assignment
2. Multiple route assignment model
3. Capacity restraint assignment model
4. Capacity restraint multipath route assignment model
5. Diversion curves technique model

Urban mass Transportation System

The term "Urban Mass Transit" generally refers to scheduled intra-city service on a fixed route in shared vehicles.

The urban mass transportation system includes:

1. Road based transit: Busses and coach, City buses/ commuter buses, BRTS

2. Rail based Transit: Trains, commuter rails and sub-urban rails, metro rails, mono rails, light rail transit system, sky rail

Personalised/ Private Vehicle System

The personalised motor vehicles have grown popularity because of greatest advantage it has over other forms of transport system like flexibility in travel route and travel time, door to door service. But the problems of fuel shortages, congestion, parking, environmental pollution etc. hampered the further development in this system. Developed technologies includes:

a) Automated Highways:

It consists of a specially designed highway carriage way with control cables embedded in the pavement. The operations normally performed by a driver such a speed selection and adjustment of space between successive vehicles would be handled by a centralise computers. It is reported that capacity of 9000vehicles/hour/lane is possible with this system

b) Dual- mode system:

Consists of a small personalised car, capable of moving on roads as well as on rail lines. They are automatically driven and controlled when it is on rail

c) Battery powered small cars offers new power source and are likely to be popular in near future.

Bus Rapid Transit System (BRTS)

Bus rapid transit is a bus-based public transport system designed to improve capacity and reliability relative to a conventional bus system. BRTS includes roadway that is dedicated to buses and gives priority to buses at intersections where buses may interact with other traffic. A capacity upto 40,000 seats per hour or 550 buses per hour is possible on exclusive bus lanes.

- A BRTS corridor has been constricted in New Delhi where in in two lanes (one for each direction) have been carved in the centre on multi lane road.
- 22km BRTS of 6 lanes is built to serve the twin city Hubli-Dharwad in 2018
- BRT corridors are also being planned in cities like Vishakhapatnam, Pune and Bangalore

Rapid Rail Transit System

Railway transit is a well-known means of rapid transit along high density corridors. They can be surface/ underground/ elevated.

- Surface rapid rail transit service serves an important role in Bombay, Madras and Delhi. The lines are electrified.
- Underground system lines between Dum Dum and Tollygunge has built in Calcutta. This line is 16.4km long.
- Bangalore city is running elevated metro line for 33km Long.

- First rapid rail system in India is Kolkata Metro (1984)
- Delhi metro has largest network in entire country (288km running)

Advantages of Mass Transit

1. *Reduction in Congestion*: The main idea behind mass transit is to reduce the number of vehicles on the road by providing a larger facility which carries higher number of passengers thus eliminating congestion

2. *Saves Time*: Mass transit reduces the travel time to a great extent as it moves at high speeds and stops only at specific spots

3. *Cost effective*: Mass transit is comparably cheaper than other modes of public transport

<u>Other impacts</u>

4. *Environmental impacts*: Mass transit is believed to be more environmentally friendly than other public transport facilities. Private vehicles emit about twice as much carbon monoxide and other volatile organic compounds than public vehicles.

Mass transit reduces number of cars on the road which in turn reduces the pollution caused by cars

5. *Social Impact*: All the members of the society irrespective of their financial status, religion or cast can travel which enhances the social integrity of the country

6. *Economic Impacts*: Mass transit development can improve both the usefulness and efficiency of the public transit system as well as results in increased business for commercial development and thus serves to improve the economy of the country

Disadvantages

1. Mass transit systems are economically feasible only in areas that have relatively large population. As the number of inhibits per square km decreases, the efficiency of mass transit system also decreases.
2. Mass transit system are also very expansive to build and operate. When this system has to be installed in cities where development had already taken place and disruption of existing structure is a serious problem
3. While using mass transit people need to wait for a long time to have a bus or train. Flexibility in time to reach the destination in desired time is not possible.
4. Risk of being the criminal victim is high. Rapes and snatch crime is the most common cases that caused by the public transport
5. In addition, people cannot have a comfortable journey to their destination. Some of the mass transit system are usually crowded, dirty and smelly. Also, some special people such as disables person and old folks may be treated bad.

Para-Transit Transport:

- Paratransit service is the general terms for a "demand-response" service which a passenger must reserve a ride in advance.
- It includes all public and private automobile travel and fixed route and fixed schedule bus and rail transit.
- It also includes carpools and vanpools (shared ride modes), public autos (station cars), charter buses, exclusive and shared ride taxi cabs and bus transportation operating on flexible routes and flexible schedules in response to individual request for service. Hence termed as " Demand-Responsive" or 'Dial-a-ride" service.

Light Rail Transit (LRT)

LRT is popularly known as the tram or the street car. Trams used to operate on the roads of Delhi and Bombay where they have now been discontinued. However, continue to be run in Calcutta. Word light rail not refers to the strength of the rail, but to the lighter cars, shorter trains and method of operation.

Advantages:

1. Trams is an electrically based system. The fuel crisis has made oil-based bus transport system costly. Trams is free from the uncertainties associated with availability of oil.
2. Trams are relatively cheaper than conventional sub-urban rail systems.
3. Trams are suitable for pedestrian malls.

Magnetic Levitation (Maglev) System

Maglev is a rail system running on monorail and capable of running at high speeds of 400 km/hr. The technology based on the principle of magnetic levitation. Entire trains are suspended and propelled towards by magnetic farces without touching the rail track.

Advantages:

1. Tracks requires less maintenance
2. High speeds are possible
3. Low noise

A line of 0.6km long is already operation in Birming Ham (UK)

Modal Integration (Co-ordination of System)

Modern day transportation more than one mode.

Eg: The goods produced in the factory are stuffed into a container and moved by road to an Internal Container Depot (ICD) or Container Freight Station (CFS). From there it is by rail to a port and then on it travels by help.

This system is known as multi-modal or intra model transportation.

Need: All modes of transportation have their own role to play. This should be clearly recognised by National Transportation Planning. No single mode should be allowed to develop at the cost of any other or to the detrimental of the nation's overall economy. Hence requires a co-ordinated approach.

Other example of this system are:

- "Piggy-back" system or trailer-on-flat-car (TOFC) where in the trailer of truck is moved of flat rail wagons over long distance which helps in saving fuel, reducing congestion, and reliving the truck driver from the long-distance driving.
  Konkan Railway Corporation in India is operating this system
- "Road-trailer" is a new technology where in the trailer of the truck can directly be moved on the rails.
- "Roll-on-Roll-off" (RORO) is a system where in the trucks are carried on ships over long distance

Integrated Transportation System (In-Trans Sys)

In this system motorist drives his car to the nearest station, drivers the car to a loading stall and attaches a simple electrical connection between the platform and his car. The system then checks the identity of the car for billing. The driver dials the number of the station he wants to reach. His role as a trip maker is finished and the In-Trans Sys takes over and reaches his destination on the best possible routes.

Maximum speed of 100kmph on urban links and 250kmph on rural highway with capacity of 14,400veh/hour and 36,00 per hour respectively is possible in this system. Though the system appears very futuristic, one can expect it to be operational sooner than expected.

MODULE 2

DATA COLLOECTION AND INVENTORIES

The first stage in formulation of a transportation plan is to collect data on all factors that are likely to influence travel pattern. The work involves a number of surveys which includes

- Inventory of existing travel pattern
- Inventory of existing land use
- Economic activities

Definition of study area

Transportation planning can be at national level, regional level or at the urban level. The study area for which transportation surveys are being planned is to be defined first.

The imaginary line representing the boundary of the study area is termed as 'External Cordon'. The area inside the external cordon line determines the travel pattern to the large extent hence surveyed in detail. The land use pattern and economic activities are also studied.

The selection of external cordon line should be done carefully considering the following factors:

i. The external Cordon line should circumscribe all areas which are already built up and those areas which are considered likely to develop during period of study.

ii. The external cordon line should contain all areas of systematic daily life of the people oriented towards the city centre.

iii. The external cordon lines should be continuous and uniform in its course so that movements cross it only once. The line should intersect roads where it is safe and convenient to carry out traffic surveys

iv. The external cordon lines should be compatible with previous studies of the area and of studies planned for future

Zoning

The defined study area is sub-divided into smaller areas called Zones.

The purpose such a sub- division is to facilitate the spatial quantification of land use and economic factors which influence travel pattern. The data collected on the individually household basis can’t be conveniently considered and analysed unless they are aggregated into small zones.

Sub-division into zones further helps in geographically associating the origins and destinations of travel. In large study projects, it is more convenient to divide the study area into sectors, which are sub-divided into smaller zones

A convenient system of coding 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 1 to 8 in a clockwise manner. The prefix 9 is reserved for external zones.
- Each sector is sub-divided into 10 zones bearing number 0 to 9. Thus a system of 3 digits denotes a sub-zone
- Ex: A sub zone bearing the 481 belongs to sector 4 and to zone 8 in that sector and is sub-zone 1 in that zone

Followings points are to be considered while dividing area into zones:

1. Land use is the most important factor in establishing zones for transportation survey
2. The zones should be of homogeneous land use
3. Anticipated changes in land use should be considered
4. The sub-division should follow closely that adopted by other bodies for data collection which helps in correlation of data
5. The zones should not be too large to cause considerable errors in data
6. The zones should preferably have regular geometric forms
7. Sectors should represent catchment of trip generated
8. Zones must be compatible with screen lines and cordon lines
9. Zone boundaries should be preferably be water sheds of trip making
10. Natural or physical barriers such as canals, rivers etc. Can form convenient zone boundaries

There may be number of internal cordon lime arranged as concentric rings to check the accuracy of survey data.

Screen lines: Runs through the study area to check the accuracy of data collected and it is located along physical or natural barriers like rivers, railway lines, canals etc.

TYPES OF SURVEYS

The basic movements for which survey data are required are:

- Internal to Internal
- Internal to External
- External to Internal
- External to External

These are symbolically illustrated in the fig below:

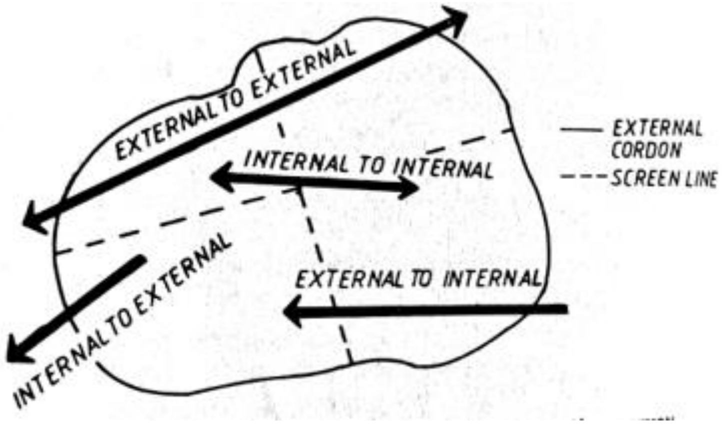


Fig: Basic Movements in a Transportation Survey

For large urban areas, the internal to internal travel is heavy where as small areas having small population internal to internal travel is insignificant. The internal to internal travel is studied by Home Interview Technique by screen line surveys. The internal-external, external-internal, external-external can be studied by Cordon surveys.

The surveys can collect the data

a) At home b) During the trip c) at the destination end of the trip

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 modelling 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 house-hold, 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.
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 trans-port 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.

Following are some of the surveys that are carried out

1. Home Interview Survey
2. Commercial Vehicle Survey
3. Taxi Survey
4. Road Side Interview Survey
5. Postcard Questionnaire Survey
6. Registration number Survey
7. Tag survey
8. Public Transport Survey

1. Home Interview Survey

- It is the most reliable type of survey for collection of origin and destination data. The survey is based on the travel pattern of the residents and general characteristics.
- The information on travel pattern includes number of trips, travel mode, their origin and destination, purpose of trip, travel mode, time of departure from origin and destination and

so on.

- The information on house hold characteristics includes type of dwelling unit, number of residents, age, sex, 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 and hence sampling procedure is employed
- The size of samples usually determined on the basis of the population of the study area. The standards are given in table below:

  Bureau of Public Roads (BPR) Standards for Sampling Size in Home Interview Survey

Population of Study Area	**Sample Size**
Under 50,000	1 in 5 households
50,000-1,50,000	1 in 8 households
1,50,000-3,00,000	1 in 10 households
3,00,000-5,00,000	1 in 15 households
5,00,000-10,00,000	1 in 20 households
Over 10,00,000	1 in 25 households

Table: Standards for Sampling Size for Home-interview survey

- A number of techniques are available for home interview survey:

  Full interview technique: Involve interviewing as many as members of households as possible and directly recording all the in formations.

  Home questionnaire technique: The interviewer collects only details of household characteristics, leaving forms for household residents to complete in regard to travel information. The completed forms are collected by interviewer after a day or two.

3. Commercial Vehicle Survey

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 Survey is conducted to obtain information on journeys made by all commercial vehicles based within the study area.
- The address of the vehicle operators are obtained, contacted and forms are issued to the vehicle drivers with the request that they record particulars of all the trips they would make.

3. Taxi Survey

- Taxi survey is necessary in large urban areas where sizable about of travel by taxis
- The survey consists of issuing questionnaires or log sheets to the taxi drivers and requesting them to complete the same.

4. Road Side Interview Survey

- Road side interview survey is one of the methods of carrying out screen line or cordon line survey.
- It is done by either directly interviewing drivers of the vehicles at selected survey points or by issuing prepaid post cards containing the questionnaire to all or a sample of the drivers.
- The survey points are selected along the junction of screen line or cordon line. The cordons may be in the form of circular rings or radial lines of rectangular grids.
- For small cities with population less than 5,000 single circular cordon lines is used. For medium sized cities with population 5,000- 75,000 two cordon line are necessary where as for large cities, cordon line and screen lines may be complicated.
- For dual carriage ways with less traffic, the traffic survey for both the direction is conducted simultaneously. In other cases the traffic in two directions will be interviewed at different time.
- It is impractical to stop and interview all the vehicles, hence the sampling technique is used. A convenient method of sampling i.e. fixed number of vehicles, every tenth, fifteenth or twentieth vehicle etc is selected.
- A 24 hours count will not normally be needed and the survey is often restricted to 16 hours or 12 hours in a day
- The analysis of data by computer will be easy. Expansion factors are needed to calculate total number o trips and it depends on each class of vehicles and time period of survey.

  Eg: if x_c represents number of cars interviewed in a particular time period and if X_c is number of cars counted during this period, then the Expansion factor is $\mathbf{X_c / x_c}$
- The only **disadvantage** with this method is that the vehicles are delayed when being interviewed.

5. Post Card Questionnaire Survey:

- In this method, reply-paid questionnaires are handed over to each of the rivers or a sample of them at the survey points and requesting them to complete the information and return by post.
- The method avoids delay caused to the drivers by the direct road side interview method but suffers from the disadvantage that the response may not be good.
- The method is simpler and cheaper than many others. It is reported that well planned and publicized post card questionnaire surveys have yielded returns of 50% or more.

6. Registration Number Plate Survey:

- Registration number plate survey consists of noting the registration number of vehicles entering or leaving an area at survey points located on cordon line.
- By matching the registration numbers of vehicles at the point of entry and exit from the area, one is enabled to identify two points on paths of vehicles.
- The method neither gives origin and destination of trip nor the trip purpose. The advantage of this method is that work doesn't interfere with traffic movement.
- Generally, at the roads intersecting the cordon line is taken as survey point. At each survey point one or two observers are stationed to record the data in each direction of travel. If actual time at entry and exit are noted, an estimate of the journey speed of the vehicles can also be obtained.
- For heavy traffic sampling techniques can be adopted. Like, only numbers ending with pre-selected digits are recorded
- The manual analysis of the data is complicated and hence electronic computers are often used.

7. Tags on Vehicle Survey:

- In this method at each point where the roads cross the cordon line, vehicles are stopped and a tag is fixed, usually under a windscreen wiper. The vehicles are again stopped at the exit points and tags are removed.
- The tags for different survey stations have different shapes or colors to identify the survey station. The time of entering and leaving the area are marked on the tags to know the journey times.
- Regular sampling (such as every 2^{nd}, 3^{rd}, 5^{th}) may be used and the expansion factors are determined accordingly.
- The survey can be conveniently divided into 15 or 30-minutes intervals.

- The analysis is simple and errors are not very large.

8. Public Transportation Survey:

- The survey is conducted to assess the number of bus passengers passing through an external cordon. The survey can be either by direct interview with the passengers or by issuing post card questionnaires.
- Direct interview is likely to result in large delays and requires large number of interviews. In order to minimize delays, the interviewer my enter the vehicle and carry out the interviews while vehicle in motion. Post-card questionnaires eliminate delay, but are likely to get poor response or contain an element of bias.

INVENTORY OF TRANSPORT FACILITIES

The inventory of existing transportation 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:

1. Inventory of street forming the transport network
2. Traffic volume, composition peak and off-peak
3. Studies on travel time by different models
4. Inventory of public transport buses
5. Inventory of rail transport facilities
6. Parking inventory
7. Accident data

1. Inventory of streets: it covers details such as classification of street system, length, cross sectional dimensions, type and condition of the surface, capacity, intersections, control devices, structures, street furniture etc.

2. Traffic Volume: the data pertaining to traffic volume and its composition will be needed to check on the survey data collected by home interview and cordon survey.

The variation of the traffic volume over different hors of the day, different days of the week and different month of the year is also needed.

3. Travel time studies: an estimate of travel time between different zones by various modes is necessary for transport planning. Travel times are usually measured for the peak hour conditions non-peak hour conditions.

4. Inventory of public transport buses: The inventory on public transport buses include information on the total number of buses, their capacity, schedules, routes, operating speeds, terminals, number of passengers carried and the fare structures.

5. Inventory on rail transport facilities: It includes length, capacity, schedules, operating speed, stations, number of passengers carried and fare structures.

6. Parking Inventory: it should collect information on the existing on street and off street parking facilities, parking demand data, parking charges and system used for charging should be collected.

7. Accident data: Accident data over the past year will help to understand the nature and extent of the hazards inherent in the present system and the need to improve the situation.

INVENTORY OF LAND USE

- Since travel characteristics are closely relate to the land-use pattern, it is of upmost importance that an accurate inventory of land use be prepared
- The zones are classified into land use activity such as residential, industrial, commercial, recreational, open space and so on.
- If any master plan has to be prepared for Unban Transport Planning, the same land use pattern should be given due consideration.
- Aerial photography has also been used as a source of land use data.

INVENTORY OF ECONOMIC ACTIVITIES

Data on economic activities should be collected to include the following:

1. Population of the survey area and the various zone
2. Age, sex, and composition of the family
3. Employment statistics
4. Housing statistics
5. Income
6. Vehicle ownership

Some of the data pertaining to the economic activities will be already available from periodic census. The population census data helps in the estimation of the future trip making behaviours. Population density maps indicating the density, school enrolment, institutional population and sociological factors will facilitate a better understanding of the travel pattern

EXPANSION DATA FROM THE SAMPLES

In order to derive the travel characteristics of the whole population from the data derived from the sampling, certain expansion factors have to be used.

The expansion factor for home interview survey is calculated on a zonal basis as follows:

Expansion factor $= \frac{A-\left(\frac{A}{B}\right)[\ C+\frac{C}{B}*D]}{B-C-D}$

Here, A= total number of addresses in the original list

B= total number of address selected a original sample

C= number of sample addresses that are ineligible

D= number of sample addresses where no response is obtained

TYPES OF SAMPLING: SAMPLING METHODS

Population - The entire group that you want to draw conclusions about.

Sample - The specific group of individuals that you will collect data from.

Sampling frame - The sampling frame is the actual list of individuals that the sample will be drawn from. Ideally, it should include the entire target population (and nobody who is not part of that population).

Sample size - The number of individuals you should include in your sample depends on various factors, including the size and variability of the population and your research design.

Sampling

Sampling is a technique of selecting individual element of the population to make statistical inferences from them and estimate characteristics of the whole population. Different sampling methods are widely used in transportation surveys which includes:

- **Probability sampling:** Probability sampling is a sampling technique where surveyor sets a selection of a few criteria and chooses samples from the population randomly. All the members of population have an equal opportunity to be a part of the sample with this selection parameter.
- **Non-probability sampling**: In non-probability sampling, surveyor chooses sample at random. This sampling method is not a fixed or has predefined selection process which makes it difficult for all elements of a population to have equal opportunities to be included in a sample.

Types of probability Sampling:

1. Simple random sampling

In a simple random sample, every element of the population has an equal chance of being selected. The sampling frame should include the whole population.

To conduct this type of sampling, surveyor can use tools like random number generators or other techniques that are based entirely on chance.

Example:

It is required to select a sample of 100 household from zone X of total population 1000, assign a number to every household in that zone from 1 to 1000, and use a random number generator to select 100 numbers.

2. Systematic sampling

Systematic sampling is similar to simple random sampling, but it is usually slightly easier to conduct. Every element of the population is listed with a number, instead of randomly generating numbers, individuals are chosen at regular intervals.

Example:

All the households in the zone are listed in order based on parameters like family size/income/car ownership. From the first 10 elements, randomly select a starting point: number 6. From number 6 onwards, every 10th household on the list is selected (6, 16, 26, 36, and so on), and until end up with a sample of 100 households.

3. Stratified sampling

Stratified sampling involves dividing the population into various categories/subgroup. It allows surveyor to draw more precise conclusions by ensuring that every subgroup is properly represented in the sample.

To use this sampling method, divide the population into subgroups (called strata) based on the relevant characteristic (eg: age range, income, car ownership).

Based on the overall proportions of the population, calculate how many households should be sampled from each subgroup. Then use random or systematic sampling to select a sample from each subgroup.

Example:

The zone has 800 households with car ownership rate as 1 and 200 households with car ownership rate 2. Sort the population into two strata based on car ownership rate. Then use random sampling on each group, selecting 80 from households with car ownership 1 and 20 from households with car ownership rate 2, which gives a representative sample of 100 households.

4. Cluster sampling

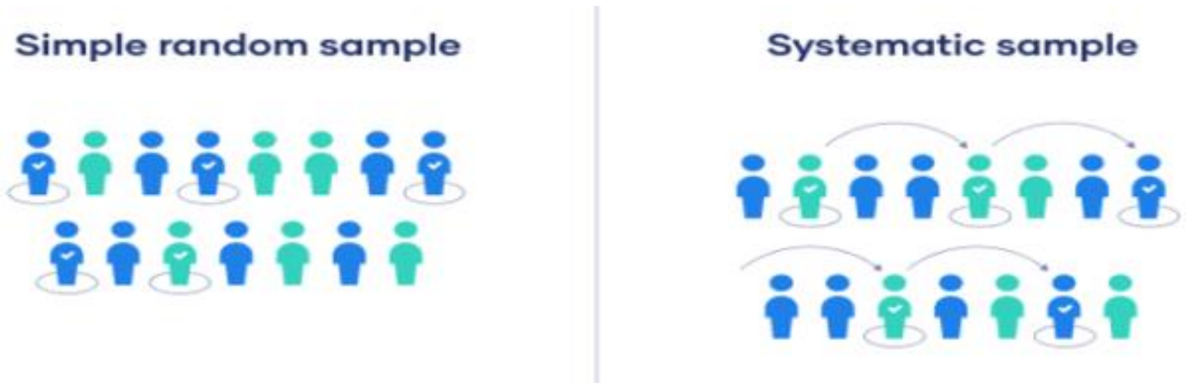
Cluster sampling also involves dividing the population into subgroups, but each subgroup should have similar characteristics. Instead of sampling individuals from each subgroup, randomly select entire subgroups.

If it is practically possible, surveyor might include every element from each sampled cluster. If the clusters are large, sample the element from within each cluster using one of the techniques above. This is called multistage sampling.

This method is good for dealing with large and dispersed populations, but there is more risk of error in the sample, as there could be substantial differences between clusters. It’s difficult to guarantee that the sampled clusters are really representative of the whole population

Example:

The study area has 10 zones (all the zones with roughly the same land use characteristics). When it is not possible to collect data from all the zones, surveyor use random sampling to select 3 zones as a cluster and surveys will be conducted.



Non-probability sampling methods

1. Convenience sampling

A convenience sample simply includes the elements which are more accessible to the surveyor. This is an easy and inexpensive way to gather initial data, but there is no way to tell if the sample is representative of the population, so it can't produce generalizable results.

Example:

You are researching opinions about student support services in your university, so after each of your classes, you ask your fellow students to complete a survey on the topic. This is a convenient way to gather data, but as you only surveyed students taking the same classes as you at the same level, the sample is not representative of all the students at your university.

2. Purposive sampling

This type of sampling, also known as judgement sampling, involves the surveyor using their expertise to select a sample that is most useful to the purposes of the studies. An effective purposive sample must have clear criteria and rationale for inclusion.

Example:

You want to know more about the opinions and experiences of disabled students at your university, so you purposefully select a number of students with different support needs in order to gather a varied range of data on their experiences with student services.

3. Quota sampling

This method of sampling surveyors is given a quota of elements of a specified type for the studies.

Example:

an interviewer might be told to go out and select 20 adult men, 20 adult women, 10 teenage girls and 10 teenage boys so that they could interview them about their television viewing. Ideally the quotas chosen would proportionally represent the characteristics of the underlying population.

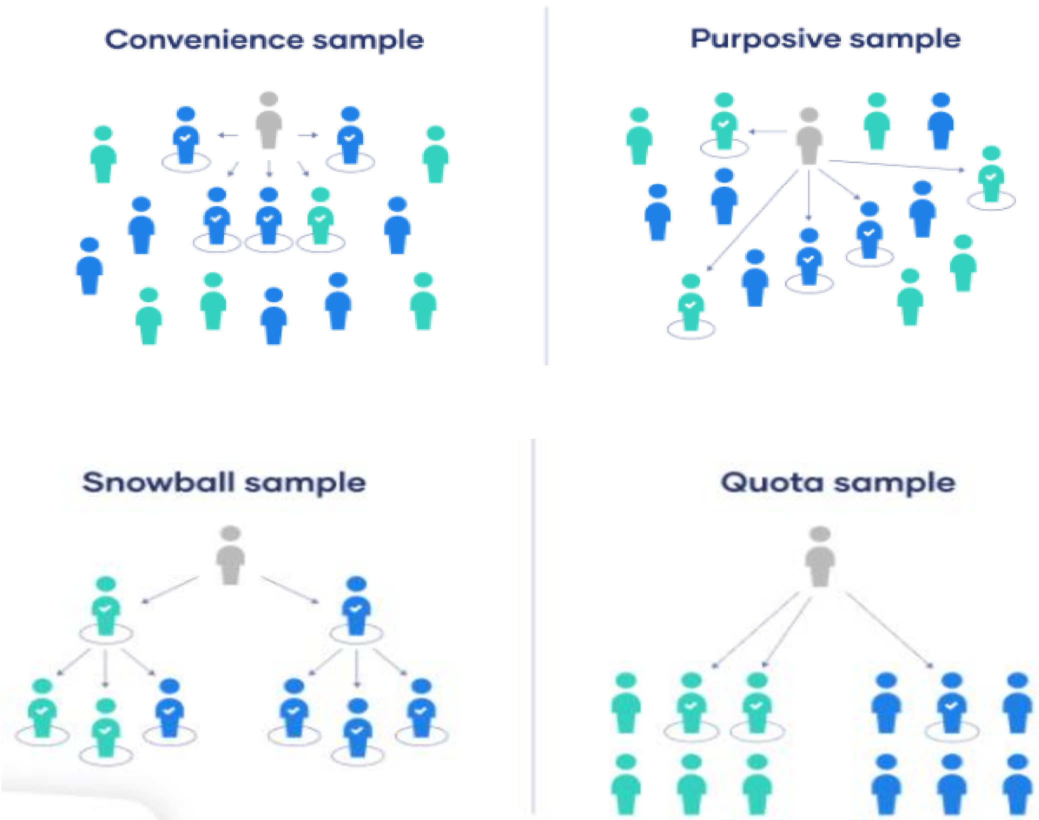
Whilst this has the advantage of being relatively straightforward and potentially representative, the chosen sample may not be representative of other characteristics that weren't considered (a consequence of the non-random nature of sampling). 2

4. Snowball sampling

If the population is hard to access, snowball sampling can be used to recruit participants via other participants. The number of people you have access to "snowballs" as you get in contact with more people.

<u>Example:</u>

You are researching experiences of homelessness in your city. Since there is no list of all homeless people in the city, probability sampling isn't possible. You meet one person who agrees to participate in the research, and she puts you in contact with other homeless people that she knows in the area.



MODULE 3

TRIP GENERATION AND DISTRIBUTION

The first phase of transportation planning 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 describe trip making behaviour. The analysis and model building phase start with the step **Trip Generation.**

Definition: Trip generation is a general term used in the transportation Planning Process to cover the field of calculating the number of trip ends in the given area.

Objective: To understand the reason behind the trip making behavior and to produce mathematical relationship to synthesis the trip making pattern on the basis of observed trips, land-use data and house hold characteristics

Trip: a trip is a one-way person movement by a mechanized mode of transport having two trip ends, origin (start of trip) and destination (end of trip).

Trips are divided into Home-based trips and Non- Home based trips

Home-based trips: If either origin or destination of the trip is the home of the trip maker, such trips are termed as Home-based trips

Ex: School trips, work purpose trips

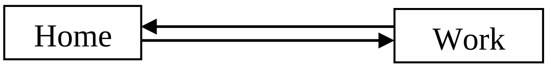


Fig: Home based trip

Non- Home based trips: Non- Home based trips are those having neither end at the home of the person making the trip.

Ex: Work to shop, work to bank

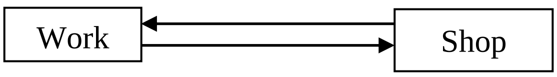


Fig: Non home based trip

- Consider a trip from home-work and then return trip from work-home (fig: a). both these trips are home-based, but both these trips are considered to have been generated at home zone and attracted to the work zone. We but we thus have two work-purpose trip end generation in home zone and two work-purpose attraction in work zone
- Consider another example of the trip from work-shop and then return trip from work-shop (fig: b). both these trips are non home-based, but both these trips are considered to have been generated at work zone and attracted to the shop zone. We but we thus have two

shopping-purpose trip end generation in work zone and two shopping-purpose attraction in shopping zone

Thus, Total number of trips generations = Total number of trips generations

Trip Purpose

The following are some of the important classes of trip purpose:

- Work
- School
- Business
- Social or recreational, sports
- Others

Among above mentioned types, work purpose and school purpose trips are home based trips and contributes to about 80-90% of total trips.

Factors Governing Trip Generation and Attraction Rates

The various factors governing trip generation and attraction rates/ factors affecting travel demand are:

1. Income
2. Car Ownership
3. Family size and Composition
4. Land use characteristics
5. Distance of the zone from the town centre
6. Accessibility to public transport system and its efficiency
7. Employment opportunities, floor space in the industrial and hopping unit and offices, sales figures in shops etc

1. Income: family income represents its ability to pay for a journey. In general, higher the income higher is the trip generation rate.

2. Car ownership: A represents easy mobility, and hence a car owing household will generate more trips than a non-car-owning household. More cars in a household generates more number of trips.

3. Family size and composition:

- The bigger the family, the more trips are likely to be generated.
- Composition of the family also influences trip generation. For instance, if both husband and wife are employed, the trip generated will be more than only the husband is employed. If there are many school goings children, the number of school trips will be large.

- The age structure of the family also governs the trip rates. Old persons are not expected to generate as many trips as younger ones.

4. Land use characteristics: Different land uses produces different trip rates. Ex: a residential area with a high density of dwellings can produce more trip than one with low dwelling. On other hand the area with low dwelling represents dwellings of affluent society, which produces a greater number of private car trips.

5. Distance of the zone from the town centre: The distance of the zone from the town centre is an important factor determining number of trips. The farther the town center, the less the numbers of trips are likely to be

6. Accessibility to public transport system and its efficiency: the accessibility to a public transport and its efficiency determines to some extent the desire of person to make trips. An easily accessible and efficient public transport system generates more trips.

7. Employment opportunities, floor space in the industrial and hopping unit and offices, sales figures in shops etc: The employment potentiality of an industrial or shopping unit or an office establishment directly governs the trip attraction rate.

TRIP GENERATION MODELS

1. Multiple Linear Regression Analysis

- Multiple linear regression analysis is a well-known statistical technique for mathematical relationships between dependent and independent variables
- In trip generation equations, the dependent variables is the number of trips and the independent variables are various factors influencing trip generation like land-use and socio-economic characteristics

Assumptions in Multiple Linear Regression Analysis

- All the variables are independent of each other
- All the variables are normally distributed
- All the variables are continuous
- A linear relationship exit between the dependent and independent variables
- Influence of independent variables is additive that is the inclusion of each variable in the equation contributes a distinct portion of the trip number

Problem: The following information was obtained from a transportation survey of a town:

Traffic zone number	Population in the zone (in thousand)	Total trip generated (in hundreds)
1	26	12
2	28	11
3	31	17
4	33	15
5	22	12
6	30	15
7	20	9
8	25	13

Develop a linear regression model for estimating the trips generated from a zone. If the population in a particular zone increases to 40,000 predict the expected trip generation from that zone.

Solution:

In this case there is one dependent variable population and problem is to develop multiple linear regression equation of form:

$$Y = b_0 + b_1X_1$$

Y = total number of trips in hundred per zone, being the dependent variable

X_1= Population in the zone (in thousand), being independent variable

b_0= regression constant

b_1= regression co-efficient

The equation is calibrated for b_0 and b_1 by the following formulae:

$$b_1 = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2}$$

$$b_0 = \frac{(\Sigma y - b_1\Sigma x)}{n}$$

Also, the correlation co-efficient r which tells about goodness of fit, is obtained by:

$$r = b_1\left[\frac{n\Sigma x^2 - (\Sigma x)^2}{n\Sigma y^2 - (\Sigma y)^2}\right]$$

Here, n= total number of observations

Zone	**x**	**y**	**xy**	**x^2**	**y^2**
1	26	12	312	676	144
2	28	11	308	784	121
3	31	17	527	961	289
4	33	15	495	1089	225
5	22	12	264	484	144
6	30	15	450	900	225
7	20	9	180	400	81
8	25	13	325	625	169
n=8	$\Sigma x = 215$	$\Sigma y = 104$	$\Sigma xy = 2861$	$\Sigma x^2 = 5919$	$\Sigma y^2 = 1398$

Substituting the values in the above formulae,

$$b_1 = \frac{8 \times 2891 - 215 \times 104}{8 \times 5919 - (215)^2} = 0.469$$

b_0 = (104- 0.469×218)/8 = 0.396

Therefore, the trip[generation model is

$$y = 0.396 + 0.469\,x$$

The co-relation coefficient for this mode is

$$r = 0.469\left[\frac{8 \times 5919 - (215)^2}{8 \times 1398 - (104)^2}\right] = 0.82$$

The linear regression model is given by:

$$y = 0.396 + 0.469\,x, r = 0.82$$

(b) If future population of a zone = 40,000

$x = 40\ for\ use\ in\ model$ (in thousands)

The total trips generated , $y = 0.396 + 0.469 \times 40 = 19.16\ in\ thousands = 19160$

Limitations

i. The independent variables in the regression equations are not truly independent of each other and some sort of correlation normally exit among them. Ex: Car-ownership, family income, residential density is inter-related etc
ii. Many of the variables are not normally distributed
iii. Some of the variables are not continuous. Ex: being the car ownership, the number of cars owners by the family can only be a discrete variable

With all the above imperfections, the method gain popularity because of its easy adoptability for computer programming when handling voluminous data

Multiple linear regression analysis is of two types:

i) Aggregated or Zonal least-square regression
ii) Disintegrated or Household least-square regression

Aggregated or Zonal least-square regression: In this analysis each traffic zone is treated as one observation. Aggregate analysis is most widely used and is based on the assumption that contiguous households exhibit a certain amount of similarities in travel characteristics. This assumption allows the data in zone to be grouped and the mean value of the independent variables used in further calculation.

Disintegrated or Household least-square regression: Though the method not so widely used, analysis treats each household as an observation. In this process all the enormous amount of data is used more efficiently resulting in a more meaningful description of characteristics.

Disadvantage of Multiple Linear Regression Analysis Technique

1. The equation derived is purely empirical in nature and fails to establish a meaningful relationship between the dependent and independent variables.
2. The technique is based on the premise that the regression co-efficient initially established remain unchanged in the future and can be used in the equation for predicting future travel. How far the prediction is valid is a question.
3. Difficulties arise in evaluating the effect of statistical problems relating to non-linearity of the response surface and high correlation amongst the explanatory variables.

2. Category Analysis / Cross-Classification Technique

Category analysis is based on determining the average response or average value of the dependent variable defines categories of independent variables. A multi-dimensional matrix defines categories, each dimension in matrix representing one independent variable. The independent variables themselves are classified into a definite number of discrete class interval.

Assumptions:

The technique is based on the following assumption:

1. The household is the fundamental unit in the trip generation process, and most journeys begin and end in response to the requirement of family
2. The trip generated by the household depend upon the characteristics of that household and its location relative to its required facilities such as shops, school and work place
3. Households with one set of characteristics generate different rates of trips from households with other sets of characteristics
4. Only three factors are of prime importance in in affecting the amount of travel a household produces: car-ownership, income and household structure
5. Within the above three factors, a limited number of ranges can be established so as to describe the trip-generating capacity of a household by a limited number of categories
6. 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.

Categorization of Households

Households are classified on the basis of three factors: Car ownership, Income and Household Structures. These are then classified into different ranges as indicated below:

- Car Ownership- 3 levels (0 car, 1 car and more than 1 car)
- Income – 6 Classes:

  i) < 500 pa ii) 500-1000 pa iii) 1000-1500 pa

  iv) 1500-2000 pa v) 2000-2500 pa vi) >2500 pa
- Household Structure- 6 classes
  i) No employed resident and one non-employed adult
  ii) No employed resident and two or more non-employed adults
  iii) One employed resident and one or less non-employed adult
  iv) One employed resident and two or more non-employed adults
  v) Two or more employed residents and one or less non-employed adult
  vi) Two or more employed residents and two or more non-employed adults

The above system gives in all 3×6×6 = 108 categories

In addition it is possible to consider 3 modes of travel viz self-driven car, public transport, passenger in a car and 6 trip purpose (work, school, business, shopping, social- recreational and sport others). Thus we have 3×6=18 mode purpose combinations.

Advantages:

1. The whole concept of household trip making is simplified in this technique. The technique categories the household according to certain socio-economic characteristics and this appears rational.
2. Unlike regression analysis technique, no mathematical relationship is derived between trip-making and household characteristics. This takes away many of the statistical drawbacks of the regression analysis.
3. Since data from the census can be used directly, it saves considerable effort, time and money spent on home-interview survey
4. The consumptions are relatively simpler
5. Since disaggregate data used, the technique simulates human, behaviour more realistically than zonal aggregation process normally employed in regression analysis

Disadvantages:

1. It is difficult to test the statistical significance of various the various explanatory variables
2. The technique normally makes use of studies in the past made else ware, with broad corrections
3. New variables cannot be introduced at the future date
4. Large samples are needed to assign trip rates to any one category

TRIP DISTRIBUTION

After obtaining the details of trip generated from and attracted to various zones, it is necessary to determine the direction of travel. The number of trips generated in every zone in the study area has to be distributed to the zones to which these trips are attracted.

If g_i is the number of trips generated in zone *i* and a_j is the number of trip ends attracted to zone *j*, the trip distribution stage determines the number of trips t_{i-j} which would originate from zone *i* and attracted to zone *j*. Trip distribution between any two zones can be represented by O-D matrix as shown below

Production \ Attraction	1	2 . . .	j . . .	n	$\sum_j n_{ij}$
1	n_{11}	n_{12}	n_{1j}	n_{1n}	G_1
2 ⋮	n_{21}	n_{22}	n_{2j}	n_{2n}	G_2
i ⋮	n_{i1}	n_{i2}	n_{ij}	n_{in}	G_i
n	n_{n1}	n_{n2}	n_{nj}	n_{nn}	G_n
$\sum_i n_{ij}$	A_1	A_2	A_j	A_n	$\sum_{ij} n_{ij} = N$

- Horizontal axis represents zones of attraction/ destination D, 1,2,3,4……*j*…. n
- Vertical axis represents zones of generation/ origin O, 1,2,3,4……*i*…. n
- t_{i-j} represents number of trips originating in zone *i* and attracted to zone *j*
- Total of any individual row, *i* represents the total number of trips generated in zone, G_i
- Total of any individual column, *j* represents the total number of trips attracted to zone, A_j

Methods of Trip Distribution

1. Growth factor methods

a) Uniform factor method
b) Average factor method
c) Fractor method
d) Furness method

2. Synthetic models
   a) Gravity models
   b) Tanner models
   c) Intervening opportunities model
   d) Competing opportunities model

Growth Factor Methods

It is based on assumption that the present travel pattern can be projected to the design year in the future by using certain expansion factors. In general, it is represented as:

$$T_{i-j} = t_{i-j} \times E$$

Where T_{i-j} = design year(future) number of trips from zone i to zone j

t_{i-j} = observed base year number of trips from zone i to zone j

E = growth factor

1.Uniform growth factor

This method assumes that the growth rate for the whole are a is valid for predicting future inter-zonal trips. A single growth factor, E for entire area is obtained by dividing the future number of trip ends expected in the survey area for the design year by the trip ends in the base year.

The future trips between zone i and j is calculated as:

$$T_{i-j} = t_{i-j} \times E$$

Example: The distribution of present trips among zone 1,2, and 3 are given in O-D matrix below. The future trips generated in zone 1, 2 and 3 are expected to be 360, 1260 and 3120 respectively. Distribute the future trips among various zones.

	1	2	3
1	60	100	200
2	100	20	300
3	200	300	20

Solution:

	1	2	3	t_i	T_i

1	60	100	200	360	360
2	100	20	300	420	1250
3	200	300	20	520	3120
Total				1300	4740

t_i – represents the row total, i.e. total of the trips generated in the three zones = 1300

T_i – represents the future trips generated in the three zones = 4740

Growth factor, $E = \frac{Ti}{ti} = \frac{4740}{1300}$ = **3.646**

Multiplying the cells in the matrix by the uniform growth factor of E= 3.646, results in following matrix

	1	2	3	T_i (Calculated)	T_i (Given)
1	218	365	729	1312	360
2	365	73	1094	1532	1260
3	729	1094	73	1896	3120
Total				v4740	4740

The trips have been distributed among three zones resulting in total trips of 4740, which is same as the total of future trips as per data given. But the total trips generated in each zone is not tally with the values given, this is because of assumption of uniform growth.

Disadvantage of Uniform growth rate method

- The assumption of a uniform growth rate for the entire study area is not correct, because each zone will have its own growth rate and the growth rate of traffic between any two zones will be different
- The method underestimate movements where present-day development is limited and over-estimates movements where present-day development is intensive
- If present trip movement between any two zones is zero, the future trip moment also becomes zero as per this method. This may rarely be the case in reality.

2. Average Factor Method

In this method, a growth factor for each zone is calculated based on the average of the growth factors calculated for the both ends of the trip. The factor thus represents the average growth associated with both with the origin and destination zones.

Thus, $T_{i-j} = t_{i-j} \times [\frac{Ei+Ej}{2}]$

Where, T_{i-j} = design year (future) number of trips from zone i to zone j

t_{i-j} = observed base year number of trips from zone i to zone j

$E_i = \frac{P_i}{p_i}$ =growth factor for zone i

$E_j = \frac{A_j}{a_j}$ =growth factor for zone j

P_i = future generated trips for zone i

p_i = present generated trips for zone i

A_j = future attracted trips for zone j

a_j = present attracted trips for zone j

After the distribution is completed on the above basis, the sum of the trips from zone i will probably not agree with the projected trip ends in zone i and the sum of the trips to zone j will not agree with projected trip ends in zone j. This is overcome by an iterative process using the new values for E_i and E_j calculated from:

$$E_i' = \frac{P_i}{p_i'}$$

$$E_j' = \frac{A_j}{a_j'}$$

Where p_i' and a_j' are total generations and attraction to zone i and j respectively obtained from first stage of distribution. The iteration is carried out till the growth factor approaches unity and the values matches within, say plus or minus 1%

Example: The distribution of present trips among zone 1,2, and 3 are given in O-D matrix below. The future trips generated in zone 1, 2 and 3 are expected to be 360, 1260 and 3120 respectively. Distribute the future trips among various zones.

	1	2	3
1	60	100	200
2	100	20	300
3	200	300	20

Solution:

	1	2	3	p_i	P_i	$E_i = P_i / p_i$

1	60	100	200	360	360	1
2	100	20	300	420	1250	3
3	200	300	20	520	3120	6
a_j	360	420	520	**1300**	**4740**	
A_j	360	1260	3120			
$E_j = A_j / a_j$	1	3	6			

Average Growth factor, $E = [\frac{Ei+Ej}{2}]$

Future trips generated, $T_{i-j} = t_{i-j} \times [\frac{Ei+Ej}{2}]$

Thus,

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

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

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

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

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

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

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

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

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

Thus, the matrix becomes:

	1	2	3	p_i	P_i	$E_i' = P_i / p_i$
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	960	1610	2170	**4740**		
A_j	360	1260	3120		**4740**	
$E_j' = A_j / a_j$	0.375	0.783	1.438			

For the next iteration the new values of interzonal movements are calculated with the new E, shown as E' in the last column of the above matrix

II Iteration

	1	2	3	p_i	P_i	$E_i' = P_i / p_i$
1					360	
2					1260	
3					3120	
a_j				**4740**		
A_j	360	1260	3120		**4740**	
$E_j' = A_j / a_j$						

Disadvantages:

- The average factor method has same disadvantages of the uniform factor method. The multiplying factor has no real significance and only a convenient tool to balance the movements.
- If t_{i-j} is zero T_{i-j} also becomes zero a in case the case of uniform factor method
- It has additional disadvantage that a large number of iterations is required

3. Fratar Method

In this method, the total trips for each zone are distributed to the interzonal movements, as a first approximation, according to the relative attractiveness of each movement. Thus, the future trip estimated for any zone would be distributed to the movement involving that zone in proportion to the expected trips between it and each other zone and in proportion to the expected growth of other zone. It is expressed mathematically as follow:

$$T_{i-j} = t_{i-j} \times \frac{P_i}{p_i} \times \frac{A_j}{a_j} \times \frac{\sum^k t_{i-k}}{\sum^k [\frac{A_k}{a_k}] t_{i-k}}$$

Where T_{i-j} = design year (future) number of trips from zone i to zone j

t_{i-j} = observed base year number of trips from zone i to zone j

P_i = future generated trips for zone i

p_i = present generated trips for zone i

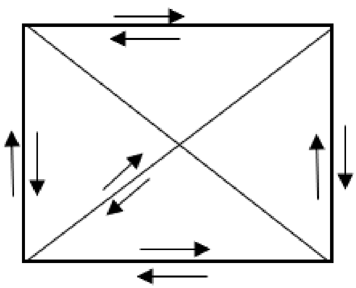
A_j = future attracted trips for zone j

a_j = present attracted trips for zone j

k = Total number of zones

when the future traffic into and out of all zones is similarly distributed, each interzonal trips has been assigned two tentative values.

- The result of distribution for one of the zones involved
- The result of distribution for another zone involved



As a first approximation those pair of tentative values are averaged and anew growth factor for each zone is then calculated. The process is repeated till the growth factor approaches unity and the values matches within, say plus or minus 1%

Problem: The distribution of present trips among the zone A, B, C and D are given in the O-D matrix below. The future trips generated in zones A, B, C and D are expected to be 80, 114, 48 and 38 respectively. Distribute future trips among the zones.

	A	B	C	D
A	-	10	12	18
B	10	-	14	14
C	12	14	-	6
D	18	14	6	-
Present Total	40	38	32	38
Estimated Future Total	80	114	48	38
Growth Factor	2	3	1.5	1

Solution:

We have $$T_{i-j} = t_{i-j} \times \frac{P_i}{p_i} \times \frac{A_j}{a_j} \times \frac{\sum^k t_{i-k}}{\sum^k [\frac{A_k}{a_k}]t_{i-k}}$$

$$T_{A-B} = t_{A-B} \times \frac{P_A}{p_A} \times \frac{A_B}{a_B} \times \frac{t_{AB}+t_{AC}+t_{AD}}{t_{AB}\,E_B+t_{AC}E_C+t_{AD}E_D}$$

$$= 10 \times \frac{80}{40} \times \frac{114}{38} \times \frac{40}{10(3)+12(1.5)+18(1)} = 36.4$$

Zone	A	B	C	D	Sum of product of trip ends and growth factors	Desired Trips	Ratio of new total trips to sum of products
Growth factors	2	3	1.5	1			
For zone **A**							
1	–	10	12	18			
2	–	30	18	18	**66**		
3	–	36.4	21.8	21.8		**80**	1.21
For zone B	–						
1	10	–	14	14			
2	20	–	21	14	**55**		
3	41.5	–	43.5	29		**114**	2.07
For zone C							
1	18	14	–	6			
2	24	42	–	6	**72**		
3	16	28	–	4		**48**	0.667
For zone D							
1	18	14	5	–			
2	36	42	9	–	**87**		
3	15.8	18.3	8.9	–		**38**	0.437

The pair of interzonal volumes obtained by the above computation are averaged and shown below to obtain fair approximation for inter zonal trips

	A-B	A-C	A-D	B-C	B-D	C-D
	36.4	21.8	21.8	43.5	29	3.9
	41.5	16	15.8	28	18.3	4
Total	77.9	37.8	37.6	71.5	47.3	7.9
Average	39.9	18.9	18.8	37.5	23.6	40

The average of trips radiating from each zone are summarized to obtain new goth factors

	A	B	C	D

A	–	39.9	18.9	18.8
B	39.9	–	37.5	23.6
C	18.9	35.7	–	7.9
D	18.8	39.9	7.9	–
New totals	77.6	115.5	64.3	50.3
Desired Total	80	114	48	38
New GF	1.04	1.16	0.82	0.82

The procedure is repeated to obtain a second approximation using new growth factor.

4. Furness Method:

This method to distribute the traffic, an estimate of future traffic originating and terminating at each zone are required, thus yielding origin growth factors and destination growth factors for each zone. The traffic movements are made to agree alternatively with the future traffic originating in each zone and the estimated future terminating in each zone, until both these conditions are roughly satisfies.

Problem: The distribution of present trips among the zones A, B, C and D are given below in the O-D matrix below. Distribute the future trips among zones.

	A	B	C	D	Total present trips	Predicted future trips	Origin Growth factor
A	8	3	16	15	42	147	3.5
B	6	9	8	5	28	42	1.2
C	10	8	3	8	29	32	1.1
D	2	4	7	12	25	30	1.2
Total present trips	26	24	34	40	124		
Predicted future trip	39	24	68	120		251	
Destination Growth factor	1.5	1.0	2.0	3.0			

Solution:

The values of predicted future origin and destination growth factors are calculated for each zone.

Step:1 Each column is multiplied by destination GF such that column total become equal to predicted future trip totals

	A	B	C	D	Total present trips	Predicted future trips	Origin Growth factor

A	12	3	32	45	92	147	1.6
B	9	9	16	15	49	42	0.86
C	15	8	6	24	53	32	0.60
D	3	4	14	36	57	30	0.5
Total present trips	39	24	68	120	**251**		
Predicted future trip	39	24	68	120		**251**	
Destination Growth factor	1	1	1	1			

Step:2 Each row is multiplied by origin GF such that row total become equal to predicted future trips totals

	A	B	C	D	Total present trips	Predicted future trips	Origin Growth factor
A	19.2	4.8	51.2	72	147.20	147	1
B	7.74	7.74	13.76	12.9	42.14	42	1
C	9.0	4.8	3.6	14.4	31.8	32	1
D	1.59	2.12	7.42	19.08	30.21	30	1
Total present trips	37.57	19.46	75.98	118.38	**251.35**		
Predicted future trip	39	24	68	120		**251**	
Destination Growth factor	1.04	1.23	0.89	1.01			

Columns are now scaled again using the new destination growth factors and the iterative procedure is repeated until all growth factors are unity or near to unity

MODULE 4

TRIP DISTRIBUTION AND MODAL SPLIT

Synthetic Models

In the synthetic models of trip distribution, an attempt is made to discern the underlying cause of movement between places and relationship are established between places and relationship are established between trips measures of attraction, generation and travel distance.

It is used not only to predict future trip distribution but also to synthesize the base year flow.

1. Gravity Model

The model assumes that the interchange of trips between zones in an area is dependent upon the relative attraction between the zones and the spatial separation between them as measured by an appropriate function of distance. This spatial separation adjusts the relative attraction of each zone for the ability, desire or necessity of the trip maker to overcome the spatial separation.

This interchange is directly proportional to the relative attraction between the zones and is inversely proportional to the measure of spatial separation.

$$T_{i-j} = \frac{KP_iA_j}{d_{i-j}}$$

The following formula was also used in earlier studies dispensing with the proportionality constant.

$$T_{i-j} = P_i \times \frac{\frac{A_j}{(d_{i-j})^n}}{\frac{A_j}{(d_{i-j})^n} + \cdots\ldots\frac{A_k}{(d_{i-j})^n}}$$

In order to simplify the computation requirements, the following formula is used

$$T_{i-j} = \frac{P_iA_{jm}F_{i-j}K_{i-j}}{\sum_{x=1}^{k} A_{km}F_{(i-k)}K_{(i-k)}}$$

Where, T_{i-j} = design year (future) number of trips from zone i to zone j

P_i = future generated trips for zone i

A_j = future attracted trips for zone j

d_{j-j} = distance between zone i and zone j, or time or cost of travelling between them

K = a constant, usually dependent on i

n = exponential constant, whose value is usually found to lie between 1 to 3

k = total number of zones

F_{i-j} = Empirically derived travel time factor which expresses the average area wide Effect of spatial separation on trip interchange between zone i-j

K_{i-j}= a specific zone to zone adjustment factor

Example:

1. A self-contained town consists of four residential areas A,B,C & D and two industrial estates X and Y. Generation equations shows that, for the design year in question, the trips from home to work generated by each residential area per 24 hour/day area as follows:

A	1000

B	2250
C	1750
D	3200

There are 3700 jobs in industrial estate X and 4500 in industrial estate Y. It is well known that attraction between zones is inversely proportional to the square of the journey times between zones. The journey times in minutes from home to work are

Zones	X	Y
A	15	20
B	15	10
C	10	10
D	15	20

Calculate and tabulate the inter zonal trips for journey from home to work

Solution: We have

$$T_{i-j} = P_i \times \frac{\frac{A_j}{(d_{i-j})^n}}{\frac{A_j}{(d_{i-j})^n} + \cdots\ldots \frac{A_k}{(d_{i-j})^n}}$$

Given n=2

$$T_{A-X} = 1000 \times \frac{\frac{3700}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(20)^2}} = 604$$

$$T_{A-Y} = 1000 \times \frac{\frac{4500}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(20)^2}} = 396$$

$$T_{B-X} = 2250 \times \frac{\frac{3700}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(10)^2}} = 604$$

$$T_{B-Y} = 2250 \times \frac{\frac{4500}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(10)^2}} = 1646$$

$$T_{C-X} = 1750 \times \frac{\frac{3700}{(10)^2}}{\frac{3700}{(10)^2}+\frac{4500}{(10)^2}} = 790$$

$$T_{C-Y} = 1750 \times \frac{\frac{4500}{(10)^2}}{\frac{3700}{(10)^2}+\frac{4500}{(10)^2}} = 960$$

$$T_{D-X} = 3200 \times \frac{\frac{3700}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(20)^2}} = 1980$$

$$T_{D-Y} = 3200 \times \frac{\frac{4500}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(20)^2}} = 1220$$

The results are tabulated in the matrix below:

Zones	X	Y	Total Production

A	604	396	1000
B	604	1646	2250
C	709	960	1750
D	1980	1220	3200
Total Calculated attraction, C_j	3978	4222	8200
Total predicted attraction, A_j	3700	4500	8200

Total attraction do not tally with the predicted attraction.

Therefore, the attractions are first adjusted as follows:

$$A_{jm} = \frac{A_j}{C_j(m-1)} A_{j(m-1)}$$

Where, A_{jm} = Adjusted attraction function, for iteration 'm'

A_j = Desired attraction

$A_{j(m-1)}$ = Attraction factors, iteration m-1

$C_{j(m-1)}$ = Actual attraction factor, iteration m-1

$$A_{j2}\ for\ zone\ X = \frac{3700}{3978} \times 3700 = 3440$$

$$A_{j2}\ for\ zone\ Y = \frac{4500}{4222} \times 4500 = 4800$$

Recalculating

$$T_{A-X} = 1000 \times \frac{\frac{3440}{(15)^2}}{\frac{3440}{(15)^2}+\frac{4800}{(20)^2}} = 560$$

$$T_{A-Y} = 1000 \times \frac{\frac{4800}{(15)^2}}{\frac{3440}{(15)^2}+\frac{4800}{(20)^2}} = 440$$

$$T_{B-X} = 2250 \times \frac{\frac{3440}{(15)^2}}{\frac{3440}{(15)^2}+\frac{4800}{(10)^2}} = 540$$

$$T_{B-Y} = 2250 \times \frac{\frac{4800}{(15)^2}}{\frac{3440}{(15)^2}+\frac{4800}{(10)^2}} = 1710$$

$$T_{C-X} = 1750 \times \frac{\frac{3440}{(10)^2}}{\frac{3440}{(10)^2}+\frac{4800}{(10)^2}} = 730$$

$$T_{C-Y} = 1750 \times \frac{\frac{4800}{(10)^2}}{\frac{3440}{(10)^2}+\frac{4800}{(10)^2}} = 1020$$

$$T_{D-X} = 3200 \times \frac{\frac{3700}{(15)^2}}{\frac{3700}{(15)^2}+\frac{4500}{(20)^2}} = 1790$$

$$T_{D-Y} = 3200 \times \frac{\frac{4800}{(15)^2}}{\frac{3440}{(15)^2}+\frac{4800}{(20)^2}} = 1410$$

The results are tabulated in the matrix below

Zones	X	Y	Total Production
A	560	440	1000
B	540	1710	2250
C	730	1020	1750
D	1790	1410	3200
Total Calculated attraction, C_j	3620	4580	8200
Total predicted attraction, A_j	3700	4500	8200

Further iteration is carried if more accuracy is required.

2. The total trips produced in and attracted to the three zones A,B & C of a survey area in the design year are tabulated as :

Zone	Trips Produced	Trips Attracted
A	2000	3000
B	3000	4000
C	4000	2000

It is known that the trips between two zones are inversely proportional to the second power of the travel time between zones, which is uniformly 20minutes. If the trip interchange between zones B and C is known to be 600, Calculate the trip interchange between zone A&B, A &C, B&A, C&B

Solution:

We have

$$T_{i-j} = \frac{KP_iA_j}{(t)^n}$$

Given T_{B-C}= 600 P_B= 3000 A_c=2000 n=2 t=20

$$T_{B-C} = \frac{KP_BA_c}{(t)^n}$$

$$600 = \frac{K \times 3000 \times 2000}{(20)^2}$$

$$K = \frac{1}{25}$$

$$T_{A-B} = \frac{1}{25} \times \frac{2000 \times 4000}{(20)^2} = 800$$

$$T_{A-c} = \frac{1}{25} \times \frac{2000 \times 2000}{(20)^2} = 800$$

$$T_{B-A} = \frac{1}{25} \times \frac{3000 \times 3000}{(20)^2} = 900$$

$$T_{C-A} = \frac{1}{25} \times \frac{4000 \times 3000}{(20)^2} = 900$$

$$T_{c-B} = \frac{1}{25} \times \frac{4000 \times 4000}{(20)^2} = 1600$$

2. Tanner Model

Tanner has suggested that the inverse of the n^{th} power, $1/(d_{i-j})^n$ in the gravity model formula cannot give valid estimates at both very small and very large distances. In this place, tanner model proposes the function $e^{\gamma d} / d^n$, where γ and d are constants.

The model can be represented as follows:

$$t_{i-j} = \frac{mP_iP_je_{i-j}^{-\gamma d}}{d_{i-j}} \left[\frac{1}{C_i} + \frac{1}{C_j}\right]$$

Where t_{i-j} = number of trips per day between zone i and j

m= Constant

P_i and P_j are proportioners or other measures of size of two zone i and j respectively

d_{i-j} = distance between i and j or the time or cost of travelling between them

C_i and C_j = consents, one for each place, C_i being defined by

$$C_i = \sum P_j e^{-d_{i-j}}$$

MODAL SPLIT

Modal split is a process of separating person trip by the mode of travel. It is generally expressed as fraction or ratio or percentage of total number of trips.

The objective of modal split is to analyse people’s decision regarding the mode of travel such as auto, bus, train and so on.

Factors affecting Modal Split

The factors affecting choice among alternatives modes are heterogeneous and numerous and is conveniently categorised as follows:

1. Characteristics of trip

2. Household Characteristics
3. Zonal Characteristics
4. Network Characteristics

Characteristics of trip

i. Trip purpose: The choice of mode is guided to certain extent by the trip purpose.
   Example: Home based school trips have high rate of usage of public transport whereas home-based shopping journey can have higher rate of private car usage.
ii. Trip length: The length can govern an individual choice of particular mode. A measure of the trip length is also possible by travel time and cost of travelling.

Household Characteristics

i. Income: The income of the person is the direct determination of the expenses he is prepared to incurred on a journey. Higher income group are able to purchase and maintain private car and thus private car trips are frequent as the income increases.
ii. Car ownership: Car ownership is determined by income and for this reason income and car ownership are inter related in their effect on modal choice.
iii. Family size and composition: The number of persons in the family, the number of school going children, the number of wage earners, the number of employed, the age-gender structure of the family and some other factors connected with socio economic status of the family influence the modal choice.

Zonal Characteristics

i. Residential Density: The use of public transport increases as the residential density increases. In general, higher density areas are served well in public transport system and such areas are oriented towards a better use of public transport system.
ii. Concentration of workers
iii. Distance from CBD

Network Characteristics

i. Accessibility Ratio: It is the measure of the relative accessibility pf that zone to all other zones by means of mass transit network and highway network.
ii. Travel time ratio: The ratio of the travel time by public travel time by public transport and travel time by private car give measure of the attractiveness of public transport system

   The travel time by public transport itself composed of:

- Time spent walking to the public transport vehicle at origin

- Time spent foe waiting for public transport vehicle
- Time spent in public transport vehicle
- Time spent in transfer from one public transport vehicle to another
- Time spent in walking from public transport vehicle to destination.

The travel time by private car is composed of:

- Time spent in driving the car
- Time spent in parking at destination
- Time spent in walking from parked vehicle to destination

In general, as the travel time ratio increases, the usage of public transport system falls down.

iii. Travel-cost ratio: The ratio of cost of travel by public transport and cost of travel by car is one of the most important factors influencing modal choice. The importance of travel cost is related to the economic status. People with high income are unmindful of cost and prefer more expensive modes.

Modal Split in Transport Planning Process

Modal split is considered in transport planning at various stages:

a. Pre-distribution modal split or Trip end modal split
b. Post-distribution modal split or x

Pre-distribution modal split or Trip end modal split

This process can again be carried out at two different stages:

i. At trip generation stage itself
ii. After trip generation but before trip distribution

At trip generation stage

- If modal split is considered at trip generation stage itself, separate multiple linear regression equation for each mode of transport viz car, public transport, rail etc has to be derived.
- The factors normally considered to influence the mode of choice are car ownership, residential density, distance of the origin from CBD and the relative accessibility of the zone of origin to the transport facilities.

- The methods reflect different trip generation patterns for different trip purposes and but fails to take into account future changes in public transport system, improvement in highway system and the restraint on the use of private car by economic means

After trip generation but before trip distribution

- If modal split is carried out after generation but before distribution, the trip generation but before distribution, the trip generations are calculated on the assumption that the mode of travel has no influence on the trip generation.
- The total trip productions and attractions which are determined are allocated to the public transport system and private car by considering the relative attractiveness of each mode as measured by variables considered to govern modal split.
- The distribution is hence carried out as follows

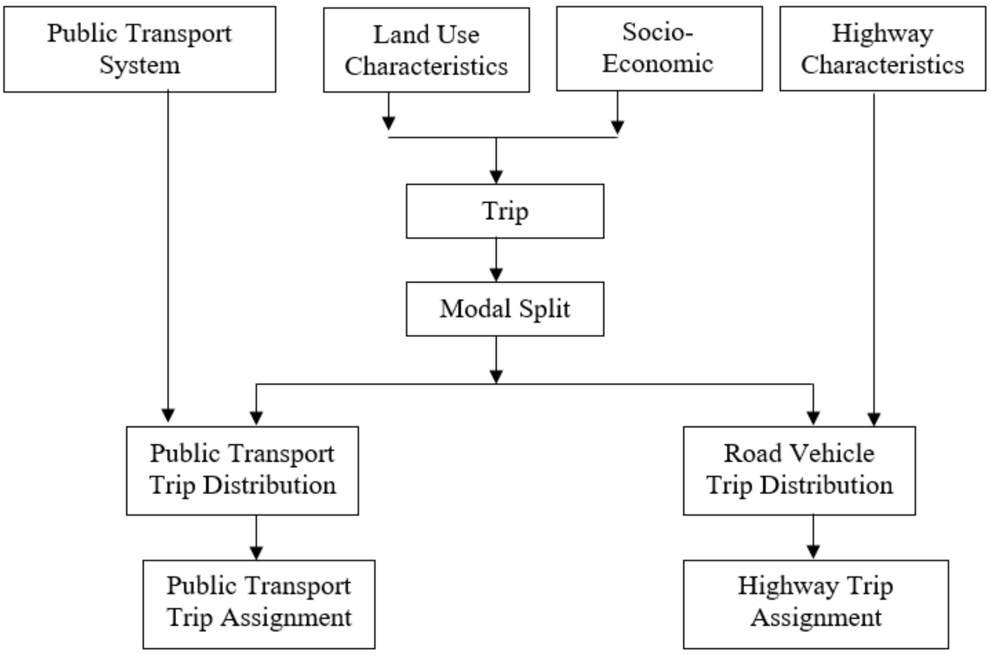


Fig: Modal Split carried out after Trip Generation

<u>Advantages of Trip-end Modal split:</u>

1. Less difficult and less costly when compared with trip interchange modal split
2. The possibility of separate public transport and private car distribution afforded by this method is desirable feature because of the differing trip length by car and public transport
3. This method reflects factors such as the income, car ownership, family structure, employment etc. which are the characteristics affecting trip generation

Disadvantages of Trip-end Modal split:

1. Since the method is reliable on existing and historical levels of public transport service, they are inappropriate to studies involving planning of improvements to public transport system where significantly different levels of service are contemplated.
2. In this method, the characteristics of the transportation system are fed on an average area wide basis. As such, this procedure fails to reflects the particular zone to zone combinations as precisely as trip interchange models.
3. It does not consider the trip generation characteristics fully.
4. It is insensitive to future development in inter-zonal travel.

Trip Interchange Modal Split or Post-Distribution Model

- In post distribution modal split, modal split is carried out after trip generation stage and before trip assignment
- Prior to modal split, zone to zone home based trips are known
- Using home based trips as an input, zone to zone public transport travellers are determined based on variables such as
    a. Characteristics of the person making the journey
    b. Characteristics of the destination end of the journey
    c. Characteristics of the transportation system

  All the variables are measured on zone to zone basis
- Relative travel time and relative travel costs are also considered in the model
- By substituting the zone to zone persons trips, the persons trips made by motor vehicle are derived.

Advantages:

1. It is useful in situations where serious consideration is given in public transport planning
2. The method makes it possible to develop modal split relations based on a wide range of transport system variables influencing modal choice
3. The method considers private car and public transport usage on zone to zone basis instead of a zonal basis as in the pre-distribution methods.

Disadvantages:

1. It is very complex, especially if the number of zones is large
2. In this method, total person trip is considered before any modal choice is considered. This ignores the differing lengths by car and public transport.

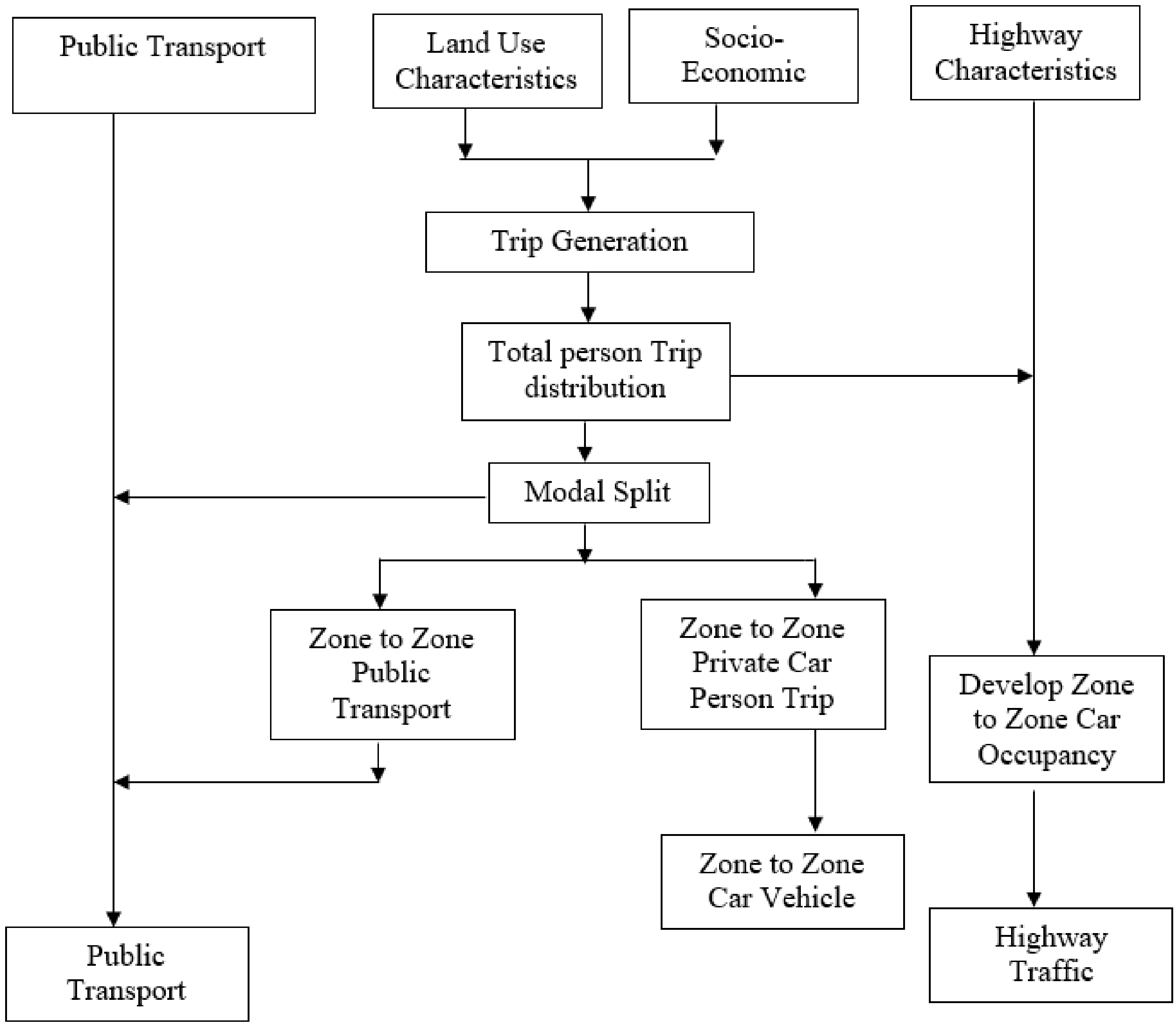


Fig: Post Distribution Model Split

NOTE:

The probability of using a mode of travel is generally given by equation i.e based on logistic model is as follows.

$$P_i = \frac{e^{v(i)}}{\sum_{r=1}^{n} e^{v(r)}}$$

Where $V_{(i)}$ = utility of mode 'I'
$V_{(r)}$= utility of mode 'r'
n = number of modes of consideration

Example:1 The calibrated utility functions for auto and bus travel are as follows:
Auto: V_a= - 0.3 - 0.04x - 0.1y - 0.03C
Bus: V_t= - 0.04x - 0.1y - 0.036

Where x = in vehicle travel time
y = out vehicle travel time

C = cost of travel/income

The traffic zone has the following characteristics

	Auto	Bus
In vehicle time (min)	20	40
Out vehicle time (min)	10	15
Travel cost (Rs)	60	20

What is the probability that a person with an income of 25,000/- will travel by bus.

Solution:

Auto: V_a= - 0.3 - 0.04 (20) - 0.1(10) - 0.03(60/25000) = - 2.1

Bus: V_t= - 0.04(40) - 0.1(15) - 0.036(20/25000) = - 3.1

The probability of trips maker bus trips

$$e^{v(i)} \qquad where\ v(i) = v(t)$$

$$P_t = \frac{e^{-3.1}}{e^{-3.1} + e^{-2.1}}$$

$$= \frac{0.045}{0.045+0.1225} = 0.2687 \text{ or } 26.87\%$$

Example:2 The calibrated utility functions for a travel in a medium by automobile, bus and motor-rail is as follows.

$$U = a - 0.002\, x_1 - 0.005 x_2$$

Where x_1 = cost of travel(in Rs)

x_2 = Travel time (in min)

Calculate the modal split for the given values

Mode	a	x_1	x_2
Automobile	−0.30	120	30
Bus	−0.35	20	45
Metrorail	−0.40	60	35

If parking fee of 5/- per trip is imposed on automobiles, what would be the split to the other two modes?

Solution: Automobile, $U_a = -0.30 - 0.002\,(120) - 0.005(30) = -1.77$

Bus, $U_b = -0.305 - 0.002\,(20) - 0.005(45) = -2.64$

Metrorail, $U_m = -0.40 - 0.002\,(60) - 0.005(35) = -2.27$

Mode	U	e^u	$P_i = \frac{e^u}{\sum_{r=1}^{n} e^u}$	$P_{in(\%)}$
(a) Automobile	−1.77	0.1703	0.4936	49.36
(b) Bus	−2.64	0.0714	0.2069	20.69
(c) Metrorail	−2.27	0.1033	0.2994	29.94

$$P_a = \frac{e^{a}}{e^{ua} + e^{ub} + e^{uc}}$$

When additional Rs. 50 is imposed on automobile for parking

Automobile, $U_a = -0.30 - 0.002\ (125) - 0.005(30) = -2.05$

Mode	U	e^{u}	P_i	P (%)
(a) Automobile	-2.05	0.1287	0.4242	42.42
(b) Bus	-2.64	0.0714	0.2353	23.53
(c) Metrorail	-2.27	0.1033	0.3405	34.05

Due to increase in parking charges difference in automobile trips are = 49.36-42.42 = 6.94 = 7%

URBAN TRANSPORTATION PLANNING

(18CV745)

MODULE 5

TRAFFIC ASSIGNMENT

MODULE 5
TRAFFIC ASSIGNMENT

Traffic assignment is the stage in the transport planning process where in the trip interchange are allotted to different parts of the network forming the transportation system. In this stage,

a) The route to be allotted is determined
b) The inter-zonal flows are assigned to selected routes

The applications of traffic assignment are:

1. To determine the deficiencies in the existing transportation system by assigning the future trips to existing system
2. To evaluate the effects of limited improvements and additions to the existing transportation system by assigning estimated future trips to the improved network
3. To develop construction priorities by assigning estimated future trips for intermediate years to transportation system proposed for those year.
4. To test alternative transportation system proposals by systematic and readily repeatable procedures
5. To provide design hour traffic volumes on highway and turning movement at junctions.

General Principle

All assignment techniques are based on route selection. The choice of route is made on the basis of a number of criteria such as journey time, length, cost, comfort, convenience and safety. Journey time is often considered as the sole craterisation since length and cost can be considered as function of time in most cases.

As a first step, the highway network is described by a system of links and nodes.

Node: A node is either the centroid of a zone or the intersections of two or more links.

Link: A link is a section of a highway network between two intersection

For computer analysis the network description is coded, key punched and stored in the memory of the computer. The computer is then made to select the minimum path between the zones and assign predicted trips to these paths. Traffic volumes are thus accumulated for each section of the network.

- *Minimum path* many be that route of travel which has least accumulation of time, distance or other parameters.
- The sequence of nodes which defines the link comprising the minimum path between any two zone centroids is called the *tree.*
- The tree is determined by the computer starting from the zone centroid and progressively selecting the shortest path to the terminal zone centroid.
- The traffic accumulated in various links may so happen that at certain individual links gets overloaded. In that case adjustment will have to be made in accordance with travel time flow relationship fed to the computer.

Moor's Algorithm for Minimum Path Tree

Moor's Algorithm explain the procedure to build minimum path in a network. The network is as shown below and consists of a zone centroid 1 and a number of links and nodes. The travel time on each link is indicated in figures in brackets. It is required to build minimum path tree from zone centroid

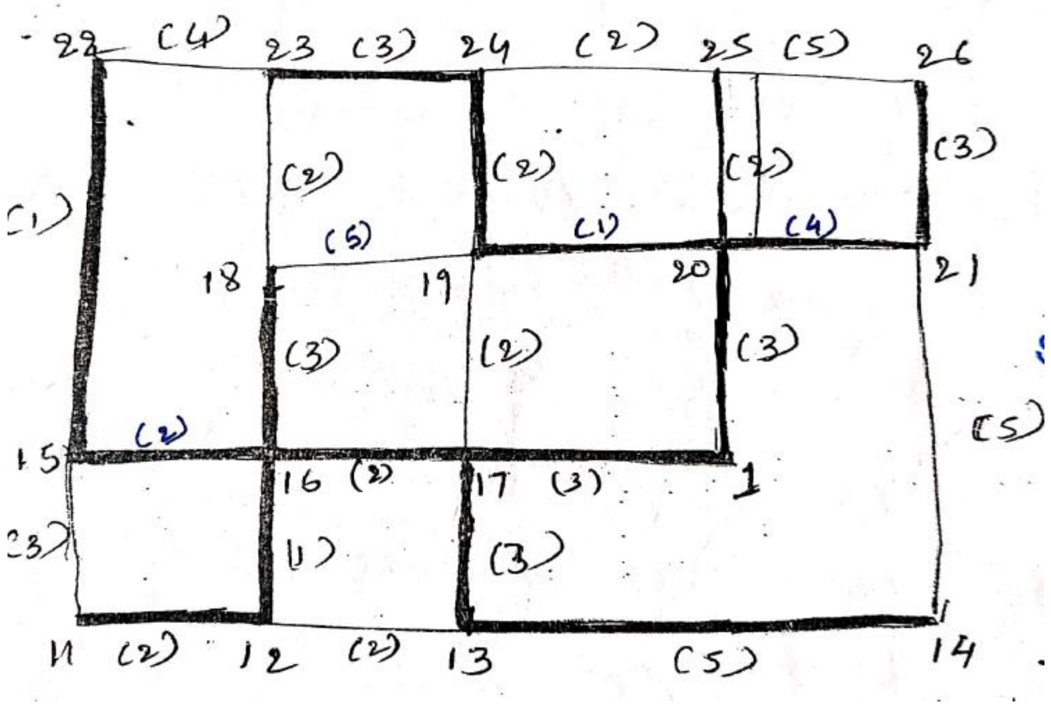


Fig: Minimum Path Tree - Denoted by thick line

Starting from centroid 1, we go to each connecting node and note the time of travel to the node.

Thus, $T_{1-20} = 3$

$T_{1-17} = 3$

The node close to the centroid 1 in time is considered next. In this example, the time taken to reach both the nodes being the same, the node having lower number, viz node 17 is taken up.

From node 17, the cumulative time to travel from centroid connected directly to note 17 is noted.

$T_{1-17-19} = 5$ (3+2)

$T_{1-17-16} = 5$ (3+2)

$T_{1-17-13} = 6$ (3+3)

The next closest node to centroid 1, i.e node 20 is now considered and cumulative time to travel from centroid 1 to all nodes connected directly to it are noted.

$T_{1-20-19} = 4$

$T_{1-20-25} = 6$

$T_{1-20-21} = 7$

It will be seen from the above that there are two possible routes to reach node 19, i.

$T_{1-17-19} = 5$

$T_{1-20-19} = 4$

The latter is shorter in time and is therefore chosen and former is discarded. This process is repeated until all nodes have been covered by the shortest path. The minimum path tree is indicated in fig.

Assignment Techniques

The different techniques of traffic assignment are

1. All-or-nothing assignment (free assignment or desire assignment)
2. Multiple route assignment
3. Capacity restraints assignment
4. Diversion Curves.

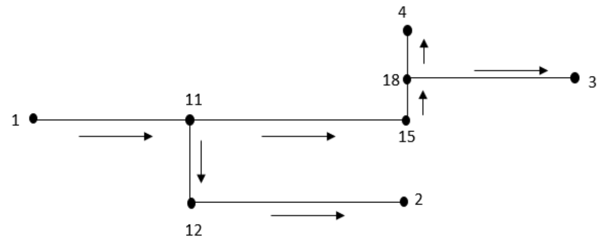
All-or-Nothing Assignment

- This is the simplest technique and is based on the premise that the route followed by traffic is one having the least travel resistance.
- The resistance is measured in terms of travel time, distance or a suitable combination of these parameters.
- The procedure of network description and tree building is done considering the minimum travel path. The next stage is to assign the traffic flows to the minimum path tree.

Example: Figure below shows the minimum path tree connecting zone centroid 1 with zone centroid 2, 3, & 4. The traffic volume from zone centroid 1 to zone centroid 2, 3, & 4 are given

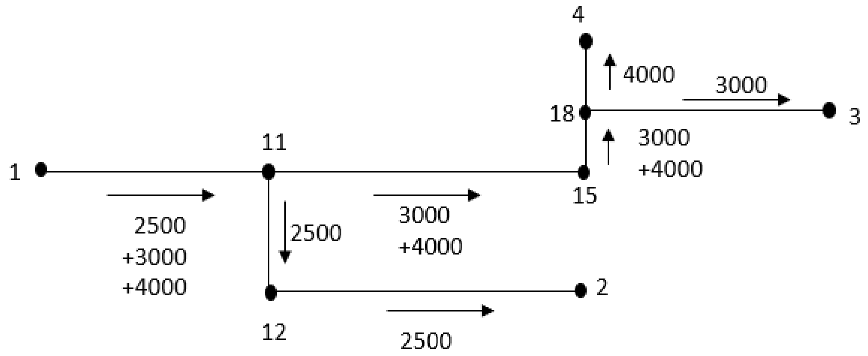
From zone centroid	To zone centroid	Traffic volume (Vehicles/hour)

1	2	2500
1	3	3000
1	4	4000



It is required to assign the flow from zone centroid 1 to zone centroid 2, 3, & 4

Solution:



It will be seen from the above figure, the traffic volume assigned to the various link are

Link	Traffic Flow (Vehicles/hour)
1-11	9500
11-12	2500
12-2	2500
11-15	7000
15-18	7000
18-3	3000
18-4	4000

Once the traffic volume is assigned to the various links, a check is made to see that no link is loaded beyond its capacity. If overloading is found to exist, the journey times on this overloaded links are altered and assignment is repeated.

Disadvantages

1. If time alone is used as governing factors for the choice of the minimum path, other equally important factors as cost, reliability, convenience and safety will be neglected.

   But a driver may attach more value to these neglected factors, thus causing errors in assigned flow.

2. Because of the very principle on which the technique is based, too many vehicles tend to be assigned to more attractive routes. This may cause increasing congestion on these routes and the technique takes no account of this factor. All the facilities in the network are not effectively utilized under this procedure.
3. If superior facility is available, say for example a motorway, people tend to prefer to use this facility for longer journeys. If the travel time or cost is the sole factor, the all-or-nothing assignment might not reflect this tendency.
4. Small difference in journey times by different routes between the same origin and destination can results in unrealistic journey path.

Multiple Route Assignment

- All road users may not 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 recognised in the multiple route assignment technique.
- The method consists of assigning the inter-zonal flow to a series of routes, the proportion of the total flow to a series of routes, the proportion of the total flow assigned to each being a function of the length of that route in relation to the shortest route.
- In this approach, it is assumed that a driver does not know the actual travel times, but that he associates with each link a supposed time. The mean of this supposed time gives actual link time.
- The driver is then assumed to select the route which minimises the sum of his supposed time gives actual link time.
- Multiple route models found to yiels more accurate assignment than all-or-nothing assignment.

Capacity Restraints Assignment

- Capacity restraint assignment is a process in which the travel resistance of a link is increased according to the 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 vof the capacity of the system between a pair of zones.

- The capacity restraint system, clearly restrains the number of vehicles that can use any particular corridor. If the assigned volume are beyond the capacity of the network, redistributes the traffic to the realistic alternative paths.
- The procedure is similar to all-or-nothing assignment as far as 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-nothing technique by building minimum path trees.
- Traffic is then assigned to the minimum paths, 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 on the link is calculated. This results in a new network with a different minimum path tree, differing from the earlier minimum path tree.
- As a result of assigning the 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.
- Because of iterative nature if calculations involved, the capacity restraint technique is carried out entirely by an electronic computer.

Methods of Capacity Restraint Techniques

1. **Smock Method:** In this method, all-or-nothing assignment is first worked out. In an iterative procedure, the link travel time is modified according to the function

$$\boldsymbol{T_A = T_0 e^{\left(\frac{V}{C}-1\right)}}$$

$$\boldsymbol{T_A \leq 5T_0}$$

Where, $\boldsymbol{T_0}$ = original travel time or the travel time on a link when volume equals capacity

$\boldsymbol{T_A}$ = adjusted travel time

e = exponential base

V = assigned volume

C = computed link capacity

In the second iteration, the adjusted travel time $\boldsymbol{T_A}$ are used to determine the minimum paths tree.

2. **Bureau of Public Roads (BPR) methods:**

The formula used to update the link volume time is

$$T_N = T_o\left[1 + 0.15\left(\frac{V}{C}\right)^4\right]$$

Where, T_N = link travel time at assigned volume

T_o = base travel time art assigned volume (equals 0.81times travel time at particular capacity)

V = Volume

C = Capacity

Diversion Curves

(a) One of the frequently used assignment techniques is the diversion curves. These curves represent empirically derived relationship showing the proportion of the traffic that is likely to be diverted on a new facility (by pass, new expressway, new arterial streets etc.). Once such a facility is constructed, the data collected from the pattern of road usage in the past serve to build up such curves. Diversion curves can be constructed using a variety of variables such as

- Travel time saved
- Distance saved
- Travel time ratio
- Distance ratio
- Travel time and distance saved
- Distance and speed ratio
- Travel cost saved

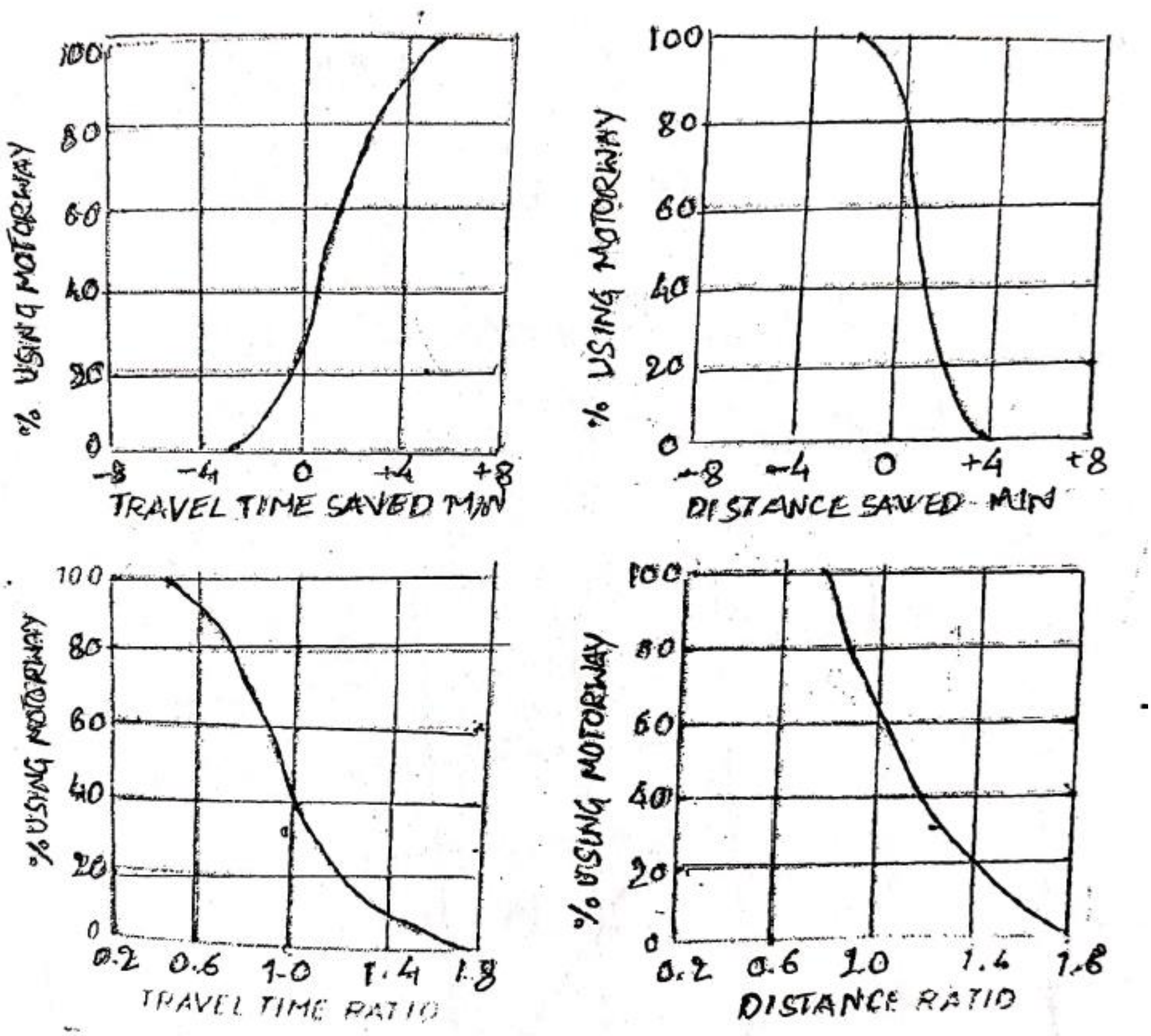


Fig: Simple Diversion Curves using one variable

(b) The equations for diversion curves used in India for estimating the traffic that get diverted to expressway are as follow

Item	Cost Ratio Interval	Equation
Cars	≤ 0.634	$\% \, Div = 98.75 - \left(\frac{CR}{0.634}\right) \times 8.125$
	0.634< CR<1.464	$\% \, Div = 90.625 - \left(\frac{CR - 0.634}{0.831}\right) \times 84.12$
	1.465 to 2,000	$\% \, Div = 6.25 - \left(\frac{CR - 1.465}{0.535}\right) \times 5.25$
Trucks & Buses	≤ 0.750	$\% \, Div = 100 - \left(\frac{CR}{0.75}\right) \times 5$
	00750<CR<1.250	$\% \, Div = 95 - \left(\frac{CR}{0.75}\right) \times 90$
	1.250 to 2,000	$\% \, Div = \left(\frac{2 - CR}{0.75}\right) \times 5$

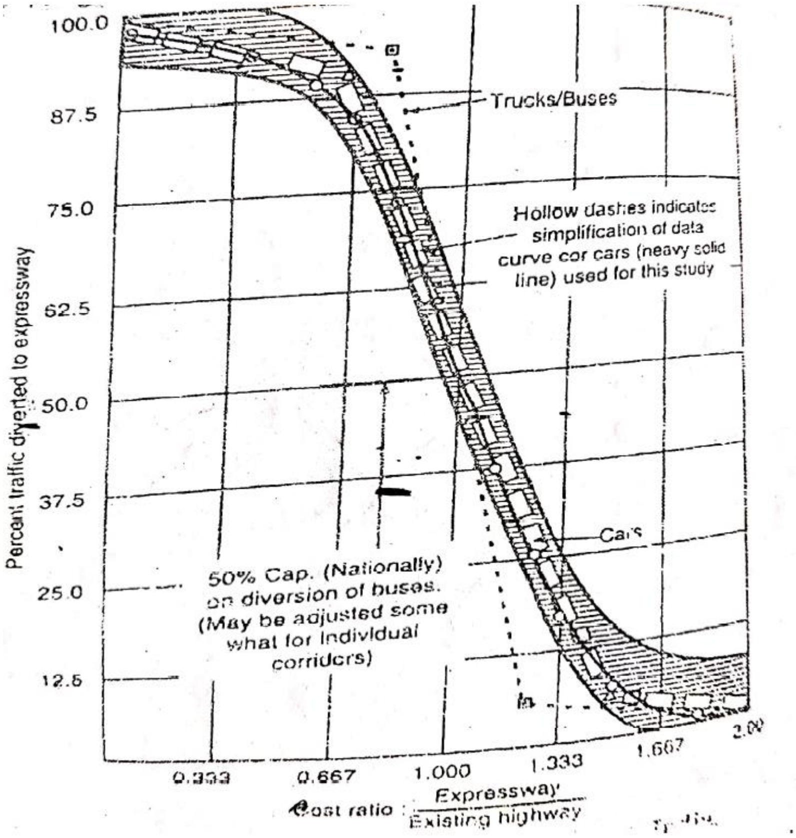


Fig: Diversion curves for Expressway in India

(C) A well known examples of diversion curves using travel time ration to determine the traffic diverted to expressway is the Bureau of Public Road Curves. The curve is 'S' shaped as given in fig below

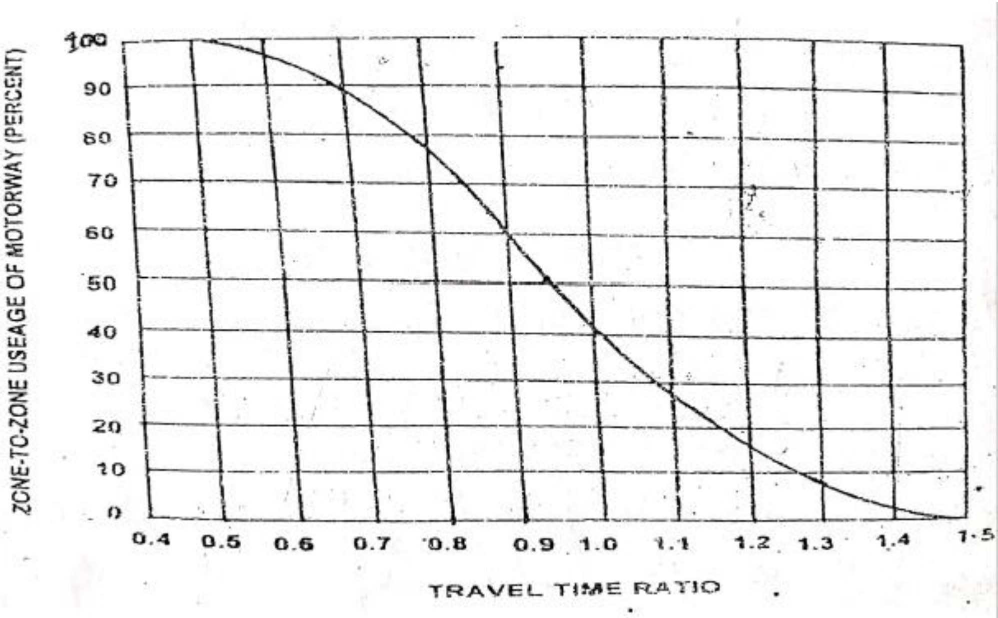


Fig: Bureau of Public Roads Diversion Curves

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

Problems: In order to relieve congestion on the urban street network a motorway is proposed to be constructed. The travel time from zone centroid to another via the proposed motorway is estimated to be 10 min whereas the time for same travel via the existing street is 18min. min. The flow between the two zone centroid is 1000vehicles/hour. Assign flow between the new motorway and existing street.

Solution:

We have ,

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

T_R = Travel time ratio $= \frac{Time\ on\ new\ system}{Time\ on\ old\ system} = \frac{10}{18}$ == 0.56

Percentage motorway usage, $P = \frac{100}{1+t_R^6} = \frac{100}{1+0.56}$ = 96.5%

Traffic diverted to new motorway = 1000 x 96.5 = 35vehicles/hour

Alternatively:
Using graph, percentage of traffic using motorway corresponding to travel-time ratio 0.56 = 97%

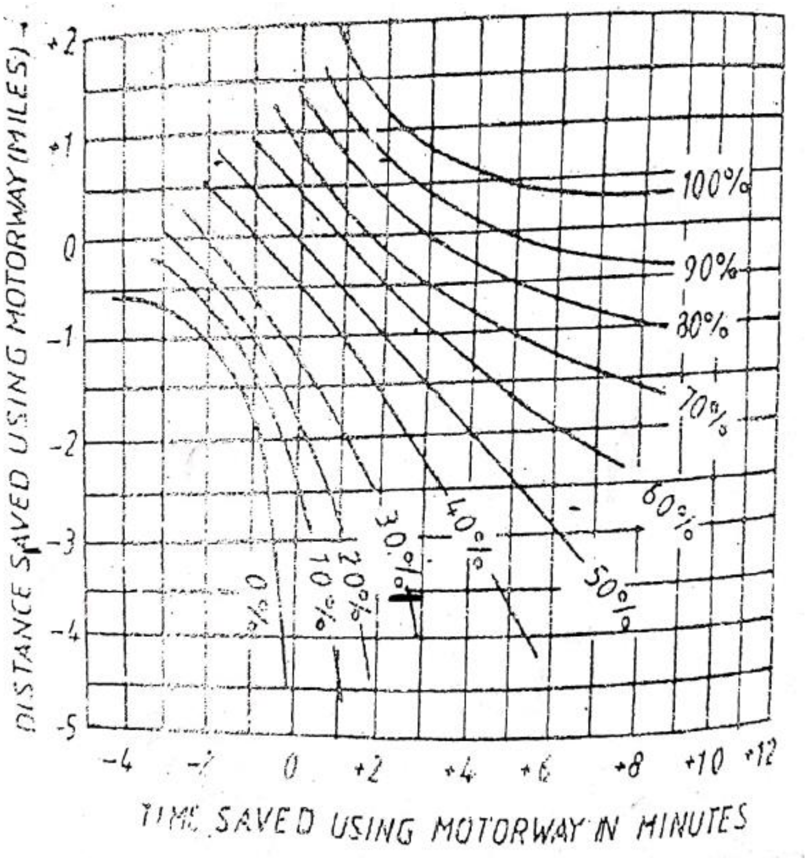
(d) Another well known example using two variables, distance and travel time saved usina a motorway, is the **California Diversion Curve**. Figure shows family of curves, the following has been developed to fit the above curves.

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

Where, P = percentage of motor way usage

d = distance saved in miles via the motorway

t = time saved via the motorway



LAND-USE TRANSPORT MODELS

It is seen that land-use determines transport demand and it is made use in building up the system of transport planning. The basic requirement in this technique is to study the land-use activities and to determine the travel demand. This technique suffers from drawback that:

a) Travel demand estimated by it tens to be high in the principal travel corridors
b) Also, it requires a completely specified land-use allocation both at the production and at the attraction end of the trips

Attempts are made to overcome the above deficiencies which given rise to an entirely different transport planning techniques, where by land use allocation and travel demand are determined simultaneously with the help of land-use transport models.

Selection of Land-use Transport Model

A variety of land use transport models have been developed and it includes

- Research models:
  - → Has excellent capabilities for sensitive forecasting
  - → Requires extensive data collected through spatial surveys
- Operational Models
  - → Needs data collected routinely by planning department
  - → Lowry derivative models are widely used

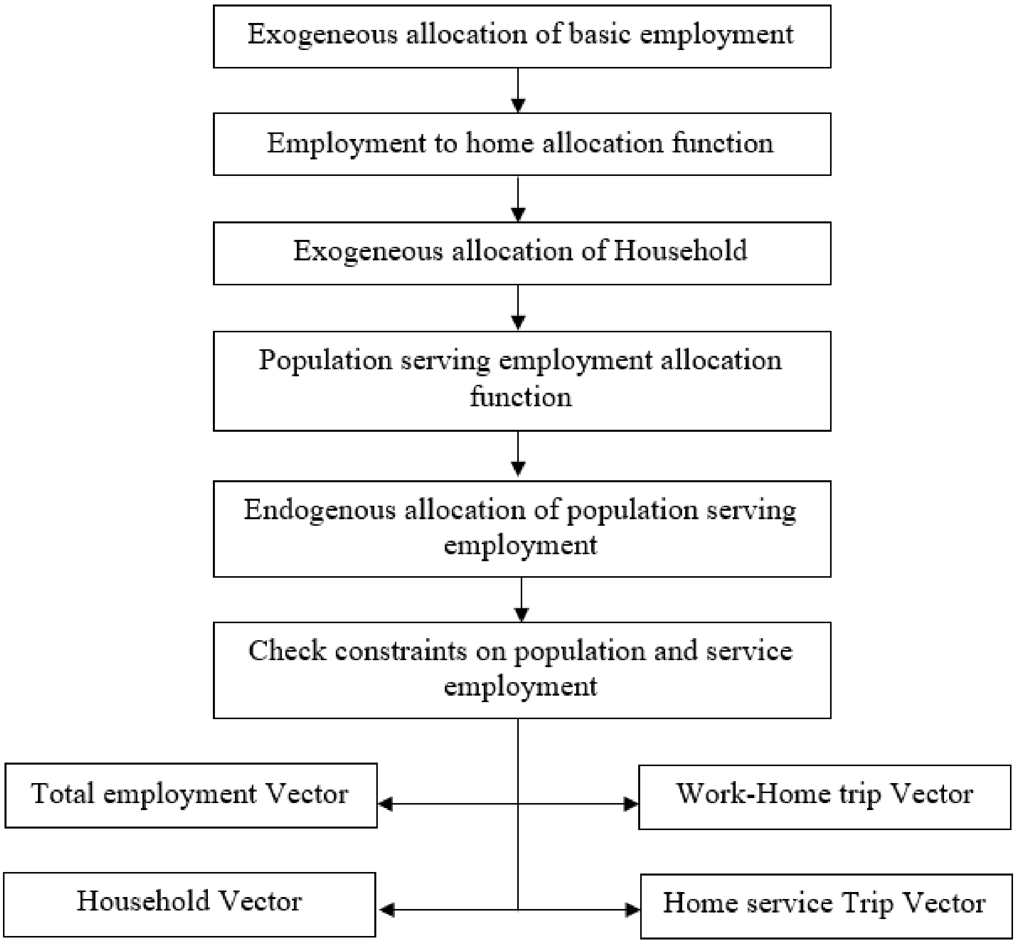
Important Consideration for selecting model

1. Simplicity- The model should have a simple structure which should be easy to comprehend. A simple model will generally consume less time and resource
2. Modest data requirement- The good models makes use of data routinely available with the planning department
3. Adoptability- The model should be adoptable to any given location
4. Comprehensiveness- The model should be comprehensive and should synthesise the relationship between activities housing and transportation adequately
5. Operationality and rapidity- the model should be operational, capable of easy interpretation and should be able to rapidly a wide range of policy options
6. Computer cost- The model should be operational at relatively cheap computer cost

Lowry Derivative Models

Lowry derivative models are simple to use, requires modest data, are comprehensive and economical, have good response to change in input variables and have simple casual structure. Therefore, been used extensively and successfully in number of studies.

The fundamental structure of the model is illustrated in figure below:



The Lowry model relates three principal components of the urban area:

1. Population
2. Employment
3. Communication between population and employment

The basic employment is defined s employment industries whose output and services are sold in market external to the region under study. The location of basic employment within a region is independent of the population and the service employment distribution of that region

Example: Primary industries, manufacturing, national financial institutions, universities etc trade, utilities, personal services, elementary and high school employment etc

Service employment: The category of employment which services the population in a region. The location of service employment depends upon the population distribution of that region
Example: Distribution and retail, trade, utilities, personal services, elementary and high school employment etc

The household sector consists of residential population

- In the model, spatial distribution of basic employment is allocated exogenously. The spatial distribution of households and population serving employment are calculated by the model
- The zonal allocation rules for both households and service employment are specified with in the model structure
- Constraints on maximum number of households for each zone and minimum population serving employment for zone are also specified.
- The minimum represents an equilibrium situation which would eventually come to pass if all other factors had remains constant while equilibrium being achieved

The equation used in the model are as follows:

1. Land use i.e. total land available in the zone

$$A_j = A_j^u + A_j^B + A_j^R + A_j^H$$

2. Total employment and land occupied by the employment zone

$$E_j = E_j^B \sum_{k=1}^{m} E_j^k$$

$$A_j^k = E_j^B \sum_{i=1}^{m} e^k E_j^k$$

3. The regions population of household is a function of total employment given by equation

$$N = f \sum_{k=1}^{n} E_j$$

A= Area of land

E= Employment (number of person employment)

N= population

T= Index of trip distribution

u= unusable land

B= basic sector

R= retail sector

H= household sector

K= class of establishments within the retail sector (Eg: clinics, schools, cloths shop, groceries etc.)

m= number of classes of retail establishment

n= number of zones (i= 1,2,3…….n ; j= 1,2,3……..n)

Drawback

The model is not an actual forecasting procedure. This is because it is not possible to associate points in real time with the model solutions, since it is not clear if and when such an equilibrium solution would come to pass

Application of Land-use Transport models in India groups.

Land use transport modes have been applied on a very limited scales in India.

Sarna's work on the application of the land-use transport model for Delhi is the first of its kind. The model disaggregates by socio-economic and spatial. The model has been applied to solve several horizon years planning problems in Delhi urban areas. Alternative land use transportation system are generated by varying the locations of employment and population

URBAN TRANSPORTATION PLANNING
(18CV745)

QUESTION BANK

Question Bank

MODULE 1

1. What are the impacts of transportation on environment?
2. Explain the effects of air pollutants from vehicle exhaust gas.
3. Explain the difficulties in urban transportation condition.
4. Write a note on
   (i) Para Transit Transport (ii) Public Transport System (iii) Private Transport
5. Explain System Approach to transportation planning with a flow diagram.
6. Explain the interdependence of land use and transportation.
7. Explain the 4-Stage transport planning model?

MODULE 2

1. Describe how the study area is divided into Zones and mention the factors to be considered while dividing area into zones.
2. List the various methods available for data collection. Explain a) Home Interview Survey b) Registration Number Survey
3. It is required to find origin and destination detail for the given study area. Choose the appropriate methods and explain any three methods.
4. Discuss the various inventory required to collect information related to travel facilities

MODULE 3

1. Explain the various factors governing the trip generation.
2. State the important criteria for the evaluation of regression equation with relative assumption made in analysis of trip generation and discuss the limitations of multiple linear regression analysis and the suitability.
3. Enlist the different methods of trip distribution and discuss the method which considers the average value of trip as the future distribution
4. Discuss the methods to distribute the interzonal trips based on growth factor.
5. The distribution of present trips among zone 1,2 and 3 are given in O-D matrix below. The future trips generated in zone 1,2 and 3 are expected to be 360, 1260 and 3120 respectively. Distribute the future trips among various zone using i) Uniform factor Method ii) Average growth factor method and draw the conclusion based on result.

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

6. Determine the future trip distribution by Furness method from the following data (upto two iteration)

O/D	1	2	3	4	Future Trips
1	-	50	60	30	280
2	40	-	70	20	390
3	20	60	-	40	300
4	50	70	30	-	220
Future Trips	200	500	340	150	

7. The following table gives trip distribution between four zones 1, 2,3 and 4. Estimate the future interzonal trip between the four zones. (upto two iteration)

	1	2	3	4	Future Trips
1	10	20	15	18	140
2	21	16	17	14	150
3	30	21	25	27	200
4	10	9	16	13	100
Future Trips	150	120	180	160	

MODULE 4

1. The total trips produced in and attracted to the three zones A, B, and C of a survey area in the design year are tabulated below

Zone	Trip Produced	Trip Attracted
A	2000	3500
B	3500	4800
C	4800	2000

   It is known that the trips between two zones are inversely proportional to the second power of the travel time between zones, which is equally 25 min. If the trip interchange between zones B and C is 300. Calculate the trip interchange between zones A-B, A-C, B-A and C-B
2. Explain Opportunity model of trip distribution.
3. A self-contained town consists of four residential areas A, B, C and D and two industrial areas X & Y. The trips from home-work generated by each residential area are as follows

A	B	C	D
1000	2250	1750	3200

   There are 3700 jobs in industrial estate X and 4500 in industrial estate Y. It is known that attraction between zones in inversely proportional to the square of the journey times between zones. Calculate and tabulate the inter zonal trips for journey from home to work. The journey time in minutes from home to work are as follow:

Zone	X	Y
A	15	20
B	15	10
C	10	10
D	15	20

4. Explain the factors affecting Modal Split
5. With the flow diagram explain Pre-distribution modal split
6. With the flow diagram explain Post-distribution modal split.

7. The calibrated utility function for travel in a medium city by automobile, bus and metro is given by $U= a - 0.002X_1 -0.005X_2$; X_1 = Cost of travel(Rs) , X_2 = Travel time (min)

   Calculate modal split for given values

Mode	a	X_1	X_2
Automobile	-0.3	120	30
Bus	-0.35	20	45
Metro	-0.40	60	35

   Is a parking fee of 10/- per trip is imposed on automobile, what would be the split to the other two modes?

MODULE 5

1. State traffic assignment and its applications? Explain its general principle.
2. Explain the following
   All -or-nothing assignment b) Methods of capacity Restraint
3. Discuss the important considerations for selecting land-use model
4. Explain the concept of Lowry derivative model with a flow diagram.
5. To overcome congestion on the urban street network, a motorway is proposed. The travel time from one zone centroid to another via the proposed motorway is estimated to be 10min where as the time for same travel via existing street is 18 min. the flow between the two zone centroid is 1000veh/hour. Assign the flow between the new motorway and existing street.
6. Explain the following
   a) Capacity Restraint Method b) Diversion Curves

1	Which of the following model is not used for Modal Split analysis? a) Competing opportunity model b) Probit model c) Logit model d) None of the above
2	Utilities of two transport modes are 1.0 each. Estimate the probability of one of the modes a) 0.45 b) 0.55 c) 0.5 d) 0.6
3	The modal split share CAR:BUS:METRO for a city is 35:20:45. The number of trips made by CAR, BUS & METRO out of total 2500 trips made from origin to destination are __________ , __________ & __________ respectively. a) 500, 875, 1125 b) 875, 500, 1125 c) 1125, 875, 500 d) 500, 1125, 875
4	The estimation of what proportion of total forecasted trips between two zones, shall use the available alternative routes is known as __________ a) Trip generation b) Modal split c) Route assignment d) Trip distribution
5	The basic factor, that lead people to choose one route over the another is _____ a) Travel time b) Travel cost c) Level of service d) All of the above
6	Route assignment is related to _________ a) Assigning existing trips to existing transport network b) Assigning future trips to existing transport network c) Assigning future trips to future transport network d) All of the above
7	Which of the following is not used for route assignment technique? a) Intervening opportunity model b) All or nothing method c) Diversion curve technique d) Multiple route assignment technique
8	____________ is the simplest method for route assignment analysis. a) Diversion curve method b) All or nothing assignment c) Capacity restraint assignment technique d) Multiple route assignment algorithms
9	Which of the following method uses distance ratio as independent variable? a) All or nothing method b) Multiple route assignment method c) Capacity restraint method d) Diversion curve method
10	__________ method is used to estimate the proportion of person or vehicles likely to reroute to a new or improved facility. a) Capacity restraint b) Fratar c) Detroit d) Diversion curve
11	Travel time (Tt) by car and bus is 46 and 72 minutes respectively. The utility function is U = -0.004 (Tt). The probability of car and bus for being chosen by the rider is ______ & ______ a) 47% & 53% b) 53% & 47% c) 50% & 50% d) 60% & 40%
12	Land-use and Transportation are ________ a) Dependent on mobility b) Interdependent on each other

	c) Not dependent on each other d) None of the above
13	In Lowry's Land-use-Transport model ____________________ is considered as endogenous element. a) Retail sector b) Residential sector c) Basic sector d) Employment
14	In Lowry's Land-use-Transport model the basic employment is ______________________ allocated to the city planning process a) Endogenously b) Exogenously c) Both A & B d) None of the above
15	A unique property of land-use is its ability or potential to _____traffic a) Divert b) Merge c) Generate d) None of the above
16	Minimum path tree defines a) Route of travel which has least travel time b) Route of travel with less traffic volume c) both a &b d) none of the above
17	In capacity restraint assignment V/C ratio is maintained by a) Reducing number of vehicles assigned b) altering the link travel time c) choosing alternate route d) none of the above
18	The principle component Lawry model includes. a) Population & employment b) Communication between population & employment c) both a & b d) none of the above
19	Diversion curves are derived based on a) travel time saved b) distance ratio c) travel cost ratio d) all of the above
20	A section of a highway network between two intersection a) Node b) Tree c) Link d) Path
21	the procedure to build minimum path in a network a) Columbs Algorithm b) Fratar Algorithm c) Darcy's Algorithm d) Moor's Algorithm
22	The time taken to reach the nodes 21 and 17 from node 1 is given below, which is chosen in critical path a) $T_{1-20} = 3$ b) $T_{1-17} = 3$ c) $T_{1-20} = 4$ d) $T_{1-14} = 4$
23	The method in which driver associates with each link a supposed time to obtain minimum path is ___ a) All or nothing method b) Multiple route assignment method c) Capacity restraint method d) Diversion curve method

24	The basic employment refers to a) employment industries whose output and services are sold in market external to the region under study b) employment industries whose output and services are sold in market internal to the region under study c) Both A and B d) None of the above
25	Distribution and retail is an example for a) Service employment b) Basic employment c)Community employment d) None of these
26	Node defines a) Study area b) Boundary of study area c) Centroid of Study area d) Centroid of network
27	Which of the following method is inappropriate to studies involving planning of improvements to public transport system where significantly different levels of service are contemplated? a) Trip-end modal split b) Trip interchange modal split c) Both A and B d) None of the above
28	Travel time ratio is given by a) The ratio of the travel time by private car and travel time by public travel b) The ratio of the travel time by public transport and travel time by private car
29	In vehicle travel time is a) time spent in public transport vehicle b) time spent in transfer from one public transport vehicle to another c) Time spent in walking from parked vehicle to destination d) All the above
30	Trip end model do not account for____________ a) Trip generation characteristics b) Improvement in future transit service c) Both A and B d) None of the above