

A Transportation Modeling Primer

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Introduction:

Urban transportation planning can appear to be a complex and bewildering process when first encountered. This primer is intended to explain how the process works, the assumptions made and the steps that are used in urban transportation planning. This is done in order to help more people understand the process and its implications and to help people to interpret and comment on its results. This primer is divided into two sections, an overview of transportation planning in general - the what, why, who and how of transportation planning and a more specific description of the actual models used to forecast future travel. Since the basic purpose of transportation planning is to answer questions about future travel, the primer will use a question and answer format to explain how transportation planning takes place.

The General Process:

What is transportation planning?

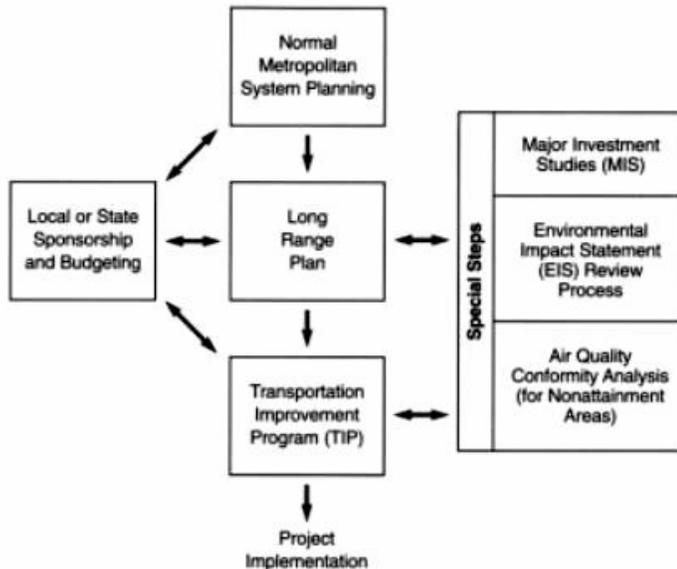
Transportation planning is a process that develops information to help make decisions on the future development and management of transportation systems, especially in urban areas. It involves the determination of the need for new or expanded highways, transit systems, freight facilities, and transportation terminals, their location, their capacity and the management of their demand. Typically transportation planning involves a forecast of travel patterns 15 to 25 years into the future with an aim to develop a future transportation system that will work effectively at that time.

Why is transportation planning necessary?

Transportation can have significant effects on mobility, economic development, environmental quality, government finance and the quality of life. Wise planning is 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 required by federal and state law in order to receive most types of federal, state and local funding for transportation projects. Significant transportation projects require a long lead time for their design and construction. Furthermore they can have major effects on future land use patterns which need to be assessed.

What is the legal basis for transportation planning?

Transportation planning is required in the United States as a condition to receive federal transportation funds for larger urban areas. The first requirements for urban transportation planning were enacted in legislation passed on 1962. These have been expanded and modified in subsequent legislation, such as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Transportation Efficiency Act for the 21st Century (TEA-21 and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Under this legislation regulations for transportation planning have been issued that have many requirements, especially to deal with air quality issues, multimodal planning, better management of existing systems, expanded public input and financial requirements. Generally they have led to a greater role for transportation planning in urban areas, especially with a need to consider a wider range of alternatives and consequences of transportation.



Who does transportation planning?

Regional transportation planning is a cooperative effort between different units of local, state and federal government with opportunities for citizen input and participation. Normally, an agency designated as the metropolitan planning organization (MPO) in a region conducts the project. This is usually an agency such as a council of governments,

regional planning commission. In some cases it could be a state department of transportation or a county government. The MPO works cooperatively with local government and units of state government such as the state departments of transportation and natural resources in preparing the plan. State and local government might also engage in transportation planning for specific issues that relate to their jurisdictions. Citizen participation needs to be an important part of the planning process. This should begin early and continue throughout the process. This process is used to help elected officials to make decisions for the future development of their transportation systems.

Who are the transportation planners?

Transportation planners are professional who usually combine the techniques used by a traditional (town) planner with the methods and skills of a traffic engineer. Transportation planners work in an area between these two professions, as well as between engineers and administrators. Typically transportation planners have an educational background in transportation planning through a master's degree in engineering, although degrees in urban planning, geography or other areas with graduate work specializing in transportation or planning are possible.

What types of problems involve transportation planning?

Transportation planning is primarily focused on developing long range (15-30 years) urban 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
- Urban form/transportation coordination
- Fuel reduction measures
- Air quality measures
- Safety measures
- Economic development/redevelopment activity
- Consideration of the use of pricing and tolls
- Freight movement issues
- Recreational/tourism access
- Environmental compliance issues
- Public participation process
- Permit documentation
- Improvements in intermodal linkages between modes

What alternatives are considered?

Transportation planning should consider a broad range of alternatives. There can be alternative modes of transportation, alternative locations of different systems, alternative levels of capacity or alternative policies. This would include the following:

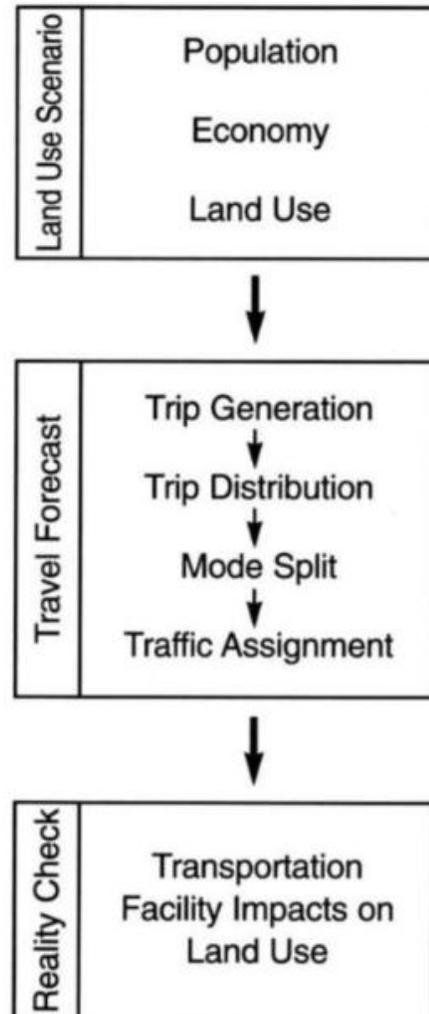
- **Travel demand management policies:** Transportation services require a broad range of policies to function. Travel demand management involves efforts to make the current system more efficient and to use techniques to reduce demand during critical periods. This is not unlike programs that utility companies have used to promote energy conservation among their customers. Some of the techniques that could be used include: use of priority techniques for high occupancy vehicles, parking regulation, efforts to shift when travel occurs, promotion of telecommuting, transit service improvements, use of pricing techniques, etc.
- **A no build alternative:** This is basically the status quo with continuing maintenance and operation of the current transportation system. It may include substantial efforts to improve the efficiency and utilization of existing transportation systems. These are considered as an alternative to building new systems.
- **Land use alternatives:** Different land use patterns and policies can be used to affect travel demand and to affect the use of natural resources. These could include concentrated urban development patterns, increased suburban growth or some combination.
- **Modal alternatives:** Different modes of transportation — highway, transit, ride sharing, freight etc. — should be considered. Generally transportation plans are concerned with picking the best combination of modes that deals with a particular problem. Single mode plans — highway plan, transit plan, etc. — should not be done without considering other modes. All options should be considered to develop a balanced transportation system.
- **Capacity Changes:** The capacity of each mode (number of lanes, how often transit vehicles operate) can be varied in different alternatives. Highway capacity depends on many factors besides the number of lanes such as intersection characteristics, traffic signal systems and the characteristics of access along the highway.
- **Alternative locations:** Proper location of transit and highway facilities is an important part of their success. Facilities should be located to serve travel markets and to facilitate land development patterns that are good for the community.

What are the steps for transportation planning?

Transportation planning goes through a basic sequence of steps. Several can take place at once and it is not unusual to repeat some of the steps several times. The basic steps in the transportation planning process are the following:

- **Problem definition:** What are the key transportation, economic and land use issues and problems facing the community? This step may also involve definition of the size of an area to be studied, determination of the scope of the study and the establishment of a committee structure to oversee the planning process.
- **Define goals, objectives and criteria:**
A consensus should be developed by elected officials and citizens about the future of the community and its transportation system. Goals are developed for the quality of transportation service, environmental impacts and costs. These will likely be in conflict. A good planning effort will identify the trade-offs between these factors among alternatives in a clear, concise way to help make decisions.
- **Data collection:** Data must be compiled about the present status of the transportation system and its use. This could include traffic data, transit ridership statistics, census information and interviews of households about their travel patterns. Data are also gathered on land use, development trends, environmental factors, and financial resources. This will assist in problem definition and in developing methods to forecast future travel patterns. Good data are essential to the planning process. The statement 'garbage in/garbage out' applies in transportation planning. Without good data, the results of the planning process have little real meaning and can lead to the wrong projects selected and a wrong direction for the region.

Figure 2.
The Overall Forecasting Process



- **Forecasts:** Data from existing travel is used to make forecasts of future travel using travel demand models. This requires forecasts of future population, land use and economic conditions as well as understanding of how people make travel choices. Forecasting requires large amounts of data and is done under many assumptions. The basic assumptions and procedures of travel demand forecasting are given in section II of the primer.
- **Develop alternatives:** Forecasts are used to determine the performance of alternative future land use and transportation systems. Alternatives normally include different land use and transportation patterns with different mixtures of highway and transit services and facilities. Since land use affects travel and travel affects land use, both must be considered.
- **Evaluation:** Results of forecasts are used to compare the performance of alternatives in meeting goals, objectives and criteria. This information may be extensively discussed by interested citizens, elected officials, different government agencies and the private sector. Ultimately decisions are made by appropriate elected or appointed officials and groups.
- **Implementation plan:** Once decisions are made, plans should be further developed and refined for implementation. This may include more detailed analysis for design and evaluation following a similar process as above.

How long does it take?

Transportation planning is a continuous process. The length of time for an individual planning effort depends on the size of the problem, the availability of data, opportunities for citizen input and planning requirements. Development of a major update of a regional transportation plan can take several years or more depending on the need to collect new data. Attempts to rush the process usually lead to later delays to correct problems and bad assumptions at later phases.

How accurate are the results?

Transportation planning involves complex forecasts of human behavior and economic conditions into the next ten to thirty years. Many assumptions are needed to develop these forecasts and it is unlikely that all of these assumptions will prove to be correct. Transportation forecasts can give reasonable results if they are based on good data and reasonable assumptions. It is important that the assumptions behind a planning effort be clearly stated and that a reasonable range of future conditions be examined. The differences between alternatives are likely to be more accurate than the absolute values. These differences should be the basis for decision making.

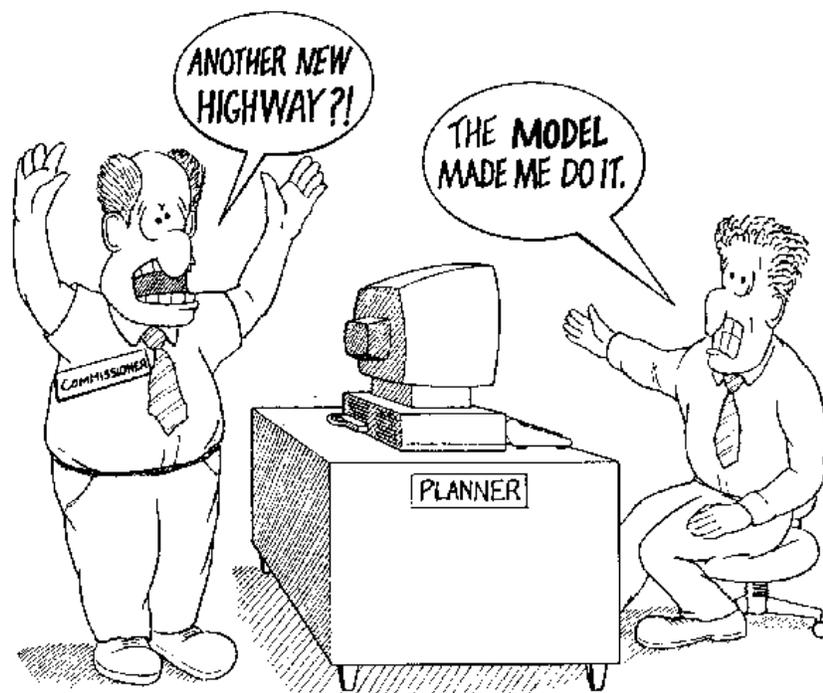
What happens after a regional plan is complete?

Regional plans should be formally adopted by local and state governments to guide their programs. The regional plan then provides a basis for the preparation of a Transportation Improvement Program (TIP) which lists the specific projects to be implemented for the next six years. Once that a regional transportation plan is complete further efforts are needed to refine and implement the plan. Corridor studies are undertaken to refine the location of major new facilities. This may involve a major investment analysis which could also include an environmental impact statement. Other studies that are needed may be the development of transit operational plans, preliminary engineering studies, and jurisdictional studies. These studies may be done by the MPO or by state or local government depending on the problem to be addressed. Regional transportation plans should be updated periodically, at least once every ten years.

Forecasting Models

Transportation planning uses the term 'models' extensively. The term models is used to refer to a series of mathematical equations that are used to represent how people travel. Travel demand occurs as a result of thousands of individual travelers making individual decisions on how, where and when to travel. These decisions are affected by many factors such as family situations, characteristics of the person making the trip, and the choices (destination, route and mode) available for the trip.

Mathematical relationships are used to represent (model) human behavior in making these choices. Models require a series of assumptions in order to work and are limited by the data available to make forecasts. The terms in the model are set (calibrated) to match existing data. Normally, these relationships are assumed to be valid and to remain constant in the future.



Models are important because future transportation plans are based on what the models say will happen rather than on what individual people may think will happen. Models

provide forecasts only for those factors and alternatives which are explicitly included in the equations of the models. If the models are not sensitive to certain policies or programs (i.e. policy sensitive), they will not affect the process or results. A consequence of this may be that a conclusion could be drawn that such policies are ineffective. This would be wrong because the models were not capable of testing the policy. For example, travel forecasting models usually exclude pedestrian and bicycle trips. Plans that include bicycle or pedestrian system improvements will not show any impact in the conventional modeling procedure since the models typically ignore these types of trips. It is not correct to conclude that pedestrian or bicycle improvements are ineffective. The actual impact is unknown

Models are used in a sequence of steps to answer a series of questions about future travel patterns. These basic questions asked in each modeling step are as follows:

1. What will our community look like in the future?
 - A. How many people will there be? (population forecasts)
 - B. What will they be doing? (economic forecasts)
 - C. Where will activities take place? (land use)
2. What are the travel patterns in the future?
 - A. How many trips will be made? (trip generation)
 - B. Where will the trips be? (trip distribution)
 - C. What modes will be used? (mode split)
 - D. What routes will be used? (traffic assignment)
 - E. What will be the effects of this travel? (impact analysis)

Population, Economic and Land Use Forecasts

Before forecasts are made of travel, it is necessary to determine how the community will look in the future. Transportation is directly linked to land use. Trips are assumed to follow future land use patterns. If land use is changed, there should be a change in travel.

How many people will there be? (population forecasts)

Future population forecasts are based on assumptions about birth rates, death rates and the rate of migration into or out of the study area. The forecasting process uses current information about the ages of the population and forecasts ahead by the calculation of the number of births, deaths and migrants added to the region in each year of the future. These rates are assumed to remain constant or to change in a specified way. These rates have changed substantially over the past 30 years so often several forecasts are made under different assumptions. A valuable output of this step is a forecast that indicates the age structure of the future population.

What activities will people engage in? (economic forecasts)

Forecasts need to be made of future employment levels as these are the basis for forecasts of work travel, shopping, etc. Economic forecasts have to be done in conjunction with the population forecasts since the two are highly interrelated. Employment often grows

because the populations grows, but migration rates into and out of the community depend upon the growth of the economy. Assumptions have to be made of the ability of a region to generate new basic employment and to hold onto its existing basic employment. These are based on past trends and judgments of future local economic conditions. Total employment is found by applying an economic multiplier to basic employment.

Where will these activities occur? (land use)

Population and economic growth has to be distributed over different locations in order to do travel forecasts. It is necessary to know where people will live, work shop and go to school in the future in order to get estimates of future trip making. Land use plans can be developed to continue existing trends or to change trends if it is felt that current trends are undesirable. Land use planning can be done either through a judgment technique or through a modeling process. The judgment techniques involves the allocation of growth in steps to smaller and smaller geographic areas considering past trends, availability of open land for development and local plans and zoning ordinances. It is sometimes done with the use of an expert panel that includes local planners, developers, financiers and real estate brokers. An allocation is made following rules and guidelines as set down as planning standards and land use rates. Alternative plans can be developed to reflect different assumptions. For example land use plans could be developed to continue current trends, to reduce urban sprawl, to concentrate development along major corridors or in satellite communities or to avoid environmentally sensitive areas.

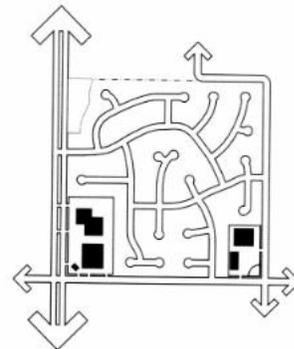
A modeling approach to land use planning can be used to determine the impact of transportation facilities on growth patterns. The locations of basic employment are set by hand and the model locates other employment and residential land use in relationship to the basic employment. Allocations are determined based on the availability of open land and upon the accessibility that is provided from a proposed transportation plan. The modeling process finds a balance between supply and demand for both land use and transportation. This approach is relatively new and has only been used in limited locations.

Assumptions and limitations: some of the assumptions used to do land use plans are

**Figure 11.
Traditional vs. Sprawl-type
Street Patterns**



Traditional "grid" street patterns shorten and reduce auto trips as well as intersection congestion.



"Hierarchical" street-patterns with long, winding collectors, and cul de sacs provide fewer route options and make walking and bicycling difficult.

the following.

1. No feedback with transportation plans. Land use plans are developed before transportation plans and assumed to not change as a result of the transportation improvements.
2. Current development is fixed. Land use plans generally only deal with new growth and assume that current development will be unchanged. Effects of redevelopment programs, changing use of neighborhoods and so forth are normally not considered.
3. Mixed use benefits are not considered. Land use patterns that facilitate walking and non automobile travel are not easily dealt with in the model

Travel Demand Modeling

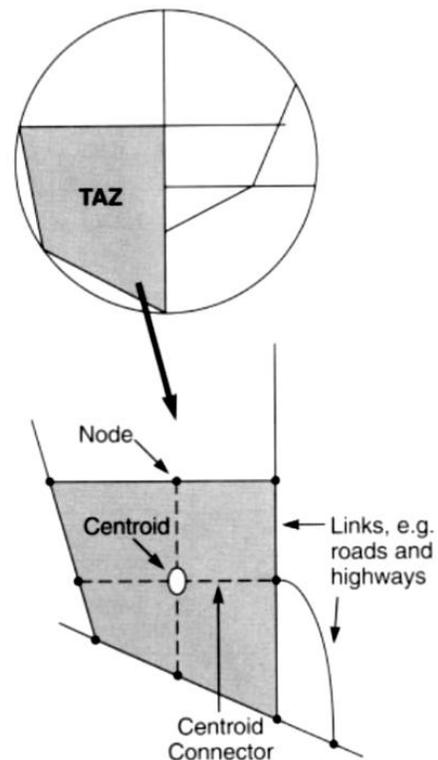
The travel forecasting process is at the heart of urban transportation planning. This process is used to estimate the number of trips that will be made on a transportation systems alternative at some future date. It involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given system of highways, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react a particular transportation alternative.

Travel demand modeling was first developed in the late 1950's as a means to do highway planning. As the need to look at other problems and issues arose, the modeling process has been modified to add additional techniques to deal with these problems. The general steps in the process are used to answer a series of questions as follows:

How is the city represented for computer analysis? (Zone/Network system)

Travel simulations require that an urban area be represented as a series of small geographic areas called travel analysis zones (TAZs). Zones are characterized by their population, employment and other factors and are the places where trip making decisions are made (trip producers) and the trip need is met (trip attractors). Trip making is assumed to begin at the center of activity in a zone (zone centroid). Trips that are very short, that begin and end in a single zone (intrazonal trips) are usually not directly included in the forecasts. This limits the analysis of pedestrian and bicycle trips in the process. Zones can

Figure 4.
Area map is divided into
Traffic Analysis Zones (TAZs)



be as small as a single block but typically are 1/4 to one mile square in area. A planning study can easily use 500-2000 zones. A large number of zones will increase the accuracy of the forecasts but require more data and computer processing time. Zones tend to be small in areas of high population and larger in more rural areas. Internal zones are those within the study area while external zones are those outside of the study area. The study area should be large enough so that nearly all (over 90%) of the trips begin and end within the study area.

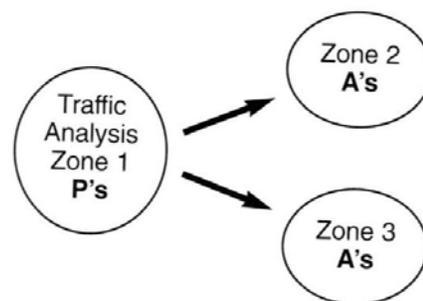
The highway system and transit systems are represented as networks for computer analysis. Networks consist of links to represent segments of highways or transit lines and nodes to represent intersections and other points on the network. Data for links includes travel times on the link, average speeds, capacity, and direction. Node data is more limited to information on which links connect to the node and the location of the node (coordinates). Node data could also include data on intersections to help calculate delay encountered at intersections.

The travel simulation process follows trips as they begin at a trip generation zone, move through a network of links and nodes and end at a trip attracting zone. The simulation process is known as the four step process for the steps of trip generation, trip distribution, mode split and traffic assignment.

How many Trips will there be? (trip generation)

The first step in travel forecasting is trip generation. In this step information from land use, population and economic forecasts are used to estimate how many trips will be made to and from each zone. This is done separately by trip purpose. Some of the trip purposes that could be used are: home based work trips (work trips that begin or end at home), home based shopping trips, home based other trips, school trips, non-home based trips (trips that neither begin or end at home), truck trips and taxi trips. Trips are calculated based on the characteristics of the zones. Trip productions are based on household characteristics such as the number of people in the household and the number of vehicles available. For example a household with four people and two vehicles may be assumed to produce 3.00 work trips per day. Trip attractions are typically based on the level of employment in a zone. For example a zone could be assumed to attract 1.32 home based work trips for every person employed in that zone. Trip generation uses trip rates that are averages for large segments of the study area.

Figure 7.



Assumptions and limitations: Some of the assumptions in trip generation are as follows:

1. Independent decisions. Travel behavior is a complex process where often

decisions of one household member are dependent on others in the household. For example, child care needs may affect how and when people travel to other places. This interdependency for trip making is not considered.

2. Limited trip purposes. With no more than four to eight trip purposes, a simplified trip pattern results. All shopping trips are treated the same whether shopping for groceries or lumber. Home based "other" trip purposes cover a wide variety of purposes - medical, visit friends, banking, etc. which are influenced by a wider variety of factors than those used in the modeling process.

3. Combinations of trips are ignored. Travelers may often combine a variety of purposes into a sequence of trips as they run errands and link together activities. This is called trip chaining and is a complex process. The modeling process treats such trip combinations in a very limited way.

4. Feedback, cause and effect problems. Trip generation models sometimes calculate trips as a function of factors that in turn could depend on how many trips there are. For example shopping trip attractions are found as a function of retail employment, but it could also be argued that the number of retail employees at a shopping center will depend on how many people come there to shop. This 'chicken and egg' problem comes up frequently in travel forecasts and is difficult to avoid. Another example is that trip making depends on auto availability, but it could be also argued that the number of automobiles a household owns would depend upon how active they are in making trips.

Where do the trips go? (Trip distribution)

Trip generation only finds the number of trips that begin or end at a particular zone. The process of trip distribution links the trip ends to form an origin-destination pattern. Trip distribution is used to represent the process of destination choice, i.e. "I need to go shopping but where should I go to meet my shopping needs?". Trip distribution leads to a large increase in the amount of data which needs to be dealt with. Origin-destination tables are very large. For example a 1200 zone study area would have 1,440,000 possible trip combinations in its O-D table for each trip purpose. The most commonly used procedure for trip distribution is called the gravity model. The gravity model takes the trips produced at one zone and distributes to other zones based on the size of the other zones (as measured by their trip attractions) and on the basis of the distance to other zones. A zone with a large number of trip attractions (say a large shopping center) will receive a greater number of distributed trips than one with a small trip attractions (a small shopping center). Distance to possible destinations is the other factor used in the gravity model. The number of trips to a given destination decreases with the distance to the destination (it is inversely proportional). For example, you would expect more trips to a nearby shopping center than one further away. The distance effect is found through a calibration process which gives travel times to destinations from the model similar to that found from field data. "Distance" can be

measured several ways. The simplest way this is done is to use auto travel times between zones is as the measurement of distance. Other ways might be to use a combination of auto travel time and costs such as tolls as the measurement of distance. Still another way is to use a combination of transit and auto times and costs (composite cost). This method involves using a percentage of the auto time and cost and a percentage of the transit time/cost. Because of calculation procedures, the model must be used a number of times (iterated) in order to balance the trip numbers to match the initial values.

Assumptions and limitations: Some of the assumptions in trip distribution are as follows:

1. Constant trip times: In order for the model to be used as a forecasting tool it must be assumed that the average lengths of trips that occur now will remain constant in the future. Since trip lengths are measured by travel time this means that improvements in the transportation system that reduce travel times are assumed to be balanced by a further separation of origins and destinations. Thus faster speeds on the network will result in longer trips, measured by distance.

2. Use of automobile travel times to represent 'distance'. The gravity model requires a measurement of the distance between zones. This is almost always based on automobile travel times rather than transit travel times and leads to a wider distribution of trips (they are spread out over a wider radius of places) than if transit times were used. This process limits the ability to represent travel patterns of households that locate on a transit route and travel to points along that route.

3. Limited effect of social-economic-cultural factors. The gravity model distributes trips only on the basis of size of the trip ends (trip productions, trip attractions) and travel times between the trip ends. Thus the model would predict a large number of trips between a high income residential area and a nearby low income employment area or between a Spanish speaking neighborhood and a nearby non-Spanish speaking neighborhood. The actual distribution of trips is affected by the nature of the people and activities that are involved and their socio-economic and cultural characteristics as well as the size and distance factors used in the model. Furthermore, groups of travelers might avoid some areas of the city and favor others based on socio-

Figure 8.
Trip Distribution

	To:		
	1	2	3
From: 1			
2			
3			

Intrazonal trips are not assigned to the road network that connects *interzonal* traffic.

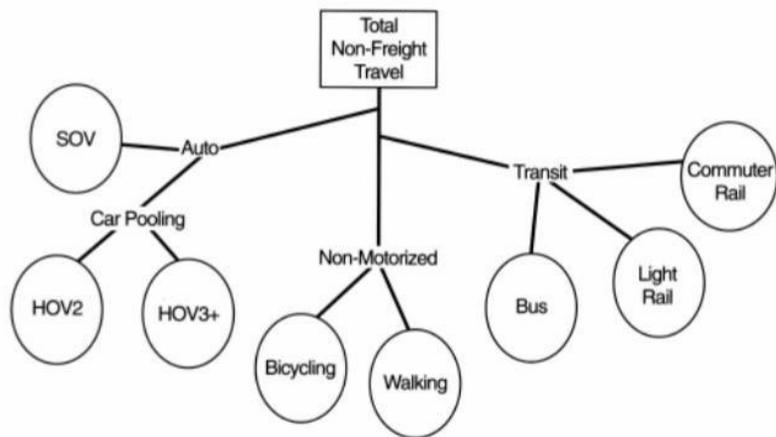
Separate tables are used for each trip purpose.

economic-cultural reasons. Adjustments are sometimes made in the model to account for such factors, but it is difficult since the effects of these factors on travel is difficult to quantify much less to predict how it would change over time.

4. Feedback problems: Travel times are needed to calculate trip distribution; however travel times depend upon the level of congestion on streets in the network. The level of congestion is not known during the trip distribution step since that is found in a later calculation. Normally what is done is that travel times are assumed and checked later. If the assumed values differ from the actual values, they should be modified and the calculations should be redone.

How will people travel? (mode choice, auto occupancy analysis)

Mode choice is one of the most critical parts of the demand modeling process. It is the step where trips between a given origin and destination are split into trips using transit, trips by car pool or as automobile passengers and trips by automobile drivers. Calculations are conducted that compare the attractiveness of travel by different modes to determine their relative usage.



All proposals to improve public transit or to change the ease of using the automobile are passed through the mode split/auto occupancy process as part of their assessment and evaluation. It is important to understand what factors are used and how the process is conducted in order to plan, design and implement new systems of transportation.

Mode split is done by a comparison of the "disutility" of travel between two points for the different modes that are available. Disutility is a term used to represent a combination of the travel time, cost and convenience of a mode between an origin and a destination. It is found by placing multipliers (weights) on these factors and adding them together. Travel time is divided into two components: in-vehicle time to represent the time when a traveler is actually in a vehicle and moving and out-of-vehicle time which includes time spend traveling which occurs outside of the vehicle (time to walk to and from transit stops, waiting time, transfer time). Out-of-vehicle time is used to represent "convenience" and is typically multiplied by a factor of 2.0 to 7.0 to give it greater importance in the calculations. This is because travelers do not like to wait or walk long distances to their destinations. The size of the multiplier will be different depending upon the purpose of the trip. Travel cost is multiplied by a factor to represent the value that travelers place on time savings for a particular trip purpose. For transit trips, the cost of the trip is given as the average transit

fare for that trip while for auto trips cost is found by adding the parking cost to the length of the trip as multiplied by a cost per mile. Auto cost is based on a "perceived" cost per mile (on the order of 5-10 cents/mile) which only includes fuel and oil costs and does not include ownership, insurance, maintenance and other fixed costs (total costs of automobile travel are much higher). Disutility calculations may also contain a "mode bias factor" which is used to represent other characteristics or travel modes which may influence the choice of mode (such as a difference in comfort between transit and automobiles). The mode bias factor is used as a constant in the analysis and is found by attempt to fit the model to actual travel behavior data. The disutility equations do not normally recognize differences within travel modes. A bus system and a rail system with the same time and cost characteristics will have the disutility values. It is possible that mode bias factors could be different for different technologies, to represent a preference for light rail over bus, but this must be specifically included.

Once disutilities are known for the various choices between an origin and a destination, the trips are split among various modes based on the relative differences between disutilities. A large advantage will mean a high percentage for that mode. Split are calculated to match splits found from actual traveler data. Sometimes a fixed percentage is used for the minimum transit use (percent captive users) to represent travelers who have no automobile available or are unable to use an automobile for their trip.

Mode split and auto occupancy analysis can be two separate steps or can be combined into a single step, depending on how a forecasting process is set up. In the simplest application a highway/transit split is made first which is followed by a split of automobile trips into auto driver and auto passenger trips. More complex analysis splits trips into multiple categories (single occupant auto, two person car pool, 3-5 person car pool, van pool, local bus, express bus, etc.). Auto occupancy analysis is often a highly simplified process which uses fixed auto occupancy rates for a given trip purpose or for given household size and auto ownership categories. This means that the forecasts of car pooling are insensitive to changes in the cost of travel, the cost of parking, the presence of special programs to promote car pooling, etc.

Assumptions: Some of the assumptions in mode choice analysis are as follows:

1. Choice only affected by time and cost characteristics. An important thing to understand about mode choice analysis is



Most auto occupancy models are insensitive to carpooling incentives, such as employer TDM programs.

that shifts mode usage would only be predicted to occur only if there are changes in the characteristics of the modes, i.e. there must be a change in the in-vehicle time, out-of-vehicle time or cost of the automobile or transit for the model to predict changes in demand. Thus if one adds a lot of amenities to transit or substitutes a light rail transit system for a bus system without changes in travel times or costs, the model would not show any difference in demand, unless a 'mode specific constant' were used. People are assumed to make travel choices based only on the factors in the model. Factors not in the model will have no effect on results predicted by the models.

2. Omitted factors. Factors which are not included in the model such as crime, safety, security, etc. concerns have no effect. They are assumed to be included as a result of the calibration process. However, if an alternative has different characteristics for some of the omitted factors, no change will be predicted by the model. Such effects need to be done by hand and require considerable skill and assumptions.

3. Access times are simplified. No consideration is given to the ease of walking in a community and the characteristics of a waiting facility in the choice process. Strategies to improve local access to transit or the quality of a place to wait do not have an effect on the models.

4. Time and cost can be added. The disutility calculations assume that a traveler considers time and cost separately and mentally adds them up to determine their best choice for a trip.

5. Constant weights. The importance of time cost and convenience is assumed to remain constant for a given trip purpose. Trip purpose categories are very broad (i.e. 'shop', 'other'). Differences within these categories of the importance of time and cost are ignored.

What routes will be used? (traffic assignment)

Once trips have been split into highway and transit trips, the specific path that they use to travel from their origin to their destination must be found. These trips are then assigned to that path in the step called traffic assignment. Traffic assignment is the most time consuming and data intensive step in the process and is done differently for highway trips and transit trips. The process first involves the calculation of the shortest path from each origin to all destinations (usually the minimum time path is used). Trips for each O-D pair are then assigned to the links in the minimum path and the trips are added up for each link. The assigned trip volume is then compared to the capacity of the link to see if it is congested. If a link is congested the speed on the link needs to be reduced to result in a larger travel time on that link. When speeds and travel times are changed the shortest path may change. Hence the whole process must be repeated many times (iterated) until there is an equilibrium between travel demand and travel supply. Trips on congested links will be shifted to uncongested links until this equilibrium, condition occurs.

There are a variety of ways in which the calculations are done to reach network equilibrium, in order to keep the computer time to a minimum. One way to get a feel for the accuracy of the models is to look at the resulting speeds on the network. These should be realistic after equilibrium.

Transit trip assignment is done in a similar way except that transit headways are adjusted rather than travel times. Transit headways (minutes between vehicles) affect the capacity of a transit route. Low headways mean that there is more frequent service and a greater number of vehicles. Transit supply and demand are also recalculated to reach an equilibrium between supply and demand.

It is important to understand the concept of equilibrium. If a highway or transit route is congested during the peak hour, its excess trips will be shifted to alternative routes. If the alternative routes are also congested the final results will show congestion over a wide part of the network. In the real world this congestion will eventually dissipate over time.

Another important step in assignment is the time of day analysis. Daily trip patterns need to be converted to peak time period traffic. A key assumption needed is the portion of daily travel that occurs during the peak period. This is normally used as a constant and conventional travel models have very limited capability to describe how travelers will shift their trips to less congested times of the day.

Assumptions and limitations: Some of the assumptions in traffic assignment are as follows:

1. Delay occurs on links. Most traffic assignment procedures assume that delay occurs on the links rather than at intersections. This is a good assumption for through roads and freeways but not for highways with extensive signalized intersections. Intersections involve highly complex movements and signal systems. Intersections are highly simplified in traffic if the assignment process does not modify control systems in reaching an equilibrium. Use of sophisticated traffic signal systems or enhanced network control of traffic cannot be analyzed with conventional traffic assignment procedures.
2. Travel only occurs on the network. It is assumed that all trips begin and end at a single point in a zone (the centroids) and occurs only on the links included in the network. Not all roads streets are included in the network nor all possible trip beginning and end points included. The zone/network system is a simplification of reality.
3. Capacities are simplified. To determine the capacity of roadways and transit systems requires a complex process of calculations that consider many factors. In most travel forecasts this is greatly simplified. Capacity is found based only on the number of lanes of a roadway and its type (freeway or arterial). Most travel demand models used for large transportation planning

studies do not consider intersection capacity and the use of sophisticated traffic control systems in their calculations.

4. Time of day variations. Traffic varies considerably throughout the day and during the week. The travel demand forecasts are made on a daily basis for a typical weekday and then converted to peak hour conditions. Daily trips are multiplied by a "hour adjustment factor", for example 10%, to convert them to peak hour trips. The number assumed for this factor is very critical. A small variation, say plus or minus one percent, will make a large difference in the level of congestion that would be forecast on a network. Most models are unable to represent how travelers often cope with congestion by changing the time they make their trips.

5. Emphasis on peak hour travel. As described above, forecasts are done for the peak hour. A forecast for the peak hour of the day does not provide any information on what is happening the other 23 hours of the day. The duration of congestion beyond the peak hour is not determined. In addition travel forecasts are made for a 'average weekday'. Variations in travel by time of year or day of the week are usually not considered.

What are the effects of the travel?

Equilibrium traffic assignment results indicate the amount of travel to be expected on each link in the network at some future date with a given transportation system. These link traffic volumes are the basic information that is used to determine a wide variety of effects of travel for plan evaluation. Some of the key effects are congestion, accidents, travel times, air pollution emissions. Each of these effects needs to be estimated through further calculations. Typically these are done by applying crash or emission rates by highway type and speed. Assumptions need to be made of the speed and characteristics of travel for non-peak hours of the day and for variation in travel by time of the year.

	Traffic Engineering	Transit (Planning)	Transportation Planning
Time frame for Study and Implementation	Short (to medium)	Short (to medium)	Medium to long-term
Modes Studies	Mainly motor traffic	Almost exclusively public transit vehicles	All
Evaluation Criteria	Experience, safety	Mainly economic	Mainly economic
Use of Existing Infrastructure	Maximum	Significant	Often Minor, major consideration of new infrastructure
Consideration of Modal Interaction	Minor	Of importance	Of paramount importance
Typical Study Costs	Small	Small	Large
Disciplines Involved	Few	Few	Many
Type and number of issues addressed	Relatively few and narrow	Relatively few and narrow	Many and broad
Level of Study Detail	Often great	Usually large	Usually more "broad-brushed"
Consideration given to Land Use	Small	Medium	Extensive

How can models be improved?

Transportation models are being called upon to provide forecasts for a complex set of problems that in some cases can go beyond their capabilities and original purpose. Travel demand management, employer based trip reduction programs, pedestrian and bicycle programs, time of day shifts, changing age structure of the population and land use policies may not be handled well in the process.

Transportation travel forecasting models use packaged computer programs which have limitations on how easily they can be changed. In some cases the models can be modified to accommodate additional factors or procedures (quick fix) while in other cases major modifications are needed or new software is required. The following are some potential modifications of the models that may help to improve their usefulness.

Better data. All models are based on data about travel patterns and behavior. If this data is out-of-date, incomplete or inaccurate the results will be poor no matter how good the models are. One of the most effective ways of improving model accuracy and value is to have a good basis of recent data that represent all components of the population to use to calibrate the models and to provide for checks of their accuracy. Models need to demonstrate that they provide an accurate picture of current travel before they should be used to forecast future travel.

Improve representation of bicycle and pedestrian travel. Travel by bicycle and by walking is not handled well in conventional travel demand models. Improved methods of dealing with these types of trips are needed. This can be done by incorporation of factors in trip generation models that relate trip making to pedestrian or bicycle amenities. Also methods of mode choice could be expanded to include these types of trips.

Better Auto Occupancy Models. Current auto occupancy procedures tend to be insensitive to a wide range of policies that may lead to more or less carpooling. Auto occupancy procedures need to be sensitive to the cost of parking and costs of travel as well as the number of trips that occur between an origin and destination. Also it may be desirable to treat ride sharing among family members differently than carpooling between persons from different households. Procedures that increase the number of trip purposes to deal with market segments that are likely to share rides could help with this problem.

Better time of day procedures. Levels of congestion in hours other than the peak period are needed to get a better understanding of the nature of congestion as it occurs throughout a day and over time into the future. Methods are needed to represent how travelers choose the time of travel, especially for non-work and non-school trips. Hourly conversion factors need to be looked at very carefully to insure that they represent actual variations in traffic.

Use more trip purposes. Additional trip purposes (market segments) may provide a way to get a better representation of complex household trip patterns and trip chaining. This would also provide trip generation procedures that are

sensitive to more factors that would follow from travel management techniques.

Better representation of access. Land use policies that facilitate transit use or that provide high quality site design with good pedestrian access are not well represented in the transportation models. Improved methods are needed to measure the disutility of the access portion of transit and highway trips. Such methods would involve the calculation of an access index that was sensitive to the ease of access and waiting for transit vehicles in areas that used more transit/pedestrian/bicycle friendly design.

Incorporate costs into trip distribution. Trip distribution models should use a generalized measure of distance that includes costs of travel by different means including parking costs. Such models would then better show the sensitivity of travel patterns to cost changes.

Add Land Use Feedback. It is important to take steps to close the loop of the forecasting process to enable a better representation of the interaction of land use and travel demand. Land use simulation models should be added to the sequence of models to help to determine how a proposed transportation system will lead to land use changes.

Add intersection delays. In an urban traffic network most delay is encountered at traffic signals or stop signs rather than on the roads between intersections. Travel forecasting models should include routines that calculate the delay encountered at intersections. Moreover, intersection signal splits should be treated as a variable that would be modified as the traffic assignment process iterates to reach an equilibrium.