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Incorporating TDM Strategies into the Travel Forecasting Process

**Stated Preference Design and Analysis for  
Demand-Oriented Transportation Solutions:  
Phase One—Underlying Research and  
Proposed Methodology**

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# Table of Contents

<b>INTRODUCTION</b> .....	<b>1</b>
<b>CHAPTER I: BACKGROUND</b> .....	<b>5</b>
TRANSPORTATION DEMAND MANAGEMENT .....	6
LEGISLATION AND POLICY.....	9
EXISTING REGIONAL SURVEYS AND MODELS .....	13
<i>Puget Sound Regional Surveys</i> .....	13
Panel Survey.....	13
Activity Survey .....	14
<i>Regional models</i> .....	16
Puget Sound Regional Council Forecasting Model .....	16
Sound Transit Mode Choice Model .....	24
<b>CHAPTER II: LITERATURE REVIEW</b> .....	<b>25</b>
MEASURING TDM EFFECTIVENESS .....	25
Examples of Survey Based Analysis.....	26
TDM within Travel Demand Forecasting .....	28
General Empirical TDM Models.....	30
Examples of MPO Models .....	33
Drawbacks of Existing TDM Evaluation Methods .....	35
STATED PREFERENCE DESIGN AND ANALYSIS.....	35
<b>CHAPTER III: METHODOLOGY</b> .....	<b>39</b>
DISCRETE CHOICE ANALYSIS .....	41
<i>Economic Theory and Discrete Choices</i> .....	41
<i>Probabilistic Choice Theory</i> .....	42
<i>Random Utility Theory</i> .....	44
Logit Model.....	45

Scaling SP Data within the MNL model.....	47
<i>Consumer Choice Measures</i> .....	49
Marginal Rate of Substitution.....	49
Elasticity Calculation.....	49
<i>Multiple Response Issues</i> .....	50
<b>CHAPTER IV: SURVEY DESIGN AND IMPLEMENTATION .....</b>	<b>51</b>
MODE ALTERNATIVES .....	51
IDENTIFICATION OF TDM STRATEGIES.....	51
DESIGN OF ALTERNATIVES .....	55
IDENTIFICATION OF SOCIOECONOMIC AND REVEALED PREFERENCE DATA .....	59
SURVEY IMPLEMENTATION.....	65
<i>Respondent Selection</i> .....	65
<i>Interview Procedure</i> .....	65
<i>Presentation of Alternatives</i> .....	65
<b>NEXT STEPS.....</b>	<b>71</b>
<b>REFERENCES.....</b>	<b>73</b>

## List of Tables

Table 1: WSDOT Classification of TDM Strategies.....	8
Table 2: Highlights of COMSIS Model .....	31
Table 3: Highlights of JHK Model.....	32
Table 4: Mode Alternatives for Work and Shop Trips.....	51
Table 5: TDM Actions and Mode Impacts – 1 of 3 .....	52
Table 6: TDM Actions and Mode Impacts – 2 of 3 .....	53
Table 7: TDM Actions and Mode Impacts – 3 of 3 .....	54
Table 8: Attributes & Levels for Mode Alternatives – Work trip, No car available.....	55
Table 9: Attributes & Levels for Mode Alternatives – Work trip, Car available.....	56
Table 10: Attributes & Levels for Mode Alternatives – Shop trip, Car Available.....	57
Table 11: Attributes & Levels for Mode Alternatives – Shop trip, No car available.....	58
Table 12: Household Data from PSRC Activity Survey .....	60
Table 13: Person Data from PSRC Activity Survey – 1 of 2 .....	61
Table 14: Person Data from PSRC Activity Survey – 2 of 2 .....	62
Table 15: Vehicle Ownership Data from PSRC Activity Survey .....	63
Table 16: RP Travel Data from PSRC Activity Survey .....	64

## List of Figures

Figure 1: “Four-Step” Travel Demand Forecasting Process .....	18
Figure 2: Nesting Structure for PSRC Recommended Work Mode Choice Model .....	22
Figure 3: TDM Strategies in Travel Demand Forecasting Process .....	29
Figure 4: Deterministic Choice Model .....	43
Figure 5: Probabilistic Choice Model .....	43
Figure 6: Survey solicitation packet .....	66
Figure 7: Presentation of Choices – Work trip, Car available .....	67
Figure 8: Presentation of Choices – Work trip, No car available .....	68
Figure 9: Presentation of Choices – Shop trip, Car available .....	69
Figure 10: Presentation of Choices – Shop trip, No car available .....	70

## Introduction

Increasing urban and suburban traffic congestion has focused much attention on transportation solutions that include enabling more efficient use of existing roadway capacity through eliminating or combining trips, and encouraging use of high occupancy modes (such as transit or carpool) or non-motorized modes (such as bicycling or walking). Transportation demand management (TDM) is a policy tool used to promote these solutions. In contrast to traditional capacity-oriented approaches, TDM consists of a variety of strategies that target demand on a transportation system, either through incentives for alternative mode users, or disincentives for single-occupant-vehicle (SOV) users.

The goal of this project is to incorporate alternative transportation modes and policy options that support TDM solutions into established planning and programming processes. This project is part of a collaboration with the Washington State Department of Transportation (WSDOT) and the Puget Sound Regional Council (PSRC) in their endeavor to refine the region's travel analysis procedures to include a more complete range of transportation solutions.

The specific objective of this research is to employ innovative travel surveys, combined with statistical analysis methods, to calculate utility equations for alternative transportation choices travelers could make as a result of increasing congestion levels and demand-oriented strategies. *Utility* is an empirical measure of the relative attractiveness of different choices for an individual, and has traditionally been used for mode choice modeling. Utilities are a function of measured attributes of the choices in question. Utility theory assumes that a decision-maker (in this case, a traveler) selects the alternative that provides the highest personal utility. Utility-based models, such as the typical mode choice model, are compensatory, meaning that one attribute can be traded off for another. Utility equations can be used to estimate what magnitude of change in one or more attributes in a set of travel alternatives would be required to change the mode choice of a traveler. For example, what amount of reduction in transit fare or travel time would cause a traveler's utility for riding the bus to exceed utility for driving alone, causing that person to

choose transit over driving? For some travelers, the magnitude may be greater than that which can be reasonably effected through demand management strategies. However, for other sets of travelers, the magnitude might be more readily achieved. Armed with this type of detailed information, transportation professionals can determine the level of investment necessary to impact mode choice, and target strategies to where they will be most effective.

Utilities for driving alone, for transit and to some extent for carpooling have long been used in mode choice modeling. However, the attributes on which utility calculations are based are quite limited. For instance, transit utility in mode choice is typically based upon fares and travel times. Factors such as comfort, convenience, or the extent of a traveler's familiarity with the system are not included in utility calculation, even though they may play a significant role in the decision of whether or not to choose transit. There are practical reasons for these limitations. First, characteristics such as comfort and convenience are very difficult to quantify within typical traveler surveys. Second, mode choice models are often developed for utilization in long range travel forecasts, and consequently they require that included variables must be forecast over time periods as high as 20 or 30 years. As difficult as it is to quantify comfort and convenience in present time, forecasting these qualities over a long-range period is even more problematic. Another limitation of traditional mode choice models is that they often exclude TDM-targeted alternatives such as telecommuting or travel by non-motorized modes, due mainly to the small proportion of travelers who can or do choose these alternatives. As a result, unless surveys are specifically designed to capture them, the resulting data is typically not sufficient to include these alternatives in meaningful analysis.

It is the hypothesis of this research that more rigorous survey and analysis methods could be employed to develop mode choice models that include a wider array of attributes and modes. This in turn would allow a greater variety of strategies, such as those included in transportation demand management, to be evaluated at a more useful level of detail. If this type of evaluation predicted that an investment in a non-traditional transportation improvement could effectively reduce demand, it would more likely be funded than if there were no such means for projecting

the level of its success (as is currently the case). Additionally, TDM strategies in which a high level of investment would *not* have a significant impact on demand could likewise be more effectively identified.

The primary expected benefit of this project would be a mode choice model that will allow the effectiveness of TDM strategies to be evaluated. If utility functions sensitive to TDM options are established, they could:

1. be used to estimate the tradeoffs that individual travelers would be willing to make with regard to their travel options, and
2. be applied macroscopically to estimate the level of financial investment required for TDM to have a noticeable impact on traffic conditions in a given area or corridor.

This Phase I report documents the groundwork that has been completed for this project, and consists of the following components:

- Background of project
- Literature review of current practice
- Proposed research methodology
- Survey design

Preliminary research shows that surveys can indeed be designed to capture the unique types of data required to develop TDM sensitive mode choice models. Phase II of this project will document the stated preference data that is actually collected, and the analysis of that data to develop a TDM model.

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## Chapter I: Background

The traditional solution to transportation deficiencies has been to increase capacity, usually through construction of additional infrastructure. However, added capacity may not be financially feasible in developed urban areas. Where construction is feasible, added capacity can result in depletion of green space, and may attract an even greater number of vehicles, which results in increased levels of air and noise pollution. TDM covers a broad range of strategies that are intended to reduce or redirect demand within a transportation system. TDM alternatives are attractive because they are typically lower in cost than build-alternatives. In some cases where TDM would not provide long-term solutions it may instead allow a larger construction project to be deferred. In addition to reducing vehicle-miles-traveled (VMT), reducing demand on the roadways has the further advantage of reducing parking demand at the travelers' destinations.

In this current era of growing traffic congestion coupled with increasing fiscal constraints, these stated advantages of TDM are tremendously appealing to decision-makers. As a result much legislative effort has been made to promote alternative modes that are facilitated through TDM. Problems arise, however, in that analytical methods are not in place to either assess the true impacts of TDM in practice, or to determine the level of investment required to achieve desired results. Thus, implementation of demand-oriented transportation solutions that support current policies is extremely difficult.

This chapter defines specific transportation strategies that fall under the umbrella of TDM, and describes the legislation and policy under which the need for TDM analysis methods has emerged. Additionally it will describe existing surveys and forecasting methods utilized in the Puget Sound region, and their degrees of compatibility with this project.

## Transportation Demand Management

Transportation Demand Management seeks to address congestion by implementing strategies that control demand on a facility, rather than increase capacity. The results of successful TDM strategies can be:

1. Travelers switch mode from SOV to carpool or transit.
2. Travelers stop making certain trips altogether (stay home).
3. Travelers seek alternative routes.
4. Travelers change destination choice.
5. Travelers retime trips to less congested times.

The State of Washington is currently directing much policy focus toward TDM strategies, which often target peak period travelers because that is the time when congestion is at its worst. The objectives of a TDM program can be to (1) improve environmental conditions or (2) improve the effectiveness of a transportation facility or system, through trip reduction or through more efficient distribution of trips. Mode shift or the elimination of trips most dramatically satisfy the objective of improving environmental conditions, as well as improving system efficiency, so these are arguably the most desirable of the possible TDM results. However, if travelers adjust their destinations, routes, or departure times to accommodate congestion, this can be considered a secondary desired result of TDM. Whether they drive alone or carpool, this at least allows more efficient use of the existing transportation system, allowing more trips to be accommodated without increasing roadway capacity.

The WSDOT Office of Urban Mobility (OUM) completed a study in which they examined the potential for including TDM projects into transportation alternative analysis (McBryan et al. 1996). For this project, OUM compiled a comprehensive list of TDM strategies, which they grouped into the following six major categories.

- **Public Mode Support Strategies** include services or facilities provided by public agencies that encourage and support use of alternative modes.

- **Employer-Based Strategies** are private-sector programs and services that encourage employees to change commuting patterns. The strategies include incentives that make carpooling or transit more attractive, disincentives that make solo commuting less attractive, and management policies that allow more flexibility in employee work schedules.
- **Pricing Strategies** consist of public tax and pricing schemes that typically discourage certain types of travel by making it costlier to drive or park an automobile.
- **Telecommunications Strategies** promote the use of emerging telecommunications technologies to perform a portion activities from home that have traditionally required travel, such as personal business, shopping or work.
- **Land Use Strategies** target travel patterns in the long term by promoting population and employment densities, urban design and land use mix to encourage the use of transit and non-motorized modes.
- **Public Policy and Regulatory Strategies** consist of restrictions and regulations that hinder auto use or promote alternative modes. Additionally, they provide political support or guidance for other institutional relationships.

The specific strategies in each category are presented in Table 1. The OUM report summarizes the characteristics of the each of the TDM strategies, begins to screen the strategies for the type of measures that could be quantified, and identifies many issues that must be considered when integrating TDM into transportation alternative analysis.

Transportation System Management (TSM) is related to TDM, but differs in that it focuses on improving the operation and management of transportation facilities to maximize their efficiency. Examples of TSM strategies include ramp metering, incident management, signal optimization, channelization improvements and reversible lanes. Advanced information systems are TSM strategies that are also associated with Intelligent Transportation Systems (ITS). Some examples of traveler information systems are variable message signs, radio broadcasts, cellular phone numbers, or web sites that inform travelers of current traffic conditions.

**Table 1: WSDOT Classification of TDM Strategies**

<b>Category</b>	<b>Strategy</b>
Public Mode Support Strategies	Public Education and Promotion
	Area-Wide Ride Matching Services
	Transit Services
	Vanpool Services
	Transit and Vanpool Fares
	Non-Motorized Modes
	High Occupancy Vehicle (HOV) Facilities
	Park and Ride Lots
Employer-Based Strategies	Monetary Incentives
	Alternative Work Schedules
	Commuter Support Programs
	Guaranteed Ride Home
	Parking Management
	Facility Amenities
	Transportation Management Associations
Pricing Strategies	Gasoline Tax Increases
	Vehicle Miles Traveled (VMT) Tax
	Congestion Pricing
	Parking Tax
Telecommunications Strategies	Telecommuting
	Advanced Telecommunications
Land-Use Strategies	Development Impact Mitigation
	Mixed Land-Use, Jobs / Housing Balance
	Transit-Oriented / Pedestrian-Friendly Design
	Residential Density Increases
	Employment Center Density Increases
	Parking Management
	On-Site Amenities
Public Policy and Regulatory Strategies	Trip Reduction Ordinances
	Restricted Access to Facilities
	Support of New Institutional Relationships
	Increase of HOV Lanes Restriction to 3+
	Parking Restrictions

(Source: McBryan et al 1996)

Some TSM or ITS strategies can help promote TDM by establishing conditions that impact travelers' choices. For instance, travelers who hear about roadway conditions through advanced information systems may be able to adjust their routes, destinations, or departure times to avoid congested areas or times of the day. Alternatively, a reversible transit-only lane might improve

transit travel time to the point where a traveler prefers to take transit instead of driving. This project is concerned with operations strategies only in terms of how they change individual travelers' perceptions of the differences between modal alternatives, and ultimately whether or not travelers make different choices as a result.

## **Legislation and Policy**

Many measures have been enacted at the federal level and within the State of Washington that direct efficient use of existing transportation systems, in part through the encouragement of modes alternative to the SOV.

The **Transportation Equity Act for the 21<sup>st</sup> Century (TEA-21)** was signed into federal law in 1998, assuring a guaranteed level of Federal funds for highway, highway safety, transit and other surface transportation programs through the year 2003 (USDOT 1998). TEA-21 builds upon initiatives established in 1991 in the **Intermodal Surface Transportation Efficiency Act (ISTEA)**. ISTEA is landmark piece of legislation that established flexibility in federal funding to State and local governments for projects and programs that would help meet the requirements of the 1990 Federal **Clean Air Act Amendments (CAAA)**, which require states to adopt plans to achieve and maintain federal air quality standards. TEA-21 continues flexibility in funding for measures targeted for environmental improvement. Eligible activities include transit improvements, travel demand management strategies, traffic flow improvements, and public fleet conversions to cleaner fuels, among others (USDOT 1998). TEA-21 also continues ISTEA's emphasis on the role of State and local officials to identify the projects that best meet metropolitan and statewide transportation needs, based upon a strong planning process.

Under TEA-21, the Puget Sound Regional Council is responsible for approving the programming and maintenance of the region's three-year Transportation Improvement Program (TIP). At a minimum, the TIP must contain all federally funded transportation projects that are approved to be undertaken in the four-county region. The TIP must also contain all projects that are approved for "state managed" and "regionally managed" federal transportation funding programs. The

programming process for the regional TIP focuses to the greatest extent possible on maintaining the development and implementation of projects that support local, regional/metropolitan and state plans. Recognizing the gap between total transportation system needs and the reality of limited financial resources, the PSRC developed nine policy objectives to guide the region's near-term funding decisions. "Improve/Implement Transportation Demand Management Programs" is one of these nine stated objectives on which TEA-21 controlled investment decisions are based (PSRC 1999).

Within the State of Washington, alternative transportation solutions are further necessitated by the objectives of the Commute Trip Reduction Law and the Growth Management Act. Passed in 1991, the **Commute Trip Reduction (CTR)** Law seeks to reduce workplace commute trips in the nine most populous counties in the state. This law requires that in the nine designated counties, private and public employers with 100 or more employees implement TDM programs with various incentives to encourage use of alternative transportation modes, other than the SOV. The original goal of CTR was for commute-related VMT to be reduced by 35 percent under the 1991 baseline by the year 1999. In 1997, the Washington legislature extended the 1999 deadline to the year 2005. However, even with the extension, these goals are very far from being achieved. The most recent survey-based evaluation estimates that a 7 percent reduction has been achieved thus far (Lovich et al. 1999). The purpose of CTR is to help maintain air quality in metropolitan areas by reducing congestion and air pollution. Note however that since CTR targets only commute trips, which are a small proportion of total trips in the transportation system, even if its ambitious goal is achieved it may not profoundly improve congested conditions. As CTR targets employers specifically, corridor-wide or area-wide TDM programs could also contribute to the achievement of its objectives while possibly reaching a broader spectrum of travelers.

The **Growth Management Act (GMA)** was adopted in 1991, and outlines a series of requirements for developing industrial, commercial or residential spaces in an effort to control the dispersion of jobs and residences. For counties either with populations over 50,000, or for

those who have experienced greater than 10 percent growth in the past ten years, the GMA requires the creation of a comprehensive plan to direct growth. Currently 29 out of Washington's 39 counties meet one or both of these thresholds and are required to plan under the GMA (Kavage 2000). In addition to defining urban growth boundaries, the comprehensive plans must contain the following elements: land use, housing, utilities, capital facilities, shorelines (if applicable), transportation, and rural.

The intention of the GMA is to concurrently manage land use plans and transportation plans so that they compliment each other. It mandates six sub-elements that must be included in the transportation element of comprehensive plans. These sub-elements include a directive that urban transportation plans should aim to relieve congestion and air pollution through a number of TDM measures that encourage high occupancy and non-motorized modes. Additionally, land use patterns should encourage rather than discourage these transportation options. The GMA also requires that Regional Transportation Plans be based upon least cost planning methods that identify the most cost-effective projects, services and programs (Kavage 2000). In order to fully comply with the requirements of GMA, jurisdictions should not only be ready to implement TDM alternatives, but also need to demonstrate that these alternatives are chosen because they are most cost-efficient.

The **Washington State Policy Plan** was established in 1990 by the Washington State Transportation Commission to promote the development of policies and strategies that will bring about a balanced multi-modal transportation system. Mobility objectives in the State Policy Plan include an emphasis on the movement of people and goods over vehicles, linking of land use and transportation policy, support for transportation alternatives including public transit and non-motorized modes. The plan specifically calls for the provision of cost-efficient alternatives to the SOV. Each year, the State Transportation Policy Plan Steering Committee recommends policy and strategy proposals to the Transportation Commission, who in turn transmits them to the Legislature. The first Policy Plan was adopted in 1990, and since then new policies have been developed and added to the plan on a regular basis. These policies form the basis for state

transportation program funding and direction, and are organized according to eight policy objective categories, as follows:

1. **Protect Our Investments** by keeping transportation infrastructure in sound operating condition.
2. **Operate Transportation Systems** to work reliably and responsibly for the customer.
3. **Improve Safety** through continuous reduction in the societal costs of accidents.
4. **Provide Viable Mobility Choices** for the customer and expand the system to accommodate growth.
5. **Support the Economy** through reduced barriers to the movement of people, products, and information.
6. **Meet Environmental Responsibilities.**
7. **Cooperate and Coordinate** with private and public transportation partners so that systems work together cost effectively.
8. **Continuously improve** the efficient and effective delivery of agency programs.

(Washington State Transportation Commission 2000)

TDM and alternative transportation modes figure predominantly into two of these eight categories. **Operate Transportation Systems** not only lists the preservation of transit and rail among its specific service objectives, but it dedicates a detailed policy sub-section to the “employment of TDM strategies and the expansion of mobility options to increase the efficiency of the transportation system.” Additionally, the majority of service objectives listed under **Provide Viable Mobility Choices** are committed to the promotion of alternative transportation modes, including high capacity transit, HOV lanes, rail, and non-motorized modes. This category contains a policy sub-section that calls for “emphasizing the movement of people and goods rather than vehicles in planning for capacity improvements to a regional transportation system,” and specifies TDM as a major strategy to reduce congestion.

In order to meet the requirements of legislation and policy federal, state and regional levels, regions must consider a broad range of issues when making transportation project funding decisions. These issues include the relief of traffic congestion, linkage of land use and transportation, as well as the social, economic, energy, and environmental impacts of transportation decisions. TDM alone will not meet the goals established in this series of legislation, but it is a key element in the combination of strategies that are proposed to address increasing congestion. In any case, for TDM to be considered to the extent that it is promoted in government policies, better methods for analyzing its actual effectiveness are required.

## **Existing Regional Surveys and Models**

The Puget Sound Region is distinctive in that a substantial amount of data is collected through local travel surveys, which in turn provides a first-rate source for estimating travel models. The following sections describe local survey and modeling efforts that are potentially pertinent to this project.

### ***Puget Sound Regional Surveys***

#### **Panel Survey**

The Puget Sound Transportation Panel (PSTP) Survey was initiated to gather data that would allow travel behavior to be evaluated over time. The panel is comprised of a random sample of approximately 1700 households from four counties (King, Kitsap, Pierce, and Snohomish) in the central Puget Sound region. The sample is blocked to ensure that includes households with at least one regular bus rider, households with at least one regular carpooler, and households with members who drive alone for most of their trips. For the complete panel, members of each household have recorded their trips for a two-day period in each of eight years, beginning in 1989. The most recent panel was completed in 1999. When a participating household moves out of the Puget Sound Region, a new household is recruited for the panel. (PSRC 1997a)

In addition to providing demographic information, all persons in the household age fifteen and older complete a two-day travel diary in which the following information is recorded for *each trip* the person makes:

- Destination of the trip
- Purpose of the trip
- Trip mode
- Whether they drove or rode (if a vehicle was used)
- How many people in their group
- The relationship of the members in the group to the respondent
- Times the trip started and ended
- Amount they pay for parking, when applicable

Each person is asked to record the origin of his or her first trip of the day. For all trips after that, the origin is defined as the destination of the previous trip. Participants are provided with guidelines regarding what constitutes a “trip” and what does not.

Each trip is indexed to a specific household, person, and day. Trip characteristics such as starting time, ending time, purpose, origin location, and destination location are recorded for each trip taken. Socioeconomic and demographic information is indexed by person and by household. Additionally, in some years, a number of panel members answer an “attitude survey” that asks about factors, situations or circumstances that affect their daily travel choices (PSRC 1997a).

### **Activity Survey**

The conventional approach to transportation modeling has studied travel behavior in terms of the actual trips that are made. However, in recent years this paradigm has begun to evolve from trip-based to activity-based approaches. Recognizing this shift in focus, the PSRC implemented a massive activity-based survey in 1999. The survey pool was comprised of approximately 6,000

households in the four-county region. Note, this effort was independent of the panel wave survey that was also conducted in 1999.

Similar to the panel survey, respondents were asked to provide demographic information and complete a two-day travel diary. However, the activity survey contrasts the panel approach in that it asked participants to provide information about the places to which they travel throughout the day, rather than the actual trips they make. Each person is asked to record the following information for *each place* to which he or she travels:

- Name and location of the place
  - Arrival time at the place
  - Mode traveled to get to the place
  - Number of household members who traveled with the person
  - Number of non-household members who traveled with the person
  - The main activity conducted
  - All other activities conducted
  - Departure time from the place
- (PSRC 1999, unpublished)

Activity-based travel analysis is characterized by a more holistic framework, in which travel is analyzed as patterns of behavior, derived from the lifestyles and activities of the members of the population. The traditional focus on the trips themselves is replaced by a focus on the reasons behind the trips. Some of the features unique to activity-based travel analysis include the following (Jones et al, 1990):

- explicit treatment of travel as a derived demand
- focus on sequence or patterns of behavior rather than discrete trips
- emphasis on decision-making in a household context, taking into account the linkages between members

- emphasis on the detailed timing as well as the duration of activity, rather than the traditional categorization of “peak” and “off-peak”
- explicit consideration of spatial, temporal and inter-personal constraints on travel and location choices
- recognition of the interdependencies among events which occur at different times, involve different people, and occur in different places
- use of household and person classification schemes (such as stage in family life-cycle) based on differences in activity needs, commitments and constraints

While activity-based modeling theoretically addresses many of the shortcomings of the traditional methods, it also requires a substantially more complex treatment of travel. Thus it has so far been carried much further in research efforts than in actual practice. Nevertheless, it is emerging as the cutting edge in travel analysis.

The survey pool for *this* project has been randomly drawn from the larger pool of people who completed the PSRC activity survey. This will greatly assist in the implementation of the stated preference interviews. Participants will have already provided all of the demographic information that will be required for analysis. Additionally, the activity data provides information about participants actual travel decisions, which is crucial for calibrating their stated preference responses. The role of the activity survey will be discussed in greater detail later in this report.

### ***Regional models***

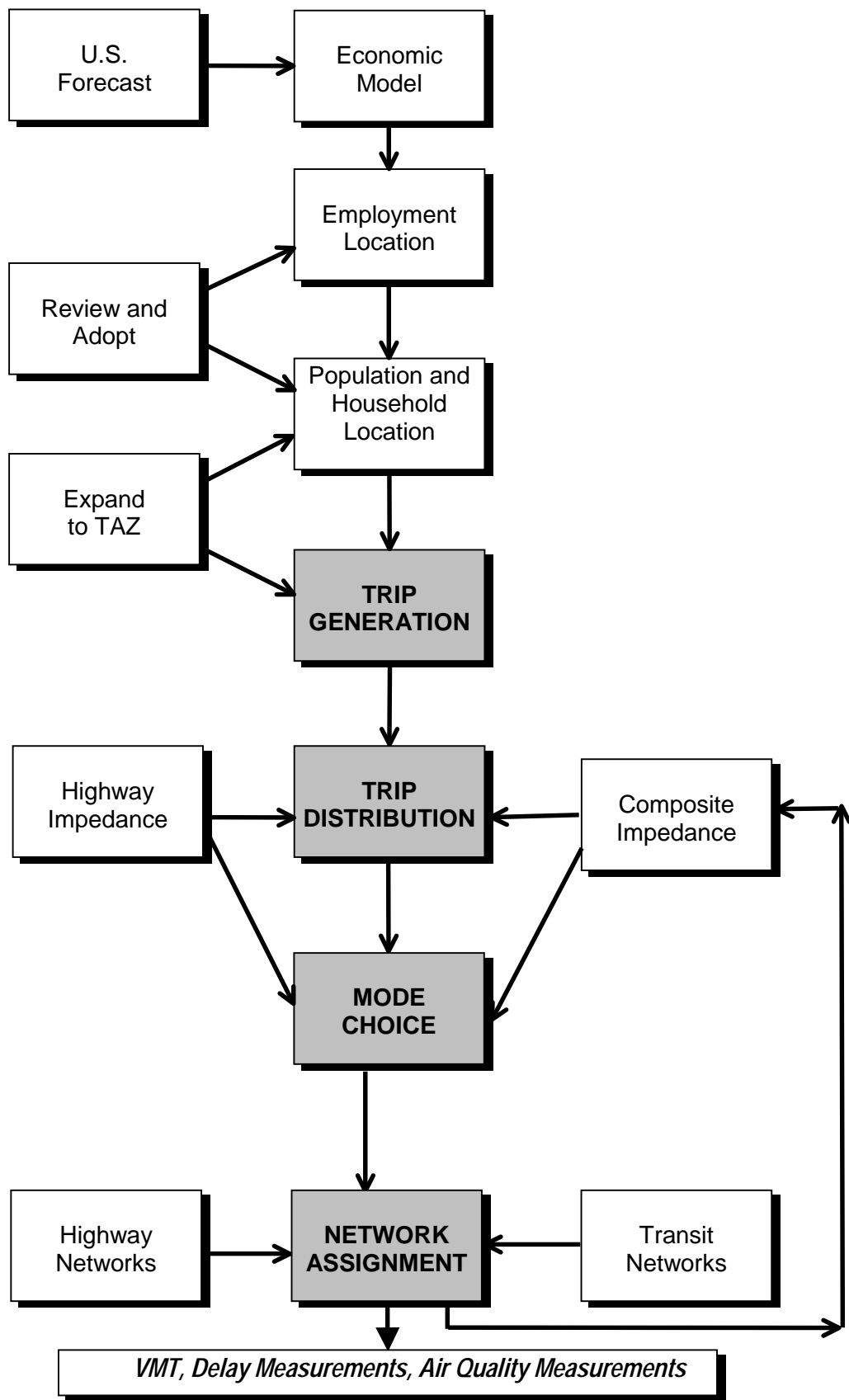
#### **Puget Sound Regional Council Forecasting Model**

The PSRC has developed an extensive travel demand-forecasting model for the four-county region. The PSRC model is based essentially upon the traditional four-step forecasting process, with some added improvements that target characteristic drawbacks of that approach. The sub-models contained in the PSRC model were estimated using single waves of the panel survey data (utilized as cross-sectional data).

The PSRC continuously works to update the forecasting model to reflect the state-of-the-art to the greatest extent possible. However, because the model is so large and complex, there is usually considerable lag time between recommended improvements and their implementation. Many components of the model have been refined to encourage the inclusion of alternative transportation modes. However, there remains a lack of relevant data with respect to why travelers do or do not make choices alternative to the SOV. Thus, even though the model structure has been improved to accommodate these alternative choices, it is still not very sensitive to the factors that encourage or discourage them.

Figure 1 shows the process that is employed by a typical four-step travel demand-forecasting model, such as the PSRC model. The approach begins by dividing the area under study into transportation analysis zones (TAZ), which are usually based on census tract and block boundaries, and developing the transportation network to be modeled. The transportation network is coded by a series of links (that represent roadways or transit lines) and nodes (that represent intersections). Once the TAZ and transportation network have been defined, travel demand is estimated by carrying out the following four steps:

1. Trip Generation
2. Trip Distribution
3. Mode Choice Analysis
4. Network Assignment



**Figure 1: “Four-Step” Travel Demand Forecasting Process**

These steps are described in the following sections.

### Trip Generation

Trip generation is the first of the four basic phases in the traditional travel demand forecasting process. The trip generation model estimates the total number of trips produced by and attracted to each transportation analysis zone in the study area. Inputs into this model include population and household characteristics, employment information, economic model output, and land-use information. Typically, either regression equations or cross classification tables are used to generate trip rates (daily trips per household) on the basis of independent variables such as household sizes, income groups, and auto availability. The PSRC trip generation model utilizes cross-classification tables, which are based upon household sizes and auto availability.

Trips generated are categorized by their general purpose. Typical trip purpose categories are:

- Home-based-work: any trip with home as one end and work as the other end
- Home-based-shop: any trip with home as one end and shopping as the other end
- Home-based-other: any non-work or non-shopping trip with home as one end
- Non-home-based: any trip that does not have home at either end

The trip generation model generally estimates the number of trips that are generated per household during the analysis period for each of the purposes under consideration. For its output, the trip generation model estimated the total number of trips produced in each TAZ and the total number of trips attracted to each TAZ, categorized by trip purpose.

### Trip Distribution

The trip distribution model allocates the trips estimated by the trip generation model to create a specific zonal origin and destination for each trip. The result is a trip matrix (for each of the trip purposes specified in trip generation) that estimates how many trips are taken from each zone to every other zone. The trips are often referred to as trip interchanges. The most common technique for determining trip distribution is the *gravity model*, which distributes trips according to two somewhat simplistic assumptions: (1) more trips will be attracted to larger zones (the size

of a zone is defined by the number of attractions estimated in the trip generation phase, not the geographical size), and (2) more trip interchanges will take place between zones that are closer together than the number that will take place between zones that are farther apart. Another method for trip distribution is the utility maximization method, which is based upon the theory that people will travel to the destination that has the highest utility for their purpose. Although utility maximization is theoretically more aligned with how travelers actually make choices about their destinations, it is not yet widely utilized in industry.

The PSRC has made some progress toward incorporating utility-based methods into their trip distribution process by integrating a “workplace choice” model with their work mode choice model. Other than that, they still rely primarily depends upon the gravity model for trip distribution (PSRC 1999, unpublished).

#### Mode Choice

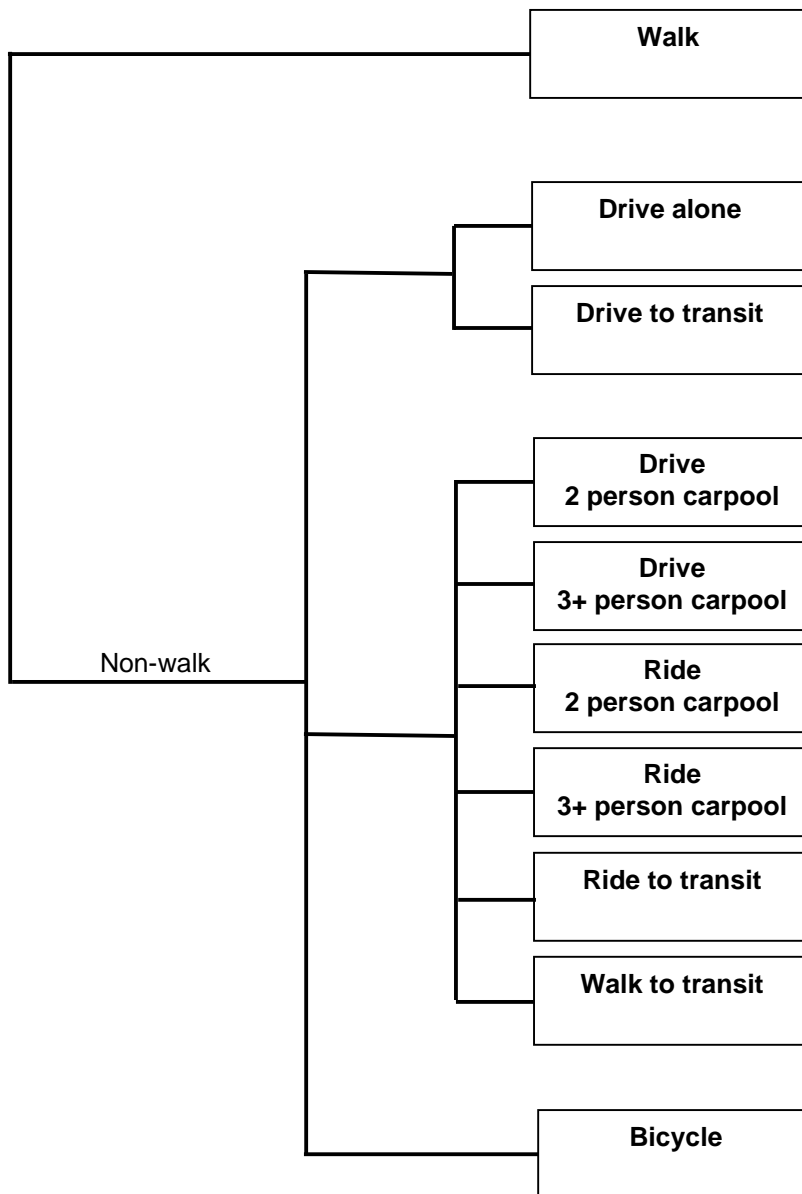
The mode choice model is used to predict the share of total trips that will be made by each available mode. Modes that have been traditionally modeled are single-occupant-vehicles, carpools, and transit. However, non-motorized modes such as bicycling and walking are increasingly being included in mode choice models. Varying forms of a *logit model* are most typically utilized for mode choice in the four-step process. Logit models measure the relative attractiveness of the modes on the basis of attributes such as travel times by mode, travel costs by mode, and the household characteristics of the travelers who make the mode choice. These relative attractiveness measures are used to predict the percentage of trips made using each mode, for each trip purpose. The percentages are applied to the trip matrices that are generated in the trip distribution step. The final result is a series of trip tables that reflect every combination of trip purpose and available mode. Each trip table specifies how many trips occur from each zone to every other zone, for the mode and trip purpose unique to that table.

The PSRC utilizes a nested logit structure for its mode choice model. In its current form, the models include the following mode alternatives:

- Drive Alone
- Shared ride, 2 occupants
  - as driver
  - as passenger
- Shared ride, 3+ occupants
  - as driver
  - as passenger
- Transit, walk access
- Transit, drive access
- Bicycle
- Walk

In their recommended models, the number of walk trips are estimated a priori through a “pre-mode choice” model. The remaining mode choices are incorporated into a nested logit model. The PSRC has developed work and non-work mode choice models. The nesting structure for the work model is shown in Figure 2. The PSRC found that segmentation of the mode choice models according to “car competition” categories (number of household workers verses number of household vehicles, segmented by income quartile) to be most effective (PSRC 1999, unpublished).

Developing TDM-sensitive inputs for a mode choice model are the primary focus of this research project. The theory of the logit model will be described in the “Modeling Methodology” chapter of this report.



**Figure 2: Nesting Structure for PSRC Recommended Work Mode Choice Model**

### Network Assignment

The network assignment model assigns the trips by each mode to their corresponding networks. Many methods can be used to perform network assignment, and most recognize the effect of traffic congestion on route choice. Network assignment is typically based on “generalized cost” of traversing the links in the network, which includes measures of time and/or cost.

The most basic form of network assignment is the *all-or-nothing* method, which simply assigns all trips to the network simultaneously along the routes that have the least impedance. All other routes are assigned nothing. This method should only be applied alone where no congestion is anticipated because it does not consider the effect that increasing congestion will have on the impedance of a route. However, all-or-nothing assignment is also the starting point for other iterative assignment methods that do account for congestion, namely the *capacity restraint* and *equilibrium* methods. The capacity restraint method involves a number of iterations and builds on the original all-or-nothing assignment by incrementally changing link travel time (and thus impedance) as congestion increases. The equilibrium method takes that one step further by applying a linear programming solution and iterating until no vehicle or person can improve its trip impedance by changing paths. The PSRC model utilizes an equilibrium method for network assignment.

Although these assignment procedures consider the effects of congestion, they do have drawbacks. The interactions between links are not considered, so travel time on one link is independent of the volumes on adjacent links. Also, there is no temporal dimension to the traffic assignment, so fluctuation within an hour, or the effects of queuing are not recognized. Finally, because the trip table is fixed, the entire table must be assigned from origin to destination during the analysis period, regardless of whether sufficient capacity exists (Cambridge Systematics et al 1996).

### **Sound Transit Mode Choice Model**

In November 1996, voters within the King, Pierce, and Snohomish Counties approved an increase in local taxes (a 0.4 percent increase in local sales tax and a 0.3 percent increase in the local motor vehicle excise tax) to fund the local share of a regional transit plan. Sound Transit is the agency that was formed to design and build the transit system. Sound Transit has designed new regional services integrate with services provided by local transit agencies, offering a region-wide integrated system of routes, schedules and fares.

Sound Transit's plan has been developed to fit within the region's comprehensive Metropolitan Transportation Plan. It reflects the plans of local transit agencies that have been partners in regional transit planning. In addition to light rail and local transit, the plan includes provisions for numerous other transportation improvements, namely: HOV lane improvements, ferry service improvements, airport facilities, automobile facilities, improvements for freight traffic, and bicycle and pedestrian facilities (Sound Transit 2000).

To analyze the impacts of proposed improvements, Sound Transit utilizes an *incremental logit model*, which is founded upon observed baseline mode shares. Sound Transit is able to capitalize on the detailed demand forecasts provided by the PSRC regional model. Given the baseline demand, the incremental logit model estimates *changes* in demand that result from transportation improvements. This is much simpler and less data intensive than estimating and calibrating a complete demand model, but it is an option only if such a demand model already exists. The relative effectiveness of various proposed improvements can be assessed by comparing their respective estimated changes in demand (Parsons Brinckerhoff 1993).

The Sound Transit approach to mode choice analysis is particularly noteworthy because it illustrates a variation in mode choice modeling that could potentially be utilized for this project.

## Chapter II: Literature Review

### Measuring TDM Effectiveness

When evaluating TDM, there is a distinction between TDM effectiveness and TDM cost-effectiveness. *TDM effectiveness* indicates how successful a particular strategy or combination of strategies has been or will be at achieving the three types of travel reduction:

1. Reduce the number of vehicle trips in the system through mode shifts from SOV to HOV or non-motorized modes.
2. Reduce the number of trips during peak periods through drivers changing their routes or times of travel.
3. Reduce the number of person-trips in the system.

Most available information on TDM has focuses on the reduction in vehicle trips due to shifts from SOV to HOV or non-motorized modes. Less information is available regarding the elimination of person-trips. This is because TDM programs are primarily directed at work trips, which most often result in mode shifts. The only cases in which work trips could possibly be eliminated are though the implementation of telecommuting and condensed workweeks. *TDM cost-effectiveness* (or cost-efficiency) takes the measurement of effectiveness one step further and actually weighs the costs of implementing a program against its benefits.

The most predominant approach found for evaluating the success of TDM strategies relies on surveys and case studies. Typically, employers who have been required to implement TDM programs are asked to complete surveys before and after their programs are put into practice. The survey data is then used to derive simple measures of effectiveness. In some cases, efforts have been made to use this type of data to create a general framework for predicting the impact of TDM programs. There are also occurrences of Metropolitan Planning Organizations (MPOs) making adjustments to their four-step models in an attempt to assess TDM impacts. The

following pages will describe the cases found for all of these efforts, and discuss the drawbacks of the approaches.

## **Examples of Survey Based Analysis**

### *State of Washington*

Part of mandate of the Commute Trip Reduction Law is that WSDOT monitor its effectiveness. The WSDOT Commute Trip Reduction Office is responsible for conducting the effectiveness evaluation, which they accomplish by surveying the participating major employers. Based upon the analysis of survey results, the CTR Task Force reported an average reduction of 18,500 vehicles from the state's roadways every morning as a result of the CTR Law (WSDOT 1999). However, while this type of before/after survey analysis represents a concerted effort to evaluate the impact of the legislation, it is vulnerable to a major flaw. Namely, the questions are often not able to capture external influences over the measures in question. For example, an aggressive TDM program surely will result in some level of reduction in VMT for the company that implements it, but so would laying off a portion of that company's work force. Survey questions must be framed very carefully to minimize the impact that non-TDM factors have on the calculated effectiveness of TDM.

Another recent effort surveyed over 900 private and public sector employees throughout the State of Washington (Lovrich et al. 1999). The study was conducted by the staff of the WSDOT Commute Trip Reduction Office, assisted by the Washington State Transportation Research Center (TRAC). The research team identified 18 organizations within the state that represented a wide range of geographic areas and economic sectors. Employees were randomly selected from within these organizations to complete the survey.

A stated goal of this project is to gain insight into the "cognitive processes" that employee use to decide to switch from SOV to alternative modes. Rather than use an empirical basis, the survey instrument primarily utilizes ordered preference questions that do not lend themselves to any type of strict evaluation. The study concludes that people who claimed to switch modes as a

result of TDM also tended to have environmental concerns and bought into the concepts behind the implementation of CTR. However, these conclusions are based on responses that are practically anecdotal. Thus, they could not be applied to a more general predictive effectiveness model.

### *State of California*

In 1988, the State of California enacted the predecessor to Washington's CTR law, Regulation XV. This legislation requires all sites employing 100 or more workers to develop trip reduction plans encouraging employees to use modes other than driving alone to get to work. Similar to the CTR law, the original target reductions of Regulation XV have been revamped and relaxed by the California legislature, as it became clear that the targets were unrealistically optimistic. Regulation XV was the first piece of legislation of this type, and it has been the target numerous evaluations.

The Institute of Transportation Engineers (ITE) produced an extensive survey-based analysis that documents changes in the average vehicle ridership (AVR) of participating employees, due to the implementation of the employer-based trip reduction plans in southern California (ITE, 1994). AVR was calculated by dividing the total number of employees arriving at work during the morning peak period by the total number of vehicles they drove. This value was averaged over the course of one week.

For this analysis, a baseline AVR calculated prior to Regulation XV was compared to values calculated two years after its implementation. The results of this calculation ranged from an increase in AVR of 4.5 percent in the central city region, to an AVR increase in 2.5 percent in the greater metropolitan region. The results reflect a sample of 1,110 trip reduction plans, representing 77 percent of all employer sites with approved plans.

### *COMSIS Data*

COMSIS Corporation compiled a substantial amount of case study data from all over the US. This report uses employee modal split as a measure of effectiveness, mainly because it was the most universally available information from surveys of TDM programs (COMSIS 1990). This project employed the index “Number of Vehicle Trips per 100 Travelers” to estimate vehicle trip reduction impact from modal split. This was done by assuming an occupancy level for each mode:

- Drive Alone - 1 vehicle trip for every person trip
- Carpool - 0.4 vehicle trips for every person trip (assumes 2.5 persons per carpool)
- Vanpool - 0.083 vehicle trips for every person trip (assumes 12 persons per vanpool)
- Transit - 0.033 vehicle trips for every person trip (assumes 30 persons per vehicle)
- Bicycle/Walking - no vehicle trips per person trip

Using this index, a net trip reduction was calculated, by taking the difference between the number of vehicle trips made under the TDM program, and the number of trips that would have been made without the TDM program (represented by a control site where no TDM program is in place).

This study assessed TDM effectiveness at area-wide levels, and also at individual program level. The area-wide trip reduction rate ranged from 2.4 percent to 17.8 percent, while trip reduction rates at individual employment sites ranged from 5.5 percent to 47.6 percent.

### **TDM within Travel Demand Forecasting**

Several cases exist where agencies have attempted to incorporate TDM into empirical models. Some agencies include TDM elements in their travel demand forecasting models, at varying levels of detail. Figure 3 illustrates the specific components of the traditional four-step model that would be impacted by various TDM strategies. No model has been found that incorporates TDM to the degree shown in the figure.

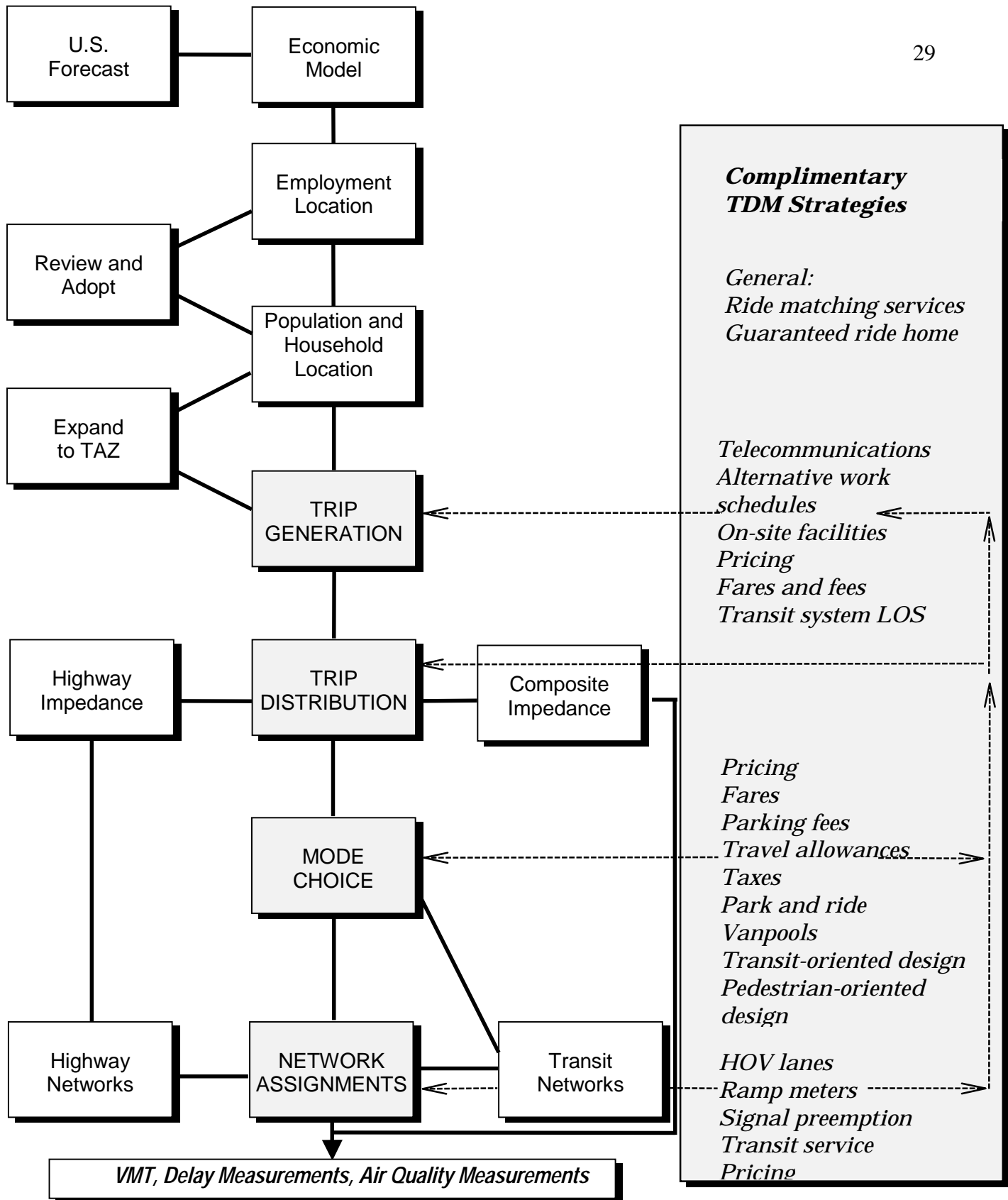


Figure 3: TDM Strategies in Travel Demand Forecasting Process

A network-based forecasting model provides a logical basis for estimating area-wide impacts of TDM programs. But most forecasting models do not include many variables that are sensitive to TDM strategies, due to either insufficient survey data or the inability to forecast the variables over a long-term horizon. As a result, the majority of forecasting model applications considers TDM strategies only to the extent that they affect the time and cost parameters of the transportation network being modeled. Some attempts do exist, however, at a more comprehensive inclusion of TDM strategies in empirical models.

### **General Empirical TDM Models**

Research uncovered two major efforts in developing generalized models to evaluate TDM effectiveness.

#### ***COMSIS Model***

The COMSIS model uses trip tables from these four-step forecasting models as inputs to calculate what changes in travel characteristics can be expected from the implementation of specific TDM strategies. The model output includes changes in mode split, vehicle occupancy, vehicle miles traveled, number of person trips, and number of vehicle trips. The user defines parameters such as the level of participation in carpool programs, the timesaving that result from using an HOV facility, etc. Although this approach assesses the impact that a given level of TDM participation will have on the transportation network, it relies on the user to know ahead of time what the effectiveness of each TDM measure will be. Some of the highlights of this model are presented in Table 2.

**Table 2: Highlights of COMSIS Model**

<b>Application</b>	Measures apply to both employer-based and broad-based programs
<b>TDM Strategies Evaluated</b>	Transit Service Improvements Carpool Programs Vanpool Programs Bicycle/Pedestrian Facilities & Site Improvements Employer Complimentary Support Measures Preferential HOV Treatments Economic Incentives Parking Supply and Pricing Management Tolls and Congestion Pricing Flextime Condensed Work Weeks Telecommuting
<b>Cost Variables</b>	Addresses costs in terms of three stakeholders: Society at Large Employers Individual Travelers
<b>Output</b>	Can calculate a cost savings per shifted mode trip
<b>Database</b>	Case studies of several successful TDM programs throughout the country
<b>Other Comments</b>	Model relies heavily on the user to input the effectiveness of many of the strategies rather than predicting the effectiveness.

***JHK Model***

JHK & Associates created a model to measure the effectiveness of employer-based TDM, for the City of Pleasanton, CA, and the FTA. Table 3 presents the features of this model (Dagang 1993).

The JHK Model does not provide analysis of the impacts of TDM strategies on an area-wide level. This model requires an even greater amount of user input regarding the effectiveness of each strategy than the COMSIS model.

The JHK model is basically a spreadsheet that calculates cost-effectiveness of TDM programs, based almost entirely on user inputs of program effectiveness. As a result, this model is not able to analyze the *potential* effectiveness of proposed TDM projects – in other words, it can't calculate TDM effectiveness unless the user inputs the TDM effectiveness.

**Table 3: Highlights of JHK Model**

<b>Application</b>	Designed to evaluate site-specific programs
<b>TDM Strategies Evaluated</b>	<ul style="list-style-type: none"> <li>Telecommuting*</li> <li>Compressed work weeks*</li> <li>Reduction in employer-subsidized parking*</li> <li>Transportation allowance*</li> <li>Bicycle lockers and showers*</li> <li>Transit pass subsidies*</li> <li>Monetary incentives for alternate mode users*</li> <li>Preferential parking for carpools &amp; vanpools</li> <li>Employee transportation coordinator</li> <li>Reduction in parking supply</li> <li>Vanpool program</li> <li>Shuttle service to transit stations</li> <li>Employee ridematching program</li> <li>Employee commute information program</li> <li>Guaranteed ride home</li> </ul>
<b>Cost Variables</b>	<ul style="list-style-type: none"> <li>Annual Labor Cost</li> <li>Annual Direct Operational Cost</li> <li>Annual Capital Cost</li> <li>Annual Overhead Cost</li> <li>Annual Cost Savings</li> <li>Total Daily Cost</li> </ul>
<b>Output</b>	<ul style="list-style-type: none"> <li>Reduction of Daily Trips &amp; Peak Period Trips</li> <li>Strategies ranked by “Average Daily Cost Per Daily Trip Reduced”</li> </ul>
<b>Database</b>	<ul style="list-style-type: none"> <li>Literature Review</li> <li>Extensive Employer Survey</li> <li>Review of Existing Databases with Employer Based Programs</li> </ul>
<b>Other Comments</b>	Trip reduction estimated by the model for 7 of the 15 TDM strategies (marked above with *) - the other 8 must be estimated by the user

### **Examples of MPO Models**

A number of regional MPOs have attempted to incorporate TDM strategies into their regional travel demand models. COMSIS worked with the MPOs for both the Washington, DC metropolitan area and the Philadelphia, PA metropolitan area to incorporate TDM into the mode choice components of their four-step models. This approach exclusively incorporated the time and cost aspects of TDM strategies into the model. The strategies included:

- Pricing strategies: congestion pricing, parking pricing, taxes, and fees
- Transit improvement strategies: increased service frequency and increased bus speeds in high-volume bus corridors

The Washington, DC model also included one land use strategy – shorter distances from bus stops to buildings – by adjusting the transit access time downward (MWCOG 1994).

Time and cost TDM elements were also integrated into all major components of the TRIPS model for the San Francisco Bay Area. The model allowed for the following strategies to be included:

- Pricing strategies: tolls, taxes, parking charges
- Travel time strategies: HOV facilities

This model includes walking and bicycling as mode alternatives. While the TRIPS model improves upon the COMSIS models by incorporating the TDM elements into all of the steps, rather than just mode choice, its primary shortcoming is that it does not employ a refined network assignment algorithm. Instead, it uses a simplistic routing method to estimate changes in level of service that result from tested strategies (Johnston and Rodier 1994).

The Portland Metropolitan Service District (Metro) employs some very innovative land use factors into its regional model. Metro has expanded the traditional four-step process to six steps with the development of “pre-generation” and “pre-mode choice” steps. Land use factors such as a PEF (pedestrian environment factor), the number of retail employees located within one mile,

and number of employees within 30 minutes by transit are input into the auto ownership model, which in turn is input into the actual trip generation model. Inclusion of these land use variables in this stage is designed to give a more accurate representation of trips taken by alternative modes. Alternative modes is also taken into account in the “pre-mode choice” model through a set of algorithms designed to separate person trips made by non-motorized modes (walk or bicycle) from motorized modes (auto or transit).

The PEF, which is used in the pre-generation, pre-mode choice, and mode choice steps, is designed to reflect the character of the pedestrian environment, including ease of street crossings, sidewalk continuity, local street characteristics, and topography. The PEF score is obtained by adding ratings of 1, 2, or 3 (corresponding to “bad”, “average”, and “good”) in each of these categories. Use of the PEF has been somewhat controversial, and Metro intends to develop more objective environmental estimators (Cambridge Systematics 1996). Nevertheless, Metro’s model structure is quite unique in its attempt to incorporate land use considerations.

Another attempt to incorporate TDM into a forecasting model can be found in the Greater Vancouver Regional District (GVRD) in British Columbia, Canada. In addition to considering travel time and pricing measures, similar to the Washington, Philadelphia and San Francisco models, GVRD considers numerous factors that affect other aspects of the forecasting model. Specifically, GVRD considers the following strategies (TRANSPORT 2021 1993):

- Parking charges, fuel tax, CBD licensing fees, bridge tolls: pricing strategies are incorporated into the cost parameters of the model.
- Telecommuting: trips in the work trip table produced by the trip distribution step are reduced by an assumed effectiveness rate.
- Bus priority facilities (bus lanes, queue jumps): transit travel times in the mode choice model are modified.
- HOV lanes: modifications are made to the auto-occupancy sub-model, which is used as an input to the trip distribution and mode choice models.

### **Drawbacks of Existing TDM Evaluation Methods**

Existing methods and models that have been developed to assess TDM strategies employ a variety of approaches to estimate the impacts on transportation systems. The most common approach to evaluating TDM is to summarize before/after data from surveys completed by employers or employees who are affected by mandatory TDM programs. While this approach is simple and direct, it has two major drawbacks. First, it is difficult to frame questions so that the impact due to TDM is independent of impacts due to other external factors. Second, no goodness of fit measure can be calculated using this method.

Some agencies do incorporate time and cost factors of TDM into their mode choice models. However, no utility-based models were found that include a broader spectrum of variables. Another concern with current TDM effectiveness data is that there has been little effort to account for the synergistic effects that may occur when several TDM strategies are applied in combination with each other.

### **Stated preference design and analysis**

Through research to date, several reasons have emerged for the general failure of traditional analysis methods to support demand-oriented transportation solutions:

- Implementation of transportation solutions traditionally relies on the results of economic analysis in which benefits are defined largely in terms of travel time reduction. This heavily favors capacity-oriented solutions because more cars and faster cars will produce higher 'benefits'.
- Benefits are also defined in terms of improved safety. While an argument can be made that eliminating vehicle trips should improve safety, empirical data does not exist as it does for the safety impacts of capacity-improvements, and it is thus more difficult to quantify the safety impacts of demand-oriented solutions.

- The relatively intangible nature of some benefits of demand-oriented solutions (such as preservation of green space) does not lend itself to simple quantitative analysis.
- Transportation analysis is based on travel forecasts that predict traveler behavior based on the results of travel surveys. Typically, these surveys are *revealed preference surveys*. Revealed preference consists of a comparison of actual chosen and rejected travel alternatives, simply based on direct observation of travel behavior. Thus it is difficult, if not impossible, to forecast mode choices that result from strategies that have not yet been implemented.

While some of these points indicate a potential need to redefine benefits to better reflect current policies and priorities, the focus of this project will be the deficiencies in empirical data that inhibit analysis of demand-oriented strategies. Many of the deficiencies can be attributed to the use of revealed preference data for travel forecasting. Although revealed preference methods are appropriate for deriving travel utilities, they have limitations that restrict the inclusion of non-traditional transportation alternatives, namely,

- Revealed preference methods cannot be used directly to evaluate demand under conditions that do not yet exist
- Revealed preference methods require that variables be expressed in quantitative terms (such as time or cost). Thus, more qualitative variables that often dictate why a traveler will or will not choose a less traditional mode (such as comfort or convenience) can rarely be included in evaluation.
- It can be difficult to obtain sufficient variation in revealed preference data to evaluate a wide range of variables of interest (Kroes and Sheldon, 1988).

Even if alternative modes are included as options in the mode choice component of a network model, it is unlikely that revealed preference data will yield the broad range and combinations of reasons that may induce travelers to change their mode of travel. It seems clear that a more robust survey would address these analysis drawbacks. Additionally, if more detailed utility tradeoffs could be established, benefits could possibly be defined as some type of relation between the number of trips accommodated by the system and the capacity of its transportation

infrastructure (for example, more trips accommodated with no increase in capacity would result in higher benefit than more trips accommodated with increase in capacity).

The objective of this project hinges primarily on the development of a survey and analysis method that would allow a more comprehensive set of travel choices to be analyzed. Many of the drawbacks associated with the analysis of TDM alternatives can be directly addressed through the use of *stated preference* analysis of travel choices. Stated preference methods consist of a family of techniques to estimate relative utility functions, based on individuals' statements about their preferences in a set of actual *or hypothetical* transportation alternatives. Stated preference analysis must be carefully controlled, with transportation alternatives or contexts defined as levels of attributes that are designed by the researcher. A good design should consist of a rich set of travel choices and conditions, combined with sufficient variation to produce meaningful behavioral responses within the context of the strategies under study. In addition, it is important that a no-choice response should be included in the design to allow predictions of total demand (Louviere and Hensher, 1983).

Revealed preference data describes actual choices in terms of market-based measurements of attributes of alternatives (the known outcome). Stated preference, on the other hand, can describe potential choices in terms of constructed measures of real or hypothetical alternatives (the potential outcome). The survey can be constructed so respondents rank their preferences, rate their preferences, or simply state their first choice (Hensher 1993). Stated preference is a favorable method for researching the potential impacts of aggressive TDM strategies because

- It is flexible and capable of dealing with a variety of variables, both quantitative and qualitative.
- It provides a researcher with multiple observations per respondent for a variety of situations.
- It is easier to control because the researcher defines the conditions that are being evaluated by the respondents. (Kroes and Sheldon 1988)

The major drawback (and criticism) of stated preference is that respondents may not do in reality what they say given hypothetical situations. Following are three measures that greatly enhance the reliability of stated preference analysis:

***1. Conduct survey in interview form***

There is no doubt that demand estimates derived through a stated preference method require extremely careful survey construction and statistically solid interpretation. Conducting the survey in interview form is superior to a written format because it allows the researcher to verbalize the instructions for the choosing alternatives. It also allows the respondents to easily ask questions if something is not clear. A key to stated preference analysis is that the choices are clearly defined with nothing open to varying interpretation. This is much more easily accomplished if the survey is conducted face-to-face.

***2. Utilize a sound experimental design for choice sets***

Once the attributes are identified and attribute levels defined, they are combined into choice sets using a fractional factorial design (full factorial requires unrealistically high number of observations, if the experiment contains a large number of attributes.) The fractional factorial allows orthogonality to be preserved between main effects and in some cases, certain interactions. Orthogonality is the key to identification and precision in choice model estimation. It allows effects to be estimated independently from one another.

***3. Calibrate stated preference data using revealed preference data***

It is not necessary, nor recommended that stated preference be conducted to the exclusion of revealed preference. Indeed, the use of stated preference data in conjunction with revealed preference data can yield much richer results, and minimizes the discrepancy (through scaling) between stated preference and actual behavior. Although the two types of data cannot be pooled “naively”, statistically sound approaches exist through which they can be combined (Hensher 1993).

## Chapter III: Methodology

This project consists of three major components. The first component is the design and implementation of a stated preference survey to be used in conjunction with a revealed preference survey, which will result in a much richer set of data that explains conditions under which both traditional and alternative travel choices will or will not be made. The second component of this project consists of interviews to collect the mode choice data. In the third and final component, the data is analyzed to estimate a multinomial mode choice model. The result will be a model that can be used to estimate the change in mode market shares that would result from realistic innovative transportation investment scenarios that emphasize high capacity and non-motorized transportation modes.

Following is the general approach:

### Prior to interviews:

1. Identify TDM strategies that impact mode choice
2. Identify mode attributes that are impacted by TDM strategies
3. Define range of attribute values for each of the modes under consideration
4. Define mode choice sets with varying attribute values for competing modes

### Interviews:

5. Introduce project and define TDM strategies (i.e. guaranteed ride home, travel incentives)
6. Present series of choice sets to each group of participants
  - 20 to 25 sets of choices (observations) per individual
  - Each individual identifies which mode he/she would choose under each defined set of circumstances
  - Estimate that approximately 2 minutes will be sufficient to examine each set of choices
  - Supplemental illustrations where needed

7. After stated preference portion of interview, ask participants to complete a short supplemental revealed preference questionnaire. This will cover any necessary information not included in the PSRC activity and attitude surveys
8. Participants compensated \$40 after completion of interview

Analysis of data:

9. Estimate multinomial logit mode choice models
  - Models estimated using stated preference data
  - Models scaled (calibrated) using revealed preference data (from PSRC activity and attitudes surveys, and supplemental RP survey discussed in step 6)
10. Models will indicate:
  - Which mode attributes are significant and which are not
  - The elasticity of significant attributes – higher elasticities indicate attributes that will have a greater effect on demand when changed
11. Determination of significance and elasticities will indicate which TDM strategies should be most effective (i.e. high elasticity of travel time and reliability for transit would indicate that TDM strategies that target those attributes would result in higher mode shift to transit)

## Discrete choice analysis

### *Economic Theory and Discrete Choices*

Discrete choice analysis is based upon discrete variables, in that utility is a function of the alternatives available to a decision maker. In an example case where three alternatives exist, the utility (U) is defined as:

$$U = U(\delta_1, \delta_2, \delta_3)$$

Where,  $\delta_1 = 1$  if alternative one is chosen, 0 if alternative one is not chosen

$\delta_2 = 1$  if alternative two is chosen, 0 if alternative two is not chosen

$\delta_3 = 1$  if alternative three is chosen, 0 if alternative three is not chosen

Since only one alternative is chosen, the utility function can only assume the following values:  $U(1, 0, 0)$ ,  $U(0, 1, 0)$ ,  $U(0, 0, 1)$ . (Ben-Akiva and Lerman 1985)

Indirect utility (V) incorporates descriptions of alternatives and cost into the utility function, such that:

$$V_1 = V(z_1, c_1)$$

$$V_2 = V(z_2, c_2)$$

$$V_3 = V(z_3, c_3)$$

Where,  $z =$  a vector of alternative specific attributes

$c =$  cost of selecting the alternative

Utility maximization theory states that an individual will select the alternative with the highest person utility. For example, alternative one will be selected if and only if

$$V_1 \geq V_2 \text{ and } V_1 \geq V_3$$

In general, the decision rule used is that alternative  $i$  is chosen by decision maker  $n$

$$\text{if } V_{in} > V_{jn}, \forall j \neq i, j \in C_n$$

where  $C_n$  is the set of choices available to decision maker  $n$ .

In empirical work, indirect utility functions are written as:

$$V_{in} = V(Z_{in}, S_n, c_{in})$$

Where,  $z_{in}$  = attributes of alternative  $i$ , as viewed by decision maker  $n$

$S_n$  = characteristics of decision maker  $n$  (e.g. income)

$c_{in}$  = cost of all  $i$  to decision maker  $n$

### ***Probabilistic Choice Theory***

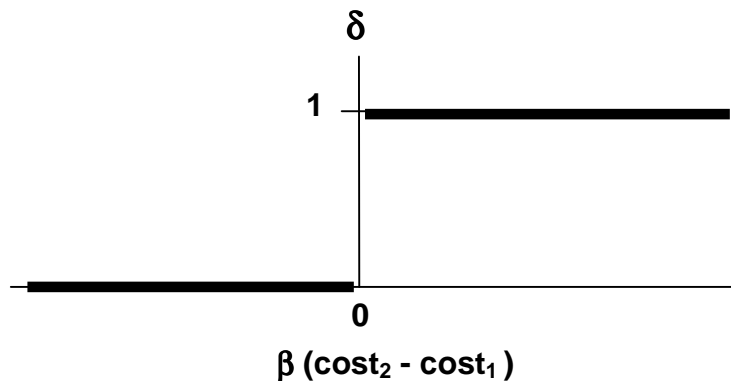
Deterministic choice theory states that the decision maker will always choose the alternative with the highest person utility: i.e. if utilities indicated that 100 people each have a  $\text{Prob}_{\text{auto}}=51$  percent and  $\text{Prob}_{\text{bus}}=49$  percent, all 100 people will choose auto. Figure 4 illustrates the cumulative density function (CDF) of a deterministic model, where

$$u_1 = \beta \text{ cost}_1 \leftarrow \text{auto}$$

$$u_2 = \beta \text{ cost}_2 \leftarrow \text{bus}$$

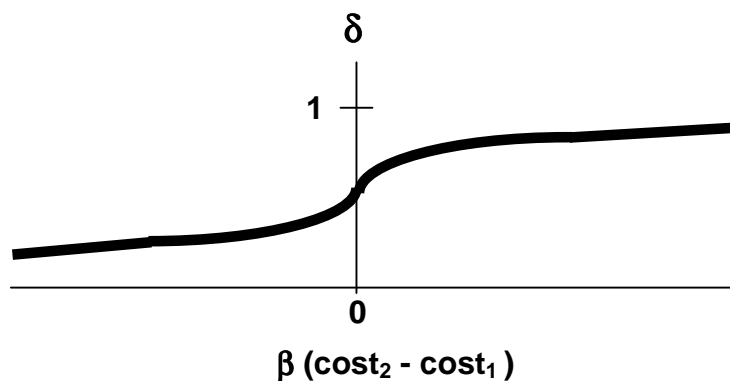
$$\delta = 1 \text{ if decision maker chooses alternative 1 (auto)}$$

$$= 0 \text{ otherwise}$$



**Figure 4: Deterministic Choice Model**

Probabilistic choice theory states that due to unobserved factors that are not included in the estimation of the decision maker's utility, that person may not always select the alternative with the highest calculated utility. Figure 5 illustrates the CDF of the more realistic probability model, where the selection probabilities depend on the difference between alternatives (Louviere et al. 2000). The greater the difference in costs between the alternatives, the higher the probability that the decision-maker will choose the lower cost alternative. However, the unobserved factors dictate that there will always be some probability that the person will choose the other alternative. Note, in this context "cost" represents all measured attributes of the alternatives in question.



**Figure 5: Probabilistic Choice Model**

### **Random Utility Theory**

Econometric probabilistic choice models are estimated based on random utility theory, which emerges from the reality that consumers' actual utilities cannot truly be measured. Sources of omission include:

1. unobserved attributes of the alternatives
2. unobserved taste variation of the individuals
3. measurement errors and imperfect information
4. use of instrumental (proxy) variables

(Ben-Akiva and Lerman 1985)

This leads to the potential misspecification of the choice process for a particular individual. Consequently, each choice process has an inherent randomness, so utility is treated as a random variable. Within this context, the utility function is defined as:

$$U(z_{in}) = V(z_{in}) + \varepsilon_{in}$$

where,  $z_{in}$  = vector of observable attributes of alternative  $i$  for individual  $n$

$V(z_{in})$  = deterministic or observable utility (estimated)

$\varepsilon_{in}$  = random component of utility

$U(z_{in})$  = total (true) utility

and the general statement of a random utility model (probability that an individual will choose alternative  $i$  over alternative  $j$ ) can be written as:

$$P_r(\text{choose } i) = P_r(U(z_{in}) \geq U(z_{jn})) = P_r(V(z_{in}) + \varepsilon_{in} \geq V(z_{jn}) + \varepsilon_{jn})$$

(Ben-Akiva and Lerman 1985)

## Logit Model

Different choice models can be derived depending on assumptions made about the distributions of the error terms ( $\epsilon$ 's). The most popular choice models are the Probit Model and the Logit Model. The Probit Model assumes that the  $\epsilon$ 's are distributed normally. Probit works well for a binary case, but for multinomial cases, Probit results in a choice function that is not closed form. Thus, due to computational reasons, the multinomial Probit is typically not practical.

The Logit Model, on the other hand, is close to Probit and can easily be extended to multinomial case. Logit assumes that the random components of utility are distributed with an IID Gumbel distribution (also called the extreme value type I distribution). This is typically the type of model that is used for mode choice analysis of greater than two alternatives. The assumption of Gumbel distributed  $\epsilon$ 's yields the multinomial logit (MNL) model:

$$P(i | i \dots j) = \frac{e^{(\beta' X_{in})}}{\sum_{i=1}^j e^{(\beta' X_{in})}}$$

where,  $i \dots j$  index alternatives (say modes)

$\beta'$  is a vector of estimated utility parameters

$X_{in}$  is a matrix of observable attributes for alternative  $i$  and individual  $n$

The utility parameters are most commonly estimated using maximum likelihood estimation (MLE). MLE is based upon the principle that a given sample could be generated by different populations, and is more likely to come from one population than another. Thus, the maximum likelihood estimates are that set of population parameters that generate the observed sample most often.

The result of the MNL model is the set of probabilities that an individual will select each of the alternatives available in the choice set – the sum of the probabilities will be 1.0. Random utility theory states that the individual is most likely to choose the alternative with the highest

probability, but some probability does exist that the individual will instead choose the other alternatives.

An important property of the MNL model is Independence of Irrelevant Alternatives (IIA), which states that the ratio of choice probabilities of any two alternatives is independent of the utilities of any other alternatives (Louviere et al. 2000). In other words, if some alternatives are added or removed from a choice set, the relative choice probabilities of the other choices will remain the same. IIA is violated if two or more alternatives share unobservable characteristics (i.e., they are not independent).

Numerous diagnostic statistical tests exist to determine whether or not IIA violations are present. IIA violations are addressed through the estimation of nested MNL models. As its name implies, the nested logit model contains subsets of choices that are nested within broader sets of choices. Alternatives that violate IIA (share unobservable characteristics) in the MNL model are grouped within the same nest. Then within the nest, the IIA property is satisfied. The probabilities that nested alternatives are chosen are conditional upon the broader choice first being chosen. For example, if the three mode alternatives are auto, bus and rail, analysis might show that an IIA violation exists between bus and rail – they share an unobserved characteristic that people who choose them have a propensity toward transit (or those who don't choose them dislike transit). Therefore, a nested structure could be designed that first determined the relative probabilities that an individual would choose auto or transit. The bus and rail alternatives would be grouped within the transit nest. Then, conditional upon the individual choosing transit, the probabilities that the person would choose bus or rail are calculated. MNL mode choice models will almost always require nesting.

### Scaling SP Data within the MNL model

The MNL model assumes utilities are Extreme Value Type I distributed, with a standard deviation of

$$\sigma_{\varepsilon} = \frac{\pi}{\sqrt{\lambda}}$$

$\lambda$  is an unknown scaling constant. In utility estimation,  $\beta$  is actually a composite coefficient – it is confounded with  $\lambda$ . The values of  $\lambda$  and  $\beta$  cannot be separated when the model is estimated from a single data source.  $\lambda$  is reflected in the MNL model as follows:

$$P(i | i \dots j) = \frac{e^{(\lambda\beta'X_{in})}}{\sum_{i=1}^j e^{(\lambda\beta'X_{in})}}$$

where,  $i \dots j$  index alternatives

$\lambda$  is the scale constant equal to  $\frac{\pi^2}{6\sigma_{\varepsilon}^2}$  ( $\sigma_{\varepsilon}^2$  is the variance of the error terms)

$\beta'$  is a vector of estimated utility parameters

$X_{in}$  is a matrix of observable attributes for alternative  $i$  and individual  $n$

The behavior of  $\lambda\beta$  depends on the error variance,  $\sigma_{\varepsilon}^2$ .  $\lambda$  is inversely proportional to  $\sigma_{\varepsilon}^2$ , and it scales the  $\beta$  estimated in choice models.

This scaling factor is a crucial component of stated preference analysis. Revealed preference data can be combined with stated preference data to estimate the value of  $\lambda$  - this is called data enrichment, and allows calibration of choice models that are estimated using stated preference data. If two data sources exist (such as SP and RP), they can be pooled under the restriction that common parameters are equal. Common parameters are those choice attributes that exist in both

data sets - but either data set can contain additional alternatives or attributes that the model does not. Louviere et al. (2000) present two methods for data enrichment. Both methods are based upon the assumption that common parameters are equal for both data sources, but their scale parameters may be different. We cannot identify both scale parameters, so one must be normalized. It is conventional to assume the scale of RP data set is one ( $\lambda^{RP}=1$ ), so the estimated value of  $\lambda^{SP}$  is relative to the RP scale.

The first method consists of estimating the desired model parameters and the relative SP scale factor by a manual search. The procedure consists of the following:

1. Define a range of values of  $\lambda^{SP}$  within which one expects the log likelihood function to be maximized (the authors state that the scale factors tend to lie between 0 and 3, based upon empirical evidence).
2. At each trial values of  $\lambda^{SP}$ , define a data matrix for the pooled data as a function of the scale factor, and estimate the remaining parameters of the pooled MNL model.
3. The estimate of  $\lambda^{SP}$  is obtained from the model solution that maximizes the value of the log likelihood function.

This method is computationally simple, and yields consistent inefficient estimates of  $\lambda^{SP}$ .

The second method yields a consistent and efficient estimate of  $\lambda^{SP}$ . A nested MNL model is estimated in which the data from the different sources is included in separate nests. This takes advantage of the MNL property that requires constant variance within nests, but allows the variance between nests to differ – the differences in variance between the SP nests and the RP nests yield the value of  $\lambda^{SP}$ .

It is possible that analysis could show that full data enrichment cannot be achieved – primarily if the basic assumption that the common model parameters are equal does not hold. In this case, alternatives such as determining if preference homogeneity still holds for subsets of the model parameters can be applied. However, the authors assert that if the design, layout and framing of

SP choices are done carefully, enriching the SP model results with RP data is typically quite successful (Louviere et al. 2000).

## **Consumer Choice Measures**

### **Marginal Rate of Substitution**

The logit model is a compensatory model, which means that the marginal rate of substitution between two independent variables in utility functions can be calculated. The tradeoff is simply determined by the ratios of the respective coefficients:

$$MRS_{BA} = \frac{\beta_A}{\beta_B}$$

where,  $MRS_{BA}$  is the marginal rate of substitution of variable  $B$  with respect to variable  $A$ .

$\beta_A$  is the estimated coefficient for variable  $A$ .

$\beta_B$  is the estimated coefficient for variable  $B$ .

### **Elasticity Calculation**

The relative impact that each continuous significant variable has on the probabilities that an individual will choose each alternative is determined through the calculation of elasticity. Direct elasticity ( $E$ ) is defined as the effect that a 1 percent change in an independent variable  $x_k$  will have on the probability that an individual  $n$  will choose alternative  $i$ , and is calculated by

$$E_{x_{ink}}^{\text{Pr}_n(i)} = \frac{\partial \text{Pr}_n(i)}{\partial x_{ink}} \cdot \frac{x_{ink}}{\text{Pr}_n(i)} = [1 - \text{Pr}_n(i)] \beta_k x_{ink}$$

where  $x_n$  is the vector of explanatory variables for that individual, and  $\beta'$  is the vector of estimated model coefficients (Ben-Akiva and Lerman 1985). After the elasticity of each explanatory variable is calculated for each individual in the response pool, the values can be averaged to estimate the average elasticity of each explanatory variable. If the average elasticity

is greater than or equal to 1.0, the variable is considered *elastic*. If the average elasticity is less than 1.0, the variable is considered *inelastic*. Whether the variables are elastic or inelastic, the relative effect that each variable will have on demand can be determined by comparing the variables' elasticities.

### ***Multiple Response Issues***

The estimation of a single model with repeated observations from each respondent gives rise to a correlation of disturbances because the unobserved influences that affect an individual's choice are likely to be correlated for all of the individual's choices. As a result, estimated standard errors of model coefficients will be understated by standard estimation packages. One conservative correction for multiple response bias is to multiply the standard error for each coefficient by the square root of the number of observations per respondent (Mannering 1987). The significance of each variable is based upon these adjusted figures.

## Chapter IV: Survey Design and Implementation

### Mode Alternatives

Table 4 shows the mode alternatives that have been identified for analysis. Potential modes have been determined for both the case where a person has a vehicle available, as well as the case where a person does not.

**Table 4: Mode Alternatives for Work and Shop Trips**

Car available	No Car Available
Drive alone Carpool Transit - walk access Transit – drive access Walk Bike	Carpool (passenger only) Transit - walk access Transit – drive access (passenger only) Walk Bike

### Identification of TDM Strategies

TDM Strategies are identified in Table 5 through Table 7. Within each strategy category, specific TDM actions are specified. Additionally, the tables show which mode attributes are affected by the successful implementation of the action, and the effect it would have on mode share. Note, in some cases the effect of a TDM action is to eliminate a trip. In this case, the actual impact would occur at trip generation, not at mode choice.

**Table 5: TDM Actions and Mode Impacts – 1 of 3**

<b>TDM Strategy</b>	<b>TDM Action</b>	<b>Impacted Mode Attribute</b>	<b>Effect on mode share</b>
Public education and promotion	<ul style="list-style-type: none"> <li>◆ Promotional campaigns, broadly focused through the use of radio, newspaper, or billboards</li> <li>◆ Promotional campaigns narrowly targeted through use of brochures mailed to target markets or employment sites</li> </ul>	<ul style="list-style-type: none"> <li>◆ Familiarity</li> </ul>	<ul style="list-style-type: none"> <li>◆ SOV ↓</li> <li>◆ HOV / NM ↑</li> </ul>
Area-wide ride matching	<ul style="list-style-type: none"> <li>◆ Develop a rideshare placement agency</li> </ul>	<ul style="list-style-type: none"> <li>◆ Familiarity</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Carpool / Vanpool ↑</li> <li>◆ transit / NM ↓</li> </ul>
Improve transit service	<ul style="list-style-type: none"> <li>◆ Add / change route</li> <li>◆ Extend hours of operation</li> <li>◆ Increase frequency</li> <li>◆ Implement flexible paratransit</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Reliability</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Transit ↑</li> </ul>
Vanpool service	<ul style="list-style-type: none"> <li>◆ Provide van</li> <li>◆ Compile and provide names of potential riders</li> <li>◆ Run subsidized promotion (free trial)</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Cost</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Vanpool ↑</li> </ul>
Subsidize transit & vanpool fares	<ul style="list-style-type: none"> <li>◆ Lower fares for target groups (i.e. children and senior citizens)</li> <li>◆ Free ride zone</li> <li>◆ Transit passes that provide 'lower than fare box' cost</li> <li>◆ Reduce fares through target corridor</li> </ul>	<ul style="list-style-type: none"> <li>◆ Cost</li> </ul>	<ul style="list-style-type: none"> <li>◆ Transit / Vanpool ↑</li> </ul>

**Table 6: TDM Actions and Mode Impacts – 2 of 3**

<b>TDM Strategy</b>	<b>TDM Action</b>	<b>Impacted Mode Attribute</b>	<b>Effect on mode share</b>
Improve non-motorized infrastructure	<ul style="list-style-type: none"> <li>◆ Provide sidewalks / walkways</li> <li>◆ Require ped/bike friendly design in new development</li> <li>◆ Build bike lanes / trails</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Comfort</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Bicycle / Walk ↑</li> </ul>
Improve bicycle amenities	<ul style="list-style-type: none"> <li>◆ Install bike racks on buses</li> <li>◆ Install bike racks and lockers</li> <li>◆ Provide bicycles</li> </ul>	<ul style="list-style-type: none"> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Bicycle ↑</li> </ul>
Improve HOV facilities	<ul style="list-style-type: none"> <li>◆ Build HOV lane</li> <li>◆ Provide HOV access priority</li> <li>◆ Provide HOV signal priority</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Reliability</li> </ul>	<ul style="list-style-type: none"> <li>◆ Transit ↑</li> <li>◆ Carpool ↑</li> <li>◆ Vanpool ↑</li> </ul>
Park & Ride Lots	<ul style="list-style-type: none"> <li>◆ Build / expand dedicated lot</li> <li>◆ Lease surplus parking space</li> <li>◆ Provide amenities (shelters, benches, sundries, bike/ped facilities) at lot</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Reliability</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Auto - transit ↑</li> <li>◆ Bike/walk - transit ↑</li> </ul>
Monetary incentives	<ul style="list-style-type: none"> <li>◆ Provide direct subsidies (i.e. transit pass, free parking for HOV)</li> <li>◆ Provide transportation allowance or parking cash-out</li> <li>◆ Provide indirect incentives (i.e. local merchant discounts, reward points)</li> </ul>	<ul style="list-style-type: none"> <li>◆ Cost</li> </ul>	<ul style="list-style-type: none"> <li>◆ Transit ↑</li> <li>◆ Carpool ↑</li> <li>◆ Vanpool ↑</li> <li>◆ Bike / Walk ↑</li> </ul>
Alternative work schedules	<ul style="list-style-type: none"> <li>◆ Allow / encourage compressed work week</li> <li>◆ Allow / encourage flextime</li> <li>◆ Allow / encourage telecommuting</li> </ul>	<ul style="list-style-type: none"> <li>◆ Time</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Don't make trip ↑</li> </ul>

**Table 7: TDM Actions and Mode Impacts – 3 of 3**

<b>TDM Strategy</b>	<b>TDM Action</b>	<b>Impacted Mode Attribute</b>	<b>Effect on mode share</b>
Commute support programs	<ul style="list-style-type: none"> <li>◆ Guaranteed ride home (motor pool or taxi)</li> <li>◆ Fleetride programs (provide cars for carpooling)</li> <li>◆ Hire Employee Transportation Coordinator</li> <li>◆ Provide facility amenities</li> </ul>	<ul style="list-style-type: none"> <li>◆ Reliability</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ Transit ↑</li> <li>◆ Carpool ↑</li> <li>◆ Vanpool ↑</li> <li>◆ Bike / Walk ↑</li> </ul>
Parking management	<ul style="list-style-type: none"> <li>◆ Control availability of parking</li> <li>◆ Control cost of parking</li> </ul>	<ul style="list-style-type: none"> <li>◆ Cost</li> <li>◆ Reliability</li> <li>◆ Convenience</li> </ul>	<ul style="list-style-type: none"> <li>◆ SOV ↓</li> <li>◆ possibly carpool ↓</li> </ul>
Transportation Management Associations (TMAs)	<ul style="list-style-type: none"> <li>◆ Provide support for organization of a TMA</li> </ul>	<ul style="list-style-type: none"> <li>◆ Familiarity</li> </ul>	<ul style="list-style-type: none"> <li>◆ HOV ↑</li> </ul>
Pricing strategies	<ul style="list-style-type: none"> <li>◆ Gasoline tax ↑</li> <li>◆ VMT tax ↑</li> <li>◆ Congestion pricing</li> <li>◆ Parking pricing</li> </ul>	<ul style="list-style-type: none"> <li>◆ Cost</li> </ul>	<ul style="list-style-type: none"> <li>◆ SOV ↓</li> </ul>
Land use strategies	<ul style="list-style-type: none"> <li>◆ Require development impact mitigation</li> <li>◆ Zone for mixed land use</li> <li>◆ Provide incentive / regulation for increased residential and employment densities</li> <li>◆ Provide incentive / regulation for transit-oriented and ped-oriented urban design</li> </ul>	<p>NOTE: Land use strategies primarily impact trip generation in traditional travel demand forecasting process. However, land use variables can also be used as proxies for variables such as 'availability of transit' in mode choice models</p>	

## Design of Alternatives

Definitions and levels of attributes are presented in Table 8 through Table 11.

**Table 8: Attributes & Levels for Mode Alternatives – Work trip, No car available**

Mode	General Attribute	Specific Attribute	# Levels	Values of attributes	
Non-mode specific	Comfort	Weather	2	dry, rainy	
Carpool	Time	In-vehicle travel time	short	3	10, 15, 25 (min)
			long		40, 50, 60 (min)
	Cost	Distance from parking to work		3	2, 5, 10 (min)
			Parking	3	0, \$10, \$20
			Toll / Congestion Pricing	3	0, \$5, \$10
Convenience	Occupancy		3	2, 3, 4	
		Driver/Rider	2	driver, rider	
Bike	Time	Travel time	3	15, 30, 45 (min)	
	Convenience	Bike rack at destination †	3	yes, no	
		Terrain †	2	level, hilly	
	Safety	Bike lane / trail †	3	none, bike lane, trail	
Walk	Time	Travel time	3	20, 40, 60 (min)	
	Convenience	Terrain †	3	level, hilly	
	Safety	Sidewalk	2	yes, no	
Transit - walk	Time	In-vehicle travel time	short	3	15, 25, 35 (min)
			long		45, 55, 65(min)
			Wait time (if on schedule)	3	1, 8, 15 (min)
	Cost	Fare	3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min after sched	2	yes, no	
	Comfort	Available seats †		2	yes, no
			Shelter / bench †	3	none, bench, shelter,
		Type of transit vehicle	3	city bus, tour bus, rail	
	Familiarity	Know stop	2	yes, no	
	Convenience	Number of transfers		3	0, 1, 2
			Stop X blocks from origin	3	1, 3, 6
			Stop X blocks from destination	3	1, 3, 6
	Safety	Security camera on transit vehicle	2	yes, no	
Patrol at shelter		2	yes, no		
Transit - drive	Time	In-vehicle travel time	short	3	15, 25, 35 (min)
			long		45, 55, 65 (min)
			Access time	3	5, 10, 15 (min)
		Wait time	3	1, 8, 15 (min)	
	Cost	Fare	3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min	2	yes, no	
	Comfort	Available seats †		3	yes, no
			Shelter †	3	none, bench, shelter
		Type of transit vehicle	2	city bus, tour bus, rail	
	Familiarity	Know stop	2	yes, no	
	Convenience	Stop X blocks from destination	3	1, 3, 6	
	Safety	Security camera on transit vehicle	2	yes, no	
		Patrol at shelter	2	yes, no	

† Requires illustrations

**Table 9: Attributes & Levels for Mode Alternatives – Work trip, Car available**

Mode	General Attribute	Specific Attribute		# Levels	Values of attributes
Non-mode specific	Cost	Travel incentive		2	yes, no
	Convenience	Guaranteed ride home		2	yes, no
	Comfort	Weather		2	dry, rainy
SOV	Time	In-vehicle travel time	short	3	10, 15, 25 (min)
			long		35, 45, 55 (min)
	Cost	Distance from parking to work		3	1, 3, 6 (blocks)
			Parking	3	0, \$10, \$20
	Toll / Congestion Pricing		3	0, \$5, \$10	
Carpool	Time	In-vehicle travel time	short	3	10, 15, 25 (min)
			long		40, 50, 60 (min)
	Cost	Distance from parking to work		3	2, 5, 10 (min)
			Parking	3	0, \$10, \$20
		Toll / Congestion Pricing		3	0, \$5, \$10
	Convenience	Occupancy		3	2, 3, 4
Driver/Rider			2	driver, rider	
Bike	Time	Travel time		3	15, 30, 45 (min)
	Convenience	Bike rack at destination ‡		3	yes, no
		Terrain ‡		2	level, hilly
Safety	Bike lane / trail ‡		3	none, bike lane, trail	
Walk	Time	Travel time		3	20, 40, 60 (min)
	Convenience	Terrain ‡		3	level, hilly
	Safety	Sidewalk		2	yes, no
Transit - walk	Time	In-vehicle travel time	short	3	15, 25, 35 (min)
			long		45, 55, 65(min)
		Wait time (if on schedule)		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3
	Reliability	Bus arrive within 5 min after sched		2	yes, no
	Comfort	Available seats ‡		2	yes, no
		Shelter / bench ‡		3	none, bench, shelter,
		Type of transit vehicle		3	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no
	Convenience	Number of transfers		3	0, 1, 2
		Stop X blocks from origin		3	1, 3, 6
		Stop X blocks from destination		3	1, 3, 6
	Safety	Security camera on transit vehicle		2	yes, no
Patrol at shelter			2	yes, no	
Transit - drive	Time	In-vehicle travel time	short	3	15, 25, 35 (min)
			long		45, 55, 65 (min)
		Access time		3	5, 10, 15 (min)
		Wait time		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3
	Reliability	Bus arrive within 5 min		2	yes, no
	Comfort	Available seats ‡		3	yes, no
		Shelter ‡		3	none, bench, shelter
		Type of transit vehicle		2	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no
	Convenience	Stop X blocks from destination		3	1, 3, 6
	Safety	Security camera on transit vehicle		2	yes, no
		Patrol at shelter		2	yes, no

‡ Requires illustrations

**Table 10: Attributes & Levels for Mode Alternatives – Shop trip, Car Available**

Mode	General Attribute	Specific Attribute		# Levels	Values of attributes	
Non-mode specific	Comfort	Weather		2	dry, rainy	
SOV	Time	In-vehicle travel time	short	3	10, 15, 25 (min)	
			long		35, 45, 55 (min)	
	Cost	Distance from parking to shop		3	1, 3, 6 (blocks)	
			Parking		0, \$10, \$20	
		Toll / Congestion Pricing		3	0, \$5, \$10	
Carpool	Time	In-vehicle travel time	short	3	10, 15, 25 (min)	
			long		40, 50, 60 (min)	
	Cost	Distance from parking to shop		3	2, 5, 10 (min)	
			Parking		0, \$10, \$20	
			Toll / Congestion Pricing		0, \$5, \$10	
	Convenience	Occupancy		3	2, 3, 4	
Driver/Rider			2		driver, rider	
Bike	Time	Travel time		3	15, 30, 45 (min)	
	Convenience	Bike rack at destination ‡		3	yes, no	
		Terrain ‡		2	level, hilly	
	Safety	Bike lane / trail ‡		3	none, bike lane, trail	
Walk	Time	Travel time		3	20, 40, 60 (min)	
	Convenience	Terrain ‡		3	level, hilly	
	Safety	Sidewalk		2	yes, no	
Transit - walk	Time	In-vehicle travel time	short	3	15, 25, 35 (min)	
			long		45, 55, 65(min)	
			Wait time (if on schedule)		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min after sched		2	yes, no	
	Comfort	Available seats ‡		2	yes, no	
			Shelter / bench ‡		3	none, bench, shelter,
			Type of transit vehicle		3	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no	
	Convenience	Number of transfers		3	0, 1, 2	
			Stop X blocks from origin		1, 3, 6	
			Stop X blocks from destination		1, 3, 6	
			Safety		Security camera on transit vehicle	2
			Patrol at shelter		2	yes, no
Transit - drive	Time	In-vehicle travel time	short	3	15, 25, 35 (min)	
			long		45, 55, 65 (min)	
			Access time		3	5, 10, 15 (min)
			Wait time		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min		2	yes, no	
	Comfort	Available seats ‡		3	yes, no	
			Shelter ‡		3	none, bench, shelter
			Type of transit vehicle		2	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no	
	Convenience	Stop X blocks from destination		3	1, 3, 6	
	Safety	Security camera on transit vehicle		2	yes, no	
			Patrol at shelter		2	yes, no

‡ Requires illustrations

**Table 11: Attributes & Levels for Mode Alternatives – Shop trip, No car available**

Mode	General Attribute	Specific Attribute		# Levels	Values of attributes	
Non-mode specific	Comfort	Weather		2	dry, rainy	
SOV	Time	In-vehicle travel time	short	3	10, 15, 25 (min)	
			long		35, 45, 55 (min)	
	Cost	Distance from parking to shop		3	1, 3, 6 (blocks)	
					0, \$10, \$20	
		Toll / Congestion Pricing		3	0, \$5, \$10	
Carpool	Time	In-vehicle travel time	short	3	10, 15, 25 (min)	
			long		40, 50, 60 (min)	
	Cost	Distance from parking to shop		3	2, 5, 10 (min)	
					0, \$10, \$20	
					0, \$5, \$10	
	Convenience	Occupancy		3	2, 3, 4	
Driver/Rider			2		driver, rider	
Bike	Time	Travel time		3	15, 30, 45 (min)	
	Convenience	Bike rack at destination ‡		3	yes, no	
		Terrain ‡		2	level, hilly	
	Safety	Bike lane / trail ‡		3	none, bike lane, trail	
Walk	Time	Travel time		3	20, 40, 60 (min)	
	Convenience	Terrain ‡		3	level, hilly	
	Safety	Sidewalk		2	yes, no	
Transit - walk	Time	In-vehicle travel time	short	3	15, 25, 35 (min)	
			long		45, 55, 65(min)	
			Wait time (if on schedule)		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min after sched		2	yes, no	
	Comfort	Available seats ‡		2	yes, no	
			Shelter / bench ‡		3	none, bench, shelter,
			Type of transit vehicle		3	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no	
	Convenience	Number of transfers		3	0, 1, 2	
			Stop X blocks from origin		1, 3, 6	
			Stop X blocks from destination		1, 3, 6	
			Security camera on transit vehicle		2	yes, no
	Safety	Patrol at shelter		2	yes, no	
			2		yes, no	
Transit - drive	Time	In-vehicle travel time	short	3	15, 25, 35 (min)	
			long		45, 55, 65 (min)	
			Access time		3	5, 10, 15 (min)
			Wait time		3	1, 8, 15 (min)
	Cost	Fare		3	0, \$1, \$3	
	Reliability	Bus arrive within 5 min		2	yes, no	
	Comfort	Available seats ‡		3	yes, no	
			Shelter ‡		3	none, bench, shelter
			Type of transit vehicle		2	city bus, tour bus, rail
	Familiarity	Know stop		2	yes, no	
	Convenience	Stop X blocks from destination		3	1, 3, 6	
	Safety	Security camera on transit vehicle		2	yes, no	
			Patrol at shelter		2	yes, no

‡ Requires illustrations

## **Identification of Socioeconomic and Revealed Preference Data**

Participants were selected for this project from a pool of people who had already completed the PSRC activity survey. As a result, socioeconomic data and actual travel diary data (revealed preference travel data) is already recorded for each person prior to their participation in this project. The socioeconomic data for each person (data about the person, data about the person's household, and vehicle ownership data) is identified in Table 12 through Table 15. The revealed preference travel data provided by each participant through completion of the activity survey is identified in Table 16.

**Table 12: Household Data from PSRC Activity Survey**

<b>Code</b>	<b>Variable Name</b>	<b>Variable Description</b>
H-1	RECTYPE	Record Type
H-2	HH_ID	HH ID Number
H-3	PHONE	HH Phone number
H-4	TRVLMONTH	Month of travel dates
H-5	TRVLDAY	First day of assigned travel date
H-6	TRVLDYWK	Day-of-week pair
H-7	ADVLT	Advance Letter
H-8	HH_ADDR	Home address
H-9	HH_CITY	Home city
H-10	HH_CNTY	Home county
H-11	HH-ZIP	Home zip code
H-12	HH_ZONE	Traffic Analysis Zone
H-13	HH_LONG	Longitude of HH location
H-14	HH_LAT	Latitude of HH location
H-15	ADDLIVE	Length of residency at address
H-16	CNTYLIVE	Length of residency in county
H-17	TOTVEH	Number of HH vehicles
H-18	HHSIZE	No. of persons in household
H-19	INCOME	Total 1998 annual household income
H-20	BIKES	Number of bicycles
H-21	RESTYPE	Residence
H-22	NO_PHLNS	Number of telephone lines
H-23	NO_PHONE	Lack of phone service
H-24	LENGTH	Length of no phone service
H-25	SHARE	Phone line sharing

**Table 13: Person Data from PSRC Activity Survey – 1 of 2**

<b>Code</b>	<b>Variable Name</b>	<b>Variable Description</b>
P-1	RECTYPE	Record Type
P-2	HH_ID	HH ID Number
P-3	PER_ID	Person ID Number
P-4	NAME	Person's name or initials
P-5	RELATION	Relation to head
P-6	GENDER	Person X -Gender
P-7	ETHN	Person X-Ethnicity
P-8	O_ETHN	Other
P-9	AGE	Person X -Age
P-10	EDUCATE	Person X-Education
P-11	LIC	Person X - Valid drivers license
P-12	PRIMACT	Primary Economic Activity
P-13	OCCUP	Occupation
P-14	VLNTDAYS	Days Volunteer
P-15	JOBS	Number of Jobs
P-16	PRMENAME	Employer name
P-17	PRIMCNTY	Employment county
P-18	O_PRCNT	Other
P-19	PRIMCITY	Employment city
P-20	O_PRMCTY	Other
P-21	PRIMZIP	Employment zip code
P-22	PRIMADDR	Employment address
P-23	PRIMZONE	Employment taz
P-24	PRIMLONG	Employment longitude
P-25	PRIMLAT	Employment latitude
P-26	DAYSWORK	Total number of days worked per week
P-27	TOWORK	Usual mode to/from work
P-28	CARONLY	Car only mode
P-29	CARPOOL	Carpool frequency
P-30	BUSUSE	Bus use

**Table 14: Person Data from PSRC Activity Survey – 2 of 2**

<b>Code</b>	<b>Variable Name</b>	<b>Variable Description</b>
P-31	POOLUSE	Carpool use
P-32	NEEDCAR	Need car at work
P-33	DAYSNEED	Days per week car needed
P-34	STUDENT	Student status
P-35	SCHOOL	Type of school enrolled in
P-36	SCHDAYS	Days to school
P-37	TOSCHOOL	Usual mode to/from school
P-38	CARONLY2	Car only mode
P-39	SCH_NAME	School name
P-40	SCH_CNTY	School county
P-41	O_SCCNTY	Other school county
P-42	SCH_CITY	School city
P-43	O_SCHCTY	Other
P-44	SCH_ZIP	School zip code
P-45	SCH_ADDR	School address
P-46	SCH_ZONE	School taz
P-47	SCH_LONG	School longitude
P-48	SCH_LAT	School latitude
P-49	USEBUS2	Bus use by 15+ age
P-50	SYSTEM	Bus system use
P-51	RIDE	Ride frequency
P-52	PASS	Transit pass holder
P-53	DISAB	Transportation disability
P-54	TRAVEL	Travel made on travel days
P-55	LOCATNS	Number of locations visited on travel dates
P-56	NOTRIPS	Explanation for zero-trips
P-57	INTRVWD	Whether or not person was interviewed
P-58	DIARY	Whether or not person used diaries to record trips
P-59	DATE	Date trip information retrieved

**Table 15: Vehicle Ownership Data from PSRC Activity Survey**

<b>Code</b>	<b>Variable Name</b>	<b>Variable Description</b>
V-1	RECTYPE	Record Type
V-2	HH_ID	HH ID Number
V-3	VEHNUM	Vehicle Number
V-4	YEAR	Vehicle X - Year
V-5	MAKE	Vehicle X -Make
V-6	O_MAKE	Other
V-7	MODEL	Vehicle X-Model
V-8	FUEL	Vehicle X-Fuel type
V-9	O_FUEL	Other type of fuel

**Table 16: RP Travel Data from PSRC Activity Survey**

Code	Variable Name	Variable Description
T-1	RECTYPE	Record Type
T-2	HH_ID	HH ID Number
T-3	PER_ID	Person ID Number
T-4	LOC_NO	Location number
T-5	TRP_PRP1	Primary Trip purpose
T-6	O_PRP1	Other
T-7	TRP_PRP2	Secondary Trip purpose
T-8	O_PRP2	Other
T-9	LOCATION	Name of place
T-10	PL_CNTY	Place county
T-11	O_PLCNT	Other
T-12	PL_CITY	Place city
T-13	O_PLCITY	Other
T-14	PL_ZIP	Place zip code
T-15	PL_ADDR	Place address
T-16	PTYPE	Where they went
T-17	PL_TYPE	Type of place
T-18	O_PLTYP	Other
T-19	PL_ZONE	Zone number of place
T-20	PL_LONG	Longitude of place
T-21	PL_LAT	Latitude of place
T-22	MODE	Mode of trip
T-23	ACCESS	Access to bus stop
T-24	EGRESS	Egress from bus stop
T-25	FARE	Fare Paid
T-26	FARETYPE	Fare media
T-27	HH_MEM	Number of household members on trip
T-28	PER_TRP	Person on trip
T-29	NON_MEM	Non-household members on trip
T-30	PRK_COST	Parking cost
T-31	PRK_UNIT	Parking cost unit
T-32	ARR_HR	Arrival hour
T-33	ARR_MIN	Arrival minute
T-34	DEP_HR	Departure hour
T-35	DEP_MIN	Departure minute

## **Survey Implementation**

### ***Respondent Selection***

1. Survey pool consists of households in King County that completed the PSRC activity survey (households randomly selected from population of King County)
2. One member randomly selected from each household for solicitation.
3. Mailed solicitation materials (shown in Figure 6) to selected household members
4. People who return card and indicate that they would like to participate are scheduled for an interview.

### ***Interview Procedure***

1. Interviews held in local public library meeting rooms
2. Participants gather in groups of 3 to 5
3. Introduce project, define TDM and TDM terms (i.e. alternative travel incentive, guaranteed ride home)
4. Present stated preference choice sets (randomly selected out of each of the four choice scenarios)

### ***Presentation of Alternatives***

Examples of the presentation of the choice scenarios are shown in Figures 7 - 10.

- work trip, car available
- work trip, no car available
- shop trip, car available
- shop trip, no car available

**Cover Letter**

Puget Sound Regional Council  
PSRC

UNIVERSITY OF WASHINGTON

«First\_Name» «Last\_Name»  
«Address»  
«City», «State» «Postal\_Code»

Thank you for completing the **1999 Puget Sound Household Travel Survey**. Your participation has provided valuable information that the Puget Sound Regional Council (PSRC) can use to determine the improvements that will best meet the transportation needs and priorities of the citizens of this region. You have contributed a great deal of time and effort to this important project, and the PSRC would like to let you know about a related project called the **Understanding Traveler Choices** study.

University of Washington researchers are conducting this study in cooperation with the PSRC. The purpose of this project is to more narrowly focus on the reasons people choose or do not choose different ways of traveling. This will be accomplished by conducting a series of focus groups, in which participants will be interviewed about the travel choices they would make under different sets of circumstances. Each person involved with this study will participate in one focus group interview, which will take approximately one hour.

We appreciate the time you have already committed to the **Household Travel Survey**, and recognize the additional commitment required for the **Understanding Traveler Choices** focus group interview. Thus if you participate in this study, we will provide a \$40 compensation in appreciation of your time and effort. Please indicate whether or not you would like to participate in this study by completing the enclosed card and returning it in the postage-paid envelope that has been provided. Participants will be selected among people who have returned the card and indicated that they would like to be a part of this project. If you are selected for this study, a University of Washington researcher will contact you to set up a time and place for your focus group interview. Focus groups will be conducted over the next four months at various public libraries throughout King County. If it is more convenient for another member of your household (age 16 or over, who has also completed the **Household Travel Survey**) to participate in this project instead, the person who wishes to participate should complete and return the reply card.

If you have any questions about this study, please contact Jennifer Barnes, University of Washington, at (206) 685-6779, or Neil Kilgren, PSRC, at (206) 464-7964.

Sincerely,

Neil Kilgren  
Program Manager, PSRC

Jennifer Barnes  
Research Assistant, University of Washington

Participant's Phone Number

**Return Envelope**

Understanding Traveler Choices Study  
121 More Hall, Box 352700  
University of Washington  
Seattle, WA 98195

attn: Jennifer Barnes

Participant's Address

**Reply Card**

Puget Sound Regional Council  
PSRC

UNIVERSITY OF WASHINGTON

Participation in the **Understanding Traveler Choices** study will consist of a one-hour interview, for which we will compensate you \$40.

**WOULD YOU LIKE TO PARTICIPATE IN THIS STUDY?**

**NO, I do not want to participate in this study**  
If so, stop here! We would appreciate if you would still return this reply card, so that we can confirm that you are not interested in participating.

**YES, I would like to participate in this study**  
If yes, please complete the rest of this card so that we may contact you and schedule an interview. This information will be kept confidential and will not be used for any purpose other than this study.

We have the following location and contact information for you:

«First\_Name» «Last\_Name»  
«Address»  
«City», «State» «Postal\_Code»  
Phone: «Phone number» «SP ID»

Please correct out any incorrect information and write in necessary corrections.

A University of Washington researcher will contact you to confirm a time and locations that will be convenient for your interview. To help us get started, please indicate which times during the week are typically best for you:

		Best time	Usually OK	Unavailable
Monday	6:30pm-8:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	7:30pm-9:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tuesday	6:30pm-8:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	7:30pm-9:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wednesday	6:30pm-8:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	7:30pm-9:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Thursday	6:30pm-8:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	7:30pm-9:00pm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Saturday	9:00am-10:30am	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	10:00am-11:30am	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please return this reply in the postage-paid envelope we have provided.

*Thank you for your time!*

Understanding Traveler Choices Study  
121 More Hall, Box 352700  
University of Washington  
Seattle, WA 98195

Return Address

**Figure 6: Survey solicitation packet**

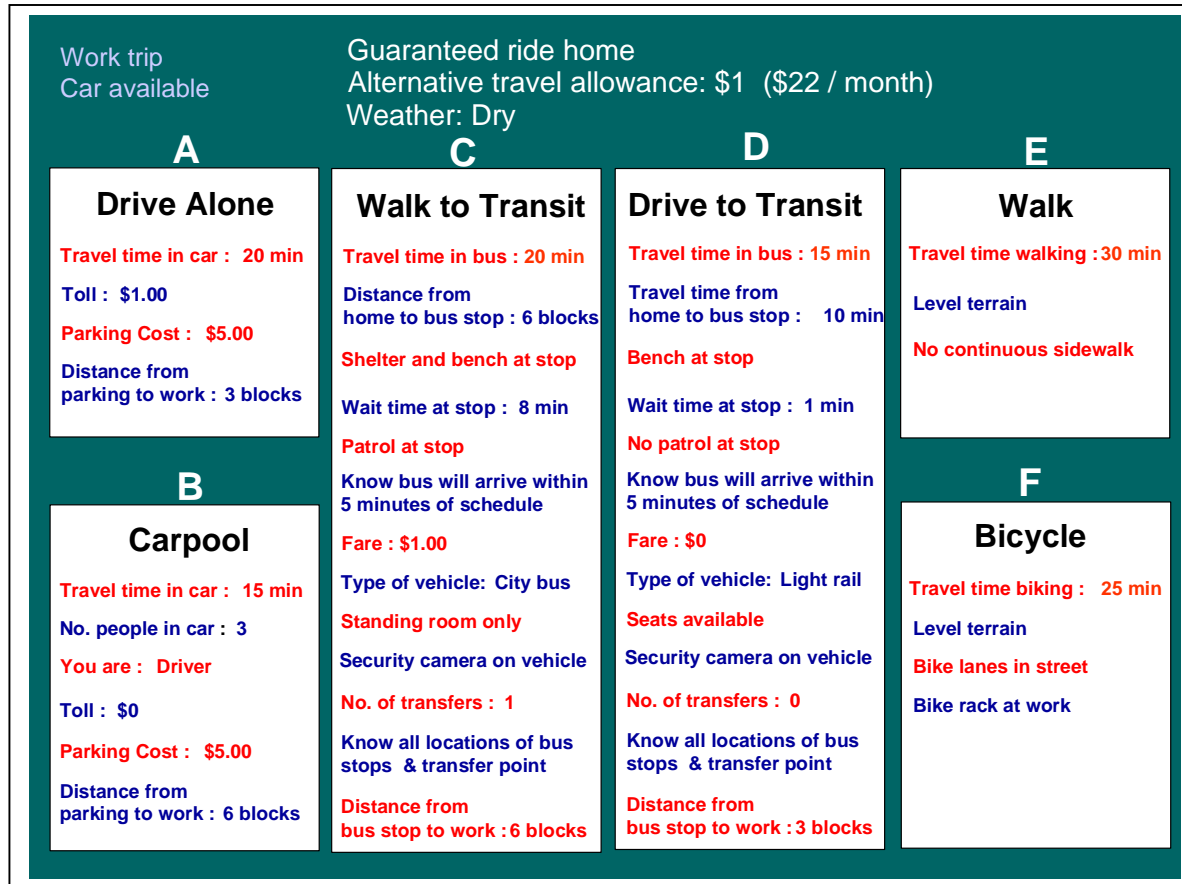


Figure 7: Presentation of Choices – Work trip, Car available

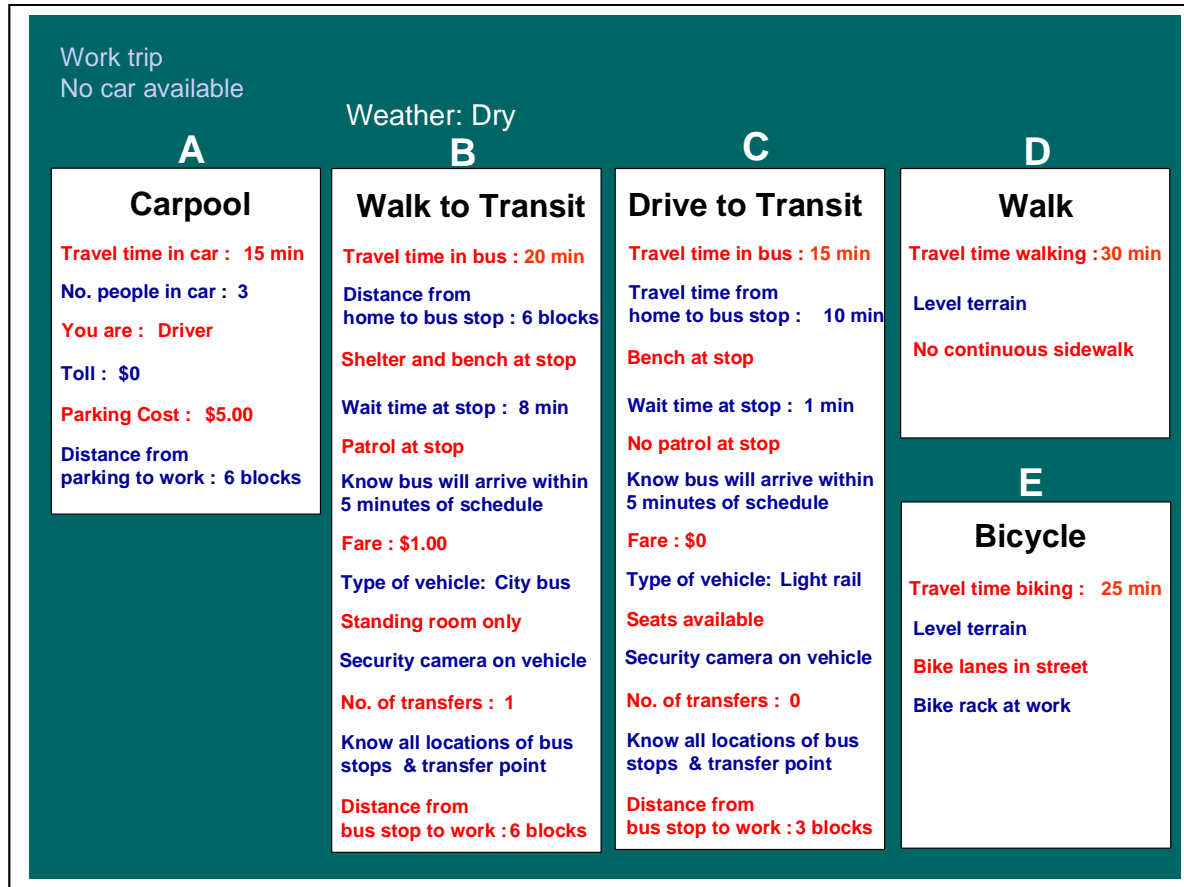


Figure 8: Presentation of Choices – Work trip, No car available

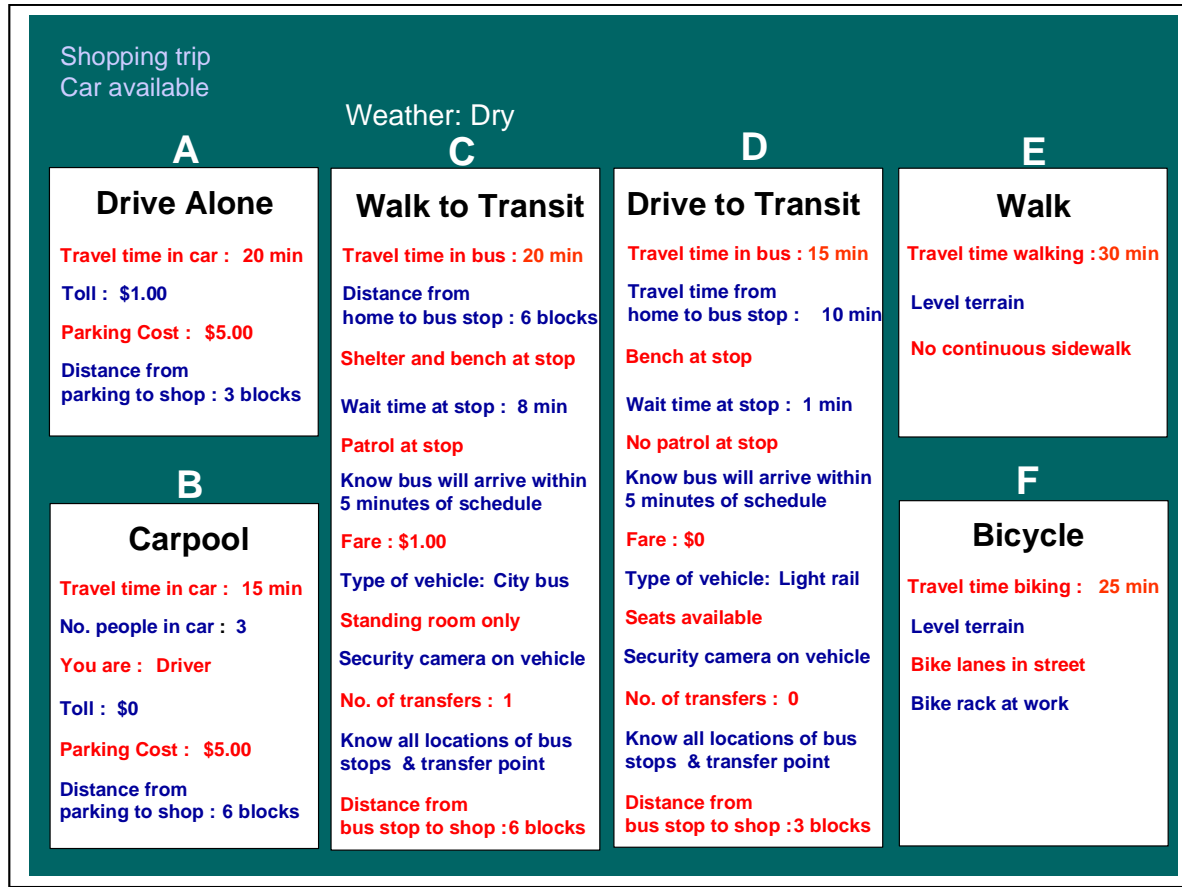


Figure 9: Presentation of Choices – Shop trip, Car available

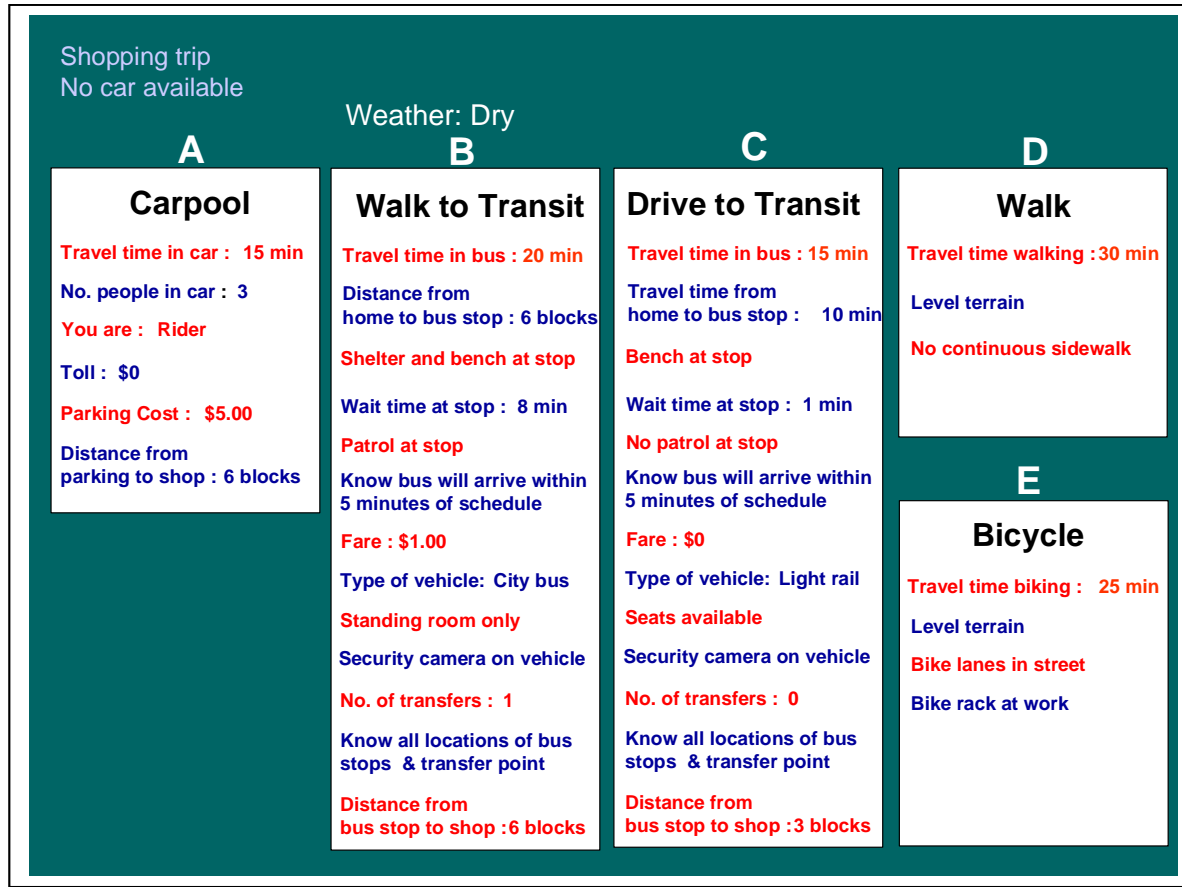


Figure 10: Presentation of Choices – Shop trip, No car available

## Next Steps

Steps for Phase II of project:

### *Near-Term (December 2000 – February 2001)*

- Confirm attribute definitions and levels, based upon input from the committee
- Confirm experimental design
- Reserve meeting rooms and schedule interviews

### *Mid-Term (March 2001 – May 2001)*

- Conduct interviews – collect SP data
- Continue writing report

### *Long-Term (May 2001 – August 2001)*

- Estimate mode choice models using combined SP and RP data
- Complete report

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