

CHAPTER TWO

Transportation Planning and Modeling

CHAPTER TWO

Transportation Planning and Modeling

2.1 Transport Planning Process

Transportation can have significant effects on *mobility, economic development, environmental quality, government finance* and the *quality of life*. Wise planning is, thus, needed to help create high quality transportation facilities and services at a reasonable cost with minimal environmental impact and to enhance economic activity. Failure to plan can lead to severe traffic congestion, dangerous travel patterns, slow economic growth, adverse environmental impact and wasteful use of money and resources. Transportation planning is a process that develops information to help make decisions on the future development and management of transportation systems, especially in urban areas. It involves the determination of the need for transport facilities such as new highways, transit systems, freight facilities, and transportation terminals. The planning process also allows determining the location, capacity and management of these facilities.

Transportation planning is primarily focused on developing long range (15-30 years) transportation plans that can be used to set priorities for project implementation in the future. Such plans should ideally balance the need to build new roads and transit facilities (supply) with future travel demand patterns with a minimum of environmental effect and within the funding capabilities of the government agencies involved.

Problems addressed can range from broad issues of policy at the federal or state level to specific programs and projects at a local level. Besides problems of congestion and travel growth, these could include the following:

- Travel demand alternatives for congestion reduction
- Land use/transportation coordination
- Fuel reduction measures
- Air quality measures
- Safety measures
- Economic development/redevelopment activity

The transportation planning process is direct application of problem solving via system analysis. It provides a framework for the identification of transportation problems and the development of alternative potential solutions.

The transportation system now in place is the product of many individual decisions to build or improve its various parts, such as bridges, highways, tunnels, harbors, railway stations, and airport runways. Most of these transportation facilities were selected for construction or improvement because those involved concluded that the project would result in overall improvement.

Among the factors believed to justify a transportation project are improvements in traffic flow and safety, savings in energy consumption and travel time, economic growth, and increased accessibility. Some transportation projects, however, may be selected for other reasons—for example, to stimulate employment in a particular region, to compete with other cities or states for prestige, to attract industry, to respond to pressures from a political constituency, or to gain personal benefit from a particular route location or construction project. In some instances, transportation projects are not selected for construction because of opposition from those who would be adversely affected. For example, a new highway may require the taking of residential property, or the construction of an airport may introduce undesirable noise due to low-flying planes. Whatever the reason for selecting or rejecting a transportation project, a specific process led to the conclusion to build or not to build.

The process for planning transportation systems is a rational one that intends to furnish unbiased information about the effects that the proposed transportation project will have on the community and on its expected users. For example, if noise or air pollution is a concern, the process will examine and estimate how much additional noise or air pollution will occur if the transportation facility is built. Usually cost is a major factor, and so the process will include estimates of the construction, maintenance, and operating costs.

The process must be flexible enough to be applicable to any transportation project or system, because the kinds of problems that transportation engineers work on will vary over time. And the activities of transportation engineers have varied considerably with time, depending on society's needs and concerns. Examples of societal concerns include energy conservation, traffic congestion, environmental impacts, safety, security, efficiency, productivity, and community preservation.

The transportation planning process is not intended to furnish a decision or to give a single result that must be followed, although it can do so in relatively simple situations. Rather, the process is intended to give the appropriate information to those who will be responsible for deciding whether the transportation project should go forward.

2.1.1 Basic Elements of Transport Planning Process

The transportation planning process comprises seven basic elements, which are interrelated and not necessarily carried out sequentially. The information acquired in one phase of the process may be helpful in some earlier or later phase, so there is a continuity of effort that finally results in a decision. The elements in the process are:

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

Situation Definition

The first step in the planning process is situation definition, which involves all of the activities required to understand the situation that gave rise to the perceived need for a transportation improvement. In this phase, the basic factors that created the present situation are described, and the scope of the system to be studied is delineated. The present system is analyzed and its characteristics are described. Information about the surrounding area, its people, and their travel habits may be obtained. Previous reports and studies that may be relevant to the present situation are reviewed and summarized. Both the scope of the study and the domain of the system to be investigated are delineated.

For instance, a new bridge is being considered, situation definition involves developing a description of the present highway and transportation services in the region; measuring present travel patterns and highway traffic volumes; reviewing prior studies, geological maps, and soil conditions; and delineating the scope of the study and the area affected. A public hearing might also be held to obtain citizen input. The situation will then be described in an environmental impact statement (EIS), a report that documents all alternatives and their impacts.

Problem Definition

The purpose of this step is to describe the problem in terms of the objectives to be accomplished by the project and to translate those objectives into criteria that can be quantified. Objectives are statements of purpose, such as these: to reduce traffic congestion; to improve safety; to maximize net highway-user benefits. Criteria are the measures of effectiveness that can be used to tell how effective a proposed transportation project will be in meeting the stated objectives. For example, the objective "to reduce traffic congestion" might use "travel time" as the measure of effectiveness. The characteristics of an acceptable system should be identified, and specific limitations and requirements should be noted. Also, any pertinent standards and restrictions that the proposed transportation project must conform to should be understood.

An objective for the bridge project might be to reduce travel congestion on other roads or to reduce travel time between certain areas. The criterion used to measure how well these objectives are achieved is average delay or average travel time. Constraints placed on the project might be physical limitations, such as the presence of other structures, topography, or historic buildings. Design standards for bridge width, clearances, loadings, and capacity should also be noted.

Search for Solution

In this phase of the planning process, consideration is given to a variety of ideas, designs, locations, and system configurations that might provide solutions to the problem. This is the brainstorming stage, in which many options may be proposed for later testing and evaluation. The alternatives can be suggested by any group or organization. In fact, the planning study may have been originated to determine the feasibility of a particular project or idea. The transportation engineer has a variety of options available in any particular situation, and any or all may be considered in this idea-generating phase. Among the options that might be used are different types of transportation technology or vehicles, various system or network arrangements, and different methods of operation.

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

In the case of our hypothetical bridge construction, a variety of options may be considered, including different locations and bridge types. The study should also include the option of not building the bridge and might also consider what other alternatives are available.

Performance Analysis

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

To analyze the performance of the new bridge we are contemplating, we would prepare preliminary cost estimates for each location being considered. Then we would compute estimates of the traffic that would use the bridge, given various toll levels and bridge widths. The average trip length and average travel time for bridge users would be determined and compared with existing or no-build conditions. Other impacts, such as land required, visual effects, noise levels, and air or water quality changes, would also be computed.

Evaluation of Alternative

The purpose of the evaluation phase is to determine how well each alternative will achieve the objectives of the project as defined by the criteria. The performance data produced in the analysis phase are used to compute the benefits and costs that will result if the project is selected. In cases where the results cannot be reduced to a single monetary value, a weighted ranking for each alternative might be produced and compared with other proposed projects. For those effects that can be described in monetary terms, the benefit-cost ratio for each project often is calculated to show the extent to which the project would be a sound investment. Other economic tests might also be applied, including the net present worth of benefits and costs. In complex situations where there are many criteria, expressed in both monetary and nonmonetary terms, the results might simply be shown in a cost-effectiveness matrix (for example, cost versus number of homes displaced) that allows the person or group making the decision to see exactly how each alternative performs for each of the criteria and at what cost.

In the bridge evaluation, we would analyze the benefits and costs to determine whether the project meets the benefit-cost criteria. If the result were positive the evaluation of alternative sites would require comparison of many factors, both for engineering and economic feasibility and for environmental impact. A cost-effectiveness matrix that compares the cost of each alternative with the effectiveness of that alternative in achieving certain goals would be produced to assist in the evaluation.

Choice of Project

The final project selection is made after considering all the factors involved. In a simple situation, for example, where the project has been authorized and is in the design phase, a single criterion (such as cost) might be used and the chosen project would be the one with the lowest cost. With a more complex project, however, many factors have to be considered, and selection is based on how the results are perceived by those involved in decision making. If the project involves the community, it may be necessary to hold additional public hearings; it is possible that a bond issue or referendum may be required. Perhaps none of the alternatives will meet the criteria or standards, and so additional investigations will be necessary. The transportation engineer who furnishes a recommendation may have developed a strong opinion as to which alternative to select. If the engineer is not careful, such bias could result in the early elimination of good alternatives or the presentation to decision makers of inferior projects. If the engineer is acting professionally and ethically, he or she will perform the task such that the information necessary to make an informed choice is available and that every feasible alternative has been considered.

In deciding whether or not to build the hypothetical bridge, decision makers would look carefully at the revenue-cost forecasts and probably select the project that appeared to be most financially sound. The site location would be selected based on a careful study of the factors involved. The information gathered in the earlier phases would be used, together with engineering judgment and political considerations, to arrive at a final project selection.

Specification and Construction

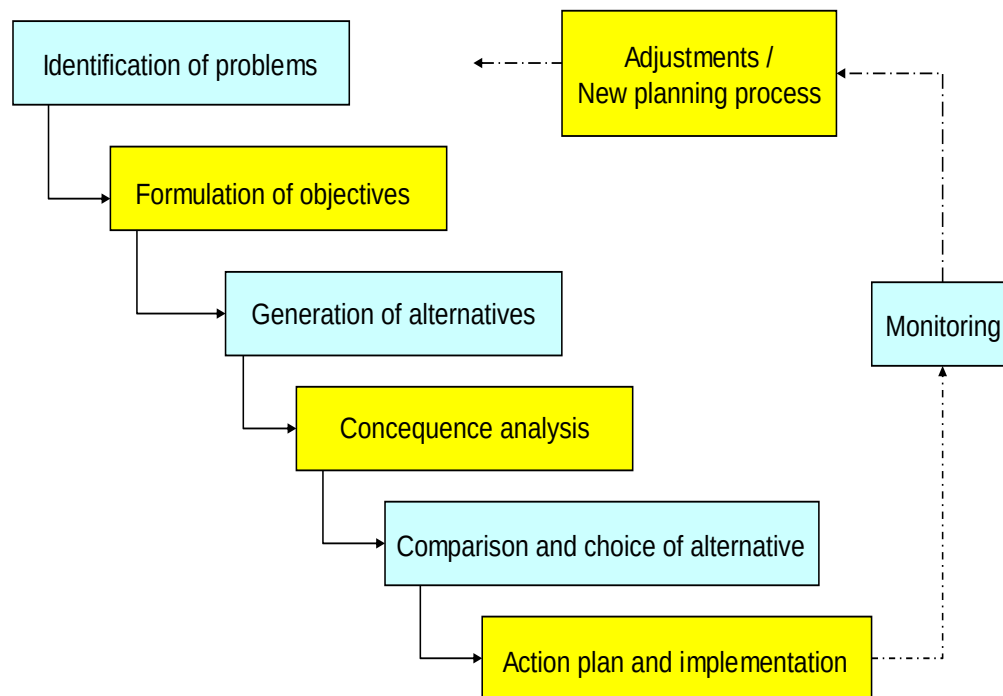
Once the transportation project has been selected, a detailed design phase is begun, in which each of the components of the facility is specified. For a transportation facility, this involves its physical location, geometric dimensions, and structural configuration. Design plans are produced that can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

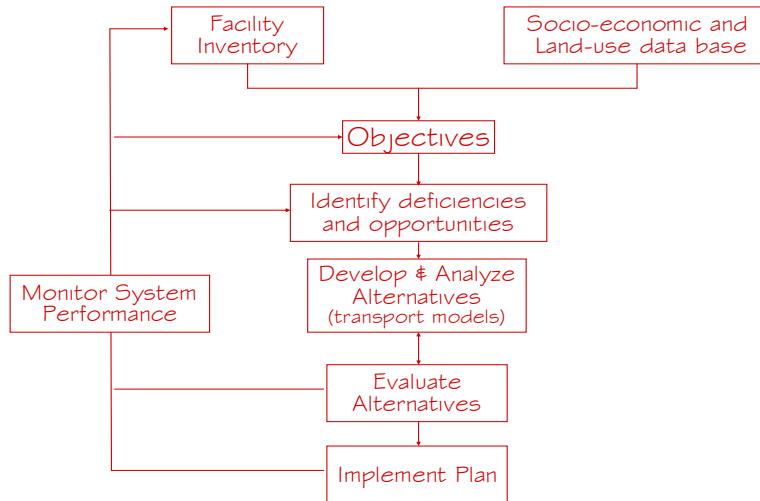
For our bridge project, once a decision to proceed has been made, we would produce a design that included the type of superstructure, piers and foundations, and roadway widths and approaches, as well as appurtenances such as tollbooths, traffic signals, and lighting. These plans would be submitted to contractors, who would prepare bids for the construction. If a bid does not exceed the amount of funds available and the contractor is acceptable to the client, the project proceeds to the construction phase. Upon completion, the new bridge is turned over to the local transportation authority for operation and maintenance.

2.1.2 Urban Transport Planning Process

The above stages or elements of the transportation planning process can be further re-arranged and summarized as shown below, in a way to encompass traffic or transport issues for urban areas. This is due to the reason that transport or traffic issues in urban areas (issues that are mostly considered in urban areas are, accident, noise, congestion, safety etc) are widely vary from the rural one. Therefore, the planning process differs to a certain extent from the general trend of planning for rural transport systems.

Problem oriented approach



Objective led approach

Facility Inventory

- Involves inventory of:
 - the existing transport services,
 - the available facilities and their conditions
 - location of routes and schedules
 - maintenance and operation costs
 - system capacity and existing traffic volumes, speed, delay, ...
 - property and equipment
 - etc.

Example

- Road X
 - is a major arterial system
 - Has n lanes of widths $w_1, \dots, w_n$
 - It has a capacity of C
 - Average flow is q veh/hr, speed is d sec
 - Has 4 signalised junctions and 6 priority junctions
 - Lanes are marked

- Travel time on Route Y is t sec
- Such data could be coded into GIS system and should be updated regularly!

Socio-economic and Land-use Data

- Transport plan focuses on the provision/supply of transport facilities and services to meet the existing or expected demand for travel.
- Transport is a DERIVED DEMAND: trips are taken to accomplish some activity at the destination
- Transport Planning should be related to the types of activities (i.e. land use, *e.g. schools, shopping centres and central business districts, residential area, ...*) in a region and the characteristics of the trip maker (*e.g. income, HH size, cars in HH, education, ...*)

Goals & Objectives (Formulation Objectives)

This element of the planning process formulate goals and objectives, which defines the purpose of the over all planning study:

- Goals/higher level objectives are general statements that indicate desired ultimate achievement of a transport plan)
- Objectives are more specific statements that indicate the means by which these goals will be achieved (the differ types of objectives are discussed below)

System Deficiencies and Opportunities (problem identification)

In some cases this stage comes/undertaken before formulation of objective (for the case of problem oriented planning approach)

- Tries to answer questions like:
 - Where do problems exist?
 - Are this problems existing now or will occur in the future?
 - Are there opportunities of better using the existing transport system

Develop and Analyse Alternatives (Generation of Alternatives and Consequence/Impact Analysis)

- At this stage different alternatives in accordance with the formulated objective will be developed and their impact in terms of, demand, level of service, revenue, environmental pollution, etc... will be assessed.

Evaluate Alternatives (Comparison and choice of alternatives)

- Evaluations should be based on the objectives set and should be based on appropriate indicators for the stated objectives.
- Efficiency: Vehicle Operating Costs, Travel Time Savings, ...
- Safety: “Value of Life”

Generally, under this category/stage of the planning process, Economic feasibility, Environmental and Social Impact studies for the proposed alternatives will be performed. And an alternative will be chosen based on pre-defined criteria.

Implement Plan

- Once the transport project is selected, a detailed design phase is begun, in which each of the components of the facility is specified.
- In case of the number of projects exceed the available funding during implementation, projects are prioritised depending on their benefits

Monitor System Performance

This is a continuous process, at this stage, after implementing the chosen alternative; the performance will be assessed and recorded.

- Need
 - To identify where improvements could be made
 - To take a lesson for future/other planning studies.
- It incorporates the results of
 - Transport management system
 - Pavement management system
 - Bridge management system
 - Safety management system
 - Public transport system
 - Inter-modal management system
 - Congestion management system

Planning Approaches: Problem-oriented and the objectives-led approach

- The problem-oriented approach is to start by defining types of problem, and to use data on current (or predicted future) conditions to identify when and where these problems occur. The objectives are implicit in the specified problems, and may never actually be stated.
- The objectives-led approach, in which broad (or more detailed) objectives are first specified, typically by the local authority or its elected members. These are then used to identify problems by assessing the extent to which current, or predicted future conditions, in the absence of new policy measures, fail to meet the objectives.

The problem-oriented approach starts by identifying problems and developing solutions to them. The objective-led approach defines problems in terms of specified objectives. Both methods converge at the stage of problem identification and then use these as a basis for identifying solutions and strategies. In either case it is essential to be comprehensive in the list of types of problem.

Types of objective

An objective is a statement of a desired end-state. However, that statement can range from the very general, such as a successful urban economy or a high standard of quality of life, to the very specific, such as avoiding pollution levels above a specified threshold. Both are helpful, the first in providing the context for the strategy, and a direction to it; the second in providing a basis for assessing whether the objective is being met.

Statements of vision

The most general specifications often appear in Statements of Vision: broad indications of the type of area which politicians or the public wish to see. These serve to identify long-term goals to which more detailed transport policy objectives can contribute.

- E.g. "A sustainable future", "Opportunities for all", "Maintain the cities role as a regional center", "Environmental improvement"

Higher level objective/Goals/Aims

These higher level objectives, sometimes referred to as aims or goals, identify attributes of the transport system, or its side effects, which can be improved as a means of realizing the vision. Typical among them are the desire to reduce congestion, protect the environment, avoid accidents and improve accessibility.

- E.g. "Accessibility within and outside the city", "Reduce congestion", "Avoid accidents"

These broad objectives indicate the directions in which strategies should be developed. They are sufficient to indicate that the appraisal procedures should predict and assess the level of congestion, noise, pollution, accidents and access. They also provide a means of assessing the relative performance of

different strategies in reducing pollution or accidents. They do not, however, indicate whether a particular solution is adequate in its impact. To do this more specific, quantified objectives are needed.

Quantified Objectives

Provide a clearer basis for assessing performance of the strategy, but they do require careful definition if the specified thresholds are to be realistic. Quantified objectives provide a direct basis for identifying problems, for current or future conditions, on the basis that a problem occurs wherever the quantified objective is not met.

- E.g. "Reduce traffic accidents with 20% by the year of xx"

Suggested indicators for different transport policy objectives

<i>Objective</i>	<i>Indicators</i>
Economic efficiency	Delays for vehicles (by type) at junctions Delays for pedestrians at road crossings Time and money costs of journeys actually undertaken Variability in journey time (by type of journey) Costs of operating different transport services
Environmental protection	Noise levels Vibration Levels of different local pollutants Visual intrusion Townscape quality (subjective)
Safety	Personal injury accidents by user type per unit exposure (for links, junctions, networks) Insecurity (subjective)
Accessibility	Activities (by type) within a given time and money cost for a specified origin and mode Weighted average time and money cost to all activities of a given type from a specified origin by a specified mode

Sustainability	Environmental, safety and accessibility indicators as above CO2 emissions for the area as a whole Fuel consumption for the area as a whole
Economic regeneration	Environmental and accessibility indicators as above, by area and economic sector
Finance	Operating costs and revenues for different modes Costs and revenues for parking and other facilities Tax revenue from vehicle use
Equity	Indicators as above, considered separately for different impact groups

Planning regulations and actors**➤ Planning regulations:**

- Laws concerning spatial and infrastructural issues
- Planning regulations pursuant to presents laws
- Guidelines
- Traditions

➤ Actors:

- Public athorities (all levels)
- Service providers
- Private actors
- Organisations
- User groups
- People, trades and functions affected by the measures

Public Participation in Road Planning

Although the public participation process can be time – consuming, it has the following advantages

- It provides a mechanism whereby planners can get a direct and timely understanding of community concerns and values, and participation of acceptable alternative alignment options.
- Potential opponents of a proposal are involved in the decision making process, thereby strengthening the planner's ability to implement the decision when eventually taken.
- The participation process is educational for the public and the transport planner.
- It reassures the final decision makers, i.e. the political process.

In concept there are three basic components of any successful public participation programs/process:

- The members of the public to be involved in the planning process must be identified,
- Timely two way communication flow must be established where by the planner provides information on the planning process, requirements to be met, public participation events, the public's role in the decision making, and alternative proposal and their impacts, while the public participation give information on the community conditions and concerns, contribute ideas and opinions on the transport problems and potential solutions, and express their values pertinent to the planning issues,
- Positive interactions must be encouraged, using techniques which get people to work together in a positive way on a shared concern.

Techniques used in the participation process may include:

- Group discussion : public meeting, search conferences, or workshops
- Contributions from individuals, via individual discussions, oral or written submissions, questionnaire surveys, or participant observation through a planner residing in the area,
- Publicity designed to provide feedback: public displays, providing a staff source of information/counseling in the area, or media releases.

The instruments of transport policy

These are the means by which the objectives can be achieved, and problems overcome. These instruments can be categorized in several ways. These are: infrastructure provision, management of the infrastructure, information provision, pricing, and land use measures. And under these measures, measures which provide for the private car, public transport, cyclists and pedestrians, and freight are considered. The key question with each of the measures is its ability to achieve one or more of the objectives.

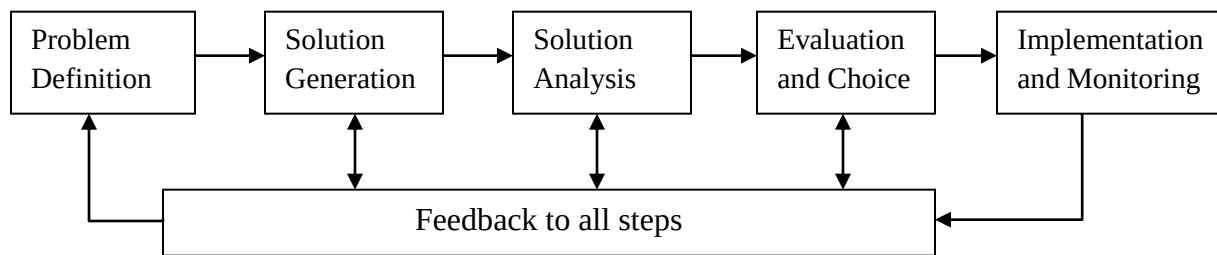


Figure 2.1-The Transportation Planning Process

The simplified planning process can be summarized as follows:

- A problem is a deviation from expected or desired performance. Goals and objectives, reflecting national or regional values, define the expected or desired performance.
- Solution generation is a subjective process that reflects regional goals and objectives, the nature of the identified problems, the nature of the existing transportation system and regional preferences, as much as it reflects technical and economic functionality.
- When the set of alternative solutions is identified, the process enters solution analysis where each alternative is subject to formal technical analysis (such as transport models) to assess resulting performance.
- The estimated performance of each generated alternative is then evaluated using various measures of performance (MOEs). These MOEs describe volumes, travel times or speed on links and intersections, and the associated impacts (such as air quality or noise). The MOEs must also be coupled with estimated cost and standard economic analysis techniques to assess the relative overall performance and cost of each alternative.
- The preferred alternative is selected for implementation, thus entering programming and project planning processes. Once the selected option is implemented, the overall system must be monitored to assess (a) real-world performance, (b) the degree that the problem has been addressed, and (c) the emergence of additional performance problems.

The transportation planning process is continuous- it is applied simultaneously at multiple levels, including various spatial scales. It is also characterized by extensive feedback. The process may iterate in defining alternatives and then estimating and assessing the associated performance. The results might be that new alternatives must be found, or perhaps the problem needs to be re-defined. Note that the planning process continues both during and after project construction to assess the effectiveness of the selected alternative in addressing the identified problems.

Transport Policy and Strategic Planning

Policy, defined conservatively, is a guiding principle that influences how a system behaves. It is a plan of action agreed on or chosen by a government, business entity etc. to satisfy the desires of a society. In this broad sense, a **transport policy** is a guiding principle that influences how the transport system should behave to achieve desired outcomes and avoid transport problems. Examples of such policies may include road expansion plans, transit system priorities, fuel tax, emission limits etc.

It is the task of politicians, and of the skilled professionals who advise them, to identify the most appropriate solutions to today's and tomorrow's transport problems. These solutions form the basis of a transport policy, which can be designed for a nation, a city, a town or a rural area. But it is essential that professionals are clear on the reasons for such solutions: that is, that the *objectives* which are to be achieved should be specified.

An objective is a statement of a desired end-state. However, that statement can range from the very general, such as a successful urban economy or a high standard quality of life, to the very specific, such as avoiding pollution levels above a specified threshold. Both are helpful, the first in providing the context for the strategy, and a direction to it; the second in providing a basis for assessing whether the objective is being met. Objectives in transport policy can be categorized into four classes:

- **Statements of Vision:** Broad indications of the type of area which politicians or the public wish to see. These serve to identify long-term goals to which more detailed transport policy objectives can contribute. These broad statements often say nothing about transport itself: instead they raise the question: "how best can transport help to realize this vision?".
- **Higher level objectives:** These higher level objectives, sometimes referred to as aims or goals, identify attributes of transport system, or its side effects, which can be improved as a means of realizing the vision. Typical among are to reduce congestions, protect the environment, avoid accidents and improve accessibility. These broad objectives indicate the directions in which strategies should be developed.
- **Quantified objectives:** Quantified objectives may indicate a requirement, for example, to avoid residents without cars being more than 30 minutes from the nearest bus station. They provide a clear basis for assessing performance of the strategy, but they do require careful definition if the specified thresholds are to be realistic. Once this is done, quantified objectives provide a direct basis for identifying problems, for current or future conditions, on the basis that a problem occurs wherever the quantified objective is not met.

- **Solution-specific ‘objectives’:** It is important to avoid specifying solutions within the objectives, since this constrains the search for solutions, and may lead to an overall strategy which is less appropriate to the area’s needs. Where politicians, or interest groups, wish to introduce general objectives such as to impose physical restrictions on car use, it is preferable to ask why this solution is being proposed and what it is designed to achieve. Answer to such questions should lead to clearer specification of the true underlying objectives.

The transport policy formulation process

There are in practice two different types of policy formulation approaches: objective-led and problem oriented approaches.

- 1. Objective-led strategy formulation:** broad (or more detailed) objectives are first specified. These are then used to identify problems by assessing the extent to which current, or predicted future conditions in the absence of new policy measures, fail to meet the objectives. Possible solutions are then identified as ways of overcoming the problems which have been identified. The potential solutions are then compared, often by means of predictive model of transport systems, by appraising them against the objectives which they are designed to meet. As the measures are implemented, their impact is assessed, through before and after studies, again in terms of achievement against objectives. Figure 2.2 presents a structure for strategy formulation in which objectives are the starting point.

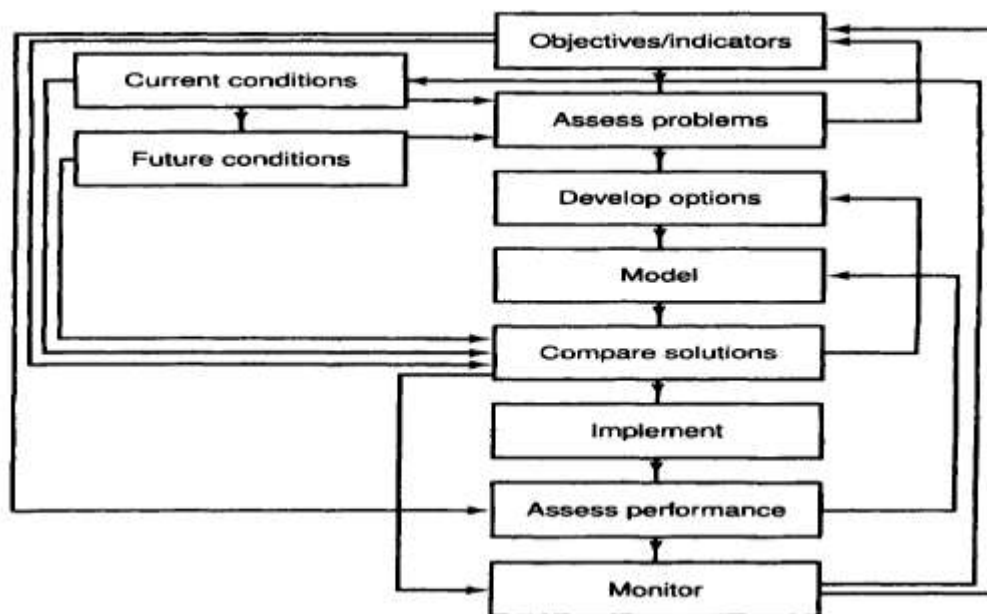


Figure 2.2 Objective-led policy formulations

This process may seem somewhat idealized and remote from standard practice, but it has several virtues. First, it offers a logical basis for proposing solutions, and also for assessing any proposals offered by others. Second, it ensures that the appraisal of alternatives is conducted in a logical, consistent, and comprehensive way against the full set of objectives. Third, assessing the performance of the implemented measures improves the ability to judge the potential of similar measures elsewhere, and to predict their impact. Fourth, regular monitoring provides a means of checking not just on the scale of current problems, but also, through attitude surveys, on the perception of those problems.

2. Problem oriented approach: The alternative problem-oriented approach is to start by defining types of problem and to use data on current (or predicted future) conditions to identify when and where these problems occur. This approach starts at the second box in the flow chart in figure 2.2. The objectives are implicit in the specified problem, and may never actually be stated.

It has the merit of being easily understood. However, it is critically dependent on developing a full list of potential problems at the outset. If particular types of problem (like access to job centers) are not identified because the underlying objective (accessibility) has not been considered, the resulting strategy will be partial in its impact. It is thus probably still wise to check with elected members and the public that the full set of problems has been identified.

As noted above, the problem-oriented approach to transport planning starts by identifying problems and developing solutions to them. The objective-led approach defines problems in terms of specified objectives. Both methods converge at the stage of problem identification and then use these as a basis for identifying solutions and strategies (Figure 2.2). In either case it is essential to be comprehensive in the list of types of problem.

Policy Instruments/Measures

Transport planners have available to them, at least in principle, a wide range of instruments/ strategies of transport policy. These are the means by which the objectives described above can be achieved, and problems overcome. These instruments can be categorized in several ways:

1. Infrastructures- new or expansion of roads, new rail lines, parking, pedestrian walk ways etc.
2. Management- traffic management, traffic calming, bus priorities, HOV lanes etc
3. Information- signs and markings, signals, real-time transit times etc.
4. Pricing- fuel taxes, bus fares, parking charges etc.
5. Land use- development densities, master plan, urban form etc
6. Attitudinal and behavioral measures

2.1.3 Evaluation of Transport Alternatives

Introduction

- A transportation project is usually proposed because of a perceived problem or need.
- In most instances, there are many ways (alternatives) to solve the problem, and each solution or alternative will result in a unique outcome in terms of project cost and results.
- Therefore, one must undertake evaluation of the different alternatives, based on economic criteria, environmental impact, or based on the social impact of the different alternative, or based on the combined multiple criteria, in order to come up with the sound/viable alternatives out of the different proposed alternative

I) Evaluation Based on Economic Criteria

Economic evaluation basis the relationship between the supply and the demand for the transport services.

Cost Benefit Analysis – a definition

- A systematic procedure for measuring and weighing up all benefits and costs with a project
- All benefits must be measurable in monetary units
- A project is said to be economically worthwhile if its benefits exceeds its costs

Theoretical basis

- Theoretical basis in the welfare theory of economics
- Endorses a project that increases the society's welfare measured in monetary terms
- Society's welfare = sum of individuals welfare
- It is assumed that the consumers are rational and there is full information
- Social cost benefit analysis is similar to private project finance analysis, except that all effects that are important for society should be considered.
- How to deal with benefits and disbenefits that can not be measured in money terms?
- A project is considered profitable if the sum of benefits exceeds the sum of disbenefits (over the total lifetime of the project).
- Distributional effects: Some groups of people gains, while other groups loses.
- In principle if a project is socially profitable those who gains could compensate those who loses.

2.2 Transport Modeling

2.2.1 Forecasting Travel Demand

- Travel demand is expressed as the number of persons or vehicles per unit time that can be expected to travel on a given segment of a transportation system under a set of given land-use, socioeconomic, and environmental conditions.
- Forecasts of travel demand are used to establish the loads on future or modified transportation system alternatives.
- The methods for forecasting travel demand can range from a simple extrapolation of observed trends to a sophisticated computerized process involving extensive data gathering and mathematical modeling.
- There are two basic demand forecasting situations in transportation planning. The first involves travel demand studies for urban areas, and the second deals with intercity travel demand.
- Urban travel demand forecasts, requires that extensive databases be prepared using home interview and/or roadside interview surveys.
- The information gathered provided useful insight concerning the characteristics of the trip maker, such as age, sex, income, auto ownership, and so forth, the land use at each end of the trip, and the mode of travel.
- Travel data could then be aggregated by zone and/or be used at a more disaggregated level-that is, household or individual-to formulate relationships between variables and to calibrate models.
- In the intercity case, data generally are aggregated to a greater extent than for urban travel forecasting, such as city population, average city income, and travel time or travel cost between city pairs.

Factor Influencing Travel Demand:

- i. Land use characteristics
 - shopping centers
 - residential complexes
 - industrial area
 - office buildings
 - recreational etc
- ii. socio-economic characteristics (income group level, household size, car ownership, etc)
- iii. Availability of transport facilities and services

- travel time,
- travel cost
- convenience
- comfort
- safety etc affect the modal choice

Basic steps in Travel Demand Forecast

1) Define the study area and also subdivide the area into traffic zones.

Subdividing the study area into traffic zones is a necessary first step before collecting and summarizing the study area

The selection of traffic zones is /may/ depend of criteria which include:

- homogeneous socio economic and land use characteristics
- minimum inter-zonal trips (the trip that is made in zone should be minimum)
- physical, political and historical boundaries
- Zone should not be defined with in other zones
- the zone system should generate and attract approximately equal trips, and equal hours holds, population area.
- use census tract boundaries where possible

2) Data Collection

It provides information about the land use as well as the socio-economic factors and the transport system. It also serves as the basis for developing travel demand estimates.

Travel surveys

- Identify where and when trips begin and end (origin and destination survey) (O-D survey)
- The trip purpose
- The mode of travel
- Socio economic characteristics of the trip makers
- The type of land use
- Automobile occupancy
- For freight transport, the type of commodity etc

Travel surveys serves as a fundamental source of data for transport planning. It is categorized in to four general classifications of travel surveys:

- Household travel surveys – prepare a questionary, and performing house to house and the data will be arranged for each household groups.
- Road side surveys – by stopping drivers
- Modal surveys - in different modes (like in bus)
- Good movement surveys

a) Household travel surveys

- The number and characteristics of person trips or auto drives trips made by residents with a specified study area.
- Socio economic characteristics of the HH,
This can be done by:
 - home interview (most important) often representative
 - telephone interview
 - mail survey

b) The road side survey

- stopping vehicles and asking drivers on
 - trip origin
 - trip destination
 - trip purpose
 - etc
- alternative ways of doing this
 - handing out post cards
 - recording the plate No and sending the questionnaires to the address of driver (especially important to record long freight trips, which are outside the survey area).

c) Modal survey

- Travel surveying of the number of trips made by each mode in the transport system (private car, bus rail, walking etc) and the survey is mostly undertaken by performing an interview at passenger terminals, through telephone, home to home survey etc.

d) Goods transport surveys

- O-D for trucks (trucks load type and weight)
- Detail information on the transport of commodities

3) Forecasting the travel demand of the study area using the transport models

Generally the travel forecast process can be summarized as:

Define the study area → Divide into traffic zone → Collect data (travel survey) → Forecasting the travel demand of the study area using the transport models

The components of future demand include:

- a. Existing traffic: the traffic that currently use the existing facility.
- b. Normal traffic growth: anticipated growth in regional population or economy.
- c. Diverted traffic: a traffic that is diverted to the improved road due to some factors.
- d. Converted traffic: change in mode of transport because of convinces.
- e. Change of destination: it is different from diverted traffic because your destination is changed. It could be either due to the changes in the land use or the transport facilities
- f. Development traffic: It is due to the development near by the road which causes changes in the transport system of the road.
- g. Induced traffic: traffic that didn't previously exist in any form but results when new or improved transport facilities are provided.

2.2.2 Transport Modeling

What is a transport model?

- *a simplified mathematical representation of a small part of the real world, aiming at describing and explaining travel behaviour and visualising the amount and patterns of transport*
- *mathematical models which on basis of data for **land use** and the **transport system**, together with an **understanding of human behaviour**, calculates the resulting traffic on the transport network for the present and future conditions. For the present situation these calculations can be compared with the traffic we can observe on the roads, in the streets and on the public transport system.*

Purpose

- *is to help transport planners make reliable forecasts of traffic demand that reflect the effects of changes in population, social, and economic conditions as well as changes in the transport network. For example, reliable forecast of future traffic reduces a risk of building facilities that will either receive little use or be prematurely overloaded.*

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 invaluable in offering a common ground for discussing policy and examining the inevitable compromises required in practice with a minimum of objectivity. During their formulation, calibration and use, planners can also learn much about the behavior and internal workings of the system under scrutiny.

However, a model is only realistic from a particular perspective. Its appropriateness is highly dependent on the context where it will be used i.e. its value is limited to a range of problems under specific conditions. Therefore, extreme care should be taken when choosing and adapting models for a particular context.

Transport models study of the behavior of individuals in making decisions regarding the provision and use of transport. Models in transportation planning are abstract mathematical models, put into the form of (systems of) mathematical equations in which the behavior of a dependent variable Y (e.g. the number of daily bus passengers in the Addis Ababa) can be derived from one or more explaining or independent variables X (e.g. number of transit lines, bus fares, etc) and related parameters a . Generally, they take the form;

$$Y = f(a, X)$$

Where, the parameters describe the sensitivity of Y to a unit change in X .

Model development starts from the formation of a hypothesis to explain the given phenomenon or system from a particular point of view. These sets of hypotheses will form the theory. The translation of such a theory into a quantitative model with quantifiable variables and associated parameters we call a conceptual model. The Estimation/ Calibration process determines the numerical values of the associated parameters from the given data. The model then needs further testing and verification on another set of data that has not been used during the calibration process. It is when the model is finally verified and approved that it can be applied to the transport system. The process of the model development is shown in the figure below.

The mathematical models have several purposes for transport planning, some of which are:

- To gain a modern structural analysis of the complex transport system
- To find out which factors play an important role, and how sensitive the transport system is to changes in the different factors

- To analyze the effect of alternative traffic projects and contribute towards their economic appraisal
- To help transport planners make reliable predictions and forecasts of future changes in usage of traffic facilities for sake of facility design, control and operation.
- To enable quantified calculations of expected effects in the transportation system when changes (policy measures or interventions) are put in the system
- To find design parameters that lead to an optimal performance of the modeled system

Thus, transport modeling contributes greatly to improved decision making and planning in the transport field. However, transport modeling is only one element in transport planning: administrative practices, an institutional framework, skilled professionals and good level of communication with decision makers, the media and the public are some of the other requisites for an effective planning system.

Prerequisite for transport modeling

Before embarking on the modeling of transport systems in the context of this chapter, the modeler should be familiar with the basic terminologies, grasp the fundamental characteristics of transport problems, gather the necessary data and understand basic regression analysis. These four prerequisites are treated in more detail below:

Characteristics of transport problems

Both the demand for travel and the supply for transport facilities exhibit distinct characteristics that the modeler should bear in mind. These characters include:

- The demand for transport services is highly qualitative and differentiated. There is a whole range of specific demands for transport which are differentiated by time of day, day of week, journey purpose, type of cargo, and so on.
- The demand for transport is derived; it is not an end by itself. People travel in order to satisfy a need (work, leisure, health) at their destination.
- Transport demand takes place over space. It is the distribution of activities over space that makes for transport demand.
- Both transport demand and supply have very strong dynamic elements. A good deal of the demand for transport is concentrated on a few hours of the day.
- Transport is a service and not a good. Therefore, it is not possible to stock it.
- The transport system requires fixed assets and the mobile units. It is often the case that the infrastructure and the vehicles are not owned nor operated by the same entity.

- Transport infrastructure is lumpy; one cannot provide half a runway or one-third of a railway station. They take a long time to carry out and significant expenses.
- Transport investment has an important political role.
- Transport services come with side effects: accidents, pollution and environmental degradation.

Data Requirements

Since transport models are applied to large systems, they require information about travelers of the area influenced by the system. Here the data requirement is very high, and can be broadly categorized into four:

- **Socio-economic data:** Information regarding the socio-economic characteristics of the study area. Important ones include income, vehicle ownership, family size, etc.
- **Travel surveys:** Origin-destination travel survey at households and traffic data from cordon lines. Former data include the number of trips made by each member of the household, the direction of travel, destination, the cost of the travel, etc. The latter include the traffic flow, speed, and travel time measurements.
- **Land use inventory:** This includes data on the housing density at residential zones, establishments at commercial and industrial zones.
- **Network data:** This includes data on the transport network and existing inventories. Transport network data includes road network, traffic signals, junctions etc. The service inventories include data on public and private transport networks.

The data required for modeling is primarily collected through surveys. These surveys include:

- Household survey
- External cordon and Intercept surveys
- Travel Diary
- O-D survey
- Questionnaire
- In-house and Roadside Interviews

Designing the data collection survey for the transportation projects requires considerable experience, skill, and a sound understanding of the study area. It is also important to know the purpose of the study and details of the modeling approaches. Further, many practical considerations like availability of time and money also has a strong bearing on the survey design.

(For more on data collection and sampling, please refer chapter 3 of Ortuzar & Willumsen 2001)

Results from the transport models

- Link flows on road network
- Travelers on public transport lines
- “Transport work”; vehicle-km, person-km
- Travel times on links and between zones

The use of transport models

- Providing traffic data for the future; thus understanding the challenges to come; congestion, environmental conditions, future transport costs for people and for business / industry, accessibility and mobility, etc
- Analyzing the effect of alternative traffic plans / projects providing traffic data for “benefit-cost-analysis”
- Providing traffic data for calculating the development of traffic accidents and environmental conditions

Organizing the transport model

The structure of the transport model will be according to “the four-step-procedure”, but there is some preparations to do before the start of the modeling work:

- Zoning and land use data
- Transport network coding
- Data acquisition (Inventories, travel surveys)

Zoning and land use data

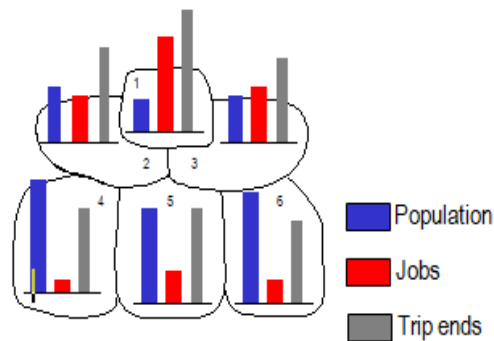
- We have some basic principles of how a zone should be organized / located, but the most important condition is the availability of land use data for the zones
 - **Population**; and when we start to look into trip production models we discover that we may wish to have population data by “households”, “age-group”, “income-group”, “sex” and “car ownership” etc.
 - **Jobs**; number of jobs in each zone, split in different type of jobs; the simplest stratification is two groups of jobs:
 - Ordinary jobs which do not attract customers or visitors, the only trips made are the journey to and from work (and may be some freight transport)
 - Jobs which attract customers (public attractive jobs)
 - **Other land use influencing on trip production**; shopping malls, cinemas, sport arenas, schools, universities, etc

The Four Stage Model

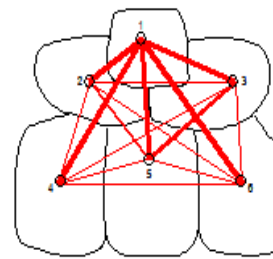
The most popular of the transport modeling approaches is the classic Four-Step Model (FSM). The FSM aims to establish the spatial distribution of travel explicitly by means of an appropriate system of zones. It is presented as a sequence of four mathematical sub models:

1. Trip production and attraction: Models based on data for land use calculate the number of trip produced and attracted to each zone in the study area
2. Trip distribution models are used to calculate the trip pattern connecting trip productions and attractions
3. Trips from an origin (zone) to a destination are distributed to the different modes of transport by mode choice models
4. Car trips and public transport trips are distributed to the road network through Traffic Assignment

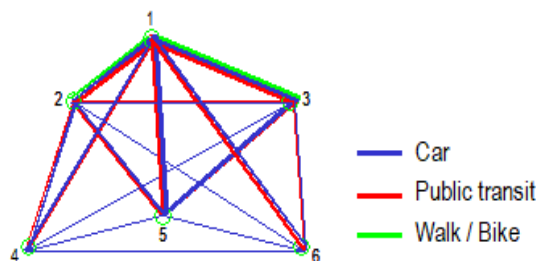
1. Trip production



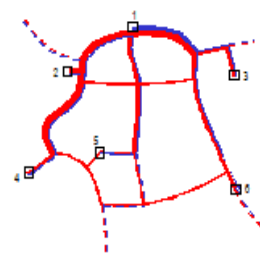
2. Zone-to-zone distribution

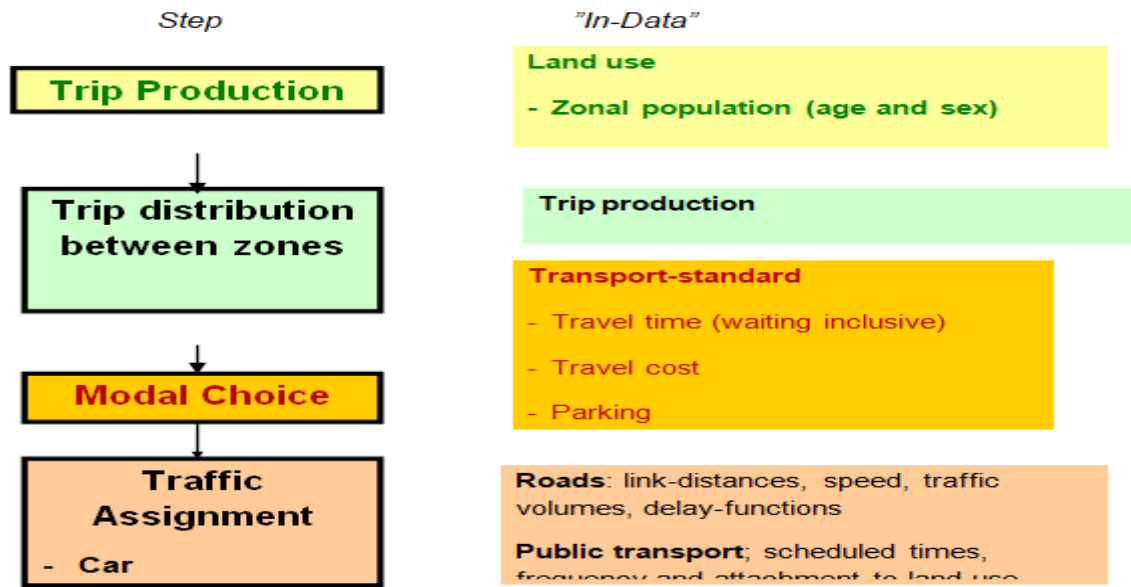


3. Mode choice



4. Traffic on roads and trips on public transit



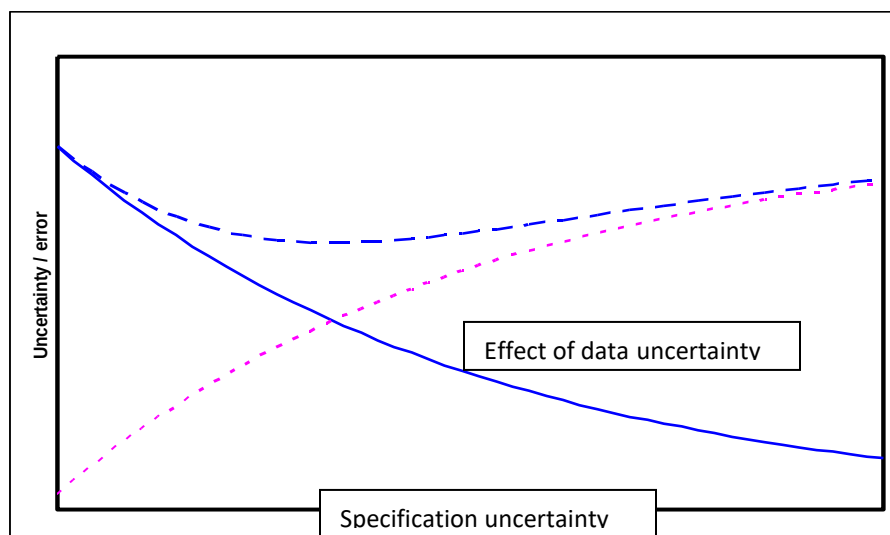


Trip definitions

When we work with transport models we need a precise definition of a trip:

- Age group (what about people less than 7, less than 13, less than 18)?
- What is the trip producing end and what is the attracting end?
- What about walking and biking trips?
- What about distance is there a minimum distance?
- What about bus drivers and taxi drivers?
- What about trips made while working?

Uncertainty in models

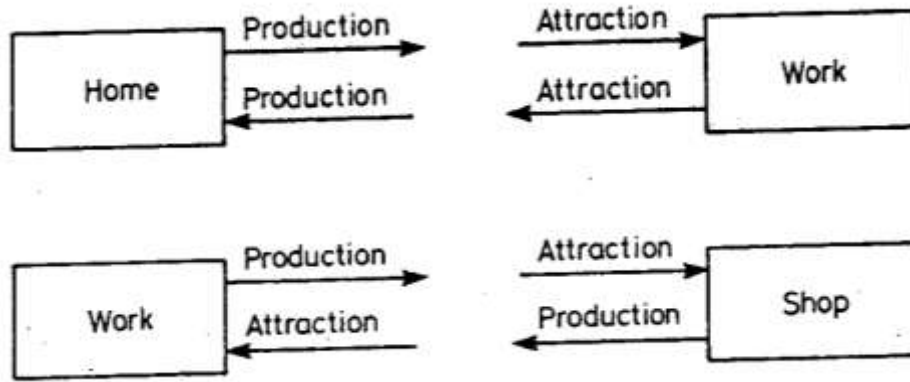


1) Trip production

- This is the first step in the four-step procedure. This step calculates the number of trips “generated from” and “attracted to” the land use in the zone. OR, it is the process of determining the number of trips that will begin or end in each traffic zone within a study area.
- When dealing with the different types of models we must distinguish between
 - Developing the model by use of data from travel surveys and by using different development tools (mathematical).
 - Using the models; providing the necessary (and correct) input data. For future years this implies forecasts for some of the data required.

Trip definition

- There exist many definitions of trips, journeys, motorized trips, home based trips, round trips etc. It is important to decide upon one definition which is held constant for the whole study.
- A trip is defined as a one-way trip from a point of origin to a point of destination
- Excluded are non-motorized trips shorter than x meters ($x = 300 - 500\text{m}$)
- Excluded are trips made by persons under the age of y ($y = 6$ or 13 years)
- We distinguish between home based (HB) trips (one of the trip ends is at own home) and non-home based (NHB) trips (neither end is at own home)
- **Trip production:** trip production is defined as the home end of a home based (HB) trip or the origin of a non-home based (NHB) trip
- **Trip attraction:** trip attraction is the non-home end of a home based (HB) trip or the destination of a non-home based (NHB) trip.
- **Home-Based (HB) Trip:-** one where the home of the trip maker is either the origin or the destination of the journey.
- **Non-Home- Based Trip:-** one where neither end of the trip is the home of the traveler.
- **Trip Production:-** is the home end of an HB trip or the origin of an NHB trip.
- **Trip Attraction:-** is the non-home end of an HB trip or the destination of an NHB trip.



Trip Generation is Define the magnitude of total daily travel in the model system, at the household and zonal level, for various trip purposes (activities).

The objective of this first stage of the FSM process is to define the magnitude of total daily travel in the model system, at the household and zonal level, for various trip purposes (activities). This first stage also explicitly translates the FSM from activity-based to trip-based, and simultaneously separates each trip into a production and an attraction. It aims at predicting the total number of trips produced in the zone and attracted by it respectively for each study area. It has two basic functions:

- To develop a relationship between trip production or attraction and land use, and
- To use the relationship developed to estimate the number of trips generated at some future date under a new set of land-use conditions.

Trip generation (both production and attraction) depends on the nature and characteristics of the activity system. In production models, estimates are primarily based on the demographics of the population within a zone. For attraction models, the variables that have been found to have the best explanatory power are those based on characteristics of the land use, such as office and retail space or the employment levels of various sectors.

Some factors which have been found to have a considerable impact on the trip producing capacity of are:

- Income
- Car ownership
- Household structure
- Family size
- Value of land
- Residential density
- Accessibility

While the following factors are widely used with the affinity of a zone to attract trips:

- Employment
- Sales
- Space available for industrial, commercial or other services

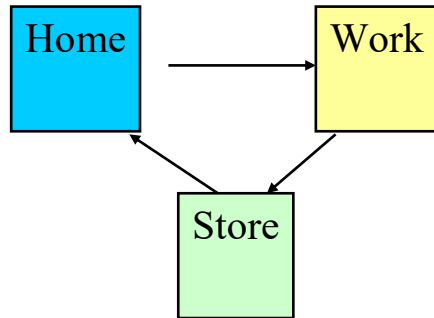
Trips can be modeled at the zonal, household, or personal level, with household level models most common for trip productions and zonal level models most common for trip attractions. Furthermore, it have been found in practice that better trip generation models can be obtained if trips by different purposes are identified and modeled separately. In the case of home-based (HB) trips, five categories have been usually employed:

- trips to work
- trips to school
- shopping trips
- social and recreational trips
- other trips

It is also important to classify trips into peak and off-peak periods as the proportion of journeys vary greatly with the time of the day. It is also wise to differentiate trips into personal and freight as the two types have significant difference in nature and characteristics.

Several modeling approaches are available for trip generation including growth factor, regression, discrete choice and category classification. In this course, only growth factor modeling and regression analysis will be discussed.

Examples of use of trip definitions



Three trips; home to work, work to store, store to home

	Trip production	Trip attraction	Total trips ends
Home	2	0	2
Work	1	1	2
Store	0	2	2
Sum	3	3	6

We get a better trip production and attraction models (and thus better transport models) if different trip purposes are modeled separately

Compulsory or mandatory trips

- Home to work
- Home to school or college

Optional trips

- Shopping trips
- Social and recreational trips
- Other trips

Factors Affecting Trip Production

- Income
- Car ownership
- Household structure (number of employed persons)
- Family size

Factors Affecting Trip Attraction

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

Trip generation analysis has two functions:

- to develop a relationship between trip end production or attraction and land use, and
- to use the relationship developed to estimate the number of trips generated at some future date under a new set of land-use conditions.

To illustrate the process we will consider three methods:

- Cross classification method
- Rates Based on Activity Units
- Regression Model

a) Cross Classification

- Cross classification is a technique developed by the Federal Highway Administration (FHWA) to determine the number of trips that begin or end at the home.
- Home-based represent up to 80 percent of all trips.
- The first step is to develop a relationship between socioeconomic measures and trip production to produce trip rates by cross classification or category analysis.
- The two variables most commonly used are average annual income and auto/car ownership.
- Other variables that could be considered are household size and stage in the household life cycle.
- Some thought should be given to:
 - What dimensions to cross-classify (no of cars owned **OR** No. of HH members)
 - What groupings of these levels (0,1,2+ **OR** 0,1,2,3+)

Example 1

Suppose a survey finds the data on weekly trip making as given in (2) and the distribution of HH car ownership as is tabulated in (3). In (4) the avg. number of trips per HH is calculated to be 43.

If the distribution of HH with a certain no. of cars changes as shown in (5), category analysis holds (2) constant and calculates new average trips per house hold.

(1)	(2)	(3)	(4)	(5)	(6)
Number of cars owned by HH	Weekly Number of trips made by HH	Initial Distribution of HH	(2)*(3)	New Distribution of HH	(2)*(5)
0	30	50%	15	30%	9
1	50	40%	20	50%	25
2+	80	10%	8	20%	16
			43		50

Example 2

Let see how a trip rate can be developed from the cross relation of household size and auto/car ownership.

No. of trips, Household size vs. Auto/Car ownership.

HH size	Auto/Car Ownership					
	0		1		2+	
	HH No.	Trips	HH No.	Trips	HH No.	Trips
1	1200	2520	2560	6144	54	130
2	874	2098	3456	9676	5921	20165
3+	421	1137	2589	8026	8642	33704

Trip rates = Trips/No. of HH

HH size	Auto/Car Ownership		
	0	1	2+
1	2.1	2.4	2.4
2	2.4	2.8	3.4
3+	2.7	3.1	3.9

b) Rates Based on Activity Units

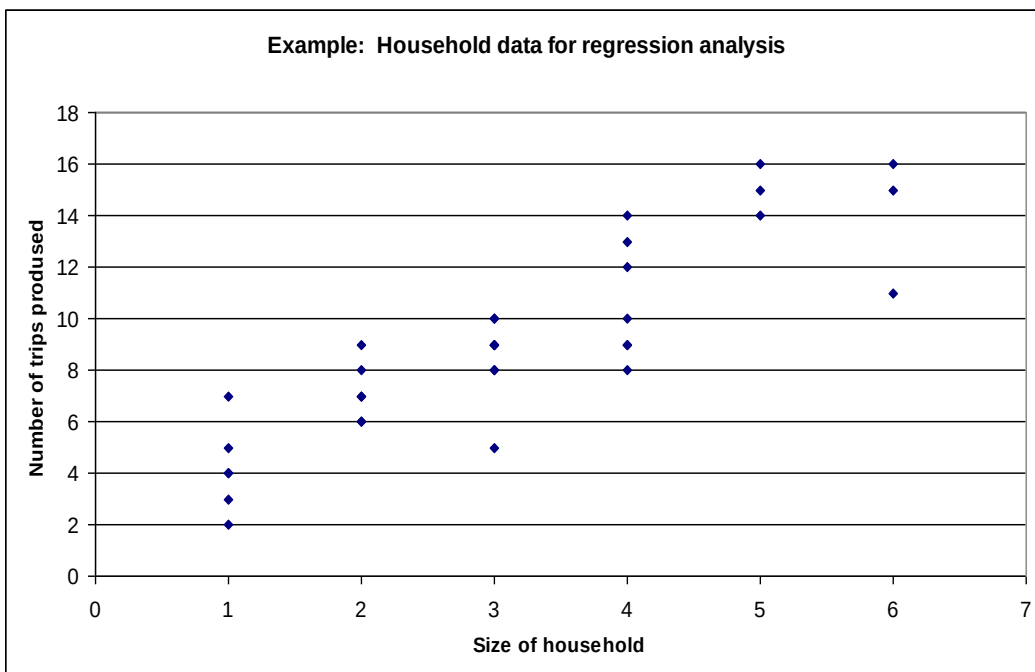
- The preceding section illustrated how trip generation is determined for residential zones where the basic unit is the household.
- Trips generated at the household end are referred to as *productions*, and they are *attracted* to zones for purposes such as work, shopping, visiting friends, and medical trips or other for other trip purposes.
- Thus, an activity unit can be described by measures such as square feet of floor space or number of employees.
- Trips generation rates for attraction zones can be determined from such survey data.

c) Regression models

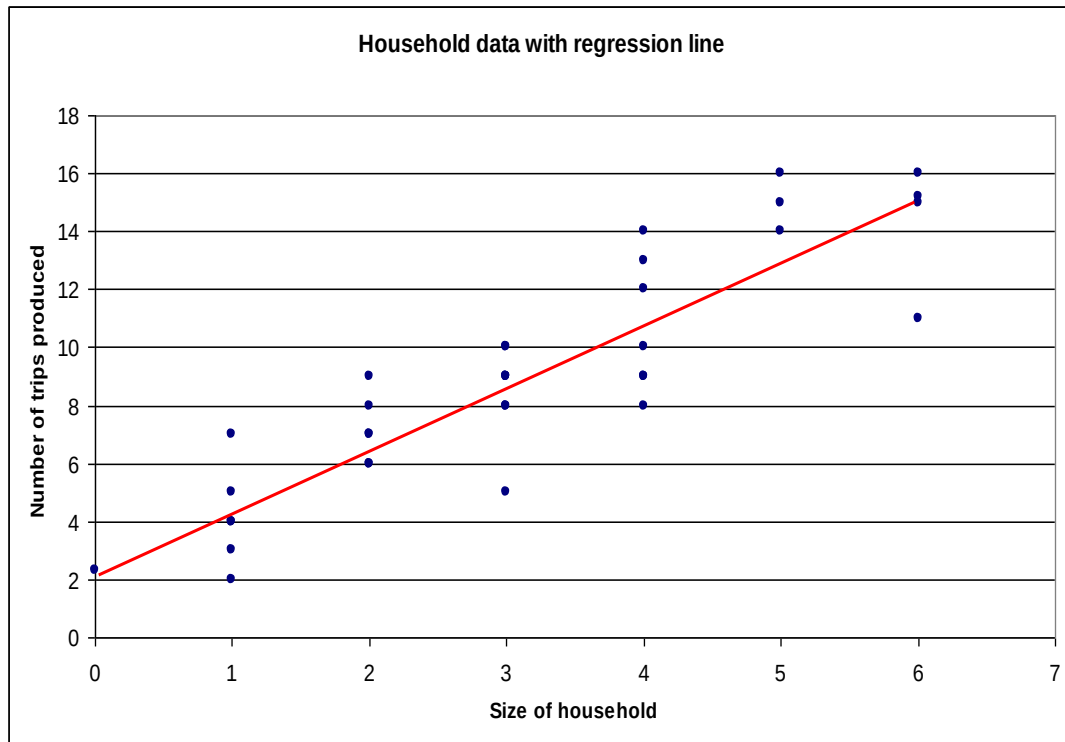
- Regression models are a family of trip production models which use regression analysis to develop a model.
- Simple general regression model:

$$Y = a + b \cdot X$$

- Here Y is number trip produced and X is the one of the socio-economic factor/parameter, e.g. as shown in the example below household size



The equation for the regression line is $Y = a + b \cdot X$



Multiple regression analysis

$$Y = \alpha + \beta_1 X_1 + \dots + \beta_n X_n + \varepsilon$$

We have already stated that trip production is influenced by many household characteristics:

- Income
- Car ownership
- Household structure
(Number of employed persons)
- Family size

If we move from households to individuals we can add even more factors:

- Sex
- Age
- Employed

Thus the simple regression model we have been dealing with so far is insufficient; we need a tool that can handle more variables. One of the answers is **multiple regression analysis**

Example

Let:

T_i = number of trips in a month, by zone i

D_j = no. of trips attracted to zone j

P_i = population for zone i

U_i = dwelling units in zone i

A = no. of automobiles in zone i

E_i = total employment in zone i

$$T_i = 0.34P_i + 0.21U_i + 0.12A$$

$$D_j = 57.2 + 0.87E_j$$

2) Trip Distribution

- Trip distribution analysis is a process by which the trips generated in one zone are allocated to other zones in the study area.
- The major product of trip distribution models is an O-D matrix that shows the no. trips originated in the study zone and where these trips are destined to.
- For example, if the trip generation analysis results in an estimate of 200 HBW trips in zone 10, then the trip distribution analysis would determine how many of these trips would be made between zone 10 and all the other zones.

Trip matrix		To Zone J				
		1	2	3	4	SUM
From Zone i	1					P_1
	2					P_2
	3					P_3
	4					P_4
	SUM	A_1	A_2	A_3	A_4	

We use the trip distribution models to create the complete O-D matrix.

Two methods are in use:

- Gravity Model
- Growth Factor Model

a) Gravity Model

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

$i \backslash j$	1	2	3			j			N	SUM
1	T_{11}	T_{12}	T_{13}			T_{1j}			T_{1N}	P_1
2	T_{21}	T_{22}	T_{23}			T_{2j}			T_{2N}	P_2
3	T_{31}	T_{32}	T_{33}			T_{3j}			T_{3N}	P_3
i	T_{i1}	T_{i2}	T_{i3}			T_{ij}			T_{iN}	P_i
N	T_{N1}	T_{N2}	T_{N3}			T_{Nj}			T_{NN}	P_N
SUM	A_1	A_2	A_3			A_j			A_N	

- Formulas and Examples are discussed on the lecture given on the blackboard.
- However, as an alternative way to perform the iteration process of the O-D matrix developed the gravity model, the following iteration approach can be applied.

b) Growth Factor Model

- Trip distribution can also be computed when the only data available are the origins and destinations between each zone for the current or base year and the trip generation values for each zone for the future year.
- This method was widely used when O-D data were available but the gravity model and calibrations for F factors had not yet become operational
- Growth factor models are used primarily to distribute trips between zones in the study area and zones in cities external to the study area.
- Since they rely upon an existing O-D matrix, they cannot be used to forecast traffic between zones where no traffic currently exists.
- Further, the only measure of travel friction is the amount of current travel.

- Thus, the growth factor method cannot reflect changes in travel time between zones, as does the gravity model.
- The most popular growth factor model is the *Fratarmethod*, which is a mathematical formula that proportions future trip generation estimates to each zone as a function of the product of the current trips between the two zones T_{ij} and the growth factor of the attracting zone G_j .

The Growth Factor Methods

In this approach a base year matrix is needed. Each cell of this matrix is multiplied by a growth factor. Growth factors may be computed in a number of ways, e.g. as the output of an economic model, a trend model, etc. However, in these course notes, we only discuss methods of computing growth factors based on trip generation modeling.

The base year matrix contains an estimate of the trips being made in the base year. Depending on these estimates, we may be able to use different growth-factor methods in our estimation of future trip patterns.

Uniform Growth Factor

If the only information available is about a general growth rate for the whole of the study area, then we can only assume that it will apply to each cell in the matrix, which is a uniform growth rate. The equation can be written as:

$$T_{ij} = \tau t_{ij}$$

Where τ is the uniform growth factor, t_{ij} is the previous total number of trips and T_{ij} is the expected total number of trips.

Advantages are that they are simple to understand, and they are useful for short-term planning. Limitation is that the same growth factor is assumed for all zones, where as in most cases differential growth for different parts of the study area is expected.

Singly Constrained Growth-Factor

If information is available on the expected growth of either trips originating or trips attracted to each zone, it will result in origin-specific τ_i and destination-specific τ_j growth factors respectively. In this case, the expected number of trips between origin-destination pairs is written as:

$$T_{ij} = \tau_i t_{ij} \text{ for origin-specific factors}$$

$$T_{ij} = \tau_j t_{ij} \text{ for destination-specific factors}$$

Doubly Constrained Growth Factor

When information is available on the growth in the number of trips originating and terminating in each zone, we know that there will be different growth rates for trips in and out of each zone and consequently having two sets of growth factors for each zone. This implies that there are two constraints for that model and such a model is called doubly constrained growth factor model. Historically a number of iterative methods have been proposed to obtain an estimated trip matrix which satisfies both sets of trip-end constraints, or the two sets of growth factors.

The best known of these methods is due to Furness (1965), who introduced balancing factors' A_i and B_j as follows:

$$T_{ij} = t_{ij} \tau_i \tau_j A_i B_j$$

Or incorporating the growth rates into new variables a_i and b_j :

$$T_{ij} = t_{ij} a_i b_j$$

With $a_i = \tau_i A_i$ and $b_j = \tau_j B_j$

The factors a_i and b_j must be calculated so that the constraints are satisfied. The procedure is:

1. Set $b_j = 1$
2. With $b_j = 1$, solve for a_i to satisfy trip generation constraint ($\sum_j T_{ij} = O_i$).
3. With a_i , solve for b_j to satisfy trip attraction constraint ($\sum_i T_{ij} = D_j$).
4. Update matrix and check for errors.
5. Repeat steps 2 and 3 till convergence.

The advantages of Growth Factor method are:

1. Simple to understand.
2. Preserve observed trip pattern.
3. Useful in short term-planning.

The limitations are:

1. Depends heavily on the observed trip pattern.
2. It cannot explain unobserved trips.
3. Do not consider changes in travel cost.
4. Not suitable for policy studies like introduction of a mode.

3) Mode Choice

- Mode choice is that aspect of the demand analysis process that determines the number (or percentage) of trips between zones that are made the different transport modes.
- The selection of one mode or another depends on factors such as:
 - the types of trip purpose (work, leisure),
 - time of day,
 - Characteristics of the trip maker (traveler's income, age, car-ownership)
 - the availability of the different modes,
 - and the relative advantages of each mode (characteristics of the mode in terms of travel time, cost, comfort, convenience, and safety).
- There are different types modal choice models/procedures exist and under the scope of this course we shall only see the widely used type of modal choice model, which is the **Logit Model**.

Logit Model

- Logit model considers the relative utility of each mode as a summation of each modal attribute. Then the choice of a mode is expressed as a probability distribution.
- Mode utilities are attributable:
 - to the user (time, price, ...),
 - to the service characteristics of a mode (reliability, safety, comfort),
 - others
- The Utility of a mode is the “satisfaction” a user derives from using a certain mode of transport. It is a linear combination of cost attributes a transport mode presents to its user

$$\text{e.g. } U = a_0 - a_1 TT - b_2 \text{ Price} + a_3 \text{ Comfort} + \dots + a_n X$$

- The Logit Model is given by the following expression:

$$P_{it} = \frac{e^{U_{it}}}{\sum_{All\ j} e^{U_{jt}}}$$

P_{it} = probability of individual t choosing mode i

U_{it} = Utility of mode i to individual t

U_{jt} = Utility of mode j to individual t

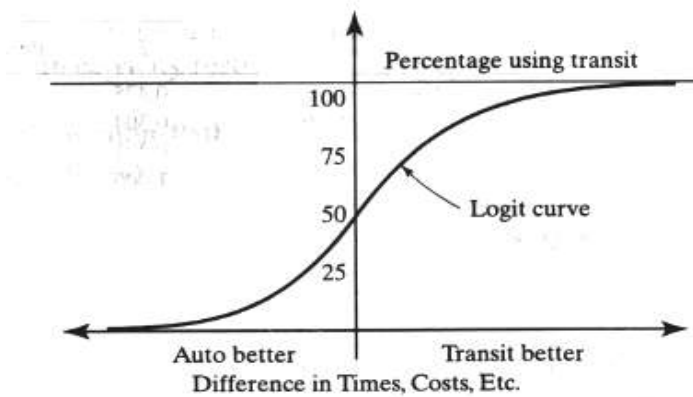


Figure 2.4- S-shaped logit mode choice curve

Note that the method is based on one individual's Utility from the different modes.

4) Traffic Assignment

Traffic assignment is the step in traffic analysis in which inter-zonal trips are assigned to the network. The traffic demand, as described in the origin-destination (OD) tables per trip purpose and per travel mode (and sometimes per period), is confronted with the infrastructure supply, which is a network of links and nodes having characteristics as capacity, maximum travel speed, one-way streets, tolls and other factors of resistance.

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, there is a separate assignment for each mode, since the networks for each of the modes is very different. For the sake of simplicity, we restrict ourselves to assignments of individual road traffic (car, bike); the more complex assignments on public transportation networks will not be discussed here.

The major aims of traffic assignment procedures are:

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

Necessary input for the assignment:

- an O-D table of trips between the zones, usually all trip purposes combined;
- a (computer)representation of the network;
- characteristics of the network elements (links and nodes);
- a route choice model.

Direct output of the assignment computation:

- the routes (consecutive series of adjacent links and nodes);
- the route characteristics (travel times, distances, costs);
- route loads: the number of trips per route;
- link and node loads: the number of trips per unit time (flow) on each link and each turn at junctions.

Technically, there are two broad assignment models: the minimum path assignment and the congested assignment. The minimum path assignment models assume that the capacity and travel cost of the links is unaffected by the volume of traffic and all the traffic will choose to travel on the shortest path. Whereas, the congested assignment models address the fact that the travel time and cost on a link increases as the volume of traffic on the link increases.

The all-or-nothing (AON) assignment is the basic form of the minimum path assignment models while incremental assignment, capacity restraint assignment, user equilibrium assignment (UE), stochastic user equilibrium assignment (SUE), system optimum assignment (SO), etc are some forms of the congested assignment models.

All-or-Nothing Assignment

In an All-Or-Nothing (AON) assignment, all traffic between an O-D pair is assigned to just one path (usually the shortest path) connecting the origin and destination. This model is unrealistic in that only one path between every O-D pair is utilized even if there is another path with the same or nearly the same travel time. Also, traffic is assigned to links without consideration of whether or not there is adequate capacity or heavy congestion; travel time is taken as a fixed input and does not vary depending on the congestion on a link.

However, this model may be reasonable in sparse and uncongested networks where there are few alternative routes and they have a large difference in travel cost. This model may also be used to identify the desired path: the path which the drivers would like to travel in the absence of congestion. In fact, this model's most important practical application is that it acts as a building block for other types of assignment techniques. 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.

One form of the AON is the *shortest path all-or-nothing assignment*. This is an assignment in which for each OD pair the corresponding flow is assigned to a single path that, according to a fixed set of link costs, has minimum path costs (congestion effects are not taken into account).

- The final step in the transportation forecasting process is to determine the actual street and highway routes that will be used and the number of automobiles and buses that can be expected on each highway segment.
- The procedure used to determine the expected traffic volumes is known as *traffic assignment*.
- To carry out a trip assignment, the following data are required:
 - Number of trips that will be made from one zone to another (this information was determined in the trip distribution phase).
 - The available highway or transit routes between zones and how long it will take to travel on each route.
 - A decision rule (or algorithm) that states the criteria by which motorists or transit users will select a route.

Three different approaches can be used, and most are based on minimum travel time, these are:

a) The Diversion Curve Method

- The traffic between two routes is determined as a function of relative travel time or cost.

b) Minimum Path Method

- The minimum path assignment is based on the theory that a user will select the quickest route between any O-D pair.
- In other words, the traveler will always select the route that represents minimum travel time.
- Thus, to determine which route that will be, it is necessary to find the shortest route from the zone of origin to all other destination zones.

c) Capacity Restraint Method

- A modification of the minimum path method.
- The number of trips assigned to each link is compared with the capacity of the link to determine the extent to which link travel times have been reduced.
- A reassignment is then made based on these new values. The iteration process continues until an equilibrium balance is achieved.

2.3 Characteristics of Road and Road users

The four main components of the highway mode of transportation are the driver, the pedestrian, the vehicle, and the road. The bicycle is also becoming an important component in the design of urban highways and streets. To provide efficient and safe highway transportation, knowledge of the characteristics and limitations of each of these components is essential. It is also important to be aware of the interrelationships that exist among these components in order to determine the effects, if any, that they have on each other. Their characteristics are also of primary importance when traffic engineering measures such as traffic control devices are to be used in the highway mode. Knowing average limitations may not always be adequate; it may be necessary to sometimes obtaining information on the full range of limitations.

For example, sight and hearing vary considerably across age groups, with the ability to hear and see usually decreasing after age 65. In addition, these can vary even among individuals of the same age group. Similarly, a wide range of vehicles, from compact cars to articulated trucks, have been designed. The maximum acceleration, turning radii, and ability to climb grades differ considerably among different vehicles. The road therefore must be designed to accommodate a wide range of vehicle characteristics while at the same time allowing use by drivers and pedestrians with a wide range of physical and psychological characteristics.

Driver Characteristics

One problem that faces traffic and transportation engineers when they consider driver characteristics in the course of design is the varying skills and perceptual abilities of drivers on the highway, demonstrated by a wide range of abilities to hear, see, evaluate, and react to information. Studies have shown that these abilities may also vary in an individual under different conditions, such as the influence of alcohol, fatigue, and the time of day. Therefore, it is important that criteria used for design purposes be compatible with the capabilities and limitations of most drivers on the highway.

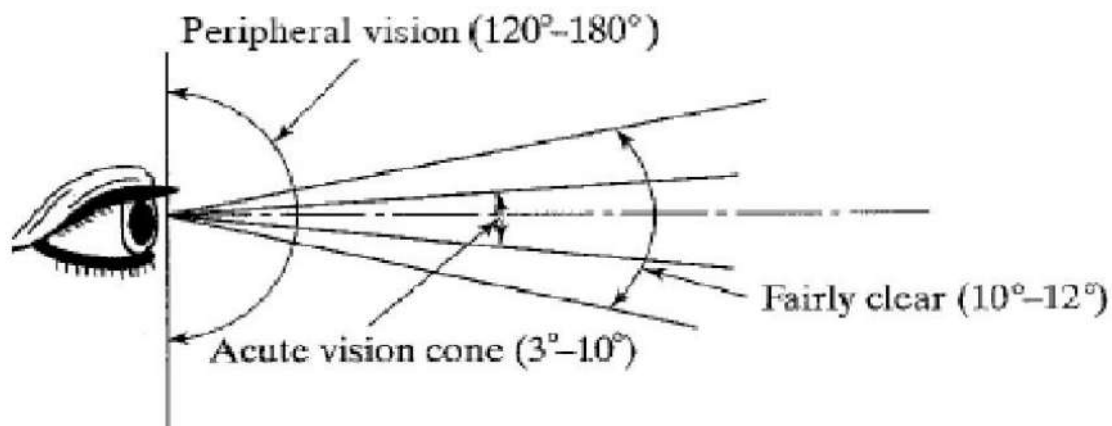
The two driver characteristics of utmost importance are visual acuity factors and the reaction process. The two overlap, in that reaction requires the use of vision for most driving cues. Understanding how information is received and processed is a key element in the design of roadways and controls. Hearing is also an important element in the driving task (i.e., horns, emergency vehicle sirens, brakes squealing, etc.)

It is said to be the most complex factor as the human performances varies from individual to individual. Thus, the transportation engineer should deal with a variety of road user characteristics. For example, a traffic signal timed to permit an average pedestrian to cross the street safely may cause a severe hazard to an elderly person.

Thus, the design considerations should safely and efficiently accommodate the elderly persons, the children, the handicapped, the slow and speedy, and the good and bad drivers.

Variability of Road User Characteristics: The most complex problem while dealing human characteristics is its variability. The human characteristics like ability to react to a situation, vision and hearing, and other physical and psychological factors vary from person to person and depend on age, fatigue, nature of stimuli, presence of drugs/alcohol etc. The influence of all these factors and the corresponding variability cannot be accounted when a facility is designed. So a standardized value is often used as the design value. The percentile value of different characteristics is taken as a standard. It represents a characteristic that 85 per percent of the population can meet or exceed. For example if we say that the percentile value of walking speed is about 2 m/s, it means that 85 per cent of people has walking speed faster than 2 m/s. The variability is thus fixed by selecting proper 85th percentile values of the characteristics.

Critical characteristic of Road Users: The road user characteristics can be of two main types, some of them are quantifiable like reaction time, visual acuity etc. while some others are less quantifiable like the psychological factors, physical strength, fatigue, and dexterity.



Visual Reception

The receipt of stimuli by the eye is the most important source of information for both the driver and the pedestrian. The principal characteristics of the eye are visual acuity, peripheral vision, color vision, glare vision and recovery, and depth perception.

Visual Acuity- Visual acuity is the ability to see fine details of an object. Two types of visual acuity are of importance in traffic and highway emergencies: Static and dynamic visual acuity.

Static acuity- The driver's ability to identify an object when both the object and the driver are stationary depends on his or her static acuity.

Dynamic visual acuity- The driver's ability to clearly detect relatively moving objects, not necessarily in his or her direct line of vision, depends on the driver's dynamic visual acuity.

Peripheral Vision- Peripheral vision is the ability of people to see objects beyond the cone of clearest vision. Although objects can be seen within this zone, details and color is not clear.

Color Vision- Color vision is the ability to differentiate one color from another, but deficiency in this ability, usually referred to as color blindness, is not of great significance in highway driving because other ways of recognizing traffic information devices can compensate for it.

Glare Vision and Recovery- There are two types of glare vision: direct and specular.

Direct glare- occurs when relatively bright light appears in the individual's field of vision;

Specular glare- occurs when the image reflected by the relatively bright light appears in the field of vision.

Depth Perception- Depth perception affects the ability of a person to estimate speed and distance. It is particularly important on two-lane highways during passing maneuvers, when head-on accidents may result from a lack of proper judgment of speed and distance. The ability of the human eye to differentiate between objects is fundamental to this phenomenon.

It should be noted, however, that the human eye is not very good at estimating absolute values of speed, distance, size, and acceleration. This is why traffic control devices are standard in size, shape, and color. Standardization not only aids in distance estimation but also helps the color-blind driver to identify signs.

Hearing Perception

Hearing is required for detecting sounds, but lack of hearing acuity can be compensated by usage of hearing aids. Lot of experiments was carried out to test the drive vigilance which is the ability of a driver to discern environmental signs over a prolonged period. The results showed that the drivers who did not undergo any type of fatiguing conditions performed significantly better than those who were subjected to fatiguing conditions. But the mental fatigue is more dangerous than skill fatigue.

Walking Characteristics of Pedestrians

Transportation planning and design will not be complete if the discussion is limited to drivers and vehicular passengers. The most prevalent of the road users are the pedestrians. Pedestrian traffic along footpaths, sidewalks, crosswalks, safety zones, islands, and over and under passes should be considered.

On an average, the pedestrian walking speed can be taken between 1.5 m/sec to 2 m/sec. But the influence of physical, mental, and emotional factors need to be considered. Parking spaces and facilities like signals, bus stops, and over and under passes are to be located and designed according to the maximum distance to which a user will be willing to walk.

Reaction time

The road user is subjected to a series of stimuli both expected and unexpected. The time taken to perform an action according to the stimulus involves a series of stages like:

Perception: Perception is the process of perceiving the sensations received through the sense organs, nerves and brains. It is actually the recognitions that a stimulus on which a reaction is to happen exists.

Intellection: Intellection involves the identification and understanding of stimuli.

Emotion: This stage involves the judgment of the appropriate response to be made on the stimuli like to stop, pass, move laterally etc.

Volition or Reaction: Volition is the execution of the decision which is the result of physical actions of the driver.

But apart from the above time, the vehicle itself traveling at initial speed would require some more time to stop. That is, the vehicle traveling with initial speed will travel for a distance, where, is the above said PIEV time. Again, the vehicle would travel some distance after the brake is applied.

Two of the important constituents of transportation system are drivers and users/passengers. Understanding of certain human characteristics like perception - reaction time and visual acuity and their variability are to be considered by Traffic Engineer. Because of the variability in characteristics, the percentile values of the human characteristics are fixed as standards for design of traffic facilities.

Vehicle Characteristics

Characteristics of vehicles are the criteria for the geometric design of highways. Since nearly all highways carry both passenger-automobile and truck traffic, it is essential that design criteria take into account the characteristics of different types of vehicles. A thorough knowledge of these characteristics will aid the highway and/or traffic engineer in designing highways and traffic-control systems that allow the safe and smooth operation of a moving vehicle, particularly during the basic maneuvers of passing, stopping, and turning. Therefore, designing a highway involves the selection of a design vehicle, whose characteristics will encompass those of nearly all vehicles expected to use the highway. The characteristics of the design vehicle are then used to determine criteria for geometric design, intersection design, and sight-distance requirements

Vehicle Characteristics

- Characteristics of vehicles are the criteria for the geometric design of highways
- It is essential that design criteria take into account the characteristics of different types of vehicles
- Designing a highway involves the selection of a design vehicle, whose characteristics will encompass those of nearly all vehicles expected to use the highway.
- The characteristics of the design vehicle are then used to determine criteria for geometric design, intersection design, and sight-distance requirements.
- The axle weights of the vehicles expected on the highway are important when pavement depths and maximum grades are being determined.

Three types of characteristics are considered:

- Static -weight and size of vehicle
- Kinematic-motion of vehicle without the force that cause motion.
- Dynamic (resistance of air, grade, curve and rolling)-motion of vehicle with the force that cause it

Static characteristics of vehicle include:

- Size of the design vehicle – to determine several physical components of the highway (e.g. lane and shoulder width).
- Weights of the vehicles – to determine pavement depths and maximum grades.

Road Characteristics

The characteristics of the highway more direct related to the characteristics of the driver and the vehicle are:

- Stopping- avoid restriction (object, vertical curve, ...)
- Passing – to maneuver easily without colliding
- Stopping Sight Distance (SSD) - is the minimum sight distance required for a driver to stop a vehicle after seeing an object in the vehicle's path without hitting that object.
- Passing Sight Distance (PSD) - is the minimum sight distance required on a two-lane, two-way highway that will permit a driver to complete a passing maneuver without colliding with an opposing vehicle and without cutting off the passed vehicle.

Road Surface

The type of pavement is determined by the volume and composition of traffic, the availability of materials, and available funds. Some of the factors relating to road surface like road roughness, tire wear, tractive resistance, noise, light reflection, electrostatic properties etc. should be given special attention in the design, construction and maintenance of highways for their safe and economical operation.

Unfortunately, it is impossible to build road surface which will provide the best possible performance for all these conditions. For heavy traffic volumes, a smooth riding surface with good all-weather anti skid properties is desirable. The surface should be chosen to retain these qualities so that maintenance cost and interference to traffic operations are kept to a minimum.

Lighting

Illumination is used to illuminate the physical features of the road way and to aid in the driving task. A luminary is a complete lighting device that distributes light into patterns much as a garden hose nozzle distributes water. Proper distribution of the light flux from luminaries is one of the essential factors in efficient roadway lighting. It is important that roadway lighting be planned on the basis of much traffic information such as night vehicular traffic, pedestrian volumes and accident experience.

Roughness

This is one of the main factors that an engineer should give importance during the design, construction, and maintenance of a highway system. Drivers tend to seek smoother surface when given a choice. On four-lane highways where the texture of the surface of the inner -lane is rougher than that of the outside lane, passing vehicles tend to return to the outside lane after execution of the passing maneuver. Shoulders or even speed-change lanes may be deliberately roughened as a means of delineation.

Pavement Colors

When the pavements are light colored (for example, cement concrete pavements) there is better visibility during day time whereas during night dark colored pavements like bituminous pavements providing more visibility. Contrasting pavements may be used to indicate preferential use of traffic lanes. A driver tends to follow the same pavement color having driven some distance on a light or dark surface; he expects to remain on a surface of that same color until he arrives a major junction point.

Night visibility

Since most accidents occur at night because of reduced visibility, the traffic designer must strive to improve nighttime visibility in every way he can. An important factor is the amount of light which is reflected by the road surface to the drivers' eyes. Glare caused by the reflection of oncoming vehicles is negligible on a dry pavement but is an important factor when the pavement is wet.

Geometric Aspects

The roadway elements such as pavement slope, gradient, right of way etc affect transportation in various ways. Central portion of the pavement is slightly raised and is sloped to either side so as to prevent the ponding of water on the road surface. This will deteriorate the riding quality since the pavement will be subjected to many failures like potholes etc. Minimum lane width should be provided to reduce the chances of accidents. Also the speed of the vehicles will be reduced and time consumed to reach the destination will also be more. Right of way width should be properly provided. If the right of way width becomes less, future expansion will become difficult and the development of that area will be adversely affected. One important other road element is the gradient. It reduces the tractive effort of large vehicles.