VEHICLE OCCUPANCY FORECASTING

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16. ABSTRACT

The design of HOV lanes and other HOV facilities depends on volumes of HOVs expected to use the facilities. Currently, there is no good method for predicting vehicle occupancy on specific highway facilities. The basic objective of this research was to incorporate the best of previous transportation models with new information on psychological and demographic determinants of mode choice into a model that forecasts vehicle occupancy for specific highway facilities. In order to do this, four different data sets were investigated. Each one allowed the investigation of one or more aspects of a comprehensive model to forecast vehicle occupancy. The basic approach tested in this research was the "integrated model of consumer choice," first proposed by Tybout and Hauser in 1981. It incorporates a wide variety of factors involved in transportation decision-making.

Most of the findings from the four data sets analyzed for this study were consistent with the literature and with each other. The research concluded that, in order for a transportation model to adequately forecast vehicle occupancy, it should take into account that 1) mode choice changes over time, 2) attitudes and perceptions are important in mode choice, 3) attitudes and perceptions can be influenced by experience, 4) household composition is important, 5) commute length varies by type of job and location, 6) constraints influence the process in complicated ways, and 7) two person carpools are different from larger carpools. The dynamic aspects of mode choice are critical to understand. Until we have more good time series data and the ability to adequately understand it, our models of mode choice and vehicle occupancy will be deficient.

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VEHICLE OCCUPANCY FORECASTING

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EXECUTIVE SUMMARY

The design of HOV lanes and other HOV facilities depends on volumes of HOVs expected to use the facilities. Conversely, design of the facilities can affect how much they are used. The evaluation of the cost effectiveness of HOV facilities depends on forecasts for usage over the lifetime of the facilities. In order to plan for, and to obtain support for HOV facilities, the potential use of the facilities must be forecast.

Currently, there is no good method for predicting vehicle occupancy on specific highway facilities. Very little is known about the ability of higher travel speeds and other preferences for HOVs to induce mode shifts from SOVs to higher occupancy modes. In addition, planners' understanding of the influence of psychological and demographic variables is inadequate outside of a fairly narrow range. Employer-based transportation demand management (TDM) policies have an effect on mode choice, but little is known about the relative effectiveness of various TDM policies, or under what conditions they are most effective.

MODE CHOICE MODELS

Numerous models exist to predict vehicle occupancy, but they are all limited in their ability to predict the use of specific facilities into the future. Most transportation models include a mode choice component that takes into account factors such as income, automobile availability, size of household, transportation costs and average travel time.

Several weaknesses exist in models that are currently used to forecast vehicle occupancy:

1) Because of the high cost of gathering data, the parameters used in the models are not often validated on populations similar to the one being modeled.

2) The models do not deal with psychological variables that influence people's decisions and cultural variables that may determine the extent to which people are inclined to share rides nor do they deal with the influence of habit on people's willingness to change.

3) Most models do not deal with temporal choice. That is, they do not explicitly deal with how people decide to shift their travel time in response to traffic conditions.

4) The models do not deal explicitly with choices people make about how many automobiles to own, where to live or where to work. The models treat these variables as givens (or independent variables) when, in fact, all of the choices influence each other.

5) Most models do not explicitly represent the context in which trips are made. They assume that trips are for single purposes and do not take into account the types of activities that necessitated the trips.

6) Existing models do not usually take into account the movements and travel needs of other members of the household.

7) Current models do not include alternatives to trip-making, such as telephone calls or stocking up on food rather than frequent purchases.

Vehicle occupancy prediction is one aspect of mode choice models. There are several approaches to modeling transportation mode choice. They can be categorized into three types:

1) rational, economic models

2) attitude-based models, and

3) activity-based models.

The first type of model assumes that people use rational processes to evaluate attributes of different modes, assign utilities to each attribute according to mode, add up the total utility for each mode, and choose the mode with the highest utility. The second type of model originates from decision theory and psychometric analysis in psychology and takes into account that **perceptions** of attributes are influential in the decision-making process. The third type of approach emphasizes the pattern and structure of activities rather than the travel itself.

There is clearly overlap among these approaches to understanding mode choice. Economic models have incorporated qualitative variables such as perceptions and attitudes. Attitude-based models sometimes employ economic analysis techniques to represent stages in the cognitive process. Activity-based analysis has influenced the types of variables that are considered in each of the other two approaches.

The basic approach tested in this research was first proposed by Tybout and Hauser.[1] Their "integrated model of consumer choice" incorporates many of the features of the three approaches to understanding transportation mode choice described above. Other authors have proposed similar models.[2] Figure 1 diagrams the essential elements of the model, which has four stages. First, the model postulates that physical characteristics determine perceptions of various aspects of the modes. These perceptions are influenced by the individual and situational characteristics of the decision-maker. In the second stage, perceptions are combined to form a preference for a mode. The process by which those perceptions are combined to form a preference is again influenced by the individual and situational characteristics of the decision-maker. In the third stage, the preference determines the mode choice, subject to constraints such as access to the preferred mode. The fourth, and important, stage is the feedback loop, illustrated with the dotted line.

In the last stage, the fact that choice influences perceptions is acknowledged. Cognitive dissonance theory[3] holds that people change their beliefs to be in tune (consonant) with their behavior. Several studies have supported this relationship between belief and behavior. Lovelock[4] segmented respondents in a survey by frequency of using transit. He found significant differences in each segment's perception of all modes. Foerster, Young and Gilbert[5] found that transit and auto users have different perceptions about mode characteristics and that

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[1] Tybout, Alice M. and Hauser, John R., "A marketing audit using a conceptual model of consumer behavior: Application and evaluation," Journal of Marketing, 1981, 45(3), 82-101.

[2] Koppelman, Frank S. and Lyon, Patricia K., "Attitudinal analysis of work/school travel," Transportation Science, 1981, 15, 233-254.

[3] Festinger, Leon, A Theory of Cognitive Dissonance, 1957, Stanford University Press: Stanford, California.

[4] Lovelock, Christopher H., "A market segmentation approach to transit planning, modeling and management," Transportation Research Forum Proceedings, 1975, 16, 247-258.

[5] Foerster, James F., Young, Forrest W. and Gilbert, Gorman, "Longitudinal changes in public preference for attributes of a new transit system," Transportation Research, 1977, 11, 325-336.

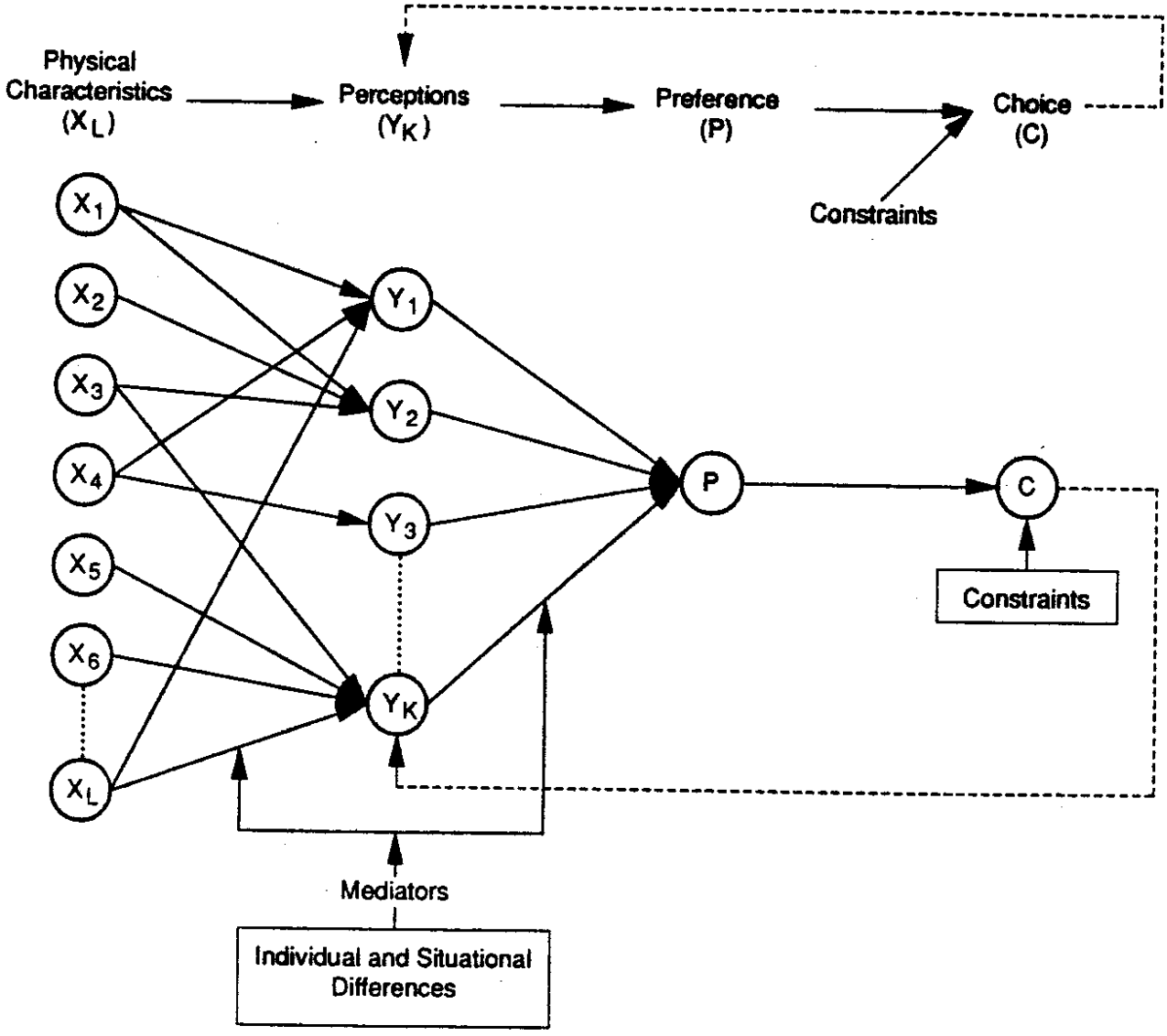

Figure 1. An Integrated Model of Consumer Choice

those perceptions change with experience. Golob, Horowitz and Wachs[6] compared auto and bus commuters' evaluations of each of the modes and found significant differences on most of the 25 attributes used in the study. All the differences supported the hypothesis that people evaluate their chosen mode most positively. Tybout and Hauser confirmed the feedback loop in their model, illustrated in Figure 1. Choices did affect perceptions. In addition to the evidence that choices influence perceptions of attributes, Levin[7] found that people place greatest importance on the attributes that support their mode choice.

More detailed discussion of mode choice models is incorporated in later sections of this report.

RESEARCH OBJECTIVES

The basic objective of this research was to incorporate the best of previous transportation models with new information on psychological and demographic determinants of mode choice into a model that forecasts vehicle occupancy for specific highway facilities. In order to do this, four different data sets were investigated. Each one allowed us to investigate one or more aspects of a comprehensive model to forecast vehicle occupancy. Briefly described, the four data sets are:

1) Puget Sound Transportation Panel — includes information from over 1600 respondents at more than one point in time concerning mode choice, attitudes, household characteristics, and detailed information on travel patterns from trip diaries,

2) I-405 HOV Operations Study — includes data from one point in time on mode choice, attitudes, and household characteristics,

3) Metro TDM/TSM Evaluation Study — includes data from over 9000 employees in North King/South Snohomish Counties on mode choice and employer-based TDM policies, and

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[6] Golob, Thomas F., Horowitz, Abraham D. and Wachs, Martin, "Attitude-behavior relationships in travel demand modeling," Behavioral Travel Modeling, 1979, 739-757.

[7] Levin, Irwin P., "The development of attitudinal modeling approaches in transport research," Behavioral Travel Modeling, 1979, 758-781.

4) Metro Market Segmentation Study — contains information from almost 3000 randomly selected residents of north King County and urban Snohomish County on mode choice, household characteristics, and attitudes.

Analysis of each of these data sets allows us insight into the mode choice process and provides a basis for a model of mode choice capable of considering vehicle occupancy choices in specific corridors.

The four data sets explored for this study have different strengths and weaknesses for developing a comprehensive model of mode choice. The PSTP has very detailed information on attitudes and preferences, and contains time series data that can help further assess the dynamic aspects of mode choice. The I-405 data set contains some information about attitudes and preferences and is very strong in allowing assessment of the importance of HOV facilities in mode choice. However, since it is one point in time, it does not allow a dynamic assessment of mode choice. The North King/South Snohomish County data also suffers from being only one point in time. However, the TDM/TSM evaluation data excel in allowing us to assess the influence of employer-based policies on mode choice, and the market segmentation data are a rich source of attitudinal data.

SUMMARY OF IMPORTANT FINDINGS

Most of the findings from the four data sets analyzed for this study are consistent with the literature and with each other. However, there are some interesting deviations. The results are summarized here for four aspects of the "integrated model of consumer choice:" 1) attitudes, 2) individual differences, 3) situational differences, and 4) constraints. These summaries are followed by a discussion of general findings about mode choice in this research.

Attitudes

Attitudes and perceptions are important in the model because they have to do with how the physical characteristics of different mode choices are perceived and evaluated by individuals. People make choices based on what they know, or think they know, not on the actual characteristics of the alternatives.

- Analysis of the PSTP data showed that attitudes were strongly correlated with mode choice. This applied for cognitive attitudes related to perceptions of modes as well as affective attitudes, which measured feelings toward modes.

- Analysis of the I-405 data and the North King/South Snohomish County data showed that a sizable number of people chose commute modes that were contrary to their preferences.

These two findings corroborate the "integrated model of consumer choice." First, attitudes and perceptions are strong determinants of mode choice. Second, the importance of understanding the constraints to mode choice is substantiated.

Individual Differences

The results concerning the importance of individual characteristics are mixed. The literature generally supports the conclusion that demographic characteristics are unimportant. However, from this research, some evidence emerges that certain kinds of individual differences are important in understanding mode choice. Results from this research include the following observations:

- In the analysis of the PSTP, demographic characteristics are not strong predictors of mode choice. A model using demographic data alone predicted mode choice no better than assuming that everyone used SOVs.

- In the I-405 analysis, some types of demographic data were correlated with mode choice. Carpoolers had less education, a greater tendency to be shop/craft workers, larger households, lower incomes than did SOV commuters. However, the differences between these two groups were less than the differences between either of these groups and bus commuters.

- The analysis of the North King/South Snohomish County data confirmed that carpoolers tended to come from households with a large number of workers.

- In the analysis of the North King/South Snohomish County data, carpoolers were more likely to come from households with high income. This may be related to having more workers per household, or to a tendency for high income people to work in areas of high employment density.

- Even though the literature supports the contention that auto ownership is a strong predictor of mode choice, it did not significantly improve predictiveness in the analysis of the PSTP data.

- The cluster analysis performed in the North King/South Snohomish County study showed that household characteristics can be used to distinguish people's rationales for their mode choice. For instance, a person from a large family may drive to work alone for very different reasons than a single person.

The fact that income (and auto ownership) are not strongly related to mode choice in this region may be due to the interaction of unique local characteristics. The existence of good bus system access and strong employer-based incentives in central business districts (where higher income people tend to be employed) may overwhelm the tendency for people with better access to a car to drive alone to work.

The number of workers per household is an important factor in the choice to carpool. It is related to opportunity for a carpool partner, the household income, and the likelihood of children being present. For all these reasons, it should be an important consideration in modeling mode choice.

Situational Differences

It is sometimes difficult to distinguish between individual and situational differences. Some individual differences are what lead to differences in situations. However, many situational differences are completely independent of individual differences. Some observations from this research conclude the following:

- In both the I-405 and North King/South Snohomish County analyses, people with the longest commutes were more likely to form large carpools or vanpools than people with short commutes.
- Analysis of the I-405 data showed that, contrary to findings in other studies, the majority of the carpool partners were co-workers, not other household members.
- Some employer-based TDM policies have an influence on mode choice. A small flexibility in work hours promotes carpooling, while large flexibility discourages it. Free parking is a strong disincentive to carpooling and transit use.
- From the North King/South Snohomish County data, access to HOV lanes increased the likelihood of carpooling.

Longer commutes being related to larger carpools and vanpooling is consistent with other studies. It seems self-evident that longer commutes promote ridesharing by making the rideshare formation time relatively less important in the overall assessment of comparative commute times. Other advantages of ridesharing assume relatively more importance. Vehicle occupancy models should take changes in commute distance into account. They should also consider how commute lengths vary for different kinds of jobs and different regions.

The perceived availability of carpool partners is important to understand. Even though this research had somewhat different results from other studies concerning the composition of carpools, it is important to note that a very substantial proportion of the observed carpools were composed of household members. Having perceived readily available carpool partners is important to the formation of carpools. Employer-based policies can have a strong influence on this perception. In addition, this research confirmed that incentives such as charging for parking and the existence of HOV lanes encourage ridesharing. These policies must be considered in the forecasting of vehicle occupancy.

Constraints

The "integrated model of consumer choice" takes constraints into account as the last influence on mode choice. In other words, the model says that all the attitudinal, individual and situational differences lead to a preference, that is then modified by constraints on the availability of different modes. This research confirms the importance of understanding constraints, but suggests that they may operate earlier in the decision-making process. Constraints, such as the **perceived** availability of rideshare partners or the **perceived** ability of the bus to get one to work on time, have an influence on the evaluation of different commute modes, and thus influence mode preference. Results from this research include the following observations:

- Contrary to assumptions imbedded in the "integrated model of consumer choice," analysis of the PSTP data showed that constraints had only a weak influence on mode choice.

- Surprisingly, the analysis of I-405 data showed that SOV commuters were no more likely to say they needed a car for work-related trips or personal errands than were people who carpooled.

These findings should be balanced with other research results.

- In the analysis of I-405 data, it appeared that having more children (and the accompanying need for non-work trips) is a barrier to carpooling for some who would prefer to do so.

- In that same study, another barrier for people who want to carpool is not having easy access to lunch locations within walking distance of work or to a tendency for high income people to work in area of high employment density.

- The greatest barrier in the I-405 study, however, was the perception that no one was available to carpool with.

Constraints to acting on one's preference obviously exist. However, a model of mode choice used for vehicle occupancy forecasting should also consider how these constraints influence the process of determining a preference.

General Findings

We should not think of mode choice as a permanent condition. Most models of mode choice either consider the decision on an aggregate basis or are based on the assumption that people always make the same decision. This research demonstrated that this can be a misleading paradigm for understanding mode choice. Consider the following observations:

- People do not use the same mode to work every day. For instance, analysis of the PSTP data showed that people use modes other than their "usual" mode about 18 percent of the time.

- People also change their commute modes over time, usually as a result of changes in jobs, residential locations, or household composition. In the PSTP, 15 percent of the respondents changed their usual mode to work in a four month period.

Not only do people make choices different from their preference, but they also make different choices under different situations, and situations change often. The "integrated model of consumer choice" should be modified to take this into account.

In applying the "integrated model of consumer choice" to the commute mode choice situation, another issue should be considered. That is the question of appropriate "choice sets." For instance, is it appropriate to distinguish between SOV commuters and all commuters who carpool, or should 2 person carpools be considered separately from larger carpools and vanpools? The research presented here has conflicting results. The following observations illustrate this conflict:

- In the COMSIS research, a nested logit model did not perform significantly better than a basic logit model. This implies that all modes should be considered independently, including different sizes of carpool.

- In the North King/South Snohomish County analysis, SOV commuters and people in 2 person carpools were more similar to each other than they were to people who commuted in carpools of 3 or more people.

The shift from a 2 person to a 3 person carpool appears to be larger than the shift from an SOV to a 2 person carpool. Different factors operate in each shift. Two person carpools are more likely to be composed of household members than large carpools. Situations that allow or encourage household members to carpool are different from those that encourage non-household members to carpool. Definitions of carpools allowed to use HOV facilities also play an important role in what kind of carpools are formed. A mode choice should include these factors in order to adequately explain and forecast vehicle occupancy.

CONCLUSION

Most of the elements of the "integrated model of consumer choice" have been evaluated and corroborated in this research. However, in order for a model of that form to adequately provide the ability for forecast vehicle occupancy, the model should take into account that 1) mode choice changes over time, 2) attitudes and perceptions are important in mode choice, 3) attitudes and perceptions can be influenced by experience, 4) household composition is important, 5) commute length varies by type of job and location, 6) constraints influence the process in complicated ways, and 7) two person carpools are different from larger carpools. The dynamic aspects of mode choice are critical to understand. Until we have more good time series data and the ability to adequately understand it, our models of mode choice and vehicle occupancy will be deficient.

PUGET SOUND TRANSPORTATION PANEL

The Puget Sound Transportation Panel (PSTP) is the first application of a general-purpose urban travel panel survey in the United States. The data collection was conducted by the Puget Sound Council of Governments under a grant from the U.S. Department of Energy administered through the Washington State Department of Transportation. The development and administration of the survey are described in detail elsewhere.[8] A brief summary of the survey is useful here.

Initial contact with households was based on a random-digit dialing telephone sample of the Puget Sound area. A supplemental sample of transit users was obtained through contacts with previous respondents to transit surveys and direct requests for volunteers on a random sample of bus routes. A total of 5,152 households were contacted by telephone in the fall (September through December) of 1989. Respondents provided demographic and commute information about all members of the household. Household members over age 15 were asked to complete two-day travel diaries. Of the households contacted, 2,896 (56 percent) agreed to receive the diaries and 1,680 (33 percent) completed them.

A few months after the initial data collection (February and March 1990), an attitudes and values survey was sent to the household members. The survey included 1) questions on the importance of 17 attributes of transportation modes, 2) scoring of each of three modes' performance on each of these attributes, 3) 23 agree/disagree statements concerning each of three modes, and 4) information on constraints to mode choice. Respondents were also asked questions concerning their normal modes for work and school commute trips.

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[8] Murakami, Elaine and Watterson, W. T., "Developing a Household Travel Panel Survey for the Puget Sound Region," presented at the 69th annual meeting of the Transportation Research Board, 1990.

A second wave of travel diary information was collected in the fall of 1990 and corresponding attitudinal data were collected in the fall of 1991. These subsequent data collection efforts provide a valuable set of time series data for analyzing mode choice.

The primary goal of this part of the analysis was to explore the relationships among mode attributes, perceptions, preferences, constraints, and mode choices implied by the "integrated model of consumer choice." This preliminary analysis had the following limitations:

- the work commute trip was the object of study;
- modes were divided among three choices: 1) drive alone (SOV), 2) carpool or vanpool (POOL), and 3) walk or drive access to transit (BUS); and
- since geocoded information on trip origins and destinations was not available, the relationship between actual and perceived characteristics of the trip was not considered.

This analysis concentrated on the relationships between different kinds of perceptions of modes and mode choices and investigated two types of factors that may modify these relationships: demographic and constraint.

DESCRIPTION OF DATA

The data used in this analysis provided an opportunity to test many aspects of the "integrated model of mode choice" shown in Figure 1. The PSTP data include information on demographics, mode choice, mode preference, and constraints. This section contains a description of each of these kinds of data.

Demographic Data

Socioeconomic factors undoubtedly play a part in mode choice. Large scale trends in travel patterns can often be accounted for by changing demographics. Arguing from the perspective of activity analysis, Koppelman[9] explains the development of new travel patterns with changing demographics, especially the changing division of roles between men and women in our society and the restructuring of the household away from the traditional nuclear family.

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[9] Koppelman, Frank S., "Introduction," Transportation, 1988, 15, 63-64.

Prevedouros and Schofer[10] account for the increase in suburban congestion with factors such as decreased household size, an aging population, more "returning young adults," and more people who have never married.

Some researchers have studied the influence of individual socioeconomic factors on mode choice. Aldana, de Neufville and Stafford[11] assumed that demographic variables could be used to segment the population and develop separate models for mode choice. Nicolaidis and Dobson[12] conducted a study of attitudes related to people movers. They found that the five groups differed considerably according to race, education and age and to a somewhat lesser extent according to income and auto license possession. How people value time influences their mode choice. Bates, Roberts, Gwilliam and Goodwin[13] showed that the value of time is influenced by a number of personal and household characteristics. Numerous other studies have shown a direct relationship between demographic variables and mode choice.

On the other hand, some researchers have studied the impact of socioeconomic variables in relation to other factors in mode choice and found that socioeconomic factors are relatively unimportant. For instance, Tardiff[14] studied the explanations for people's perceptions that different modes were available to them. He looked at three classes of variables: attitudinal, demographic, and system characteristics. Since the study was conducted in California, very few people felt that they were "bus captives." However, many felt they were "car captives." The only type of variable that predicted their perception was attitudinal. Neither the socioeconomic

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[10] Prevedouros, Panos D. and Schofer, Joseph L., "Suburban transport behavior as a factor in congestion," TRB Annual Meeting, 1989.

[11] Aldana, Eduardo, de Neufville, Richard and Stafford, Joseph H., "Microanalysis of urban transportation demand," Highway Research Record, 1973, 446, 1-11.

[12] Nicolaidis, Gregory C. and Dobson, R., "Disaggregated perceptions and preferences in transportation planning," Transportation Research, 1975, 9, 279-295.

[13] Bates, John J.; Roberts, Mick; Gwilliam, Ken and Goodwin, Phil, The Value of Travel Time Savings, 1987, Policy Journals: Old Vicarage, England.

[14] Tardiff, Timothy J., "Perception of the availability of transportation alternatives for various trip purposes," Transportation Research Record No. 592, 1976, 12-16.

characteristics of individuals and households nor the attributes of the highway or transit systems had an influence on people's perception that they were "car captive."

Dobson and Tischer[15] tested three models' ability to explain mode choice: 1) perceived system attributes, 2) sociodemographic factors and 3) network time and cost. Only the first model was able to explain mode choice. Including variables from either of the other two models did not significantly improve the model.

Most mode choice studies have concentrated on the choice between auto and transit. However, some research has failed to find demographic predictors of participation in ridesharing programs. Horowitz and Sheth[16] found that demographic variables were poor predictors of ridesharing. Ayele and Byun[17] found that gender, income and marital status were not related to the reason people gave for joining ridesharing programs.

Several explanations are possible for the mixed results in trying to find relationships between demographic variables and mode choice. One explanation that relates to demographic variables directly is the influence of automobile accessibility. Research has consistently shown that automobile accessibility is a very important determinant of mode choice. Hartgen[18] found that auto ownership predicted 70-80 percent of the variance in the choice between auto and transit use. Hsu[19] showed that multi-car owners gave consideration to transit use before car purchase, but bias against transit became stronger after car purchase. Ben-Akiva and Richards[20]

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[15] Dobson, Ricardo D. and Tischer, Mary Lynn, "Comparative analysis of determinants of modal choices by central business district workers," Transportation Research Record No. 649, 1977, 7-13.

[16] Horowitz, Abraham D. and Sheth, Jagdish N., "Ride sharing to work: An attitudinal analysis," Transportation Research Record No. 637, 1977, 1-8.

[17] Ayele, Moges and Byun, Joon, Personal, Social, Psychological and Other Factors in Ridesharing Programs, Report No. DOT-I-85-34, Urban Mass Transit Administration, U.S. Department of Transportation, 1984.

[18] Hartgen, David T., "Attitudinal and situational variables influencing urban mode choice: Some empirical findings," Transportation, 1974, Vol. 3, 377-392.

[19] Hsu, Jende, "Effects of multi-car ownership on use of public transit," Perceptual and Motor Skills, 1975(Oct), Vol. 41(2), 369-370.

[20] Ben-Akiva, Moshe E., and Richards, Martin G., "Disaggregate multinomial model for work trips in the Netherlands," Transportation Research Record, 1976, 569, 107-123.

found that the only socioeconomic variable that improved prediction in a disaggregate mode choice model was automobile accessibility. The other variables they tested included household income, number of licensed drivers, number of workers, number of adults, type of residence, and occupation of the head of household.

Tardiff[21] studied the influence of attitudes on choosing to use the bus and vice versa. He found that auto availability and occupation predicted the use of the bus, but that neither was related to attitudes. Biel[22] found that the only socioeconomic variables that predicted mode choice were automobile accessibility and whether a person was the head of the household (which also influences automobile accessibility). Williams'[23] research showed that auto availability was the most important influence on mode choice.

Research on the influence of sociodemographic characteristics of individuals and households on mode choice has had mixed results. However, one theme runs through the literature. The most important characteristic is automobile accessibility in a household. All other demographic variables appear to operate through this one. To the extent that those factors influence auto ownership, the number of auto users in the household, and the household's decision rules for use of the auto(s), they affect mode choice. However, there is very little evidence that they have a direct affect on mode choice independent of automobile accessibility.

The information on respondents' socioeconomic factors in this research included 1) gender, 2) age, 3) occupation, 4) life cycle stage, 5) income and 6) auto ownership. Table 1 shows the categories used in this paper to classify respondents according to demographic data and the relationships between auto ownership and each socioeconomic group. In all cases, the distribution of auto ownership was significantly different among socioeconomic categories.

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[21] Tardiff, Timothy J., "Causal inferences involving transportation attitudes and behavior," Transportation Research, 1977, Vol. 11, 397-404.

[22] Biel, Howard S., "Classificatory models of urban journey to work mode choice," Traffic Quarterly, 1978, Vol. 32, 433-448.

[23] Williams, Martin, "Factors affecting modal choice in urban travel," Transportation Research, 1978, Vol. 12, 91-96.

Table 1. Demographic Data and Household Vehicle Ownership

Demographic Category		N	Vehicles/Adult		
			less than one	one	more than one
GENDER	male	1009	13.1%	54.2%	32.7%
	female	941	15.6%	58.0%	27.4%
AGE	less than 25	171	29.2%	50.3%	20.5%
	25-34	508	16.5%	62.6%	20.9%
	34-44	612	10.5%	54.9%	34.6%
	more than 45	659	10.8%	53.6%	35.7%
OCCUPATION	White Collar (Prof/Man.)	718	10.3%	60.2%	29.5%
	White Collar (Other)	405	12.6%	58.5%	28.9%
	Blue Collar	569	15.8%	51.0%	33.2%
	Other	51	21.6%	52.9%	25.5%
LIFE CYCLE	Child(ren) under 6	357	12.6%	57.7%	29.7%
	Child(ren) over 6	458	12.0%	53.3%	34.7%
	Single Adult	187	9.1%	70.1%	20.9%
	Two or More Adults	951	16.0%	54.0%	30.0%
INCOME	less than $30K	493	24.1%	58.2%	17.6%
	$30-50K	848	12.4%	54.6%	33.0%
	more than $50K	484	5.8%	57.6%	36.0%

There is a tendency for males to have access to more than one auto per adult (18+) in the household. However, males and females are equally likely to have fewer than one auto per adult in the household. Access to autos increases significantly with age. Blue collar workers are more likely than other occupational groups to have fewer than one vehicle per adult **and** more than one per adult. This is likely due to a combination of lower incomes and some blue collar workers' need for a work vehicle. Households with older children are most likely to have more vehicles than adults in the household. Income is clearly related to auto ownership, with higher income people having greater access to automobiles.

Mode Choice

Three different measures of mode choice were available from the PSTP. The first two were measures of usual mode taken to work. In the initial data collection, respondents were asked "How do you usually get to and from work?" They could respond 1) "car only," 2) "bus," 3) "car/bus combination," 4) "motorcycle," 5) "bicycle," 6) "walk," or 7) "other." If they responded "car only," they were asked if they "drive alone," "drive but with others," "ride with others," or "take turns." Respondents who answered "car only" and "drive alone" were considered to be "SOV" riders. Those who answered "car only" and other than "drive alone" were put into the "POOL" category. Answers (2) and (3) were put in "BUS" category and all other responses were categorized as "OTHER."

In the attitudes and values survey, respondents were asked the same questions and categorized similarly. The latter survey was a direct mailing, in contrast to the original telephone survey. The wording of the question was the same, however. Travel diary data were categorized by the most frequently reported mode taken to work during the two-day data gathering period.

Table 2 shows the usual mode taken to work categorized by each of the three measurements of mode choice. Two phenomena are evident from this table. The first is that, on any given day, people who said they usually shared rides had a tendency to drive alone. The second is that, for this sample there was an apparent shift from rideshare modes to SOVs between the initial contact and the attitudes and values survey. This difference might be explained by the greater tendency of respondents to give the "socially desirable" response that they usually do not drive alone when questioned on the telephone rather than filling out a questionnaire in the privacy of their home.

Table 2. Distribution of Usual Mode to Work

	N	SOV	POOL	BUS	OTHER
Initial Survey	1712	71.4%	12.0%	14.0%	2.5%
Trip Diary	1525	78.4%	10.4%	8.5%	2.7%
Second Survey	1919	74.7%	10.9%	10.6%	3.9%

Table 3 shows the relationship between reported usual mode to work at the initial administration of the questionnaire and the usual mode indicated on the travel diary (at roughly the same time). These data suggest that about 18 percent of the time people use modes other than their usual modes. Disregarding the "OTHER" modes and combining the "POOL" and "BUS" categories, 10 percent of the time people who usually share rides drive by themselves. Likewise, 3 percent of the time people who usually drive alone are found on the bus or pooling.

Table 4 shows the apparent shift in usual mode to work that occurred between the two data gathering periods (about 4 months). Almost 15 percent made some sort of change in mode. Three percent of the commuters shifted toward ridesharing modes. Eight percent made a shift toward driving alone.

Table 3. Usual Mode to Work

Trip Diary vs. Initial Survey

		Trip Diary			
		SOV	POOL	BUS	OTHER
Initial Survey	SOV	982	36	3	5
	POOL	88	65		
	BUS	54	35	113	8
	OTHER	11	6		21

Table 4. Usual Mode to Work

Second Survey vs. Initial Survey

		Trip Diary			
		SOV	POOL	BUS	OTHER
Initial Survey	SOV	1155	44	8	8
	POOL	85	106	5	4
	BUS	29	33	102	12
	OTHER	12	2		27

Mode Perception and Mode Preference

The attitudes and values survey contained two types of measurements of mode perception. One was based on evaluations of each mode according to a set of mode attributes, weighted by the importance of the attribute to the respondent. The second type of measurement was based on the respondents' degree of agreement or disagreement with a set of statements regarding modes. The first measurement was intended to assess the more rational, cognitive aspects of commuters' mode choice decision. The second measurement was meant to evaluate affective responses to modes. Although one could make the case that there is overlap between the cognitive and affective components in each of these measurement methods, it is instructive to consider them separately. Henceforth, the two measurements will be referred to as the "cognitive" and "affective" mode perceptions or preferences.

The items for each of the scales were developed to represent the broadest range of dimensions possible for the mode decision-making process. A team of researchers from the Puget Sound Council of Governments, the Municipality of Metropolitan Seattle, the University of Washington, and a private survey firm developed an initial list of dimensions using all available items from mode choice research during the last 15 years. The result was approximately 250 items. Redundancies were eliminated and categories were developed to organize the remaining items. A pre-test was conducted on respondents from a class at the University of Washington. Importance ratings were used to develop the final list. Items with the greatest variance in importance were retained, as well as items that were uniformly considered important. Some items were combined to represent a more global dimension. The final selections of items for the two scales is shown in Table 5.

Table 5. Perception Items

COGNITIVE	AFFECTIVE
Ability to arrive on time	Riding a bus is a relaxing way to commute.
Ability to travel without changing vehicle	I enjoy driving by car even in heavy traffic.
Not having to deal with traffic congestion	My schedule is too erratic to be in a carpool.
Short travel time	If gas prices get much higher, I'll be less likely to drive to work.
Day-to-day costs like gas, parking & bus fare/pass	I don't know anyone to carpool with.
Protection from weather	Taking the bus doesn't fit my lifestyle.
Having a seat	I would be willing to pay higher taxes to improve bus service.
Short wait time	I hate the idea of transferring buses.
Ability to read while traveling	People who drive alone should pay more for parking than people who carpool.
Ability to travel when desired	Carpooling is an enjoyable way to travel.
Flexibility to change plans	It's easy to find someone I can carpool with.
Making few stops	Riding the bus helps reduce traffic congestion.
Parking availability	I don't want to rely on someone else to pick me up to get to work.
Safety of vehicle from accidents	Driving a car is a relaxing way to commute.
Freedom from threats to personal safety	It's not fair to have special lanes set aside for buses and carpools.
Avoiding stress	Getting bus schedule information is easy.
Minimizing pollution	It's a hassle to take the bus.
	I like the freedom of driving my own car.
	It were convenient, I would carpool with someone I don't already know.
	Taking the bus is an enjoyable way to travel.
	People only ride the bus to work if they have to.
	More freeway carpool lanes should be built.
	I'd rather drive in a car with other people than drive by myself.

Respondents were asked to rate the importance of each of the cognitive items with the following question:

> Please rate how important each of these items is to you in deciding how to **travel to work** by circling a number from "1" to "7." A "1" means "not important at all" to you and a "7" means "extremely important" to you.

Numbers one through seven were presented for each item, with the descriptions of the extreme responses shown above the table. No intermediate labels were provided.

Respondents were also asked to rate the performance of three modes of travel (Drive Alone, Bus, and Drive or Ride with Others) using the following question:

> Please rate all 3 ways of **traveling to work** on how well you think they perform on each item, with 1 being "extremely poorly" to 7 being "extremely well." Please give each mode of travel a score, even if you don't personally use it. Hint: First, score the way you travel now, then score the other two.

Three columns corresponding to each of the modes were provided next to the item descriptions. A seven-point scale was shown above the table, with intermediate labels of "somewhat poorly" at 3 and "somewhat well" at 5. Respondents entered numbers for each mode and item.

The affective mode perception items were presented in a table with a seven point scale. The instruction was,

> Please indicate to what extent you agree or disagree with the following statements.

The seven point scale was labeled from 1 to 7 as "very strongly disagree," "strongly disagree," "somewhat disagree," "neutral," "somewhat agree," "strongly agree," and "very strongly agree."

A third way to assess mode preference was to use respondents' answers to the following question:

> Given your current home and work location, which of these three ways would you MOST prefer, and which would you LEAST prefer for getting to and from work.

Respondents could check "Bus," "Drive or ride with others," or "Drive alone." Respondents' choices for most preferred mode will be referred to as "direct" mode preference.

Constraints

Trying to understand mode choice without information on commuters' constraints could easily lead to false conclusions about the relationships between attitudes and travel behavior. For example, no matter how much people prefer to drive alone, they are unable to do so if they do not own a car. Several questions on the values and attitudes survey for the PSTP were intended to measure constraints that affect mode accessibility.

The use of vehicles before, during and after work was of particular interest in this study. Four questions related to the necessity of having a vehicle were asked. In the last three questions, the respondent could answer 1) 3 or more days a week, 2) 1 or 2 days a week, 3) 2 or three times a month, 4) once a month or less, and 5) never.

> Does your job require that you use a car at work? (If yes, does your company have cars available for this purpose?)
>
> How often do you need a car to drop off or pick up children on the way to or from work?
>
> How often do you need a car for other personal errands on the way to or from work?
>
> How often do you need a car for personal trips (going to lunch, running errands) during the day?

These categories were recoded to "Often," category 1; "Occasionally," categories 2, 3 and 4; and "Never," category 5, for the question concerning children. The questions about personal errands were combined. If they answered "3 or more days a week" to either question, the answer was coded as "Often." If they answered "never" to both, it was coded as "Never." All other combinations were coded as "occasionally." Table 6 shows the distribution of these three vehicle requirement categories.

Questions related to bus availability were also included in the survey. All respondents were asked

- How far away is the nearest bus stop to your house? (3 blocks or less, 4 to 6 blocks, 7 blocks or more, don't know)
- If three blocks or less, does that bus go directly to your work/school? (yes, no, don't know)

Answers to these two questions were collapsed into four bus accessibility categories: good, fair, bad, and don't know. If the bus stop was within three blocks and there was direct access to work, accessibility was considered "good." If the bus stop was within three blocks, but there was no direct connection to work, accessibility was considered "fair." For all other cases, accessibility was considered "poor" unless the respondent answered "don't know" to either question. See Table 6 for the distribution of responses.

Accessibility to carpool partners was measured by asking people who did not carpool the following questions:

> Does anyone in your household have a commute pattern similar to yours? (same time to leave/return, compatible location)
>
> Do you know any neighbors who have a commute pattern similar to yours? (same time to leave/return, compatible location)
>
> Do you know any anyone at work who has a commute pattern similar to yours? (same time to leave/return, compatible location)

Respondents were considered to have access to rideshare partners if they already carpooled or vanpooled or if they answered "yes" to any of the above questions. Table 6 shows the distribution of responses in this category.

DATA ANALYSIS

The analysis was designed to test elements of the "integrated model of consumer choice" illustrated in Figure 1. The influence of cognitive and affective perceptions were tested independently. The importance of other factors in the decision-making process, namely the consequences of demographic factors and the influence of constraints, were tested in a comparison of models that include those factors with ones that do not. The perceptual correlates of apparent mode shift between the initial contact and the attitudes and values survey are also explored.

Table 6. Mode Constraint Data

NEED FOR CAR				
	N	Yes, but no company car	Yes, with company car	No
Use one at work	1883	20.9%	13.1%	66.1%
		Often	Occasionally	Never
Transport Children	1868	17.5%	18.5%	64.0%
Personal Errands	1611	56.0%	39.2%	4.8%

BUS ACCESSIBILITY					
	N	Good	Fair	Poor	Don't know
Degree of accessibility	1203	15.1%	58.9%	9.1%	17.0%

CAR/VANPOOL ACCESSIBILITY			
	N	Yes	No
Access to Partner	1953	35.3%	64.7%

Description of Models

Ten models were tested. Models were calibrated on half of the respondents and validated on the other half. The base model simply classified all respondents as driving alone to work. This assumption resulted in correct classifications 78.0 per cent of the time. The second model categorized mode choice on the basis of demographic data alone. The third model classified mode choice on the basis of the number of vehicles per adult in the household. The fourth model classified mode choice based on direct preference only. These four models made no direct use of perceptual data.

The next two models related cognitive and affective mode perceptions directly to mode choice for the whole sample. The second group of two models used the same perception data, but separate models were calibrated for each life cycle stage category. The last pair of models used the two types of perception data, but separate models were developed according to mode choice constraints.

The SPSS LOGISTIC REGRESSION program was used in all models except for models one and four. This statistical technique directly estimates the probability of an event occurring, such as the choice of driving alone rather than sharing a ride to work. The probability of the event is

$$\text{probability} = 1/(1 + e^{-Z})$$

where Z is a linear combination of independent variables weighted by coefficients. The coefficients are computed so that the observed results are most likely to be classified correctly by the equation. The independent variables can be either interval or categorical data.

In this analysis three probabilities were computed for each respondent. A forward step-wise procedure was used to enter variables that significantly improved the models. First, the probability that the respondent drives alone versus the other two modes was calculated. Then, the probability of the respondent using carpool or vanpool versus the other two modes was determined. Finally, the probability of the respondent using the bus versus the other two modes

was computed. The highest probability was used to categorize the respondent into the chosen mode. A simple measurement of the accuracy of the model was the number of cases that were correctly classified.

The stratification of the life cycle stage variable used in these models was the same as in Table 1. Three strata were derived from the constraint data. The first was the "auto-dependent." This group included all respondents who indicated that they had frequent use for a vehicle for personal errands, moving children, or using a car for work when a company car was not available. The second stratum was the "rideshare-inclined" group. People in this group indicated that they either had good access to rideshare partners or good access to bus. All others were included in the last stratum.

Analysis Results and Discussion

The model results are shown in Table 7. Using demographic data alone did no better than assuming that all commuters drive alone. Since no combination of demographic categories contained more ridesharers than drive alone commuters, the best classification for a respondent using any combination of demographic factors was that they would drive alone.

Table 7. Model Performance

Model #	Model Description	% Correctly Categorized
1	Base (all SOV)	78.0%
2	Demographic	77.2%
3	Vehicles/adult	78.7%
4	Direct preference	79.5%
5	Affective perceptions	84.8%
6	Cognitive perceptions	81.2%
7	Affective perceptions (life cycle)	83.1%
8	Cognitive perceptions (life cycle)	78.4%
9	Affective perceptions (constraint)	85.8%
10	Cognitive perceptions (constraint)	83.0%

Using vehicle ownership per driver to categorize respondents according to mode choice, the correct identification occurred 78.7 percent of the time. This was an insignificant improvement over the demographic model alone.

Using direct preference alone classified mode choice correctly 79.5 percent of the time. This is a statistically insignificant improvement over Model 1 (chi-squared = .56, $p>.1$) It is surprising that 20.5 percent of the respondents said that they preferred a mode other than their usual mode to work.

Models 5 and 6 were tests of preferences affecting mode choice directly. The most likely mode choice derived from the regression coefficients was a statistical way of combining perceptions to form preferences in stage 2 of the "integrated model of consumer choice." Using affective preferences resulted in a statistically significant improvement in accuracy of classification over any of the baseline models (chi-squared = 13.24, $p<.01$, compared with Model 1). The improvement using cognitive preferences was insignificant. The preference based on affective perceptions was marginally better than the preference based on cognitive perceptions in classifying mode choice (chi-squared = 3.683, $p<.1$). In addition, affective perceptions categorized respondents' direct preference better than did cognitive perceptions (76.7 percent versus 73.2 percent correct). Using the dichotomy in preferences described here, affective preferences explain mode choice better than cognitive preferences.

Models 7 through 10 tested the importance of life cycle stage and commute constraints on the relationship between preference and mode choice. Contrary to expectations, no statistically significant improvement in the accuracy of classification was observed. However, stratifying by the constraint variable did produce a marginal improvement in classification.

The results from this analysis support several aspects of the "integrated model of consumer choice," including the following:

- mode perceptions can be combined using logistic regression to determine a mode preference,
- mode preference has a significant relationship with mode choice,

- mode preference inferred from attitudinal measurements has a stronger relationship with mode choice than directly stated preference,
- with both affectively and cognitively-based preferences, the classification of mode choice cannot be improved by stratifying according to individual demographic factors, and
- stratifying by constraint factors produced marginally better classifications in mode choice.

Other specifications of the model might work better than those employed in this analysis. For instance, cluster analysis could be used to find groups of people with similar mode perceptions. Preferences could be derived from those clusters. Scales could be developed with a variety of techniques to produce preference scores for each mode. Other classifications for demographic or constraint variables might produce better results than the ones employed here. However, this preliminary analysis does support the basic elements of stages 2 and 3 of the "integrated model of consumer choice."

Analysis of Temporal Factors in Mode Choice

The Puget Sound Transportation Panel data provide a unique opportunity to analyze the directionality in the relationships between attitudes and mode choice. By measuring attitudes and mode choice at two different points in time, it is possible to determine if attitudes have a stronger effect on mode choice than does mode choice on attitudes, or if the relationship goes equally in both directions.

For this analysis, affective perceptions were used for the attitudinal data and mode choice was simplified to three modes: SOV, Pool and Bus. A factor analysis was conducted on the attitudinal data and five factors emerged that best described the structure of respondents' attitudes toward transportation mode. Table 8 shows the five factors, together with the questionnaire items that loaded most strongly on each factor.

These five factors were used in regression analyses to classify mode choice. No other variables were included in these analyses. The five factors were strongly related to classifications of both actual and preferred mode choice. While each model had slightly different relationships among the variables, the significant predictors in each regression formed a stable

Table 8. Description of Attitudinal Factors

Factor 1	Like to Commute by SOV	
		"Driving a car is a relaxing way to commute."
		"I like the freedom of driving my own car."
		"I enjoy driving by car even in heavy traffic."
		"If gas prices get much higher, I'll be less likely to drive to work." *
Factor 2	Like to Commute by Pool	
		"Carpooling is an enjoyable way to travel."
		"If it were convenient, I would carpool with someone I don't already know"
		"I'd rather drive in a car with other people than drive by myself."
		"I don't want to rely on someone else to pick me up to get to work." *
Factor 3	Like to Commute by Bus	
		It's a hassle to take the bus." *
		"Taking the bus is an enjoyable way to travel."
		"Riding a bus is a relaxing way to commute."
		"I hate the idea of transferring buses." *
		"Taking the bus is an enjoyable way to travel."
		"Taking the bus doesn't fit my lifestyle." *
Factor 4	Can't Commute by Pool	
		"I don't know anyone to carpool with."
		"It's easy to find someone I can carpool with." *
		"My schedule is too erratic to be in a carpool."
Factor 5	Supports HOV Policies	
		"More freeway carpool lanes should be built."
		"Riding the bus helps reduce traffic congestion."
		"It's not fair to have special lanes set aside for buses and carpools." *
		"People who drive alone should pay more for parking than people who carpool."
		"I would be willing to pay higher taxes to improve bus service."

* Loaded negatively on the factor

pattern. Table 9 shows how each of the five factors entered into a prediction of each type of mode choice. Besides endorsing attitude statements that were positive toward SOV travel, the people who chose SOV commuting were negative toward both rideshare alternatives, were against HOV policies, and said they were not able to form carpools. Those who chose to pool to work had negative attitudes toward the bus. Surprisingly, they did not demonstrate clear support for HOV policies. People who chose to commute by bus expressed a dislike for both driving alone and pooling. They were able to commute by carpool, however. They were the only group that clearly supported HOV policies.

Further analysis of the data allows the possibility to analyze the impact of attitudes on mode choice and vice versa. By examining the percentage of correct classifications using attitudinal data from each wave to predict actual and preferred modes from each wave, it is possible to analyze the directionality of the relationships. Table 10 shows the results of this analysis.

When attitudes from one wave are used to classify mode choice from the same wave, the model shows how consistent current attitudes are with current mode choice. When attitudes from wave 1 are used to classify mode choice from wave 2, the results show how strongly attitudes affect mode choice. When attitudes from wave 2 are used to classify mode choice from wave 1, the results show how strongly mode choice affects attitudes. With this explanation, the following observations can be made concerning the results in Table 10:

- Attitudes are more strongly related to actual mode choice than to stated mode choice preference. This does not support the contention of the "integrated model of consumer choice" that attitudes affect preferences, which are then modified by constraints.

- Current attitudes are always more strongly related to current mode choice than are attitudes and mode choice separated in time. This could indicate that the time between administrations of the panel (18 months) is longer than the ideal time to analyze temporal relationships between attitudes and mode choice.

- There is a slight (but statistically insignificant) tendency for attitudes to predict mode choice more strongly that the other way around. This is especially true for the prediction of preferred mode choice. This does not deny the possibility of the feedback loop proposed in the "integrated model of consumer choice," but it leads us to question its strength.

Table 9. Attitudinal Factors' Statistically Significant Relationships to Mode Choice

Predicted Mode	Factors: Like to Commute by SOV	Like to Commute by Pool	Like to Commute by Bus	Can't Commute by Pool	Supports HOV Policies
SOV	+	-	-	+	-
Pool	0	+	-	-	0
Bus	-	-	+	-	+

Table 10. Percentage of Correct Classifications

Actual Mode Choice

Model Uses:		% Correct Mode Classification:		
Mode	Attitude	SOV	Pool	Bus
Wave 1	Wave 1	81.6	90.7	93.0
Wave 1	Wave 2	79.7	90.3	91.1
Wave 2	Wave 2	81.9	90.0	93.7
Wave 2	Wave 1	80.2	90.9	91.2

Preferred Mode Choice

Model Uses:		% Correct Mode Classification:		
Mode	Attitude	SOV	Pool	Bus
Wave 1	Wave 1	78.2	85.1	89.9
Wave 1	Wave 2	74.2	84.4	85.6
Wave 2	Wave 2	81.1	86.6	91.2
Wave 2	Wave 1	76.0	86.4	87.0

Panel data offer the possibility to analyze the importance of attitudes in mode choice. The question of directionality of the relationship between attitudes and mode choice is not simply of academic interest. If it could be shown that mode choice has a stronger impact on attitudes than the other way around, this finding would suggest that promotional efforts will be relatively less successful than policies that promote mode choice without consideration of attitudinal change. The implication would be that positive attitudes toward ridesharing modes would result from experience with them. However, this research does not support this hypothesis, which indicates that advertising and promotions have a place in encouraging shifts to ridesharing modes.

SUMMARY

The Puget Sound Transportation Panel provides a rich source of data for analyzing the attitudinal correlates of mode choice. This preliminary analysis of the first administration of the survey shows that perceptions of modes have a significant relationship to commuter mode choice, without the influence of any independent information on socioeconomic factors, actual characteristics of commutes, or knowledge of constraints on mode choice. Taking mode choice constraints into account produces marginally better classifications of mode choice.

Further work with these data will determine whether better model specifications exist. When the origins and destinations have been geocoded, it will be possible to test other aspects of the "integrated model of consumer choice," using a wider range of commute trip characteristics and constraints. It will be important to understand the relationship between physical characteristics of commuter's mode choices as well as the influence of mode choice on perceptions.

I-405 HOV OPERATIONS STUDY

This section deals with analysis of mode choice data obtained during a study of HOV operations in the I-405 corridor. The primary objectives of this study were two-fold:

1) to provide information which can assist in the development of a coordinated plan for the I-405 high-occupancy vehicle (HOV) lane system to ensure that the existing and planned HOV facilities work together and that transitions between facilities occur smoothly, and

2) to understand the attitudes and perceptions of the commuters who use the I-405 corridor as a means of understanding their perceptions of HOV lane operations and constraints on the ability of single-occupant vehicle (SOV) commuters to rideshare.

The analysis included an overview of HOV lane operations in the United States, a public opinion survey of commuters who primarily live and work east of Lake Washington, results of focus groups with workers who live in east King County, transportation modeling centering on the I-5 corridor, traffic analysis of HOV lane options, a cost effectiveness analysis, and the results of a symposium which presented and discussed results of the project.

The results of the analysis dealing with the second objective of the study have been adapted to help with this investigation of the bases for mode choice, especially concerning vehicle occupancy.

SURVEY DEVELOPMENT

The I-405 HOV Lane Public Opinion Survey was developed in three phases; a literature review of relevant survey instruments, use of focus groups to identify issues, and the pre-testing of survey questions through the use of focus groups. The following sections describe the survey development process.

Literature Review

A literature review was conducted to assist in the development of the survey instrument. The review explored the wording of different questions regarding HOV lane issues and mode choice attitudes. One source provided examples of several survey methodologies such as; personal distribution/mail-back surveys, telephone surveys, mail-out/mail back surveys, home

interview surveys, workplace interview surveys, and on-board transit surveys.[24] Other examples of transportation survey formats and questions provided examples for the phrasing of demographic as well as technical HOV questions.[25] Locally, here in Puget Sound, surveys were obtained from the Puget Sound Council of Governments, Gilmore Research,[26] Elway Research,[27] and Altair Research.[28] Once the literature review for development of the survey was complete, a series of five focus groups were conducted to further identify issues unique to the I-405 corridor and east King County area.

Focus Groups

Focus groups were used in the survey development process because they allow insights into how the general public views HOV lane and mode choice issues. Additionally, it was felt that the focus group process would allow for the refining of the survey issues and suggest strategies for making these issues more understandable to the general public.

Focus groups have long been used by marketing agencies as a means of testing public attitudes towards products. However, focus groups are increasingly being used by public agencies as a means of obtaining qualitative information regarding public opinions of different public policies. Focus groups typically range in size from seven to ten people who are drawn at random. The participants can be from the same organization or from different organizations. The key is that they generally do not have any technical knowledge of the subject to be discussed. Discussion is guided by a moderator to ensure that the group does not get off track or become dominated by one individual or point of view.

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[24] Transportation Research Board, "Innovations in Travel Survey Methods", Transportation Research Record 1097.

[25] Uematsu, "Evaluation of Preferential Lanes for HOVs at Metered Freeway Ramps," Transportation Research Record 1130, p. 42, 1982; and Wesemann, "Comparison of Travel Behavior Before and After the Opening of HOV Lanes in a Suburban Travel Corridor," Transportation Research Record 1130,, p. 5, 1989.

[26] Gilmore Research, Municipality of Metropolitan Seattle, 1987 East King County Market Segmentation Study.

[27] Elway Research, 1989 Puget Sound Leadership Conference.

[28] Altair Research, 1989 Municipal League Transportation Study Questionnaire.

For the I-405 Analysis, five focus groups were held prior to the development of the survey with employees of the following organizations: University of Washington, City of Bellevue, U.S. West Communications in Bellevue, Totem Lake Merchants in Kirkland, and Overlake Hospital in Bellevue. Selection of the employees for participation in a focus group was made on a random basis. Random selection was considered important in obtaining a variety of people who drove alone, carpooled or rode the bus. Initial contact with the employees was made by asking if they would like to attend an informal luncheon to discuss east King County traffic congestion and commuting options. Generally, these focus groups included people who were currently ridesharing or who had rideshared in the past.

Once the focus group meeting was underway, discussion usually turned to HOV lanes as a means of encouraging carpooling and bus ridership. The participants felt that ridesharing is going to be an important aspect in decreasing traffic congestion. However, the participants had problems thinking of strategies to motivate SOV drivers to rideshare. Generally, the participants viewed carpooling and riding the bus as necessary but extremely difficult given a person's need for daycare, need to make work related trips and need to run personal errands.

Based on the findings of these five focus groups, the first draft of the survey was developed. This draft was kept in a long form which included all possible questions that could be asked regarding HOV lane operations, perceptions about mode choice, and constraints on HOV use. The first draft of the survey was submitted to the project's technical review committee for comment. Comments and suggestions were incorporated and a second draft produced.

Pre-testing of the Survey Questions through Focus Groups

The second draft of the I-405 HOV Lane Public Opinion Survey was pre-tested with employees from the University of Washington and the Microsoft Corporation in Redmond using a focus group format. Again, employees were selected on a random basis and contacted in a manner to avoid influencing their perceptions of HOV lane issues and operations. As in the previously described focus groups, participants who were ridesharing or who had rideshared in

the past were included. This second focus group process allowed for clarifying the questions and weeding out overly complex or redundant questions and statements. In addition, the focus group at Microsoft was particularly helpful in suggesting formatting styles for the survey to enhance understandability.

Survey Design

Based on the findings of the first five focus groups, comments of the technical review committee, and pre-testing with the last two focus groups, the final survey instrument was produced. The I-405 HOV Lane Public Opinion Survey was designed to collect data in three basic categories:

1) demographics, mode choice, and constraints on mode choice;

2) attitudes about and perceptions of different modes of commute; and

3) attitudes about different HOV lane operations.

The demographic questions asked respondents about their current mode choice, age, family characteristics, number of household vehicles, income level, job, cost of parking at the work site, home and work locations, and constraints on mode choice (e.g., need of car for; daycare, work related trips, personal errands).

The section on attitudes about different modes of commute was adopted from the PSTP described in the previous section of this report. It was incorporated into this survey because it had been through an extensive pre-testing process and adequately addressed many of the mode choice issues associated with the I-405 analysis. These statements were used on the I-405 public opinion survey instrument to obtain data regarding the cognitive and affective perceptions people have about different modes of commute and about commuting in general.

Since a great deal of information was sought from the survey instrument, project staff decided to use three formats in order to break down the length of the survey. The three formats were:

1) A format which asked questions about:

   a) demographics, mode choice, and constraints on mode choice;

   b) attitudes about and perceptions of different modes of commute; and

   c) attitudes about different HOV lane operations.

2) A format which asked questions about:

   a) demographics, mode choice, and constraints on mode choice; and

   b) attitudes about and perceptions of different mode commute.

3) A format which asked questions about:

   a) demographics, mode choice, and constraints on mode choice and

   b) attitudes about different HOV lane issues and operations.

Each format was used for approximately on-third of the respondents.

SURVEY ADMINISTRATION

The literature review process not only yielded excellent examples of questions to ask on the I-405 Public Opinion Survey, it also illustrated the number of opportunities available for survey administration. Consideration of the method for administering the survey was seen as important since this affected the ultimate length of the final survey instrument. The following section includes a brief examination of the methods which were considered but rejected, and a brief overview of the administration method which was used.

Survey Methods Not Employed for the I-405 HOV Lane Analysis

Four different survey methodologies were considered, but not used in the administration of the I-405 HOV Lane Public Opinion Survey. Those methods include the following:

License plate survey using video cameras. This method would employ video cameras to record the license plate numbers and number of vehicle occupants of morning commuters along the I-405 corridor. Once the license plate numbers are recorded, names and addresses of commuters would be obtained from the Washington State Department of Licensing. Postage paid mail-back surveys are sent to these commuters. This method was not used for two

reasons: 1) the short days of early spring would have resulted in insufficient light for effectively surveying the license plates; and 2) mail-back surveys generally do not have a high level of response. A literature review revealed that a survey undertaken with this methodology resulted in only a 19 per cent response rate.[29]

Survey handed out at local on-ramps. This method would use a postage paid mail-back survey format handed out to commuters as they entered freeway on-ramps in the I-405 corridor. This method was not used because of historically low response rates associated with mail-back surveys.

Fixed location computers. This method would have survey respondents using a computer at a fixed location in order to answer the survey. The computer program would automatically guide the respondent through the survey instrument while simultaneously coding the data for later analysis. Fixed location computers could be used at supermarkets, shopping centers, and shopping malls. This method was rejected for two reasons: 1) it was not known how long it would take to collect data by this method and the project time-line specified that data collection run from the middle of April through May 1990; 2) it was felt that this method would attract people who were at ease with computers or people who frequent shopping centers or malls and not produce a representative sample.

Telephone survey. This method would involve contracting the survey administration to a telemarketing firm. The primary advantage of this method over mail-out/mail-back surveys is that it would allow for personal contact with the survey respondent. Despite this advantage, this method was not used because of the associated costs. Costs for this type of survey methodology were documented in a multi-year transportation study undertaken by the Metropolitan Council of the Twin Cities Area in Saint Paul, Minnesota. The costs noted by this Council were in the $100,000 range for the telephone survey. This cost was greater than what was feasible within the budget for this part of the study.

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[29] Wesemann, op. cit, p. 16.

Survey Method Employed for the I-405 HOV Lane Public Opinion Analysis

After rejecting the methodologies covered in the previous section, the research team decided to administer the survey at driver's licensing offices in east King County, specifically the cities of Kirkland, Bellevue, and Renton. This method of administration was suggested as a result of a brainstorming session. The suggested administration process was to use a paper and pencil format with a postage paid mail-back option if people were unable to complete the survey while waiting in line for their driver's license. This survey method was used for a number of reasons:

1) It was assumed that by gathering data at driver's license office in east King County, the respondents would primarily be people who live and work in East King County, and thus be more likely to use I-405 for their commute to and from work.

2) It was assumed that this method would be an effective means to obtain a random and representative sample of commuters since everyone has to renew their license in person at some time near their birthday.

3) The bias toward people with driver's licenses was not considered problematic since over 95 per cent of all east King County residents over the age of 16 have a driver's license.[30]

4) It was felt that the time people spent waiting in line could be used to complete the survey, thereby avoiding the low response rates typically associated with mail-back surveys.

5) This method of survey administration allowed the use of project staff and Washington State Department of Transportation staff, and thus data collection could be conducted relatively inexpensively.

The I-405 HOV Lane Public Opinion Survey was administered at the Driver's Licensing offices in Bellevue, Kirkland and Renton during the months of April and May 1990. The survey was administered during all office hours to ensure that the data collection effort was not biased by collecting data only on certain days or only at certain times of the day. Additionally,

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[30] Municipality of Metropolitan Seattle (Metro), "1987 East King County Transportation Market Segmentation Study," prepared by Gilmore Research Group, October 1987, p. 24, 1987.

data collection on Saturdays allowed contact with people who did not have the opportunity to renew their license during weekday office hours (8:00 a.m. to 4:30 p.m.).

The survey was administered by staff of the Washington State Transportation Center (TRAC) and the Washington State Department of Transportation (WSDOT). This was important because the survey staff had clear understandings of HOV lane operations and transportation planning issues, and thus could be of assistance in answering any questions.

Since the goal of the survey was to gather data about commuter attitudes, potential survey respondents were screened before being asked to complete a survey. This screening process included asking respondents if they were willing to complete a survey about their trip to and from work and their perceptions about HOV lane issues and operations. If they did not commute during peak hours, they were not asked to fill out the survey. This method screened out retired people, people who do not commute on a regular basis, and people under 18 (generally students) who do not commute during peak hours. It was felt that this bias was acceptable since the goal of the survey was to concentrate on people who commute to and from work along the I-405 corridor. For the most part, respondents completed the survey on the premises.

SURVEY RESPONSE RATE

A high response rate is desirable in order to avoid a bias resulting from respondents differing on important issues from non-respondents. This data collection effort was very successful in this respect. An 87 per cent response rate was achieved by taking advantage of the fact that people have to wait in line at the Driver's Licensing Offices. People were very receptive to completing the survey and many actually said it was interesting. Table 11 displays the total number of surveys collected at each survey administration site.

As can be seen from Table 8, the number of survey collected from each driver's licensing office was roughly the same. The number of surveys collected from the Renton

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Table 11. Response Rate I-405 HOV Lane Public Opinion Survey

Location	Number of Surveys Handed Out	Number of Surveys Received	Response Rate	% of Total
All Locations	1775	1545	87.00%	100.00%
Bellevue	581	518	89.00%	33.50%
Renton	483	436	90.00%	28.20%
Kirkland	566	516	91.00%	33.40%
Mailed Back	145	75	52.00%	4.90%

driver's licensing office was lower than the Bellevue and Kirkland offices because this office generally has less business. Equality in the numbers collected from each office was seen as an important means of ensuring that the overall survey results were not biased by the results of one office.

MODE CHOICE ANALYSIS

The mode choice analysis used a series of t-tests and chi-square tests to determine the statistical differences between the three mode choice groups with respect to:

- personal characteristics (age, sex, education, occupation);
- home characteristics (household size, average number of workers, average number of children, household income, average number of household vehicles, and level of vehicle availability for commute purposes);
- daycare characteristics (use, responsibility for dropping off a child and/or picking up a child, average weekly daycare use, average closing time of daycare facilities, and the distance of the daycare facility from the respondent's home);
- workplace characteristics (work start and end times, morning and evening commute times, company size, parking problem, parking cost, and availability of a company car); and
- daily activity characteristics (use of personal vehicle for work related trips, use of personal vehicle for personal errands, and use of personal vehicle to drive to lunch off-site).

The examination of the differences between SOV commuters and carpoolers and bus riders was conducted to identify constraints to HOV use by SOV commuters. By identifying these constraints to HOV use, policies can be developed which can encourage more SOV

commuters to carpool or ride the bus. The information derived from these questions will be used to address the question "what are the differences between people who use different modes for commuting to and from work with respect to personal, home, daycare, workplace and daily activity requirements?"

A second part of survey analysis attempted to determine if there were differences in the perceptions of HOV lane issues and operations according to a person's support for HOV lanes. This variable is referred to as the "favor HOV" variable. The purpose of creating this variable was to determine if there were some global attitude influencing attitudes about specific issues concerning HOV lanes. One hypothesis is that people who favor HOV lanes are supportive of HOV lane treatments regardless of their current mode choice. The "favor HOV" variable was created based on responses to the statement "HOV lanes are a good idea." Those who agreed or agreed strongly were placed in the "favor" group, those who disagreed or disagreed strongly were placed in the "not favor" group, and the neutral respondents were placed in the neutral group.

Table 12 displays the observed frequencies. From this table it is very clear that the respondents overwhelmingly think HOV lanes are a good idea despite the fact that nearly 80 per cent of them are not able to use HOV lanes for their commute to and from work because they drive alone.

Table 12. Favor of HOV Lanes

"Favor" of HOV Lanes	Number of Responses	Percent of Total
Favor	599	89.0%
Neutral	32	4.7%
Not Favor	43	6.4%
Total	674	100.0%

MODE PREFERENCE ANALYSIS

In addition to testing the differences among the three modes with respect to their demographic characteristics and constraints on HOV use, two types of preference analysis were conducted:

1) cognitive preference analysis — a set of statements requesting respondents to rate different commute modes (SOV, carpool, and bus) with respect to mode attributes such as travel time, cost, and plan flexibility and the importance the respondents placed on each of the mode attributes, and

2) affective preference analysis — a set of statements that had respondents agree or disagree with attitudinal statements such about issues such as increases in taxes for more bus service, increases in parking costs for single-occupant vehicles, ease of using the bus, and ease of using a carpool.

By analyzing commuter mode preferences, SOV commuters who have a tendency to think carpooling or riding the bus is more effective than driving alone could be identified. Once these commuters are identified, an examination of constraints on their ability to use HOV modes could be undertaken. This analysis can be used to address the second research question, "what are the differences between people who actually rideshare and people who prefer ridesharing yet continue to commute alone with respect to personal, home, daycare, worksite, and daily activity requirements?"

Cognitive Analysis

The cognitive analysis used data from the respondents' ratings of three different commute modes with respect to mode attributes such as travel time, cost, and plan flexibility and the importance they placed on those attributes to identify the mode they rated as most effective for commute purposes. The respondents' effectiveness ratings were then compared with their actual mode use in order to determine which commuters rated a different mode as more effective than their current mode. The goal of the cognitive preference analysis was to analyze the characteristics of respondents whose cognitive preference differed from their actual mode choice.

A cognitive preference score was computed by multiplying the individual's **importance** ratings for each of ten variables by their rating of the **performance** of buses, carpools and

driving alone with respect to each of these ten variables. Performance scores were determined for each mode from these responses indicating a respondent's perception of the effectiveness of the three difference modes. The mode with the highest preference score was considered the cognitively preferred mode.

The cognitive preferences were then cross-tabulated with the respondents' actual mode use to determine correspondence between preference and actual choice. Respondents who cognitively preferred ridesharing yet drove alone were compared with the people who cognitively preferred ridesharing and actually rideshared. Those who cognitively preferred carpooling yet drove alone were referred to as the "Want to Pool" group, those who cognitively preferred carpooling and actually carpooled were referred to "Actual Pool" group, those who cognitively preferred using the bus yet drove alone were referred to as the "Want to Bus" group, and those who cognitively preferred using the bus and actually rode the bus were referred to as the "Actual Bus" group. T-Tests and chi-square tests were then used to determine the statistical differences between the "Real Pool" and "Want to Pool" groups and the "Real Bus" and "Want to Bus" groups on several variables indicating personal, home, daycare, workplace and errand characteristics. This analysis was used to help understand why people who drive alone, but prefer ridesharing modes do so. This should lead to the identification of constraints on HOV use and identify strategies to encourage the use of carpools and buses.

People who prefer driving alone and do so are less likely to shift modes and require a different approach. It was assumed that these people viewed carpools and buses as less effective than driving alone, and thus policies to change their behavior have to address their basic views of carpool and bus commute modes.

Affective Analysis

The affective analysis used data from the respondents' agreement or disagreement with statements about the three commute modes (SOV, Carpool, Bus) that were designed to touch on subjective responses to the modes. Items included such issues as enjoyment of driving, lifestyle fits, feelings about increases in taxes for more bus service or parking costs for single-occupant

vehicles. The respondents' support for the three commute modes was then compared with their actual mode use in order to determine which commuters favored a mode that differed from their current mode use.

Affective preferences for a mode were identified through cluster analysis. This analysis method produces groups of respondents who react similarly to a set of variables. By using the respondents' agreement and disagreement with the statements, three affective preference clusters were identified; the drive alone cluster, the carpool cluster, and the bus rider cluster. Each cluster had response patterns that indicated agreement with statements supporting the use of one mode and disagreed with or were ambivalent about with statements supporting the use of the other modes.

The three mode preference clusters were cross-tabulated with actual choice of commute mode. Those who affectively preferred carpooling yet drove alone were referred to as the "Want to Pool" group, those who affectively preferred carpooling and actually carpooled were referred to "Actual Pool" group, those who affectively preferred using the bus yet drove alone were referred to as the "Want to Bus" group, and those who affectively preferred using the bus and actually rode the bus were referred to as the "Actual Bus" group. T-tests and chi-square tests were then used to determine the statistical differences between the "Actual Pool" and "Want to Pool" groups and the "Actual Bus" and "Want to Bus" on several variables indicating personal, home, daycare, workplace and errand characteristics. This analysis mirrored the analysis of cognitive preference and mode choice with the same objectives of identifying strategies for producing modal shift to HOV commute modes.

GENERAL FINDINGS

This section provides general information about the survey sample. The sample is described in terms of normal commute mode, characteristics of carpools, reasons for driving alone, general comments, origin and destination patterns, and a comparison of the sample with the general population.

Mode Usage

The mode choice variable was created using the number of days they reported using a particular mode for travel to and from work. Four mode choice categories were created: SOV, POOL, BUS and OTHER. The SOV group was composed of respondents who used a personal vehicle three or more days per week for commuting to and from work. The POOL group included respondents who commuted three or more days per week in a carpool or vanpool with at least one other person. The BUS group constituted respondents who rode the bus two or more days per week. Since there were so few bus riders in the sample, this method of coding allowed for the examination of as many bus riders as possible. The OTHER group was comprised of respondents who walked, motorcycled or rode a bike three or more days per week. Table 13 shows the sample's frequencies and percentages of use of the four mode choice groups.

As can be seen from this table, the majority of the survey respondents drive alone to and from work. The mode choice analysis examines and compares the characteristics of SOV, POOL and BUS groups. The results of the analysis are presented in a later section.

Carpool Characteristics

Thirteen per cent of the respondents carpooled to and from work at least three days per week. The average carpool size was 2.64 people. The majority of the carpools were comprised of co-workers, not spouses or children. This was an interesting finding since the literature

Table 13. Mode Usage

Mode Choice Group	Number of Responses	Percent of Total
SOV	1137	79.00%
POOL	181	13.00%
BUS	91	6.00%
OTHER	30	2.00%
Total	1439	100.00%

reviewed suggested that, in general, the majority of carpools are made up of spouses and children.[31]

Only **four** respondents reported carpooling with a worker from a different company that worked at a different site. The formation of carpools was largely done by the carpool members themselves. Eighty-eight per cent of the carpoolers reporting forming their own carpools; only 9.9 per cent of the carpools were set up as the result of an employer program and only 2.5 per cent were set up by a transit agency. This finding shows that these people are out there on their own setting up these carpools even though a regional program could be assisting them.

Reasons for Driving Alone

Nearly 80 per cent of the survey respondents drove alone. The primary reasons that people reported for driving alone were:

- "No co-workers live near me" or "No neighbors work near my worksite." (14.7 percent)
- "It is convenient to drive alone."(11.1 percent)
- "I need my car for work."(11.1 percent)
- "I have an odd schedule. or "No one has the same schedule as me." (7.5 percent)

Of all the reasons given for driving alone, only four people stated that they did so because they simply like to drive alone. Responses to this question show that commuters strongly believe that there is no one else to commute with, that they are "alone" when it comes to commute routes and schedules. The responses also show a reliance on their personal vehicle for accommodation of an odd work schedule and work related trips. Additionally, a fair number of respondents noted that they use their vehicle for commuting because it is convenient. These perceptions demonstrate both real and psychological barriers to the formation of carpools and use of the bus. Any policies to increase the use of HOVs should take these real and perceived barriers to HOV use into account.

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[31] Booth, Rosemary and Robert Waksman, "Analysis of Commuter Ridesharing Behavior at Five Urban Sites," Transportation Research Record 1018, 1984.

Comments

Seventeen per cent of the survey respondents provided comments on the survey form. Caution should be exercised in generalizing too much from a few comments. However, they do provide another perspective on the attitudes of I-405 commuters. The most frequently made comments were:

- favor for light rail or recommendation for light rail — 2.6 percent of total comments or 39 people
- observation that current Metro service is inadequate — 2.4 percent of total comments or 36 people
- being in favor of HOV lanes — 2.1 percent of total comments or 32 people
- about why they could not carpool or use the bus — 2.0 percent of total comments or 30 people

The most frequent comment made by bus riders was that Metro service was inadequate. The most frequent comment made by carpoolers was that HOV lanes were a good idea and that more should be constructed. The most frequent comment made by the SOV drivers was being in favor of or recommending light rail. Thus, respondents generally made comments which were consistent with their current mode choice. However, the fact that the SOV drivers desire light rail does not necessarily mean that they will use such a system. Using light rail is inconsistent with the reasons SOV commuters gave for not carpooling or taking the bus (e. g., it is inconvenient, they need a vehicle for work, they have an odd schedule, it takes too long, it is too difficult to use, and the like).

MODE CHOICE ANALYSIS

The objective of this part of the analysis was to determine if differences exist among people who use different modes. The mode choice analysis examined personal, home and work and daily activity characteristics of the three mode choice groups to identify barriers to HOV use. Examination of this set of characteristics may suggest potential policies which could be implemented to encourage shifts to HOV. Following is a summary of variables used in the analysis and an indication of their relationship to mode choice:

Variables with No Statistically Significant Differences

The analysis of the mode choice groups did not reveal statistically significant differences among the three groups for the following variables:

- Sex
- Age
- Household Size
- Average Number of Children
- Dropping Off a Child at Daycare
- Picking Up a Child From Daycare
- Average Number of Days per Week that Daycare is Used
- Average Daycare Closing Time
- Distance of Daycare Facility from Home
- Average Work Starting Time
- Average Work Ending Time
- Average Number of Days with a Parking Problem at Work
- Average Number of Days Personal Vehicle is Used for Work Related Trips
- Average Number of Days Personal Vehicle is Used for Personal Errands

The lack of statistically significant differences among the three mode groups for the average number of a days per week that a personal vehicle is used for work related trips and personal errands is contrary to other findings in this study. For instance, focus group participants indicated that they could not carpool or take the bus on a regular basis because of their need to make work related trips and to conduct personal errands. Other research has also shown this factor to be important in mode choice. Since no statistically significant differences were observed among the three groups for these variables, they are not discussed in this analysis. The responses to these questions are shown in Tables 14 to 18.

Variables with Statistically Significant Differences

Statistically significant differences for the following variables were observed:

- Education
- Occupation
- Average Number of Workers per Household
- Household Income
- Average Number of Household Vehicles
- Vehicle Availability for Commute Purposes
- Use of Daycare
- Morning and Evening Commute Times
- Company Size
- Parking Fee at Work Site
- Availability of Company Car for Work Related Trips
- Use of Personal Vehicle for Driving to Lunch

Table 14. Personal Characteristics

Variable	Overall	SOV	POOL	BUS
Sex				
(% in cat)				
Male	55.20	55.30	54.30	52.30
Female	45.80	44.70	47.70	47.70
Age				
(% in cat)				
<31	35.90	34.20	44.90	40.00
31 - 40	29.60	30.10	28.40	28.20
41 - 50	23.30	24.60	20.70	20.00
51 - 64	10.00	10.20	6.00	11.80
65 +	1.10	0.90	0.00	0.00
Education				
(% in cat)				
High School	17.80	15.90	31.00	13.30
Comm Coll	23.00	24.20	23.00	14.50
College	42.30	42.20	31.90	55.40
Post-Grad	16.90	17.70	14.10	16.90
Occupation				
(% in cat)				
Mgr/Adm	22.80	25.00	21.80	18.10
Pro/Tech	29.00	29.90	19.10	36.10
Shop/Craft	13.20	13.10	27.80	7.20
Secretary	8.40	7.50	7.80	16.90
Sales/Serv	17.90	18.40	14.80	13.00
Other	8.70	6.10	8.70	8.70

Table 15. Home Characteristics

Variable	Overall	SOV	POOL	BUS
Hshold Size	2.96	2.95	3.04	2.79
Avg#Workers	1.86	1.91	2.26	1.40
Avg#Children	1.24	1.70	1.11	0.90
Life Stage (% in cat.)				
Single	23.60	24.50	14.10	25.70
Mul Ad/No Ch	9.50	9.30	18.30	14.30
Mul Ad/6<	21.90	20.70	25.30	20.00
Mul Ad/7>	45.50	45.50	42.30	40.00
Hshold Income (% in cat)				
15 - 24999	15.60	11.20	24.00	35.70
25 -34,999	12.60	13.30	20.00	7.20
35 -54,999	32.80	35.20	24.00	28.60
55 -74,999	20.20	19.90	32.00	7.10
75 -99,999	11.10	12.20	0.00	14.30
100,000+	7.60	8.20	0.00	7.10
Avg#Hshold Vehicles	2.41	2.42	2.47	1.99
Avg#Days/Wk Car Available for Commute	4.85	4.91	4.57	4.43

Table 16. Daycare Characteristics

Variable	Overall	SOV	POOL	BUS
Avg # Days/Wk Use Personal Car for Work Related Trips	3.57	3.56	4.02	3.32
Avg # Days/Wk Use Personal Car for Own Errands	3.14	3.10	3.32	2.80
Avg # Days/Wk Use Personal Car to Drive to Lunch	2.42	2.49	2.42	1.53

Table 17. Work Characteristics

Variable	Overall	SOV	POOL	BUS
Work Start Time avg.	8:24 AM	8:24 AM	7:54 AM	8:00 AM
Work End Time avg.	4:35 PM	4:43 PM	4:05 PM	4:02 PM
Morning Commute Time - Min.	25	24	27	32
Evening Commute Time - Min.	27	28	33	39
Company Size (% in cat.)				
1 - 25	37.90	38.00	39.30	17.60
25 - 100	19.50	20.50	17.90	5.90
100 - 1000	22.00	24.00	10.70	23.50
1000+	20.00	17.50	32.10	52.90
Avg # Days/Wk Parking Prob	0.47	0.45	0.63	0.33
Parking Fee (% in cat.)				
Yes	9.00	8.30	9.40	27.50
No	91.00	91.70	90.60	72.50
Company Car (% in cat.)				
Yes	31.80	30.10	35.00	60.00
No	54.20	55.80	50.00	40.00
Sometimes	10.90	11.60	5.00	0.00
Don't Know	3.00	2.50	10.00	0.00

Table 18. Daily Activity Characteristics

Variable	Overall	SOV	POOL	BUS
Avg # Days/Wk Use Personal Car for Work Related Trips	3.57	3.56	4.02	3.32
Avg # Days/Wk Use Personal Car for Own Errands	3.14	3.10	3.32	2.80
Avg # Days/Wk Use Personal Car to Drive to Lunch	2.42	2.49	2.42	1.53

Table 19 summarizes the specific differences between the mode choice groups. Since statistically significant differences for these variables exist among the mode choice groups, they may give insight into mode choice. The relationship between these variables and mode choice are described in the following sections. They are divided into personal, home and work characteristics.

Table 19. Summary of Differences — Mode Choice Groups

SOV compared with Carpoolers Statistically Significant Differences	SOV compared with Bus Riders Statistically Significant Differences	Carpoolers compared with Bus Riders Statistically Significant Differences
• Education • Occupation • Daycare • Household Income • Average Number of Days Car Available for Commute Trips • Morning Commute • Evening Commute	• Occupation • Average Number of Workers per Household • Household Income • Average Number of Household Vehicles • Average Number of Days Car Available for Commute Trip • Morning Commute Time • Evening Commute Time • Company Size • Parking Fee at Worksite • Availability of Company Vehicle • Average Days per Week Drive to Lunch	• Occupation • Average Number of Workers per Household • Average Number of Household Vehicles • Morning Commute Time • Evening Commute Time • Parking Fee at Worksite • Availability of Company Vehicle • Average Days per Week Drive to Lunch

Personal Characteristics

Table 20 summarizes the personal characteristics responses of the three mode choice groups and shows the statistical differences (based on chi-square tests) observed between mode choice pairs.

The SOV and POOL groups differed significantly by level of education. The POOL group reported the largest proportion of high school graduates and the smallest proportion of college graduates. The lower education level of the carpoolers is consistent with the fact that the POOL group reported a larger proportion of shop/craft workers. The POOL group had the largest proportion of shop/crafts workers. These people may be carpooling because of opportunities to commute with co-workers and also because these types of companies are frequently located in suburban areas rather than urban cores like downtown Seattle. The rate of carpooling is not related to owning fewer vehicles.

Table 20. Personal Characteristics of Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig POOL/BUS
Education (% in cat)						
Hi School	15.9	31.0	13.3			
Comm Coll	24.2	23.0	14.5	0.002	n/a	n/a
College	42.2	31.9	55.4			
Post-Grad	17.7	14.1	16.9			
Occupation (% in cat)						
Mgr/Adm	25.0	21.8	18.1			
Pro/Tech	29.9	19.1	36.1			
Shop/Craft	13.1	27.8	7.2	0.0037	0.0008	0.0068
Secretary	7.5	7.8	16.9			
Sales/Serv	18.4	14.8	13.0			
Other	6.1	8.7	8.7			

*Mgr/Adm = Managerial/Administrative; Pro/Tech = Professional/Technical; Shop/Craft = Shop or Production Worker, Craftsman or Foreman; Sales/Serv = Retail Sales, General Sales (Real Estate, Broker, etc.), Personal Services Worker; Other = Student, Truck Driver, Delivery, etc. Chi Square Tests were used on the Education and Occupation variables. n/a refers to no statistically significant difference observed between the two groups with respect to the variable.

Differences were observed between all three pairings of the groups for the occupation variable. The predominate occupation categories for the SOV and BUS groups were managerial/administrative and professional/technical. The BUS group had a higher proportion of professional/technical workers and secretaries than either the SOV or POOL groups. These professional/technical workers probably use the bus because they are traveling to an urban core such as Bellevue or downtown Seattle where these professions are commonly located. Secretaries are less likely to have a car available.

Home Characteristics

Table 21 summarizes the responses by mode choice group for home characteristics and presents the statistical differences observed between the pairs of groups.

The average number of workers per household differed between the SOV and BUS groups and between the BUS and POOL groups. The BUS group had a lower average number of workers per household than either the SOV or POOL groups. The POOL group, on the other hand, had the highest average number of workers. This probably indicates that people who have more opportunities for carpool formation within their household do so.

The carpoolers had the highest level of daycare use of the three mode choice groups. This suggests that the use of daycare does not rule out the ability to carpool. Generally, people who use daycare (the minority of this sample) are largely responsible for dropping off and picking up the child and use daycare a majority of the workweek. Carpoolers appear to have reconciled their daycare responsibilities with their commute schedules. This reconciliation is contrary to the common perception by SOV drivers that they cannot carpool because of their daycare needs. It should be noted here that people were defined as carpoolers only if they drove with others to work. Child passengers bound for daycare were not counted as part of a carpool.

Household income differed according to mode choice. In general, the SOV group had the largest proportion of respondents in the middle to upper income categories than either the POOL or BUS groups. Both the POOL and BUS groups had a larger number of respondents in the $15,000 to $24,999 category than the SOV group. In general, lower household income

Table 21. Home Characteristics of Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig BUS/POOL
Avg#Workers	1.91	2.26	1.40	n/a	0.038	0.007
Use Daycare (% in cat.)						
Yes	11.90	19.00	6.80			
No	88.90	81.00	93.20	0.043	n/a	0.01
Hshold Income (% in cat)						
15 - 24999	11.20	24.00	35.70			
25 -34,999	13.30	20.00	7.20			
35 -54,999	35.20	24.00	28.60	0.004	0.00	n/a
55 -74,999	19.90	32.00	7.10			
75 -99,999	12.20	0.00	14.30			
100,000+	8.20	0.00	7.10			
Avg#Hshold Vehicles	2.42	2.47	1.99	n/a	0.001	0.004
Avg#Days/Wk Car Available for Commute	4.91	4.57	4.43	0.00	0.00	n/a

*Hshold=household; Avg= average; Vehicle availability of 4+ refers to always having a vehicle available for commuting purposes. T-Tests were used for Average Number of Workers per Household, Average Number of Vehicles per Household, and Average Number of Days per Week that a Vehicle is available for commute. Chi Square Tests were used for Use of Daycare and Household Income. n/a refers to no statistically significant differences between the two groups with respect to the variable

probably motivates carpoolers and bus riders to seek alternative modes of commute to save money possibly either in the form of general transportation costs or parking fees. However, there were a couple of anomalies. A substantial number of higher income households had people who carpooled to work. This may be related to having more workers per household, resulting in higher incomes and more opportunities to commute. There were also some very high income bus riders. Almost 30 per cent of the bus riders had annual incomes over $55,000.

Almost all of those bus riders had CBD destinations. Good bus service, combined with TDM programs, can be attractive even when there are no financial barriers to driving a car.

The average number of household vehicles was lowest for bus riders. This is not unexpected. However, a surprising finding is that the number of vehicles per worker is **highest** in households with bus riders. On the average, the SOV group had a car available more of the time than the POOL and BUS groups. The fact that the SOV groups had a vehicle readily available for commute purposes means that this group does not have to consider other commute alternatives, and thus they choose the most convenient alternative which is driving their personal vehicle. The fact that bus riders had more vehicles per worker, yet the lowest car availability is puzzling. No data were collected on type of vehicle in the household, but this may be explained by a large number of special purpose vehicles in bus rider households.

In general, the analysis shows that there are more differences between people who ride the bus and SOV commuters than there are differences between carpoolers and SOV commuters. This indicates that bus riders on the Eastside are a distinct group. They either are forced by economics to use a bus or have a convenient commute to high paying jobs in downtown Seattle or Bellevue. The similarities between carpoolers and SOV commuters suggests that it may be easier to shift SOV commuters into a carpool than onto the bus.

Workplace Characteristics

Table 22 summarizes the responses of the three mode choice groups concerning their workplace characteristics.

The BUS group reported the longest morning and evening commute times followed by POOL people and the SOV drivers. The disparity in commute times is explained partially by the fact that bus riders and carpoolers have longer distance commutes. People are more likely to take the time to form carpools when the distance is longer. Longer bus commutes are explained by the large number of people who commute to downtown Seattle by bus. In addition, bus speeds are lower, which accounts for longer travel times.

Table 22. Workplace Characteristics — Mode Choice Groups

Variable	SOV	POOL	BUS	Stat Sig SOV/POOL	Stat Sig SOV/BUS	Stat Sig BUS/POOL
Morning Commute Time — Min.	24	27	32	0.029	0.00	0.011
Evening Commute Time — Min.	28	33	39	0.001	0.00	0.018
Company Size (% in cat.)						
1 - 25	38.00	39.30	17.60			
25 - 100	20.50	17.90	5.90			
100 - 1000	24.00	10.70	23.50	n/a	0.0029	n/a
1000+	17.50	32.10	52.90			
Parking Fee (% in cat.)						
Yes	8.30	9.40	27.50	n/a	0.0001	0.0086
No	91.70	90.60	72.50			
Company Car (% in cat.)						
Yes	30.10	35.00	60.00			
No	55.80	50.00	40.00			
Sometimes	11.60	5.00	0.00	n/a	0.026	0.047
Don't Know	2.50	10.00	0.00			
Avg # Days/Wk Use Personal Car to Drive to Lunch	2.49	2.42	1.53	n/a	0.008	0.039

T-Tests were used for Morning and Evening Commute times and Average Number of Days per Week that a Personal Vehicle is used for Work Related Trips. Chi Square tests were used for Company Size, Parking Fee, Company Car. n/a refers to no statistically significant differences between the two groups with respect to that variable.

The survey instrument had respondents report the number of employees who worked at their organization. However, it should be noted that the results do not reflect the number of employees at a given worksite. The results showed that bus riders tend to work at larger companies than SOV drivers. Typically, these large companies are located near bus lines. Thus, it is convenient and often a direct route to use a bus for travel to a large company. On the other hand, bus service to small companies outside the urban core is inconvenient or non-existent or involves several transfers and a walk. The inconvenience of bus service makes it more attractive

to drive alone. Employees in small companies who cannot drive alone tend to choose carpooling for their commute.

Very clear differences in having to pay to park at work were observed among mode choice groups. Nearly 30 per cent of the bus riders report that their company charges to park at the worksite compared with less than 10 per cent of the carpoolers and SOV drivers. Paying to park is a significant factor in accounting for the differences between this sample's mode choices. The influence of the cost of parking on mode choice is consistent with all other studies which include this factor.

Of the people who pay to park, 57 per cent work in the downtown core of Seattle, 24 per cent worked in downtown Bellevue, and 12 per cent worked in the University District area. Other work locations where there was a charge for parking include the Beacon Hill neighborhood in Seattle, the Overlake area in Bellevue, downtown Kirkland, Totem Lake Mall in Kirkland, downtown Bothell, downtown Kent, South Center Mall in Tukwila, SeaTac Airport, and downtown Tacoma. The findings confirm the observation that employees who work for companies located in dense urban areas are more likely to pay to park than people who work for companies located in less dense suburban areas.

The BUS group reported the highest level of company car availability compared with the SOV and POOL groups. The unavailability of a company car probably means that some SOV commuters use their personal vehicles for commuting because they need to them to make work related trips during the workday, when they might share rides otherwise.

The high average number of days per week that a personal vehicle is used for work related trips (3 or more days per week for all three groups) combined with the fact that the majority of SOV and POOL respondents do not have access to a company car for these trips, suggests these respondents are using their personal vehicle by necessity and not completely by personal choice or preference. In addition, the fact that the BUS people have to use their personal vehicle for work or for personal errands probably accounts for their not using the bus on a daily basis. The high average of personal vehicle use for personal errands (3 or more days

per week for the SOV and POOL groups) suggests these respondents do not have alternatives available such as walking or using the bus. Furthermore, the use of their personal vehicle for running errands during the weekday is a habit many people have difficulty breaking in order to accommodate a carpool or bus schedule. People may rely on their personal vehicle out of necessity and habit to complete errands during the workday.

Unlike personal and home characteristics, factors relating to workplace characteristics present more opportunities for public and private policy actions to encourage the use of HOVs. For instance, a comprehensive system of HOV lanes can be implemented to provide a travel time savings advantage to commuters with long commutes. Public policy cannot mandate company size. However, policies can be developed which encourage small companies to locate in areas of high density which provide the critical mass necessary to support transit service. Policy could also influence the location of companies so that they are coordinated with support services such as restaurants, retail uses and professional offices. This coordination of land uses could make commuters less dependent on their personal vehicles for workday trips, and thus more able to rideshare to work. Additionally, policies to assist small companies in acquiring a company vehicle for employee use could be effective in increasing the ridesharing ability of their workers by making them less reliant on their own vehicles for getting their job done.

Summary

It should be noted here that the sample for this study does not represent the typical commuter population in the region. They tend to be young, middle to upper middle income, professionals with access to a personal vehicle for commuting to and from work. These respondents also do not tend to pay to park at their worksite and are dependent on their personal vehicle for making work related trips three or more days per week. The origin and destination data shows there are opportunities for matching carpool members. However the comments show that psychological barriers to carpool formation prevent respondents from recognizing that they live or work near anyone with whom they can carpool. Policies to stimulate mode shift from SOV will have to address both the real and the psychological barriers to HOV use.

CONSTRAINTS TO HOV USE

One of the goals of this part of the study was to determine the differences between people who actually rideshare and SOV commuters who would prefer to rideshare. The cognitive and affective preference analyses address this issue. A description of these analysis methods is provided in the methodology section. The analyses were undertaken to identify those SOV commuters who think carpooling or riding the bus is more effective than driving alone. Once these commuters are identified, then an examination of their constraints to HOV use can be undertaken.

Tables 23 and 24 summarize the findings of both the cognitive and affective preference analyses. The tables cross-tabulate actual mode use with the respondents' preference for SOVs, carpools, and buses as a means of commuting to and from work.

Table 23. Cognitive Preference Compared with Actual Mode Use

	SOV	POOL	BUS
Cognitively Prefer SOV	n=255 74%	n= 19 32%	n = 7 23%
Cognitively Prefer Carpool	n=52 15%	n = 31 53%	n = 7 23%
Cognitively Prefer Bus	n = 37 11%	n = 9 15%	n = 17 54%

Table 24. Affective Preference Compared with Actual Mode Choice

	SOV	POOL	BUS
Affectively Prefer SOV	n = 336 62%	n = 20 24%	n = 2 5%
Affectively Prefer Carpool	n=123 23%	n = 43 51%	n = 3 7%
Affectively Prefer Bus	n = 80 15%	n = 22 25%	n = 38 88%

These tables show that, as might be expected, SOV commuters tend to prefer the SOV mode. However, a substantial number of SOV commuters indicate a preference for carpooling or bus riding. Twenty-six per cent of the SOV commuters express a **cognitive** preference for other modes and 38 per cent express an **affective** preference for other modes.

Other studies have shown that 40 per cent of the SOV commuters would shift out of their personal vehicle if the circumstances and incentives for HOV use were right.[32] Therefore, further analysis was conducted on the SOV respondents who rated carpooling and riding the bus higher than driving alone in order to determine what barriers exist to these people's use of HOVs for commute purposes.

An analysis of the origin and destination patterns by mode preference did not reveal many differences between the "Actual Pool" and "Want to Pool" groups. However, the "Want to Bus" group generally exhibits a dispersed suburban work pattern that is very unlike the downtown Seattle work destinations reported by the "Actual Bus" group. Thus, it would appear from the origin and destination data that the "Actual Bus" group is using the bus for commute trips because it is convenient and serves their work destination. The "Want to Bus" group, however, does not work in areas that typically have convenient transit service. If it existed, they would probably use it.

The fact that origin and destination patterns of the "Actual Pool" and "Want to Pool" groups are similar suggests that many opportunities exist for matching carpool members. However, because of psychological ("I don't live near any one to carpool with") and actual barriers, the "Want to Pool" group has not acted upon their preference for carpooling.

Constraints to Carpooling

A significant difference in the average number of children per household was observed between the "Actual Pool" and the "Want to Pool" groups. The "Want to Pool" group had a

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32 Berman, Wayne, Presentation Notes, Effective Demand Management Actions, 1991 and Commuter Transportation Services, Commuter Computer, The State of the Commute: Research Findings from the 1989 Commuter Survey, Prepared for the California Department of Transportation, Los Angeles, CA, 1990.

higher average number of children than the "Actual Pool" group. The fact that the "Want to Pool" group had more children may mean that they are less able to participate in a carpool because of the need to drop-off and pick-up a child from daycare or to be available for extra-curricular activities for older children.

Analysis shows that the "Actual Pool" group has a much longer commute time than the "Want to Pool" group. Short commute distances may be a factor that keeps "Want to Pool" people from acting upon their preference for carpooling. As long as other incentives for carpooling are minimal, the formation time for short carpool commutes will be a barrier to would-be carpoolers. However, the longer commute times for "Actual Pool" people may simply be due to the extra time for carpool formation.

In conclusion, both the "Actual Pool" and "Want to Pool" groups were young, well-educated, and employed in white collar occupations. The home-to-work travel patterns show that the majority of these respondents live and work in areas along the I-405 corridor, specifically between and within the cities of Kirkland, Bellevue and Renton. Since the travel patterns of both groups are similar, psychological barriers to carpool use may be important for the "Want to Pool" respondents. Psychological barriers to carpool use are indicated by the comments the "Want to Pool" group gives for not carpooling. The most frequent reasons were:

- "nobody lives or works near where I do" (28 percent)
- "I need my car for work" (25 percent)
- "I do not know anyone to carpool with" (18 percent)
- "driving alone is convenient" (17 percent)
- "I have odd hours or changing schedule" (8 percent)

Constraints to Bus Use

The "Want to Bus" group had a higher average number of household workers than the "Actual Bus" group. A possible reason that the "Want to Bus" group has not been able to act upon their affective preference for taking the bus, could be the difficulty or inability to

coordinate family schedules. The "Actual Bus" group may be able to more easily take the bus because there are fewer people in the household and thus fewer schedules to coordinate.

The "Want to Bus" group reported nearly 2.5 vehicles per household compared with 2.0 per "Actual Bus" household. This finding is consistent with the literature review which showed that access to a personal vehicle for commute purposes encourages SOV use. While policies to directly limit vehicle ownership would be difficult to implement, these findings illustrate the importance of taking auto ownership into account.

Unlike the "Actual Bus" respondents, the majority of the "Want to Bus" group were responsible for both dropping off and picking up a child from daycare. These daycare responsibilities mean that the "Want to Bus" respondents have less flexibility in their daily schedules and will find it difficult to use infrequent bus service. Another major limitation was reported by the "Want to Bus" group. They reported an earlier daycare closing time than the "Actual Bus" group. While the majority of "Want to Bus" respondents do not use daycare, the people who do are faced with a tremendous constraint on their schedule with the need to pick up a child from daycare, typically by six o'clock pm.

On average, the "Actual Bus" group starts work earlier than the "Want to Bus" group. The "Want to Bus" group, on the average, starts work at 9:10 am. This means that their ability to use a bus may be constrained by a lack of bus service which would get them to work on time. In addition, many of these respondents can avoid the morning peak hour traffic and thus reduce this disincentive for commuting alone.

The "Actual Bus" group reported a much higher number of respondents whose employers charge for parking at the worksite. Only 10.8 per cent of the "Want to Bus" group pays to park at their worksite, in comparison with 25 per cent of the "Actual Bus" respondents. This finding is consistent with the literature review which shows that when SOV drivers perceive parking to be free and do not personally pay for parking, they will likely drive alone.

Access to a company vehicle for work related trips was very different for the two groups. Seventy five per cent of the "Actual Bus" group reported having a company vehicle

available for work related errands, whereas 57.2 per cent of the "Want to Bus" did not have access to a company vehicle. The fact that companies do not have vehicles available for employee use means that many employees may be unable to ride the bus because they need their personal vehicle to make work related trips.

In conclusion, both the "Actual Bus" and the "Want to Bus" groups are young, well educated, and employed in white collar occupations. The home-to-work travel patterns indicate that the "Actual Bus" respondents take the bus because service is available and generally convenient. Furthermore, the majority of these respondents use the bus for travel to work in downtown Seattle (67 per cent) and downtown Bellevue (25 per cent). The "Want to Bus" group does not tend to work in downtown Seattle. They tend to work within the I-405 corridor and commute between and within the cities of Kirkland, Bellevue and Renton. Current bus service for suburb-to-suburb commutes is not as rapid or as plentiful as bus service to downtown Seattle. Therefore, the "Want to Bus" respondents may not be able to use a bus because there is no service between their suburban home and suburban work locations. While the "Want to Bus" group rates the bus as more effective, in general, than an SOV for commute purposes, current transit service is not effective enough to cause them to shift out of their SOV. In order to attract commuters who are not transit dependent, transit service will have to provide time savings and attractive scheduling that rivals SOV use.

METRO TDM/TSM EVALUATION STUDY

Transportation demand management has received increasing attention in recent years as an important component in approaches to improve the transportation system. Recent legislation has encouraged and, in some cases, required employers and jurisdictions to implement TDM programs. The attention to TDM measures is not expected to diminish in the coming years. Employers and local jurisdictions are very interested in understanding and forecasting the impacts of various TDM options.

Another approach to transportation system improvement is the use of HOV facilities. An extensive system of HOV facilities exists in the I-5 corridor between Seattle and Everett. Additions are being implemented or are planned to alleviate the increasing congestion on or near this already heavily utilized freeway. The design of these HOV facilities and the policies governing them depends on the anticipated use of the system. Forecasts provide the basis for planning, project evaluation, and obtaining public support for future improvements to the system.

Despite the importance of accurate mode forecasts, current mode choice methodology is insufficiently responsive to factors that influence shifts to ridesharing modes, particularly TDM policy factors that are important in encouraging commuters to shift from SOVs. Planners and policy analysts need to understand these factors to improve mode shift predictions and evaluate policy changes that can increase vehicle occupancy. The objective of this part of the study is to identify these mode choice factors and use them to improve the ability to analyze HOV policies for the north I-5 corridor.

TDM MEASURES

TDM measures, which include just about anything that encourages the use of the HOV system, are critical to the efficient functioning of the transportation system. Throughout the U.S. there are many examples of major successes with TDM measures. The U.S. Department of

Transportation sponsored a study of examples of several successful programs.[33] Pacific Northwest Bell in Bellevue, Washington, reduced solo driving from 87 percent to 19 percent of the work force through a combination of TDM measures. Similarly, Commuter Computer in Los Angeles reduced its SOV (single occupancy vehicle) share from 42 percent to 8 percent by eliminating free parking. Another survey of TDM programs,[34] analyzed the effectiveness of some TDM programs implemented around the U.S. In that study, the programs reduced the number of vehicle trips by an average of over 20 percent. This level of trip reduction can have a significant effect on congestion in a metropolitan area, if it could be achieved by all employers. Studies such as Giuliano's [35] question how widespread TDM successes will be.

In the I-5 North area, TDM measures are provided largely by public transit agencies, WSDOT, and to a lesser extent, by employers. The measures include rideматching and ridesharing services; marketing efforts; the HERO program, which allows motorists to report HOV lane violators; traffic information; bus and vanpool subsidies; and city ordinances and business policies concerning parking control.

TDM Programs Recommended by Metro

Metro, in coordination with PSCOG, has published recommendations for local jurisdictions to establish ordinances that would require employers to establish transportation demand management (TDM) programs. The following is a compilation of their recommendations:[36]

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[33] Comsis Corporation, Evaluation of Travel Demand Management (TDM) Measures to Relieve Congestion, Prepared for the Federal Highway Administration, Report Number FHWA-SA-90-005, February 1990.

[34] Kuzmyak, Richard J., and Schreffler, Eric N., "Effectiveness of Existing TDM Programs," Research Paper, Federal Highway Administration, 1989.

[35] Giuliano, Genevieve, "Transportation Demand Management: Promise or Panacea?' APA Journal, Vol. 58, No. 3, Summer, 1992, pp 327-335.

[36] Municipality of Metropolitan Seattle, Transportation Demand Management Policy Guidelines (1989)

Small projects (25-49 employees)

Appointed transportation coordinator
Pedestrian and bicycle amenities
Transit/rideshare information
Preferential HOV parking
Alternative work hours
Surveys and monitoring

Medium size projects (50-149 employees), add:

Financial subsidy ($15 per month minimum)
Commuter information center

Large Projects (150+ employees), add:

Parking fee program (discount for HOVs)
HOV road improvements
Van/shuttle bus to park and ride lots or transit
Land for transit facility
Guaranteed ride home program

Existing Employer-Based Services

In the Metro employer-based survey of 24 employers in the north I-5 corridor, only three had any programs to promote the use of transit and ride-sharing.[37] Some employers did have some aspects of a TDM program in place. These ranged from Microsoft, with a 5 percent full-time equivalent transportation coordinator, bus pass subsidy, ridematch services, rideshare information, and bike facilities, to smaller businesses with none of the TDM services. Boeing, by far the largest employer surveyed, had a 20 percent rideshare goal, vanpools, rideshare information, a transportation fair, and bicycle facilities. All employers offered free parking that essentially covered the demand. Three businesses responded that some employees parked off-site, but none felt their employees had to pay for the parking.

These results contrast with the Seattle CBD and the University of Washington district, which have significant parking costs and parking congestion. Additionally, the University of

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37 McCutcheon, Laurie, *Marketing Commuter Programs: Surveys of North King County and Urban Snohomish County Employees*, Municipality of Metropolitan Seattle (METRO), December, 1989.

Washington has a strong TDM program, which consists of a majority of the TDM measures recommended by Metro.

SELECTED CHARACTERISTICS OF MODE CHOICE

The initial objective in this part of the study was to select characteristics of mode choice that were available in the data sets and consistent with current mode choice literature to be used in the analysis. They were grouped into four types: (1) trip characteristics, (2) "home-end" characteristics, (3) employment site characteristics, and (4) psychological aspects of mode choice.

Trip Characteristics

Commute time and distance. The evidence that travel time is the most important aspect in mode choice has been generally supported by research. McGillivray[38] found that travel time is always more important than travel cost in affecting mode choice. Paine, Nash, Hille and Brunner[39] found that the largest difference in satisfaction between auto and bus is related to travel time. Horowitz and Sheth[40] found that time loss is the most important deterrent to people's choice of carpooling as a travel mode.

Obviously, commute time is related to the distance of the commute. However, it is not directly correlated, because congested roads may make certain commutes longer than other commutes, despite a shorter distance. Different modes also have different commute times and distances for the same household because of HOV lanes, mode accessibility, or logistics, as in the case of gathering individuals for a car or vanpool.

Researchers have found that perceived travel time (and likely distance) is more critical than actual travel time and have urged the use of perceived time values in modeling mode choice.

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[38] McGillivray, Robert G., "Demand and Choice Models of Modal Split," *Journal of Transport Economics and Policy*, 1970, Vol. 4, 192-207.

[39] Paine, F. T.; Nash, A. N.; Hille, S. J. and Brunner, G. A., "Consumer Attitudes Toward Auto versus Public Transport Alternatives," *Journal of Applied Psychology*, 1969, Vol. 53, 472-480.

[40] Horowitz and Sheth, op. cit.

Spear[41] discovered that perceived time better predicts mode choice than does actual time. Dobson and Tischer[42] compared three different models for mode choice by using (1) actual times and costs, (2) perceived times and costs, and (3) demographic variables. The second model performed better than either of the other two or a combination of the other two.

Travel costs. Researchers have had mixed results in determining the importance of travel costs in mode choice. Henley, Levin, Louviere, and Meyer[43] found that car users are generally inaccurate in estimating the full cost of driving a car to and from work, and tend to underestimate the fixed-plus-operating costs of using a car in comparison to taking the bus. Dobson and Tischer[44] demonstrated that perceived costs work better than actual costs in predicting mode choice. As an example of this, Westin and Watson[45] found that 90 percent of the people in their survey included only gas and oil in their estimates of costs, despite the fact that costs of vehicle operation and ownership far exceed these two items.

The literature shows that parking costs are especially important in mode choice. Shoup[46] estimated that at least 20 percent of all those who park free and are SOV commuters would switch to a rideshare mode if they had to pay for parking. He showed that for most commuters, free parking is a larger financial incentive than free gasoline. He further estimated that nationwide, 93 percent of all commuters park free at work.[47] Feeney[48] also expressed the

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41 Spear, Bruce D., "Generalized Attribute Variable for Models of Mode Choice Behavior," *Transportation Research Record No. 592*, 1976, 6-11.

42 Dobson and Tischer, op. cit.

43 Henley, Davis H.; Levin, Irwin P.; Louviere, Jordan J. and Meyer, Robert J., "Changes in perceived travel cost and time for the work trip during a period of increasing gasoline cost," Transportation, 1981, Vol. 10, 23-34.

44 Dobson and Tischer, op. cit.

45 Westin and Watson (1975)

46 Shoup, Donald C., "Cashing Out Free Parking," *Transportation Quarterly*, Vol. 36, No. 3, July, 1982, 351-364.

47 Shoup, Donald C., "Free Parking as a Transportation Problem," U.S. Department of Transportation, 1980.

48 Feeney, Bernard P., "A Review of the Impact of Parking Policy Measures on Travel Demand", *Transportation Planning and Technology*, Vol. 13, 1989, 229-244.

view that parking policy measures (which include parking costs and parking taxes) are a relatively important influence on modal choice.

The Gilmore Research Group,[49] which researched one of the sets of data used in this study, found that of the urban Snohomish County commuters interviewed, 36 percent of the bus commuters parked free when they drove to work, whereas 92 percent of the SOV commuters paid nothing to park. Bus commuters paid an average of $5.05 per day when they drove, while SOV commuters averaged $2.50 per day. In comparison, for north King County, they found that only 10 percent of bus commuters parked free when they drove to work, whereas 84 percent of SOV commuters paid nothing to park. Bus commuters paid an average of $5.18 per day when they drove, while SOV commuters averaged $2.43 per day.

Home-End Characteristics

These attributes are related to the characteristics of the household and its members. The attributes used for the research included a variety of demographic factors, such as size of household, number of workers per household, ages of household members, income, educational levels, and the like.

However, there is some evidence that individual demographic factors are not important in themselves. For instance, in a report on the psychological aspects of mode choice,[50] the following observation was made:

Research on the influence of sociodemographic characteristics of individuals and households on mode choice has had mixed results. However, one theme runs through the literature. The most important characteristic is automobile accessibility in a household. All other demographic variables appear to operate through this one. To the extent that those factors

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[49] Gilmore Research Group, *1989 North King County & Urban Snohomish County Transportation Market Segmentation Study*, Volume I and II, Municipality of Metropolitan Seattle (METRO), August, 1989.

[50] Ulberg, Cy, "Psychological Aspects of Mode Choice," Research Project GC8286, Task 20, Prepared for the Washington State Transportation Commission in cooperation with the U.S. Department of Transportation, 1989.

influence auto ownership, the number of auto users in the household and the household's decision rules for use of the auto(s), they affect mode choice.

If a family has two or more workers in the household and only one car, obviously some of the workers will have to find modes other than an SOV. Similarly, if a household has one auto and one or more young children with day care needs, the mode choices of individuals will be severely constrained.

The type of household dwelling owned by a commuter may have an important relationship to mode choice. Although this factor has not been explored in previous research, it was examined in this study to test the hypothesis that home ownership has an influence on mode choice. This hypothesis is based on the assumption that renters can more easily relocate near a new job location and reduce commute time than home owners can purchase housing near a new job.

Employment Site Characteristics

Characteristics of mode choice associated with the commuter's employment site that were investigated included the following:

- errand need (both personal and work-related),
- schedule flexibility,
- arrangements for emergencies, and
- other employer policies to encourage HOV use.

Errand need. McCutcheon[51] found that north King County and urban Snohomish County commuters who rarely or never need their car at work during the day or for errands on the way to and from work are less likely to commute by SOV. Perceived errand need was therefore included in the initial analysis for this study.

Schedule flexibility. Another characteristic of commuters that appeared to be correlated with mode choice was the degree of flexibility one had in one's work schedule. McCutcheon found that

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[51] McCutcheon, op. cit.

. . . those with variable hours are the most likely to use travel by SOV. When hours are fixed and regular, by either the employees or the employer, the commuter is more likely to use carpools, vanpools, or ride the bus.[52]

Arrangements for emergencies. One factor that has been postulated to discourage SOV commuters from using HOV commute methods is the inability to get home in case of an emergency. McCutcheon found emergency backup cars to be the most popular new service desired by commuters. Of the people she interviewed, 40 percent answered that they definitely or probably would use this service. Although popular, very few employers provide such a service. None of the 23 employment sites used in this study had such a service.

Other employer policies to encourage HOV use. Employers in the study area have begun to employ a variety of TDM methods designed to encourage employees to shift from SOV to HOV modes to commute to work. They include parking policies such as charging for parking or providing preferred parking for carpools and vanpools. Subsidies for bus passes or vanpool use are available at many companies. Some larger companies provide special ridematching services for their employees.

Psychological Characteristics

Another important category of mode choice characteristics is based on the psychological aspects of decision-making and mode choice. These psychological aspects are related to an individual's decision-making style and belief system.

The way in which an individual approaches a particular decision-making task is more complex than a simple weighing of the pros and cons of each mode. A large body of research in both transportation and psychology supports this conclusion; details may be found in a recent literature review.[53] Intangible factors such as value systems can have a strong influence on the decision-making process. For instance, Hogarth[54] stated that the decision-making task

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52 McCutcheon, op. cit., p. 12

53 Ulberg, op. cit.

54 Hogarth, Robin, *Judgment and Choice: the Psychology of Decision*, New York: John Wiley and Sons, 1980.

environment is affected by memory capacity and each individual's schema or belief system, among other factors. Tischer and Phillips[55] found a strong, mutually causative relationship between the belief structure and behavior for both SOV and bus users. The literature suggests that commuters probably make decisions on the basis of a limited number of factors, which are not always logical, that confirm their existing behavior and reflect their belief system.

Unfortunately, measuring these psychological aspects of mode choice in a survey can be a difficult and complex endeavor. However, a few variables included in the data used in this study relate to these psychological factors. They include questions about discomfort around strangers and discomfort when learning something new. These are include in the analysis reported below.

SOURCES OF DATA

Two major sets of data were analyzed in this study, both collected by Metro in cooperation with Community Transit. In one study, some 9,324 employees of 23 cooperating businesses were surveyed in north King and urban Snohomish counties. This study is called the "employer-based survey" in this report.

The second data set is called the "Transportation Market Segmentation Study of North King and Urban Snohomish County." This was a 1989 telephone survey of a random sample of 3,586 residents in the study area.

Employer-Based Survey

The employer-based survey targeted companies with 50 or more employees in north King County and urban Snohomish County. From an initial list of 38 companies, 23 cooperated in the study. The response rate by company varied from 0 percent to 89 percent, with a mean of 30 percent. The total number of respondents was 9,534.

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[55] Tischer, Mary Lynn and Phillips, Robert V., "The relationship between transportation perceptions and behaviors over time," Transportation, 1979, Vol. 8, 21-33.

McCutcheon[56] identified bias among the respondents toward white collar employees, who were 69 percent of the total sample. She explained that some companies were operating with extensive overtime and would not allow employees to fill out the questionnaire during work hours, thus likely reducing the response rate for those companies. Also, the questionnaire required a literacy level that may have deterred foreign-born workers or those with educational deficits.

Another factor that may indicate a bias toward white collar workers was that the median household income of respondents was $42,248. In contrast, PSCOG estimated that the 1987 median household income for King County at $28,930 and for Snohomish County at $27,880.

Additionally, McCutcheon mentioned great variability in the support of management toward administering the questionnaire. Some contact persons had little or no time to devote to the survey.

Telephone Survey

This survey was conducted for Metro by Gilmore Research Group. It consisted of 3,586 telephone interviews conducted in 1989 among a random sample of north King County and urban Snohomish County residents. Of the 3,586 respondents, 3,063 were urban Snohomish County residents and 523 were from north King County. On the average, the interview took 27 minutes to complete. Telephone numbers were selected through random-digit dialing.

The sample was stratified by mode to provide enough interviews to ensure statistical reliability for each mode subgroup. The sample contained 2,949 commuters. Data in Table 25 were derived using variables measuring typical commute mode and the number of people in the car, to determine typical modes or mode combinations.

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56 McCutcheon, op. cit.

Table 25. Typical Mode or Mode Combinations Metro Telephone Survey

Typical Mode	Frequency	Percent	Valid Percent
SOV	1829	51.0	61.9
BUS	209	5.8	7.1
CARPOOL	587	16.4	19.9
VANPOOL	26	0.7	0.9
OTHER	59	1.6	2.0
SOV/BUS	129	3.5	4.3
SOV/VANPOOL	4	0.1	0.1
SOV/OTHER	89	2.5	3.0
BUS/VANPOOL	1	0.0	0.0
BUS/OTHER	18	0.5	0.6
TOTAL COMMUTERS	2949		
REFUSED	5	0.1	0.2
NON-COMMUTER	632	17.6	----
TOTAL	3586	100.0	100.0

SOV commuters made up 61.9 percent of the commuters. These were respondents who answered that they typically used the "car/drive" method of commuting with one person in the car. Those with greater than one person in the car were considered a carpool. The "OTHER" category included those who traveled by bicycle, motorcycle, foot, or any other miscellaneous mode.

The original mode categories were recoded for the cluster analysis of this study and simplified into four groups:

- SOV;
- BUS, composed of BUS, SOV/BUS, BUS/VANPOOL and BUS/OTHER;
- POOL, composed of CARPOOL, VANPOOL, and SOV/VANPOOL; and
- OTHER, composed of OTHER and OTHER/SOV.

ANALYSIS AND MODEL DEVELOPMENT

The primary objective of this part of the study was to improve the ability to analyze the impact of TDM policies and HOV facilities. Ideally, policy analysts would like to have a **predictive model** of mode choice that can be used to quantitatively forecast the transportation impacts of various alternatives. Most current predictive mode choice models are based on discrete behavioral choice models that use the multinomial logit formulation. One of the goals of this study was to validate a modeling approach developed by the COMSIS Corporation by using similar data from elsewhere in the region.

Other modeling approaches were also investigated. The primary reason for looking at other methods to understand the data is that discrete behavioral choice models based on the logit function have little direct relationship to actual cognitive decision-making processes.[57] Even if a predictive model of mode choice behavior is successful in forecasting mode choice in one situation, it may not be valid in a situation that is different from the one with which it was calibrated. It is important that our understanding of the decision-making process is based on multiple modeling methods, so that we can have some confidence in predictions of mode choice in novel situations. Therefore, a **descriptive model** of mode choice can be very valuable in assessing the transportation implications of alternative TDM polices or HOV facilities.

Multinomial Logit Model

The commute decision is a "discrete" choice. In other words, a choice to use a mode is not made along a continuum but among a finite number of distinct alternatives. A commonly used discrete choice model is called a multinomial (meaning many choices) logit formulation. For each decision-maker, the logit formulation produces a set of probabilities. The mode choice with the highest probability is that which has the highest "attractiveness" in relation to the

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[57] Ulberg, op. cit. for a further discussion of this assertion.

combined attractiveness of all the other mode options. This modeling approach was investigated for this project.

COMSIS model. The COMSIS Corporation, located in Maryland, contracted with Metro to develop a model that would accurately reflect the effects of HOV incentives and other workplace conditions on commuter mode choice. COMSIS used employer-based data, similar to that collected for this study, but from employers in the Bellevue CBD and I-90 corridor.

The basic logit structure assumes that an improvement in the attractiveness of one alternative is equally likely to draw commuters from each of the other alternatives. However, COMSIS speculated that modes were probably "grouped." That means, for instance, that some commuters were more likely to shift among transit modes, and others among carpooling modes. A nested, rather than the basic logit model represents this tendency. For this reason, COMSIS included the nested model among those to be tested in the analysis of the Seattle CBD commuter data.[58]

The COMSIS model included the physical characteristics of the commute faced by each commuter who lived in a particular area for a particular employment site. These characteristics included variables such as calculated commute times (including in-vehicle and out-vehicle time) for each mode, commute costs, and estimated parking costs. Employment site characteristics included how working hours were set, the worksite's employment density, and employer-based incentives. Commuter characteristics included in the model were number of workers per household, occupation, income, and gender.

The results of the COMSIS model calibration are presented in detail elsewhere.[59] A few highlights of the findings are as follows:

- carpoolers tended to come from households with the largest number of workers and the fewest vehicles per worker;

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[58] COMSIS Corporation, "Technical Memorandum 1: Specification of Requirements, Approach, Data Needs, And Application Software," memorandum prepared for the Municipality of Metropolitan Seattle, July, 1989.

[59] COMSIS Corporation, "Technical Memorandum 2: Calibration Results, memorandum prepared for the Municipality of Metropolitan Seattle, July, 1990.

- males tended to use transit more than females;
- small flexibility in work hours promoted carpooling, while large flexibility discouraged it;
- free parking was a strong disincentive to transit use and carpooling; and
- bus pass discounts, transportation coordinators and reserved parking for carpools and vanpools were strong incentives for ridesharing.

COMSIS found that nested logit models did not perform significantly better than a basic logit model.

Logit modeling for this project. Two of the objectives of this part of the study were (1) to determine whether a logit model could be calibrated on the data from the employer-based survey in north King and south Snohomish Counties and (2) to compare the results with the COMSIS work that was based on responses from workers in the Bellevue CBD and I-90 corridor.

The responses from 9,534 employees in the corridor were converted from a SAS file to an ASCII file. This data set was unmanageably large, so the number of variables was reduced considerably to concentrate on factors thought to be related to mode choice. At the same time, some of the variables were recoded or reduced to save space. Additionally, skims from 1990 model runs were obtained from the Puget Sound Council of Governments, and data concerning travel times and costs were added appropriately to each record. The result was a manageable data file containing the following variables:

Trip Characteristics

- **mode choice** - mode choices were simplified into six categories, corresponding to the work conducted by COMSIS (SOV, HOV2, HOV3, HOV4+, WALK/BUS and DRIVE/BUS)
- **SOV travel time** - the average travel time between home and work during the peak hour
- **HOV travel time savings** - the difference between SOV and carpool travel time, indicating savings due to use of the HOV lanes on I-5 and SR99

- **walk access to bus** - time to walk from home to the nearest bus stop
- **drive access to bus** - time to drive from home to the nearest bus stop

Individual Characteristics

- **gender** - an indicator variable for male
- **age** - converted to two indicator variables, one for over 45 and one for under 25
- **occupation** - eleven occupational categories were converted to one indicator variable with a value of one for professionals

Household Characteristics

- **income** - converted to two indicator variables, one for household income over $50,000 per year and one for household income under $30,000 per year
- **number of workers** - the total number of employed household members
- **number of vehicles** - the total number of vehicles in the household
- **car availability** - an indicator variable, with one meaning a vehicle was available to the respondent for work trips on a regular basis
- **number of household members over 16 years of age**
- **need car to or from work** - an indicator variable with a value of one if the respondent needed to use a car for errands before or after work at least three times a week

Employer Site Characteristics

- **hours fixed by employer** - an indicator variable with a value of one if the employee had no flexibility in working hours
- **flexible hours** - an indicator variable with a value of one if the employer could choose which hours to work, but maintained a regular schedule
- **variable hours** - an indicator variable with a value of one if work hours varied from day to day
- **need car at work** - an indicator variable with a value of one if the respondent needed to use a car during work at least three times a week
- **bus pass discount** - an indicator variable with a value of one if the employee indicated awareness of a bus pass discount at his/her place of work

- **free parking** - an indicator variable with a value of one if the employee indicated awareness of free parking at his/her place of work

- **carpool discount** - an indicator variable with a value of one if the employee indicated awareness of a carpool discount at his/her place of work

- **reserved carpool parking area** - an indicator variable with a value of one if the employee indicated awareness of a reserved carpool parking area at his/her place of work

- **vanpool fare discount** - an indicator variable with a value of one if the employee indicated awareness of a vanpool fare discount at his/her place of work

- **guaranteed ride home program** - an indicator variable with a value of one if the employee indicated awareness of a guaranteed ride home program at his/her place of work

- **information center** - an indicator variable with a value of one if the employee indicated awareness of an information center at his/her place of work

- **transportation coordinator** - an indicator variable with a value of one if the employee indicated awareness of a transportation coordinator at his/her place of work

Note that variables concerning employer-based policies appearing at the end of the list of employer site characteristics represented awareness of the programs. It was quite evident that some employees were unaware of programs offered by employers while others indicated that employers offered programs that did not exist.

Calibration of logit modeling. Tables 26 to 28 show the results from the logit analysis. Each analysis used the same basic approach. All variables were included in the first specification of the model. Variables that did not contribute significantly ($p < .1$) to the explanation were eliminated one by one until only statistically significant variables remained. A cross-correlation matrix for all variables was created. If a variable remaining in the model correlated greater than 0.2 with some other variable, both were introduced independently into the model. The variable that gave the best results was retained. The tables show only the final results.

Table 26 shows the results when the three major mode choices were the alternatives. To see whether a logit model could distinguish among different sizes of carpools, a second analysis was run of carpools only (POOL category from the first analysis). Table 27 shows the results from that analysis. Because the characteristics of HOV2 commuters appeared to be more similar to SOV commuters than HOV3 or HOV4+ commuters, a separate analysis to distinguish SOV and HOV2 commuters was conducted. The results are shown in Table 28. An interpretation of the results of the three analyses follows.

Three major mode choices. Two aspects of the trip influenced mode choice. People were more likely to take the bus or carpool than drive alone if their commute was long. This is similar to findings from most other studies. Secondly, HOV travel time savings was positively related to the likelihood of carpooling. People showed a significant tendency to choose carpooling over driving alone if HOV lanes were between their home and place of work. However, there was a puzzling negative relationship between the existence of HOV lanes and the tendency to take the bus. This may have been due to the characteristics of bus service in the north King and south Snohomish county area. Buses that use the HOV lanes on I-5 are primarily long distance express runs, and do not serve destinations in that area very well. In fact, the people most likely to use the bus for local trips probably travel on north-south arterials, not on I-5. Carpooling becomes the most attractive ridesharing alternative.

In this group of respondents, males were more likely than females to carpool. Workers under the age of 25 and over 45 were more likely to carpool than workers between those two ages. For the younger workers, this tendency was probably due to less access to an automobile. For older workers, having a working spouse may have been the explanation. Both of these explanations are supported by the data.

Among the findings for household characteristics there was one surprise. People from households with high income were more likely to carpool than those from households with low income. This unusual finding was difficult to explain. However, it may have had to do with the fact that two worker households have higher household incomes and more opportunity to share

Table 26. Predictors of Mode Choice from Logit Analysis Three Major Mode Choices

	SOV	POOL	BUS
Trip characteristics:			
SOV travel time	- - -	+++	+
HOV travel time saving	- - -	+++	- - -
Individual characteristics:			
Gender	- -	+++	
Age < 25	- -	++	
Age > 45	- -	+++	
Household characteristics:			
# of workers	- - -	+++	
Income > $50K	- - -	+++	
Need car to/from work	+++	- - -	
Car available	+++	- - -	- - -
Employer site characteristics:			
Variable hours	++	- -	
Free parking	+++	- - -	- - -
Information center	++	- -	
Vanpool fare discount		- -	++
Need car at work	+++	- - -	

Positively related:

+++ p<.01
++ p<.05
+ p<.1

Negatively related:

- p<.1
- - p<.05
- - - p<.01

Table 27. Predictors of Mode Choice from Logit Analysis Choice among Carpool Modes

	HOV2	HOV3	HOV4+
Trip characteristics:			
SOV travel time	- - -	+++	+++
Individual characteristics:			
Age < 25		++	
Employer site characteristics:			
Vanpool fare discount		++	
Need car at work	+++		-

Positively related:

+++	p<.01
++	p<.05
+	p<.1

Negatively related:

-	p<.1
- -	p<.05
- - -	p<.01

Table 28. Predictors of Mode Choice from Logit Analysis Choice of SOV over HOV2

	SOV
Trip characteristics:	
HOV cost advantage	- - -
Household characteristics:	
# of workers	- - -
Income > $50K	- - -
Need car to/from work	+++
Car available	+++
Employer site characteristics:	
Variable hours	+++
Free parking	+++
Information center	+++
Need car at work	+++

Positively related:

+++	p<.01
++	p<.05
+	p<.1

Negatively related:

-	p<.1
- -	p<.05
- - -	p<.01

rides. This was supported by the fact that a larger number of workers per household related positively to carpooling. Since most carpools are household based, the availability of a convenient carpool partner is a strong influence to share a ride. People who need a car for purposes to and from work are more likely to drive alone than carpool or ride transit. Access to a vehicle has an obvious positive relationship with driving alone. It could also be that higher income people tend to work in higher density locations where there are more incentives and opportunities for forming carpools. Destinations in this data set are at the ZIPcode level which makes exploration of this hypothesis difficult.

Needing a car at work also influenced people to drive alone at the expense of carpooling, as did variable hours. Other employer-based policies had relationships with mode choice that were difficult to explain. Three significant employer-based policies influenced mode choice in this analysis: (1) free parking, (2) availability of an information center and (3) provision of a vanpool fare discount. Free parking appeared to encourage driving alone. Availability of an information center also appeared to encourage driving alone. Provision of a vanpool fare discount apparently discouraged pooling (including vanpooling) and encouraged bus riding, according to this analysis.

The relationship between free parking and driving alone was not surprising. However, it must be recalled that the questionnaire asked about awareness of these employer-based polices and **no employer in the sample required employees to pay for parking**. Virtually all the employees in the sample parked in parking lots owned by the employer.

What did it mean that only 30 percent of the respondents replied that they were aware that their employer provided free parking and that those 30 percent were also more likely to drive alone than the other 70 percent? The 70 percent of the respondents who did not indicate that their employer provided free parking may not have perceived parking in an employer-owned lot as "free parking." They may have thought that the employer provided it free only when there was a charge and the employer paid it. The fact that people who were aware that they had free parking were more likely to drive alone to work may have had to do with their tendency to view

the free parking as a part of their benefit package, and their desire to take advantage of that benefit. This analysis cannot be used to infer a causal relationship between the **actual** provision of free parking and mode choice, but it does highlight the sensitivity of people's perception of provision of free parking to their travel decisions.

Choice among carpool modes. The fact that the number of workers in the household and household income were both positively related to the tendency to carpool points out the importance of home-based carpools. The fact that home-based carpools were more likely to be composed of two persons and larger carpools were more likely to include members from the workplace leads to the hypothesis that people in two-person carpools differ from larger carpools and vanpools. This hypothesis was tested using a logit analysis of poolers only, distinguishing among different sizes of carpools.

Table 27 shows the results of that analysis. Very few variables entered into the model significantly. Because 27 variables were used in the initial analysis, the fact that only four were significantly related to choice among different sizes of carpools leads to some question about their importance. It is possible that the significant relationships were the result of chance.

The influence of travel time was not unusual. The longer the trip, the more reasonable it is to spend the time necessary to form carpools of three or more people. Hence, two-person carpools tend to be used by people with short trips and larger carpools and vanpools are used by people with longer trips. If someone needs a car at work, it is better to be in small carpool than in a large one, because the likelihood of being able to use the car is greater. The positive relationship between needing a car at work and being in a two-person carpool supported this contention. However, the fact that people under 25 were more likely to be in three-person carpools and that awareness of vanpool fare discounts was also related to participation in a three-person carpool were both difficult to explain, other than that the relationships occurred by chance.

Choice between driving alone and two-person carpool. The fact that carpools and vanpools with more than three people tended to include people who were not from the same

household makes it possible that two-person carpools are unique types of ridesharing arrangements. The findings in the previous section supported this contention but did not make a strong case for it. As a further test of this hypothesis, a logit model was used to distinguish between people who drove alone and those who commuted in two-person carpools. All other mode choices were left out of the analysis. Table 29 shows the results of this analysis.

The pattern of relationships in this analysis was very similar to that in Table 27, which contrasted choice among the three major commute modes. This was partly due to the fact that there were many more two-person carpools than larger ones, so the "POOL" category was dominated by that mode. On the other hand, it seems likely, from this analysis, that two-person carpools formed for many of the same reasons that larger carpools formed, with the exceptions that larger ones tended to travel further and provided less flexibility than smaller ones.

Comparison of results with COMSIS work. The analysis conducted for this work differed from the COMSIS analysis in some ways that may have affected the comparative results.

- The populations differed. While both study areas were primarily suburban, the COMSIS sample included companies from downtown Bellevue, which is rapidly losing suburban characteristics.
- The variables differed in the two studies. Different information was available in each of the studies.
- The analysis approach was slightly different in the two studies. The COMSIS analysis assessed trade-offs among all six modes at once. This analysis focused on specific comparisons. (A six-mode analysis was conducted for this study, but it revealed no insights that were not apparent in the results reported here.)

Many findings were similar in the two studies. However, there were some substantial differences.

- The number of vehicles per person was not related to mode choice in this study.
- In this study, higher income people were **more** likely to carpool, in contrast to the COMSIS analysis, in which they were less likely to carpool.
- Except for free parking, workplace incentives had less clear relationships with mode choice in this study than in the COMSIS study. Bus pass discounts and reserved parking did not enter significantly into any of the models. The lack of

clear relationships may have been due to the fact that they were less salient among the employers in this study's sample than in the COMSIS study's sample.

Exploration of Other Modeling Approaches

In addition to the multinomial logit modeling approach used with the employer-based data, other statistical procedures were explored with the telephone survey data to investigate the important factors in model choice. One approach explored the potential for reducing the number of variables needed to explain mode choice through factor analysis. This procedure examines variables for underlying commonalties and groups them into a relatively small number of factors that can provide insight into the basic structure behind the responses. For example, variables that describe the size of the household, the number of household members per worker, or the number of youths in a household may all be combined into one factor called "family size."

In addition, a second procedure used in this study, cluster analysis, is designed to combine respondents into groups that are "like-minded" and respond similarly to a given set of conditions. If one determines from a cluster analysis, for example, that what characterizes a group of commuters is that they (1) have a strong aversion to feeling out of control and (2) do not tend to ride the bus, one could conclude that these two factors are strongly related.

The initial strategy attempted for this analysis was to

1. select an initial set of the most important determinants of mode choice,
2. simplify the variable descriptions through factor analysis,
3. group individual commuters into clusters with common traits,
4. using analysis of variance (ANOVA), check for differences among the clusters for other variables (because the SPSS cluster analysis procedure can handle only a limited number of variables), and
5. repeat the cluster analysis when other important variables were identified through ANOVA.

Using this process, the research team could identify the variables in the data set that were most important for understanding mode choice. The analysis was performed iteratively until only the most important variables were included. As will be seen below, the second step

(employing factor analysis) did not contribute successfully to predicting mode choice, but it did provide a possible means for simplifying the variables used in an explanatory model.

Initial selection of primary independent variables. As discussed earlier, transportation researchers have identified a set of important factors that influence mode choice. To the extent that the available data measured these factors, they were used to provide a starting point for the factor and cluster analysis. For clarity, the variable name used for each variable is included in the narrative and used in the tables. It is placed in parentheses following the variable's description.

Trip characteristics. Perceived commute times were used both in bus commute (BUSTIME) and car commute times (COMTIME). Research has shown that perceived commute times are a stronger factor in mode choice than actual commute times. Because of the relative importance of parking cost to other travel costs in the mode choice process and the high correlation between travel time and other travel costs, the only travel cost included in the analysis was parking costs (PKG$MO).

Home-end characteristics. Car availability was measured by the ratio of cars per worker (CARSPWKR). Family characteristics were represented by household members per worker (HMEMPWKR) and youths per worker (YTHPWKR) ratios. The existence of a working spouse (WKGSPOUS) also was included. The type of dwelling of a household (HOMETYPE) was also an initial variable. It was recoded as an indicator variable for a single-family dwelling (SINGLFAM). Some of these variables, of course, were correlated; but each represented different aspects of household characteristics and was therefore included in the initial analysis.

Employment site characteristics. Unfortunately, little information on employer policies concerning commuting was available in the telephone survey data. However, errand need (ERRANDS), schedule flexibility (DLYSCHED), number of shopping and other personal trips (PRSWKLY), and arrangements for emergencies (BACKUPCR) are related to commuting

to the work site and were included. McCutcheon (1989) identified these as significant correlates of mode choice.

Psychological aspects. Decision-making styles were not directly measured in the data. However, some aspects of an individual's decision-making process were indirectly measured through attitudes related to the process. They were (1) the level of discomfort around strangers (UNKNWNB), (2) the degree of dislike toward waiting for others (NOWAIT) and, (3) the level of discomfort with feeling inexperienced while learning something new (INEXPER).

Factor Analysis

As mentioned earlier, factor analysis searches for commonalties among variables and groups highly correlated variables into factors. In this way, a large number of variables can be grouped into a more focused number of factors that can more concisely describe major influences on the dependent variable, mode choice.

The following is a detailed description of the process used in the factor analysis.

Correlation between variables and variable groupings. The initial list of variables derived from the research literature was used in the factor analysis conducted for this study. The procedure analyzed the pattern of correlation among these variables as a basis for factor extraction. This factor extraction phase of the analysis measured the **communality**, or the proportion of variance explained by each factor. If a factor explained no more than the variance explained by a single variable, its communality or **eigenvalue** was equal to one. The greater the eigenvalue, the greater the percentage of total variance that was explained by that factor. Figure 2 provides a graphical display of eigenvalues, called a **scree plot**. As can be seen in Figure 2, after the first four selected factors, the slope of the eigenvalues changes markedly. This indicates a major change in the degree to which each of the subsequent factors explained the total variance. Using five factors does not lead to a significant improvement over using four factors. Because of this, the first four factors were selected for the next phase of the

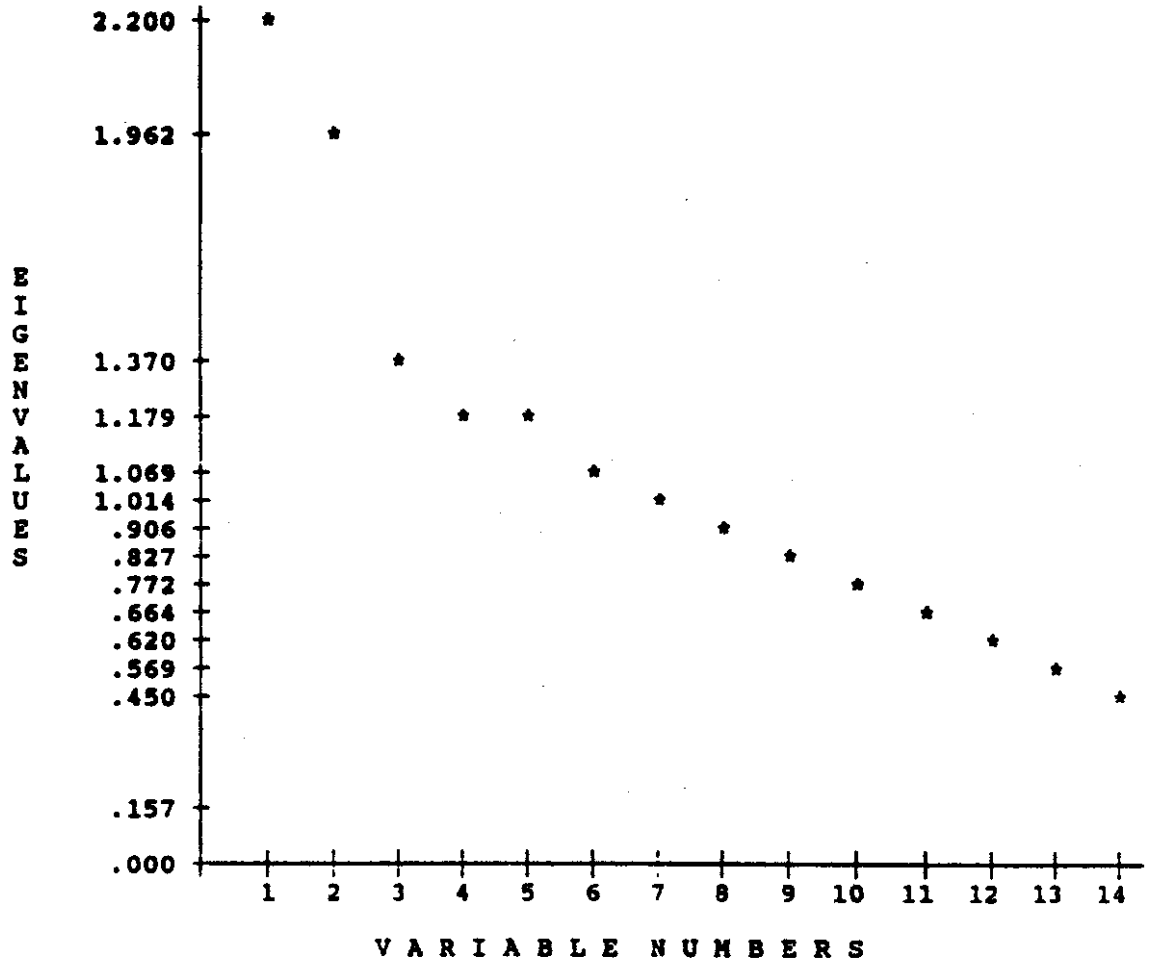

Figure 2.

Scree Plot of Eigenvalues for Selected Variables

analysis. They described 45.2 percent of all variance accounted for by the entire set of selected variables.

Rotation. Once the factors had been selected, they were established as axes in a multidimensional space within which each variable's communality was graphed. These axes were mathematically rotated until the greatest number of variables had the least distance to an axis. The resulting table became the rotated factor matrix described in Table 30. In this table, each factor has a group of variables that are highly correlated with each other. Correlation values of greater than .5000 in absolute value were considered strong enough to remain in the analysis and were listed in Table 29, and conversely, variables with correlations less than .5000 in absolute value were disregarded.

The four factors and their associated variables. The initially selected variables are listed on the left-hand column of Table 30. The degrees of correlation for each variable with each factor are in the columns under each factor.

The grouping of the variables describes four factors. In order of importance, they were (1) family composition, (2) perceived car need and ease of use, (3) perceived commute time, and (4) a "control" factor, i.e. the degree of control over daily affairs considered desirable by the respondents.

The first factor was called "Family Composition." The ratio of household members per worker (HMEMPWKR) and youths per worker (YTHPWKR) were the most strongly correlated variables with this factor. (A youth was defined as someone between five and 15 years of age.) Negatively correlated with this factor was whether a working spouse was in the household (WKGSPOUS). The number of cars per worker(CARSPWKR) and whether the household was a single family dwelling (SINGLFAM) were positively, but weakly, correlated with this factor. A positive score on the factor indicated the degree to which the household was the so-called "traditional" family, with one worker and several children at home with a non-working adult.

Table 29. Rotated Factor Matrix for Four Factors

	Family Characteristics	**Car Need and Ease of Use**	**Commute Time**	**"Control"**
	Factor 1	Factor 2	Factor 3	Factor 4
HMEMPWKR	.92915			
YTHPWKR	.80353			
WKGSPOUS	-.59479			
CARSPWKR	.40645			
SINGLFAM	.29108			
ERRANDS		.71319		
NEEDCAR		.68368		
PKG$MO		-.63528		
PRSWKLY		.43410		
BUSTIME			.86419	
COMTIME			.71304	
INEXPER				.70260
UNKNWNB				.65503
DLYSCHED				.30652
BACKUPCR				-.18206

The second factor was called "Car Need and Ease of Use." Most positively correlated in this factor were the degree of perceived need to run errands while traveling to and from work (ERRANDS), the respondent's estimate of the number of days per week that the car was needed for errands to/from work or during the day (NEEDCAR), and the number of shopping or other personal trips taken per week (PRSWKLY). Negatively correlated was whether the respondent faced parking fees upon arriving at work (PKG$MO).

The third factor was called "Commute Time." Most positively correlated was the time needed to travel from home to work by bus as perceived by the respondents (BUSTIME). Less positively correlated was the time required to travel by car from home to work (COMTIME). Differences between these two correlations was probably related to the fact that home sites have differing access to transit.

The fourth factor was called "Need for Control." A high degree of discomfort with inexperience when learning something new (INEXPER) was most positively correlated with this

factor. A high degree of discomfort with strangers (UNKNWNB) was also positively correlated, but to a lesser degree.

Comparing factors with actual mode chosen. An ANOVA procedure was conducted to detect differences among these four factors according to the four groupings of mode choice used in this analysis: SOV, bus, car/vanpool, and other modes. The procedure yielded the information in Table 30, which shows F ratios and an indicator of the statistical probability that the factors differentiated commute modes (the number is the probability that the differences resulted from random variation, rather than actual effects).

Factor 1 (Family Composition) was not significantly related to mode choice. This was surprising, since one would expect that large families with only one worker would have quite different commute needs than other types of households. Factor 2 (Car Need and Ease of Use) varied strongly among modes. This result highlights the importance of parking costs and the perceived need for a car to run errands in modifying mode choice behavior.

Interpretation of the factor analysis. Factor analysis provides an idea of the variables that belong together to form major factor groups, and provides a basis for understanding the underlying structure of commuter mode choice. Among the initial variables then, family composition, the perceived need of the car and the ease with which it can be used, commute time, and some measurement of the degree of control desired in one's life, described

Table 30. Analysis of Variance: Factor by Typical Commute Mode

Factor	Differentiation Between Modes (Scheffe Test)	F Ratio	F Probability
Family Characteristics	none	0.2800	0.8399
Car Need/Ease	1-2,1-3,2-3,2-4*	113.7196	0.0000
Commute Time	none	3.6437	0.0127
"Control"	none	2.1427	0.0922

* 1 = SOV, 2 = Bus, 3 = Pool, 4 = Other

the major factors. Factor analysis does not identify ways in which individual commuters can be grouped by mode according to these selected variables. The next step of the analysis, called cluster analysis, was conducted to provide further insight.

Cluster Analysis

Cluster analysis searches for commonalties among individual respondents. If two people have similar behavior, values, and decision-making patterns, they will likely answer a questionnaire similarly and will be in the same cluster or group. For this analysis, the initial list of variables described above was used again, this time for the cluster analysis. The analysis assumes these variables are indicators of mode choice behavior, and that a cluster analysis using these variables would be useful to group individuals by mode choice.

The cluster analysis proceeded iteratively. The first clustering used the initial selection of primary independent variables described above. Using analysis of variance, variables were added and subtracted from the list used in the cluster analysis. They were taken off the list if they were not significantly different among the clusters or added to the list if they were thought to add explanatory power and were not directly related to mode choice.

The cluster analysis was accomplished with two SPSS procedures, CLUSTER and QUICK CLUSTER. CLUSTER used a sample of respondents to identify cluster centers. The number of cases CLUSTER can handle depends on the number of variables. The cluster centers identified with CLUSTER were used as initial cluster centers for QUICK CLUSTER. The latter statistical package can handle a larger number of cases. Using that procedure, all cases for which there were data could be assigned to a cluster.

Final grouping. The cluster analysis used 511 responses, all of those that had included data responses for all of the variables, a requirement of the cluster analysis. After the cases were grouped into four clusters (see Table 31), cross-tabulations of cluster membership and mode choice revealed three major clusters:

1. a group predominantly of bus riders, called in this report cluster 1 or the "Bus-oriented cluster;"

Table 31. Cross-tabulation of Cluster Grouping by Typical Mode Taken

Typical Mode	Bus-oriented Cluster 1	Non-driver Cluster 2	Traditional Commuter Cluster 3	Auto-oriented Cluster 4	Row Total
SOV	4	0	117	142	263 51.5
Bus	41	13	60	19	133 26.0
Pool	3	5	40	43	91 17.8
Other	1	0	14	9	24 4.7
Column Total	49 9.6	18 3.5	231 45.2	213 41.7	511 100.0

2. another of commuters who had a lower tendency to take the bus than other clusters, called cluster 4, or the "Auto-oriented cluster;" and

3. the largest cluster, a blended cluster of bus, pool and SOV commuters whose family composition and commute distance predominantly differentiated it from other groups, called cluster 3 or the "Traditional Commuter cluster."

A fourth, small group of commuters had no driver's licenses and were grouped together in cluster 2, the "Non-driver cluster." This group will be discussed in a later section of this paper.

It is interesting to note how non-SOV modes were distributed among the three major clusters. One cluster clearly was composed primarily of bus riders. However, a sizable number of bus riders were in the Traditional Commuter cluster (and, to a lesser extent, are found in the so-called Auto-oriented cluster). The following analysis examines the differences among bus riders in the different groups.

In contrast with bus riders, no cluster was clearly composed of carpoolers and vanpoolers. However, they were fairly evenly split between the Traditional Commuter and SOV clusters. Again, the following analysis will examine the differences between the poolers in these two clusters.

Analysis of all other variables. Once the clusters had been established, t-tests were conducted on the original variables used for the clustering and all other continuous variables in the Metro telephone survey. This procedure was done to identify further variables

that could distinguish among the clusters and to determine why people with similar mode choices were included in different clusters. Table 32 is a tabular representation of the differing means and associated t-test probabilities for each variable.

Three comparisons were made:

- SOV commuters split relatively evenly between the Traditional Commuter cluster and the Auto-oriented cluster; therefore, these two groups were compared.
- Pool commuters also split relatively evenly between the same two clusters, and were analyzed similarly.
- Bus commuters split between the Bus-oriented cluster and the Traditional Commuter cluster, and the two groups were compared.

Figure 3 provides graphically the results of these analyses. The predominant characteristics for all modes of the Traditional Commuter cluster (cluster 3) are summarized in the center of the diagram. Within each of the sectors of the Traditional Commuter cluster, labeled SOV3, POOL3 and BUS3, are the characteristics that differentiate the modes within the Traditional Commuter cluster. The other two predominant groups resulting from the analysis, the Bus-oriented cluster (cluster 1, called BUS1), and the Auto-oriented cluster (cluster 4, called BUS4), are both outside of the Traditional Commuter cluster circle. The Auto-oriented cluster is broken graphically into two parts, labeled SOV4 and POOL4, to assist visually with the creation of separate circles for each of the modes: SOV, Bus, and Pool. The figure illustrates several characteristics of the groups.

Characteristics of the Traditional Commuter cluster. SOV, pool, and bus commuters in the Traditional Commuter cluster shared the characteristics of (1) larger families, (2) longer commutes, (3) an emphasis on convenience and time-saving, (4) more employer-provided transportation services available to them, and (5) less interest in "control" in their daily lives.

Larger families in the Traditional Commuter cluster. The "Household Characteristics" section of Table 32 shows that both SOV and pool commuters in the Traditional Commuter cluster had higher household members per worker and youths per worker ratios than

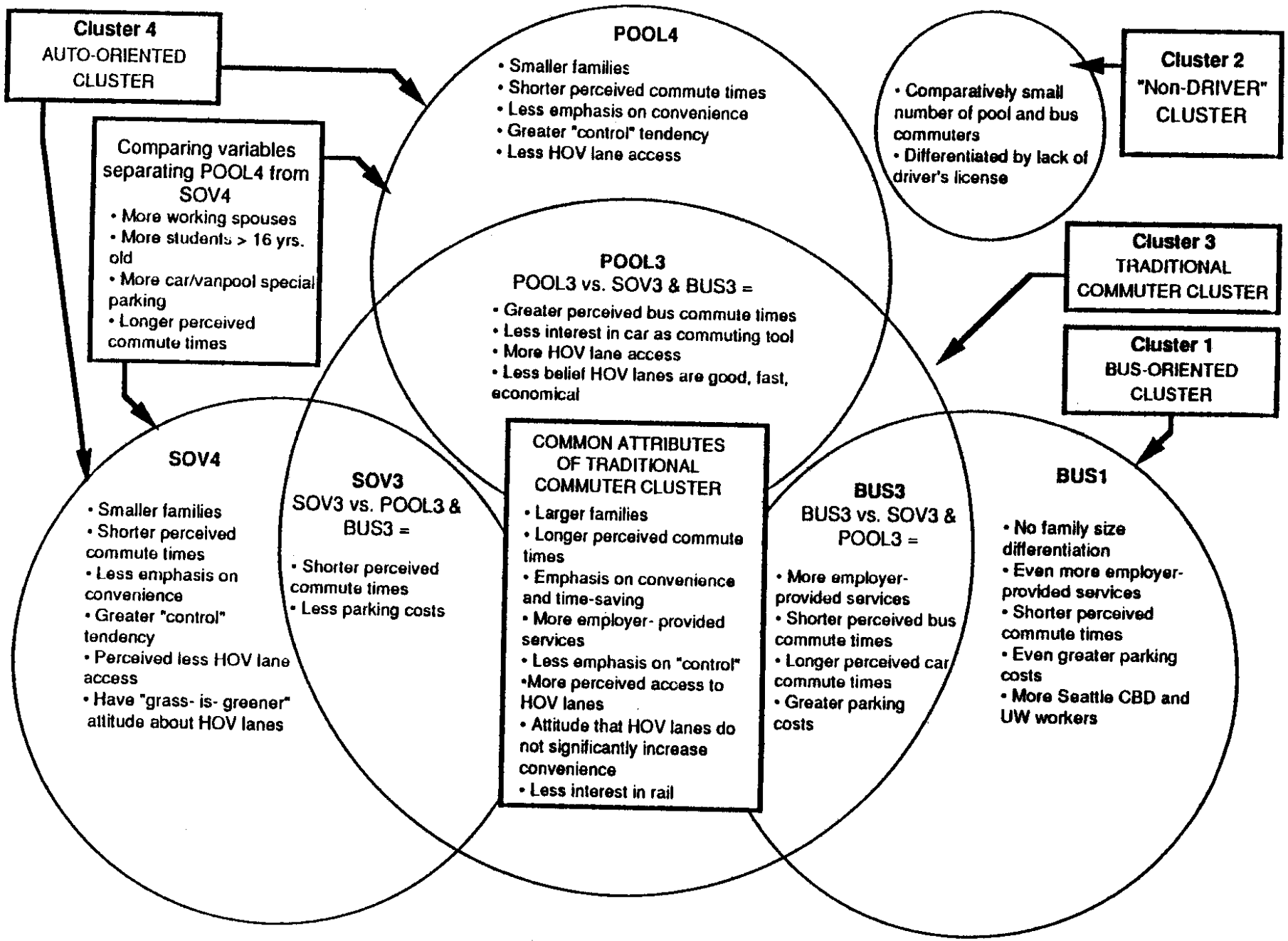

Figure 3. Diagram of Mode Clusters and Their Characteristics

Table 32. Comparing Means and t-test Probabilities Between Selected Mode Clusters

X INDICATES MEAN IS LARGER FOR THAT VARIABLE

DESCRIPTION	VARIABLE NAME	SOV3 CLUSTER 3	SOV4 CLUSTER 4	SOV T-TEST PROB	BUS3 CLUSTER 3	BUS1 CLUSTER 1	BUS T-TEST PROB	POOL3 CLUSTER 3	POOL4 CLUSTER 4	POOL T-TEST PROB
EST. CAR COMMUTE TIME	COMTIME	X		0.010	X		0.006			
EST. BUS COMMUTE TIME	BUSTIME	X		0.001	X		0.034	X		0.039
HOUSEHOLD CHARACTERISTICS:										
NO. OF CARS IN HOUSEHOLD/WORKER	CARSPWKR				X		0.012			
HOUSEHOLD MEMBERS/WORKER	HHEMPWKR	X		0.011				X		0.017
YOUTH/WORKER	YTHPWKR	X		0.012				X		0.040
NO. HOUSEHOLD 5 TO 15 YEARS OLD	FIVFIFT	X		0.011				X		0.047
NUMBER OF STUDENTS OVER 16 YRS	SCHOOL	X		0.042						
COMMUTER HAS WORKING SPOUSE	WKGSPOUS								X	0.042
EDUCATION LEVEL OF COMMUTER	EDUCLEVL	X		0.032						
EXISTING CONDITIONS:										
DEGREE OF DAILY SCHEDULE FLEXIBILITY	DLYSCHED					X	0.034			
HAS PARKING COSTS	PKGSNO					X	0.017			
PRESENTLY USE HOV LANES TO COMMUTE	HOVLANE							X		0.028
NO. RIDES/WEEK ON LOCAL BUS	LOCBUS					X	0.042			
DISTANCE TO NEAREST BUSSTOP	BUSDIST				X		0.001			
CT/METRO SERVICE USED TO UNIV OF WA	TRANSV4					X	0.000			
HHLD MEMBERS USE METRO TRANSIT CENTER	MTSV8							X		0.038
BUS PASS SUBSIDY FROM EMPLOYER	BUSPASS	X		0.026		X	0.000			
VANPOOL PASS SUBSIDY FROM EMPLOYER	POOLPASS	X		0.051				X		0.037
SPECIAL PARKING FOR POOL FROM EMPLOYER	POOLPARK	X		0.020						
ATTITUDES ON CONTROL:										
NOT COMFORTABLE WITH STRANGERS	UNKNWNG		X	0.000		X	0.034		X	0.000
DISLIKE FEELING INEXPERIENCED	INEXPER		X	0.010					X	0.028
COMMUTING GIVES TIME TO SELF	ALONETIM		X	0.000						
DISLIKE WAITING FOR OTHERS	NOWAIT		X	0.000						
ATTITUDES ON HOV LANES:										
HOV LANE NOT FAIR	NOHOVLN		X	0.000					X	0.018
HOV LANE GOOD, FAST, ECONOMICAL	POOLFAST		X	0.000					X	0.026

Table 32. (continued) Comparing Means and t-test Probabilities Between Selected Mode Clusters

DESCRIPTION	VARIABLE NAME	SOV CLUSTER 3	SOV CLUSTER 4	SOV T-TEST PROB	BUS CLUSTER 3	BUS CLUSTER 1	BUS T-TEST PROB	POOL CLUSTER 3	POOL CLUSTER 4	POOL T-TEST PROB
ATTITUDES ON CAR USE:										
IF CHOICE, ALWAYS USE CAR	ALWYSCAR	X		0.000				X		0.002
IF GAS PRICE REMAINS LOW, WILL USE CAR	GAS$	X		0.000				X		0.000
OFTEN RUN ERRANDS WHILE TO/FROM WORK	ERRANDS					X	0.050			
ATTITUDES ON BUS USE:										
DISLIKE WALK TO BUSSTOP	NOWALKB	X		0.000				X		0.002
UNWILLING TO BUS TRANSFER	NOTRANSB	X		0.000				X		0.001
ENJOY READ/RELAX WITH COMMUTE	RELAXB		X	0.000					X	0.003
WORRY ABOUT DISTURBANCES ON BUS	BDISTURB		X	0.000						
BEST THING, NO PARK PROB IN CBD W/BUS	NOPKGB	X		0.021						
DONT MIND PACKAGES ON BUS	PAKBUS							X		0.004
WILLINGNESS TO USE NEW SERVICES:										
WOULD USE EMPLOYER-PROVIDED BACKUPCAR	BACKUPCR	X		0.000				X		0.023
WOULD USE CONVENIENT RAIL	USERAIL		X	0.000		X	0.019		X	0.003
IF CONVENIENT WOULD BUS (SOV ONLY)	LIKLBUS	X		0.000						
IF CONVENIENT WOULD POOL (SOV ONLY)	LIKLPOOL	X		0.002						
IF " WLD USE PR LOTS (SOV ONLY)	LIKLPR	X		0.002						
WOULD USE SUBURB TO SUBURB TRANSIT	SUBCOMM	X		0.000						
IF HOV LANE ACCESS, WOULD USE MORE BUS	MOREBUS		X	0.006						
IF HOV LANE, WOULD USE MORE CPOOL	MORECPL		X	0.004						
IF HOV LANE, WOULD USE MORE VPOOL	MOREVPL		X	0.000						
WOULD USE TRANSIT CENTERS IF AVAILABLE	TRANCTRS		X	0.000						
WOULD LIKE CASH MACHINE FOR BUS PASS	CASHMACH	X		0.024						
WOULD USE SHUTTLE IN NBRHOOD FOR STORES	SHUTTLE	X		0.008						
WOULD USE ADD'TL SERVICES AT PR LOTS	PRSERV	X		0.002						
WOULD USE COMBO PR LOTS AND TRAIN	PRTRAIN	X		0.000						
WOULD USE SPECIAL RESERVED BUS	SPECBUS	X		0.000				X		0.051
WOULD USE NEW BUS ROUTE	NEWBUS		X	0.004					X	0.037

those outside of the Traditional Commuter cluster. However, this did not differentiate the two bus commuter groups, one inside and the other outside of the Traditional Commuter cluster.

Family size for bus commuters in the Traditional Commuter cluster. A comparison of all cases in the Traditional Commuter cluster with bus commuters in the cluster (see Table 33) revealed that the difference in number of household members per worker was not statistically significant. However, the youths per worker ratio was significantly less for the bus commuters in the Traditional Commuter cluster.

Longer commute times in the Traditional Commuter cluster. A comparison of Table 32's perceived commute times for each mode within and outside the Traditional Commuter cluster shows that all three major modes within the Traditional Commuter cluster had larger mean perceived commute times.

Convenience and time-saving in the Traditional Commuter cluster. The "Attitudes on Car Use" section of Table 32 shows that both the SOV and pool commuters in the Traditional Commuter cluster shared a stronger tendency to always choose the car if given a choice, or as long as gas prices remained low. However, these same SOV commuters would use the bus, carpool, or park-and-ride lots, if convenient. This result implies a desire by this group to pick the mode that would most quickly and conveniently satisfy their transportation needs.

Willingness to use new services in the Traditional Commuter cluster. SOV commuters in the Traditional Commuter cluster expressed a stronger interest in new services than did the SOV counterparts outside the Traditional Commuter cluster. This could also be interpreted as an indication that these SOV commuters were willing to try something new as long as it addressed their underlying need for increased convenience and/or time-saving that would reduce their longer commutes.

Table 33. Comparing Means and t-test Probabilities Between Modes within the Traditional Commuter Cluster

X INDICATES MEAN IS LARGER FOR THAT VARIABLE

DESCRIPTION	VARIABLE NAME	SOV3 CLUSTER 3	OTHER CLUSTER 3	SOV3 T-TEST PROB	BUS3 CLUSTER 3	OTHER CLUSTER 3	BUS3 T-TEST PROB	POOL3 CLUSTER 3	OTHER CLUSTER 3	POOL3 T-TEST PROB
EST. CAR COMMUTE TIME	CONTIME		X	0.000	X		0.000			
EST. BUS COMMUTE TIME	BUSTIME					X	0.000	X		0.044
HOUSEHOLD CHARACTERISTICS:										
NO. OF CARS IN HOUSEHOLD/WORKER	CARSPWKR									
HOUSEHOLD MEMBERS/WORKER	HHEMPWKR									
YOUTH/WORKER	YTHPWKR					X	0.001			
NO. HOUSEHOLD 5 TO 15 YEARS OLD	FIVFIFT					X	0.002			
NUMBER OF STUDENTS OVER 16 YRS	SCHOOL									
COMMUTER HAS WORKING SPOUSE	WKGSPOUS									
EDUCATION LEVEL OF COMMUTER	EDUCLEVL									
EXISTING CONDITIONS:										
DEGREE OF DAILY SCHEDULE FLEXIBILITY	DLYSCHED	X		0.025		X	0.021			
HAS PARKING COSTS	PKG$NO		X	0.000	X		0.000			
PRESENTLY USE HOV LANES TO COMMUTE	HOVLANE									
NO. RIDES/WEEK ON LOCAL BUS	LOCBUS									
DISTANCE TO NEAREST BUSSTOP	BUSDIST				X		0.008			
CT/METRO SERVICE USED TO UNIV OF WA	TRANSV4									
HHLD MEMBERS USE METRO TRANSIT CENTER	MTSV8		X	0.000	X		0.001			
BUS PASS SUBSIDY FROM EMPLOYER	BUSPASS				X		0.018			
VANPOOL PASS SUBSIDY FROM EMPLOYER	POOLPASS									
SPECIAL PARKING FOR POOL FROM EMPLOYER	POOLPARK									
ATTITUDES ON CONTROL:										
NOT COMFORTABLE WITH STRANGERS	UNKNWN8									
DISLIKE FEELING INEXPERIENCED	INEXPER									
COMMUTING GIVES TIME TO SELF	ALONETIM					X	0.008	X		0.017
DISLIKE WAITING FOR OTHERS	NOWAIT									
ATTITUDES ON HOV LANES:										
HOV LANE NOT FAIR	NOHOVLN					X	0.033			
HOV LANE GOOD, FAST, ECONOMICAL	POOLFAST				X		0.014		X	0.027

Table 33. (continued) Comparing Means and t-test Probabilities Between Modes within the Traditional Commuter Cluster

DESCRIPTION	VARIABLE NAME	SOV3 CLUSTER 3	OTHER CLUSTER 3	SOV3 T-TEST PROB	BUS3 CLUSTER 3	OTHER CLUSTER 3	BUS3 T-TEST PROB	POOL3 CLUSTER 3	OTHER CLUSTER 3	POOL3 T-TEST PROB
ATTITUDES ON CAR USE:										
IF CHOICE, ALWAYS USE CAR	ALWYSCAR		X	0.001	X		0.000		X	0.008
IF GAS PRICE REMAINS LOW, WILL USE CAR	GASS		X	0.000	X		0.000		X	0.051
OFTEN RUN ERRANDS WHILE TO/FROM WORK	ERRANDS		X	0.001	X		0.000			
ATTITUDES ON BUS USE:										
DISLIKE WALK TO BUSSTOP	NOWALKB									
UNWILLING TO BUS TRANSFER	NOTRANSB									
ENJOY READ/RELAX WITH COMMUTE	RELAXB	X		0.001		X	0.000			
WORRY ABOUT DISTURBANCES ON BUS	BDISTURB									
BEST THING, NO PARK PROB IN CBD W/BUS	NOPKGB									
DONT MIND PACKAGES ON BUS	PAKBUS									
WILLINGNESS TO USE NEW SERVICES:										
WOULD USE EMPLOYER-PROVIDED BACKUPCAR	BACKUPCR									
WOULD USE CONVENIENT RAIL	USERAIL									
IF CONVENIENT WOULD BUS (SOV ONLY)	LIKLBUS									
IF CONVENIENT WOULD POOL (SOV ONLY)	LIKLPOOL									
IF " WLD USE PR LOTS (SOV ONLY)	LIKLPR									
WOULD USE SUBURB TO SUBURB TRANSIT	SUBCOMM									
IF HOV LANE ACCESS, WOULD USE MORE BUS	MOREBUS									
IF HOV LANE, WOULD USE MORE CPOOL	MORECPL									
IF HOV LANE, WOULD USE MORE VPOOL	MOREVPL							X		0.019
WOULD USE TRANSIT CENTERS IF AVAILABLE	TRANCTRS									
WOULD LIKE CASH MACHINE FOR BUS PASS	CASHMACH									
WOULD USE SHUTTLE IN NBRHOOD FOR STORES	SHUTTLE									
WOULD USE ADD'TL SERVICES AT PR LOTS	PRSERV									
WOULD USE COMBO PR LOTS AND TRAIN	PRTRAIN									
WOULD USE SPECIAL RESERVED BUS	SPECBUS									
WOULD USE NEW BUS ROUTE	NEWBUS									

More employer-provided services in the Traditional Commuter cluster. All three modes in the Traditional Commuter cluster tended to have more employer-based services than their counterparts in other clusters, such as bus pass subsidies and preferred parking for carpools and vanpools. These were the only employer-provided services that showed statistically significant differences between groups.

Less "need for control" in the Traditional Commuter cluster. Both the SOV and pool commuters in the Traditional Commuter cluster expressed less agreement with variables indicating a desire for "control" over their life than similar commuters outside the cluster. They expressed less discomfort around strangers and less dislike of feeling inexperienced when learning something new. The SOV commuters in the Traditional Commuter cluster additionally felt less dislike in waiting for others and less interest in time to oneself while commuting than SOV commuters outside the cluster.

HOV lane convenience to SOV commuters. SOV commuters in the Traditional Commuter cluster did not perceive that HOV lanes significantly increased convenience. SOV commuters within the Traditional Commuter cluster responded with a greater tendency than the SOV commuters "outside" the Traditional Commuter cluster to want to use other modes and HOV facilities **if convenient**, and a decreased tendency to use other modes and HOV facilities **if they had HOV lane access**. At first glance, it seems this SOV group contradicted itself. They can be interpreted as saying that they would use almost any mode or facility as long as it increased their commuting convenience; but in their estimation, HOV lanes, at this time at least, do not increase that convenience level.

HOV lane convenience to pool commuters. Pool commuters in the Traditional Commuter cluster did not perceive that HOV lanes significantly increase convenience. A similar conclusion could be derived for the POOL3 and POOL4 commuters inside and outside of the Traditional Commuter cluster. POOL3 commuters exhibited a greater tendency to use HOV lanes than the POOL4 group, but they also responded with a decreased tendency to believe that HOV lanes are good fast and economical. A similar conclusion was therefore derived, that HOV

lanes do not significantly enhance the commute times for pool commuters in the Traditional Commuter cluster at this time.

The "grass-is-greener" phenomenon. According to the previous discussion, congestion has not quite reached a level sufficient for HOV lanes to be seen as a great advantage by the commuters that use them. On the other hand, HOV lanes do seem like an important advantage to those that do not use them. By far the largest majority of commuters in the study area drove alone; it could be inferred that commute conditions have not yet deteriorated to a level to cause SOV commuters to change their behavior but have deteriorated sufficiently for them to begin to change their attitudes. This "grass-is-greener" attitude by SOV commuters about the advantages of using HOV lanes may be an optimistic sign that conditions are ripe for policy changes that will cause a significant mode shift to HOV modes.

Less interest in rail within the Traditional Commuter cluster. All mode clusters "outside" the Traditional Commuter cluster exhibited a greater willingness to use a convenient rail system. This is consistent with the "grass-is-greener" attitude exhibited by SOV commuters about the advantages of using HOV lanes. However, in this case it extends to both POOL4 and BUS1 commuter groups outside the Traditional Commuter cluster as well. The mode groups within the Traditional Commuter cluster seemed consistently cynical about the convenience of HOV lanes under present conditions, and carried that cynicism to the potential advantages of a new rail system for the region.

Characteristics that separate modes within the Traditional Commuter cluster. Table 34 identifies the variables that statistically differentiate each mode within the Traditional Commuter cluster. These variables are listed in Figure 3 within SOV3, BUS3 and POOL3. The main determinants for separating modes within the Traditional Commuter cluster seemed to be perceived commute times, HOV incentives, and the existence of parking costs.

Table 34. Comparing Means and t-test Probabilities Between SOV and POOL Modes in the Traditional Commuter Cluster

X INDICATES MEAN IS LARGER FOR THAT VARIABLE

DESCRIPTION	VARIABLE NAME	SOV4 CLUSTER 4	POOL4 CLUSTER 4	T-TEST PROB
EST. CAR COMMUTE TIME	COMTIME		X	0.006
EST. BUS COMMUTE TIME	BUSTIME			
HOUSEHOLD CHARACTERISTICS:				
NO. OF CARS IN HOUSEHOLD/WORKER	CARSPWKR			
HOUSEHOLD MEMBERS/WORKER	HMEMPWKR			
YOUTH/WORKER	YTHPWKR			
NO. HOUSEHOLD 5 TO 15 YEARS OLD	FIVFIFT			
NUMBER OF STUDENTS OVER 16 YRS	SCHOOL		X	0.019
COMMUTER HAS WORKING SPOUSE	WKGSPOUS		X	0.047
EDUCATION LEVEL OF COMMUTER	EDUCLEVL			
EXISTING CONDITIONS:				
DEGREE OF DAILY SCHEDULE FLEXIBILITY	DLYSCHED		X	0.011
HAS PARKING COSTS	PKG$MO			
PRESENTLY USE HOV LANES TO COMMUTE	HOVLANE			
NO. RIDES/WEEK ON LOCAL BUS	LOCBUS			
DISTANCE TO NEAREST BUSSTOP	BUSDIST			
CT/METRO SERVICE USED TO UNIV OF WA	TRANSV4			
HHLD MEMBERS USE METRO TRANSIT CENTER	MTSV8			
BUS PASS SUBSIDY FROM EMPLOYER	BUSPASS			
VANPOOL PASS SUBSIDY FROM EMPLOYER	POOLPASS			
SPECIAL PARKING FOR POOL FROM EMPLOYER	POOLPARK		X	0.015
WILLINGNESS TO USE NEW SERVICES:				
WOULD USE EMPLOYER-PROVIDED BACKUPCAR	BACKUPCR			
WOULD USE CONVENIENT RAIL	USERAIL			
IF CONVENIENT WOULD BUS (SOV ONLY)	LIKLBUS			
IF CONVENIENT WOULD POOL (SOV ONLY)	LIKLPOOL			
IF " WLD USE PR LOTS (SOV ONLY)	LIKLPR			
WOULD USE SUBURB TO SUBURB TRANSIT	SUBCOMM		X	0.025
IF HOV LANE ACCESS, WOULD USE MORE BUS	MOREBUS	X		0.023
IF HOV LANE, WOULD USE MORE CPOOL	MORECPL			
IF HOV LANE, WOULD USE MORE VPOOL	MOREVPL			
WOULD USE TRANSIT CENTERS IF AVAILABLE	TRANCTRS			
WOULD LIKE CASH MACHINE FOR BUS PASS	CASHMACH			
WOULD USE SHUTTLE IN NBRHOOD FOR STORES	SHUTTLE			
WOULD USE ADD'TL SERVICES AT PR LOTS	PRSERV			
WOULD USE COMBO PR LOTS AND TRAIN	PRTRAIN			
WOULD USE SPECIAL RESERVED BUS	SPECBUS			
WOULD USE NEW BUS ROUTE	NEWBUS			

Pool commuters within the Traditional Commuter cluster. Pool commuters in this cluster expressed less interest in the car than bus or SOV commuters and less belief that HOV lanes are good, fast, and economical. However, this group used HOV lanes more than the pool commuters outside of the Traditional Commuter cluster. This result could indicate that they were not realizing significant time-savings through use of HOV lanes, and therefore did not see them as a significant advantage.

SOV commuters within the Traditional Commuter cluster. The SOV commuters had fewer incentives to use HOV facilities in that they had shorter commutes than the rest in the Traditional Commuter cluster and were less likely to be faced with parking costs. This indicates that they had a greater tendency to work in suburban locations. They were also less likely to feel that they needed the car as a commuting tool, perhaps indicating that they would be willing to change modes if incentives existed. Conversely, this tendency of the other two modes in the Traditional Commuter cluster to want to use the car as a commuting tool could indicate a degree of frustration toward carpooling and transit use, but acceptance of these modes because of HOV incentives and SOV disincentives. This conclusion is plausible because (1) all modes in the Traditional Commuter cluster shared an emphasis on convenience and speed and (2) SOV commuters had an average commute time that was shorter than all other modes.

Bus commuters within the Traditional Commuter cluster. The bus commuters in the Traditional Commuter cluster were differentiated from other modes in the cluster by more incentives to rideshare, perceived shorter bus commutes, perceived longer car commutes, and greater parking costs. Despite these tendencies, they still scored higher in preference for a car if given a choice.

SOV and pool commuters "outside" the Traditional Commuter cluster. Both of these commuter groups shared many commonalties and were grouped by the cluster analysis procedure into cluster 4, the Auto-oriented cluster. The converse of what was true for the Traditional Commuter cluster applied to them: they had smaller families, generally shorter commutes, less emphasis on convenience, more of a "control" tendency, and less perceived

HOV lane access. Table 34 lists the differentiating factors between these two groups. They are additionally summarized within SOV4 and POOL4 in Figure 3.

Pool commuters in the Auto-oriented cluster. The POOL4 commuters had a greater tendency to have a working spouse or student over 16 years of age, a longer perceived car commute, and special parking for car and vanpools than the SOV4 commuters. Implied here, as elsewhere in the analysis, is that employer-based services, such as preferred parking for car and vanpools, are effective in changing mode behavior. The POOL4 commuters desired suburb to suburb transit service more than the SOV4 commuters; whereas the SOV4 commuters had a greater willingness to use the bus more if they had HOV lane access.

Bus commuters outside the Traditional Commuter cluster. The bus commuters who were "outside" of the Traditional Commuter cluster are within the Bus-oriented cluster, or BUS1, in Figure 3. This group differed from the BUS3 commuters in the Traditional Commuter cluster in that they were more likely to pay parking costs, had a greater likelihood of possessing a bus pass subsidy as an employer-provided service, had more daily schedule flexibility and a shorter perceived commute time. These results reinforce the observation that employer-based services, parking limitations and significant parking costs encourage HOV use.

Summary of Cluster Analysis

Two clusters were composed primarily of bus riders, one because members did not have driver's licenses and the other because of strong incentives to use a bus, such as employer-provided subsidies and high parking charges. Two other clusters contained a mix of modes. The Traditional Commuter cluster was differentiated from the non-Bus-oriented cluster because members of the cluster tended to have larger families and only one worker in the household. It also turns out that there was a much higher proportion of bus commuting in the first group than the second (hence, the name for the second).

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