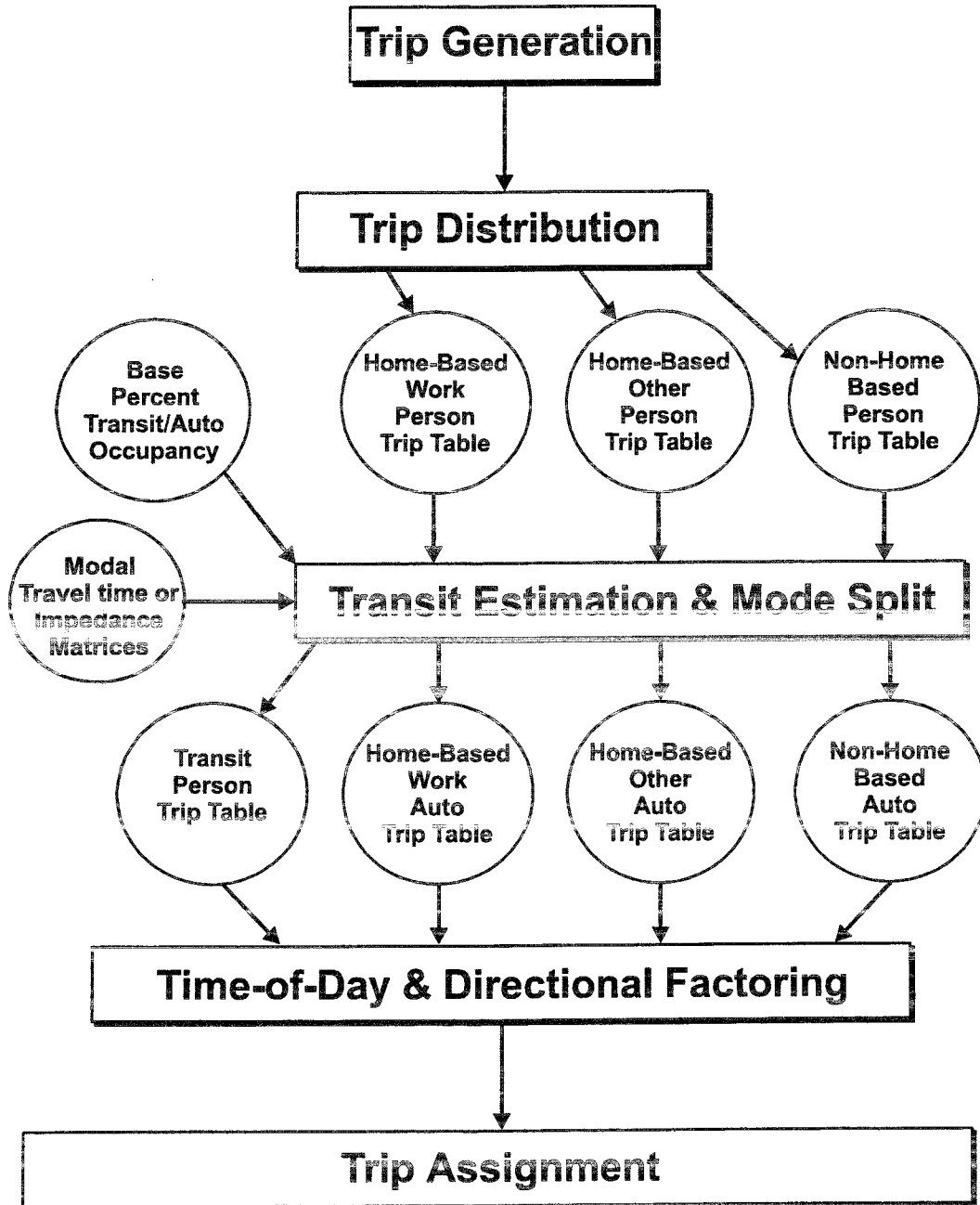


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# Session 7: Transit Estimation and Mode Split

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# Session 7: Transit Estimation and Mode Split

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## Objectives:

- Identify traveler characteristics impacting traveler mode split
- Identify mode characteristics impacting mode split
- Identify trip purpose characteristics impacting mode split
- Identify factors impacting choice of mode split methodology
- Explain concept of utility function
- Explain concept of logit model

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# Session 7: Transit Estimation and Mode Split

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## Session Outline

- Mode split overview
- Terminology
- Key concepts
- Inputs and outputs
- Forecasting for future assignments
- Example problem

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# Session 7: Transit Estimation and Mode Split

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## SESSION OUTLINE

The preceding sections outlined:

- development of socio-demographic estimates and projections for TAZs (zonal demographics)
- development of person trip generation rates for a variety of trip purposes (travel surveys)
- application of the person trip generation rates to the population and employment numbers for the TAZs and created person production and attraction tables for a variety of trip purposes (trip generation)
- linking trip productions and attractions to create person trip tables for a variety of trip purposes (trip distribution)

This section discusses the process of splitting the person trip tables into mode-specific trip tables. There are several mode split techniques that vary by complexity, required data, and appropriate application. Most mode split techniques require some combination of the following inputs:

- person trip tables for each trip purpose (for example HBW, NHB, and HBO)
- characteristics of the trip, characteristics of the traveler, and characteristics of the available modes (for example auto, bus, rail, bike, and pedestrian).

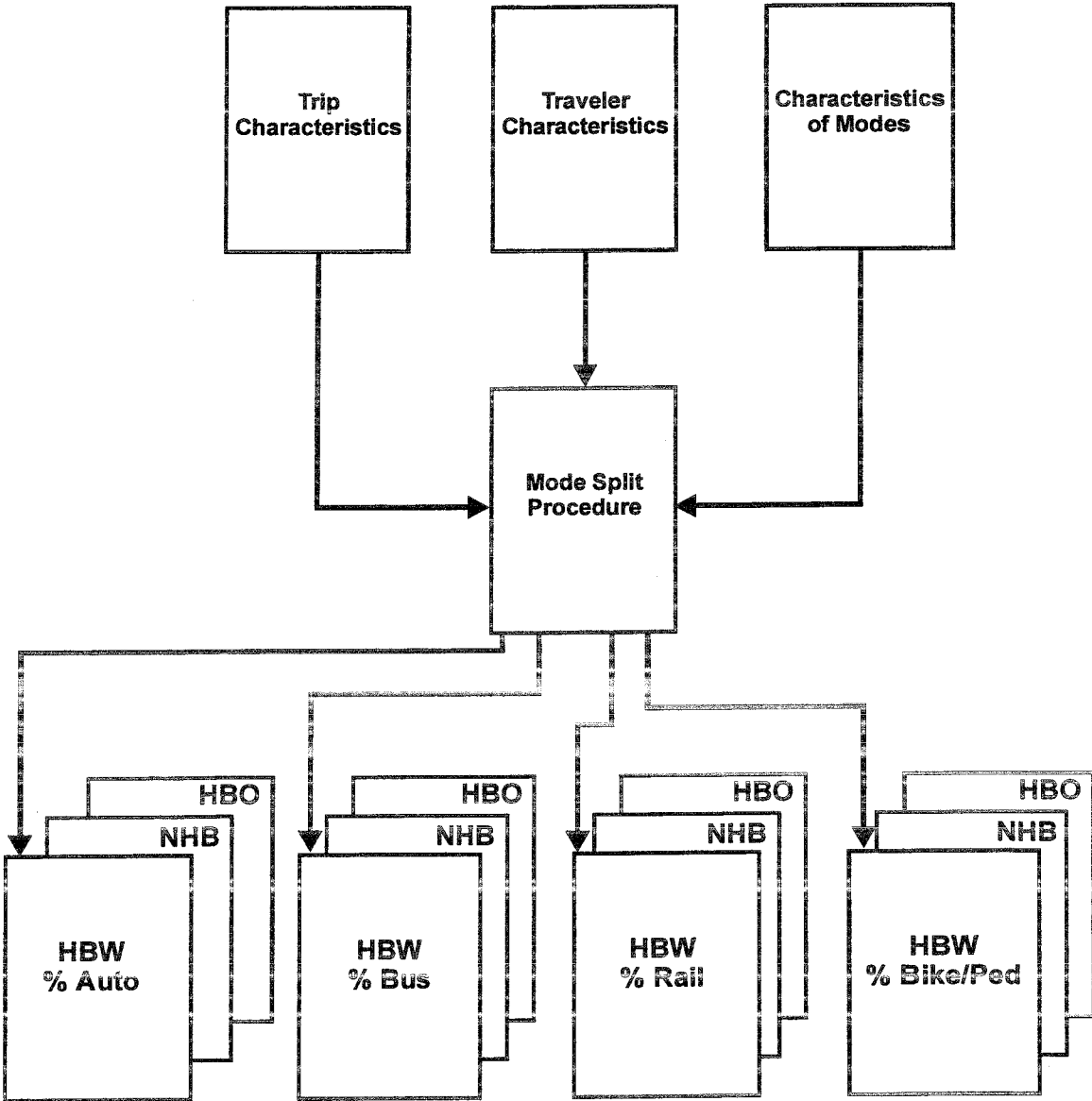
Note the use of the term “mode split” rather than the more common “mode choice.” This distinction is critical because often there is no “choice” in the decision of which mode to use. For example, a zero car household may have no choice but to use transit, car pool, or walk. Similarly, if there is no transit service available, an auto trip may be the only alternative.

This section begins with definitions for terminology, discussion of what factors influence mode split, and a description of the modes and their characteristics that influence travel decisions. Then, the various techniques for estimating mode splits, how to choose between the methods, and more details on four specific techniques are described.

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# Mode Split Overview

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# Mode Split Overview

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A traditional mode split process produces trip tables for each purpose by each mode. By using the example inputs shown, mode shares for each trip purpose would be produced:

- HBW auto
- HBW bus
- HBW rail
- HBW bike/ped
- NHB auto
- NHB bus
- NHB rail
- NHB bike/ped
- HBO auto
- HBO bus
- HBO rail
- HBO bike/ped

The figure shows a generalized mode split procedure with its inputs and outputs.

There are several important factors concerning mode split. Issues of air quality, congestion, social equity, the connection between land use and transportation, and other sensitive political issues are considered in the mode split step. Mode split can be complex, data intensive, time consuming, and expensive. Undertaking a traditional mode split model, therefore, is reserved for only those analysis questions that truly require this tool. Finally, it is important to note that, as with all steps in the four-step process, the goal of mode split is to predict traveler decisions and to evaluate the effects of those decisions. The ability to predict these decisions is limited by data, software, cost, time, and staff expertise. However, the underlying goal of predicting behavior should guide decisions on mode split techniques and the application of the techniques.

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**Notes:**

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# Terminology

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- HOV
- Light rail
- Heavy rail
- Commuter rail
- Local bus service
- Express bus service
- Paratransit service
- Busways
- Headways/frequency
- Transit captive

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# Terminology

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**HOVs** are vehicles that carry two or more persons, in contrast to single occupancy vehicles (SOVs). Examples of HOVs are buses, vanpools, and carpools.

**LRT** are passenger rail cars operating on fixed rails in a right-of-way that is not separated from other traffic for much of the way. LRT vehicles are electrically powered, with power drawn from overhead electric lines via a trolley or pantograph.

**Heavy rail** consists of high speed passenger rail cars operating singly or in trains of two or more cars, on fixed rails in separate rights-of-way from which all other vehicular and foot traffic is excluded.

**Commuter rail** is passenger train service operating between a central city, its suburbs, and/or another central city.

**Local bus service** stops at all marked bus stops along its route and/or upon demand.

**Express bus service** is expedited by limiting its stops between origin and destination.

**Paratransit service** consists of public transportation services without fixed-routes or fixed-stops. This service is normally available to selected segments of the public on demand.

**Busways** are special roads, sometimes exclusive, for buses. It can be a separate right-of-way or merely a reserved bus lane on a highway.

**Headways/frequency** are the time, in minutes, between buses on the same route. A 60-minute headway would indicate one bus on a given route every hour.

**Transit captive** is a transit rider with no alternative to transit use. These captives can include zero-car households, disabled people, and the very young or very old.

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Notes:

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# Key Concepts

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## Factors Affecting Mode Split

- Person/household characteristics
- Trip characteristics
- Land use characteristics
- Service characteristics

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# Key Concepts

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## **Factors Affecting Mode Split**

Mode split is determined by the relative cost/time for making the trip by each mode and the person/trip/land use characteristics, including those listed below. Not all of these factors are used in all mode split models. In some cases, although from a behavioral perspective the characteristics logically influence travel decisions, the available data or the model structure precludes the use of the characteristics.

### **Person/Household Characteristics**

- Automobile availability
- Household income
- Household size
- Life-cycle

### **Trip Characteristics**

- Trip purpose
- Trip chaining
- Time of departure
- Origin and destination
- Trip length

### **Land Use Characteristics**

- Sidewalk or pedestrian facilities
- Mixture of uses at both ends of trip
- Distance to transit
- Parking availability and cost at both ends of trip
- Density at both ends of the trip

### **Service Characteristics**

- Facility design (HOV lanes, bike facilities)
- Frequency
- Congestion
- Cost (parking, tolls, fares, out-of-pocket costs)
- Stop spacing

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**Notes:**

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# Modes and Characteristics

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- SOV
- HOV
- Non-Motorized (NM)
- Bus
- Rail
- Ferry

---

# Modes and Characteristics

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**SOV.** Some cost factors (tolls and parking) can vary between destinations, but generally for TDF, all SOV vehicles are considered identical.

**HOV.** HOV service is described in two ways: the vehicle occupancy (two people, three-plus, etc.) and the type of HOV facility design and operation. The HOV facility characteristics used in the modeling process include: is the lane reversible, is access to and egress from the facility limited, is the lane taken from the general use lanes, or is the lane newly constructed, etc.

**Non-Motorized (NM).** NM facility characteristics that are thought to affect the mode split process should be included in the process to identify NM trips. These characteristics include: separate bike paths, bike lockers, shower or changing facilities at the destination end of the trip, sidewalks, intersection configuration, safety, topography, and weather.

**Bus.** A traveler's perception of transit service is affected by both quantitative and qualitative measures. The quantitative measures (bus system characteristics that are obtained from the transit provider) include: bus routes, costs, stop spacing, headway or frequency, off-peak versus peak service levels, transfer cost, actual operating speed, and transfer timing. Qualitative characteristics that are difficult to obtain or measure include: safety, comfort, reliability, and how far travelers are willing to walk or drive to access a bus.

**Rail.** Most of the characteristics described above for bus services also apply to rail service. Station design, such as how convenient transfers are from buses, is also important in specifying rail service.

**Ferry.** The characteristics that are critical to bus service apply to ferry service; however congestion levels (how often are ferries over-booked) are more important in ferry service due to the longer headways and fewer alternative modes or paths.

# Urban Bus Transit System Characteristics

## System Characteristics for Selected Transit Agencies

Urban Area Population	Service Area Population	Daily Unlinked Trips	Daily Bus VMT	Vehicles Operated in Peak Period	Vehicles Operated in Off Peak Period
Amarillo	95,869	3,499	3,296	16	13
Austin	604,621	107,946	54,416	376	236
Detroit	1,065,567	183,147	69,089	471	322
Houston Metro	2,457,673	283,009	131,302	1,286	374
Indianapolis	823,424	34,458	26,849	167	74
Lansing	241,751	15,440	12,371	94	38
Madison	219,185	35,500	18,691	226	59
Milwaukee	990,700	225,790	59,491	458	350
Nashville	528,103	17,446	15,794	159	46
San Antonio	1,363,247	135,148	89,542	626	224
Spokane	365,660	29,140	28,163	230	100
Waco	103,590	2,541	2,205	18	10

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# Urban Bus Transit System Characteristics

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The table provides information on urban area population operating characteristics data for selected transit agencies for U.S. cities. Notice that the daily unlinked trips per capita varies greatly among these cities. Also, notice that the ratio of the number of peak period buses to off peak period buses varies greatly.

The source of the data is the 1998 National Transit Summaries and Trends report prepared by the Federal Transit Administration. The unlinked trips and VMT data, reported in the reference as annual, were converted to weekday unlinked trips and weekday VMT. Since travel demand is usually modeled for a school year weekday, the weekday values are of greater interest for this application.

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**Notes:**

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# Mode Split Model Applications

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- Route or service changes
- Major investment studies
- New rail or other capital investment project design
- Policy changes

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# Mode Split Model Applications

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The type of mode split analysis conducted should be driven by the types of questions the analyst needs to answer. The following are the major types of analyses in which mode split plays a critical role.

## **Route or Service Changes**

Planning for changes in cost, frequency, transfer system, extension or cutbacks of routes, or adding new routes rarely is done with the complete TDF model. A full TDF model application is too expensive and not accurate enough in this setting. Instead, analogy or elasticity methods generally are used.

## **Major Investment Studies (MIS)**

Determining the costs/benefits of various alternative transportation investments is one of the most important uses of a TDF model with a mode split step. For example, a MIS would use the results of a TDF model to analyze the effects of HOV lanes in a corridor versus additional general travel lanes or additional bus service.

## **New Rail or Other Capital Investment Project Design**

The ridership or link volumes from TDF models are used in the design of a rail system (including station design, train selection, etc.) and the design of roadway facilities (number of lanes, ramp design, etc.). Extensive engineering and operational models are used to produce final design volumes, with TDF models providing traffic volumes or passenger loads.

## **Policy Changes**

There is an increasing effort to use TDF models, and the mode split step in particular, to evaluate policy actions. Examples of the policy actions under consideration are parking costs, urban growth boundaries, congestion pricing, etc. These types of analysis push the capabilities of the models and the basic research into the connection between these policy actions and travelers' corresponding travel decisions.

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# Choosing A Mode Split Technique

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- **Mode split**
  - Application
  - Time and budget constraints
  - Project costs
- **Existing data**
- **Transit and other non-SOV service**
  - Current
  - Proposed
- **Ridership characteristics**

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# Choosing A Mode Split Technique

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Consider the following factors when selecting a mode split technique.

## **Mode Split**

### Application:

- What type of question is being answered? For example, bus route changes and other small service changes do not warrant the development of a disaggregate mode split model.

### Time and Budget Constraints:

- Disaggregate mode split models are expensive to develop and are time consuming to use.

### Project Costs:

- The cost of the project under consideration influences the analysis technique. Rail projects are studied for many years at a large cost—due, in part, to the large project costs.

## Existing Data

- The availability, quality, and timeliness of the household survey data, on-board transit survey data, zonal household characteristic data, transit inventory and service characteristic data, and highway inventory and service characteristic data, impact the time and cost required to develop and calibrate a disaggregate mode split model.

## **Transit Service and Other Non-SOV Service**

- A region with no history of transit service or HOV facilities will have a hard time performing a mode split analysis for new transit service or HOV facilities. Data with which to perform an analysis will have to be “borrowed” from another region that has the transportation service being proposed. This region needs to have an urban form, density, household characteristics, and transportation system similar to the region under study.

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# Selecting Analogy Routes

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## Selection based on:

- Household characteristics
- Transit service

## Adjustments

- Service area household characteristics
- Service differences
- Fare differences

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# Selecting Analogy Routes

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Analogy methods are sketch-planning tools for predicting transit ridership on a new route or to answer similar questions. Analogy methods assume that an existing route (or routes) can be identified, and the route is similar enough to the proposed new route to serve as the basis for estimating the ridership for the new route. This straightforward approach is often used in the business world. Consider, for example, how one would estimate the sales for a proposed new convenience store. If a store already existed in the metropolitan area, with a similar customer base and similar products, one could use the existing store's sales as a reasonable estimate for the sales at the proposed site. In the same way, there are two dimensions to identifying a similar existing transit route. The first dimension is that the route serves an area with similar household characteristics to the proposed route (the customer base in the convenience store example). The second dimension is that the transit service on the route is similar to the proposed service on the new route (the product line cited above).

To account for differences in household and service characteristics between the existing and proposed routes, adjustments may be necessary. For example, if an existing route is twice as long as a proposed route, the number of riders on the existing route may have to be halved to obtain a reasonable estimate for the new route.

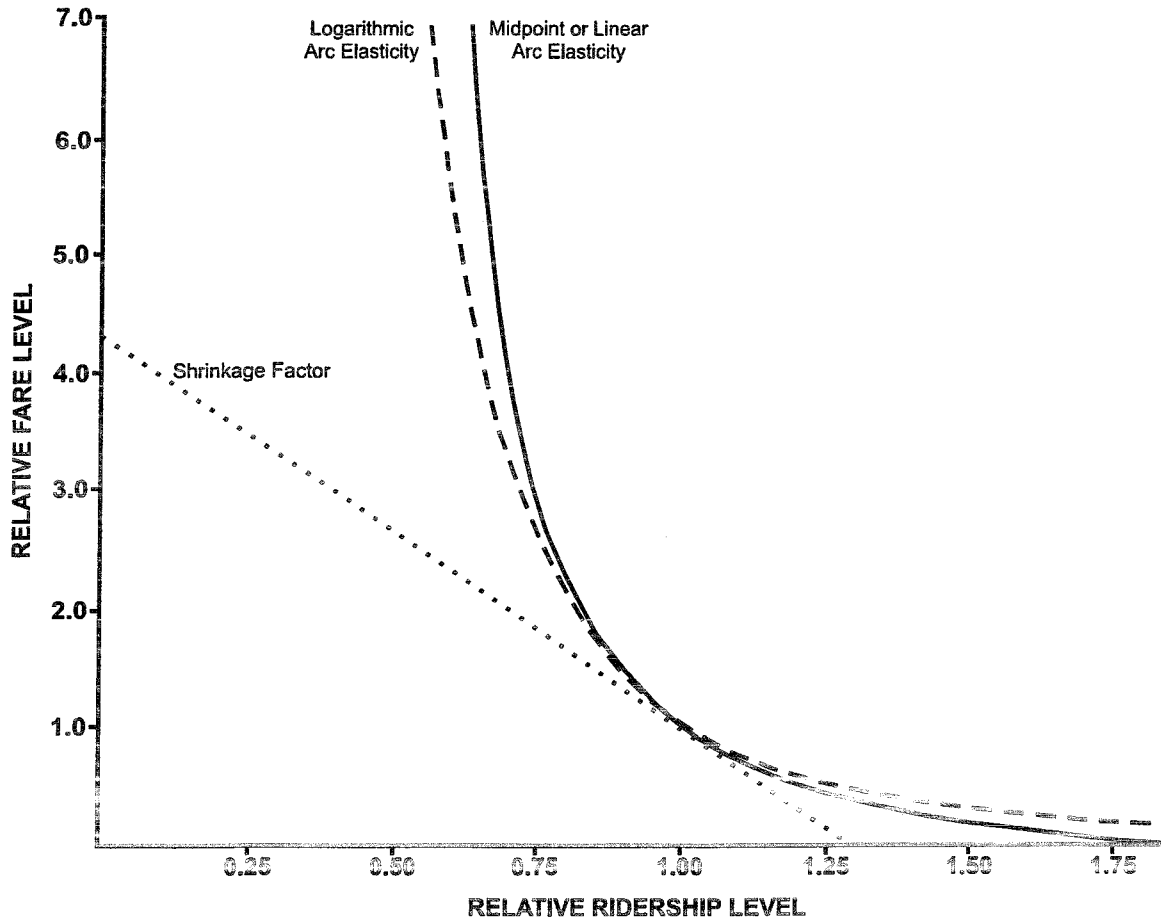
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**Notes:**

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# Elasticities

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**Elasticity of Demand Curves Based on Initial Point Elasticity of -0.30**

Source: Traveler Response to Transportation System Changes, July 1981

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# Elasticities

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Transportation elasticities are the ratios of change in travel demand in response to a change in the transportation system. The concept is derived from the classical economics measure of “price elasticity.” Transportation elasticities, when used properly, provide a technique to quickly prepare a first-cut, aggregate response estimate for transportation system changes such as transit service, transit frequencies, transit fares, parking charges, and gasoline costs. Elasticities also are a valuable “reasonableness check” for results from a disaggregate mode split model.

Proper use of elasticities requires similar consideration as described in the analogy session. Communities, transit service, and other characteristics should be similar, or the elasticities used may produce unrealistic results. For example, transit service oriented to the CBD in a region with high parking costs and limited parking available in the CBD would have low fare elasticities because the alternatives to paying the higher fare still are expensive. Also, elasticities can be used only when the transit service of interest already is in place. Ridership for an HOV facility could not be estimated with elasticities in a region with only bus service.

If a 1% change in a service characteristic causes more than a 1% change in demand, the demand is elastic. If a 1% change in a service characteristic results in less than a 1% change in demand, the demand is inelastic. The figure to the left shows elasticity demand curves for a community with a fare elasticity of -0.30. A doubling of the fare would result in a reduction in ridership between 20% and 30%, depending on the calculation techniques.

There are three different methods commonly used for computing elasticities: the point elasticity, arc elasticity, and shrinkage factor methods. The shrinkage factor method is illustrated on the next page. See *Traveler Response to Transportation System Changes*, U.S. DOT, FHWA, Second Edition, July 1981, page 393 for a discussion of elasticity methods.

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Notes:

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# Elasticities

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## Example of Elasticity

If transit fares are raised from \$1.00 to \$1.25 and there is a resulting drop in daily transit ridership from 8,000 to 7,200, the elasticity, as calculated below, would be - 0.40.

$$\begin{array}{l} \text{Elasticity} = \frac{\text{change in ridership} \div \text{original ridership}}{\text{change in fare} \div \text{original fare}} = \frac{-800 \div 8000}{.25 \div 1.00} = -0.40 \\ \text{(Shrinkage Factor)} \end{array}$$

This elasticity, -0.40, indicates that a 1% fare increase has caused or is expected to cause a 0.40% loss in ridership.

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# Elasticities

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There are several equations that are used to calculate elasticities; the most common is a shrinkage ratio. The various equations yield the same results when the fare or other changes are small, but the choice of the equation should be made carefully when the changes are large. The document, *Traveler Response to Transportation System Changes*, contains a good summary of elasticity measures and their use, along with a good (but dated) compendium of studies of transportation elasticities.

## Examples of Measured Elasticities

Where service levels have remained constant, the following fare elasticities for a 1% increase in fares were reported:

Average (all hours, all cities)	-0.40
Average (all hours, more than 1 million population)	-0.36
Average (all hours, less than 1 million population)	-0.43
Average (all peak hours)	-0.23
Los Angeles (9.5 million)	-0.23
Dallas (2.4 million)	-0.13
Atlanta (1.6 million)	-0.28
Sacramento (0.8 million)	-0.16
Honolulu (0.6 million)	-0.65
Richmond (0.5 million)	-0.62
Madison (0.2 million)	-0.40

Source: *Effects of Fare Changes on Bus Ridership*, APTA, May 1991.

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## Notes:

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## **Direct Estimation of Transit Share**

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- In small-to-medium regions with limited transit use
- Particularly when transit use is limited to specific populations (zero-car household, students, and elderly)
- Generally estimate district-to-district transit share
- Subtract resulting transit trips from person trip table

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# Direct Estimation of Transit Share

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Small and medium regions with limited transit use generally will not use a disaggregate mode split model to estimate transit use. If transit riders generally fall into specific population groups such as zero-car household, students, and elderly, and there are no indications that transit rider characteristics will change, direct estimation of transit trip procedures can be used.

These procedures begin with estimates of the district-to-district or TAZ-to-TAZ transit share. These estimates are developed using household characteristic data available by TAZ or developed from Census data and ridership characteristic data developed from on-board transit surveys. For the model calibration year, district-to-district or TAZ-to-TAZ shares are estimated from the observed data. Transit trip rates based on district or TAZ household characteristics and observed ridership are developed. Forecast trip rates are estimated using the base year trip rates which are assumed to remain constant, and the forecast district or TAZ household characteristics. The estimated zone-to-zone or district-to-district transit trips are subtracted from the person trip table. This can be done by trip purpose where the data supports this or for all trip purposes combined where the data do not support transit trip estimation by trip purpose.

This same estimation approach can be used for bicycle, pedestrian, and HOV shares and trips where there is observed data with which to develop trip rates.

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**Notes:**

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# Disaggregate Mode Split Models

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## **Disaggregate Mode Split (DMS)**

Travel is a result of choices

Elasticity, analogy, and direct estimation of transit share  
are limited (particularly in policy analysis)

## **Utility functions**

Building blocks for DMS models

Deterministic equations

Rank desirability of the alternate transportation modes

## **Probability models**

Logit the most common

Incorporate utility equations into probabilistic equations

## **Binomial logit models**

Predict choice between two alternatives

## **Multinomial logit models**

Predict choice between more than two alternatives

## **Output**

Share of person trips using each mode (by trip  
purpose) for each production-attraction cell

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# Utility Functions

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The building blocks of DMS models are utility equations. Utility equations rank the desirability of the potential travel modes. These equations incorporate characteristics of the alternatives and the traveler that are believed to influence the choice between alternatives. An analyst studying the relative utilities of alternatives then could predict which alternative would be chosen. Utility equations are deterministic—meaning the equations assume travelers presented with a set of relative utilities for a choice of alternatives would always choose the alternative with the highest utility or lowest disutility. This assumption, of course, violates what one knows about travel choice processes. The limits to utility equations and how those limits are overcome will be discussed later.

Utility equations are estimated using a travel survey (Census data or a home interview survey) and travel time and cost data for the transportation alternative. The travel cost and the travel time information generally come from the TDF networks. Using the individual's characteristics, the alternative characteristics, and the chosen alternative, equations are developed to predict the mode choice. The figure to the left shows a utility equation and the results of applying the equation for two individuals with different incomes. The higher income (\$40,000) individual would choose to use an SOV for this particular trip. The lower income (\$10,000) individual would choose to carpool, mainly because of the lower cost. This equation is very simple compared to those actually used by metropolitan areas, which could contain 10 or more factors. The coefficients reflect the relative value of each factor.

*The utility equation generally is not used due to several factors. Travelers rarely know the entire set of alternative transportation modes, rarely know the relative merits of that choice set, and their travel decisions are based on personal variables that cannot be or are not measured. The analyst, who cannot include every factor influencing travelers' decisions, encounters measurement errors in trying to characterize the alternatives and travelers, and is forced to use proxy variables that may not capture exactly the effects that were intended. Finally, people make different choices based on non-recurring circumstances; for example, "I usually ride the bus, but today I have a doctor's appointment, so I will pay the extra cost to drive to work."*

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**Notes:**

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# Probability Equations

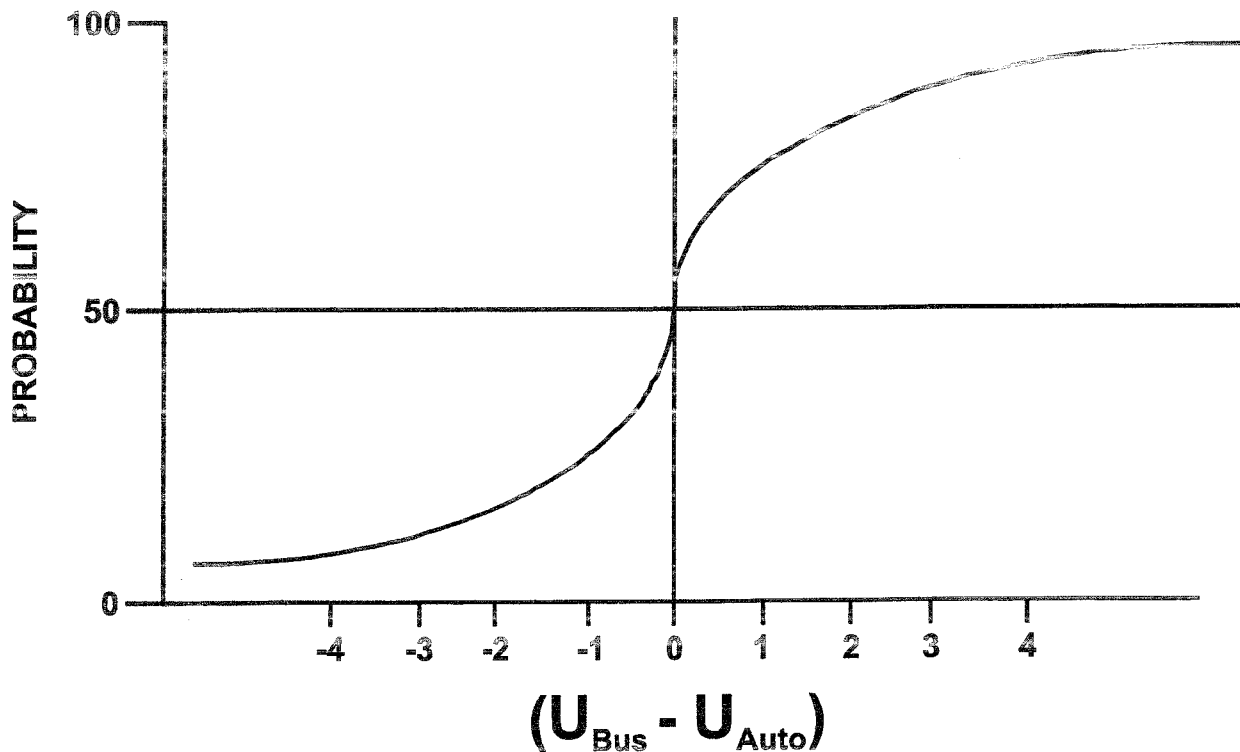
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## Probability Equations

$$P_B = \frac{e^{(U_B)}}{e^{(U_B)} + e^{(U_A)}}$$

Where:

- $P_B$  = probability of the individual choosing a bus
- $U_B$  = utility of bus
- $U_A$  = utility of auto
- $e$  = natural log



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# Probability Equations

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The predictive powers of utility equations are limited due to the following:

- omission of relevant variables,
- measurement error,
- proxy variables,
- differences between individuals, and
- day-to-day variation in choice.

Due to the above, it is now standard practice to use the utility concept set in a probabilistic equation. By making the decision probabilistic, a set of individuals faced with an identical set of utilities will make a variety of decisions. This range of choices is intended to overcome the limitations described above.

Logit equations are the most common form of probability equations used today. The equation shown to the left is a binomial logit equation. This equation predicts the probability of choosing one of two possible alternatives. The graphic shows the change in probability with varying utilities of the bus and auto. Note that where the difference between the utilities is zero (they are equal), the probabilities of choosing the bus or the auto also are equal.

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Notes:

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# Binomial Logit Model Example

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Auto Utility Equation

$$U_A = -0.025(\text{IVT}) - 0.050(\text{OVT}) - 0.0024(\text{COST})$$

Transit Utility Equation

$$U_B = -0.025(\text{IVT}) - 0.050(\text{OVT}) - 0.10(\text{WAIT}) - 0.20(\text{XFER}) - 0.0024(\text{COST})$$

Where :

IVT	=	in-vehicle time in minutes
OVT	=	out of vehicle time in minutes
COST	=	out of pocket cost in cents
WAIT	=	wait time (time spent at bus stop waiting for bus)
XFER	=	number of transfers

For a particular trip:

Auto IVT = 20, OVT = 4, COST = \$1.00

Transit IVT = 30, OVT = 8, WAIT = 10, XFER = 0,  
COST = \$0.50

Auto Utility

$$U_A = -0.025(20) - 0.050(4) - 0.0024(100) = -0.94 \quad e^{(-.94)} = 0.39$$

Transit Utility

$$U_B = -0.025(30) - 0.050(8) - 0.10(10) - 0.0024(50) = -2.27 \quad e^{(-2.27)} = 0.10$$

$$P_A = \frac{0.39}{0.39 + 0.10} = .80$$

$$P_B = \frac{0.10}{0.39 + 0.10} = .20$$

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# Binomial Logit Model Example

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The example of a binomial logit model shown to the left is again a simplified version of a model that would be used in a metropolitan area. The coefficients show the difference in the importance of the variables. In-vehicle time (IVT), the time spent in the auto or on a bus, is “worth” less than half the time out of vehicle (OVT). Utility equations will contain alternative-specific constants that account for factors affecting utility, that are not explicitly accounted for by a variable in the utility equation. For simplicity, the alternative-specific constants are omitted from this example.

Binomial logit models can be extended to more than two alternatives; these are called multinomial logit equations.

$$P_i = \frac{e^{U_i}}{\sum_{i=1}^n e^{U_i}}$$

Where:

$P_i$	=	probability of mode $i$
$U_i$	=	utility of mode $i$
$n$	=	number of modes
$e$	=	natural log

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Notes:

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# Error Checking, Validation, and Calibration

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- Comparison to national and other regions
- Baseline
  - Screen line ridership
  - Mode shares against changes in travel times
- Disaggregate validation
- Aggregate validation

---

# Error Checking, Validation, and Calibration

---

Validation and calibration are critical steps in developing and applying a mode split model. The following are suggestions that apply to the disaggregate choice techniques, but similar checks should be used for any technique.

Comparisons to national or other regional coefficients or factors:

- Model coefficients
- Mode shares

Regional factors and changes:

- Bus route assigned volumes against actual ridership
- Mode shares against the differences in travel times, etc. between the alternative modes

Disaggregate validation:

- Checking the predicted mode splits for subgroups of the traveler population. *For example, checking zero-car households, low-income households, shopping trips against actual decisions*
- Checking demands against elasticities

Aggregate validation checks:

- Average auto occupancies, by trip purpose
- Percent SOV, by trip purpose
- HBW transit trips, as a percent of total transit trips
- Mode shares to/from area types or major districts
- Average auto occupancies to/from area types or major districts

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# References

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1. *Transit Fact Book*. 50<sup>th</sup> ed, American Public Transit Association, Washington, D.C., January 1999.
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