Civinnovate

Discover, Learn, and Innovate in Civil Engineering

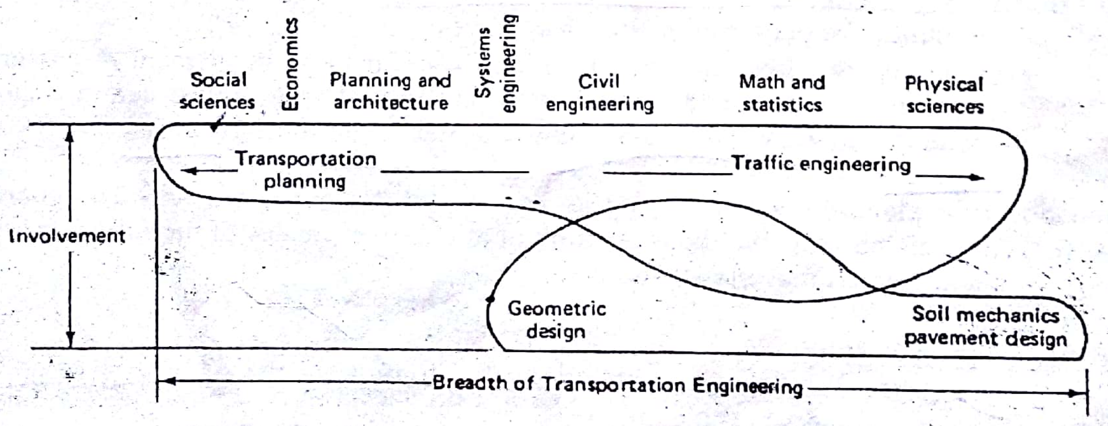
CHAPTER I.   INTRODUCTION:

Transportation:
Transportation is the movement of entities covering some geographical space. Movement of entities includes people's movement between urban activities (e.g. work, school, shopping, recreation, etc.) or goods movement from producers to consumers

Engineering:
Application of science and mathematics for the optimum conversion of resources of nature to the use of mankind is called Engineering.

Transportation Engineering:
The application of scientific principles, tools, technology for planning, design, operation and management of facilities related to various modes of transportation (road, air, rail, and ropeway) in order to provide safe, rapid, comfortable, convenient, economic and environmental compatible movement of people and goods.
Transportation engineering encompasses various fields of transportation such as: Highway Engineering, Ropeway Engineering, Airways Engineering, Railway Engineering, etc and consists several scopes as: Transportation Planning, Geometric Design, Pavement Design, Traffic Engineering and many more. It not only deals about traffic, geometric design, we also covers various aspects of civil engineering as well as general science, and mathematics, which can be illustrated by the following figure. Thus transportation engineering covers a multidisciplinary area of study and is regarded as a comparatively new profession that has acquired theoretical underpinnings, methodological tools and a vast area of public and private involvement.

Interdisciplinary Breadth of Transportation Engineering



Planning:
In simple words a process of looking ahead and setting a course of action to satisfy future needs is called Planning. Planning is defined as the future oriented activity which guides a situation or a system toward a desired direction i.e. toward the attainment of positive goals and / or avoidance of problems involving evaluation, assessment, analysis, etc.
In other way, Planning can be defined as a process of creating and maintaining a plan, and also thinking about the activities required to achieve the desired goal. It is said that "Plan the Work and Work the Plan", i.e. first we need to elaborate our ideas based on its goal, objective, sequence of

activities, and then the elaborated idea need to be traced on paper and then it must be implemented on real field. The purpose of planning tools is to provide systematic and neutral information to decision maker to make appropriate decision as the world moves into the future as a result of decisions and not plans.

Transport planning:

The ongoing process of developing and maintaining a transportation system for the safe and efficient movement of goods and people is called Transportation Planning. It is a cyclical process which deals with safe and efficient operation of transportation modes, planning for future requirement or improvement & also about technical & economic aspect of transportation system. It involves the use of mathematical models to predict the impact of various alternatives policies for long term development of transportation system. It is concerned with short & long term development of transportation system and supporting policies such as:

– To identify needs & problems
– To maximize benefits while reducing costs and adverse effects.
– Developing alternatives, evaluating them, and selecting the best one.

Types of Transportation Planning:

(a) Short Term Planning and Medium Term Planning

- Planning for short period (5-10 years or less.)
- Comparatively less complex and mainly concerns with obtaining maximum capacity or optimal operation from existing facilities.
- Small problems that can be solved quickly, with a small investment and minor infrastructure improvements such as: congestion at intersections; turning lanes for developments; resurfacing, etc.

(b) Long Term or Comprehensive or Strategic Planning:

- Planning for period of greater than 10 year
- Planning requires extensive resources and financial investment & has great impact on economic, social and natural environments. Large infrastructure changes, complex staging i.e. state highways; subways and Light Rail Systems; sewers and municipal services.

Transportation planning must be seen as an integral part of a much wider process of decision making. All decisions involve the evaluation of alternative images of the future and the selection of the most highly valued feasible alternative.

Transportation System:

System is a group of independent and interrelated component that form a complex and unified whole intended to serve some purpose through the performance of its interacting parts. Transportation system consists of fixed facilities, flow entities and control system that permit people and goods to overcome the friction of geographical space efficiently in order to participate in timely manner in some desired activity.

It consists of three components:

(a) Fixed Facilities: Physical component of system that are fixed in space and contribute the network of link and nodes.

(b) Flow entities: Unit that traverse the fixed facilities such as vehicles. The dimension, weight, acceleration and deceleration capacity of vehicle are considered

(c) Control System: It consists of two components Vehicular Control (Vehicle guided in fixed facility) and Flow Control (Efficient & smooth operation of vehicle with reduction of conflicts between them i.e. by use of sign, marking, etc)

Interaction between Land Use and Transportation Planning:

Land use means the spatial distribution or geographical pattern of the city: residential areas, industry, commercial areas, retail business, and the space set aside for governmental, institutional and recreational purposes. Land-use potential is a measure of the scale of socioeconomic activity that takes place on a given area of land. A unique property of land use is its ability to generate traffic.

Naturally there is a direct interaction between the type and intensity of land use and the supply of transportation facilities provided. The connection between transportation and land use is a fundamental concept in transportation. Everything that happens to land use has transportation implications and every transportation action affects land use. Actions by transportation agencies shape land use by providing infrastructure to improve accessibility and mobility. This increases the utility of land and leads to more intensive land use. Land development generates travel, and travel generates the need for new facilities, which in turn increases accessibility and attracts further development.

The primary objectives of planning any land-use and transportation system is to ensure that there is an efficient balance between land-use activity and transportation capability. If the land uses of a city is known, it is possible to estimate the traffic generated. Trip generation provides the linkage between land use and travel as depicted in the above cycle.

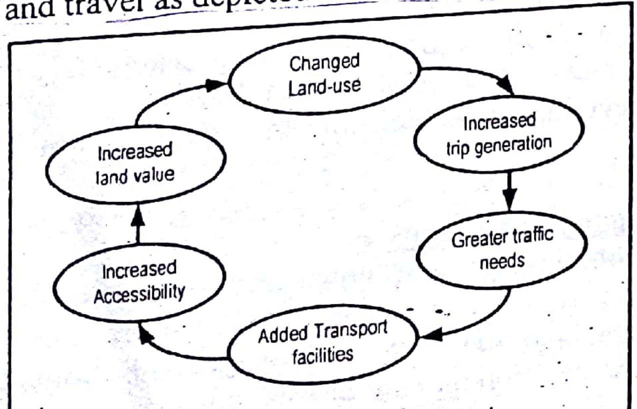


Fig. 1.1 Land-use Transport Cycle

Current dispersion of the population raises new issues as to the long-term impact on transportation effectiveness. Land use and transportation always forms a closed loop. Like most other equilibrium systems, the land-use /transportation configuration eventually stabilizes. A coordinated approach to transportation and land planning yields many benefits to communities: land planners can better anticipate which areas, previously inaccessible or less accessible, are likely to become attractive for development due to a transportation project.

Scope of Transportation Planning and Transportation System Engineering:

The scope can be summarized into following points

- System characteristics
  - System component: (Fixed facility, Flow entity & control system)

- System hierarchy: (Expressway – arterial – Distributor – Local roads)

❖ System purpose:
  - Mobility: Travel to destination within reasonable time and acceptable cost.
  - Accessibility: Accomplishment of some economic or social activity of an individual
❖ System performance: Level of service, speed, frequency, etc
❖ System capacity: Person flow or vehicle flow per hour. Highest priority need to be given to improve the efficiency/capacity of bottleneck (weakest link of the network)
❖ System impact
  - Natural system impact: terrestrial & aquatic ecology
  - Physical impact: air, noise & water pollution, vibration during construction, energy consumption, erosion and sedimentation
  - Social & cultural impact: displacement of people & wild habitat, community cohesion, resource consumption, land use, aesthetics, accessibility of facilities, employment, etc
❖ Demand analysis: Prediction of vehicular and goods flow, pedestrian flow.
❖ Supply analysis: Characterized in terms of the performance of the transportation system (e.g. travel times, headways, and capacities), impacts and associated costs.
❖ System evaluation: Continuous monitoring and determination of alternatives and the desirability over other based on various criteria.
❖ Decision making: Evaluation leads to decision.

- **The philosophy of the long term planning:**

  ➢ **Value:** the underlying basic qualities upon which the ethics, morals and preferences of societies, groups and individuals are based.
  ➢ **Goal:** the idealized desired end at which the planning process is aimed.
  ➢ **Objectives:** measurable operational statements of individual goals
  ➢ **Criteria:** indices of measurement capable of defining the degree to which and objective or goal has been attained.

Rational System Approach of Transportation Planning

Transportation problems are very complex (system consisting of sub systems) as they are interrelated as well as dependent on various other discipline. There are various approaches of transportation planning, among them the most basic and common type is Rational System Approach of Transportation Planning, in which the decision making process consists of:

- System analysis: a clear evaluation of the combinations of all elements related to the problem, and strategies needed for the achievement of an objective.
- System engineering: organizing and scheduling the complex strategies for problem solution and the development of procedures for effecting alternate solutions.

The procedure adopted in rational system approach planning is summarized in the following points:

1. Identification and formulation of the problem.
2. Establish goal and objective as per community values and needs
3. Establish criteria for design and evaluation
4. Design of all possible alternatives that may help in achievement of established goal and objectives
5. Collect relevant data required for evaluation for each and every defined alternative.
6. Test and evaluate the alternative in terms of established criteria (mostly cost and effectiveness)

7. Question objective and assumption. If it is not satisfied we need to establish new alternative or even we need to refine the objective.
8. If evaluation is satisfactory the best evaluated alternative is suggested to plan and policy maker for proper implementation.

The planning process doesn't ends here. proper monitoring for the implemented action is required for planning in the nearest future. The above process can be summarized into following chart.

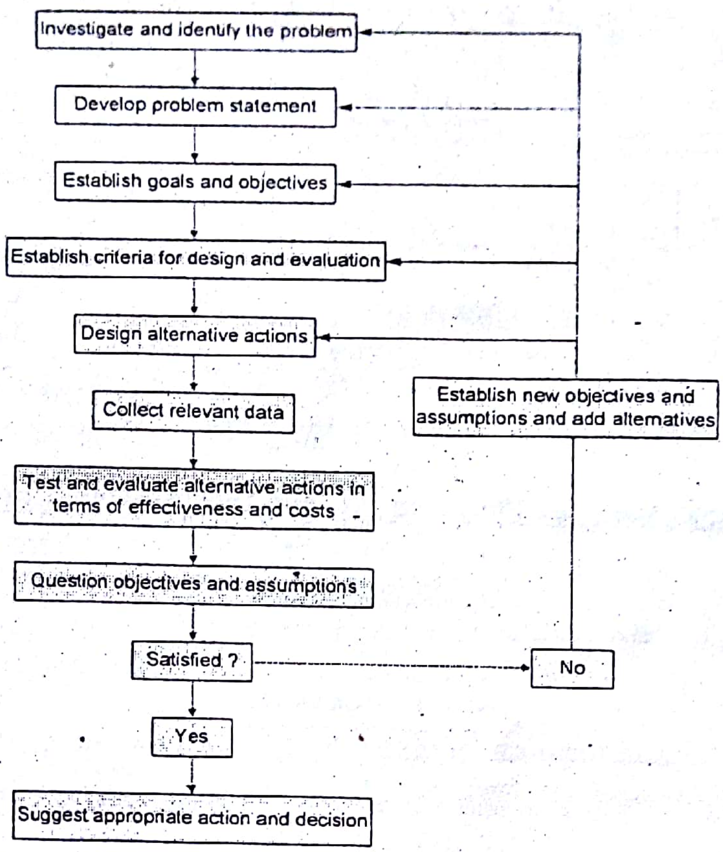


Figure: System Approach of Transportation Planning Process

Urban Transport Planning Process

The urban transportation planning process can be summarized into following points:

(a) First regional population and economic growth is forecasted for the targeted year for the given metropolitan area.
(b) Allocation of the land uses and socio-economic projections to individual analysis zones according to land availability, local zoning, and related public policies.
(c) Generation of alternative transportation plans based on the results of step (a) & (b)
(d) Calculation of the capital and maintenance costs of each alternative plan.
(e) Application of calibrated demand forecasting models to predict the targeted year equilibrium flows expected to use each alternative, provided land-use & socio-economic projection of step 'b' & characteristics of the transportation alternative 'c'.
(f) Conversion of equilibrium flows to direct user benefits, such as saving in travel time and travel cost attributable to the proposed plan.
(g) Comparative evaluation & selection of the best alternatives based on estimated cost and benefits.

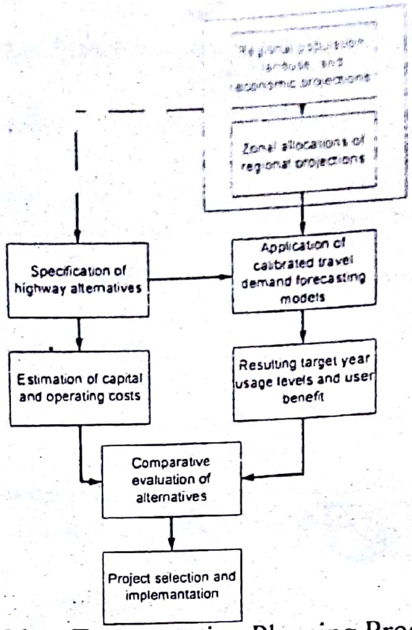
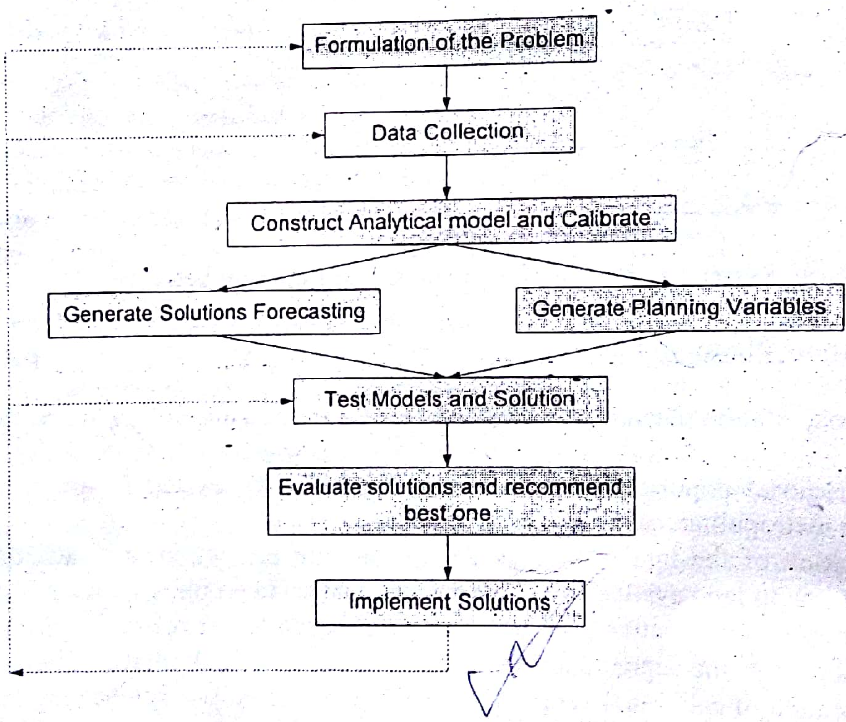


Figure: Urban Transportation Planning Process

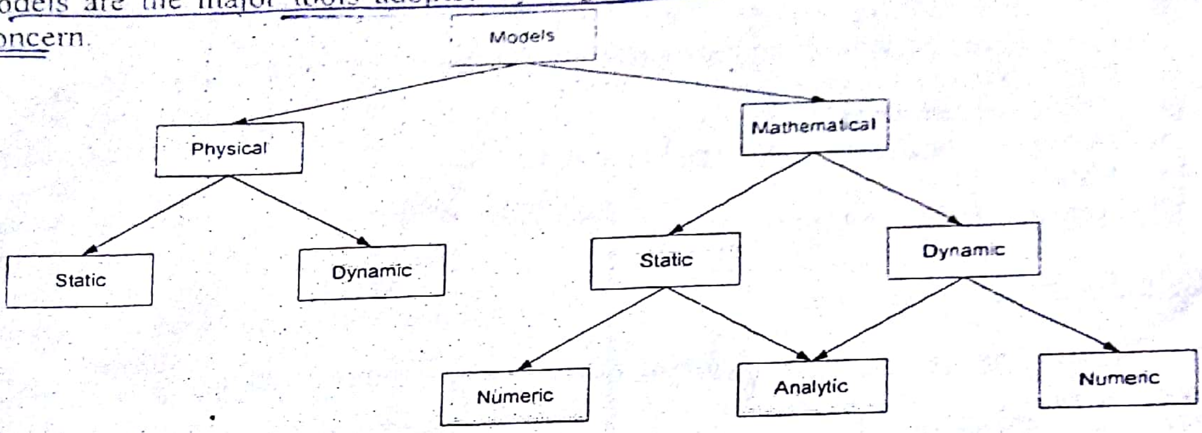
Rational Decision Making Process for Planning, Design and Implementation:



Framework for Rational Decision Making

Models:

Models are a simplified representation of a part of reality. Their function is to give insight into complex interrelationships in the real world and to enable statements about what (most probably) will happen if changes occur or put in that (part of) reality. Models are problem and viewpoint specific. Models are the major tools adopted by engineer and planner to study and analyze the system of concern.



As illustrated in the above chart, the model can be in either of the following form:

(a) Physical or Mathematical Model (Physical model are represented in physical form with distorted scale whereas Mathematical model employ mathematical equation to represent a system and its behavior, i.e. it shows a mathematical relation between dependent and independent variables)

(b) Static or Dynamic Model (Static Model represent the structure of system whereas Dynamic model incorporated the change with time)

(c) Analytic or Numeric Model (Numeric model just provide us with the numeric solution of the existing problem whereas analytical model enables 'what-if' calculations i.e. expected effects on output for varying condition of inputs.)

Mathematical Abstract model are the major concern of transportation engineer and planner, as these models attempt to replicate the system of interest and its behavior by means of mathematical equation based on certain theoretically established framework.

Simulation technique is the latest development in modeling process specially in field of traffic engineering, where the model is represented dynamically by a complex program that gives information about System being investigated having certain constraints and input. In other words simulation is defined as creating the working analogy of real life problems into computer based model. Various Software used in simulation techniques are Synchro, Highway Capacity Software (HCS), Transcad, Vissim, etc.

Advantages & Disadvantages of Simulation Techniques

1. Cheaper than field experience. Powerful tool for comparing the consequence of various alternatives strategies.
2. Help to prepare the analytical model.
3. Less time consuming
4. High initial cost of purchase.
5. Requirement of highly technical person to perform the task.
6. Error may occur while representing the real life problem through a small model.
7. It can be employed to check certain analytical solution

Steps in Simulation:

1. Problem definition.
2. Field studies to determine Inputs required for model formulation
3. Development of logic
4. Calibration model
5. Development of computer simulation program.
6. Validating the model
7. Running of simulation

Model Developing Process:

Model (Mathematical model) developing process can be summarized in major three steps which are as follows:

(a) Model Specification
(b) Model Calibration
(c) Model Validation

(a) Model Specification:

- All the independent variables are postulated and the interdependency between them is analyzed i.e. Analysis of identification of dependent and independent variables (Trips depend on HH size and Income level)
- Identification of functional form: whether the relationship is linear or complex one between dependent and independent variables.
- Identification of process by which the numerical values of the parameters of a postulated model are determined.
- Identification of Statistical methods, no. of samples required for analysis, etc.
- Choice is made among various mathematical formulation and model is postulated which might get modified during calibration process.

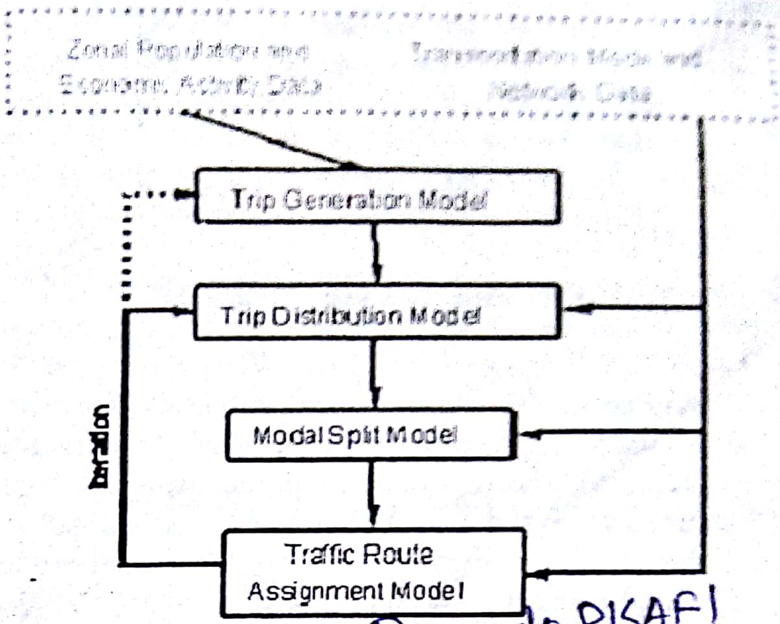
(b) Model Calibration (model Estimation):

- It refers the procedure that are used to adjust the values of model parameter to make them consistent with observation (data collected)
- Numerical values associated with various independent variables and constant of the postulated model are determined.
- The functional form with large goodness of fit (i.e. R^2 value) is considered to be the best model.
- Adjusted R^2 value is considered while to check whether the addition of extra independent variable has the positive/negative impact on outcome.

(c) Model Validation

- It refers to the testing of calibrated model using data other than those used to calibrate the model and check them with field results and if the outcome of the model is within permissible range then the model is properly calibrated else further modification is necessary.

Classical Four Step Modeling Process:



The traditional four step modeling process specially target to urban transportation planning process has four major steps as shown in adjacent figure. Before the first stage started we need to collect information regarding social-economical and system characteristics (as Nodes and Links). Then the four steps modeling are conducted in sequential order as Generation, distribution, modal split and assignment model. Though sometime Model split model is used prior to distribution model based on its characteristics.

Role/Importance of Models:

The role of models can be summarized in the following points:

1. Models provides decision makes the idea about the solution of existing problems (Policy such as making some zone as Pedestrian only zone or Converting two way road to one way road, speed limit at certain section)
2. **Transportation models are used to design transport facilities** such as the required road capacity, design of environmentally friendly road alignments, design of footpath, design of intersection, signal timing design at intersection, etc.
3. **Models helps in development of various plan, policies and analyze them**
4. **Models are also used for planning of new or improvement of existing infrastructure** (gives the conclusion that widening of road is required to accommodate the present flow effectively).
5. **Models are used to quantify the expected impacts of proposed various alternative plans and evaluate the best option to solve existing or expected problems.** (To reduce the delay and conflict at intersection grade separated intersection).
6. Traffic models are used to forecast or predict design year traffic volume, vehicle composition, O-D matrix, parking demand, accident statistics, etc, which in turn helps in necessity of supply measures: (design of road network, footpath, bicycle lane, parking facilities, etc)
7. Models can help in designing the networks of public transport lines, optimum location of bus stops, distance of stop from intersection and can also help in calculating the patronage of the services given, and also indicate to what extent new or improved services attract car users.
8. **Land use model provide us idea about the land use pattern** in the given locality. **Models can helps in better utilization of available capacity:** (It can assist in designing traffic lights and ramp metering facilities to control traffic flows such that less congestion will occur. Planning and design of special target group facilities such as carpool and truck lanes may be facilitated by advanced traffic flow models. The planning of maintenance of the roads (where, when, and how) is another issue where models can assist in decision making that minimizes costs and troubles (time losses) to the road users.)
9. Models can indicate the implications of transportation planning actions for spatial changes. Such model applications are important for the calculation of transport flows that are

consistent with projections of population and employment; impacts of bottlenecks in the road network on spatial developments, the influence a good public transport policy can have to counteract further urbanization of the big cities.

10. Demand model helps in urban transportation planning (to check adequacy of present transportation network, measures that need to be taken to reduce demand, evaluate various improvement alternatives and select the best one)

Aggregate and Disaggregate Modeling

Model can be developed for data item representing an average over a group representing the behavior of a single individual. When the model aims at representing the behavior of more than one individual say in a group, such models are called aggregate models. But when the model at base attempts to represent the behaviour of individuals then such modelling is called disaggregate modeling. If the model is prepared using HH size, then the model called Disaggregate Modeling whereas when the model is prepared using population, then the model called Aggregate modeling.

Transportation Network:

Transportation network consists of major two elements namely: Zoning system and Networking The division of study area into small number of unit so as to make out task easier is called Traffic Analysis Zone (TAZ). Zones are represented by single point called zone centroid assuming that all the activities are concentrated on it. It is linked to network through centroid connectors representing the average costs (time, distance) of joining the transport system for trips with origin or destination in that zone.

The following are a list of zoning criteria, which must be kept in mind while dividing the study area into number of zones:

- Zones size must be such that the aggregation error caused by assumption that all activities are concentrated at centroid is not too large.
- Zones should be compatible with other administrative divisions as census zones
- Zone boundaries should be compatible with cordon and screen lines and previous zoning system, but should not match major roads. Natural or physical barriers such as river canal etc can form convenient zone boundaries.
- Zones should have homogeneous characteristics, especially in land use, population composition etc.
- Zones should preferably have regular geometric form for easy determination of the centroid connector.
- Zones need not to be of same size. They could be of similar dimension in travel time units i.e. smaller zones in congested areas and larger zones in uncongested areas.

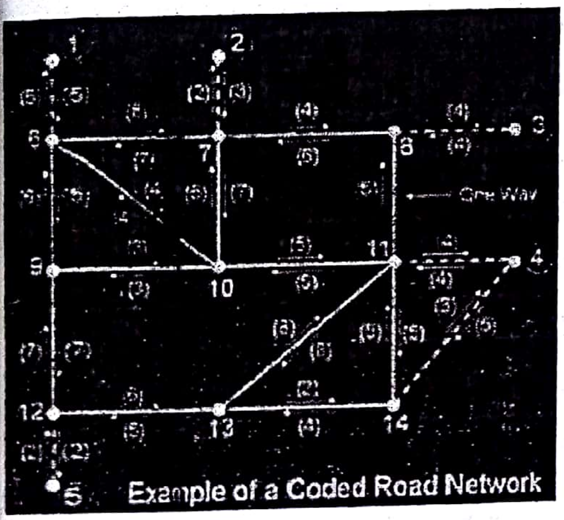
Transportation Network is the computerized description of the system consisting of nodes (intersection) and links (homogeneous stretches of road between nodes). Links are characterized by several attributes such as: length, speed, number of lanes and so on. Each node is specified by a numerical code and each link is described by its end nodes. Zonal centroids are connected to nodes of the modeled network by one or more links. Each link in the network can be attached a functional class according to the degree it serves a flow or access purpose for the trips on the link.

For example, nodes that lie exclusively on arterial streets may be denoted by one range of numerical codes (say, between 100 and 1000) whereas nodes that lie on higher type facilities may be coded with numbers in another range (say, greater than 1000). Thus a link connecting nodes 525 and 666 is clearly a segment of an arterial street, whereas link 1212-1213 is a segment of freeway.

Moreover, links 729-1432 and 1198-888 represent an on ramp (i.e. connecting arterial to a freeway) and an off ramp (i.e. connecting a freeway to an arterial)

Connection of dummy nodes to centroidal links is suggested rather than directly connecting centoidal link to intersections so as to ensure that the traffic flows on the centroidal connectors do not unrealistically load the intersections from non-existing approaches and thus adversely affect subsequent level of service calculations.

The following simple network consists of five zonal centroids (i.e. nodes 1 to 5), six centroidal connectors, nine street intersections (i.e. nodes 6 to 14), and 13 arterial street links. The numerical values in parentheses correspond to the link impedances (which can be either time, distance or cost) in the direction shown. This network is normally described by the link array (table), each cell of which represents a possible direct link between the row and column nodes.



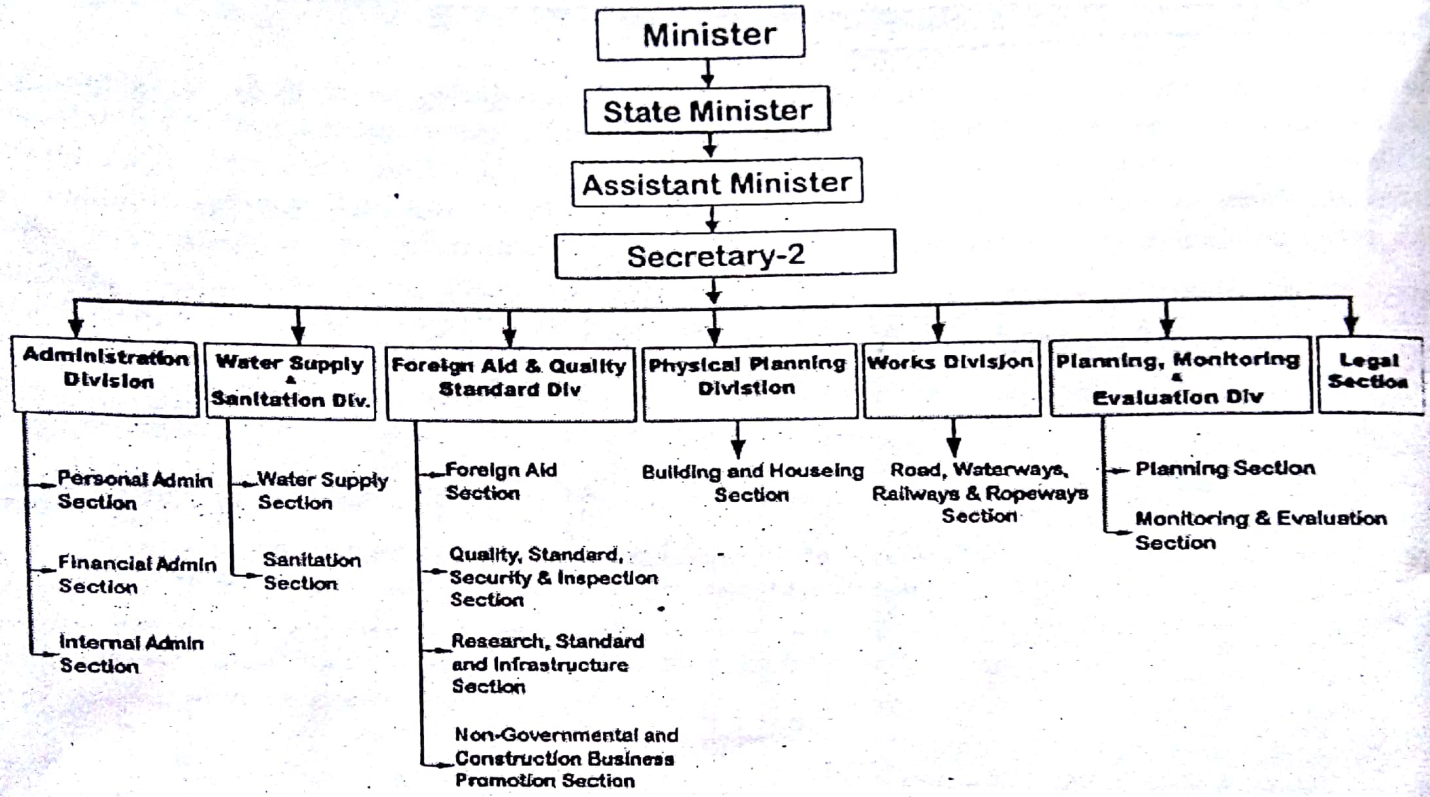
Example of a Coded Road Network

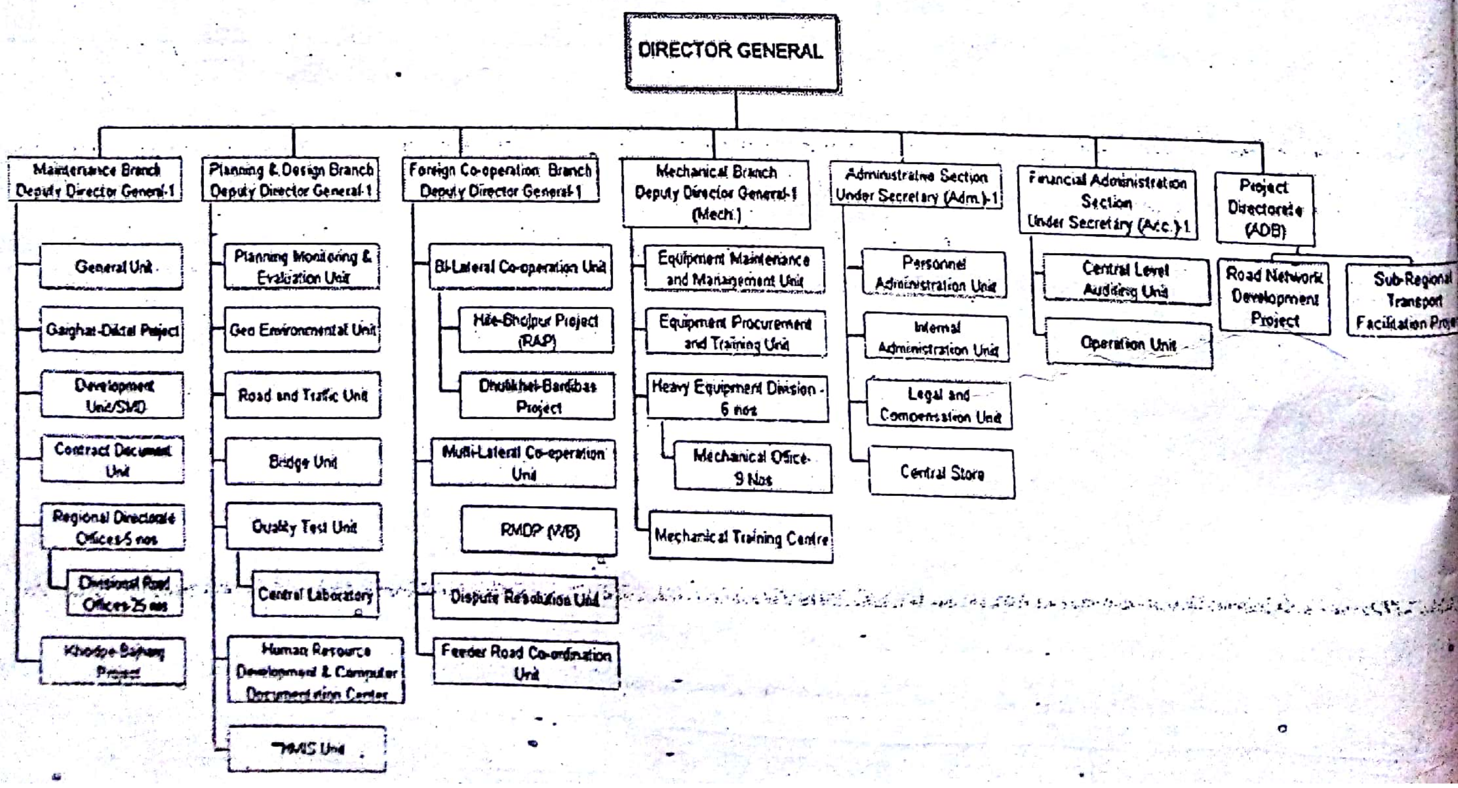
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1						5								
2							3							
3								4						
4											4			5
5												3		
6	5						8		5	4				
7		2				7		4		7				
8			4				6							
9						6				3		7		
10						4	5		3		5			
11				4				5		5			8	5
12					2				7				6	
13											8	5		2
14				3							5		4	

A numerical entry in a cell means that there is in fact such a link, the cell value being, say the link's performance. The dimensions of the link array may be increased to include other link attributes as well such as free flow speed, length and capacity. Travel analysis zones are coded as a set of imaginary nodes that are referred to as zone centroids. To distinguish them from the actual network nodes, they are usually designated by numerical codes at the lower range of positive integers.

Organizational structure

Organization Chart of Ministry of Physical Planning and Works





2. Roles and Responsibilities in the Planning Stage

2.1 Introduction

The principal agencies involved in the planning stages of a project include

- National Planning Commission
- Ministry of Finance
- The executing agency, normally a line ministry
- The implementing agency, normally a department within the line ministry
- District Development Committees and Village Development Committees.

The general relationship between the different agencies in the planning stage is illustrated in Figure 2.1.

2.2 National Planning Commission

NPC has a major involvement in the planning of projects as follows:

- Prepares long-term development plans, strategies and visions.
- Prepares medium-term (five-year) development plan, policies and strategies within the framework of the long-term plan and vision.
- Formulates development programmes and assists HMG/N in their implementation.
- Provides guidelines, advice and suggestions to sectoral ministries, departments, other agencies and local bodies and assists them in the formulation of plans and projects.
- Explores internal and external resources as well as indigenous and foreign technology, and recommends suggestions to HMG/N to accelerate the pace of development.
- Reviews requests for new projects in respect of their conformance with the provisions and priorities in the five-year development plan and long-term plans (master plans) for the concerned sector and provides its approval or rejection.
- Approves new programmes and project proposals submitted by the sectoral ministries. In this process, it examines whether or not the proposed programmes/projects comply with the approved annual programmes and the government's existing policies and the five-year development plan's objectives and targets.
- Sets objectives, policies and criteria for prioritising development projects and programmes.
- Sends annual development budget ceilings approved by the Resource Committee to the sectoral ministries and agencies along with development budget preparation guidelines and forms for the formulation of the forthcoming fiscal year's development budget.
- Sends district development budget ceilings and guidelines to all the District Development Committees for the preparation/formulation of the forthcoming fiscal year's district programmes.
- Carries out inter-ministerial co-ordination.
- Issues circulars to concerned bodies to submit their development programmes and budgets as per limits and guidelines and within the specified time.
- Can make alterations to development programmes and the budgets prepared and submitted to MOF.
- Issues guidelines or directives, as necessary, on criteria for identification, screening, feasibility studies, and reporting on new projects based on feedback from past projects, policy considerations and research

- The Technical Audit Branch conducts technical audits to verify the extent to which a project has followed HMG/N rules, regulations and the PWD, following the directives laid down in the Technical Audit Manual as approved by HMG/N.

2.3 Ministry of Finance

MOF's role and responsibility in the planning stage are as follows:

- In consultation with NPC, fixes the development and regular budget ceilings for each line ministry and prepares guidelines to be followed by the sector agencies while preparing their annual programmes and budgets.
- Negotiates and approves the donor-aided programme of assistance and individual projects in consultation with NPC, line ministries and other relevant organisations.
- Improves, updates and amends the Financial Administration Regulation (FAR) as per changes required for efficiency and effectiveness.
- Presents the regular and development budgets (after the approval of the cabinet) to the parliament for discussion and approval.
- Evaluates whether or not the proposed projects are within the capacity of the proposing ministry based on the previous year's performance.
- Reappraises within the framework of national policy the projects which have been appraised and submitted by the line ministries.
- Holds budget discussions with the line ministries and finalises annual budget amounts project-wise and budget head-wise for inclusion in the budgetary document.
- Adjusts the budget depending on the resources available.

2.4 Executing Agency (Line Ministry)

Even though NPC and MOF are responsible for finalising the long-term plans (5,15, 20 years), the annual programme and the required budget provisions, the line ministry is responsible for the following activities in response to requests from departments and other related agencies:

- Initiates project requests.
- Requests budget provision for project feasibility studies.
- Requests annual budgets for on-going and new projects.
- Approves district level annual programmes of projects already approved.
- May approve projects of an urgent nature costing less than NRs 1.5 million, informing NPC of the reasons why due processes of approval could not be followed.
- Provides data for ensuring quality, quantity and overall robustness of projects.
- Scrutinize the budget estimate and programme to check whether it is within budget limits, conforms to periodic plans and is result oriented and finalizes it.

2.4.1 Project Identification In Five-Year Plan

The ministry shall in line with the long-term development strategy, sector policies, and vision of the government, generate a list of projects that generate income and provide equitable development. The ministry shall consider the following:

- Development of sector master plans at central and local levels.
- Feedback and subsequent revisions in the master plan.
- Project requests through local bodies and political representations.
- Existing pre-feasibility/feasibility studies.
- Priorities in the master plan and other plans.

- Uniqueness of the project in terms of urgent relief, early benefits, funding availability, environmental inputs and sustainability.

The ministry shall submit to NPC the details of the following:

- On-going projects, their costs, time for completion and their priorities in terms of net present value (NPV) and internal rate of return (IRR).
- Maintenance and improvement of completed projects showing costs, time, NPV and priorities.
- New projects with costs, time, NPV and priorities.
- Projects that are not economically viable but socially urgent with costs, priorities, and time.
- Database of identified projects enlisting salient features of the project.
- Information dissemination.
- Feedback for future ministry plans and programmes.

The electronic record shall be maintained for all the five-year and annual project requests. Computer disks and hard copy shall be sent to NPC.

2.4.2 Project Preparation

The ministry shall ensure that the implementing agencies (e.g. departments) have sufficient planning units, manpower and adequate planning tools to generate and analyse the data and reports and to support NPC.

It provides a technical group or support to carry out detailed feasibility studies of the technical, institutional, economic and financial aspects of the project and to carry out the necessary social and environmental assessments.

It instructs division/district/project staff to develop the preliminary engineering design of the project specifying its objective, location, size, components costs, phasing, manner of execution, schedule and expected results of the project.

2.4.3 Project Appraisal

In collaboration with the MOF, the ministry carries out an appraisal of the project, reviewing all the aspects of the project and if necessary modifies and remodels the project.

2.4.4 Project Funding

In collaboration with MOF and NPC, the ministry arranges for including the appraised project in the five-year plan development budget or identifying funding from foreign assistance.

2.4.5 Annual Budget Requests to NPC/MOF

The ministry ensures that the implementing agencies (departments) consider the following in preparing and submitting their annual plans:

- On-going projects included in the five-year plan along with their status in relation to the plan period targets.
- Feasibility and pre-feasibility studies of the project.
- Justification for new projects not included in the five-year plan.
- Appraisal of projects for which feasibility studies have already been carried out.
- Priorities with reference to the five-year plan.

2.4.6 Annual Work Programme After Budget Approvals

Actual work programmes are prepared in detail within the annual budget approved for each project by the parliament. Executing agencies should ensure that the implementing agencies consider the following in preparing the annual work programme:

- The programme shall reflect the total project work to date and the work planned for the year and the timetable.
- The unit rates, time for completion, procurement process, specifications and design standards should match the expected levels of service and do not differ significantly among similar projects.
- Directives for annual plans are prepared so that uniformity, cost effectiveness and efficiency are well addressed.
- Annual work programmes are approved by the concerned ministry.

2.4.7 Project Implementation Plan

In collaboration with the Ministry of General Administration and MOF, the ministry obtains sanction of staff establishment and their placement in the project.

In collaboration with FCGO, it arranges for accountant staff required for the project and their placement in the project.

For co-ordination and eliciting co-operation from all concerned, it may form a coordination committee comprising representatives from all departments and ministries which will have an involvement in the project.

2.4.8 Institutional Arrangement

Each ministry shall establish a strong planning and monitoring division with adequate manpower, logistic support and appropriate incentive mechanisms.

2.5 Implementing Agency (Department)

2.5.1 Five-Year Development Plan Requests

The department's principal role and responsibility are:

- Develops criteria for review, analysis and prioritisation of projects requested from field offices employing computer based techniques.
- Estimates costs required for the selected projects
- Prepares a list of income growth-based and social needs-based projects and indicates their priority.

2.5.2 Annual Plan and Work Programme Requests

The ministry shall ensure that the departments or other implementing agencies under it are competent enough to maintain proper records in paper and electronic form so that annual plans are prepared and submitted to the executing agency in proper formats. Each department is responsible for:

- Prepares a prioritised list of on-going and feasible new projects within the current five-year plan.
- Prepares a list of on-going and new projects outside the five-year plan with detailed justification for their inclusion.

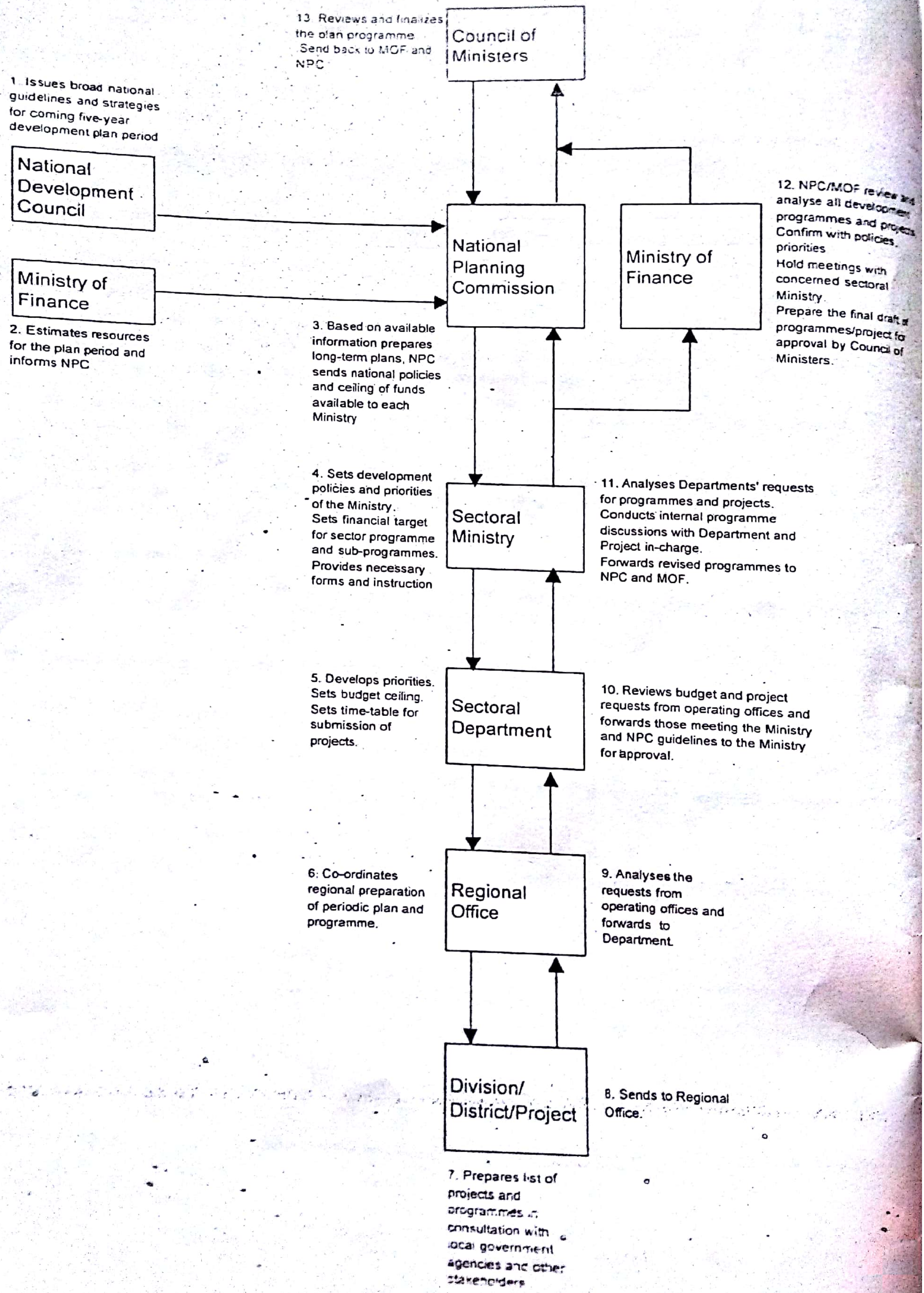
For each project based on the budget allocated in the Fiscal Year Amountwise Expenditure Details (red book):

- Prepares a trimester and annual work plan for each project.
- Ensures uniformity of standards and costs and the cost-effectiveness.

2.5.3 Institutional Arrangement

Each department shall establish a strong planning division/unit with adequate manpower and logistic supports.

Figure 2.1 Relationship of Different Nepali Agencies in the Planning Process



Chapter 2 Urban and Regional Transportation Planning

Regional Planning

Regional planning is a category of planning and development that deals with the efficient placement of land-use activities, infrastructure, and settlement growth across a larger area of land than an individual city or town. It is the planning for a geographic area, also called spatial planning that transcends the boundaries of individual governmental units but that shares common social, economic, political, cultural, and natural resources, and transportation characteristics. It is the science of efficient placement of infrastructure and zoning for the sustainable growth of a region, which includes addressing region-wide environmental, social, and economic issues.

The key to regional planning is anticipating the needs of a community or group of communities before those needs arise. Experts in this field might try to predict how and where the population of a region is going to grow over the next decade and recommend the building of roads and other infrastructure to support that growth before it happens. Regional planner, also called planning commissioners works with local governments and urban planners within their planning zone to discuss such issues as regional development, land use, community development, long-range planning, environmental planning, housing, and economic development. Regional planning also deals with the improvement and conservation of the natural environment via effective and comprehensive utilization of natural materials and technical (labor resources).

Regional planning often walks a fine line between serving the needs of the community, protecting the environment, and taking into account the rights of individual land owners and community members. Commissioners should have sufficient knowledge in many areas, including engineering, environment, transportation, sociology, legal aspects and geography.

Thus, regional planning is oriented to the future with the following objectives:

- Natural as well as human resources are used at their optimal level.
- To increase the economy rate of the country as well as of each of its regions rapidly.
- Equitable distribution of resources and infrastructure among different regions and among groups within the same regions.
- To minimize the gap between national and regional development is minimized.

Theory of regional planning covers all of the following theories:

- Economic location theory (finding site for an activity at minimum cost)
- Central place studies (source of goods & services to the surrounding areas)

- Theories relative to urbanization, spatial integration of rural and urban areas
- Theory of inter-regional migration, resource use & investment pattern

Economic location theory:

Objective: To find out the site for an activity corresponding to minimum cost

The concept of cost has been changed from production cost to delivery cost and presently to distance cost. While economic location theory furnishes answers for optimal location of different activities, optimally depends upon regional considerations. As regional planning has got much to do with the spatial differentiation of human activities, a special link between location theory and regional planning should be established.

The major problems associated with regional economies are:

a) Natural resource advantages
b) Economies of constraints
c) Cost of transport and communications

The relative desirability of a location depends upon four types of location factors:

i) Local input: Supply of non-transferable resources at the location
ii) Local demand: Demand for non-transferable outputs at the location
iii) Transferable input: Supply of transferable inputs from outside sources to the location
iv) Output demand: the net receipts obtainable from sales of transferable outputs to the outside markets.

Central place Studies and Geography of Concentration:

Location theory can be extended to cover the spatial distribution of human settlements i.e. location of people. Center place is the source of goods and services to the surrounding area beyond its own. Its main purpose is to explain size, number and distribution of towns. Besides the population, several factors contribute to the importance of the central place as:

a) The supply of goods to the population of the surrounding area
b) Provision of resort amenities
c) Nodes or transportation network
d) The provision of banking and commercial facilities
e) Educational and cultural facilities
f) Governmental and other administrative facilities

Urban planning or Town Planning or City Planning:

Urban planning is a technical and political process concerned with the use of land and design of the urban environment, including air, water, and the infrastructure passing into and out of urban areas such as transportation and distribution networks. It is the integration of land use planning and transport planning, to explore a very wide range of aspects of the built and social environment of urbanized municipalities and communities, covering research and analysis, strategic thinking, architecture, urban design, public consultation, policy recommendations, implementation and management. Urban planning reemerged as a professional discipline during the latter part of the nineteenth century. It guides and ensures the orderly development of settlements and satellite communities which commute into and out of urban areas or share resources with it.

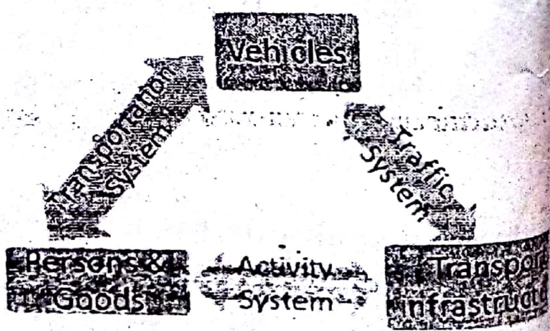
In broadest terms, urban and regional planning is process by which communities attempt to control and/or design change and development in their physical environments. Both concepts are covered in spatial planning. Though both are related in category, they actually have distinctive objectives. Urban planning focuses on shaping a city setting through effective land and ecosystem development and design. However, regional planning focuses on development of larger areas. Thus, urban planning deals with small cities/community but in greater details, whereas regional planning deals with a larger environment, but at less detailed level. Urban planning deals with the specific issues of city planning.

Regional planners will be concerned with protection of farmland or other valued resource sites (e.g.: forests, mineral deposits, seashores, lakeshores); the preservation of unique natural or historical features; transport facilities (such as pipelines or airports) and the growth prospects of communities located throughout the region. If the region is organized around a large city, the planners must also take account of the problems caused by the city's expansion, and its impact upon the surrounding countryside and nearby towns too.

Urban Planners basically need to address two issues. First, thinking ahead to accommodate the city's growth - deciding which lands should be built on and when, and for what purpose (residential development vs. industry vs. shopping centre or playing fields etc). Second issue concerns for those parts of the community that are already developed, to maintain the built environment at its existing quality (without much deterioration), example: widening of road with consideration of HERITAGE CONSERVATION.

Goods Movement Planning:

Planning agencies have devoted more attention to passenger movement than they have to urban goods movement, as goods movement was considered the responsibility of the private sector, whereas the passenger movement are the responsibility of government.



Activity system: Movement of persons and goods between two or more points or positions in space

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relative to infrastructure. This can be conceived as a market for movement.

Transport system: Movement of persons and goods via some of vehicles from one position to another. Each movement is transport service.

Traffic system: It is a physical movement and it is realized in space and time, assuming that people and goods move together with the means of transport along physical network.

Problems associated with freight transport

- The interaction between commodity flows and the spatial arrangement of land uses.
- The general efficiency and economy of goods movement in urban areas.
- The environmental problems of noise and air pollution created by truck movements.
- The provision for truck movement and loading in zones of concentrated land use such as the central business district.
- Phenomena influencing freight demand were more complex and inter dependent than those influencing passenger demand

Why Freight demand prediction is too complex?

- Decision by shippers, carries and receiver affect choose of mode and route for particular shipment
- Different types of commodities making up the freight may have wide range of prices or values
- Freight movements are measured in various units such as monetary value, quantity, weight, volume, container, carload, and truck load and so on.
- The cost of moving freight is much harder to determine compared to the cost of moving passengers because more specialized services are required for handling, loading, unloading, classifying, storing, packing, ware house etc.

Forecasting Freight Movement:

Forecasts of urban goods movement should include consideration of the following:

- Changing patterns of urban development and structure
- Locations of terminals and transfer points
- Land use patterns
- Changing economics and costs of the goods movement industry
- Labor practices within the industry
- Potential technological innovations in goods movement

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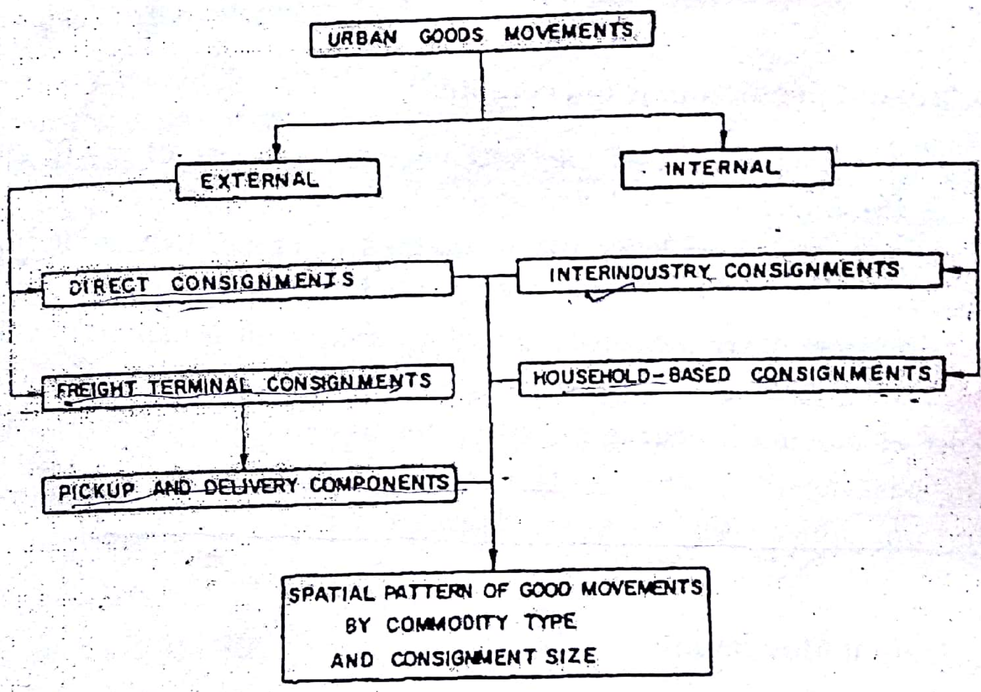
- Effects of governmental policy, financial aid, and regulation on the movement of goods
- Social and environmental considerations.

Following are the methods of forecasting

A. **Growth Factors Method:** Using historical volume data, an annual growth factor can be calculated and then used to determine future volumes for design year. In advanced version, freight traffic is assumed proportional to some economic activity. Forecasting future freight traffic for specific commodities thus requires estimating the growth of future economic activity.

B. **Regional Models:** Incorporating goods movement into the Urban Transport Modeling Approach is another way of estimating freight demand, this approach is almost similar to four step modeling process for passenger travel only using freight trip data.



Difference between movement of goods and persons

1. Mode of transport: freight transport and passenger transport
2. Operator: Mostly government and Private
3. Hierarchy of movement:

Freight transport: raw material-factory-depots (stores)-retailer-households-consumers

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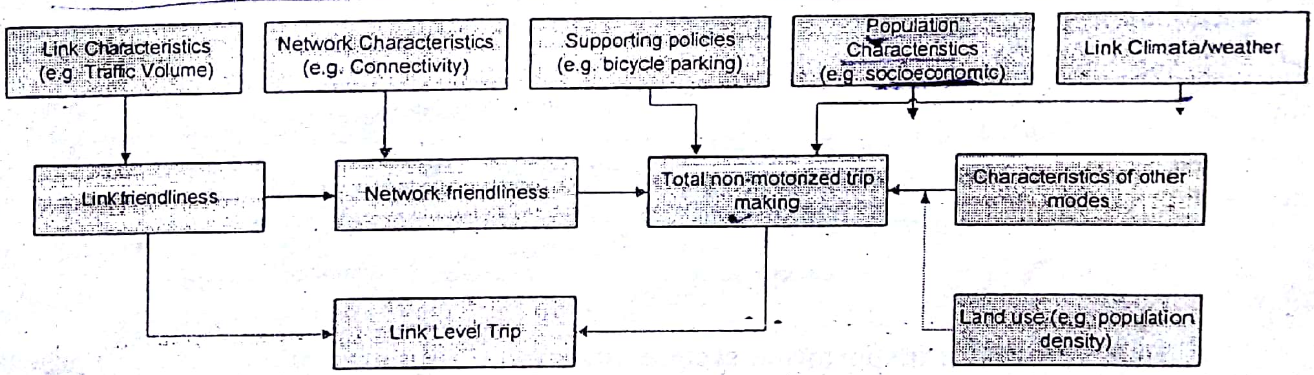
Passenger transport: Home based trips and non-home based trips

4. Route in passenger movement is selected based on time, cost, distance, whereas in goods movement, selected by driver.
5. Expressed as Vehicle per hour or pedestrian per hour or passenger per hour per direction in case of person movement, whereas expressed as kilogram or litre or carton or ton per day.
6. Most often the timing of delivery can be changed in case of goods movement transport, whereas it is almost fixed in case of passenger movement transport.

Non- motorized travel demand

Anything that don't require any motor/engine for their movement are termed as Non motorized travel (NMT). It mainly includes cyclist, pedestrian, rickshaw, etc. They are most often ignored while designing any sorts of infrastructure. But at present, cycle lane are constructed, adequacy of footpath is also in question, thus we need to have idea about it.

The factors influencing non motorized travel demand is given in the chart below.



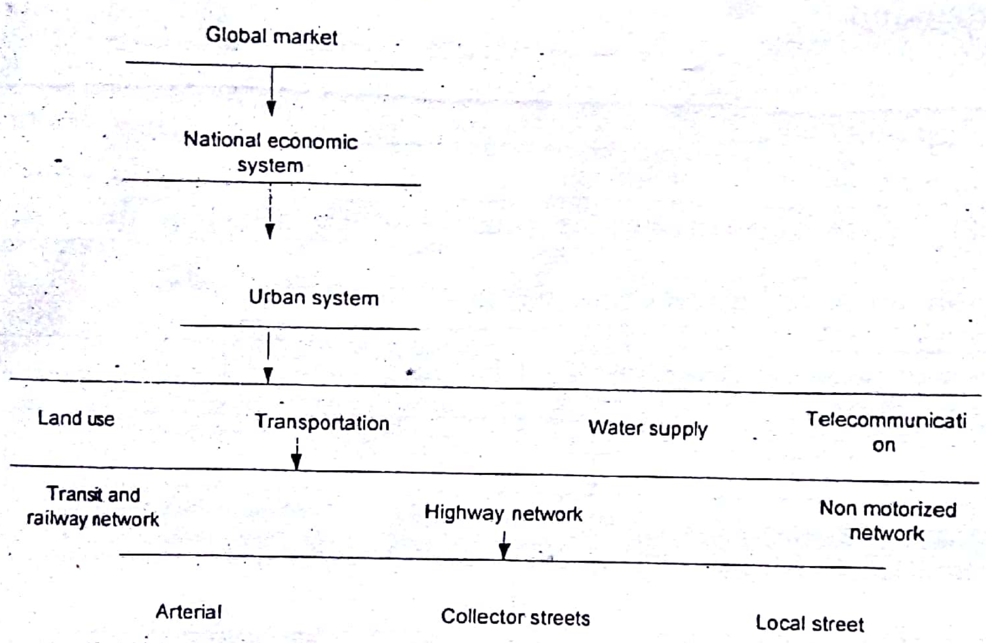
Following approaches are used for estimating non motorized travel demand.

Demand estimation	Description
Comparative studies	Predict NMT demand by comparing it to usage and to surrounding population and land use characteristics of other similar facilities
Aggregate behavior method	Relate NMT in an area to its local population, land use and other characteristics, usually through regression analysis
Sketch plan methods	Predict NMT demand based on simple calculation and rules of thumb about trip lengths, mode shares, and other aspects of travel behavior
Discrete choice models	Predict an individual's travel decision based on characteristics of the alternative available to them, use of utility function
Regional travel	Models that predict total trips by trip purpose, mode and O-D and

models	distribute these trips across a network of transportation facilities based on land use characteristics such as population and employment and on characteristics of the transportation network.

Hierarchical structure to transportation planning

Every system is a part of another system. A system hierarchy provides orders and functions to the operation of individual components in the contexts of global system goals. Functionally, the transportation system is just one of many systems that allow areas to exist. Relevant planning questions at each level in the hierarchy includes:



- How does the transportation system interrelate with these other system to provide livable community?
- What is the cause and effect of relative investment in transportation as compared to other infrastructure system as it relates to community development?
- What is the demand placed on transportation system by changes in the urban system?

Urban systems however are just part of larger ecological, community land use and economic system. For these larger systems, hierarchy influence can range from community level to regions, nations and to the world. Relevant planning questions from this prospective are:

- How What does the transport system as it operates in an urban system affect larger economic and environments?

- What goals can be established for transportation system that will achieve desirable effects at higher levels?
- How is the cause-effect relationship between transportation system performance and other system's performance modified as gets to higher levels of the hierarchy?

Multimodal transportation planning is defined as the process of defining problems, identifying alternatives, evaluating potential solutions and selecting preferred actions that meet community goals in a manner that includes all feasible transportation modes.

There are many transportation facilities and services available in an area that provide opportunities for mobility and accessibility. The system consists of different modal transportation networks (including the information/communications network) which allows traveler to move from one location to another. Intermodal connections provide the ability to transfer from one modal network to another. In addition, land use patterns and the institutional structure for providing transportation service affect the overall performance of the system.

At its most fundamental level, multimodal transportation planning recognizes the fact that there is no single solution to the transportation problems facing a metropolitan area. A coordinated program of action is necessary to deal with the complex nature and interactions of the transportation phenomenon.

Example: We have air transportation service at Kathmandu, near Gausala. Once a passenger get to the terminal building, he need to have access to other mode of transportation. Initially, there were only taxis but nowadays we have Sajha Yatayat, i.e. road transportation links with air transportation.

Transportation Problems:

- Traffic congestion
- Lack of mobility and accessibility:
- Disconnected transportation modes
- Increased number of crashes and injuries
- Inadequate Capacity of the present road network.
- Unreliable and unsystematic Public Transportation
- Unavailability of Parking space.
- Budgetary constraints for construction of transportation facilities or upgrading.
- Air, Noise Pollution
- Less importance is given to pedestrian and bicycle users.
- Poor Appearance of Urban cities

(a) Traffic congestion: This is almost unavoidable in the urban city due to increased traffic demand and poor supply characteristics. The problem can be solved either by capital based alternative (alternative route construction, widening of roads) or adopting various TSM (Transport supply management) measures such as : provision of High Occupancy Vehicle (HOV) lanes, carpooling, exclusive right of way for public transit services, reduction in travel demand, spreading the demand over time (having different working time for private and public organization such as: 9-4 for private & 10-5 for governmental organization) and space (having separate location for different facilities such as: commercial places in one location, educational organization in other area, governmental offices in other areas, and so on)

(b) Disconnected transportation modes: For better operation, there must be the link between multiple modes, e.g. No public bus services inside airport to connect airways with roadway, but in recent days SAJHA YATAYAT has its starting point inside the airport.

(c) Increased crashes, injuries and fatalities: Poor road condition, inadequate sight distance, speeding and overtaking and other various reason has contribute to increase in accident. For the betterment in safety condition, we need to improve roadway geometry, provide adequate sight distance, proper rules and regulation, driver training, installation of traffic signal, speed limits/ post warnings in problem areas and various Intelligent Transport System (ITS) (partially and fully automated vehicle control system, vehicle condition monitoring system, driver condition monitoring system, vehicle warning and road view notification, automated emergency notification) can be used.

(d) Unreliable Public Transportation: Due to unreliable and unsystematic public transportation services, the private vehicle ownership has increased, thus again trigger the transportation problems. As a remedial measures the proper upgrading of public transportation need to be done either by adopting new Mass Transit Technologies such as Bus Rapid Transit (BRT), Metro system with proper scheduling and reliable operation.

(e) Parking Problem: On street parking need to be removed in the place where it is affecting the capacity and multi storey building, parking garage should be considered the feasible solution. Also "Park and Ride" solution must be implemented so as to reduce the parking demand on the core city.

Transportation survey

Transportation survey helps in collection of the required primary data associated with our objectives, related to planning and design of transportation facilities. First we need to identify the study area (outline of our study). The study area is defined by external cordon line, which represents the boundary of studying and non-studying area. Internal cordons (Also called Screen lines) are also arranged as concentric rings to check the accuracy of the survey data obtained by household interview survey. Internal cordons can be located along physical or natural barriers. If we are concern with the traffic flow parameter inside the Ring Road then boundary of Ring Road can be consider as External cordon. Then, four types of possible movements as illustrated in above figure are:

(a) Internal to internal: Within inside of Ring Road (Ratnapark to Kalimati)

(b) Internal to external : From inside of Ring Road to outside (Ratnapark to Kirtipur)

(c) External to internal : From outside of Ring Road to inside (Bhaktapur to Pulchowk)

(d) External to external: From outside to outside of Ringroad, but using the study area while movement. (Thankot -Kalanki -Kalimati - Baneswor –Koteshwor – Bhaktapur)

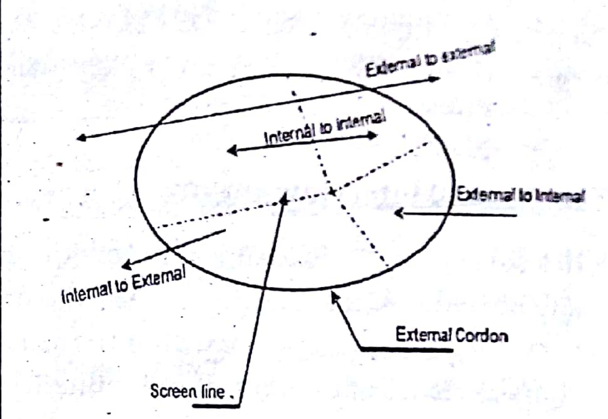


Fig. Basic movements in a transportation syrvey

Internal to internal survey is done by home interview & checks by screen line surveys, whereas others (internal - external, external - internal & external to external travels) can be studies by cordon survey.

Survey can be conducted at following location based on the detail of data required:

(a) At Home (Household(HH) Survey): As home is consider as origin of most of trips

(b) At Destination points, such as bus stops, terminal, parking spot, factory, etc.

(c) During trip such as Roadside Interview, spot speed, moving observer, etc.

Methods or Types of Transportation Survey:

There are various methods of transportation surveys, which can be performed for the collection of required data, but the suitable survey method need to be assessed based on our requirements.

1. Household (HH) interview method
2. Road side interview Survey
3. Origin – Destination Survey Methods:
   - Return Post card Method
   - Registration number plate method

- Tags on vehicle method
- Telephone Survey

4. Traffic Flow/ Volume count Survey:
   - Classified traffic volume count at roadway section
   - Turning movement count at intersection to design signal timing
   - Pedestrian flow count to design footpath or green time for passenger
5. Speed and Travel Time Measurement Survey
   - Spot Speed Measurement
   - Moving Observer / Floating Car/ riding Check Method
6. Commercial vehicle survey
7. Taxi Survey
8. Public Transport survey

Household Interview survey

HH survey is considered as the major source of information on characteristics, behavior and attitudes of traveler. This is the most reliable method of survey for the collection of O-D data. All sorts of data regarding the travel pattern of residents of the household, general characteristics of the household influencing trip making are obtained.

Despite its reliability, it is an expensive method of survey. As each and every HH can't be surveyed, thus sampling needs to be done. With use of various Statistical tools we need to select the sample size to achieve desired accuracy. During this survey it is necessary to send a letter to the selected households prior to the proposed interview, explaining the nature, importance and objectives of survey and asking them for proper cooperation.

Mostly, it is performed by interviewing all the members above 12 year individually and interviewing Head of Household on the behalf of HH member that ranges between 5-12 years. Thus proper questionnaire need to be designed, which should be simple, direct, should take minimum time, answer should cause minimum burden to the respondent. First date, days and time to conduct survey is determined. Usually within Monday to Thursday at evening time (6PM – 9 PM) is considered the best time to conduct study.

Three major types of information are collected:

1. Household characteristics: (Interviewed to head of HH)
   - HH size, HH annual income, no. & type of vehicle ownership, no. of employed members in the HH
2. Personal characteristics: (Interviewed individually)
   - Sex, age, possession of a driving license, educational level, activity & relation to the head of the household (e.g. wife, son)
3. Trip Data: (Interviewed individually)

- Origin and Destination of trip, No. of trips per day.
- Trip purpose, trip start and ending times, Mode and route used for the trip.
- Walking distance, waiting time and transfer distance and station or bus stop (if public transportation is used)
- Parking location, parking charge and duration & vehicle occupancy? (If private vehicle is used).

Road Side Interview Survey

Road Side Interview Survey is one of the common an easiest method of Origin and Destination Study. It is one of the methods of carrying out a screen line or cordon survey. It is usually adopted to check the accuracy or reliability of the information obtained from Household (HH) survey.

The method can be summarized as below:

- ➢ Decide stations which may be along the junction of the cordon-line or screen-line
- ➢ Stopping of vehicles at previously decided stations randomly, as it is impractical to stop and interview all the vehicles (i.e. Sampling is done), by a group of persons through the help of traffic police.
- ➢ Then Drivers are asked to co-operate with the interviewer team for providing sufficient information.
- ➢ Information that may be collected includes place & time of O-D; route location, stoppages, purpose, vehicle and number of passengers.

The number of samples depends upon the number of interviewers and the traffic using the road. Thus, it is a quick, simple and economical method of survey, but it may cause the delay for traffic flow and it needs sufficient space to stop vehicles & take interviews. At the same time it is useful in obtaining information regarding trips which are not registered in Household surveys (i.e. External – External trips). In large cities the cordon lines and screen lines may be complicated. These cordon and screen survey by road side interview serve to check the accuracy of the home interview survey.

Return Postcard Method:

In this method reply paid questionnaires are handed over each driver or even to pedestrian/passenger based on its purpose and are requested to complete the information and asked them to post it back. The received cards are analyzed and conclusions are drawn. In developing country, this method may not be suitable.

Registration number plate survey

Entire study area is cordoned and observers are stationed at all points of entry and exit on all routes. Each party at the station notes the license plate number of the vehicles entering and leaving the cordoned area and the time, thus journey speed could be determined.

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Separate sheets are maintained for each direction. This method is quite easy and quick in field, but it involves a lot of office work. This method does not give the information about O D points, and may not give information about trip purpose, delay and its cause.

Tags on vehicle method

In this method vehicles are stopped and a tag is fixed usually under the windscreen wiper at entry point. Tags may be of different color and shape for different routes. The vehicles are stopped again the exit point when tags are collected. Times of entering and leaving could be recorded on tag to find out the journey time.

Spot Speed Survey:

Spot speed is an instantaneous speed of a vehicle at a specific location. It can be either measured manually or by use of enoscope, Radar speed meter or Photographic and video camera method. In manual method suitable stretch of road is selected and two point are fixed (Recommended distance depend on speed i.e. for<40kmph -27m; 40-65kmph – 54m; >65 – 81m) and then time to cross the distance is noted, based on which speed is determined.

Moving observer / Floating car / Riding check method:

In this method a test vehicle is driven in the required direction with three observers on the test vehicle: The first observer counts opposite traffic using hand tallies, second observer with stopwatches records time for each individual delays and total time duration for the trip of predefined route and third observer records the number of overtaking and overtaken vehicles and ultimately by using specified formula traffic flow, journey time and journey speed can be calculated.

Classified Vehicle Count:

In this method traffic volume of various types of vehicle are individually measured based on their Passenger car unit (PCU), if possible both lane wise vehicle count is performed in both direction. In practical approach, hourly traffic count is divided into four section (i.e count is usually done at interval of 15 minute) so that we can have the idea about the volume distribution even in particular hour.

Turning Movement in Intersection:

In intersection we need to count classified volume of departing vehicle and the respective volume of turning vehicle so as to design signal timing. Along with this we need to record the queue length so as to have idea about arrival volume.

Pedestrian and Non- motorized Volume Count:

The non-motorized (pedestrian, bicycle, rickshaw) volume is of great importance in designing facilities like bicycle lane, footpath width, etc. The crossing pedestrian volume at intersection helps in signal timing for pedestrian.

Commercial vehicle and Taxi Survey

It is conducted to obtain information on journey made by all commercial vehicles or taxi within the study area. The survey consists of issuing questionnaire or interviewing taxi or commercial vehicle driver on the characteristics of the trips. Information to be obtained in taxi survey includes: average trip length, average passenger per trips, cost of trips, approximate total passenger per day, etc. as obtained from interview, whereas total no. of taxi or taxi's volume at study area can be obtained from observation. Similarly, Information to be collected in commercial vehicle survey includes destination, time of travel, total volume or weight of goods, route, commercial vehicle volume, location of terminal for commercial vehicles, etc.

Public Transportation Survey

In case of public transportation we also need to interview passenger to obtain time required to complete a trip, no. of stop within the route, delay at each stops, etc. or we can ask the operator about the service frequency of vehicles at various course of time (peak and off peak), fare, origin and destination of each public transportation. We ourselves can collect various data such as: average trip length, average trip time, running and journey speed of vehicle, service frequency at different time, passenger accommodated per hour, etc.

Inventories of transportation facilities:

To identify deficiency of present system and improvement required, we need to have idea about the various data (inventories) related to transport facilities which are:

- Inventory of streets forming transportation network
- Traffic volume, composition, peak and off peak period and Peak hour factor (PHF)
- Journey time by different modes
- Inventory of Public transportation (No. of passenger alighting, boarding, no. of station, schedule of operation, and so on)
- Inventory related to pedestrian, cyclist and other non motorized modes
- Parking Inventory (Parking demand, occupancy, supply)
- Accident Inventory

Inventories of land use:

Zonal information based on its land use, whether it is used for residential, commercial, industrial, recreational, agricultural, institutional purpose or it is an open space, is of great importance in transportation planning, especially in determining the relationship between land use and transportation. It also plays important role in trip generation modeling.

Inventory of Economic studies:

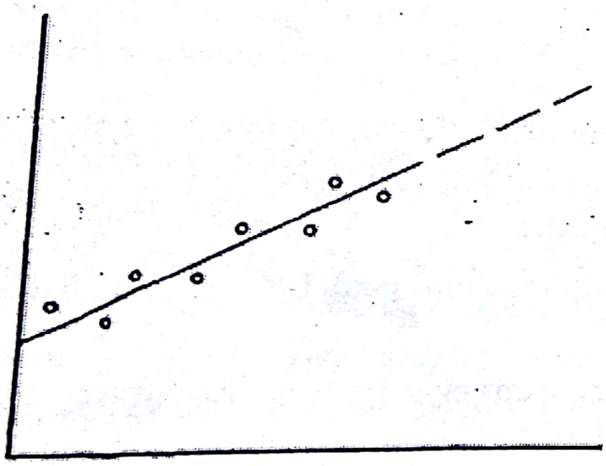
It includes following:

- Zonal population
- Age, sex and family composition of the zone
- Employment and vehicle ownership statistics
- Housing statistics
- Income study

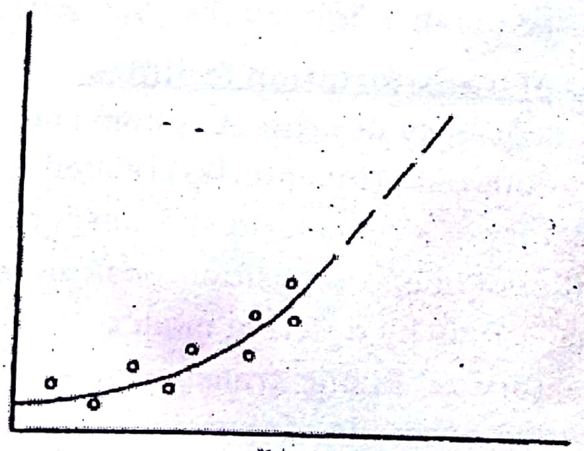
Predicting Future Demand:

As discussed earlier, there are various method of predicting future demand, which is important for design of any infrastructure or operation point of view. There are various method of predicting future demand as discussed below:

(a) **Forecast based on Past Trend or Trend Analysis:** It is the one of the simplest method of forecasting. It analyze the available traffic volume data, the past trend can be identified and extrapolated to estimate future volumes. It is relatively cheap and easy to conduct method of forecasting. It is much appropriate method if the trend is expected to continue in the future too. It gives better result for short range forecasts



(a) Linear



(b) Non-linear

(b) **Elasticity models:** In regression models policy variables could be included in the model specification. If one is engaged in relatively short-term planning, such that other influences can be assumed constant, it is possible to specify a model which is solely concerned with the sensitivity of the forecast to key policy variables. Such a model is known as an elasticity model and it is one of the most widely used models of marginal change. Elasticity is the measure of the sensitivity of demand to changes in system condition.

Its general form is:

$$Y_t = Y_{t-1}\{1 + E(X_t - X_{t-1})/X_{t-1}\}$$

Where Y_t = quantity demanded in year t,

X_t = value of a supply variable (e.g. price or journey time) in year t,

E is the elasticity coefficient for Y with respect to X.

Elasticity model can also be used to predict the effect of marginal changes in a wide range of supply variables. For example, to represent the effect on demand of changes in petrol prices, car parking charges, road-user tolls, expenditure on advertising, frequency of bus service, etc on the usage of public transportation.

(c) **Four Step Modeling Process** or **Classical Transport Demand Model:** Includes trip generation, trip distribution, modal split and trip assignment model (To be discussed in chapter 3)

(d) Land use models: The demand for movement or trip making is directly connected to the activities undertaken by people, which ultimately depend on land use. Thus, using various land use model we can predict demand for specified type of land use.

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Chapter – 3 Urban Transport Planning Process

The urban transportation planning process can be summarized into following points:

(a) First regional population and economic growth is forecasted for the targeted year for the given metropolitan area.
(b) Allocation of the land uses and socio-economic projections to individual analysis zones according to land availability, local zoning, and related public policies.
(c) Generation of alternative transportation plans based on the results of step (a) & (b)
(d) Calculation of the capital and maintenance costs of each alternative plan.
(e) Application of calibrated demand forecasting models to predict the targeted year equilibrium flows expected to use each alternative, provided land-use & socio-economic projection of step 'b' & characteristics of the transportation alternative 'c'.
(f) Conversion of equilibrium flows to direct user benefits, such as saving in travel time and travel cost attributable to the proposed plan.
(g) Comparative evaluation & selection of the best alternatives based on estimated cost and benefits.

Travel Demand forecasting:

Travel demand forecasting is the estimating the demand for transport facilities and services for future design period. We need to deal with the following factor during forecasting, which is the important component of transportation planning

- Trip production and Attraction (How many trips)
- Decisions on destination (Where to go)
- Modal decisions (Which mode to use)
- Spatial decisions (Which route to use)

Four distinct traffic models are then used sequentially to predict the movement of specific segments of the area's population at a specific time of day. And the combined form of four step sequential process is called **Four Step Modeling Process** or **Classical Transport Demand Model.** An overall model of this type may also require information relating to the prediction of future land uses within the study area, along with projections of the socio-economic profile of the inhabitants, to be input at the start of the modeling process.

The models are described briefly as:

(a) Trip generation: First we have to estimate no. of trips production and attraction at each zone (study area). This can be done through various mathematical models as regression model and cross classification models. First these models need to be calibrated using various variables which may be HH size & income, auto ownership, no of employee member, population density, etc.

(b) Trip Distribution: After trips generation the generated trips must be distributed to the available zones based on the various factors sometime attractiveness of each zone whereas sometime distributing as per impedance factor. Thus O-D matrix is being generated in this step. Trip distribution are analyzed by mainly two types of methods; Growth factor methods (uniform & average GF method, Fratar & Furness method) or Synthetic methods (Gravity method which consider the impedance between the zones)

(c) Modal split Model: It predicts the no. of trips using the particular mode say private vehicle or public vehicles. This model can be used even after trip generation considering only personal characteristics called <u>Trip End Type Modal Split Model</u> or after distribution model considering both personal as well as trip characteristics called <u>Trip Interchange Modal Split Model</u>. Logit model is based upon the probability of choosing a particular mode, which further depend upon the utility and disutility (generalized cost of travel) function.

(d) Route Assignment Model: It predicts the route selected for each distributed trips. The user or travelers select the shortest route having low generalized cost of travel (shortest distance, less time). The route is selected based on various available techniques as All or Nothing, User & System equilibrium method, multipath assignment method and so on.

TRIP GENERATION MODELING:

The trip generation stage is the first stage of classical transport model which aims at predicting the total number of trips generated and attracted in each zone of the study area, in conjunction with the land use and the socio-economic characteristics of each zone. The basic outcome of the process is the solution of a following question such as:

- How many trips originate at each zone
- No. of various types of trip (shopping, works trips, social & recreational trips) produced.
- Probability that this person type will undertake 0,1,2 or more trips
- What are the independent variables on which the trips are governed?

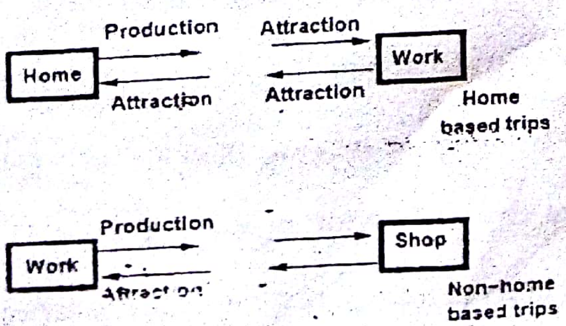
The planner must understand and quantify the relationship between present urban activity and present trip-making, which is cover by trip generation modeling.

<u>Trip:</u> The basic unit of travel demand is trip, which is defined as the movement of an individual with single purpose and having two trip ends, an origin (start of trip) and a destination(end of trip). The journey from home to work is an example of a single trip.

<u>Household (HH):</u> HH is usually a group of persons who normally live together and take their meals from a common kitchen unless the work prevents any of them from doing so. A group of unrelated persons who live in an institution and take their meals from a common kitchen is called an institutional household.

<u>Home based (HB) & Non Home based (NHB) trip</u> : If either the trip end (origin or destination) of trip maker is home then the trip is called HB trip, else it is NHB trip.

<u>Trip Generation and Attraction:</u>
A generation or production is the home end of HB trip and origin of NHB trips whereas attraction is the non home end of HB trip or destination of NHB trip. Trip production and attraction are different from Origin and Destination in case for home Based (HB) trips as no matter the trips starts or ends from home, home is always production end but not the case in origin and destination point of view.



Trip Classification:

(a) Trip Classification based on Purpose:

Home Based (HB) trip purpose may be classified under following headings:

- Trips to work (home-based work (HBW))
- Trips to school or college (Education trips);
- Shopping trips;
- Social and recreational trips;
- Other trips.

The first two are compulsory (or mandatory) trips & others are discretionary (or optional) trips. HB trips constitute about 80-85 percent of trips.

Non Home based (NHB) trips, which contributes small proportion (only 15-20%) are not normally treated separately.

(b) **Trip classification based on the time of the day:**

Trips are often classified into peak and off-peak period trips. Normally morning (8:30am - 10:30am) and evening (4pm -6pm) is considered peak hour and the trip at that period of time is high compared to other.

(c) Trip Classification based on person type:

This is another important classification, as individual travel behavior is heavily dependent on socioeconomic attributes. The following categories are usually employed:

–Trip based on income level (high income level HH has more trips);

– Trip based on vehicle ownership (Number of vehicle each HH has affect the no. of trips);

– Trip based on Household size and structure (single, married, joint family, etc).

Factors affecting personal trip production

Trip production is performed by relating the number of trips to the characteristics of the individuals, of the zone, and of the transportation network. In production models, estimates are primarily based on the demographics of the population within a zone.

The following factors have been proposed for consideration in many practical studies:

- Income and standard of living
- Vehicle ownership
- Household structure and size;
- Number of employed and non employed member in HH
- Value of land;
- Population and Residential density;
- Accessibility (Distance from central business district)

The first four variables are considered in disaggregate (HH based) studies, while value of land, population and residential density are used in aggregate (Zonal based) studies.

(a) Factors affecting personal trip attraction

- Characteristics of the land use
- Retail floor area, service and office floor area and manufacturing and wholesaling floor area
- Employment opportunities.
- Distance of zone from core city or location of various facilities (commercial, industrial, social, recreational, etc)
- Accessibility (Extend and Quality of transport services to the zone)

(b) **Freight trip productions and attractions**

Freight trips has also significant contribution on total trips, thus they also need to be addressed. Important variables include:

- Number of employees;
- Number of sales;
- Roofed area of firm;
- Total area of firm

For residential land uses, character is described in terms of socioeconomic variables like family size, family income, and car availability. Generally, high-income or large families make more trips than low-income or small families. And obviously, three-car families generally make more trips than one-car families.

Trip generation Model and their analysis:

Trip generation model can be derived at two level of aggregation, whether aggregate or Zonal based or disaggregate or household (HH) based.

Three major operational approaches to trip generation modeling are:

- Growth factor models
- Linear regression models
- Cross-classification (category analysis) models

(a) Growth factor modeling

Growth factor modes tries to predict the number of trips produced or attracted by a house hold or zone as a linear function of explanatory variables. The models have the following basic equation:

$$T_i = F_i * t_i$$

Where T_i and t_i are respectively future and current trips in zone i and F_i is the growth factor. The growth factor F_i depends on the explanatory variable such as population (P) of the zone, average house hold income (I), average vehicle ownership (V). The simplest form of fi is represented as follows

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

Where superscripts d and c represents the design and current years respectively.

NUMERICAL Consider a zone with 500HH, among which 250 HH have vehicle and rest have no vehicle. Take 6 trips per day per HH having their own vehicle and 2.5 trips per HH having no vehicle. Calculate the total present day trips. Determine the future trip assuming all the HH will have vehicle and that the population and Income level remains constant. Also determine the future trip assuming constant trip rate.

Solution: Trips from HH having car = 6*250 = 1500

Trips from HH having car = 2.5*250 = 625

Total present day trips = 1500+625 = 2125 trips

Total number of HH = 500

Growth factor (F) = Present vehicle ownership/Future vehicle ownership

= (250/500) = 2

Future trips = present day trip * Growth factor = 2125 * 2 = 4250 trips

If trip rate remains constant, then the future trips = 500 *6 = 3000 trips

Thus we conclude that Growth factor model gives much higher value This growth factor models are normally used in the prediction of external trips where no other methods are available. But for internal trip, regression methods are considered much suitable method.

(b) Regression methods:

Two types of regression models are commonly used. The first uses data aggregated at the zonal level, with average number of trips per household in the zone as the dependent variable and average zonal characteristics as the independent (explanatory) variable. The second uses disaggregated data at the household or individual level, with the number of trips made by a household or individual as the dependent variable and the household and personal characteristics as the independent variables.

The general form of a trip generation model is $T_i = f(x_1; x_2; x_3; \ldots\ldots)$
Where xi's are prediction factor or explanatory variable or independent variables and T_i is dependent variable.

The principal assumptions of regression analysis are:

- The variance of the Y values about the regression line must be the same for all magnitudes of the independent variables.
- The deviations of the Y values about the regression line must be independent of each other and normally distributed.
- The X values are measured without error
- The regression of the dependent variable Y on the independent variable X is linear, which may not be true in all cases.

$$T_i = a_0 + a_1 * X_1 + a_2 * X_2 + \ldots\ldots a_n * X_n$$

Where, a_i's are the coefficient of the regression equation to be determined.

Single independent variable case:

A linear regression model is to be developed between dependent variable (Y) & independent variables(X) in the form of Y= a + b * X
The constant value of "a" and "b" is determined as:

$$b = \frac{\sum xy}{\sum x^2} \quad \& \quad a = \bar{Y} - b\bar{X} \quad \text{Where } x = X - \bar{X} \quad y = Y - \bar{Y}$$

The ratio of the sum of squares explained by the regression to the total sum of squares is known as the coefficient of determination (R^2 value) is given as: $R^2 = \frac{\sum y_e^2}{\sum y^2}$

$\sum y^2 = \sum y_d^2 + \sum y_e^2$, total sum of squares of the deviations of Y observations about the mean value.
$\sum y_d^2$ = sum of squares of deviations of the Y observations from the regression line.
$\sum y_e^2$ = the sum of squares of the deviations of the estimated value of Y (Y_e) about the mean value (regression of sum of squares)

The residual sum of squares, $\sum y_d^2$ provides a measure of the variability of Y observations about the regression value. If $\sum y_d^2$ is small, then the regression equation may be considered to fit the observed data well. Higher the R^2 value better the goodness of fit of data in the equation.

NUMERICAL: Develop the trip production equation for the following data and calculate relevant statistics to check the validity of equation developed.

Average HH size	2	3	4	5	6
Average total trips per day	5	7	8	10	10

Solution:

Let us suppose the equation be Y= A+ B*X

Where, A and B are constants and Trips (Y) represent dependent variables whereas HH size (X) represent independent variable.

X	Y	$y = Y - \bar{Y}$	$x = X - \bar{X}$	x^2	y^2	xy	Y_e	$y_e^2 = (Y_e - \bar{Y})^2$	$y_d^2 = (Y - Y_e)^2$
2	5	-3	-2	4	9	6	5.4	6.76	0.16
3	7	-1	-1	1	1	1	6.7	1.69	0.09
4	8	0	0	0	0	0	8	0	0
5	10	2	1	1	4	2	9.3	1.69	0.49
6	10	2	2	4	4	4	10.6	6.76	0.36
20	**40**	0	0	10	18	13		**16.9**	**1.1**

Here , $\bar{Y}$ = 40/5 = 8 & $\bar{X}$= 20/5= 4

Then,

$b = \frac{\sum xy}{\sum x^2}$ = 13/10 = 1.3 & $a = \bar{Y} - b\bar{X}$ = 8 – 4 *1.3 = 2.8

Hence the equation becomes, **Y= 2.8+1.3*X**

$\sum y_d^2$ = sum of squares of deviations of the Y observations from the regression line = 1.1

$\sum y_e^2$ = sum of squares of deviations of the estimated value about the mean value = 16.9

$\sum y^2$ = Total sum of squares of the deviations $=\sum y_d^2 + \sum y_e^2$ = 1.1+16.9 = 18

Then, coefficient of determination $R^2 = \frac{\sum y_e^2}{\sum y^2}$ = 16.9/18 = 0.94

Category analysis or Cross classification Analysis:

Category analysis or Cross classification techniques is the method developed by Wotton and pick for the determination of trips generated. It overcomes the disadvantage of Regression analysis of assuming the linear relationship between dependent and independent variables. Category analysis is a technique for estimating the trip production characteristics of households, which have been sorted into a number of separate categories according to a set of properties that characterize the household (household size, income level, vehicle ownership, etc). A multidimensional matrix is formed which defined the categories and each dimension in the matrix represents the one independent variable.

For example, one may classify households in an area by both family size (1, 2, 3, 4, ≥5 persons/HH) and by auto ownership (0, 1, ≥ 2 vehicle/HH), which results in 15 classes as:

Vehicles per HH	Person per household				
	1	2	3	4	5
0	a	b	c	d	E
1	f	g	h	i	j
2 and more	k	l	m	n	o

Here though the major independent variables are vehicle per HH and person per HH, in the category analysis all the dimension in the matrix represent the independent variables that b,c,......o all represent the variables.

Then based on the present day trips made by each category the trips rate (Trips made by certain category/number of HH in particular category) are estimated. In the example above, 15 average trip rates would be derived. If one knows the future composition of a zone in terms of categories of inhabitants (in the same category as present), one can calculate future trip behavior assuming the present trip rate to be constant even in future. Zonal trips can be obtained just by summation of trips generated by all categories found in the zone.

Basic Assumption:

- The present trips rate remains stable for long period of time i.e. trip rate is constant.

Advantages:

- No prior assumptions about the shape of the relationship are required (i.e. no linear relationship need to be assumed).
- Relationships can differ in from class to class (e.g. trips made by HH with no vehicle may differ significantly from HH with 2 vehicles).

Disadvantages:

- Does not permit extrapolation beyond its calibration strata, although the lowest or highest class of a variable may be open-ended (e.g. households with two or more vehicles and HH size of five or more).
- Large samples are required, otherwise cell values will vary in reliability because of differences in the numbers of households being available for calibration at each one. Least of 50 observations per cell is tentatively required to estimate the mean reliably.
- There is no effective way of choosing best groupings of a given variable; the minimization of standard deviations requires an extensive 'trial and error' procedure which may be considered infeasible in practical studies.
- No proper measures to check on reliability of outcome as it was in the case of regression analysis by use of R^2 value, "t" value, etc

NUMERICAL A number of household and total trips made, categorized by household size and car ownership level and forecasted number of HH in each category is provided below. Calculate the future number of trip in each category and also the total trips of the zone.

	Automobile ownership					
	0		1		2 or more	
HH SIZE	HH No.	Total trips	HH No.	Total trips	HH No.	Total trips
1	150	150	200	450	50	90
2	350	420	500	1500	200	420
3	500	750	600	2100	500	2250
4 or more	400	800	800	3200	600	3000

Forecasted number of HH in each category for design year

	Automobile ownership		
HH size	0	1	2 or more
1	100	350	[illegible]
2	400	1000	3[illegible]
3	600	1200	7[illegible]
4 or more	150	1200	15[illegible]

Solution:

First step of solution is the determination of HH trips rate which is easily obtained just by dividing total trips of each category by HH number. Then by multiplying the trip rate of each category with projected number of HH we can easily obtain the trips made by each category

Average HH trips rate			
	Automobile ownership		
Family size	0	1	2 or more
1	1	2.25	1.8
2	1.2	3	2.1
3	1.5	3.5	4.5
4 or more	2	4	5

Projected future trips			
	Automobile ownership		
Family size	0	1	2 or more
1	100	787.5	144
2	480	3000	630
3	900	4200	3375
4 or more	300	4800	7500

Thus total trips of the zone = 26216.5 (say 26217 trips)

Trip distribution modeling

After all available and relevant information on the number of trips generated or attracted in each zone have been collected, the next step in transport modeling is to distribute these trips over origin-destination (OD) cells. Trip distribution is defined as the 'interchange' between zones and deals with the spatial interaction between them. Thus, trip distribution models connect the trip origins and destination estimated by the trip generation models to create estimated trips.

	Attractions								
Generations	1	2	..	..	j	..	..	Z	$\sum_j T_{ij}$
1	T_{11}	T_{12}	..	..	T_{1j}	..	..	T_{1z}	O_1
2	T_{21}	T_{22}	..	..	T_{2j}	..	..	T_{2z}	O_2
:	:	:	..	..	:	..	..	:	:
:	:	:	..	..	:	..	..	:	:
I	T_{i1}	T_{i2}	..	..	T_{ij}	..	..	T_{iz}	O_i
:	:	:	..	..	:	..	..	:	:
:	:	:	..	..	:	..	..	:	:
Z	T_{z1}	T_{z2}	..	..	T_{zj}	..	..	T_{zz}	O_z
$\sum_i T_{ij}$	D_1	D_2	..	..	D_j	..	..	D_z	$\sum_{ij} T_{ij}$

The decision to travel for a given purpose is called trip generation. These generated trips from each zone are then distributed to all other zones based on the choice of destination. This is called trip distribution which forms the second stage of travel demand modeling. The trip pattern in a study area can be represented by means of a trip matrix or origin-destination (O-D) matrix, which is a two dimensional array of cells where rows and columns represent each of the zones in the study area. The matrices can be formed either in aggregate level (zonal wise) or it can further disaggregated by person type (n) and/or by mode (k).

The cells of each row represent origin whereas destinations are represented by corresponding columns. The sum of the trips in a column is the total trips attracted to that zone, whereas sum of trips in a particular row represents the total trip originated from that zone. The main diagonal represents the intra-zonal trips. The meanings of some notation are:

- T_{ij}= Number of trips between origin i and destination j.
- O_i = Total number of trips between originating in zone i
- D_j =Total number of trips attracted to zone j.

While distribution, we need to check either one or two constraints, based on which the model are named singly & doubly constraint distribution method. When the model is checked against either total produced or total attracted trips of each zone, it is called singly constraint model. When the constraint is on origin, it is called origin based singly constrained model (e.g. $T_{11}+T_{12}+T_{13}+... = O_1$) and when the constraint is on destination it is called destination based singly constrained model (e.g. $T_{11}+T_{21}+T_{31}+...... = D_1$). If the model is to be checked against both production & attraction, it is called doubly constrained model.

The aim of a distribution model can now be described as follows:

- Distribute the trips that originate in a particular zone over all destinations
- Distribute the trips with a destination in a particular zone over all origin.
- Determine the OD table for a particular forecast year.

Methods of Trip Distribution:

(a) **Growth Factor Models**: Uniform Factor Method, Average Factor Method, Detroit Method, Fratar Method, Furness Method

(b) **Synthetic Models**: Gravity/Spatial Interaction Models, Opportunity Model, Regression/Econometric Models, Optimization Models, Tanner Model

Growth Factor Methods

1. Uniform growth factor

A single growth factor for the entire area under study is calculated by dividing the future number of trip ends for the horizon year by trip ends in the base year. The future trips between zones I and J are then calculated by multiplying the uniform factor thus obtained to the base year trips between zones I and J

Uniform growth factor = (Total future trips) / (Total present trips)

This method is simple to understand, & thus useful for short-term planning. But the assumption that the entire study area has same growth factor for both production and attraction is not valid in reality.

Numerical The base year trip matrix (O-D matrix) is given in adjacent table. If the future trip generated in zone 1, 2 and 3 are 360, 1260 and 3120 respectively. Calculate design year O-D matrix using Uniform Growth factor method.

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

Solution:

Present year total trips = 60+100+200+100+20+300+200+300+20 = 1300 trips
Future Year total trips = 360+1260+3120 = 4740 trips
Hence uniform growth factor = 4740/1300 = 3.65

Now multiplying each element of matrix by 3.65 to obtain the future year trip matrix as:

Origin	Destination		
	1	2	3
1	218	365	729
2	365	73	300
3	729	300	73

Total future trips generated in each zone (future year total production of zone 1 = 218+365+729=1312 but the provided future trip originated from zone 1 is 360) calculated do not tally with the values given, this is because of assumption that the entire area has have growth factor.

This is because of a uniform growth rate for all zones.

i) This is not correct because each zone will have its own growth rate and the rate of growth traffic movement between any two zones will be different.
ii) The method under estimates movements where present day development is limited and over estimates movements where present day development is intensive.
iii) If the present trip movement between any two zero, the future trip movement also become zero. This may rarely be the case in reality.

2. **Average factor method:**

In this method, the growth factor represents the average growth associated with both the origin and destination zones. If F_i and F_j are the growth factors for the zones I and j respectively, then:

$$T_{ij} = t_{ij} * (F_i + F_j)/2$$

T_{ij} & t_{ij} represents future and present trips from zone i to j.
F_i & F_j represents trip growth factor for zone I and J respectively calculated by dividing the future trip of each zone by present trip of that particular zone.

Even after the distribution, the trips originating from zone 'i' will probably not agree with the projected trip ends in zone "I" and same the case for trips attracted to zone j, thus iteration need to be done until and unless the desired accuracy is obtained.

NUMERICAL The base year trip matrix (O-D matrix) is given in adjacent table. If the future trip generated in zone 1, 2 and 3 are 360, 1260 and 3120 respectively. Calculate design year O-D matrix using Average GF method

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

Solution:

For average growth factor method we use the following formula.

$$T_{ij} = t_{ij} * (F_i * F_j)/2$$

Where, T_{ij} & t_{ij} represent base and future year trip interchange of zone I-J respectively
F_i & F_j represents growth factor for zone I and J respectively

Origin	Destination			Base trip (t)	Future trip (T)	Growth factor (F)
	1	2	3			
1	60	100	200	360	360	1
2	100	20	300	420	1260	3
3	200	300	20	520	3120	6
Base trip (t)	360	420	520			
Future trip (T)	360	1260	3120		4740	
G.F. (F)	1	3	6			

For trip interchange 1-1

$T_{11} = (1+1)/2*60 = 60$

For 1-2

GF of zone 1 = 1 and GF of zone 2 =3, Base year trips of 1-2= 100

Thus, Future year trip interchange (T_{12}) = (1+3)/2 * 100 = 200

For 1-3

GF of zone 1 = 1 and GF of zone 3 =6, Base year trips of 1-3= 200

Thus, Future year trip interchange (T_{12}) = (1+6)/2 *200 = 700

For 2-3

GF of zone 2 = 3 and GF of zone 3 =6, Base year trips of 2-3= 300

Thus, Future year trip interchange (T_{23}) = (3+6)/2 *300 = 1350

As GF methods deals with trips interchange T_{32} = T_{23} and no further calculation is required.

Now we can obtain the future O-D table, but as the calculated trips do not coincide with the required future trips, further iteration need to be done. Then again, we calculate the growth factor for each zone taking the calculated trip interchanges as base year trips as

Origin	Destination			Calculated future trip (t)	Required Future trip (T)	GF (F)
	1	2	3			
1	60	200	700	960	360	0.375
2	200	60	1350	1610	1260	0.783
3	700	1350	120	2170	3120	1.438
Calculated future trip (t)	960	1610	2170			
Required Future trip (T)	360	1260	3120		4740	
GF (F)	0.375	0.783	1.438			

In similar way we can obtain the following table:

Origin	Destination			Calculated future trip (t)	Required Future trip (T)	GF (F)
	1	2	3			
1	22	116	634	772	360	0.466
2	116	47	1499	1662	1260	0.758
3	634	1499	173	2306	3120	1.353
Calculated future trip (t)	772	1662	2306	4740		
Required Future trip (T)	360	1260	3120		4740	
GF (F)	0.466321	0.758	1.353			

The iteration is continued till the desired accuracy is obtained.

Thus, Average GF method gives more accurate results then uniform GF methods as each zone may have their own growth factor. which was not considered in uniform growth factor method. The method is too much tedious because of large number of iterations.

Advantages and Limitation of Growth factor Trip Distribution Model:

The growth factor methods of trip distribution are based on the assumption that the present travel patterns can be projected to the design year using certain expansion factor.

The limitations of these growth factor methods of Trip distribution are;

- As it just multiply the present trips by growth rate, it may underestimate the future movement where present day movement is limited (newly developed city) & overestimates the traffic when development of city is near to saturation.
- If present traffic is 0, the future traffic will also be 0 using GF method which may not be the case.
- If there is error in present day traffic, it will be accommodated in the calculation of future traffic.
- Tedious method as large number of iteration need to be done. Sometime the iteration may not converge and we may not yield with the desired output.
- It doesn't provide a measure of the resistance to travel.
- Not suitable for policy studies like introduction of a mode, impact on trip distribution pattern by restricting autos in certain zones.
- They neglect the effect of changes in travel pattern by the construction of new facilities and new network.
- In case of Uniform Growth factor method the future trips of each zone may not tally with the predicted value.

Despite of above limitations, it can be advantageous when:

- Advantageous for short term forecasting at urban area where growth factor is more or less constant.
- Used to estimate trip interchanges involving traffic outside traffic area (external area) where other models are difficult to adopt.
- It can be used as a check for the values obtained from other model
- Used when forecast is to be done in quick time.

Gravity model:

Gravity model is the mostly used synthetic model of trip distribution. By name illustrates the principle of Newton's gravity model and gravity model have similar principle. Newton's law of gravity states that the attractive force between any two bodies is directly related to their masses and inversely related to the distance between them. Similarly, the first/ ancient gravity model was based on principle that the number of trips between two zones is directly related to activities (trip production at origin and attraction at destination) in the two zones and inversely related to the separation between the zones as a function of travel time as:

$$T_{ij} = K\frac{P_i A_j}{d^n}$$

T_{ij} represents number of trips from i to j

P_i & A_j represents production of zone i and attraction of zone j

K and n represents constant, which value need to be calibrated and d be the distance between zone i and j

Further it was found that the travel time was not only the factor that affect the trip distribution patter and modified version of Gravity model was developed which introduced a new term generalized function of travel cost. That function incorporates all the parameter regarding to trip attractiveness such as travel time (walking time, waiting time, transfer time), travel distance and travel cost (out of pocket cost for public transportation, fuel and parking cost for private vehicles)

Modified Version: $T_{ij} = K * P_i * A_j * f(C_{ij})$

$f(C_{ij})$ may take any of the following function:

Exponential function: $f(C_{ij}) = \exp(-\beta * C_{ij})$

Power function $f(C_{ij}) = C_{ij}^n$

Combined function $f(C_{ij}) = C_{ij}^n * \exp(-\beta * C_{ij})$

Present day gravity model states that the trips produced in zone 'i' (P_i) will be distributed to zone 'j' according to the relative attraction of zone 'j'($A_j/\sum A_j$) and relative accessibility of the zone j $[F(t_{ij})/\sum F(t_{ij})]$. The factor $F(t_{ij})$ represents the Impedance factor which can represents travel time (waiting, walking, travel, transfer time), travel cost (fares, operating cost, parking cost, etc), travel distance or combination of all factors. Impedance function for each zone needs to be calibrated. The general friction factor indicates that as travel times increase, travelers are increasingly less likely to make trips of such lengths.

Trips 'i' to 'j'= $\textit{production at 'i'} * \frac{\textit{attractiveness \& accessibility characteristics of zone j}}{\textit{attractiveness \& accessibility characteristics of all zone in the area}}$

Thus from the above formula we conclude that trip from one zone(i) to other(j) is mainly depend on production of zone (i) and the probability of attraction of trip toward zone(j) produced at 'i'.

The model was further modified by use of another parameter K_{ij} that reflects the socioeconomic characteristics of various zone which may affect the trips pattern. The socioeconomic factor also needs to be calibrated.

Thus the latest gravity model appears in the following form:

$$T_{ij} = \frac{P_i * A_j * F(t_{ij}) * K_{ij}}{\sum_{j=1}^{n} A_j * F(t_{ij}) * K_{ij}}$$

Where:
T_{ij}=trips produced at zone 'i' and attracted to zone 'j'
P_i = trip production at zone 'i'
A_j = total trip attraction at zone 'j'
$F(t_{ij})$ = friction factor ($F=A/W^c$), where C=calibration factor, W = Impedance
K_{ij} = a socioeconomic adjustment factor
n = number of zones

NUMERICAL Total trips production and attraction for three zones A, B and C are:

Zones	Trips produced	Trips attracted
A	2000	3000
B	3000	4000
C	4000	2000

It is known that the trips between two zones are inversely proportion to the 2nd power of the travel time between zones, which is uniformly 20 minutes. If the trip between zones B and C is 600, calculate the trips from zones A to B and A to C.

Solution:

Using the initial gravity model equation for trips from B to C & determining the value of constant (K) and further using it for determination for other trips as:

$$T_{ij} = \frac{KP_iA_j}{t^n} = \frac{KP_BA_C}{t^n}$$

$$600 = \frac{K \times 3000 \times 200}{20 \times 20}$$

Thus, K= 0.04 = (1/25)

Now the other required trips are determined as:

$$T_{AB} = \frac{1}{25} \times \frac{2000 \times 4000}{20 \times 20} = 800$$

$$T_{AC} = \frac{1}{25} \times \frac{2000 \times 2000}{20 \times 20} = 400$$

NUMERICAL Distribute 602 work based trips from zone 3 to zone 1, 2, 4 and 5 using following information, neglecting intra-zonal trips.

Zone From	Zone To	Work trip Attraction	travel time (min)	Frictional factor
3	1	1080	20	6
	2	531	7	26
	3	76	5	45
	4	47	10	18
	5	82	25	4

Solution:

The trips are distributed using gravity model as

$$T_{ij} = \frac{P_i * A_j * F(t_{ij}) * K_{ij}}{\sum_{j=1}^{n} A_j * F(t_{ij}) * K_{ij}}$$

where the symbols have their usual meaning.

Now trips originating from 3 and having destination zone as 1 & denoted as T_{3-1} & given as:

$$T_{3-1} = \frac{602 * 1080 * 6 * 1}{6 * 1080 + 531 * 26 + 18 * 47 + 82 * 4} = \frac{3900960}{21460} = 182 \text{ trips}$$

Similarly, $$T_{3-2} = \frac{602 * 531 * 26 * 1}{6 * 1080 + 531 * 26 + 18 * 47 + 82 * 4} = 387$$

Similarly, we will get T_{3-4} =24 trips & T_{3-5} = 9 trips

NUMERICAL Trips production and attraction in three zone city are as follows:

Zones	1	2	3	Total
Trips produced	700	200	0	900
Trips attracted	0	400	500	900

The impedance and corresponding frictional factors have been calibrated as follows

Impedance (travel time in minute)	2	4	6	8
Frictional factors	10	7	6	5

Distribute trips between the zones assuming socio-economic factor as 1.

Perform only two iterations.

Origin	Destination		
	1	2	3
1	2	4	6
2	4	2	8
3	6	8	2

Solution: The trips are distributed using gravity model equation as

$$T_{ij} = \frac{P_i * A_j * F(t_{ij}) * K_{ij}}{\sum_{j=1}^{n} A_j * F(t_{ij}) * K_{ij}}$$

$T_{3\text{-}1} = T_{3\text{-}2} = T_{3\text{-}3} = 0$ (As production is zero) $T_{1\text{-}1} = T_{2\text{-}1} = T_{3\text{-}1} = 0$(As Attraction is zero)

$$T_{1\text{-}2} = \frac{700*400*7*1}{0*10+400*7+500*6} = 338 \text{ trips}$$

$$T_{1\text{-}3} = \frac{700*500*6*1}{0*10+400*7+500*6} = 362 \text{ trips}$$

$$T_{2\text{-}2} = \frac{200*400*10*1}{0*7+400*10+500*5} = 123 \text{ trips}$$

$$T_{2\text{-}3} = \frac{200*500*5*1}{0*7+400*10+500*5} = 77 \text{ trips}$$

Origin	Destination			Tot
	1	2	3	
1	0	338	362	700
2	0	123	77	200
3	0	0	0	0
Total	0	461	439	
Desired Attraction	0	400	500	

Now tabulating the zone to zone trip after 1st iteration, we will obtain

As we can observe that, Trip production of each zone matches the desired trips production, trips attraction does not match desired attraction. So, adjustment needs to be done using follow expression.

Adjusted Attraction factor **(A_{jk}) = A_j * ($A_{j(k-1)}$/$C_{j(k-1)}$)**

where, C_{jk} = Actual Total Attraction for zone J in iteration K
A_j = Desired Total Attraction for attraction zone J
K = No. of iteration

Zone 1 Adjusted attraction (A_1) = 0
Zone 2 A_2 = 400*400/461 = 347
Zone 3 A_3 = 500*500/439 = 569

Then,

$$T_{1\text{-}2} = \frac{700*347*7*1}{0*10+347*7+569*6} = 291 \text{ trips}$$

$$T_{1\text{-}3} = \frac{700 * 569 * 6 * 1}{0 * 10 + 347 * 7 + 569 * 6} = 409 \text{ trips}$$

$$T_{2\text{-}2} = \frac{200 * 347 * 10 * 1}{0 * 7 + 347 * 10 + 569 * 5} = 110 \text{ trips}$$

$$T_{2\text{-}3} = \frac{200 * 569 * 5 * 1}{0 * 7 + 347 * 10 + 569 * 5} = 90 \text{ trips}$$

Origin	Destination			Total
	1	2	3	
1	0	291	409	700
2	0	110	90	200
3	0	0	0	0
Total	0	401	499	
Desired Attraction	0	400	500	

After second iteration, the trip matrix takes the form as in adjacent table.

Modal split models

Going somewhere not only involves a choice of route but also a choice of transport mode. The distribution of trips over the various transport modes (car, bike, public vehicle, etc) is called the modal split. Modeling transport mode choice is one of the classical problems in traffic engineering. It predicts the no. of trips using the particular mode say private vehicle or public vehicles. The model split modeling can be either done before or after trip distribution, accordingly they are classified as trip end and trip interchange modal split model respectively.

Types of modal split models:

1. **Trip end modal split models**

The models which are used after trip generation considering only personal characteristics called Trip End Type Modal Split Model. The basic assumption of the trip end type models is that transport patronage is relatively insensitive to the service characteristics to the transport modes and is determined principally by the socio economic characteristics of the trip makers (income, residential density and car ownership). Trip end modal split models are used today in medium and small sized cities. The advantage is that these models could be very accurate in the short run, if public transport is available and there is little congestion and limitation is that they are insensitive to policy decisions; for example, improving public transport, restricting parking etc. would have no effect on modal split according to these trip end models.

2. **Trip interchange modal split models**

Modal split models that followed the trip distribution phase are normally termed trip interchange modal spit models. This is post distribution model that is modal split is applied after the distribution stage. This has the advantage that it is possible to include the characteristics of the journey and that of the alternative modes available to undertake them. Most of the trip interchanges modal split models incorporate measures of relative service characteristics of competing modes as well as measures of the socio economic characteristics of the trip makers. It is also possible to include policy decisions in Trip interchanges modal split and thus is beneficial for the long term modeling.

Factor affecting Mode Choice:

I. **Trip Maker Characteristics**

If the living standard or economic status of people is high he will prefer to go by his own private vehicle, whereas the lower class people would prefer to go by bus or even on foot. Also the HH size and structure also affect mode choice. If the family is large they would prefer to use either car, public bus or taxi as bike may not be the feasible solution in that case.

- Income
- Vehicle ownership & availability of vehicle in HH
- Family size and composition (couple with children, retired people)
- Possession of driving license
- Habit of the trip maker and standard of living
- Residential/ population density

II. Characteristics of trip

- Trip purpose (Mostly work trip are undertaken on public mode due to its regularity)
- Time of day (Late night trips are difficult to accommodate by public modes)
- Trip length (Trips of longer length are undertaken through public vehicle)
- Accessibility to our destination. (If we can't reach exactly to our destination from public mode, we will look at option of private vehicle, but at the same time if there is shortage of parking spot or if the parking cost is very high we will prefer to go by public mode.)

III. Modes or Transportation system characteristics:

Our will while using any mode is to reach the destination as quick as possible but maintaining comfort level and safety. This is rare to be achieved by public vehicle thus preference is given to private vehicle. If public services are made reliable with lesser station and less delay then the usage of public transport may increase. We also prefer to use that mode which has low travel cost.

- Relative travel time of each mode (in-vehicle time, waiting time, walking time).
- Monetary cost of each modes.
- Comfort and convenience of each mode
- Reliability and regularity of each mode
- Parking availability and costs
- Protection and security level of each modes.

IV. Environmental characteristics:

- Climatic Condition (High rainfall forces to shift to mode like car, bus rather than bike)
- Road condition and visibility (Poor visibility and worst road condition discourage the private vehicle use)

V. Extraneous factor:

- Nepal Banda, Lack of petrol, Odd and Even registration number plate operation

Utility and Disutility Function:

A **utility function** measures the degree of satisfaction that people derive from their choices. A **disutility function** represents the **generalized cost of travel** associated with all the possible models. The utility or disutility function is typically expressed as the linear weighted sum of various independent variables (mostly travel time and costs). Various modes may have same or different utility function. A utility based modal choice model estimates the market share of each mode based on utility or disutility associated with it. If the traveler can select the mode with highest utility, then the modal is called deterministic model, but the modes are selected in proportion based on the modal utilities (all the modes have certain share), then the model is called probabilistic model.

relationship between this proportion and utilities of competing modes has been formulated in various forms, but the most popular one is Logit model, which can be applied for multiple competing modes. When applied to discrete number of alternatives, these random utility models are called discrete choice model.

Multinomial Logit (MNL) model

The logit formulation is a share model that divides the group of travelers between the various modes depending on utilities associated with each mode. If an individual has to make a choice between available "i" number of modes. Then the utility or disutility function associated with each available mode is calibrated and required data of independent variables (cost, time) are obtained. If the model is deterministic, he will choose mode with highest utility value. But the means of perception of highest utility may varies from individual to individual and different individual may choose different mode choice. So each mode has certain share of total proportion.

The probability of choosing alternative mode "i" out of a total of "n" available modes is as per multinomial logit model or simply logit model is:

$$P_i = \frac{e^{\mu U(i)}}{\sum_{i=1}^{n} e^{\mu U(i)}}$$

Here, μ is called dispersion parameter, whose value need to be determined through detailed investigation and for simplicity μ=1 is assumed. Thus the logit model becomes

$$P_i = \frac{e^{\mu U(i)}}{\sum_{i=1}^{n} e^{\mu U(i)}}$$

Where, P_i= Probability of choosing alternative "I"

U = Observable utility of travel mode "I"

n= number of alternative travel modes.

If instead of utility, disutility function is provided we need to convert it to utility function.

For this, $U_i = -\beta * C_{ij}$

For numerical purpose we can consider β = 1

NUMERICAL: A mode choice model for a city includes following modes: Autos(A), Light rail (L), buses (B) & Rapid rail (R) with the utility function (U) as shown in tables.

Function:	**Cost (C)**	**Time (T)**
U(A)=3.2-0.3*C-0.04*T	5	30
U(L)= 1-0.3*C-0.04*T	3	25
U(B)= 0-0.1*C-0.01*T	2.5	40
U(R)= 1.5-0.3*C-0.05*T	6	20

Where C is cost in dollars and T is time in minute.

(a) Based on estimate that 12,000 workers will head for downtown each morning, how many workers will choose to take a particular mode?

(b) If government subsides light rail by 30%, buses by 20%, and rail rapid by 10% and the same time increases automobile cost by 15%, what will be the new modal distribution?

Solution: just by substituting values to utility function we obtain:

U(A) = 0.5; U(L)= -0.9; U (B) = -0.65; U(R) = -1.3

Now using Logit model for probability of usage of each mode $P_i = \frac{e^{U(i)}}{\sum_{i=1}^{n} e^{U(i)}}$

Now probably of usage of bus P(A) = 57.85%

P(L) = 14.27%, P(B) = 18.32%, P(R) = 9.56%

Thus no. of worker choosing various modes are as:

Auto = 57.85% *12,000 = 6942

Light rail = 14.27%* 12,000 = 1713

Bus =2198

Rapid Rail =1147

After subsidies cost of L, B and R decreases whereas cost of Auto increases whereas time remain constant

Cost of Light rail = 3-3*30% =2.1

Cost of bus = 2.5-2.5*20% =2

Cost of Rapid rail = 6-6*10% =5.4

Cost of automobile = 5+5*15% = 5.75

Now the utility function becomes:

U(A)= 0.275- -U(L)= -0.63 U(B)= -0.6 & U(R) = -1.12

Then probability of usage becomes:

P(A)= 48.33% P(L).=19.55% P(B)=20.16% & P(R)= 11.96%

Now, no. of worker choosing various modes is summarized as below:

Using Auto = 5800, Light rail = 2346, Bus = 2419 & Rapid Rail = 1435

Traffic Assignment Model:

Route assignment, route choice, or traffic assignment is the final step of traditional or classical fo step modeling process that concerns with the selection of routes (alternative called paths) betwe origins and destinations in transportation networks. To determine facility needs, costs and bene we need to know the number of travelers on each route & link of the network (a route is simpl chain of links between an origin & destination), which is determined by trip assignment mode.

Assignment deals with the supply side of transport modeling and the equilibrium between demand and supply. Traffic assignment involves computing one or more optimal (usually shortest) routes between each origin and destination and distributing travel demand over these routes. The sum of all trips along these routes over all OD pairs results in a traffic load on all links and nodes.

Usually trip generation and trip distribution is computed separately per trip purpose, while traffic assignment is carried out for all trip purposes simultaneously, i.e. after combining the OD tables per trip purpose in one table.

The fundamental aim of the traffic assignment process is to reproduce on the transportation system, the pattern of vehicular movements which would be observed when the travel demand represented by the trip matrix, to be assigned is satisfied. The major aims of traffic assignment procedures are:

1. To estimate traffic volume on the links of the network and obtain aggregate network measures.
2. To estimate inter zonal travel cost.
3. To analyze the travel pattern of each origin to destination (O-D) pair.
4. To identify congested links and to collect traffic data useful for the design of future junctions.

Basic Inputs of trip assignment model are: Trip matrix (representing traffic demand), vehicular demand (personal trips need to be converted to vehicular trips) and route selection rules.

Trip assignment process: An overview:

- The process begins by constructing a network map showing all the possible paths that trips can make within the study area.
- The intersections (called nodes) are identified and the sections between them (called links) can be identified.
- After identification of links & nodes, the length, type of facility, location in the area, number of lanes, additional information (fares, headways) and route description is included in a separate network.
- These all information helps to determine the paths that the traveler might take between any two points on the network and to assign trips between zones to these paths.
- The output of the analysis shows the paths that all trips will take and therefore the number of vehicles on each roadway and the number of passengers in each transit routes.
- The terms "shortest and cost" typically refer to travel time, but elaborate equilibrium formulations account for generalized costs, which include travel time, fuel consumption or fare price or other parameter. As far as possible driver choose the shortest route, but criteria of choosing may differ significantly between drivers.
- Though the route choice is depend on journey time, distance, monetary, congestion and queues, type of road, scenery, road works, reliability of travel time and habit, but as it is difficult to incorporate all these factors in quantitative way, a term "generalized cost of travel" is used for selection of short route, which incorporates time and monetary costs (fuel charges, parking cost, fare, toll, etc).

Application of traffic assignment:

(a) **Gaining insight in the characteristics of the network:** Shortcomings/deficiencies of the existing network (missing links, capacity deficiency) by assigning the present or even future trips in the existing system.

(b) **Traffic forecasts**: With regard to current and future network scenarios, a number of aspects (link loads, travel time, speed, congestion, junction resistance, etc) are computed to be able to forecast the future traffic situation.

(c) **Supply of design data**: The evaluated network scenarios (computed link loads, design hour traffic volume, turning movements) should be translated into a design of physical infrastructure.

(d) To evaluate the effects of limited improvements and additions to the existing transportation system by assigning estimated future trips to the improved network.

(e) To develop construction priorities by assigning estimated future trips for immediate years to the transportation system proposed for those years.

(f) To test alternative transportation system proposals by systematic and readily repeatable procedures.

(g) To provide design hour traffic volume on highways and turning movements at junctions.

(h) Computation of derived impacts: On the basis of computed traffic assignment, impacts noise, air pollution, energy consumption and traffic safety, which are of importance for the evaluation of plans, can be computed.

Types of traffic assignment models:

- User equilibrium assignment (UE) Method,
- System optimum assignment (SO)
- All-or-nothing assignment (AON)
- Incremental assignment method
- Capacity restraint assignment Method
- Diversion Curve method, etc.

Wardrop [1952] has established two mutually independent principles of route choices, based underlying behavioral assumption of route choice.

(a) User Equilibrium (Wardrop's first principle) : Assign O-D flows so that no user of the sys can unilaterally reduce his/her travel costs by shifting to another route. Users choose route that minimizes their own travel time.

(b) System Optimization (Wardrop's second principle): Assign O-D flows to paths so a minimize the total (average) system travel time. Based on this principle the traff arranged in congested networks in such a way that average (or total) travel cost of whole network is minimized.

Minimum path technique or All or Nothing method::

It is based on the assumption that travelers are rational travelers and they want to use minimum impedance (least generalized cost of travel) route between two points. Thus the f shortest path (i.e. path with minimum impedance) will be loaded with all the volume and have zero volume. Thus the method is termed "All or Nothing Method".

Assumptions:

- Link costs are fixed i.e. no congestion
- All travelers think in similar way i.e. each driver chooses the same route for same O-D pair.
- All travelers are assigned to one particular route and none to others.

These assumptions are reasonable for uncongested networks with few alternatives routes. The all or nothing approach really gives a desire line i.e. what drivers would do if all choices were available to them and if congestion was not an influence, but the main drawback may be it can cause some links to be assigned more travel volume than the its capacity at the original assumed speed. It has a limitation that it ignores the fact that link travel time is a function of link volume and when there is congestion or that multiple paths are used to carry traffic.

Minimum path with capacity restraints:

As the flow increases towards the capacity of the stream, the average stream speed reduces from the free flow speed to the speed corresponding to the maximum flow. That means traffic conditions worsen and congestion starts developing. Thus the assumption of ALL OR NOTHING doesn't validate. Thus minimum path with capacity restraint technique has been developed with following steps:

- First calculate the shortest path from each origin to all destinations (usually the minimum time path is used) based on the impedance coded on links of network.
- Trips for each O-D pair are then assigned to the links in the minimum path and the trips are added up for each link.
- The assigned trip volume is then compared with link capacity to see if it is congested.
- If a link is congested the travel time is adjusted to result in a longer travel time on that link. Changes in travel time means that the shortest path may change.
- In such case, the whole process is repeated several times (iterated) until there is an equilibrium between travel demand and travel supply i.e. trips on congested links will be shifted to uncongested links until this equilibrium condition occurs.

This traffic-flow-dependent travel-time relationship is represented by the general polynomial function as per Bureau of Public Roads (BPR) method:

$$T_q = T_0 * \left[1 + \alpha\left(\frac{Q}{Q_{max}}\right)^{\beta}\right]$$

Where, T_Q & T_0 are travel time at "Q" traffic flow and zero flow respectively
T_0 = Travel time at practical capacity * 0.87
Q = Traffic flow
Q_{max} = Practical capacity = (3/4th of saturation flow)
α & β = constant paramter usually 0.15 and 4 is adopted.

(a) Multiple route assignment:

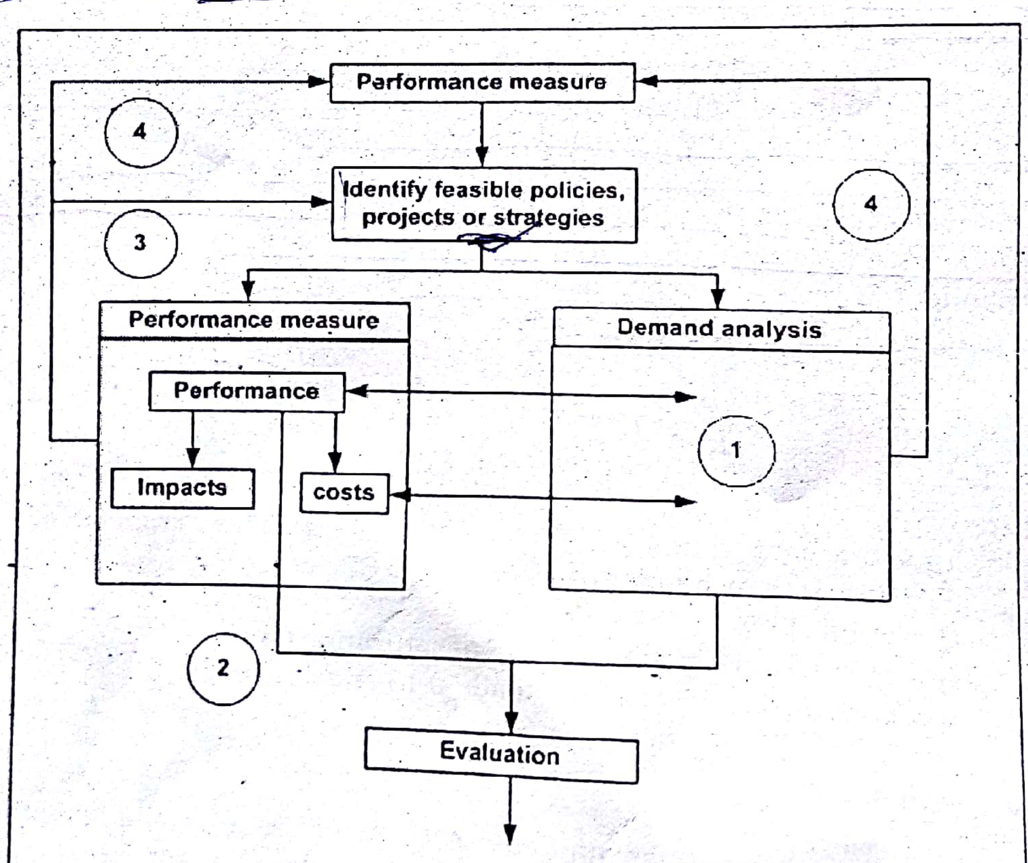
All travelers may not judge the same path as minimum path as the criteria for judging the shortest route may vary within them. Then the traffic load/flow are distributed in all the available routes based on the generalized cost of travel as done in multinomial logit model. Thus all the available routes have certain flow based on its impedance factors (generally cost or travel time)

Supply Analysis in Transportation Planning:

Transportation system is consists of system user, mode or technology of travel, insfrastructurem intermodal connection for transfer and stakeholder that either influence or are affected by performance, impacts and cost of transportation system. An economic system including numerous activities located in different areas generates movements that must be supported by the transport system/supply. Thus we need to have idea about two terms Transportation Demand and Transportation Supply. Above discussed four step modelling and land use models basically deal with the demand aspect of transportation system.

Transportation network, facilities and services (vehicles and their frequency) and their characteristics are referred as transportation supply. Supply is expressed in terms of infrastructures (capacity), services (frequency) and networks (coverage). Capacity is often assessed in static and dynamic terms. Static capacity basically deals with infrastructure aspect i.e. wider road or larger terminal will increase the capacity. Similarly, Dynamic capacity relates to improvement in capacity via use of technology or some special management strategy. Capacity of the road can be improved by use of co-ordinated traffic signals.

The number of passengers, volume (for liquids or containerized traffic), or mass (for freight) that can be transported per unit of time and space is commonly used to quantify transport supply. **Passenger-km** (or passenger-mile) and **ton-km** (or ton-mile) is a common measure expressing the realized passenger and freight transport demand (as well as supply) respectively.



Supply analysis in transportation planning

The above chart shows the role of supply analysis in transportation planning process and it can explain via use of four linkage as discussed below

(A) Linkage 1: Performance and cost of transportation services as perceived by system are important determinants of the demand for these services. Transportation system performance in turn generally depends upon the level and character of travel demand. Also demand and supply analysis are inherently linked together. Remember that transport demand is derived demand. Higher the demand higher will be supply side.

Linkage 2: Demand for transportation, measure of performance, impacts and costs are important evaluation criteria for selection of best or most appropriate alternative or proposal from the bundle of alternatives. Evaluation of various alternatives are considered based on Measures of Effectiveness (MoE) which includes efficiency, equity, feasibility, adequacy, financial analysis etc.

Linkage 3: The estimation of current and forecasted system performance, impact and cost characteristics leads to the identification of project alternatives and after the evaluation process we come with the most appropriate solution, policies or strategies to meet with present demand.

Linkage 4: This linkage is relatively new to transportation planning and reflects the trend toward continual monitoring of transportation system performance. The feedback from both demand and supply analysis is used to determine where deficiencies exist in the transportation network that can then lead to the identification of strategies for solving potential problems. Thus, the cycle goes on and on.

Transportation system performance can be viewed from the perspective of the users and operators:

1. User Perspective: Interest in travel cost, travel time (in-vehicle and out of vehicle), reliability, etc.
2. Operator perspective: route frequency, vehicle cycle times, route capacities, and operating costs, etc.

Performance characteristics of transportation facilities includes average speed, Volume, Rate of flow, Peak Hour Factor (PHF), Density, Capacity, Level of service, Headway, etc

Role of Supply Analysis in Transport Planning

(a) Metropolitan level network analysis for strategic investment: Includes examining alternative model networks at a regional or area wide scale. Adding road, lane, or adding transiting facilities to the existing network, adding new ITS technologies, adopting regional land use or taxation policies etc. The planning time frame is comparatively long (5 years onwards) and so does the complexity of problem.

(b) Operational and tactical planning: The analysis of individual routes, links, or terminals etc comes under this category. These sorts of planning is particularly important for the operating agencies. How should a transit route be modified to improve performance? How can traffic signals be better coordinated to reduce vehicle delay? etc. are some of the examples. The usual time frame for these sorts of planning is about 1-3 years.

(c) Scheduling of transportation services: Scheduling of public transportation to route and assigning driver and conductor (helper) is the major task for public transportation operator. It helps to minimize operating cost and usual time frame for these sorts of planning is about 3-6 month.

Major Supply Variables for Transportation Modes

Road. The main supply variables are road width, number of lanes, capacity of the vehicle, speed, inventory and frequency of service (for mass transit).

Rail. The main supply variables are the number of tracks, capacity of stations and railyards, capacity of the vehicle, and speed of the vehicle.

Air. The main supply variables are capacity of airports, capacity of aircrafts, frequency of services and speed of the vehicle. The capacity of an airline corridor is enormous.

Maritime. The main supply variables are port capacity, capacity of ships, frequency of services and speed of the ship. The capacity of a maritime route is enormous.

Telecommunications. They represent a special category where the main supply variables are the capacity of transmission infrastructures (cables, antennas, satellites, etc.). Depending on the transmitted information, supply will be expressed in bps (bytes per second), in numbers of calls per unit of time or the number of minutes of available transmission (antenna) time. The development of the information highway has expended tremendously supply for the transmission of information.

Project Evaluation

- It is the process of determining relative importance of individual alternatives i.e. differ... courses of action and desirability over other alternatives and of presenting informatio... decision makers in a comprehensive and useful form for decision maker.
- For a Single Proposal too, decision maker has two choice: Do it or Do Nothing
- Evaluation provides information on estimated Impacts (positive and negative), trade... and major areas of uncertainty associated with each alternatives and finally helping... decision making.
- Determining the desirability of an alternative requires
  - Defining how value is to be measured
  - Estimating the source and timing of the benefits and costs of the proposed action
  - Comparing these benefits and costs to determine a level of effectiveness for ... alternative.
- Multimodal transportation planning presents a special challenge to the evaluation proce... Multimodal transportation planning is best carried out when all modes are analy... simultaneously and interactions among the modes are accounted for.

Project Evaluation History

- Before 1960, the basis of evaluation was just comparison of monetary benefit & cost
- Then Maximized return from the investment was taken as the best criteria for proj... selection
- After 1960s, Intangible factors (air quality, community cohesion, energy consumpti... equity, economic development) were also considered.
- Nowadays evaluation are based on effectiveness, the efficiency of resource allocation, ... equitable distribution of resources, feasibility of implementation, etc

Principle of Generation of Alternatives:

- Alternatives should be defined in terms of their concept and scope.
- Alternatives should be developed based on all reasonable option and criteria's and later be confined to most competitive alternatives.
- Alternatives should be compatible with need/purpose of improvement i.e. it must b... compatible with community values, goal and objective.
- Pros and cons of each alternative has to be developed for future trade off which inclu... costs, impacts and benefits.
- Alternative should be developed to make evaluation a competitive task and should b... refined in the light of the information developed on its performance.
- Should be identified and refined in an open and well documented process with review and feedback from all participant and stakeholders.

Major Question during Evaluation Process:

- How evaluation techniques be selected?
- How intangible impacts are be quantified?
- How can equity be considered in evaluation?
- How concept of time be treated in evalution?
- How can discount rated be estimated?

Characteristics of Evaluation Process:

- Careful consideration of issues or problem
- Consideration of uncertainty.
- Evaluation of alternative considering goal and objective

- It should be oriented towards the decision. (Selection of evaluation criteria, planning horizon, scope of analysis, etc)
- Should access financial feasibility.
- Should determine how different groups are affected by each alternatives i.e. impact associated with each alternatives.
- Provide information regarding community value in understandable form
- Should analyze implementation requirement of each alternatives.
- Should be Sensitive to time frame in which the project impact is likely to occur.
- Evaluation should produce information on the likely impacts of alternatives at a level of aggregation that permits levels of assessment (regional transportation planning).
- Evaluation should provide information to decision makers on the value of alternatives in a readily understandable form and in a timely fashion.

CRITERIA/BASES FOR PROJECT EVALUATION

1. **Appropriateness:**
   - Does alternative satisfy community value, goal and objectives?
   - What information required on impacts and trade-offs is required for the decisions that need to be made?
2. **Equity:**
   - Is there is proportionate distribution of benefits and costs among different groups of community?
   - What is the impact of project on the non-user of the project?
3. **Effectiveness:**
   - Can alternative likely to produce the desired results & to what extent community goals are attained?
4. **Adequacy:**
   - Are all alternatives considered?
   - Does the alternative correspond to the scale of the problem and to the level of expectation of problem solution?
5. **Efficiency:**
   - Does the alternative provide sufficient benefits to justify the cost?
   - Does additional benefits is worth the extra cost (While comparing with alternative of least cost).
6. **Implementation feasibility:**
   - Is funds are available to implement the alternative on schedule.
   - Consideration administrative or legal barriers to alternative implementation. (Are there any groups who are likely to oppose the alternative?)
   - Margin of safety for financial feasibility.
   - What adjustment is necessary if this margin of safety is exceeded?
7. **Sensitivity analysis:**
   - How are the predicted impacts modified when analysis assumptions are changed?
   - What is the probability of occurrence of these changes?

Evaluation Criteria for Major Investment Studies or Stages of Evaluation:

1. Prescreening Criteria.
2. Screening Criteria.
3. Detail Criteria.

1. **Prescreening criteria:**

Here we perform Yes-No Question. In this step we decide whether to take the alter... evaluation step or not by answering the following question.

- Is the alternative consistent with regional goals and objectives?
- Is alternative affordable?
- Does the alternative have irresolvable environmental impacts?
- Does the alternative have an irresolvable community or agency opposition?
- Is the technology available?

2. **Screening criteria:**

Here we go in detail of those alternative which have passed in above stage

- How consistent is the alternative with regional goals /policies?
- How affordable is the alternative?
- What are the primary environmental Impacts?
- How well does the alternative address the corridor's mobility problem?

3. **Detail Criteria**

(a) Performance Criteria

- Travel Time, Delay, Reliability, User, Corridor congestion, capac... utilization, Impacts to goods movement.

(b) Impact Criteria

- Displacement, Endangered species, neighborhood disruption, haz... material, air quality, Direct user benefit, environmental justice, Increa... value, etc

Various Benefit & Cost in Transportation Project Evaluation

Several characteristics of benefits and costs affect how they are used in the evaluation proc...

1. **Real and pecuniary (financial) impacts:**
   - real benefits are realized by consumers or that add to a community's overall welfare
   - Pecuniary benefits are gained at the expense of other individuals or groups. Inc... land values resulting from improved transportation accessibility.
2. **Direct or indirect Impact:**
   - Directs are related to the objectives of the investment. (Reduction in travel time)
   - Indirect are by-product. (Increased demand for trade near airport, buspark)
3. **Tangible & Intangible**
   - Tangible can be assigned any monetary value.
   - Intangible can't be easily measurable. (Aesthetic beauty gained/destroyed b... construction)
4. **External & Internal**
   - Internal & External impact means impacts within and outside of study area.
   - Pollution of vehicle within Kathmandu valley is considered as internal imp... whereas outside Kathmandu valley is considered as External impact.
5. **User & Non User Cost/Benefit**
   - Fare of transit is user cost whereas Increased Tax imposed on private vehicle to public transportation is the example of non-user cost.

Selection Consideration: Capital and Operating

While evaluation we compare cost with benefit. Mostly the cost is capital cost as well as... cost. But in case of benefit, we only experience benefit only after the completion of the p...

Thus Capital Cost associated with each alternative has important parts to play in Evaluation. Initial capital costs include cost of infrastructure development (starting from the conceptual design to the point where the project is being completed). Capital cost may be both direct as well as indirect. Direct Capital cost related to transport project includes Land acquisition charge, Cost associated to demolition works, Earth work, purchase of vehicles, etc. Operating cost includes cost associated with operations (fuel charge, expenditure on employee) maintenance of roadway as well as vehicles, and rehabilitation. These Indirect operating costs include expenditures required of other government agencies (i.e. additional costs for police agencies to enforce speed limits, parking restriction), and the societal costs of additional air and noise pollution as well environmental degradation, increased congestion, Dislocation of business and agricultural area and many other.

Also the benefit also may be in any of the above discussed form such as direct, indirect, social, intangible as well as tangible benefit. Benefit can be summarized in the following points:

- Reduction in travel time, delay
- Benefit from reduction in crashes
- Increase in employment level
- Increase in mobility, accessibility, trade
- Benefit from reduced operating cost. and so on.........

REFERENCES:

4.1. Urban Transportation Planning, Michael D. Meyer & Eric J. Miller, Second edition

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