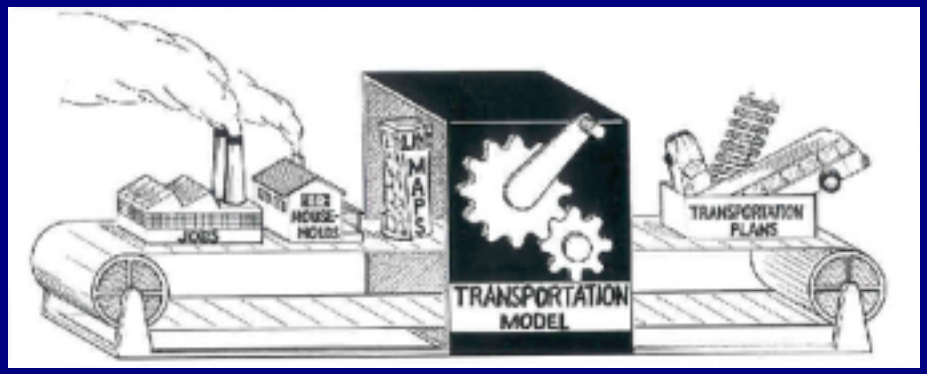
Inside the Blackbox:



Making Transportation Models Work For Livable Communities

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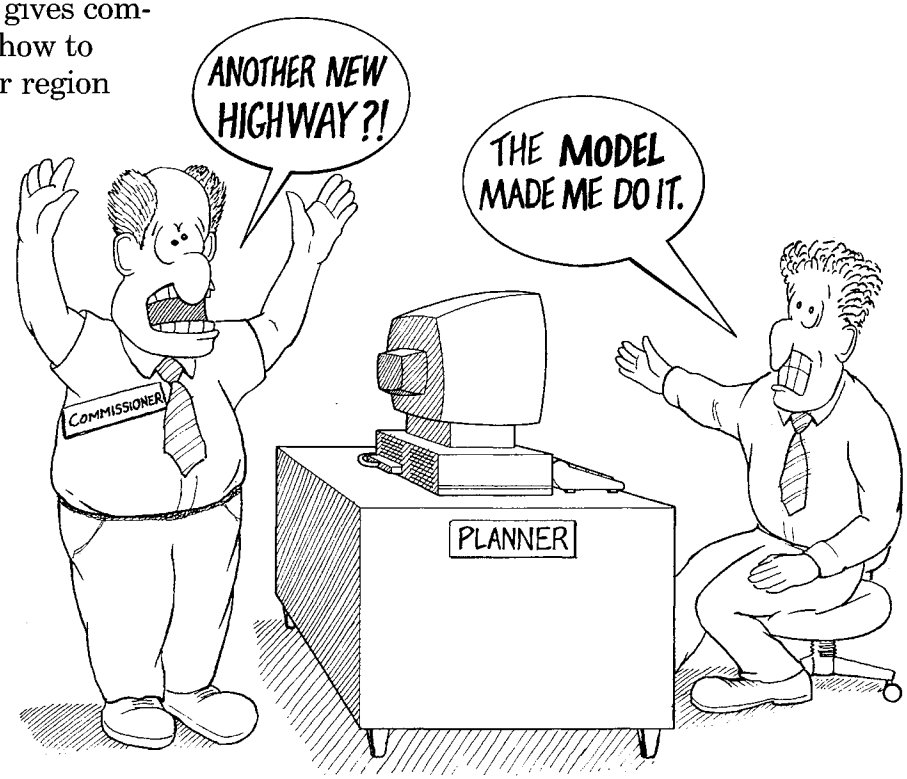
Inside Transportation Planning's Black Box

Introduction: Inside the Black Box

Despite the fact that it plays an extremely important role in transportation planning and budgeting, transportation modeling is viewed by most citizen transportation and planning commissioners and members of the public as a "black box." Somehow, in a fashion apparently knowable only to professional modelers, statistics, maps, and other information go in one side of this box and come out the other side as travel forecasts to become the basis for widening roads or expanding transit systems.

The purpose of this booklet is to look inside the black box and shine some light on the assumptions underlying the urban transportation modeling process and how it works. Moreover, this primer will suggest improvements that can be made to correct some of the typical biases and other problems that can affect the forecasts that modeling produces. Finally, it gives commissioners, planners, and citizens specific suggestions for how to advocate ways to improve the modeling being done in their region so as to ensure greater accuracy and sensitivity to land use and transportation policies designed to promote alternatives to driving.



What is a transportation model?

The term "model" is used to refer to a series of mathematical equations that represent how choices are made when people travel. Travel demand occurs as a result of thousands of individual travelers making 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 of travel) available for the trip. Mathematical relationships are used to represent (to 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.

Travel demand modeling was first developed in the 1950s for highway planning and has only recently been improved and expanded to address transit, pedestrian, land use, and air quality issues. However, because the models were not originally intended to deal with these issues, they may not do so very well.

Before any forecasts are done, the coefficients in the model are estimated or "calibrated" to match existing data. Normally, these relationships are assumed to be valid and to remain constant for a given region for a long time into the future. The modeling explained below applies to the typical urban regional transportation and land use system that usually falls within the jurisdiction of a metropolitan planning organization (MPO). It is a more complex form of modeling than the "corridor studies" used for relatively long and isolated highways or other transportation facilities.

Why are models important?

Models are important because transportation plans and investments are based on the projections models make about future travel. Models are used to estimate the number of trips that will be made for a given land use and transportation system alternative at some future date, usually 15 to 25 years from now. These estimates are the basis for long range transportation plans and are also used in major investment studies (MISs), environmental impact statements (EISs), and in setting priorities for investments, including local and state Transportation Improvement Programs (TIPs). (See Glossary at end of booklet for acronyms and the definitions of other terms.) In short, these numbers provide the numbers for the plan and help determine how billions of transportation dollars are spent. Wise planning is needed to help create high quality transportation services at a reasonable cost with minimal environmental impact. Failure to plan well can lead to severe traffic congestion, dangerous travel patterns, undesirable land use patterns, adverse human and environmental impacts, and the wasteful use of resources and increasingly scarce public transportation funds.

Why models need improving:

Travel demand modeling was first developed in the late 1950's as a means to do highway planning. However, as the need to look at other issues such as transit, land use, and air quality impacts arose, the modeling process has been modified to add techniques that deal with these issues. These improvements to modeling have been fueled in part by efforts in communities like Portland, Oregon and Montgomery County, Maryland to model the effect of policies designed to encourage alternatives to driving.

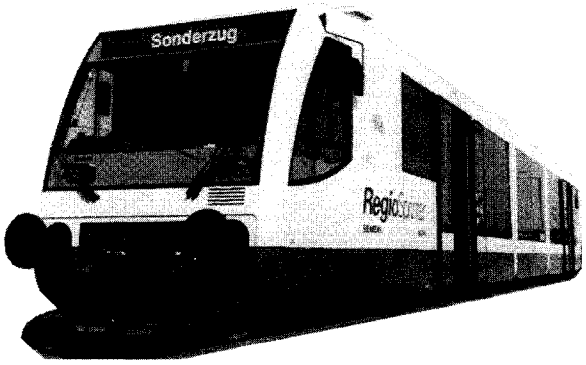
However, the biggest general impetus to improving modeling has probably been two federal laws, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the Clean Air Act Amendments of 1990. These new laws require multimodal planning that considers a list of new factors along with policies to reduce emissions of ozone producing pollutants in regions designated as "non-attainment" areas by the Environmental Protection Agency. In all cases transportation planning must be based on land use plans and consider land use impacts. Moreover, in nonattainment areas, planning must consider transportation control measures (TCMs) that include transit improvements, compact and pedestrian-friendly land use designs, and travel demand management (TDM) strategies such as car pooling programs, discounted bus passes, and pricing measures such as increased parking fees.

It is important to realize that no model can take into account all of the factors that affect travel behavior and thus no model can perfectly replicate or predict reality. All models are limited by the assumptions, factors, and alternatives that are explicitly included in the equations used by those models. In particular, today's models can be insensitive to policies that encourage non-automobile modes of travel—that is, transit, rail, walking, and bicycling. This weakness may result in overestimating the demand for roadways and underestimating the effectiveness of alternative transportation policies and alternative land use scenarios. For example, travel forecasting models usually exclude pedestrian and bicycle trips. These models therefore will not show any impact from plans that include improved bicycle or pedestrian elements. Similarly, if a model does not include certain factors that affect access or use of alternatives to driving, then it may be incapable of testing whether or not policies designed to encourage alternatives to driving can be effective.

It is no secret that transportation funds are likely to become more scarce in the future and that transportation investment decisions are often part of very heated political debates. In short, it is crucial now and will become increasingly important that decision makers and the public have accurate technical information to inform their debates. This should include an awareness of transportation models to assure that the policies being debated are analyzed fairly.

Federal Laws:

- **Clean Air Act Amendments of 1990**
- **Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)**



Flexible ISTEA money can be used to fund capital projects for commuter rail.

While virtually all regional models need significant improvements, not all regions will benefit as significantly from all of the improvements suggested below. For example, all areas need to be able to account for pedestrian trips and check the effects of transportation facilities on land use—something they by and large cannot do now. Finally, it is important that the following suggestions, and those listed later for other parts of the modeling process, be understood within the context of the inherent limitations and inaccuracies of all modeling. Like any other tool, it must be handled with skill to be useful.

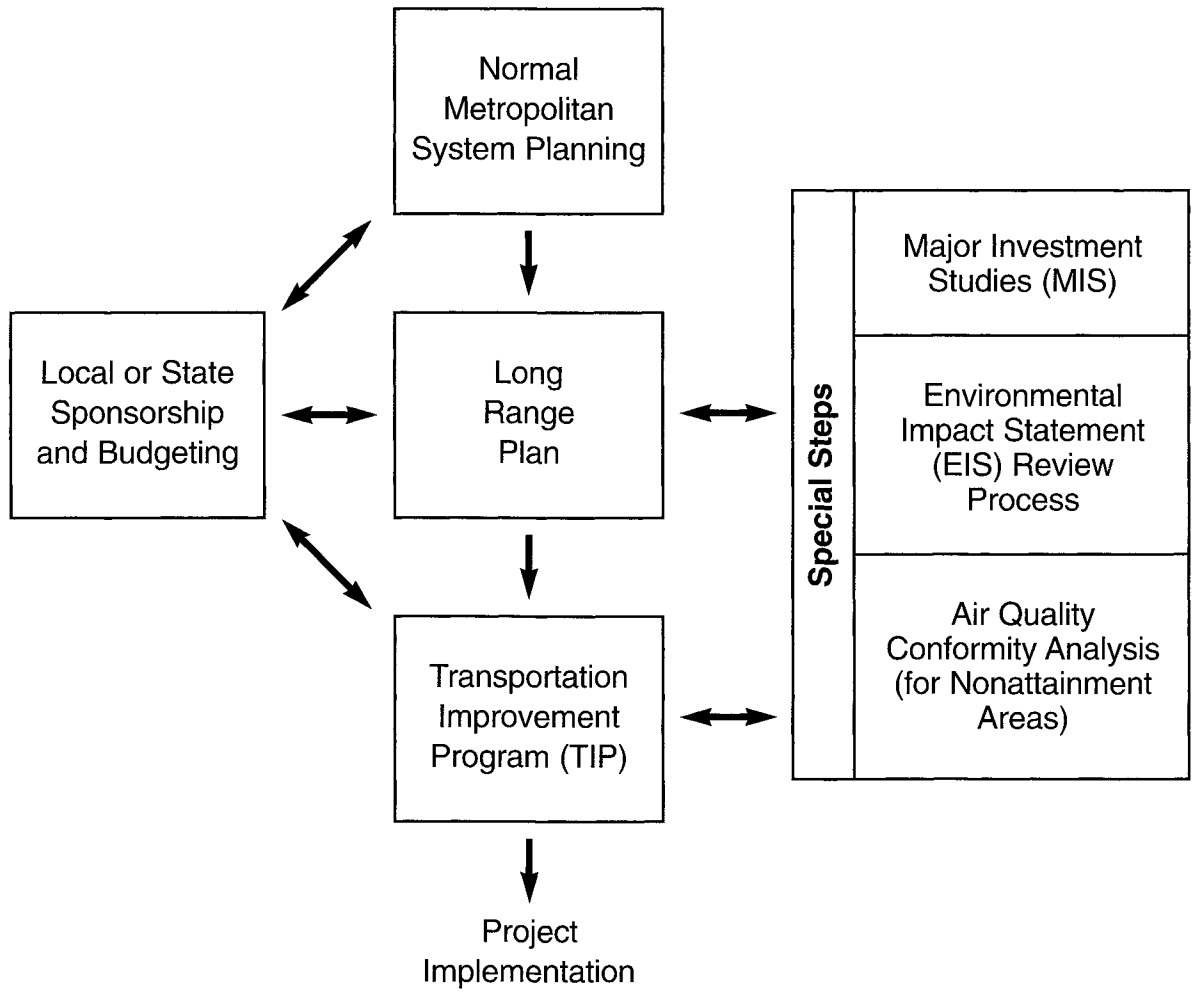
How do models fit into the overall transportation planning process?

Transportation planning is a complex process that involves a large number of steps. Several steps can take place at once and it is not unusual to repeat some of them several times. Travel demand models are used in the forecasting step of the process as the means to predict how well alternative plans perform in meeting goals. The basic steps in the transportation planning process are:

- Define Problem, Scope, Area, Issues
- Set Goals, Objectives, and Criteria
- Collect Data
- Calibrate and Validate Model (Modeling)
- Develop Alternatives and Scenarios
- Forecast Future Travel Behavior (Modeling)
- Evaluate Alternatives
- Select Preferred Plan
- Implement Plan through Projects in TIP and Land Use Management Activities

After being adopted by the MPO, the long range regional transportation plan provides the basis for the preparation of an annual or biannual regional Transportation Improvement Program (TIP) or budget which lists the specific projects to be funded for the next three to six years. Once 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 study (MIS) which can include an environmental impact statement (EIS). Other more detailed studies that may be needed include public transit system plans, preliminary engineering studies, and jurisdictional studies such as a county highway plan. These studies may be done by the MPO or by state or local governments depending on the problem to be addressed. Regional transportation plans should be updated periodically, at least once every five to ten years. TIPSs typically are revised every one to three years.

Figure 1.
The MPO is responsible for transportation and programming within its jurisdiction. The state is responsible for rural projects outside the MPO's boundaries. The state and MPO work together on many major projects, especially state highways within the MPO's jurisdiction.



Forecast Modeling Steps

Models are used in a sequence of steps to answer questions about future travel patterns. The steps and basic questions asked are as follows:

1. Land Use: What might our community look like?

- Population Forecasts: How many households and of what size?
- Economic Forecasts: What activities will people likely engage in?
- Land Use Development Patterns: Where will people live and what activities will take place?

While a single trend forecast is often the sole set of assumptions used in regional modeling, under ISTEA and the Clean Air Act regions need to consider alternative future visions, policies, and investment strategies that will lead to alternative land use development patterns. The public should be given opportunities early in the planning process to identify these alternatives.

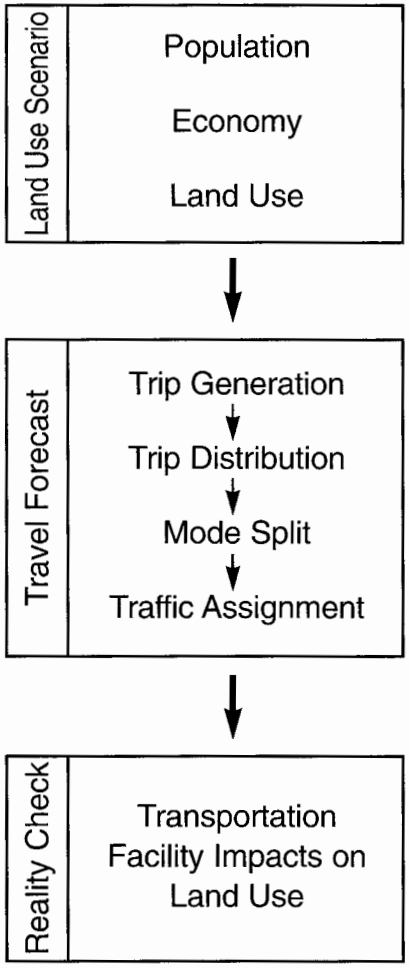
2. Travel Forecast: What are the travel patterns in the future?

- Trip Generation: How many trips will be made?
- Trip Distribution: Where will the trips be?
- Mode Split: What modes will be used?
- Traffic Assignment: What routes will be used? (And at what time of day will these trips be made?)

3. Transportation Impacts: What will the effects of this travel be?

ISTEA requires that regions consider the land use impacts of transportation plans, particularly in long range and major investment planning studies. Although integrated land use/transportation models can play a useful role in evaluating these effects, they are not a replacement for expert judgement and policy driven alternative forecasts.

Figure 2.
The Overall Forecasting Process



1. Land Use

Before forecasts are made of travel, it is necessary to develop forecasts of future population, households, economic activity, and land use. Transportation planning is directly linked to land use planning. Trips are assumed to follow future land use patterns. If land use is changed, there will be a change in travel patterns.

Land Use Development

Population Forecasts: How many households of what size will there be?

Future population forecasts are based on assumptions about birth rates, death rates and the rate of migration into or out of the study area. Current information about the ages of the population is used to calculate the number of births, deaths and migrants added or leaving the region in each year of the future. These rates are assumed to change in a specified way into the future. These rates have changed substantially over the past 30 years, so often several forecasts are made under different growth rate assumptions. Forecasts are also used regarding household size, which has decreased steadily over the past 50 years. Population and economic forecasts can be made by the planning agency itself or they can use forecasts done by others such as state agencies.

Economic Forecasts: What activities will people engage in?

Forecasts need to be made of future employment levels as these are the basis for forecasts of travel to work, school, shopping, etc. Economic forecasts are done in conjunction with the population forecasts since the two are highly interrelated. Employment grows because the population 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. Basic employment is the employment that exports goods and services outside of the region. It is different from the non-basic or "local" sector of the economy which circulates the money brought into a region by the basic sector. Total employment is found by applying an economic multiplier to basic employment.

Migration rates into and out of the community depend on the growth of the economy.

Land Use: Where will activities occur?

Population, households and employment growth need to be distributed to 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 estimate future trip making. Future allocation of land use may be based on past trends, assumptions about changes in trends, or through a negotiation process among local officials. Land use plans can be developed to change existing trends if it is felt that current trends will not continue or are undesirable.

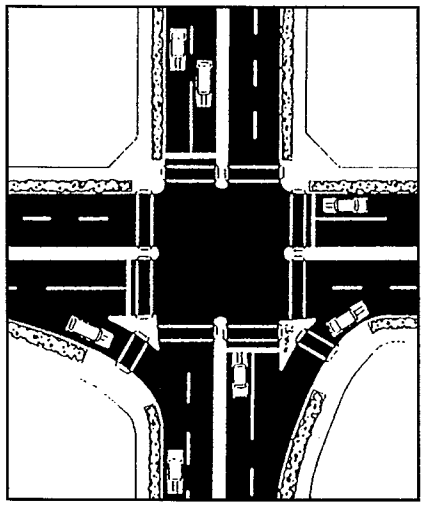
Merely forecast trends?
OR
Change trends to meet goals?

The first step in a land use planning process is to establish specific land use goals and associated land use policies. Goals need to be set concerning preservation of open space, wetlands and environmental corridors as well as land use mixes and densities. Quantities of currently vacant land required for various uses are established to meet projections of population and employment. Goals may also be set for redeveloping and infilling existing urban areas more intensely and efficiently—something that is rarely done and often controversial, especially if a local government's exclusionary zoning conflicts with attainment of regional objectives. Alternative scenarios can be developed to reflect different goals, land use policies and assumptions. For example, land use plans can be developed to continue current trends, to reduce low density suburban development, or to concentrate development along major corridors or in satellite communities. Different assumptions can be made regarding the extent to which environmentally sensitive areas and prime agricultural land will be protected.

Transportation facilities and the access they provide can dramatically influence land use.

The second step is to allocate overall regional growth in population, households, and employment to specific locations. A regionally determined allocation of local growth is important since local communities often overestimate their future growth. Individual community zoning often allocates far more commercial and industrial land use than may be necessary when looked at from a regional perspective while underestimating the potential for residential infill development (for example, through the creation of accessory apartments in single family houses and town houses, adaptive reuse of old commercial buildings, or redevelopment of parking lots). This land use allocation can be done either through a judgement technique or through a modeling process. The judgement technique involves the allocation of growth in steps to smaller and smaller geographic areas considering past and potential future trends, availability of land for future

Figure 3.
Auto-oriented streets have wider turning radii and often other features such as "free right turns" that allow cars to go faster. However, these features also make pedestrian crossings less attractive and more dangerous.



Source: Florida DOT.

potential development, federal and state policies, local plans and zoning ordinances, and all other factors. It is rarely but often best accomplished with the use of an expert panel that includes local planners, developers, and lenders with experience in both auto and transit-oriented development.

The modeling approach to land use allocation 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, the accessibility that is provided from a proposed transportation plan, and the current distribution of households by income. Better land use models also consider real estate market forces and prices. The modeling process finds a balance between supply and demand for both land use and transportation. As such it can indicate how land use change is driven by changes in the transportation system. This can be helpful in that it could indicate undesirable trends and/or suggest policies to avoid them. This approach is relatively new and has only been used in limited locations. (See p. 36 for a more detailed discussion of transportation effects on land use, including land allocation models and other approaches such as expert panels.)

Problems and improvements for conventional land use allocation procedures:

1. Land use plans are considered independent and fixed. Common practice is that land use plans are developed before transportation plans and are then assumed to not change as a result of different transportation improvement scenarios. That is, there is no feedback to the land use alternatives or plan from the transportation alternatives despite the phenomena of both facility-induced travel and facility-induced development (and attendant secondary travel effects). This is especially common in the preparation of environmental impact statements and highway location studies.

> ***Improvement:*** Install a step in the modeling—e.g., an expert panel—that specifically forecasts the effects of transportation facilities and travel on land use. (See section on this topic, p. 36.)

2. Existing development is considered unchangeable. Land use plans generally deal only with new growth on vacant land and assume that current development will be unchanged. Effects of redevelopment programs, changing use of neighborhoods, and specific policies attempting to increase "urban infill" and use existing development more intensely are normally not considered.

Improvement: Make sure that at least some of the land use plan alternatives being considered specifically incorporate major redevelopment and other changes to existing urbanized areas.

3. Benefits of pedestrian-friendly, mixed land use are not considered. Land use patterns that facilitate walking and non-automobile travel are not easily dealt with in the modeling process and generally not considered. That is, most models cannot differentiate between land use plans with good pedestrian features and those without. Indeed, typical plans assume that all new development will be auto-oriented in nature with residential areas separated from retail, civic, and other uses. Auto-oriented development often makes walking and transit virtually impossible and thus generates excessive automobile trips.

Improvement: Clarify the difference between auto-oriented development and the kind of development which generates more transit and pedestrian trips, including mixed-use, transit-oriented development, and traditional neighborhood development. Studies indicate that these land use designs can reduce the average trips generated by a household by 5-25%. Be sure your modeling has a way to represent the extent to which a land parcel is pedestrian- and transit-oriented. For example, models can use an approach similar to the pedestrian environment factor (PEF) used in Portland, Oregon's transportation model.

Factors important to pedestrian friendliness include ease of crossing streets, the quality and spacing of pedestrian paths, sidewalk connectivity, topography, density, building orientation, and a mix of land uses at a pedestrian scale. Improvements to bicycle friendliness can also have a significant effect on vehicle use. This is affected by the availability of bicycle friendly streets and

Land Use Model Issues:

- **Land use considered to be a fixed input to travel model**
- **No redevelopment modeled**
- **Pedestrian-friendly, mixed-use benefits not considered**

dedicated paths or lanes, the quality and spacing of these routes, the difficulty of crossing streets, auto traffic volumes and speeds on shared rights of way, and the availability of secure bicycle parking. These factors can be included in regional models by devising a bicycle environment factor (BEF) or a composite PBEF.

Does your model use a pedestrian environment factor?

4. Planning horizons are too short to show changes. Generally land use plans only look ahead 15 to 25 years. Since a major part of future development may already be in place, it may be difficult to see much impact from land use policies, including pedestrian-and transit-oriented development designs. This may lead to such policies being ignored.

Improvement: Use a longer term planning horizon, say 30-50 years, as a basis for initial discussions on how an area might change. Consider major long term development scenarios and find a process where their implications can be discussed. This discussion can set the framework for the development of land use plans with a shorter horizon for transportation planning purposes.

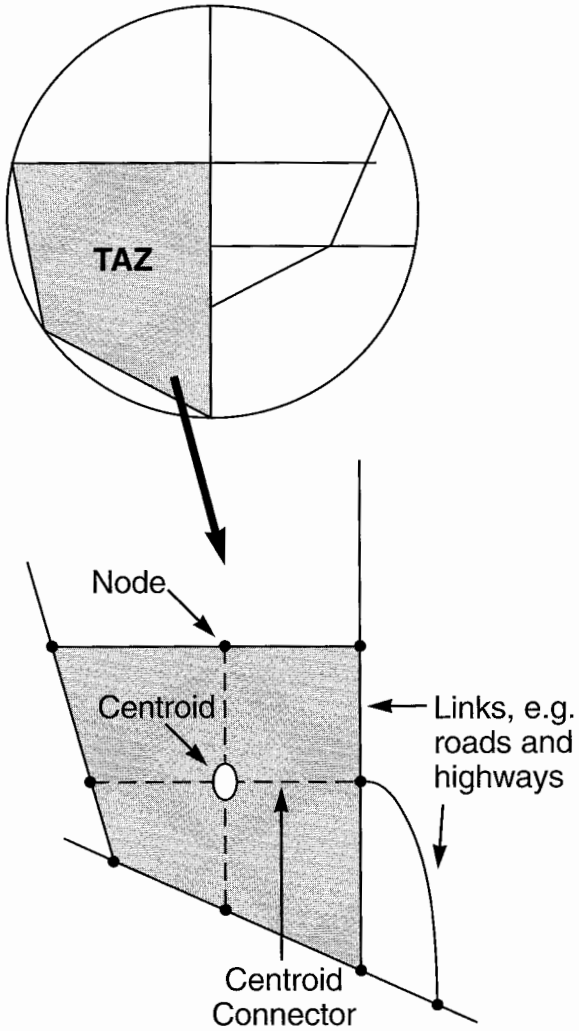
2. Travel Demand Models

The travel forecasting process is at the heart of urban transportation planning. Travel forecasting models are used to project future traffic and are the basis for the determination of the need for new road capacity, transit service changes, and changes in land use policies and patterns. Travel demand modeling involves a series of mathematical models that attempt to simulate human travel behavior. 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 to particular transportation alternatives.

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

Travel simulations require that an urban area be represented as a series of disaggregated trip producers (where trips begin) and trip attractors (where they end). In some more sophisticated models, simulation is done at the level of the individual household or trip. However, in most regional computer transportation models average characteristics are used at a more aggregate level, working with geographic areas called travel analysis zones that range in size from a few blocks to several miles in rural areas (TAZs). These zones are characterized by their population, employment and other factors and are the places where trips begin or end. Trip making is first estimated at the household level by trip purpose and then aggregated to the zone level. Trip making is also assumed to begin at the center of activity in a zone (zone centroid). Intrazonal trips—that is, very short trips that begin and end in a single zone—are usually not directly included in the forecasts. Instead, the model usually forecasts only the trips that can be assigned to the interzonal network or "grid." This practice limits the analysis of pedestrian and bicycle trips in the typical travel demand modeling process since they tend to be short trips.

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



Zones can be as small as a single block but typically range from 1/4 to one mile or even several miles square. A planning study can easily use 500-2000 zones. A large number of zones will increase forecast accuracy but will 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 will likely begin and end within the study area through the 20 or more year future period typically evaluated in long range plans.

Four Step Process

1. Trip Generation

2. Trip Distribution

3. Mode Split

4. Traffic Assignment

If the model is to be used to examine compact pedestrian and transit-oriented development, it is highly desirable that the traffic zones be defined small enough to distinguish between areas of auto dominance and areas with good walking and transit access.

The highway and transit systems are represented as networks for computer analysis. Networks consist of links to represent highway segments or transit lines and nodes to represent intersections, transit stops, and other points on the network. Data for links include travel times on the link, average speeds, capacity, and direction. Node data includes information about intersections and the location of the node (coordinates). (See Figure 4.)

The Four Step Process

The travel simulation process follows trips as they begin at a trip generating 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 each of the four basic models used in the overall process. These are:

- Trip Generation
- Trip Distribution
- Mode Split/Auto Occupancy
- Traffic Assignment

Step #1. Trip Generation: How many trips will there be?

The first step in travel forecasting is trip generation. In this step information from land use, population and economic forecasts is used to estimate how many person trips will be made to and from each zone. (See Figure 5.) This is done separately by trip purpose. Typical trip purposes used include: 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 nor end at home), truck trips and taxi trips.

Trip generation uses trip rates that are averages for large segments of the study area. 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 (one way) per day. Trips per household are then expanded to trips per zone. 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. (See Figure 6 on p. 17.) (Note: The number of work trips may exceed the number of employees due to various factors, such as: employment of salespersons who stop at the office before going to work in another zone; carpoolers who drop off passengers before heading to work in another zone; or adjustments made to match the number of trip attractors and producers.) Trip generation is used to calculate person trips. These are later adjusted in the mode split/auto occupancy step to determine vehicle trips.

Problems and improvements for conventional trip generation modeling: Some of the typical limitations and weaknesses encountered in the trip generation step of travel forecast modeling include:

1. No discrimination between pedestrian-likely trip purposes and those which require motor vehicles: With few (four to eight) trip purposes, a simplified trip pattern results. All shopping trips are treated the same whether shopping is done for groceries or lumber. Yet shopping for groceries can often be done on foot while buying lumber always requires a truck or car. Home-based "other" trip purposes cover a wide variety of purposes—e.g. medical, visiting friends, banking—which are influenced by a wider variety of factors beyond those used in the modeling process.

Trip Generation

Figure 5.

Trips Produced*

Autos Owned

Household Size	1	2	3+
1			
2			
3+			

Rate

*By trip purpose

Trip Attractions*

Attractors	Trips
Dwelling Units	
Retail Employment	
Non-Retail Employment	
Other Attractors	

*By trip purpose

Improvement: Expand the number of trip purposes. Additional trip categories can provide a way to get better representation of pedestrian-prone trips as well as complex household trip patterns, trip chaining (combining trips), and different behavioral patterns within traditional trip categories.

Trip Generation Issues

- **Too few trip purposes?**
- **No trip chaining?**
- **Poor pedestrian and transit sensitivity?**
- **Poor auto availability model?**

2. Combination trips (trip-chaining) 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 difficult to simulate. The modeling process treats such trip combinations in a very limited way. For example, non home-based trips are calculated based only on the employment characteristics of zones and do not consider how members of a household coordinate their errands.

Improvement: Again, expand the number of trip purposes.

3. Insufficient variables sensitive to transit and walking: Trip making is found as a function of only a few variables such as auto ownership, household size, and employment. Other factors that help predict transit and pedestrian trips which are typically not included are: the quality of transit service, overall transit accessibility (e.g., number of jobs within 30 minutes of transit travel time), proximity of jobs and homes to transit stops, access to park-n-ride lots, ease of walking or bicycling, fuel prices, and auto-oriented vs. pedestrian-friendly, mixed land use design.

Improvement: Collect and include data on pedestrian- and transit-sensitive variables that vary among TAZs. In the short term, zones can be classified into several types according to pedestrian-sensitive factors with different trip generation tables.

4. Inadequate auto ownership models: Conventional models usually rely solely on income and household size data to estimate the average number of automobiles in a TAZ. They ignore additional variables capable of predicting fewer automobiles in denser, mixed use urban areas with higher levels of transit access and moderate and higher incomes.

Improvement: Relate auto availability to land use characteristics that encourage more transit and pedestrian trips such as residential density, mixed (vs. separated) land use, pedestrian amenities (pedestrian environmental factor), and quality of transit service (transit accessibility indices). Also, auto availability should be related to the cost of owning and operating a vehicle.

5. Other problems without good solutions currently:

• **Interdependence of trip-making ignored:** Travel behavior is a complex process where decisions of one household member are often dependent on others in the household. For example, child care needs may affect how and when people travel to work. This interdependency for trip making is not considered. Instead, decisions of the traveler are considered to be independent for each trip.

• **Chicken-or-egg 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 that the number of retail employees at a shopping center depends 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 also be that the number of automobiles a household owns depends upon how active they are in making trips.

• **Presumption that all trips begin and end at the centroids of TAZs:** In real life, people don't just travel from the center (centroid) of a TAZ to the center of another zone, which may range in size from a few blocks to several miles wide. Rather, persons may travel from one part of a zone to the edge of another. The inaccuracy of presuming centroid to centroid travel is most problematic for estimating walk and bicycle trips, which are inherently shorter. Problems arise in estimating transit trips due to the inaccuracies that result in assumptions for transit access time. Transit routes generally follow arterial streets which are usually the boundaries of TAZs, since they were laid out with auto access in mind. Ideally, for transit ridership forecasting, the transit routes should run through the middle of the TAZs so that the entire service area (1/4 mile surrounding each transit stop) is within the zone.

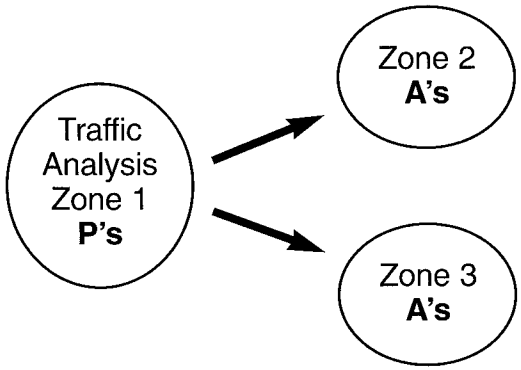
Figure 6.
Trip Generation Output by Trip Purpose

TAZ	P's	A's
1		
2		
3		
• • N		
Total		

Balance Attractors (A's) to Producers (P's)

Trip Distribution

Figure 7.



Gravity Model

- **Accessibility**
- **Attractiveness**

Step #2. Trip Distribution: Getting people from here to there

Trip generation only finds the number of trips that begin or end at a particular zone. These trip beginnings and ends are linked together to form an origin-destination pattern of trips through the process of trip distribution. (See Figure 7.) Trip distribution is used to represent the process of destination choice—that is, "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 (O/D) tables are very large. For example, a 1,200 zone study area would have 1,440,000 possible trip combinations in its O-D table. Separate tables are also done for each trip purpose. (See Figure 8 on p. 20.)

Gravity Model

The most commonly used procedure for trip distribution is the "gravity model." The gravity model takes the trips produced at one zone and distributes them 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 will receive a greater number of distributed trips than one with a small number of trip attractions. Distance to possible destinations is the other factor used in the gravity model. The number of trips to a given destination decreases—is inversely proportional—with the distance to the destination. The distance effect is found through a calibration process which tries to lead to a distribution of trips 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 as the measurement of distance. Other ways might be to use a combination of auto travel time and cost 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 multiplying auto travel times/costs by one percentage and transit time/cost by another percentage to calculate the composite time and cost of both modes.

Because of calculation procedures, the model must be iterated—run through its calculations using the last run's output—a number of times in order to balance the trip numbers to match the trip productions and attractions found in trip generation.

Problems and improvements for conventional trip distribution modeling:

1. Use of only 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. This may be particularly important if a rail transit system is being analyzed.

Improvement: Use an accessibility variable (the logsum variable) that can represent the composite costs associated with a trip for various modes of travel. This variable can also represent not only in-vehicle travel time but also out-of-vehicle time and costs, a major issue for transit/pedestrian trips that corresponds to the higher transit ridership rates for origins and destinations that are pedestrian-friendly. Where walking and bicycling offer good accessibility and attract a significant share of trips, this should also be factored into trip distribution.

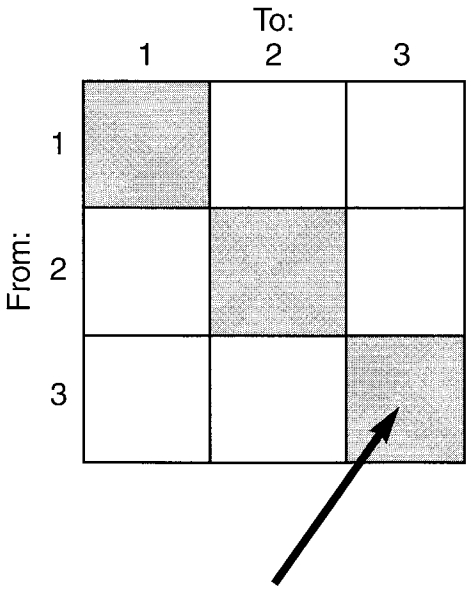
2. No check for congestion or other feedback effects: Travel times are needed to calculate trip distribution, however travel times depend upon the level of congestion on streets in the network. The level of congestion is not known during the trip distribution step since that is estimated in a later calculation. Some MPOs do not have feedback loops from traffic assignment back to earlier steps. Some MPOs feed travel time back to mode choice. Normally what is done is that travel times are assumed and checked later.

Improvement: The effect of congestion and changes in highway capacity should be fed back to the beginning of the four-step modeling process. Trip generation, distribution, and mode split should be based on values that represent actual levels of congestion in the networks. Ideally, the feedback process should extend to representing the effects on land use patterns.

Trip Distribution Issues

- **Only uses auto trip lengths?**
- **No check on congestion?**

Figure 8.
Trip Distribution



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

Separate tables are used for each trip purpose.

3. Insensitivity to socio-economic-cultural factors: Many gravity models distribute trips only on the basis of size of the attractions and productions at the end of the trips and travel times between the trip ends. It is common for such models to thus overestimate travel 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. That is, regardless of their proximity, available autos, or retail establishments, these neighborhoods may actually experience relatively few connecting trips. On the other hand, some neighborhoods can experience a disproportionate share of connecting trips. The actual distribution of trips is affected by people's activities, their socio-economic and cultural characteristics, and the size and distance factors used in the model. Important factors usually not considered by the model include: the affordability of housing in an area and the distribution of wages for jobs nearby, differences in income, crime conditions, and the attractiveness of the route. Furthermore, groups of travelers might avoid some areas of the city and favor others based on socio-economic-cultural reasons. Adjustments (often called "K-Factors") are sometimes made in the model to account for such factors, but it is difficult since the effects of such factors on travel are difficult to quantify and even harder to predict over time.

Improvement: Income stratified trip distribution models have been developed in a number of metro areas, reducing the need for "K-Factor" adjustments. Montgomery County, Maryland's travel model separately generates and distributes linked and unlinked work trips by direction by time of day, stratified by household size, dwelling unit type (single vs. multi-family) and age of individual, which captures many income effects—e.g., distinguishing the shorter trip length distribution of home-to-work trips in the PM peak hours (made mostly by low-paid service workers) from the longer trip length distribution of home-to-work trips in the AM peak hours (made by higher paid salaried workers). Microsimulation models, such as Greig Harvey's STEP model can further distinguish these effects by reducing aggregation problems. This approach uses a "logit" discrete choice model at the household level to evaluate key components of travel behavior, including distribution and mode choices.

Step #3. Mode Split: How will people travel?

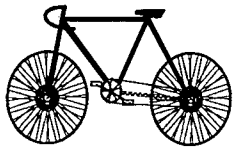
Mode choice is a critical part of the travel demand modeling process. It is the step where trips between a given origin and destination are split into trips by transit, by automobile passengers (car pooling), by automobile drivers, and possibly by walking or bicycling. Calculations are conducted that compare the attractiveness of travel by different modes to determine their relative usage. All proposals to improve public transit or to change the cost or ease of using the automobile should be reflected in the mode split/auto occupancy process as part of assessment and evaluation. It is important to understand what factors are used and how the process is conducted in order to plan and design new transportation facilities and practices.

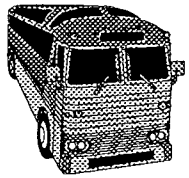
Comparing the "disutility" of travel modes

The most commonly used process for mode split is the "Logit" model. Essentially, the logit model tries to predict which mode of travel people will choose—or "buy"—based on the "price" of each of these travel modes for travel between a given origin and destination. This price for a mode is called its "disutility" and represents a combination of the mode's travel time, cost, and convenience for a given trip.

Travel time is typically divided into two components: in-vehicle time to represent the time when a traveler is actually in a vehicle and out-of-vehicle time which includes time spent traveling outside of the vehicle. Out-of-vehicle time (OVT)—that is, the time needed to walk to and from transit stops or parking places, waiting time, and transfer 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. This is because people tend to be more willing to wait or walk longer distances for some purposes, e.g. work trips, than for other purposes, e.g. shopping trips. People will walk longer distances (implying a lower multiplier for this component of OVT) if the conditions are pedestrian-friendly. Wait times are less onerous, and hence have a lower multiplier if conditions are comfortable and/or if the traveler knows how long the wait will be.

Mode Split





The perceived cost of auto travel is much lower than its actual cost, which includes upfront fixed costs (e.g. vehicle purchase, insurance) that don't vary with travel.

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 multiplied by a cost per mile. Auto cost is typically based on a "perceived" cost per mile (on the order of 5-10 cents per mile) which only includes fuel and oil costs and does not include ownership, insurance, maintenance and other fixed costs (which increase the total direct costs of automobile travel to 25-40 cents per mile). Travelers have been found to only consider the costs that vary with an individual trip rather than all of the costs—e.g. insurance and other non varying expenses—when making mode choice decisions. These other costs can and should be accounted for in vehicle choice and vehicle ownership models. Other factors can and should be considered in mode choice, including auto availability, income, separate parking costs, urban design characteristics such as pedestrian and bicycle friendliness, and traveler characteristics such as age.

Disutility calculations may also contain a "mode bias factor" which is used to represent other characteristics of travel modes which may influence the choice of mode (such as a difference in privacy and comfort between transit and automobiles). The mode bias factor is used as a constant in the analysis and is found through attempts to match the model to actual travel behavior data. The disutility equations may not recognize differences within travel modes. For example, a bus system and a rail transit system with the same time and cost characteristics will have the same disutility values. Special factors can be estimated from stated and revealed preference surveys that allow for the difference in attractiveness of alternative technologies but these are difficult to estimate and are often subject to controversy.

Once disutilities are known for the various mode choices between an origin and a destination, the trips are split among various modes based on the relative differences between disutilities which are converted into possibilities of a given choice being selected. A large advantage in disutility will mean a high percentage for that mode. Mode splits are calculated to match splits found from actual traveler data. However, it is often the case that some travellers cannot use a mode of travel regardless of a mode's apparent disutility, since it is not available to them. For instance, they may simply not own a car regardless of its disutility.

Hence, a fixed percentage is sometimes 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. Income-sensitive or income stratified mode choice models should not require such a model "fix."

Automobile trips must be converted from person trips to vehicle trips with an auto occupancy model. 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.). "Nested" logit models are an appropriate way to evaluate these families of related choices. (See Figure 9.)

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 forecasts of car pooling would be insensitive to changes in the cost of travel, the cost of parking, or the presence of special employer-based travel demand management (TDM) programs to promote car pooling which may occur as a result of the Clean Air Act.

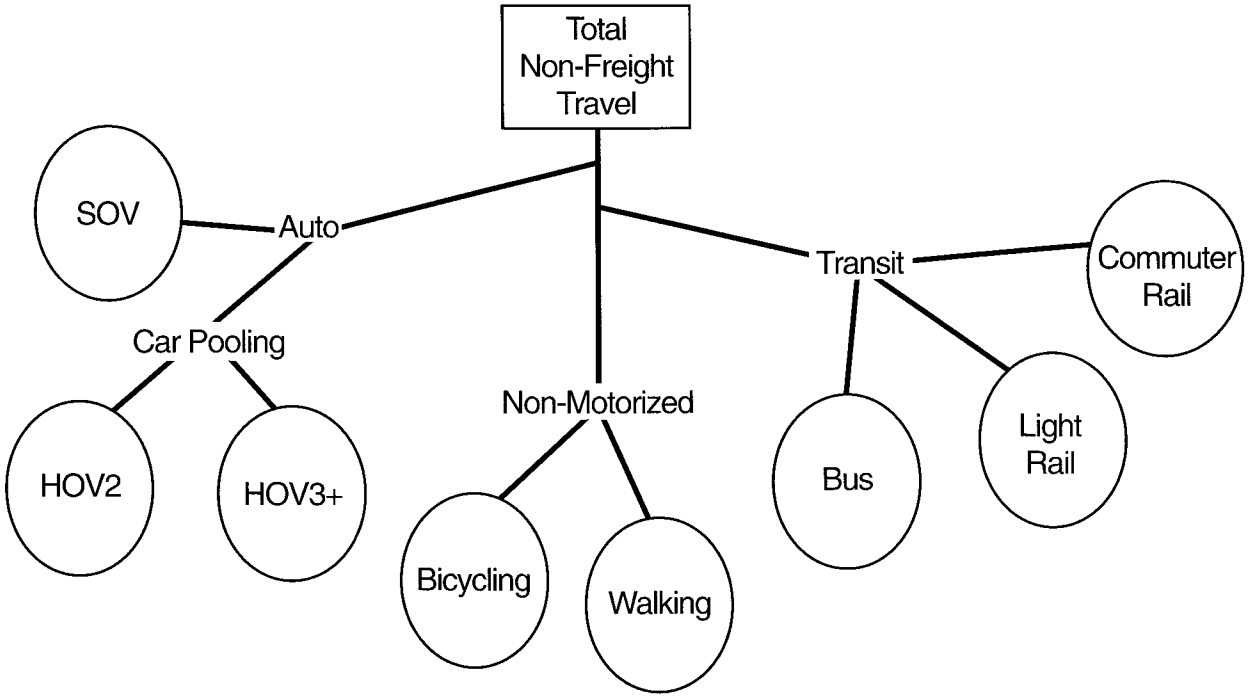


Figure 9.
A Nested Logit Model Groups Similar Modes for More Careful Analysis

Problems and improvements for conventional mode split modeling

1. Mode choice variables are insensitive to some differences between modes: An important thing to understand about mode choice analysis is that shifts in mode usage are only predicted to occur if there are changes in the characteristics of the modes—that is, 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. Mode choice variables are generally limited to only time and cost. Thus, if one substitutes a light rail transit system for a bus system without changes in travel times or costs from the bus system, the model would not show any difference in demand unless the model included a modal bias coefficient difference for rail vs. bus. 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.

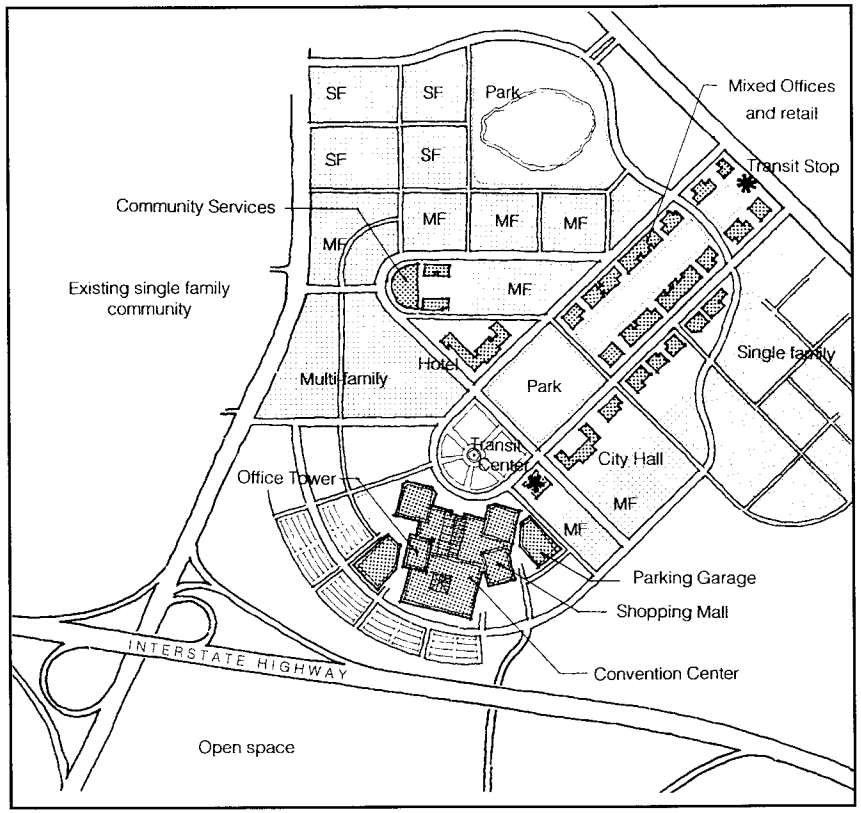
Improvement: Models may be able to incorporate factors such as attitudes towards different modes using revealed or stated preference surveys to estimate appropriate bias coefficients that reflect the values people bring to their choices. In the short term, other adjustments can be made "by hand" to estimate the difference other factors might make. For example, the effect of light rail's potential to generate pedestrian and transit-oriented development and its attendant increase in ridership can be added in directly after estimating the development potential along a light rail corridor. In addition, the special ability of some transit modes, such as light rail, to attract special events travel or other off-peak travel should be estimated separately.

2. Important factors omitted: Factors which are not included in the model such as pedestrian friendliness, crime, safety, and security concerns are treated as if they 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 than those presumed by the model, no change will be predicted by the model.

Mode Split Issues:

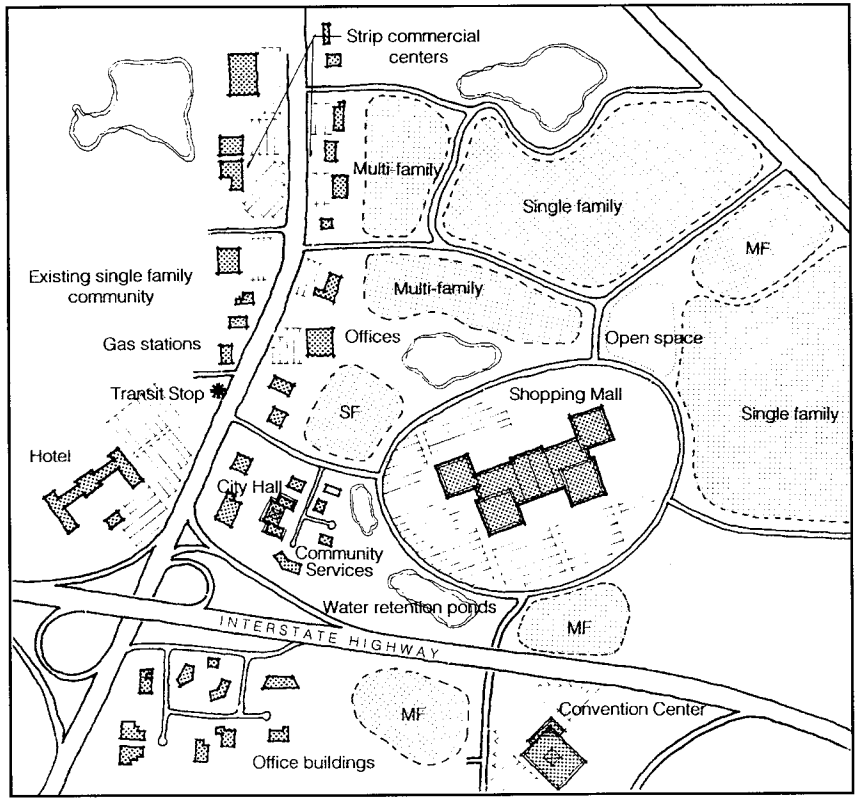
- **Variables insensitive to some modes?**
- **Some factors omitted?**
- **Trip purpose categories are too broad?**

Figure 10.
Many mode split models remain insensitive to pedestrian/transit friendliness. How big a difference in mode of travel might there be between these two arrangements of essentially the same trip producers and attractors?



Urban Center Alternative

- Pedestrian friendly
- Efficient for transit
- Scaled to people
- Attractive, endurable buildings and landscaping
- Public places and amenities
- Community identity



Typical Suburban Center

- Auto-scaled/auto-dependent
- Hostile to pedestrians
- Disconnected activities
- Inefficient for transit
- Impermanent, poor quality architecture
- Lack of public places and community identity

Source: Snohomish County (WA) Transportation Authority, *A Guide to Land Use and Public Transportation, Vol. II: Applying the Concepts*, 1993.

Improvement: Logit model coefficients can be borrowed from other regions to restructure mode choice models for enhanced sensitivity or to adjust model outputs for otherwise neglected factors. For example, in preparing its long range plan, the Dane County Regional Planning Commission in Madison, Wisconsin has recently adapted a mode split model that was originally prepared for Louisville and Indianapolis. Such effects need to be factored in with considerable skill and knowledge of logit models and travel behavior.

3. Insensitivity to non-auto mode strategies: Access time and character are over-simplified. That is, no consideration is given to the ease of walking in a community and the characteristics of a waiting facility in the mode 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.

Improvement: Use an access index such as a pedestrian environment factor—for example, as used in Portland, and Montgomery County, Maryland—that is sensitive to the ease of access and waiting for transit vehicles in areas with more transit-, pedestrian-, and bicycle-friendly land use design. An index could include such factors as: amount of sidewalks, connectivity of sidewalks, land use mix, building setbacks, transit stop conditions, and bicycle infrastructure.

4. Trip purpose categories are very broad: The importance of time, cost, and convenience are assumed to remain constant for a given trip purpose. Trip purpose categories are so broad—for example: "shop" or "other"—that important differences in time and cost within these categories are ignored. For example, the weights used for a shopping trip for groceries are the same (e.g. "retail") as one for building supplies.

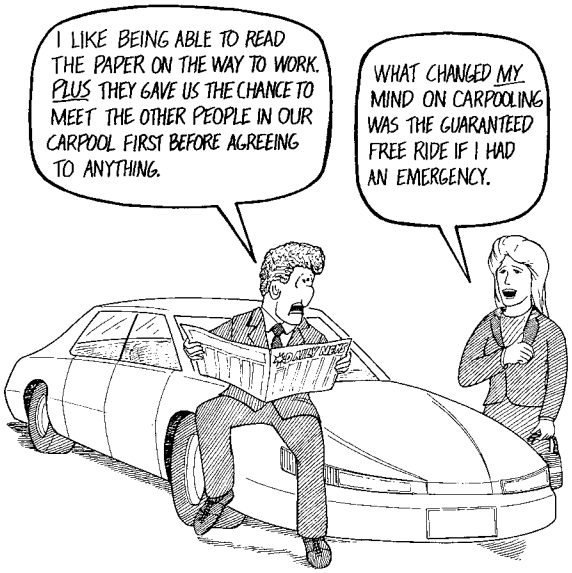
Improvement: Increase the number of trip purposes and stratify by time of day to expose important variations among modes. Then, vary the weight for these different trip purposes specifically according to their potential for each different non-automobile mode of travel.

5. No calculation for portion of TAZ served directly by transit: Different parts of the same TAZ may have different transit ridership potentials depending on whether or not they are directly served by a transit system.

Mode Split Issues:

- **No calculation of portion of TAZ served directly by transit**
- **Auto-occupancy variables not sensitive to TDM policies**
- **Mode choice only for commuters**

Improvement: Mode choice equations should use an area split factor to relate to the portion of a zone directly served by transit. Alternatively, the mode choice model can be applied to different portions of zones, stratified by walk access distance to transit stops for jobs and households. Ideally, microsimulation would treat each household's mode choices in a discrete way, expanding household surveys to represent the full population using statistical methods. However, micro-simulation models are not yet in general use.



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

6. Auto-occupancy variable not policy-sensitive: Conventional auto occupancy models tend to be insensitive to policies that lead to more or less carpooling.

Improvement: Use a nested mode split model and make auto occupancy procedures sensitive to the cost of parking, the cost of travel, the number of employees within 30 minutes via transit, retail employment density of the zone, the pedestrian environment factor, and the number of trips that occur between an origin and destination. If necessary, use a post-mode split procedure that is sensitive to policies dealing with these factors. Also it may be desirable to treat ride sharing among family members differently than car pooling 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.

7. Mode choice model used only for commute trips: Smaller MPOs may not even perform mode splits on all trips and this makes them incapable of knowing what is happening with most of their trips most of the time. It also renders them incapable of testing policies designed to reduce auto trips.

Improvement: All trip purposes should be subject to mode split analysis. If trip generation is done for only vehicle trips, these trips can be reduced by "pivot point" models in the short run to reflect scenarios including vehicle travel reducing measures. In the mid-term, new models should be estimated that account for all person trips, including non-motorized, and the factors that shape the use of all modes.

Step #4. Trip Assignment: What routes will be used?

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 can be the most computationally time consuming and data intensive step in the process and is done differently for highway trips and transit trips.

Trip Assignment

The process first involves the calculation of the shortest path from each origin (O) to all destinations (D) (usually the minimum time path is used). Next, trips for each O-D pair are 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. (See discussion of LOS levels on p. 31.) If a link is congested, then the speed on the link needs to be reduced to result in a longer travel time on that link. Changes in travel times mean that the shortest path may change. Hence the whole process must be repeated several 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, in which further travel time savings for an individual traveler cannot be achieved by changing the selected path.

Transit trip assignment is done in a similar way to auto trip assignment. Trips are assigned to transit vehicles depending on available vehicle space and headways (minutes between vehicles) which may be either fixed or allowed to vary in the model with the number of assignable trips. The process of assignment is repeated until supply and demand are balanced. The actual transit traffic assignment procedure used depends greatly on application and may utilize a "multipath stochastic transit assignment" method. This is a method where trips are assigned to not only the shortest path but also to paths that are nearly as short—that is, the second shortest, third shortest, and so on. This method uses a fairly complex procedure of path finding called vine building. Transit networks are more complex than highway networks since there are intermediate waits for transfers which complicate the mathematics of the trip assignment process.

Transportation models are unable to fully account for "induced" travel—that is, trips that did not occur prior to the expansion of a roadway or other facility.

LOS congestion ratings may only apply to a short peak hour period. It is important to consider the time of day and duration of traffic congestion.

To understand the trip assignment process 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 shift to other routes, to other destinations, to other modes, or to other times of day. Increases in capacity will cause shifts back to the facility to reach a new equilibrium point. Furthermore it may also lead to additional trip making in the form of "induced" trips. These are trips that did not take place before the facility was expanded. The addition of induced trips may mean that the congestion is reestablished on the facility. As Walter Kulash puts it, "In some cases, widening a highway is like loosening your belt to solve obesity." Unfortunately, most models are unable to fully account for induced trips, which can make a crucial difference in the results of analysis.

Consideration of the time of day of travel is important. Traffic assignment is typically done for peak hour travel while forecasts of trips are typically done on a daily basis. A ratio of peak hour travel to daily travel is needed to convert daily trips to peak hour travel. Some agencies assign a daily trip table to the highway network and simply factor the volumes on individual road segments, (e.g., by assuming that the peak hour traffic is 8% or 12% of daily traffic and assuming a directional split factor for inbound vs. outbound trips by commuters.) Numbers used for this step are very important in that a small change in the values assumed will make a considerable difference in the level of congestion forecasted on a network. Normally the modeling process does not deal with how traffic congestion dissipates over time, and time of day factors are not adjusted for changing levels of congestion or land use pattern differences. This can cause errors in the estimation of effects of adding highway capacity to congested corridors. It also results in overemphasizing congestion in scenarios where highway capacity is not expanded in certain corridors.

Subjectivity of LOS standards

The trip assignment step of the modeling process results in forecasted traffic volumes for specific links of the highway network. The volumes are compared with traffic capacity, resulting in projected volume-to-capacity (V/C) ratios. The standard that traffic engineers have historically used to judge the adequacy of a highway to accommodate projected traffic—that is, whether or not the V/C ratio is too high—is level of service (LOS). The LOS standards range from A to F with A representing free flow conditions and F representing highly congested stop-and-go traffic.

Traffic engineers commonly recommend new or widened highways when a LOS of D is projected. There are several problems with this rigid use of LOS standards. First, traffic forecasts are based on peak (rush hour) flow conditions and usually no estimate is made of the length of time that the LOS standard will be exceeded. It may be for only 15-30 minutes once or twice a day. Second, the standards may represent conditions that are different from drivers' perceptions. What most people view as unacceptable congestion varies from community to community and for different roads. For example, people generally accept a higher level of traffic on downtown arterial streets than on suburban arterial roads. Third, and probably most important, use of roadway LOS standards as a basis for a decision to widen a road focuses solely on the needs of single occupant vehicles and ignores other transportation options, such as rail and bus transit, ridesharing, bicycling, and walking.

Using a goal of LOS C or D—that is, the elimination of congestion—makes efforts to control sprawl development, encourage more public transit use, and more efficient use of our highways through carpooling and off peak driving very difficult. Studies have shown that a policy of eliminating congestion results in more dispersed, low-density, auto-oriented development and lower public transportation use. This, in turn, may lead to more congestion, not less. On the other hand, acceptance of a moderate level of congestion in urban and suburban areas for short periods during peak hours encourages people to find alternatives to driving alone. This results in more efficient highway use and reduced construction costs.

A community may want to accept moderate congestion rather than the consequences of more lanes, including induced auto travel, sprawl, divided neighborhoods, and increased problems for walking and bicycling.

A model's lack of sensitivity to intersection delays will lead it to overestimate travel times in traditional grid street areas, and to underestimate times in suburban areas with a conventional hierarchical street system. *(See p. 33.)*

Recognizing that some level of congestion is not always a bad thing, some planning agencies are beginning to develop and use alternative LOS standards or access-oriented performance standards rather than standards that rely solely upon single-occupant vehicle mobility. For example, some communities use aggregate LOS standards for all roads in a major corridor or area rather than setting LOS standards for each road or highway link. This allows consideration of the person-carrying capacity of a multi-modal corridor. Other areas average the traffic and speeds of several roadways and set average LOS standards. Some consider the availability of transit in establishing the roadway LOS, taking into consideration the relative travel time difference between transit and automobiles.

Analysis tools are now beginning to be developed that use access-oriented rather than mobility-oriented performance standards and that take into account other considerations such as safety and neighborhood impacts in order to assess the cost-effectiveness of alternative investments.

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. Levels of congestion, travel times, speed of travel and vehicle miles of travel (VMT) are direct outputs from the modeling process. Link traffic volumes are also used to determine other effects of travel for plan evaluation. Some of the key effects are accidents and estimates of air pollution emissions. Each of these effects needs to be estimated through further calculations. Typically these are done by applying accident or emission rates by highway type and by speed. Assumptions need to be made of the speed characteristics of travel for non-peak hours of the day and for variation in travel by time of the year. For example, emission models are now in use in ozone nonattainment areas that use the outputs of the transportation modeling as inputs to estimate motor vehicle emissions of ozone precursors.

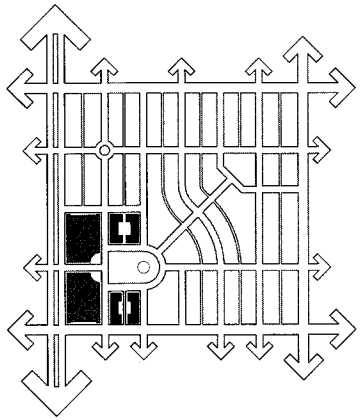
Problems and solutions regarding traffic assignment:

1. Intersection delay is ignored: Most traffic assignment procedures assume that delay occurs on the links rather than at intersections. This is a good assumption for through roads and limited access highways but not for highways with extensive signalized intersections. In an urban traffic network most delay is encountered at traffic signals or stop signs rather than on the roads between intersections. Intersections involve highly complex movements and signal systems. They are highly simplified in traffic assignment and the assignment process does not modify control systems in reaching an equilibrium. Use of sophisticated traffic signal systems, freeway ramp meters or enhanced network control of traffic cannot be easily analyzed with conventional traffic assignment procedures. Similarly, the lack of sensitivity to these effects will, on the one hand, often lead to overestimating the congestion level in dense neo-traditional grid networks which, by dispersing traffic across a richly interconnected slower street network, reduce intersection turning conflict delay. On the other hand, this lack of sensitivity will also typically underestimate congestion delay in contemporary suburban "dead worm" street systems with numerous cul de sacs which exacerbate turning conflicts and delay by forcing all traffic movements onto a few major arterial roads. (See Figure 11.)

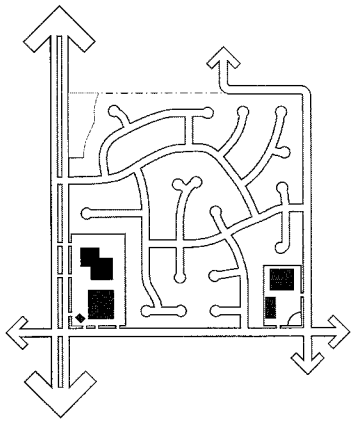
> ***Improvement:*** Add intersection delays. Travel forecasting models should include routines that calculate the delay encountered at intersections. Moreover, intersection signal splits should be treated as a variable that would be modified as the traffic assignment process iterates to reach an equilibrium. Montgomery County, Maryland has developed procedures for including these factors into its traffic models.

2. Travel only occurs on the interzonal network: It is assumed that all trips begin and end at a single point in a zone (the centroid) and occur only on the links included in the network. Not all streets are included in the network nor all possible trip beginning and end points. The zone/network system is a simplification of reality and excludes some travel, especially shorter trips.

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.

Improvement: Add a certain percentage of off-network travel to assignment results for air pollution analysis and to capture pedestrian trips which tend to happen within zones. Adjust link and intersection capacities to reflect the difference between densely interconnected neo-traditional grid systems and "dead worm" collector-arterial networks. Walter Kulash, a traffic engineer with Glatting Jackson in Orlando, Florida, has written several papers analyzing these effects. (See list of References, page 49.)

Trip Assignment Issues

- **Intersection delays ignored**
- **No intrazonal trips assigned**
- **Capacities over-simplified**
- **Time of day ignored**
- **Peak hour over-emphasized**

3. Capacities are over-simplified: Determining the capacity of roadways and transit systems requires a complex process of calculations that consider many factors. In most travel forecasts this is greatly over-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 other factors such as truck movement, highway geometry, turning movements at intersections, and other factors affecting capacity in their calculations.

Improvement: Add additional factors to the equations estimating capacity.

4. Time of day variations are ignored: 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 an "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 forecast on a network.

Improvement: Use time of day factors. 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. Hourly conversion factors need to be looked at very carefully to insure that they represent actual variations in traffic. Peaking of travel is often greater in lower density, homogeneous auto-dependent suburban areas than in higher density, mixed-use centers. Models should be adjusted for these effects using available data on employment density and measures of land use mix.

5. Peak hour travel is overemphasized: As described above, forecasts are done for the peak hour on a typical weekday while most of the day is ignored. 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, i.e. peak spreading, is not determined. As congestion increases, drivers avoid the peak period, reducing peak period congestion and spreading trips over a longer time period. In addition, travel forecasts are made for an "average weekday." Variation in travel by time of year or day of the week are usually not considered.

> ***Improvement:*** Calculate and present the forecasts for different hours of the day and base decisions regarding different transportation alternatives on more than just the peak period and average weekday.

Forecast of Transportation Effects on Land Use

Transportation Effects On Land Use

It is a cliche today to say that land use and transportation are highly interrelated, parts of a so-called "chicken or egg" conundrum, both affecting each other. However, the typical planning process confines itself to using its land use plan to determine its transportation plan—that is, what facilities are necessary to serve the planned increase in land use development. In fact, new transportation facilities have an independent and major effect on land use themselves. This effect is called "facility-induced development." That is, by increasing access to relatively more remote areas new highways can create market conditions that generate sprawling new developments where they would not otherwise occur. Conversely, with proper planning, new rail transit can generate more compact and efficient land use development than would otherwise occur. Moreover, even when a new highway is "fitted" with more dispersed development, the actual effect of the new highway might be to create a different pattern of development than that set out in the land use plan.

Will that new highway generate development that ignores your land use plan?

In short, it is very important to take steps to close the loop of the forecasting process to enable a better representation of the interaction of land development and the transportation system. Land use simulation models or expert panel techniques should be added to the sequence of models to help to determine how a proposed transportation system will lead to land use changes. In such an analysis, overall regional growth in population, households, and employment must be allocated to specific locations. This land use allocation can be done either through a judgement technique or through a modeling process.

Land Use Models

Real estate development and location decisions made by investors, employers, and households are greatly influenced by a proposed development's transportation access to jobs, shopping, or amenities. However, exactly how transportation access influences development decisions is quite complex. Adequate models of this influence need to account for the long-term changes in accessibility, cost, and amenity of travel by all available modes, not merely the automobile.

Moreover, they must incorporate the dynamics of real estate markets, and the effects of zoning and the quality of governance and public services (e.g. schools) on consumer and investor choices. Unfortunately, most of the land use models in use today cannot meet these tests.

There is ample evidence that unless an area in the periphery is just not developing for reasons other than transportation access, new highway development will have a significant effect on an area's growth patterns. The highway expansion will either redistribute growth that would have occurred elsewhere in the region, or stimulates productivity gains that result in new growth, or both. Most new highway capacity will eventually foster automobile-oriented development in the areas where the relative cost of travel is reduced by the new capacity. And increased emissions due to this highway investment may break an emissions budget or work against attainment and maintenance of federal health standards for air pollutants.

Evidence from Europe and cities with rail transit indicates that economic growth can occur while restraining highway improvements if an area invests in transit and other forms of transportation.

It is important to note here that substantial economic growth need not always be accompanied by proportional growth in traffic. Restrained investment in highways accompanied by enhancements of pedestrian, bicycle, and transit access, economic incentives encouraging alternatives to the automobile, and supportive land use policies have resulted in slower growth of traffic despite rising motorization and dramatic economic growth in many European and Asian metropolitan areas. Similarly, investments in non-auto capacity such as light rail have stimulated considerable economic investment in many American cities.

Unfortunately, while the land use forecasting models in use by MPOs in roughly two dozen regions can be used to help indicate the likely effects of changes in highway capacity, they cannot adequately gauge the effects of many types of alternative investments and policies. The existing models—mostly based on DRAM/EMPAL or ITLUP software—in many cases probably underestimate the likely change in region-wide locations of employment and households in metropolitan areas.

There are several reasons for these shortcomings. Most of these land use models were calibrated on very short time-series data, often 1980-85 or 1985-90, when substantial "hot" savings and loan money was diverted into highly speculative

Expert panels can complement or substitute for land models that remain crude.

and often non-economically viable real estate development. That is, the actual location and level of development during these years was often driven by factors different than those that prevail today and hence this time period's growth pattern is a poor predictor of future growth. Use of longer time series data would improve these models greatly, especially if they are to be used for long-range forecasting. The models used in the U.S. have mostly failed to represent land and rent values, the variable quality of key public services (education, public safety), and the potential for mix-used cluster development around nodes of high public transportation accessibility. Moreover, the results of model evaluations have usually been based on external constraints related to zoning and limitations on redevelopment, giving little room for differences between transportation investment scenarios to express themselves.

Clearly, more sophisticated land use forecasting models based on Geographic Information Systems (GIS) and better accounting for real estate market forces need to be developed. In fact, as this is being written (1996) efforts to develop and apply better models are underway. These include TRANUS, now being applied in California's Sacramento region, the California Urban Futures Model (CUFM), developed at the University of California, Berkeley, HLFM, the highway land use forecasting model developed by AJH Associates, and several other software packages. So, stay alert for important new modeling developments!

Regional Consensus and Planner Judgement Approaches

Given the problems with quantitative models, many regions use regional consensus processes to develop fixed land use forecasts that allocate jobs, households, labor force, and population to specific locations. Within the context of national and regional forecasts, the allocation of households and other characteristics to specific transportation planning zones is often done by mechanical allocation, growth factor models, or by using the judgement of planning staff to account for zoning constraints, the expressed interest of large land owners, political factors, and other variables. Important as well are the imaginations of local planners, elected officials, and development interests. The quality of these forecasts can vary widely.

It is often useful to look back at the changes between forecasts, noting what has been increased, what has decreased, and the rationale cited for these changes. A regional recession can set back the pace of job and housing growth

Tips for Advocates of an Improved Model

1. **Ozone Nonattainment Areas:** In "Severe Nonattainment" areas for ozone pollution under the Clean Air Act, make sure that your MPO's modeling meets the requirements specified by the transportation conformity rules for the Clean Air Act.

   NOTE: In spring 1996, EPA proposed to replace the requirements for transportation modeling in the CAA Transportation Conformity Rule that now apply to serious and severe non-attainment areas with weak and unenforceable guidance from the Federal Highway Administration (FHWA). Write to Margo Oge, Director, Office of Mobile Sources, USEPA (ANR-455, 401 M St. SW, Washington, DC 20460) requesting that enforceable modeling requirements be kept in the regulations to avoid years more delay in developing adequate MPO transportation models. For more information on the specific federal rule-making, contact Michael Replogle, the Environmental Defense Fund (EDF) at (202) 387-3500.

2. **Federal Model Guidance:** Write to your Governor and state air agency (e.g. DNR) requesting that their State Implementation Plan (SIP) for air quality attainment include modeling requirements drawn from the guidance issued by the Task Force on Transportation and the Environment (Ask for: A Citizen's Guide to Effective State Air Quality Planning for Transportation, TFTE, September 1994, 56 pg., $5 from EDF, 1875 Connecticut Ave. NW Wash, DC 20009). Many states have yet to submit or adopt these required plans as of 1996 and some already submitted plans will be undergoing revision. Find out the status of your plan and work to strengthen it.

3. **Public Acknowledgement of Model Problems:** Make sure that your MPO publicly acknowledges the shortcomings of its model, particularly with respect to sensitivity to alternative transportation policies, and that it adopts short-term measures and long-term plans to address these issues.

Support enforceable federal guidelines for modeling.

Does your model check the land use effects of different transportation alternatives?

4. **Short and Long Term Model Improvement Plan:** Urge your MPO—using the MPO certification process if necessary—to develop a detailed transportation modeling improvement plan.

   This plan should be divided into short term and long term improvements. Short term steps to improve your community's model might include:

   - Incorporate redevelopment in existing urban areas.
   - Use an expert panel to forecast the land use effects of potential transportation facilities.
   - Incorporate the effects of congestion on trip generation, distribution, mode split, and land use patterns.
   - Subject all trips, not just commuter trips, to mode split analysis.
   - Don't rely soley on congestion forecast for peak periods. Use time of day factors.

   Funding Note: ISTEA planning and ISTEA Capital funding in the STP, CMAQ, and NHS programs can be flexed to support this activity.

5. **Better Land Use Allocation Methods:** Urge your MPO to use an expert panel and to work on developing better methods for land use allocation to help forecast how the real estate market would respond to different transportation alternatives. This should occur early enough in the planning process to provide feedback on how alternative land use plans or scenarios should be modified to reflect the influence of different transportation alternatives.

6. **Supplemental Analysis:** Urge your MPO to do supplemental analyses using existing studies such as the LUTRAQ project and sketch planning techniques for estimating the impact of travel demand management (TDM) measures. EDF has adapted LUTRAQ's Pedestrian Environment Factor to a pivot point spreadsheet model that can quickly adjust regional travel demand models to make them sensitive to changes in pedestrian and bicycle friendliness. This model was demonstrated in the Washington DC region. Contact EDF at (202) 387-3500 for more information.

7. **Local Experts:** Seek the assistance of local experts from outside the planning agency such as university professors who are interested in model improvements and in improved local planning.

8. **In General, Participate:** Question the assumptions and the forecasts from your area's models if they don't make good sense to you and for your community. Make public participation real by working at it with patience and persistence.

Glossary

Glossary

Arterial: A roadway serving major traffic movements that carries more traffic at typically higher speeds than local roads and collectors but lower volumes and speeds than expressways and limited access highways.

Calibrate: To check a model for how well it's assumptions, constants, variables, and values fit a specific local system and predicts current conditions. This step necessarily precedes any forecasting.

Centroid: The presumed locus of activity and actual point of trip production or attraction in the center of a traffic analysis zone (TAZ), regardless of whether or not TAZ activity is actually generated there.

Collector: An urban street that provides access within neighborhoods and commercial areas and which channels traffic to and from local roads and arterials.

Disutility: A model variable that represents a combination of the travel time, cost, and convenience of a transportation mode between an origin and a destination.

DRAM/EMPAL: Direct Residential Allocation Model and Employment Allocation. A computer software package that quantitatively models the effect of transportation (with respect to access and location) on land use development.

EIS: Environmental Impact Statement. Note: the DEIS is the Draft EIS. If a DEIS falls short on evaluating meaningful alternative strategies, ask the sponsor to develop an SEIS—that is, a Supplemental EIS—prior to issuing the Final EIS.

Equilibrium: The relatively steady-state condition of a model. In the traffic assignment step of the four step process it is when any further route changes by a traveller would increase his/her travel time.

Facility-Induced Travel (or Development): Travel or development (and consequent secondary travel effects) that results from a reduced transportation price or increased capacity in the transportation system, typically a new road, expanded road, or transit facility.

Gravity model: A trip distribution model that predicts that the trips produced at one zone will be distributed 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.

HLFM: An integrated land use and travel demand model that modifies land use patterns along with providing a travel supply/demand equilibrium.

Home-based, non-home-based trip: Home-based trips are those that originate or end at home. Non-home-based trips are those that originate at work or some location other than home.

Interzonal, intrazonal: Interzonal trips or other events occur between TAZs while intrazonal events occur within them.

ISTEA: Intermodal Surface Transportation Efficiency Act of 1991. The Act created new planning requirements and provided for increased funding flexibility for alternative modes of transportation.

Iteration: To run the model again using new information, typically output from an earlier run or step of the model.

ITLUP: Integrated Transportation-Land Use Planning. A computer software package that quantitatively models the effect of transportation (with respect to access and location) on land use development.

Link: A segment of a transportation system ending at a transportation node at each end with a specified distance, capacity, and other attributes.

Linked vs. unlinked trips: A linked trip combines trips to two or more different destinations. For example, a trip home from work with an intermediary stop at a store would be considered one linked trip. A trip by car from home to a park-n-ride and then by bus to work is a linked trip that would typically be assigned to transit in a traffic forecast, the car trip being ignored.

(Nested) Logit Model: A representation of the structure of relationships between travel choices an individual makes based on empirical data that provides the basis for predicting the number of trips that will be made on each mode. A nested logit is used for travel choices that have important similarities, e.g. bus and light rail transit.

Logsum variable: Here, an accessibility variable that can represent the composite costs associated with a trip for various modes of travel. This variable can represent not only in-vehicle travel time but also out-of-vehicle time and costs, a major issue for transit/pedestrian trips that corresponds to the higher transit ridership rates for origins and destinations that are pedestrian-friendly.

Network: The system of roadways and other modal links that connects trips that have an origin in one traffic analysis zone and a destination in another zone. Trips which occur entirely within a zone do not appear on the network.

Microsimulation: A simulation of transportation demand using a model based on the behavior and attitudes of individuals and/or households. This term is also sometimes applied to a simulation of individual vehicles in a traffic system.

MIS: Major Transportation Investment Study: A study of the multimodal alternatives and impacts of any major change in a transportation system as required under ISTEA regulations. Formerly, an "alternatives analysis" was only required for transit projects.

Mode bias factor: A factor in a disutility calculation used to represent other characteristics or travel modes which may influence the choice of mode (such as a difference in privacy and 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. Often, the disutility equations do not recognize differences within travel modes, for example, a bus system and a rail transit system.

Mode split: The division of all trips in a system according to the method of travel—typically, for example: private motor vehicles (trucks/freight, drive-alone automobiles, automobile passengers, car pools), transit (express buses, local buses, intraurban rail transit, interurban rail transit), rail (passenger and freight), bicycling, and pedestrian.

MPO: Metropolitan Planning Organization, as recognized by the federal government under ISTEA, with the authority to distribute certain federal transportation funds and perform various planning duties. Typically the MPO is the regional planning commission.

Node: A specific point in a transportation system that locates an activity center and/or connection to other links, routes, or points in the system. The attributes of a link typically change in some significant way at a node.

Non-attainment area: An area designated by the EPA and federal law under the Clean Air Act that does not meet federal pollution standards. Non-attainment areas can cover one or often more metropolitan areas and counties and can stretch across state lines, for example, the Lake Michigan basin including Milwaukee, Chicago, Detroit, and many other counties and smaller jurisdictions.

O-D: Refers to information about the number of area trips going to and from origins and destinations.

"P's" and "A's": Attractors (or Attractions) and Producers (or Productions) of trips from a traffic analysis zone. For example, an attractor might be a shopping center that attracted shopping trips as well as work trips by those employed at the center's stores. A producer could be a particular residential neighborhood that produced trips for various purposes.

PEF: Pedestrian Environmental Factor: A measure of pedestrian friendliness used to predict the number of pedestrian trips in a mode split analysis. First used by Portland, OR in its LUTRAQ study that was recently extended as a Pedestrian/Bicycle Environment Factor (PBEF) in a Washington DC model application.

Pivot point analysis: A technique that can be used when there are only a few changes in the transportation system and when existing usage patterns are known. Pivot point analysis is used to see how much travel demand will change from current conditions. For example, a rule of thumb that is sometimes used is that transit ridership will decrease 3% with a 10% increase in transit fares, with all other factors held constant. It is possible to find similar values (elasticities) for other changes in the system from a standard logit mode split model.

Sketch planning: A method of approximately estimating the travel aspects of a transportation project, used typically to screen projects for more detailed modeling later.

Does your regional TIP really implement the non-highway part of your long range plan?

STEP model: A microsimulation computer program used in air quality and energy analyses and various parts of California to analyze the effects of transportation control measures (TCMs) and of pricing changes on equity. The STEP model is based on individual and household behavior as represented by eight factors, including auto ownership, work trip mode choice, and the frequencies of various trip purposes such as social/recreational trips.

TAZ: Traffic Analysis Zone, a small geographic area that serves as the primary unit of analysis in a travel forecast model.

TCM: Transportation Control Measure—any step, including TDMs, that can be taken to change travel in an area to reduce emissions or any other impacts, especially by reducing travel.

TDM: Travel Demand Management—any step that can be taken to reduce the amount of travel in an area or to and from a particular activity center. TDMs include carpooling, transit, and congestion pricing.

TIP: Transportation Improvement Program—the annualized budget for three or more years drawn up by an MPO for its transportation expenditures. All projects in a TIP must also be in an MPO's Long Range Plan.

Travel Time Skim: The estimation of origin-destination travel times (or other generalized costs) on a network. Used for travel behavior modeling as well as some types of route choice analysis.

Trip chaining: To combine more than one destination into a longer "tour," for example a trip from home to the store and then to work. The models used in many areas do not deal very well with trip chaining.

Trip producer, attractor: Trip producers (Ps) are the points at which a trip originates while attractors (As) are the points where they end.

UTPS: Urban Transportation Planning System. An older mainframe transportation modeling system no longer maintained but which is still being used by some MPOs and state DOTs.

VHT: Vehicle hours travelled.

VMT: Vehicle miles travelled.

References for Further Information

References

The following select list of references is divided into four categories: (1) information about alternative transportation and pedestrian/transit-friendly design, (2) modeling issues, (3) agencies and organizations, and (4) web sites with information.

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Modeling issues

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Agencies and organizations with more information

US DOT Travel Model Improvement Program (TMIP): Contact Kimberly Fisher, Texas Transportation Institute c/o FHWA, 400 7th St. SW, HEP 22–Rm 3232, Washington DC 20590, kifisher@intergate.dot.gov, (202) 366-4054 Fax 366-3713.

TMIP is a research, technical assistance and outreach program of US DOT in cooperation with US EPA and the US Department of Energy, established to respond to the requirements of the Clean Air Act Amendments and ISTEA. The goals of the program are to improve travel forecasting procedures—with particular attention to the linkage of transportation to air quality, energy, economic growth, land use, and overall quality of life—and to integrate these improved techniques into regional and state decision-making processes.

TMIP activities include: training and outreach, research and development of improvements in transportation and land use modeling and data collection procedures; and operation of an information clearinghouse and electronic bulletin board (web site). TMIP also publishes a regular newsletter. To receive the newsletter contact Lynette Engelke, Texas Transportation Institute, 1600 E. Lamar Blvd., Suite 112, Arlington TX 76011 or Fax (817) 277-5439.

Center for Livable Communities: A Local Government Commission Initiative, 1414 K St. #250, Sacramento CA 95184, (916) 448-1198, Fax 448-8246, Center Hotline: (800) 290-9202. Publishes educational materials, holds conferences, and offers advice on pedestrian- and transit-oriented land use design and community participation.

US EPA, Guidance on the Use of Market Mechanisms to Reduce Transportation Emissions: Contact William Schroeer, 401 1414 M St. SW, PM-221, Washington DC 20000, (202) 260-1126, Schroeer.William@epamail.epa.gov. This office provides technical guidance on how cities and states proposing to harness market forces to reduce transportation emissions should conduct analyses for State Implementation Plan (SIP) credit. Guidance document applies to five TCMs: parking pricing, modal subsidies, at-the-pump charges, emissions fees, and roadway pricing. Chapters 1 and 2 provide an introduction and overview on measures and analytical issues. Chapters 3 and the two appendices provide more technical information for the practitioner while Chapter 4 discusses implementation.

The National Bicycle and Pedestrian Clearinghouse (NBPC): 1506 21st St. NW, Suite 210, Washington DC 20046, nbpc@access.digex.net, (202) 463-8405, (800) 760 NBPC toll free, Fax (202) 463-6625. NBPC is a central point of contact for federal, state, and local agency staff, organizations, and other professionals on bicycle and pedestrian programs and issues. The clearinghouse distributes educational materials and US DOT studies, provides technical service on a broad range of topics and serves as a referral service.

University of California Center: 108 Naval Architecture Building, Berkeley, 94720-1720, (510) 643-5454 Fax 643-5456, access@uclink.berkeley,edu. The UCTC publishes a free quarterly newsletter *Access* which covers a wide array of land use and transportation issues and lists UCTC research papers that can be ordered (with one copy provided free of charge).

US DOT, Technology Sharing Program: 400 Seventh St., SW, Washington DC 20590 (202) 366-4208. Reprints significant federal and non-federal research reports and studies.

Web sites with more information

Comprehensive directory of transportation related web sites: http://dragon.princeton.edu/~dhb/index.html.

List of State Department of Transportations: http://www.nas.edu/trb/directory/states.html.

National Transportation Library of the Bureau of Transportation Statistics (BTS) of the US DOT: http://www.bts.gov/smart.html for many documents. BTS also has a list of lists at http://www.bts.gov/smart/links/transportation.html.

Technology Sharing Program, US DOT: http://199.103.189.2531. Catalogues of the office reports.

Travel Model Improvement Program (TMIP): http://tmip.tamu.edu. TMIP provides four basic services: a travel demand forecasting (TDF) clearinghouse; TMIP information, including the text of all TMIP documents; a TDF course listing; and electronic access (email) to TMIP staff.

University of Wisconsin Milwaukee Center for Urban Transportation Studies: http://www.uwm.edu/Dept/CUTS. CUTS has a list of other links at http://www.uwm.edu/Dept.CUTS/booklast.htm.

Videos about pedestrian-and transit-friendly development

1. Back to the Future: Designs for Walkable Neighborhoods
Produced by Citizens for a Better Environment, 152 W. Wisconsin Ave., #510, Milwaukee, WI 53203, (414) 271-7280. Targeted to local elected officials, planning commissioners, and a general audience. Provides an introduction to key design concepts of pedestrian-friendly development, such as mixed-use, compact, pedestrian-oriented site design, and traditional neighborhood street design. Uses examples from communities in Wisconsin and Illinois. (20 minutes)

2. Cities in the Balance
Produced by the San Diego Metropolitan Development Board, 1255 Imperial Ave., #1000, San Diego, CA 92101-7490, (619) 557-4533. Illustrates the relationship between transit and land use, and ways to make transit, bicycling, and walking more attractive. Draws on examples from throughout the U.S. (24 minutes)

3. What is an Urban Center?
Produced by the Snohomish County (WA) Transit Agency (SNO-TRAN), 1133 164th Street, S.W., Suite 102, Lynnwood, WA 98037. Explains and illustrates the concept of mixed use centers, including traditional downtowns and neighborhood commercial centers. Uses area examples. (8 minutes)

4. Transportation Choices by Design
Produced by the Snohomish County (WA) Transit Agency (SNO-TRAN), 1133 164th Street, S.W., Suite 102, Lynnwood, WA 98037. Targeted to developers and local officials, the video introduces ways to integrate development with public transit. (12 minutes)

5. Other Videos:
Contact the Center for Livable Communities, a project of the Local Government Commission (LGC). The Publications Department of the LGC has a brochure listing available videos on land use and transportation issues (916) 448-1198, 1414 K Street, Suite 250, Sacramento, CA 95814.

Consultants and Others with More Information

The following list of designers, modelers, planners, and analysts—most of whom are professional consultants—can help you with alternative transportation projects, with pedestrian-, bicycle-, and transit-oriented neighborhood planning and designs, and with transportation modeling that is sensitive to alternative transportation and land use policies. It is divided into three categories: (1) planning and designs, (3) modeling, and (3) new modeling software. Note: These groupings are not exclusive nor are the descriptions necessarily exhaustive. The list is based partly on the information compiled by the Sierra Club's John Holtzclaw in San Francisco and his list can can be found in updated form on the web at: http//www.sierraclub.org / misc / planners.html.[1]

Pedestrian-, bicycle-, and transit-oriented planning and designs

Beach, Dana, South Carolina Coastal Conservation League: P.O. Box 1765, Charleston SC 29402, (803) 723-8035.

Burden, Dan, Florida DOT: dburden@aol.com, (904) 878-2042 Fax 878-2041. Pedestrian- and bicycle-oriented design.

Calthorpe Associates, Shelley Potiche: 739 Allston Way, Berkeley CA 94710, (510) 548-6800 Fax 548-6848. Pedestrian- and transit-oriented design.

Cervero, Bob: University of California Transportation Center, Department of City and Regional Planning, 228 Wurster Hall, MC 1850, University of California, Berkeley CA 94720, rob@ced.berkeley.edu (510) 642-1695 Fax 643-9576. Transit- and pedestrian-oriented development.

Charlier, Jim: 1881 9th St. #321, Boulder CO 80302, (303) 449-1903 Fax 449-7135. Land use and transportation planning, analysis, TDMs.

Conseils, Velo, The Bicycle Consultants: 3575 Boul. Saint-Laurent #310, Montreal, Que, Canada H2X 2T7, (514) 847-8356 Fax 847-0242. Bicycle planning and analysis.

[1]John Holtzclaw, john.holtzclaw@sierraclub.org; 415-923-5534, Fax 776-0350. Please contact him with additions or corrections, or to obtain the most recent version.

Criterion, Eliot Allen: 5331 SW MacAdam Ave. #205, Portland OR 97201, crit@rain.com (503) 224-8606 Fax 224-8702. Planning/engineering, especially modeling integrated resource efficiencies, including land use, transportation, energy, water, wastes and pollutants. Markets INDEX, a desktop GIS model for measuring urban livability.

Design, Community & Environment, David Early: 2157 Vine St., Berkeley CA 94709, dcearly@aol.com, (510) 848-3815 Fax 848-4315. Sustainable development in urban design, environmental assessment and transportation, including bicycle plans and land use strategies to reduce auto trips.

Dover, Kohl & Partners, Victor Dover: 5879 Sunset Dr. #1, South Miami FL 33143. (805) 545-5919. Traffic calming, transit planning, critique of EIS/transportation analyses, alternative transport/land use planning, European (Swiss) transport concepts, traffic reduction for resorts/towns.

ECO Northwest, Moore, Terry: 99 W. 10th St. Suite 400, Eugene OR 97401, (541) 687-0051 Fax 344-0562. Growth management and land use-transportation interactions and planning.

Fehr & Peers Associates, Mike Jones: 3685 Mt. Diable Bl. #200, Lafayette CA 94549, (510) 284-3200 Fax 284-2691. Bicycle planning and transit-oriented land use design.

Ferguson, Eric, P.O. Box 8889729, Dunwoody, GA 30356, (770) 454-6342 Fax 454-6342, etferguson@aol.com.

Gladding Jackson, Walter Kulash and Tim Jackson: 33 E. Pine St. Orlando FL 32801, (407) 843-6552 Fax 839-1789. Neo-traditional neighborhood traffic planning, alternative transportation plan analysis and engineering.

Hoffman, William, Laffen & Fletcher, Peter Laffen: 8630 Fenton St. #910, Silver Spring, MD 20910, (301) 439-9681 Fax 589-9455. Bicycle, pedestrian, and community planning, railroad planning.

Integrated Transport Planning, Paul Pazetta: Chester Heights, PA (610) 558-2025 Fax 459-1981. TDM planning and analysis, modeling, road privatization.

JHK Associates, Deborah Degang and Steve Smith: 2000 Powell St., Emeryville CA 94608, (510) 428-2550 Fax 655-5730 and Riverside CA, (714) 274-0394.

TDMs, traffic analysis, transportation planning, including land use strategies to reduce auto trips.

Jud, Eugene: 1228 A Palm St. PO Box 1145, San Luis Obispo, CA 93406, ejud@calpoly.edu, http://www.slonet.org/~canderso/jud.html, (805) 545-5919.

Kennedy, Rob, New Transportation Alliance: 511 S. Baldwin St., Madison, WI 53703, robkennedy@igc.apc.org, 511 S. Baldwin St. Madison, WI 53703 Phone/Fax (608) 251-9164. Advice on alternative transportation and land use planning, modeling, policy development and organizing.

Kent, Fred, Project for Public Spaces: 153 Waverly, New York NY 10014, (212) 620-5660. Design of buildings, streets, walks, and areas to enhance pedestrian activity.

Komanoff Energy Associates, Charles Komanoff: 270 Lafayette #400 New York NY 10012, kea@igc.apc.org, (212) 334-9767 Fax 925-2151. Pedestrian and bicycle planning, analysis of auto subsidies, energy consumption and air pollution.

Konheim & Ketcham, Carol Konheim and Brian Ketcham: 175 Pacific, Brooklyn, NY 11201, (718) 330-0550 Fax 718-330-0582. Transportation analysis/planning, IVHS/ITS, GIS, critique of transport projects/plans.

Lennard, Henry & Suzzane: Atherton Drive, Carmel CA 93921, (408) 626-9080. Liveable cities planning and seminars.

Michael Baker Inc., Phillip Shucet: 770 Lynnhaven Pkwy.#210, Virginia Beach, VA 23452, (804) 431-0049 Fax 431-0812. Intelligent Vehicle Highway Systems/ITS and Environment.

Moudon, Anne Vernez: University of Washington, 410 Gould Hall, JO-40, Seattle WA 98195, moudon@u.Washington.edu, (206) 543-5996 Fax 206-543-2463. Research, analysis, and planning of pedestrian-, transit-oriented areas.

Neimeier, Debbie: University of California-Davis, (916) 752-8918. Non-motorized transport planning and analysis.

Nelessen Associates, Tom Phillips and Anton Nelessen: 909 State Rd., Princeton NJ 08540, (609) 497-0104 Fax 497-0105, 101 Steuart #200, Seattle WA 98101, (206) 441-7579 Fax 447-8194. Uses Visual Preference Survey to help design local areas.

O'Neill, Wendy: Utah State University, Department of Civil and Environmental Engineering, Logan, UT 84322, (801) 750-2932. Geographic information systems.

Oberdoffer, Jeff: 303 Potrero St. #29-306, Santa Cruz, CA 95060, (408) 423-5263. Alternative pedestrian-, bicycle-, and transit-friendly community designer.

Risse, Ed, Synergy Planning, Inc.: 12501 N. Lake, #100, Fairfax, VA 22033, (703) 968-4300 Fax 703-968-4304. Land use planning, telework/telecommuting, TDM/urban design strategies.

Rivkin, Malcom: 7508 Wisconsin Ave., Bethesda MD 20814, (301) 656-5155 Fax 656-3441. Land use planning, transportation analysis.

Ryan, Kathleen: 274 Maple St., Burlington, VT 05401, (802) 863-4091. Landscape architecture, traffic calming.

S & G Associates, Speilburg, Frank: 4200 Daniels Ave., Annandale, VA 22003, (703) 750-3363 Fax 750-3367. Traffic modeling, analysis, planning.

Schaefer, Bill, Citizens for a Better Environment: 647 W. Virginia, Milwaukee, WI 53204, cbebschaef@igc.apc.org, (414) 271-7280 Fax 271-5904. Advice on alternative transportation and land use planning, modeling, policy development and organizing.

Schroeer, Will, US Environmental Protection Agency: Washington DC, (202) 260-1126. Information about market-based TDMs. (See US EPA, Guidance in Agencies and Organizations with more information.)

Shoup, Donald: UCLA-GSAUP, 405 Hilgard Ave., Los Angeles, CA 90024, (310) 825-5705. Parking management and pricing strategies, TDM analysis.

Sperling, Dan: University of California-Davis, Institute of Transportation Studies, Davis, CA, (916) 752-7434 Fax (916) 752-6572. ITS/IVHS and environment, electric vehicles, subcars, planning and analysis.

Vermont Grass Routes: 98 Sleepy Hollow Rd., Essex Jct. VT 05452, vgr@together.org (802) 899-1132 Fax 899-2430. Neighborhood empowerment, video production, video resource list.

Zupan, Jeff, Regional Plan Association: 570 Lexington Ave., New York NY 10022, (212) 980-8530 Fax 212-980-8632. TDMs, Planning, analysis, and project management.

Modeling, analysis, and computer simulation

1,000 Friends of Oregon, Keith Bartholomew and Robert Liberty: 534 SW Third #300, Portland OR 97204, kab@friends.org, (503) 223-4396 Fax 223-0073. Advice on modeling land use and transportation plans, familiar with LUTRAQ and light rail in Portland.

Adler, Tom, Resource Systems Group, Inc.: 76 Olcott Dr., White River Junction, VT 05001-2313, tadler@rsginc.com (802) 649-1999 Fax 295-1006.

Beimborn, Edward: Center for Urban Transportation Studies, School of Engineering, University of Wisconsin, P.O. Box 784, Milwaukee WI 53201, beimborn@earth.execpc.com, (414) 229-4978 Fax 229-6958. Transportation modeling and pedestrian and transit-oriented designs.

Bruun, Eric: 4239 Baltimore Ave #5, Philadelphia PA 19104, ebruun@eniac.seas.upenn.edu, (215) 386-9424. Design and critique of transportation plans, transit ITS.

Cambridge Systematics, Inc., Tom Rossi, Steve Pickrell, and Bob Stanley: (Stanley) 5225 Wisconsin Ave. NW #409, Washington DC 20015, (202) 466-5542 Fax 466-5548; (Rossi) 150 Cambridge Park Dr., Suite 4000, Cambridge, MA 02140, (617) 354-0167, and (Pickrell) San Francisco, (510) 873-8700. Transportation modeling of TDMs, transit-oriented development, and related issues.

David Dilworth: P.O. Box 100, Carmel CA 93921, david.dilworth@sierraclub.org (408) 624-6500. EIR/EIS & computer model critiques, strategy.

Deakin Harvey Skarbodonis, Greig Harvey: P.O. Box 9156, Berkeley CA 94709, eadtra@dante.lbl.gov, (510) 841-0438 Fax 841-2024. Transportation modeling and analysis of TCMs.

Douglas, Bruce, Parson, Brinkerhoff, Quade and Douglas: 460 Spring Park Place, Herndon VA 22070, douglas@pbworld.com, (703) 742-5872 Fax 742-5800.

Federal Highway Administration, Patrick DeCorla-Souza: Federal Highway Administration, Planning Support Branch, HEP-22, 400 Seventh Street SW, Room 3301, Washington DC 20509, (202) 366-4076. Technical assistance to regional and state transportation planners, least cost planning, cost-benefit analysis, and multimodal evaluation.

Ferguson, Eric: Georgia Institute of Technology, (404) 853-9843. Transportation modeling/analysis.

Frank, Larry: College of Architecture, Georgia Institute of Technology, Atlanta GA 30332-0155, larry.frank@arch.gatech.edu, (404) 894-6488 Fax 894-1628. Analysis of transportation-land use interactions.

Genesis Group, Michael Wallwork: 8380 Baymeadows Rd # 16, Jacksonville FL 32256, wallwork@ixnetcom.com, (904) 730-9360 Fax 730-7165.

Haikalis, George, Auto Free NY: (212) 475-3394. Transit analysis, design and planning.

Hanson, Mark, Resource Management Associates: Madison, WI (608) 283-3880 Fax 608-283-2881. Energy and transportation cost analysis and planning.

Holtzclaw, John, Sierra Club: 1508 Taylor, San Francisco CA 94133, john.holtzclaw@sierraclub.org, (415) 928-8332 Fax 776-0350, (977) 5799 after 9:00 PM. Transportation-land use interactions, social and economic impacts.

Horowitz, Alan, AJH Associates: 4845 N. Newhall St., Milwaukee, WI 53217, horowitz@csd.umm.edu, (414) 963-8686 Fax: 963-0686. Modeling and licensed software.

Irwin, Neal, IBI Group: 230 Richmond St. W 5th Floor, Toronto, Ontario M5V 1V6. Long range alternative transportation and land use planning and analysis.

Johnston, Bob: Environmental Studies, University of California, Davis, rajohnston@ucdavis.edu; 5652 Alder Creek Rd., Truckee CA 96161 (916) 582-0700, (916) 582-0700 Fax 582-0707. Land use-transportation modeling, transportation demand management analysis.

Konheim & Ketcham, Brian Ketcham & Carol Konheim: Brooklyn, NY 11201, (718) 330-0550 Fax 330-0582. Transportation modeling, especially in light of IVHS/ITS, and GIS.

KPMG Peat Marwick, Jeff Bruggeman: 8200 Greensborough, McLean, VA 22102, (703) 442-0030 Fax 556-0195.

Litman, Todd, Victoria Transport Policy Institute: 1250 Rudlin St., Victoria, BC V8V 3R7 Canada, ur698@freenet.victoria.bc.ca, tel/fax: 604-360-1560. Transport cost analysis, TDMs, bicycle and pedestrian planning and analysis, EIS, public involvement, land use-transport interaction.

Mehra, Joe, MCV Associates: 1071 Spring Hill Rd., McLean VA 22102, (703) 356-7235 Fax 448-7487. Traffic impact studies and conventional highway modeling software applications.

Parsons Brinkerhof Quade and Douglas, Bruce Douglas and Sam Seskin: (Douglas) 400 SW 6 Av #802, Washington DC, (703) 478-3127; (Seskin) 400 SW 6th Ave., Portland OR 97204, seskin@pb.com, (503) 274-9554 Fax 274-1412. Computer modeling of land use and transportation.

Pivo, Gary: Dept of Urban Design and Planning, University of Washington, P.O. Box 355740, Seattle WA 98195-5740, garypivo@u.Washington.edu, (206) 543-2343 Fax 685-9597. Analysis of transportation-land use interactions.

Pratt, Richard: 11112 Rokeby Ave.,P.O. Box 158, Garrett Park, MD 20896 (301) 933-0400 Fax 301-933-0608. HOV strategies, TDM analysis, land use-transport planning.

Replogle, Michael, and Spreck Rosecrans, Environmental Defense Fund: (Replogle) 1875 Connecticut Avenue NW Washington, DC 20009, email: michaelr@edf.org, (202) 387-3500 Fax: 234-6049. Advice on market pricing strategies, pedestrian, bicycle, and transit design and land use-transportation modeling. (Rosecrans) 5655 College Oakland CA 94618 (510) 658-8008 Fax 658-0630. Transportation control measures, e.g. gas taxes, tolls, congestion pricing.

Resource Decision Consultants, Clarisse Lula and Mark Bradley, (718) 768-3485. Transportation analysis and project management.

Stevens, Ann: 389 Alcatraz Ave., Oakland CA, (510) 655-5687, UC Berkeley graduate student familiar with transportation demand analysis.

Stopher, Peter: Dept of Environmental and Civil Engineering, Louisiana State University, Baton Rouge, LA 70803, (504) 388-8898 Fax 504-388-8652. Transportation modeling, critiques, analysis, survey methods, model development.

Van Landingham, Rick: 1312 Paxton St., The Buckeye Basin, Toledo OH 43608, rick.vanlandingham@sierraclub.org, (419) 666-5291. Transportation-land use planning and modeling, including wetlands, with emphasis on regulations and historic preservation.

Transportation modeling software vendors:

There are numerous transportation modeling software packages available in the US. Three with multimodal and graphics capabilities are the following.

EMME/2: Licensed by Michael Florian, Inro Consultants, 5160 Decarie Rd. Suite 610, Montreal Quebec, (514) 369-2023.

QRSII/GNE: Licensed by AJH Associates, 4345 N. Newhall, Milwaukee, WI 53217, (414) 963-8686, Fax 963-0686.

TRANSCAD and Maptitude: Licensed by Howard Slavin, Caliper Corporation, 1172 Beacon St., Newton MA 02161, (617) 527-4700 Fax 527-5113.