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FINAL **REPORT**

CONSUMER DEMAND FOR AUTOMATED PRIVATE TRAVEL: EXTRAPOLATIONS FROM VANPOOL USER EXPERIENCES

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PATH

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The authors would like to acknowledge the assistance of Colin Cameron in some of the modelling aspects.

EXECUTIVE SUMMARY

INTRODUCTION

The market potential of vehicle automation technologies will depend on the following characteristics: cost, safety, operating speed (bounded by legal, safety and environmental constraints) convenience of operation, door-to-door travel and other convenience measures, riding comfort and ability to use travel time for useful and/or pleasurable activities and finally, image. But private, automated passenger cars cannot be thought of in isolation, for they will compete with other travel modes - primarily the non-automated automobile. All the attributes of an automated private vehicle identified above, must therefore be compared with corresponding attributes of an automobile. The primary difference between an automated vehicle and the existing drive-alone mode, will be the elimination of many driving tasks. A future commuter's mode choice between an automated and a non-automated vehicle may thus be characterized as a decision whether to drive or to ride. The purpose of this study is to investigate the reasons for an individual's decision to ride rather than drive, and to draw any appropriate extensions to a future marketplace where automated vehicles may be an available mode choice.

In order to establish the market potential for an automated vehicle, one must estimate the number of individuals who consider the improvements in all the attributes identified above to justify the greater cost of an automated vehicle. In our study we narrow the focus to a group of individuals who are currently making, or at least have a close knowledge of, some of these same trade-offs. These individuals are vanpoolers. The choice between drive-alone commuting and vanpooling will demonstrate this trade-off. However, some of the more important choice factors in this case are hard to measure and quantify - such as drive-alone cost and travel convenience for example. Therefore we decided to study the vanpool user's choice whether to drive or ride, *after* he or she had joined the vanpool. From the vanpoolers' stated choices whether to ride or drive their vanpool, we will infer whether a value may exist to future users of automated vehicles when they choose to travel in the automated mode, as opposed to driving themselves.

Elimination of the driving task may reduce physical and mental stress. In addition, travel time will be freed for other activities. We analyze this previously unexamined aspect of vehicle automation -- that is, what are the benefits to the alternative uses of travel time? It should be understood that while it is possible that automated private vehicle travel may cause speedier or more efficient flows of vehicles, and therefore bring with it absolute travel time savings for an individual, we are not primarily concerned with estimating this benefit.

RESEARCH METHOD

Measuring vanpoolers' revealed preferences for riding versus driving was excluded in favor of presenting vanpoolers with a hypothetical choice. The amount of driving a vanpooler actually undertakes is often governed by vanpool organization, and does not leave the user a free choice of driving and riding days. The question "how much would you ideally like to drive if given a free choice?", is hypothetical. Nevertheless most vanpoolers are familiar with both choices and can provide realistic answers. Many have experience with both options, as riders and drivers of the vanpool and as former drivers of their own automobiles.

We considered several hypothetical explanatory factors which might explain the idealized drive/ride choice. We used a repeated observations logit model to analyze our data. The model and variables used are discussed in detatil in the report.

A data sample of 350 vanpools was selected from two sources: 175 each from BIDES in the San Francisco Bay Area and Commuter Transportation Services (CTS) in Los Angeles. The questionnaires were sent to the vanpools in November 1991. Prior to this, a pilot was conducted to test the validity of questions and to do basic preparations for the computer analysis. 549 usable surveys were returned by 74 vanpools. In total, there were 309 men and 220 women in the sample, 20 respondents declined to state their gender. We present a summarized description of the data collected, highlighting gender and location differences.

Initial differences on important variables were identified by (1) linear regression on all the variables and pooled data and (2) a best subsets regression on the two sexes separately and the pooled data. Given the myriad differences in explanatory variables that we observed between men and women, we pursued modeling along two lines -- (1) including gender as an explanatory variable and (2) estimating separate models for men and women. In addition, we tested two formulations of travel time which incorporate different assumptions as to how vanpoolers perceive their travel time. The models which achieved most robust results were based on the assumption that in-van time is identical whether a vanpooler rides or drives and that models should be estimated separately for women and men. Many different specifications were tested for the measured explanatory variables.

Based on the differences between the vanpool and automated vehicle drive/ride choice, we state the following caveats and conditions upon our conclusions. First, we make no claims about the potential size of the market for automated vehicles based on vanpool users drive/ride choices. Second, we focus on the value to travellers of freeing their travel time from the activity of travel itself, that is, from driving. Third, because the possible rider activity sets may differ between vanpools and automated vehicles, we do not attribute the same value to automated vehicle owners of substituting other activities during travel time, as we do to vanpool users.

CONCLUSIONS

There was a strong preference over all groups to not drive at all or drive very little. For all respondent considered together, a majority of 60% preferred not to drive at all. A small percentage, 7%, would like to drive all the time, 16% would like to drive over a quarter of their monthly trips and 9% would like to drive for more than half of their commuting trips.

Our inferences regarding the extension of the vanpool results to the case of automated vehicles are that the demand for automation may depend on vehicle attributes such as its perceived safety of operation, its comfort, smoothness and ease of operation and vehicle cost. These factors differ in importance for men and women: their age and other lifecycle conditions; and on whether the commuter is likely to make use of the mode as ride-alone or shared mode; and on trip length and existing traffic conditions in the area.

There are some statistically significant demographic variables in both male and female models. However, many of the important explanatory variables for both men and women, are specific to the vanpool choice setting - van driving confidence, vanpool atmosphere and ridesharing experience. These two facts together- the few significant socio-demographic descriptors and the choice setting specific factors - imply that conceptual extensions to the automated vehicle choice are appropriate, but specific numerical results will not apply to automated vehicles. One factor left in common between vanpools and automated vehicles, however, is the substitution of non-travel activity during travel time - although even this factor is liable to have a different significance in an automated mode.

The previously unexplored aspect of travel time - the ability to accomplish non-travel activities while travelling - has yielded promising prospects. These prospects are supported by other burgeoning new technology such as cellular telephones and faxes. If automated vehicles can free drivers for other valued activities, while creating improved safety for the user and other motorists, then vehicle automation technology will be perceived as more valuable by consumers than simple travel-time savings analysis might suggest.

1 INTRODUCTION

2 THEORETICAL BACKGROUND AND APPLIED METHODOLOGY

3 THE RIDE/DRIVE CHOICE MODEL

TABLES

1 INTRODUCTION

PURPOSE

The market potential of vehicle automation technologies will depend on the following characteristics: cost, safety, operating speed (bounded by legal, safety and environmental constraints) convenience of operation, door-to-door travel and other convenience measures, riding comfort and ability to use travel time for useful and/or pleasurable activities and finally, image. But private, automated passenger cars cannot be thought of in isolation, for they will compete with other travel modes - primarily the non-automated automobile. All the attributes of an automated private vehicle identified above, must therefore be compared with corresponding attributes of an automobile. The primary difference between an automated vehicle and the existing drive-alone mode, will be the elimination of many driving tasks. Elimination of the driving task may reduce physical and mental stress as well as free travel time for other activities. A future commuter's mode choice between an automated and a non-automated vehicle may thus be characterized as a decision whether to drive or to ride. The purpose of this study is to investigate the reasons for an individual's decision to ride rather than drive, and to draw any appropriate extensions to a future marketplace where automated vehicles may be an available mode choice.

THE RESEARCH QUESTION

In order to establish the market potential for an automated vehicle one must estimate the number of individuals who consider the improvements in all the attributes identified above to justify the greater cost of an automated vehicle. In our study we narrow the focus to a group of individuals who are currently making, or at least have a close knowledge of, some of these same trade-offs. These individuals are vanpoolers.

Vanpoolers typically choose their mode due to a combination of the following reasons; unavailability of a well-running alternative vehicle, lower cost, elimination of driving task, moral concerns (for the environment), reduced wear and tear and maintenance on the alternative vehicle, convenience, availability of a vanpool service, etc. The trade-off that we are primarily concerned with when we explore the drive-ride choice, is between the higher cost of riding on the one hand, and the elimination of the driving stress plus the freed travel time on the other hand. Therefore, indeed, the choice between drive-alone commuting and vanpooling will demonstrate this trade-off. However, some of the more important choice factors would be hard to measure; particularly drive-alone cost. Therefore we decided to study the vanpool users choice whether to drive or ride, *after* he or she had joined the vanpool. The important variables were considered somewhat easier to measure in this scenario. Thus from the choices of commuters who choose whether to ride or drive their vanpool, we will infer whether a value may exist to future users of automated vehicles when they choose to travel in the automated mode, as opposed to driving themselves.

One of the objectives of this study is to identity the role of travel time spent on non-travel activities. It should be understood that while it is possible that automated private vehicle travel may cause speedier or more efficient flows of vehicles, and therefore bring with it absolute travel time savings to individuals, we are not primarily concerned with estimating the benefits of these absolute time savings for individuals. Many past studies have addressed the issue of travel time savings in general. (See for example, Goodwin 1976, Heggie 1976, Hensher 1976 and 1984, Hensher and Truong 1985, King 1983, Layton 1984.) Instead, we examine the value that travellers place on the use of travel time to accomplish non-travel activities. It should be understood that the value of time per se is only a secondary aim of this research. This, then, is not a study of value of travel time, but rather of the trade-offs travellers are willing to make to accomplish non-travel activities during their travel time.

Two observable measures of a van pool user's actual choice between driving and riding are: 1) user type (driver or rider) and 2) driving load (amount or proportion of travel undertaken as a driver). These measures do, to some extent, reflect a vanpoolers preferences. Some users alternate driving regularly with other vanpool users, some are only back-up drivers in case of emergency, some do not drive at all, and still others drive every day.

However, there are several difficulties with these observable measures. The amount of driving a vanpooler undertakes is often governed by vanpool organization, and does not leave the user a free choice of driving and riding days. In many of the vanpools we surveyed, the vehicle lease-holder or owner drives the van practically every day, and may not offer other riders the choice of sharing the driving. Seniority in the vanpool may also play a role in the allocation of driving duties, depending on if and how driving assignments are evaluated.

Another possibility was to pose the hypothetical question "how much would you ideally like to drive if given a free choice"? Although admittedly hypothetical, we believe reasonably realistic answers can be obtained to this question since most vanpoolers are familiar with both choices. Many have experience with both options, both as riders and drivers of the vanpool and as former drivers of their own autos. On the other hand, a survey of this nature, using the general commuter population would require the respondents to engage in much more speculative responses since many commuters are not familiar with riding to work as a passenger.

Based on the difficulty of identifying the effects of vanpool organizational constraints on actual behavior and our belief in vanpool users' familiarity with the hypothetical choice being offered to them, we chose to analyze the hypothetical, ideal drive/ride choice. The specific question our respondents answered was: "how many days each month would you ride as a passenger and how many days would you drive your **vanpool,** assuming you were free to choose each day and assuming existing fares and discounts/payments for driving? "

Several factors might explain this idealized **drive/ride** choice. The factors that we examine are:

Travel cost; using fares as rider cost and driver pay as driver "cost";
Travel time under two separate driving time assumptions;
Socioeconomic attributes of the users;
Vanpool organization characteristics;
Driver tasks;
Driver benefit packages;
Rider activities and duration of activity participation;
Ridesharing familiarity/commitment;
Stated van driving confidence;
Vanpool atmosphere;
Van driveability; and
van comfort.

The precise definitions of the measures used to assess these factors are presented in Chapter 4.

We recognize that vanpoolers may not be the target market for automated vehicles and we discuss the reasons for this and their implications for the inferences which may be drawn from this study. Throughout this report we refer to the distinction between **vanpools** and automated vehicles as if all automated vehicles were **light-**duty passenger cars and trucks used primarily as single occupant vehicles. We leave until the conclusions any consideration of how vehicle automation technology might change drive/ride choices within automated vanpools.

WHAT CAN WE LEARN FROM VANPOOLERS?

While we exploit the similarity between the drive/ride choices of **vanpool** users and automated vehicle drivers, there are important differences between the two which define the appropriate inferences which may be made from this study. In discussing the validity of applying our analysis of **vanpool** users' decisions whether to ride or drive to the question of drivers choosing whether or not to buy and use automated vehicles, we must therefore address the following five questions.

1) What factors will play a part in vanpoolers' decisions?
2) How are these choice factors related to observable user characteristics?
3) Do the factors important in the **vanpool** choice situation differ from the factors important in the automated vehicle choice situation?
4) Are these differences significant to predictions about automated vehicle choice behavior?
5) How does our sample of **vanpool** users **differ** from the target population for automated vehicle technology?

In order to begin to answer these questions, we build a **typology** of **vanpool** choice factors. The three main types of choice factors are mode attributes, user attributes and environmental attributes. Choice factors may be further subdivided by type of user impact -- cost, physical **&** mental stress, time utility, convenience and image.

Table 1.1 summarizes both the **typology** of choice factors (explanatory variables) and our initial hypothesized relationships between attributes of users and the choice factors.

Table 1.1 Hypothesized Relationships between Choice Factors and Their Determinants

HYPOTHETICAL FACTOR INFLUENCE	CHOICE FACTOR	FACTOR MEASURES
	Mode Attributes	
Age, Household size, **Income,** Occupation	cost	- Out of pocket cost vs. driver pay - Driver Benefits (driver pay, fare discount)
Age, Sex	Image	
Income, Marital status	Time Utility	- In-Vehicle Trip Time - Mode Access Time
Age, Sex, **Vanpool** familiarity	Physical / Mental Stress	- Safety - Other users' driving skills, - Convenience (Door-to-Door travel) - Vehicle **Driveability/Usability-** Comfort -Privacy/Atmosphere
Marital Status, Familiarity	Convenience	- Driver-Associated Tasks - Out-of-vehicle time
Marital Status	Extra benefits	- Driver Benefits (weekend van use)
	User Attributes	
Occupation, Sex, Income	Time Utility	- Possible Rider Activities
Sex, Age, Familiarity	Physical / Mental Stress	- Responsibility for others safety -Safety- Confidence in own driving skills
Sex, Occupation, Marital status, Household Size	Convenience	-Flexible trip scheduling requirements.
Age	Legal	- Permit to drive
	Environment Attributes	
Age	Physical / Mental Stress	- **Traffic** Conditions - Route Design - Weather Conditions - Scenery

The central focus of the table is the middle column; Choice Factors. The Choice Factors are outwardly measurable by Factor Measures. The influence of a particular factor on an individual's choice will be determined in part by his or her socio-economic characteristics. We call these characteristics the Determinants of Factor Influence, which are measurable characteristics of our respondents.

Ultimately, the model we estimate will indicate how the socio-economic determinants and factor measures are related to the drive/ride choice. At this point in the discussion, the table should be considered as a list of hypotheses regarding the answer to the first and second questions stated above -- what are the important factors in vanpoolers' decisions to ride or drive and what are the measurable attributes of users related to these factors?

Many of the entries in table 1.1 are self-explanatory. However, a few terms are explained below. ***Time Utilty:*** Time value or time utility is defined as the value the user derives from his use of travel time for a rider activity or the value of re-allocating his time from driving to rider activities. ***Physical/Mental Stress:*** Physical/mental stress may increase or decrease by some of the mentioned Mode Attributes. Environmental Attributes such as traffic conditions, surrounding scenery, weather, etc. may play a further role. Stress may also depend on User Attributes such as age, type of job, etc.; and even simply depend on the person's taste or temperament. For instance, some people may find it boring to be driven if they cannot find in-vehicle rider activities that are pleasant and/or useful to them. Therefore the physical or mental stress involved with driving may not always be determinable by observable user attributes, but may have a hidden 'taste' component.

Now we get back to the question of, to what extent we may be able to relate the vanpool study results to automated vehicle potential. The two choice scenarios should be kept clearly in mind. The study choice scenario is between vanpool driving and vanpool riding. The future choice scenario is between automated vehicles and non-automated vehicles.

Although automated vehicles do not yet exist for consumer purchase, we make some comparisons between the two choice situations based on a our assumptions about the attributes of the hypothetical new mode. While many choice factors are common to the two choice scenarios, some clearly only apply in the vanpool case. A few of the operational and behavioral assumptions about similarities and differences between vanpools and automated vehicles that we make are discussed here.

Convenience of Door-to-Door Travel

Automated private travel is envisioned as door-to-door travel, and in some cases vanpool travel is also door-to-door if the rider is picked up and dropped off at his work or home location. But as practical realities, both vanpools and automated vehicles offer the "ride" option for only a portion of the trip. Most vanpoolers must meet at some central pick-up point and may have to walk from a central drop-off point. Based on the quantity of road-way hardware and data required for true door-to-door navigation and operation, most automated systems will likely only guide the vehicle on major highways. In sum, the vanpool mode may not be dissimilar to an automated mode in terms of this aspect of travel convenience. On the other hand, another aspect of travel convenience is flexibility of trip scheduling. This is very limited with vanpooling, whereas it probably would not be so for automated private vehicles.

Privacy

Vanpoolers must chose to ride or drive a large vehicle which is shared with a number of other people who have a common destination; the automated vehicle owner chooses whether to drive or ride in her own vehicle. There is no privacy in a vanpool, and therefore for some, their ideal riding activity; listening to music, thinking, or working may be inhibited. Use of cellular phones and fax machines in single-occupant vehicles will be possible, whereas they might be judged too disruptive of other riders to be used in vanpools. For other vanpoolers, the company may provide interesting socialization. Face-to-face conversation, whether work related or social, will not be possible in a single-occupant vehicle. The automated vehicle provides the option of privacy. It is this difference which gives rise to the different activity sets from which vanpoolers and automated vehicle drivers may choose -- unless of course the automated vehicle itself is used for a carpool or vanpool.

User Cost

The operating cost of automated private travel may be higher or lower than the cost of vanpool riding, but perhaps most importantly, these costs may be paid in different ways. Vanpoolers usually make regular periodic payments. Automated vehicles will involve a higher initial purchase price than non-automated vehicles (or a purchase price to retro-fit an existing vehicle) and unknown future differences in operating costs between use of the automated vehicle in the manual and automated modes. If the initial purchase is amortized over several months, then automated vehicle costs are more easily compared to the periodic vanpool cost.

In addition, the vanpooler's driver benefits are very different from the automobile user's driver benefits. If the vanpool driver only receives a reduced fare, these would be easy to compare to the lower cost of using a non-automated vehicle. However, vanpool drivers also sometimes make net profits. Vanpoolers may also place underlying consideration on non-monetary compensation such as weekend use of the van. The differences in absolute amount, and type of financial impact make direct personal costs difficult to compare.

Image

The 'image' of automated private vehicles, being the latest in auto technology, may be appealing to image conscious drivers. If we hypothesize that younger people are more likely to make choices based on image, we note that younger workers are under-represented in vanpools.

Safetv Related Stress

In an automated vehicle, driving is done by machine, whereas in a vanpool the driver is human. This raises the question whether safety is perceived differently in these two cases. There will be some vanpoolers who only feel safe if they are driving and thus in a hypothetical choice, choose to always drive. For many, however, the decision to ride vs drive may be influenced by their perception of their fellow vanpoolers' driving skills. Drivers' skills will differ and there will be uncertainty regarding their actual skills. The "driving" skills of an automated vehicle will initially be uncertain. Increased certainty regarding the safety of an automated vehicle will prove important to their long-term viability.

We have discussed some of the more important differences between the study situation and a future automated scenario. These differences should be kept in mind when applying the study results, but are of secondary importance. The primary focus of this study is the value placed on substituting non-travel activities during travel time, and both todays vanpools and tomorrow's automated vehicles make this possible.

WHAT ARE THE APPROPRIATE TYPES OF STUDY INTERPRETATIONS?

The answer to the third and fourth questions regarding our ability to extrapolate to the automated vehicle case will be limited by the number of vanpool specific explanatory factors which are included in our final model specification and the extent to which any specific automated vehicle factors are excluded. Answers to these questions will be presented in the final chapter.

Based on the differences between the vanpool and automated vehicle drive/ride choice, we state the following caveats and conditions upon our conclusions. First, we make no claims about the potential size of the market for automated vehicles based on vanpool users drive/ride choices. Second, as stated earlier, we focus on the value to travellers of freeing their travel time from the activity of travel itself, that is, from driving. Third, because the possible activity sets may differ between vanpools and automated vehicles, we do not attribute the same value to automated vehicle owners of substituting other activities during travel time as we do to vanpool users.

We do analyze this previously unexamined aspect of vehicle automation -- that is, what are the benefits to the alternative uses of travel time?

2 THEORETICAL BACKGROUND AND APPLIED METHODOLOGY

PAST RESEARCH

In this section we review the literature on demand estimation for new transportation modes and other literature related to our study, such as of discrete choice analysis and value of time analysis. In our search we identified the following branches of literature connected with estimating demand for a new transportation mode:

1) demand estimation for a new transportation mode;
2) specific studies of the adoption process of a new transportation mode;
3) general theories of innovation diffusion, marketing and economics.

.Demand Estimation for a New Transportation Mode

We concentrate our survey of previous empirical work on demand estimation for new transportation modes. Methods used in the past for estimating demand for a new travel mode have varied. Some studies made aggregate predictions for specific geographical areas, while others focused on uncovering the important choice factors and finding acceptable measurement techniques for hard-to-quantify factors.

Most travel demand analysis is carried out by observing people's actual choices. However, when the new mode's attributes are not known with certainty or are substantially different from existing modes, researchers have used stated preference techniques (see for example; Costantino and Golob 1974 and Tischer and Dobson 1979). Most of these studies place little emphasis on regional aggregate projections. Where only a limited number of attributes are expected to differ in the new mode and these differences can reasonably be extrapolated from existing modes, aggregate estimates have been made using aggregate, or pseudo-disaggregate models. (see for example, Kanafani and Fan 1974 and Gordon, Williams and Theobald 1979).

Many travel demand models separate work from non-work trips in order to test the importance of differences in constraints and routine on non-discretionary and discretionary travel. Choices of mode for these trips are modelled using discriminant analysis or logit models. Factor analysis may be used to reduce the dimensionality of the choice setting by grouping explanatory variables into common factors. Verification of perceptual judgment and attitude summation theories have also been demonstrated (see for example; Costantino and Golob 1974 and Tischer and Dobson 1979).

Adovtion Process Studies

Some relevant considerations emerge from the area of adoption process studies. This research paradigm examines the innovation diffusion process; hypothesizing and categorizing different decision stages and studying the reasons for success or failure. (See Turrentine and Sperling 1989, for a synopsis). Turrentine and Sperling also extended these methods and apply them to the case of the market development of CNG (compressed natural gas) vehicles in British Columbia.

Some barriers to successful adoption are hard to quantify, eg. institutional and user barriers, which have no less important an impact than quantifiable factors. This indicates the importance of finding proxies or indicators of qualitative factors to include in a demand model. Therefore, adoption process models:

a) provide us with an understanding of the adoption process,
b) provide us with an awareness of the barriers to successful adoption, and therefore encourage us to search for as many potential barriers as possible, and
c) encourage cautious use of predictions based on quantitative models.

Travel Demand Analysis and the Value of Travel Time

Our goal is to develop a model which improves our understanding of the drive-ride choice decision process. As explained before, we do this by estimating the relative importance of different factors in the drive-ride choice of vanpoolers. In particular, we would like to be able to evaluate users' trade-offs between non-travel activities accomplished during travel time and travel cost. Below is a short overview of the methodological issues in the study of value of travel time. We have selected a few ideas and results that are directly related to our problem. Bruzelius (1979) contains a more detailed comparative analysis of the models used to determine the value of travel time.

Time Variables

In economic theory, demand for a good is estimated by constructing an individual utility function composed of the goods consumed by the individual, and maximizing this utility function subject to a budget constraint. A number of improvements which introduce consumption time into the utility function have been made, making it is more suitable for travel demand analysis. There are essentially three ways in which this has been done:

1) introducing a time budget constraint,

2) introducing an exogenously determined consumption time, that is, the consumer does not choose the amount of time each good is consumed; or

3) introducing an endogenously determined consumption time for each good, that is, the consumption time for a good is selected by the consumer.

Johnson (1966) and Baumol(1973) for example suggested use of a time budget constraint, but the time to be spent on any good is fixed and given by exogenous circumstances. Furthermore, consumption time itself is not assumed to be a direct source of utility.

A fourth approach introduces time into the utility function directly rather than treating time as a constraint. Among these models there are two further classifications: 1) those that allow the consumer to choose the amount of time spent on consuming a unit of the good (endogenous time parameters, and 2) those that don't (exogenous time parameters). Examples of the first type may be found in Evans (1972), Becker (1965) and de Donnea (1972) and examples of the second in De Serpa (1971).

Becker and de Donnea use the household production function with inputs of goods and time and outputs of activities. It is these activities, and not goods and time themselves, which produce utility. In addition, de Donnea further introduces a time utility function, and then it is not time alone that produces utility but the "time utility function", or the utility associated with spending time in a given activity. However, both Becker's and de Donnea's models also allow endogenous time requirements to be incorporated under specific assumptions about the production function; namely that the production function is not rigid and has constant returns to scale. Therefore Becker's and de Donnea's models can also be modified to incorporate endogenous time parameters(Bruzelius, 1979).

Values of Time

In all these models, values of time are derived by following the usual demand analysis. The values of time are obtained from the solution to the maximization problem which uses the Lagrangian of the utility function as maximand subject to budget constraints .

The development of the theoretical travel demand models are interesting to consider for our particular situation, since we are would like to be able to account for the differences in the utility or disutility of time spent in traveling in the two different modes - ride mode and drive mode. These models are informative about the importance of including separate time variables depending on the activity one is engaged in.

Discrete Choice Analysis

Many studies which use discrete choice analysis put the travel demand problem in a form more suitable for practical analysis by constraining the choice set from which individuals choose to only a few travel modes, for example. Further, the travellers' choices are usually restricted to one-time choices between the modes. Discrete choice models include terms to account for errors of measurement and individual deviation from the mean parameter values. Discrete choice models have been used to estimate values of time for both the in-vehicle trip and other (access time, waiting time, etc.) trip components (Quarmby; 1967 and Domenich and McFadden; 1975). Unfortunately, discrete choice models do not estimate values of time for modes between which travel time is reallocated to different activities, that is, modes between which there is no absolute time difference but only a difference in activity content.

DISCRETE CHOICE MODELS

Discrete Choice Model Derivation

Discrete choice models have their theoretical basis in the same economic theory discussed above. Refinements and departures from the above theory are summarized here (see also Ben Akiva et al (1987).

A subset of alternatives - modes, usually - is selected for the travel demand problem, and a one time choice between the two alternatives is allowed for each individual. This choice is based directly on the utilities of the two alternative modes. The chooser derives utility from each alternative based on attributes of the chooser and the choice alternative. A vector of socioeconomic attributes is introduced into the utility function to represent taste variation across individuals. It is assumed then that the individual chooses the alternative with the greatest utility. But since the model is probabilistic, the actual decision criterion states that each alternative is chosen with a probability which is some function of its utility compared to all possible alternatives.

Four different sources of error give rise to the probabilistic nature of the choice problem (Ben Akiva et.al. 1987); unobserved attributes (either of the alternative or the chooser), unobserved taste variation, measurement errors and the use of indicator or instrumental variables to represent difficult to quantify attributes.

In general the utility (U) a person (n) derives from mode(i) is expressed as a sum of observed (V) and unobserved (e) components:

$$U_{in} = V_{in} + e_{in}$$

The probability of selecting mode i for individual n is given by:

$$P_n(i) = Pr(U_{in} \geq U_{jn})$$
$$= Pr(V_{in} + e_{in} \geq V_{jn} + e_{jn})$$
$$= Pr(e_{jn} - e_{in} \leq V_{jn} - V_{in})$$

The specific statistical model we use will depend on the assumptions we make about the distribution of the set of unobserved components e_{in} and e_{jn}.

In large samples we expect the disturbances e_{in} and e_{jn} to be normally distributed. In this case, the distribution of $e_{in} - e_{jn}$ also would be normal. Using this assumption, we obtain the **probit** model. The **probit** model has not been commonly used in practice because the choice probabilities must be expressed as an integral. This "open form" presented computational **difficulties** until the recent advent of inexpensive and powerful computers. The logistic distribution is similar to the normal distribution, yet yields a closed form of the choice probability which requires less computation. Therefore the **logit** model is **often** used as an analytically simpler substitute.

The **logit** model is based on the assumption that $e_n = e_{jn} - e_{in}$ is logistically distributed, or equivalently that e_{in} and e_{jn} are Gumbel distributed. Thus the cumulative distribution function is:

$$F(e_n) = 1/(1 + e^{-\mu e_n})$$

The probability of selecting any one alternative, i, as e_n becomes arbitrarily small is then written as:

$$P,(i) = \frac{1}{1 + e^{-\mu(V_{in} - V_{jn})}}$$

$$= \frac{1}{1 + e^{-\mu\beta'(x_{in} - x_{jn})}}$$

where, without loss of generality because it is simply a scale factor, μ is arbitrarily assumed to be equal to 1. The likelihood function for a general **logit** model with one observation per respondent is defined as:

$$L^*(\beta_1, \beta_2, \ldots, \beta_k) = \prod_{n=1}^{N} P_n(i)^{y_{in}} P_n(j)^{y_{jn}}$$

and the log-likelihood function is:

$$L(\beta_1, \beta_2, \ldots, \beta_k) = \sum_{n=1}^{N} [y_{in} \log P_n(i) + y_{jn} \log P_n(j)]$$

The estimates of the β 's are obtained by solving for the maximum of L by differentiating it with respect to each of the β **'s** and setting the partial derivatives equal to zero.

Logit model with repeated observations

In our model each individual is asked to specify how she would allocate a month of van trips between driving and riding if she were given the freedom to choose. Thus instead of allowing an individual only a one time choice, she is allowed to choose many times over a month. The total number of choices each person made was usually between 20 and 22 (the range of work days in most months), but is sometimes less for people who did not use the **vanpool** 5 days per week. For reasons discussed later, we chose to adjust each user's total allocated travel days to add up to 22, while maintaining the stated desired proportion of riding and driving days.

Data File Structure

Repeated observations on the same individuals may be treated with two approaches, both yielding identical parameter estimates (see Ben Akiva et.al. 1987 and BMDP 1990). First, each individual's trip could be considered a separate observation and the usual likelihood function estimated. For example, if an individual rode the van 15 times and drove 7 times, she would have 22 data records. On each record, the explanatory variables will have the same values; but 15 records will have outcome Y = 0 (ride) and 7 will have outcome Y = 1 (drive). Alternately, a modiied likelihood function could be used with each individual having only one record, but with two outcome variables Y 1 and Y2. Using the same example as before, Y 1 = 15 and Y2 = 7. The data set in this second approach is said to be "packed". Note that with our data, the first approach has 22 times the number of records as the second, computationally simpler approach.

Likelihood Function for a Logit model with Repeated Observations

The Likelihood function for the packed version is the following (see Ben Akiva et.al. 1987);

$$L^* = \prod_{n=1}^{N} \frac{D_n!}{\prod_{j \in C_n} D_{jn}!} \prod_{i \in C_n} P_n(i)^{D_{in}}$$

where

D_{in} = number of times individual n chooses alternative i.

C_n = the set of alternatives for individual n.

and the log likelihood function is

$$L = \sum_{n=1}^{N} \left(\ln D_n! - \sum_{j \in C_n} \ln D_{jn}! \right) + \sum_{n=1}^{N} \sum_{i \in C_n} D_{in} \ln P_n(i)$$

If instead, each of the individual's 22 observations is a separate record, then the likelihood function will differ by the constant term in brackets. This fact has some relevance in the model testing stage, and will be discussed later. The difference is not important for statistical tests that use the difference between likelihood values.

In our study, each user chose a whole month's commute trips. But because not everyone travels to work the same number of days each month, respondents allocated a different number of total trips. Usually this was in the range 20-22. The data unpacking method we used did not allow us to create unequal numbers of records for each respondent. Therefore, each vanpool user's total trips were made to add up to 22. This was done by adding an appropriate number of ride and drive days to make the sum total 22 days, while maintaining the stated desired proportion of riding and driving days. Thus, in the final data tile, each respondent had 22 data records.

PRACTICAL METHODOLOGICAL ISSUES

Several methodological problems exist in any statistical analysis regardless of the models and estimation techniques chosen. Several of these issues are summarized here along with the assumptions used in this analysis to overcome them.

Missing Data

For variables which had missing data we checked the distribution of missing values and, where necessary and possible, estimated replacement values. Missing values were estimated by several methods. In some cases mean values were used and in other cases, missing values were estimated by regression. In almost all cases male and female data sets were considered separately for missing value estimation. Some data was estimated by comparisons only within the respondent's **vanpool,** and not over the whole data sample. Variables, such as expected tasks, benefits and driver pay, were considered to be heavily dependent on the **vanpool** to which one belonged.

Variable Scales

Three types of variables were not measured on interval scales: (i) variables whose underlying construct may be an interval scale; (ii) indices of related variables constructed as ordinal scales; (iii) attitudinal variables measured on ordinal scales.

Household income for instance, was measured in the questionnaire as an ordinal (ordered categories) variable for two reasons: (i) respondents may not know their household's exact income, and (ii) they may be more willing to state their best estimate of their income within a broad category rather than divulge the exact value.

For variables that were measured categorically, one would ideally wish to construct a set of dummy variables. However, in some instances, the assumption of interval scales was deemed necessary to reduce the number of dummy variables added to the model. In the latest analyses, more variables were transformed before modelling. Instead of using category **indeces,** category midpoint transformations were used on many more variables. That is, all respondents in each category were assumed to have the mid-point value of the category.

This assumption has two consequences. First, we impose the constraint that each **unit** change on the scale is the same "size" as any other unit change -- moving from the first to the second income category has the same impact on the drive/ride choice as moving from the fourth to the **fifth**. Second, statistical estimation may be less efficient and subject to potential bias. Measures of explained variance will be suppressed, for example since additional, non-experimental variance exists in the measure of income which cannot be explained by the model. Parameter estimates will be biased only if people within a category differ from the mean in some systematic but unknown way, eg. if most people within the category have incomes above the category mid-point.

Estimation Errors

There are several possible problems with using the estimated vanpool model to predict automated vehicle demand. In the first place, the estimated model may not exactly represent the vanpool drive-ride situation, and even if it does, the model may not translate exactly to the automated choice situation. The following types of errors may be identified (see also Greene 1990):

(i) Errors in coefficient estimates of included variables;

(ii) Specification errors, including

Untransformed variables,

Irrelevant variables,

Omitted variables, and

Untransferable variables

Model Specification Errors

Model specification errors may be caused by inappropriate variable specification, inappropriate functional relationships between variables, omitted variables or lack of explanatory variables which in fact are related to the dependent variable.

Non-representative Vanpool Sample

The sample may be unrepresentative of the vanpool population due to the sampling method or to non-response bias. In northern California, we were able to sample vanpoolers in a relatively random way, albeit within a single rideshare agency. Due to agency operating policy in southern California, we were able to exercise little control over the sample selection process. Thus our southern California vanpools could represent clusters having similar characteristics such as location of residence and workplace, and may therefore result in respondents with similar socioeconomic characteristics across vanpools. By including geographic region as an explanatory factor, we control for any systematic difference between vanpools from northern and southern California.

Non-response Bias

There are many possible explanations for non-response. We are interested in distinguishing random non-response from systematic non-response related to particular behavioral attitudes and population groups. We would like to identity possible causes of systematic non-response and their direction of bias in the model estimates. Three types of non-response may be identified:

1) Whole vanpools that did not respond,
2) Individual users who did not respond even when some fellow vanpoolers did, and
3) Individual non-response to particular questions only.

Whole vanpools that did not respond, may have done so because their driver did not distribute the surveys or transmitted negative attitude along with the survey or because there was a commonly held negative attitude towards surveys within the vanpool. Of the explanatory variables, rideshare duration and region may be two affected by these types of non-response in a systematic way. Newer vanpools may have many first time ridesharers who may be less committed to ridesharing, and hence less motivated to respond to a survey. On the other hand, experienced vanpoolers may have been the subject of surveys more often, and thus be more likely to reject another one. Thus the direction of bias in the case of rideshare duration is unclear. Geographical location was a non-response factor, as there were proportionally fewer returns from Southern California. The fact that vanpools in this region had been surveyed often in the recent past may offer a partial explanation. The different survey distribution method we needed to employ in the south may have played a role.

Individual vanpooler non-response may have been affected by their existing choice of rider activities. Those who do a lot of work on their trip may not have wanted to take time to answer a survey. In general, those who highly value their travel time for non-travel activities may have been less likely to respond to the survey. It is conceivable then that results of this study will underestimate the value of freeing travel time from the activity of travel itself.

Non-response to particular questions is a common problem in any survey effort. High and low income respondents may be unwilling to divulge their true household incomes. They may either refuse to answer the question or give untrue values. Some respondents may find certain questions too complicated and therefore not answer them. The connection between particular population groups and non-response to specific questions is hard to determine. Respondents with higher values of time may be more prone to answering their questionnaire hurriedly and to make omissions. These issues were addressed through careful survey design, pilot testing of questionnaire drafts and appropriate revisions to create a straightforward, clear questionnaire format.

.Model Transferability

Model transferability problems may arise even if there was a perfect vanpool drive-ride choice model. They could arise due to differences in sample and target population and/or differences in the alternative modes compared. We explore some of these expected differences here so that we may gain a better understanding of the qualifications that should be placed on our model estimates.

Differences between Actual Samples and Target Populations

This study is ultimately intended to assist in the prediction of automated vehicle travel demand within the general commuter population through an assessment of the value of freeing travel time away from driving to other travel activities. However, our survey is of a particular group of vanpoolers, while the target population is all commuters. It is apparent there are some differences between vanpoolers and other commuters. (see for example, Valdez and Arce 1990). If our vanpool sample under-represents particular commuter groups, simply applying the model results presented in this study could distort overall demand projections.

The potential transferability of explanatory variables from the vanpool model may be classified as follows:

1) Variables which have neither a direct nor indirect counterpart in the automated choice scenario (eg. expected driver tasks and expected driver benefits);
2) Variables which may have indirect relevance to the automated choice (eg. experience ridesharing, van atmosphere, van driving confidence, rider activity type "Work Discussion and Chatting"); or
3) Variables which may be directly related to the automated choice scenario (eg. socio-economic attributes).

We have discussed both sample and variable differences tbat we could expect in transferring the model to the automated situation. However, the complexity of these impacts make it difficult to predict their exact effect on an automobile drive-ride choice model. Even if we were to ignore complications of transferability, prediction of automated demand may not be directly possible. Socio-economic indicator variables which are more easily measurable did not always show up as significant in the logit regressions. Nevertheless, other explanatory factors provide insight into a commuters drive-ride choice and could thus have indirect predictive value.

3 THE RIDE-DRIVE CHOICE MODEL

In this section we move from the general review and outline of discrete choice models of the previous section to the development of our specific models of vanpool users drive/ride choice. Stated preference techniques most commonly involve a number of choice situations in which respondents must evaluate each alternative and choose one (see Kroes and Sheldon 1986). The alternatives may all be unfamiliar, hypothetical transportation modes (see for example Constantino and Golob 1974); or one of the choices may be familiar to the respondent while the others are unfamiliar (see for example Tischer and Dobson 1979).

In our study, respondents had to consider two alternatives; whether to drive or to ride in the van. The respondents were asked to give their stated preference between the two modes -- that is, how much riding and driving they would ideally do if they were free to choose. Not all users had current experience with both modes. However, both alternatives were familiar to all users; one alternative experienced; and the other, observable at first hand.

In stated preference analysis, values of each attribute (eg. time, comfort, price) of each choice are specified by the researcher. In our study, attributes of the alternative mode that a respondent had no experience with, had to be estimated. That is, if the respondent had never driven the van, then some "van driving" attributes had to be specified. Sometimes these estimates could be imputed based on data collected by actual users of the mode (by actual drivers). In some cases however, the attribute is highly subjective and the inexperienced choosers' perceptions were used to impute the attribute value, based on the assumption that these perceptions are the basis for choices.

RESPONSE VARIABLE

Each respondent in the survey was asked to state their ideal proportion of drive and ride days, assuming the existing fare and payment structure remains. The utility function used in travel choice analysis consists of mode attributes and socioeconomic attributes. It is formulated as an additive function and is linear-in-parameters. And while non-linear functions of the variables are sometimes used, it is more likely to be linear-in-variables too.

We define the systematic utilities Vin and Vjn for the two alternatives i and j for individual n as follows;

$$V_{in} = a_0 + b_{ti}t_{in} + b_{Ci}C_{in} + b_{Xi}X_{in} + b_{Zi}Z_{in} + b_S S_n \qquad \text{for alternative i;}$$

$$V_{jn} = b_{tj}t_{jn} + b_{Cj}C_{jn} + b_{Xj}X_{jn} \qquad \text{for alternative j.}$$

Where:

t_{in}, t_{jn} = time in the two alternatives i and j for person n;

C_{in}, C_{jn} = costs in the two alternatives i and j for person n;

Xin, X_{jn} = vectors of other mode attributes that have different values in the alternatives i and j for person n;

Z_{in} = vector of other mode attributes that have non-zero values in only one of the alternatives i or j, for all individuals n;

S_n = vector of socioeconomic attributes for person n;

a_0 = alternative specific constant;

b= coefficients of the variables.

If the coefficients, are alternative specific, then the utility functions are as specified in Eqns 1 and 2. If the coefficients are generic, then:

$$b_{ti} = b_{tj} = b_t$$

$$b_{Ci} = b_{Cj} = b_C$$

$b_{Xi} = b_{Xj} = b_X$ and

$$V_{in} - V_{jn} = a_{,,} + b_t(t_{in} - t_{jn}) + b_C(C_{in} - C_{jn}) + b_X(X_{in} - X_{jn}) + b_Z Z_{in} + b_S S_n$$

EXPLANATORY VARIABLES

There are three general variable types:

1) variables that have equal values in both alternatives - eg. Socio-economic descriptors of the individuals, and in our case under certain assumptions, in-vehicle time;

2) variables that have different values in the two alternatives - eg. cost, and under some assumptions, in-vehicle time and access time;

3) variables that have a non-zero value for one alternative and a zero value for the other alternative for all individuals. Examples include; expected driver benefits, expected driver tasks, rider activity times, van driveability, rider comfort, and under certain assumptions; access time.

Consider first explanatory variables which have equal values for all alternatives. Since the choice probabilities are a function of the difference in the utility of each possible choice, if we include such variables in the utility function of every alternative, when we take the difference, these descriptors disappear. In order to estimate the effect of gender, income etc. we must include them in the utility function of only one of the alternatives. In doing so, we can only interpret the resulting coefficients as the difference in effects, not some absolute effect. This is the common treatment for socioeconomic variables (see Amemiya 1981 and Ben Akiva et.al 1987).

There are two cases in which we will not obtain a definite estimate of the coefficient. That is, the parameter will not appear in our estimated utility functions. First, if the impact of the variable on each mode is the same, the coefficient difference is zero and the variable will not appear in the regression result (Amemiya 1981). Second, if the impact of the variable on each mode is zero, then also, the variable will not appear in the regression result. Unfortunately, it is not possible to distinguish the second, trivial, case from the first. If a variable does not appear in an estimated utility function we do not know if this variable is not an important factor for both modes, or if it is important but has equal effect on both modes. This may be important when we transfer a model to another choice situation where the choice alternatives are different or where we might expect the effect of the variable to be different.

Variables which have different values in each alternative's utility function may be specified as either alternative-specific or generic coefficients. If we specify generic coefficients, we assume the variable has equal impact in the driving and riding mode. If we specify alternative specific coefficients, then we assume the variable has a different impact on each mode. In general we assume the effects are symmetric between modes, and specify genericcoefficients. Only for travel cost and travel time in case 2 do we specify attributes as alternative specific.

Variables which are zero for one alternative and non-zero for others are included in only one utility function. The interpretation of the coefficient for such variables is similar to that of other variables which appear in only one of the utility functions -- they represent the difference in utility and thus the difference in choice probability between alternatives.

In summary, since the socio-economic characteristics (the vector S) of the user are the same regardless of which alternative she chooses, socio-economic attributes appear in only one of the utility functions. Those variables which have a non-zero value in only one mode, (the vector Z), are also input in only one utility function. To make interpretation simpler we include all Z and S variables in the ride choice utility function - even if a variable actually "belongs" to the drive mode. For such variables, the estimated coefficients will have the same absolute value as if they had been included in the drive mode utility function, since the logit model only calculates utility differences. Following the same convention, the alternative specific constant is in the ride utility function and will reflect a bias for (or against) the ride alternative, all other attributes being equal (Amemiya 1981 and Ben Akiva et.al. 1987). In sum, our convention is that variables appearing only once, regardless of which mode they actually characterize, would appear only in the rider utility function. This convention simply affects the sign of the estimated coefficient.

Description and Specification of Explanatory Variables

In this section we consider measurement, functional specification and coefficient specification of our explanatory variables. We classify variables into user and mode attributes as in Table 3.1. This classification is approximate since some mode attributes are dependent on the user. Mode attributes that require user ratings, for instance, make for less objective measurement. Similarly some user attributes may be dependent on the mode characteristics. For example, not only is the mode attribute "van comfort" measured on a scale by users, but it in turn may affect the possible rider activities. A complete listing of variable names, definitions and values is provided in Table 3.3.

Table 3.1 User and Mode Attributes

USER ATTRIBUTE%	MODE ATTRIBUTES
Socio-economic variables	Trip characteristics
Rider Activities	Vanpool Organization
Overtime Requirements	Van Driveability
Van Driving Confidence	Van Comfort
Ridesharing Familiarity	Atmosphere in Van

User Attribute Variables

Socio-economic Variables

As detailed above, all socioeconomic variables appear only in the utility function of the ride alternative. Household size and marital status were combined to give a set of dummy variables. Age was measured as a categorical variable and therefore the midpoint of categories was used to specify the variable as a continuous variable in the model. Number of household vehicles was measured as continuous variables and input as such. Household Income was measured as a categorical variable, so midpoints of the categories were established as variable values. Occupation was a categorical variable so was specified as several different dummy variables.

Rider Activities

Respondents indicated their rider activities from a list of more than 15 activities. For analysis we aggregated these activities into 4 similar activity types. Respondents indicated the time they spent in different activities, separately by morning and evening trips. For the analysis we summed morning and evening activity times. In some cases, the activity times did not sum to the user's stated total in-van time. In such cases the activity times were adjusted so they did sum to the user's stated total in-van time, keeping the proportions between activity times equal to the stated proportions, The final activity type categories are as follows:

Working Activities-- writing, reading, and thinking specifically for work;

Discussion/Chatting Activities-- work discussions and social chatting. The difficulty that respondents in our pilot survey had in distinguishing work conversations from other discussions convinced us to include any work conversation in a general "Discussion/Chatting" activity;

Necessary Activities -- eating, dressing, sleeping, and other activities deemed necessary to function at work;

Other Activities -- all other activities such as recreational reading, writing letters, playing games, watching videos, knitting, etc.

Rider activity variables are input into the model as time spent on each activity and are included only in the ride utility function, with the assumption that in the drive mode, the ride activity times were zero.

Overtime Requirements

We test two measures of the effect of work done outside the usual work day. Work may be taken home by some workers and each respondent indicated the number of days they took work home per week. Also, some vanpool users might be required to occasionally work overtime at their workplace. We asked respondents for the average number of days per week they worked overtime. Since these variables are descriptors of the person and her workplace and not of the travel choices, they are only input into the ride utility function.

Van Driving Confidence

Confidence driving the van was compared to confidence driving the respondents own car. The user stated whether she was either more, or less, confident driving the van than driving a car. The variable is only input into the rider utility function.

Ridesharing Familiarity

The length of time the respondent had been in this particular vanpool or ridesharing altogether is the measure of familiarity. It was measured as a categorical variable with seven categories, ranging from less than 1 month to more than 5 years. The midpoints of categories were selected to represent the data value and the variables were input as continous variables. The variable was only input into the rider utility function.

Current Van Driver Status

This variable had two categories; whether the user currently drove at all or rode only. The variable did not have any explanatory power in initial runs.

Mode Attributes

Trip Cost

Two different cost variables were tested: (i) round trip travel cost (S) and (ii) round trip travel cost divided by household wage rate per minute **($/$)**. The first was defined as the round trip fare for the ride mode and as round trip pay for the drive mode. The actual round trip fare for those who were currently riding the van was used for those who rode in the van. But for those who currently only drove the van, fare had to be estimated. The mean fare within the vanpool was used. For those who currently drove the van, a driver pay or fare discount was stated. For those who currently did not drive at all, driver pay had to be estimated. The mean driver pay within the vanpool was used. The theoretical justification for the second, non-linear specification of the cost variable is the hypothesis that choice between ride and drive will be less sensitive to cost among higher income vanpool users. Many discrete choice models use this transformed cost variable (Gaudry et.al 1989 and Ben Akiva and Lerman 1987).

In the questionnaire, incomes were presented in $10,000 brackets, so that the individual only chose the bracket she belonged to, and did not specify her exact annual household income. The midpoint of the income bracket was used as the data value. Annual income was converted to an equivalent wage per minute. The wage rate was measured per minute because in-vehicle time and other time variables were also measured in minutes, thus making interpretation of time and wage coefficients easier.

Trip Time

The time variables we considered for use were the following (all travel times refer to total of morning and evening travel):

TTMAP --	round trip total trip time from home to ultimate destination and vice versa;
VTMAP --	round trip in-vehicle time from vanpool pick-up point to drop-off point;
OUTTMAP --	round trip out-of-van or vanpool access time measured from home to pick-up point and from drop-off point to work place, and vice versa.

Thus, TTMAP = VTMAP + OUTTMAP.

For those respondents who chose to drive for some trips in their hypothetical choice, even though they did not currently drive, an assumption had to be made about their driving time. Similarly, for those who currently only drove, an assumption had to be made about riding time. We considered two possible hypotheses:

Case 1: Identical Mode Times: Riding Time = Driving Time = VTMAP;

Case 2: Different Mode Times: Riding Time = VTMAP, Driving Time = TTMAP.

Case 1 assumes the respondent acts as if driving time and riding time are equal to current in-van time, and neither driving nor riding time include access time. Access, or out-of-van, time is a separate variable, assumed equal in both modes. In this case, the time coefficient simply indicates how changes in total in-van travel time, affect vanpool users' choice to ride or drive.

Case 2 assumes that respondents act as if driving time is the door-to-door time, but riding time only includes in-van time. In this case, out-of-van time is zero for the drive mode. The trip time variable has different values for riding or driving in this case. If we specify generic coefficients for the time variables, we assume that time has equal impact on the probability of choosing to ride or drive. That is, a 10 minute increase in ride time has the same effect on the probability of choosing to ride as a 10 minute decrease in drive time.

Table 3.2 Travel Time and Trip Cost - Model Specification

Case 1: Identical Mode Times			
	Ride Utility Function	Drive Utility Function	Value of time
Time Variable	VTMAP	VTMAP	
Model Specification	VTMAP	0	
Time Coefficient	b_{VTMAP}	0	
Cost Coefficients			
a)	b_{COST}	b_{COST}	not applicable
b)	b_{RCOST}	b_{DCOST}	not applicable

Case 2: Different Mode Times				
			Values of time*	
	Ride Utility Function	Drive Utility Function	Ride Utility Function	Drive Utility Function
Time Variable	VTMAP	TTMAP		
Model Specification	VTMAP	TTMAP		
Time Coefficient	b_{VTMAP}	b_{TTMAP}		
Cost Coefficients				
a)	b_{COST}	b_{COST}	b_{VTMAP}/b_{COST}	b_{TTMAP}/b_{COST}
b)	b_{RCOST}	b_{DCOST}	b_{VTMAP}/b_{RCOST}	b_{TTMAP}/b_{DCOST}

Note: Final value of time calculations may use slightly different formulae, because of the specific cost variable used, or because of the measurement units desired.

Values of Travel Time

The value to time can be defined as the marginal rate of substitution between time and cost in a single utility function, (see for example, Bruzelius 1979, Yucel 1974 , Ben Akiva et.al. 1981). In this study, value of travel time can only be determined under case 2. In case 2, therefore, if we specify alternative specific coefficients for the time variables, then we could determine whether the value of time differs between the two modes. If we specify generic coefficients for the time variables in case 2, then only a single estimate of the value of travel time will be possible. In case 1, where travel times in the two modes are taken to be equal, value of time cannot be estimated. Model specification options for Travel Time and Travel Cost that we have discussed are summarized in Table 3.2.

Vanpool Organization Characteristics

The organization of **vanpools** may be expected to affect users choices of riding and driving -- even hypothetical choices of ideal ride/drive frequency. These organizational elements include how driving duties are assigned, expected driver tasks and benefits, and the method of driver payment.

a) Assignment of Driving Duties -This variable described different driving arrangements; if driving was open to all drivers, or done by a single driver.

b) Expected Driver Tasks - Tasks associated with being a driver - If the user was already a regular van driver, the amount of time she actually spent on driver-associated tasks was used. Users who currently did not drive, were asked to estimate the amount of time they thought was spent on driver-associated tasks by a regular driver in their **vanpool** .

c) Expected Driver Benefits - Many **different** methods for specifying the driver benefit variable were considered. If the user chose to drive exactly as much as she currently drives, expected driver benefits were equal to current driver benefits. If however, the user's stated driving allocation was more than the number of days she drove currently, expected driver benefits were estimated using current driver benefit packages available in her **vanpool**. The lowest, average and highest benefit packages currently available in her **vanpool** were identified. If the user chose to drive less than 5 days per month the minimum benefit package was assigned; if the user was going to drive between 5 and 15 days, the average benefit package was assigned; and if the user was going to drive more than 15 days, the maximum benefit package was assigned. Another method using only weekend driving availabiliy to describe driver benefits was tested, constructing dummy variables for specifying the variable.

d) Driver Payment Method - A categorical variable with two categories; if the driver was paid separately for driving, or if it was taken off her fare as a discount.

These four variables should only affect driver utility. That is, the values of the variables in the rider utility function should be zero. However, we adopted the convention that variables appearing only once, regardless of which mode they actually characterized, would appear only in the rider utility function. Therefore all four variables appear in the rider utility function. This convention simply affects the sign of the estimated coefficient.

Van Driveability and Comfort

Two separate indices of van amenities were constructed. The Van Driveability index counts driving enhancements which would make driving the van easier and more comfortable. While this variable should only affect driver utility, according to our convention, it appears only in the rider utility function. Van characteristics which primarily affect rider comfort were composed into the Van Comfort index. We assume that this variable would mainly affect rider utility and it appears only in the rider utility function.

Vanpool Atmosphere

Respondents rated the atmosphere in their vanpool on a three point scale. Unlike the other mode attributes described above, it was assumed that this variable, could affect satisfaction with either mode. However, since the value of the variable would be equal in both modes, it was input only into the rider utility function.

Table 3.3 Variable Definitions and Codes

Variable Name	Code	Value
Age	1	< 18
	2	18 - 19
	3	20 - 29
	4	30 - 39
	5	40 - 49
	6	50 - 59
	7	60 - 65
	8	> 65
Household Income - mid-point of category	$7,500	< 10000
	$15,000	10,000 to 19,999
	$25,000	20,000 to 29,999
	$35,000	30,000 to 39,999
	$45,000	40,000 to 49,999
	$55,000	50,000 to 59,999
	$65,000	60,000 to 69,999
	$75,000	70,000 to 79,999
	$100,000	> 80,000
Household Type	1	Single, no children
	2	Married, no Children
	3	Married, with Children
Occupation	1	Skilled/Unskilled
	2	Administrative/Clerical
	3	Sales
	4	Student
	5	Teacher/Professor
	6	Professional/Technical
	7	**Managerial/Executive**

Table 3.3 Variable Definitions and Codes(continued)

Geographical Region	1	Northern	
	2	Southern	
Work Activities	Total of morning and evening trip time spent in work activities		minutes
Essential Activities	Total of morning and evening trip time for sleeping dressing and eating		minutes
Other Activities	Total of morning and evening trip time for Recreational Reading conversation		minutes
Work Home Days	Number of days work is taken home		days/week
Van Driving Confidence	1	less confident driving than driving own car	
	2	as confident as driving own car	
Experience Ridesharing	1	less than 1 month	
	2	l-3 months	
	3	4-6 months	
	4	7-11 months	
	5	l-2 years	
	6	3-5 years	
	7	more than 5 years	
Current Van Driver Status	1	Not a driver	
	2	Share driving currently	
In-Van Time	Round Trip In-Van Time		minutes
Out-of-Van Time	Round Trip Out-of Van Time		minutes
Total Trip Time	Round Trip Door-to-Door Time		minutes

Table 3.3 Variable Definitions and Codes (continued)

Cost	Round Trip Travel Cost	$ per round trip
Cost / Household Income per minute	Round Trip Travel Cost divided by Household Wage per minute	($ per trip/$ per minute = minutes worked to pay for each trip)

Expected Driver Benefits	1	No late fee
	2	Weekend Van use
	3	Reduced fare
	4	**$50/month** from state
	5	Free ride to work
	6	Reduced fare + Weekend Van use
	7	Free ride to work +Weekend Van use

Expected Driver Task Time	Expected time spent on driver tasks	minutes

Van Driveability	Sum of Van Driveability attributes	*see definition below
Van Comfort	Sum of Van Comfort attributes	*see definition below

Atmosphere in Van	1	not relaxed
	2	reasonably relaxed
	3	very relaxed

The van driveability and comfort indices are defined as:

DRIVEABILITY INDEX = YEAR + AUTOTR + PWRSTR + PWRBRK + CRUISE +DBSEAT + AIRCON + TGLASS + RADIO + CASSET + PWRWIN.

COMFORT INDEX = YEAR + RRSEAT + RBSEAT + LIGHTS + DRINKH+ AIRCON + RADIO + CASSET + TGLASS + CARPET.

Where, the variables used in the van driveability and comfort indices are :

YEAR	Year of van manufacture
RRSEAT	Reclining Rider Seats
AUTOTR	Automatic Transmission
RBSEAT	Bucket Seats for Riders
PWRSTR	Power Steering
LIGHTS	Reading Lights for Riders
PWRBRK	Power Brakes
DRINKH	Drink-holders _ three
CRUISE	Cruise Control
RADIO	Radio
DBSEAT	Bucket Seat for driver
CASSET	Cassette Player
AIRCON	Air conditioning
CARPET	Carpet on floor
PWRWIN	Power Windows
TGLASS	Tinted Windows

All the variables in the driveability and comfort indices except year of van manufacture are simple dichotomies; 0 if the van did not have the attribute and a 1 if the van did have the attribute. For the variable YEAR, the following values were assigned based on the stated year of van manufacture:

1 = 1986 or less;
2 = 1987, 1988, or 1989;
3 = 1990, 1991, or 1992.

The decision to give each variable (except for YEAR) equal weight in the indices is clearly arbitrary. However, in the absence of some knowledge about attribute comparability, this system was selected in preference to exclusion of van comfort and driveability attributes in the model.

MODEL SELECTION

Our ultimate aim was to formulate the drive/ride choice as a discrete choice problem so that we could estimate values of travel time under our Case 2 travel time assumptions. The steps in devoloping our model are outlined. Domenich and McFadden (1975) detail model building strategies and variable selection methods. If one starts with a large number of explanatory variables, a method for selecting a subset is necessary. Since we have repeated observations on each individual, we initially created a dependent variable which was a proportion, (and hence continuous), for this explanatory variable selection stage. As our **first** step we ran a 'best subsets" linear regression of chosen driving proportion against all the explanatory variables. A subset of variables was selected in this way. Further refinements on this initial selection method are discussed below.

Sample Segmentation

We ran separate "best subsets" regressions on males and females to see whether the subset of significant explanatory variables or their coefficients were different between men and women. This was indeed found to be the case, so analyses from then on were done separately for males and females.

Theoretical Importance of Specific Explanatory Variables

It is sometimes recommended that variables not selected in a variable selection process such as best subsets regression, should be included in the model anyway because of their theoretical importance. We consider travel time and travel cost to be such variables. In our case, trip time and trip cost variables were not always selected by the best subsets regressions, but because of their theoretical importance they were included in further analyses.

Statistical Tests

A variety of statistical tests are available for choosing the "best" **logit** model in a discrete choice application. The criterion **-2[£(0) - £(ß)]** is a statistic used to test the null hypothesis that all the parameters are zero. It is c^2 distributed with k degrees of freedom; where f(0) is the value of the likelihood function when all parameters are zero, **£(ß)** is the value of the likelihood function when all the parameters take their estimated values, and k is the number of estimated parameters. However this test usually rejects few models. A stronger test is based on the criterion **-2[£(c) - £(ß)]**, where **£(c)** is the value of **the** likelihood function when all parameters but the alternative specific constants are equal to zero. In this case, we test the null hypothesis that independent variables add no explanatory power beyond the average utility of each choice. **Both** tests are presented with each model along with ρ^2 **and** $\bar{\rho}^2$ which are useful when comparing two models based on the same data.

Travel Time Multicollinearity

In the case 2 travel time specification, drive times and ride times may be correlated. Additionally, as is a common problem in travel demand modeling, travel time and travel cost variables are also often correlated. Separate trip time components such as access time and in-vehicle time are also frequently correlated in practical applications. We do not want to exclude these travel time components since they are of interest to the study's objectives. But they will only appear as significant variables in our model if by chance they are not correlated with each other in our sample or if their relationship to the drive/ride choice is especially strong. For all these reasons, we pursue two different definitions of travel time for the drive and ride choices. The case in which we assume that respondents perceive drive time and ride time to be equal, may seem less realistic, but it may be the only case in which travel time is a statistically significant explanatory factor of the choice to ride or drive.

4 SURVEY SAMPLE

SAMPLE SELECTION

A sample of 350 **vanpools** was selected from two sources: 175 each from RIDES in the San Francisco Bay Area and Commuter Transportation Services (CTS) in Los Angeles. Our final questionnaire was sent to the **vanpools** in November 199 1. Prior to this, a pilot survey was conducted to test the validity of questions and to do basic preparations for the computer analysis.

For privacy reasons we could not access the mailing addresses of **vanpool** drivers or coordinators directly. Rather, the rideshare agencies mailed the questionnaires to the individual drivers or coordinators. In San Francisco, BIDES used their database to randomly select vanpools, to which they then mailed questionnaires. In Los Angeles, CTS contacted the corporations with whom they had developed **vanpool** programs, and the corporation representatives in turn distributed the questionnaires to **vanpool** coordinators.

549 usable surveys were returned by 74 vanpools. The across **vanpool** response rate was thus **74/350** = 21%. Within vanpools, response rates varied from 3% to **100%,** with an average response rate of 80%. These figures are based on the number of returned questionnaires and driver/coordinator's response to a question which asked how many people were offered the survey questionnaire to be completed. The low response across **vanpools** compared to the high average response rate within **vanpools** indicates their may have been a problem with the method of questionnaire distribution. Additional evidence for this comes from the different distribution methods used in Northern and Southern California and the different response rates achieved in these two regions. We have no evidence however that the responses of non-respondents regarding the value of activity time would have been **different** from our respondents.

SAMPLE DESCRIPTION

A few descriptive characteristics of the sample are discussed here. This initial description is necessary to correctly interpret some of the model results which will be presented in section 6. We devote considerable attention to differences between men and women because the description given here and the modeling results indicated important differences in user attributes and valuations of activities based on gender. In total, there were 309 men and 220 women in the sample, 20 respondents declined to state their gender. We also present some regional differences between our two sub-samples. Initial differences on important variables based on gender were identified by (1) linear regression on all the variables and pooled data and (2) a best subsets regression on the two sexes separately and the pooled data.

Vanpool User Characteristics

The data on user type in Table 4.1 show that whereas less than half of all men only ride in their **vanpool,** nearly three-fourths of women **vanpool** users only ride. In addition, the percentage of men who drive only is nearly twice that of women who drive only. As we will show, this gender difference affects the stated value of non-travel activities and the ride/drive choices of women and men. The distributions of men and women on **usertype** are statistically **different** at a level < 0.0 1.

Table 4.1 User Type by Gender, Number (Row Percent)

	Backup Drivers	Alternate Drivers	Drive-only	Ride-only	Total
Male	53 (17.2)	81 (26.2)	34 (11.0)	141 (45.6)	309 (100)
Female	29 (13.2)	14 (6.4)	14 (6.4)	163 (74.1)	220 (100)
Total	82 (15.5)	95 (18.0)	48 (9.1)	304 (57.5)	529 (100)

Table 4.2 Regional Distribution by.Gender, Number (Row Percent)

	North	south	Total
Male	158 (55.1)	129 (44.9)	287 (100)
Female	138 (64.8)	75 (35.2)	213 (100)
TOTAL	296 (59.2)	204 (40.8)	500 (loo)

As shown in Table 4.2, while there are somewhat more men than women in both the northern and southern, California sub-samples, there are close to twice as many men as women in the southern California**sub-**sample. We do not know if this is a purely random occurrence, or if northern Californian **vanpools** had better success reaching female commuters , or **if the** proportion of females in the workplaces represented in each **sub-**sample is significantly higher in northern California. The regional differences are statistically significant.

Table 4.3 Age, Number (Row Percent)

	20-29	30-39	40-49	50-59	**60-65**	**70+**	Total
Male	23 (7.4)	71 (22.9)	120 (38.7)	76 (24.5)	15 (4.8)	5 (1.6)	310 (100)
Female	17 (7.8)	76 (34.7)	92 (42.0)	30 (13.7)	4 (1.8)	0 (0.0)	219 (100)
TOTAL	40 (7.6)	147 (27.8)	212 (40.1)	106 (20.0)	19 (3.6)	5 (0.9)	529 (100)

Overall, the distribution of respondent age shown in Table 4.3 is concentrated between 30 and 59 years, with 40% of the sample between the ages of 40 and 49. The age representation is not dissimilar to the general working population, although the under 30 years groups may contain fewer people than the general commuter population. While the median and modal age category for both men and women is 40-49 years, there are more women than men less than age 40 and overall the age distributions are statistically significantly **different**.

Table 4.4 Occupation, Number (Row Percent)

	Labor	Administrative	Professional	Management	Total
Male	20 (6.7)	22 (7.4)	162 (54.5)	93 (31.3)	297 (100)
Female	7 (3.3)	91 (42.7)	63 (29.6)	52 (24.4)	213 (100)
Total	27 (5.3)	113 (22.2)	225 (44.1)	145 (28.4)	510 (100)

Note: Administrative includes administrative and sales positions.
Professional includes professionals and teachers.

As the data in Table 4.4 show, most vanpoolers in the sample are in professional, technical, teaching, managerial or administrativeoccupations. The cross-tabulation of gender by employment type shows the proportion of females who are administrative workers is high, but perhaps not higher than the general working population. The percentage of males who have professional/technical occupations is higher than for women; the percentage of female vanpoolers who are managers is lower than for men in our sample. These differences result in statistically significant differences in the distribution of occupations between men and women.

Table 4.5 Household Income x $1000, Number (Row Percent)

	O-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80+	Total
Male	0	1		21	39	53	40	33	87	283
	(0.0)	(0.4)	(392)	(7.4)	(13.8)	(18.7)	(14.1)	(11.7)	(30.7)	(100)
Female	1		18	33	23	17	28	31	43	197
	(0.5)	(135)	(9.1)	(16.8)	(11.7)	(8.6)	(14.2)	(15.7)	(21.8)	(100)
Total			27	54	62	70	68		130	480
	(012)	(048)	(5.6)	(11.3)	(12.9)	(14.6)	(14.2)	(16343)	(27.1)	(100)

Note: Column label ‘O-10’ means $0 to $9,999.

As the household income data in Table 4.5 show, our sample includes mostly middle to high income householders -- 69% live in households with income greater than $50,000. The data also indicate men are consistently more likely to belong to higher income households than the women they travel with in the vanpool. The difference in income distributions is significant at $a < 0.01$ Differences in income may be explained by the larger number of women who live in single income households and differences in occupations.

Table 4.6 Marital Status, Number (Row Percent)

	Single	Married	Total
Male	26 (8.5)	281 (91.5)	307 (100)
Female	73 (33.6)	144 (66.4)	217 (100)
Total	99 (18.9)	425 (81.1)	524 (100)

Table 4.6 contains the distribution of respondents marital status by gender. Approximately 80% of all respondents are married. In the case of males, the percent married is even higher -- 90%. In contrast, a third of the female vanpoolers are single. Single persons are those who have never married or are divorced, separated or widowed. The differences between men and women are statistically significant.

Table 4.7 Household Size, Number (Row Percent)

	1	2	3	4	5+	Total
Male	25 (8.0)	78 (25.5)	80 (26.2)	99 (32.0)	26 (8.4)	308 (100)
Female	30 (13.9)	73 (33.3)	51 (23.3)	58 (26.1)	7 (3.3)	219 (100)
Total	54 (10.3)	151 (28.7)	131 (24.9)	157 (29.8)	33 (6.3)	527 (100)

The household size indicator tabulated in Table 4.7 shows the high proportion of non-single households, and although this indicator does not exactly show the proportion of households with children, the percentage of respondents belonging to households of 3 people or more, is 60%. The only noteworthy difference between the sexes seems to be the higher proportion of females who are single.

Table 4.8 Number Of Household Autos, Number (Row Percent)

	0	1	2	3	4	5+	Total
Male	2 (0.7)	37 (12.3)	172 (57.3)	64 (21.3)	23 (7.7)	2 (0.7)	300 (100)
Female	7 (3.2)	58 (26.6)	95 (43.6)	41 (18.8)	14 (6.4)	3 (1.4)	218 (100)
Total	9 (1.7)	95 (18.3)	267 (51.5)	105 (20.3)	37 (7.1)	5 (1.0)	518 (100)

Most women and men live in households which own two or more cars as shown in Table 4.8. But a much larger percentage of women than men live in zero or one auto households. The difference is likely due to the higher proportion of single female households. Overall the table indicates that women live in households with significantly fewer vehicles than do men.

TRIP CHARACTERISTICS

In this section we describe the trip characteristics of our sample. Comparisons between sexes are presented again, as well as some differences by region.

Table 4.9 **One-way** In-Van Time, minutes, Number (Row Percent)

	O-30	31-60	61-90	91-120	>120	Total
Male	1 (0.3)	120 (39.5)	142 (46.7)	35 (11.5)	6 (2.0)	304 (100)
Female	7 (3.3)	95 (44.8)	85 (40.1)	22 (10.4)	3 (1.4)	212 (100)
Total	8 (1.6)	215 (41.7)	227 (44.0)	57 (11.0)	2 (1.7)	516 (100)

Note: One way in-van travel time was calculated as the average of am and pm times.

The median one-way in-van travel time for the whole sample was 65 minutes. And as Table 4.9 shows, average travel times for most **vanpool** users are between 30 and 90 minutes. About 12 percent of **vanpools** travelled longer than one-and-one-half hours each way. Considering that virtually all vanpoolers travel in the van twice each day, the total in-van time which most **vanpool** riders might devote to non-travel activities is between one and three hours. The median time for males was only 5 minutes less than for females. (62 minutes versus 67 minutes). The distribution of average one-way travel times of women and men are not significantly different at a = 0.01, but are at a = 0.05. In sum, there is little evidence that in-van travel times are very different between men and women.

However, there is evidence that southern California **vanpool** users do spend more time travelling in the van than there northern California counterparts. There is a statistically significant difference (a < 0.01) in the distribution of reported average travel times for southern and northern California vanpools. Vanpoolers in southern California spend approximately 10 minutes longer in the van for each one-way trip. The median value for Southern Californians was 70 minutes and for Northern Californians it was 60 minutes. Approximately 50% of vanpoolers in northern California reported one-way in-van times of 60 minutes or less, but only 32% of Southern Californian vanpoolers did so.

Table 4.10 One-Way In-Van Time By Region, minutes, Number (Row Percent)

	O-30	31-60	61-90	91-120	>120	Total
North	7 (2.4)	139 (47.8)	111 (38.1)	29 (10.0)	5 (1.7)	291 (100)
south	1 (0.5)	65 (3 1.7)	106 (51.7)	28 (13.7)	5 (2.4)	205 (100)
TOTAL	8 (1.6)	204 (41.1)	217 (43.8)	57 (11.5)	10 (2.0)	496 (100)

Note: One way in-van travel time was calculated as the average of am and pm times.

Table 4.11 Round Trip Fare , **$,** Number (Row Percent)

	0.0	O-l	1.01-2	2.01-3	**3.01-4**	4.01-5	**5.01-6**	**>6.01**	Total
Male	8	0	3	15	48	100	39	58	271
	(3.0)	**0**)	(1.1)	(5.5)	(17.7)	(36.9)	(14.4)	(21.4)	**(100)**
Female	(015)	**(0.0)**	13	16	44	61	35	31	201
			(6.5)	(8.0)	(21.9)	(30.3)	(17.4)	(15.4)	**(100)**
Total		**0**	**16**	**31**	**92**	**161**	**74**	**89**	472
	(199)	**(0.0)**	**(3.4)**	**(6.5)**	**(19.7)**	**(34.2)**	**(15.5)**	**(18.7)**	**(100)**

No systematic significant differences between fares currently paid by males and females are apparent. That is to say, the chi-square statistic for Table 4.11 is significant at a **<** 0.01, but there is no tendency for women or men to consistently pay more than the other. Median round trip fare for the whole sample is $4.55 and the mean is $4.86; median fares for males and females are $4.60 and $4.50 respectively.

Table 4.12 Round Trip Fare By Region, **$,** Number (Row Percent)

	0	O-l	1.01-2	2.01-3	**3.01-4**	4.01-5	**5.01-6**	**>6.01**	Total
		0				**78**			
North	(159)	**(0.0)**	6	32	58	**(28.9)**	33	58	270
			(2.2)	(11.9)	(21.5)		(12.2)	(21.5)	**(100)**
South	4	0	10	2	33	74	36	33	192
	(2.1)	(0.0)	(5.2)	(1.0)	(17.2)	(38.5)	(18.8)	(17.2)	**(100)**
TOTAL		**0**	**16**	**34**	**91**	**152**	69	**91**	462
	(199)	**(0.0)**	**(3.5)**	**(7.4)**	**(19.7)**	**(32.9)**	(14.9)	**(19.7)**	**(100)**

The evidence for regional differences in fares is mixed. The difference in median values of round trip fares between north and south is a mere 4 cents. However, Table 4.12 shows no consistent differences between regional fares. Though the percentage of **vanpool** riders who pay $4.00 or less is 37% among northern Californians and 26% among southern Californians, 2 1.5 percent of northern Californian **vanpool** riders are paying more than $6.00 per trip while only 17.2% of southern Californians pay such high fares. Therefore, although there is some evidence that travel times are greater for Southern Californian vanpoolers, the evidence also suggests they may pay less per unit time travelled.

Table 4.13 Round Trip Driver Pay, **$,** Number (Row Percent)

	0	o-1	1.01-2	2.01-3	3.01-4	4.01-5	**5.01-6**	**>6.01**	Total
	57	**0**		**11**					
Male	**(36.3)**	**(0.0)**	(597)	**(7.0)**	25	26	10	19	157
					(15.9)	(16.6)	(6.4)	(12.1)	(100)
Female	**19**	**0**			**12**			**6**	**52**
	(36.5)	**(0.0)**	(747)	(328)	**(23.1)**	(137.5)	(328)	**(11.5)**	**(100)**
Total	76	0	13	13	37	33	12	25	209
	(36.7)	(0.0)	(6.2)	(6.2)	(17.6)	(15.7)	(5.7)	(11.9)	(100)

Table 4.14 Round Trip Driver Pay By **Region,$,** Number (Row Percent)

	0	O-l	1-2	2-3	3-4	4-5	5-6	>6	Total
North	(23912)		**0** **(0.0)**	(676)	**11** **(10.4)**	**19** **(17.9)**	**12** **(11.3)** **10** **(9.4)**	**16** **(15.1)**	106 (100)
south	43 (46.2)	0 (0.0)	3 (3.2)	2 (2.2)	16 (17.2)	18 (19.4)	2 (2.2)	9 (9.7)	93 (100)
Total	**74** **(36.7)**	**0** **(0.0)**	**10** **(6.2)**	13 (6.2)	**35** **(17.6)**	**30** **(15.7)**	**12** **(5.7)**	**25** **(11.9)**	**199(** 100)

There are no substantive differences between the compensation of men and women who drive their vanpools. The distributions in Table 4.13 are not significantly different and the median driver pay for males and females is $3.14 and $3.28 respectively.

There are differences in the level of compensation paid to drivers between geographic sub-samples, but in neither case does the average compensation exceed the average round-trip fare. Median driver pay in Northern California is higher than for Southern California --$3.69 vs. $2.40 . Part of this difference is reflected in Table 4.14. 46% of southern California vanpoolers receive no monetary payment or discounts for driving. Among those vanpoolers who do receive some monetary compensation, the median payments in the north and south are $4.00 and $4.30 respectively. Finally, the median driver pay is lower than median fare over the whole sample, over each sex and each region.

DRIVING PROPORTIONS

The distribution of stated choice of the ideal percent of driving days per month is shown in Table 4.15. Comparison to Table 4.1 which shows actual driving and riding duties shows the proportion of women who would ideally never drive is identical to the proportion who do not drive now. Slightly more men state they would never drive in their ideal choice (50.6%) than in fact never drive now (45.6%). For all respondent considered together, a majority of 60% preferred not to drive at all. A small percentage, **7%,** would like to drive all the time, 16% would like to drive over a quarter of their monthly trips and 9% would like to drive for more than half of their commuting trips.

The differences between the choices of respondents in the north and south are not clear. Table 4.16 shows that a slightly higher proportion of Northern Californians chose to drive more than half the time. (11% vs 7%) while a slightly higher proportion of Southern Californians chose to drive less than half the time. (93% vs **89%)**. These may give a slight indication that southern Californians were less keen to drive, but the differences are not large. On the other hand, a higher proportion of northern Californians, chose not to drive at all. (63% vs **55%)**, indicating a stronger preference for not driving at all in the north.

Table 4.15 Chosen Amount Of Driving Days,% of monthly trips, Number (Row Percent)

	0	o-25	26-50	51-75	76-99	100	Total
Male	133 (50.6)	78 (29.7)	26 (9.9)	4 (1.5)	1 (0.4)	21 **(8.0)**	263 (100)
Female	118 (75.2)	19 (12.1)	8 **(5.1)**	**1** **(0.6)**	**1** **(0.6)**	**10** **(6.4)**	157 **(100)**
Total	251 (60.0)	97 (22.9)	34 (8.0)	5 (1.2)	2 (0.5)	31 (7.3)	420 (100)

Table 4.16 Chosen Amount Of Driving Days By Region, % of monthly trips, Number (Row Percent)

	0	O-25	26-50	51-75	76-99	100	Total
NORTH	154 (63.4)	47 (19.3)	16 (6.6)	3 (1.2)	1 (0.4)	22 (9.1)	243 (100)
SOUTH	91 (55.5)	45 (27.4)	17 (10.4)	2 (1.2)	1 (0.6)	8 (4.9)	164 (100)
Total	245 (60.2)	92 (22.6)	33 (8.1)	5 (1.2)	2 (0.5)	30 (7.4)	407 (100)

SUMMARY

There were more women in northern Californian **vanpools** in than southern California vanpools. Differences in occupation between the sexes generally conformed to traditional patterns -- the women in our sample are more likely to hold administrative rather than professional and managerial positions. Women in general tend to be younger, to live in lower income households with fewer other household members and fewer autos per household, and are more likely to be divorced, widowed, separated or never married. Most importantly, three-fourths of the women in our sample only ride in their vanpools, whereas less than half of the male vanpoolers only ride. Some of the vanpooler characteristics and differences between the sexes identified here have also been noted in other **vanpool** studies (eg., Kumar and Moilov 1990).

For the whole sample, the representation of administrative workers and professional, technical and managerial workers was high; representation of **skilled/unskilled** workers was low. The income distribution of our vanpoolers appears to be skewed toward higher incomes than the general population. The lower-middle income households tend to be single person households, and thus single income households. Married households, with and without children, predominated, particularly among male vanpoolers. Differences in fare between region are slight. Median in-van time in higher in the south and median driver pay was higher in the north. Fares are usually higher than driver pay.

Both Tables 4.15 and 4.16 show a strong preference over all groups for not driving at all or driving very little. Given this background, we turn to the task of explaining the differences in drive and ride choices and estimating the value of substituting non-driving activities during travel time.

Given the myriad differences between men and women, we pursued modeling along two lines -- 1) including gender as an explanatory variable and 2) estimating separate models for men and women. The results of the latter strategy appear more robust and are the only ones discussed in detail in the following section. This outcome reinforces the conclusion that women and men perceive the alternative uses of travel time very differently, a point to which we return in the final section of this report.

5 VANPOOLERS RIDE/DRIVE CHOICES

ALTERNATIVE MODEL SPECIFICATIONS FOR DRIVING AND RIDING TIME

As we discussed before, we tested a variety of model specifications on the entire data set and on men and women separately. In addition, we tested two formulations of travel time which incorporate different assumptions as to how vanpoolers perceive their travel time. One model assumes that in-van time is identical for riders and drivers. The other model assumes that in-van times are different in the two modes: riding time = stated in-van time and driving time = stated total trip time. Thus,

Case 1) Driving time = Riding time = In-van Time;

Case 2) Driving time = Total Trip Time,
Riding time = In-van Time.

Under the first assumption, the impact of travel time on the drive-ride choice, can be obtained, but not an estimate of the value of travel time per se. The second assumption is based on a scenario where, if one is a rider one has to use designated pick-up and drop-off points, whereas if one is the driver, one is able to drive the van from door-to-door. Therefore under the second assumption in-vehicle time is longer. Unfortunately, in this second model there may be problems of multicollinearity:

Driving time = total trip time
= in-van time + out-of-van time
= Riding time + out-of-van time

Since driving time and riding time are thus linear functions of each other, models estimated with both these variables as explanatory variables may not yield significant results for either or both of the travel time variables. Since this is the only model from which values of time may be estimated, the estimated values of time may prove unreliable.

As described before, early linear regressions indicated that a difference in models between males and females would be necessary to accurately describe vanpooler choices. However, the best logit model estimated on the pooled data did not contain the sex variable. Other pooled data models which did include sex as an explanatory variable performed less well on the ρ^2 and $\bar{\rho}^2$ criterion and the variable was not of statistical significance. This could be due to correlations between sex and other choice variables.

Estimated coefficients for the case 1 model are presented in Table 5.1 Statistical significance of coefficients is usually at the 1% level. If a coefficient is only significant at the 5% or 10% levels, this is noted specifically.

Table 5.1 Coefficients for Best Models for each Gender, Case 1

Variable Name	Male β	Male est/s.e.	Female β	Female est/s.e.
Ride Constant	4.1715	9.43	1.6481	3.04
Age*	0.0375	7.63		
Single No Child Dummy	-0.1839	-1.08	0.5812	3.12
Single With Children Dummy	0.1774	0.48	0.2067	0.88
Married With Children Dummy	0.2428	2.56	-0.3078	-2.11
Number of Autos in Household	-0.2833	-4.59		
Skilled worker Dummy			-1.4523	-4.49
Professional worker Dummy			-0.0689	-0.44
Manager Dummy			-0.397	-2.62
Region			1.6669	9.86
Time in current Vanpool*	-0.0097	-5.13		
Total Rideshare Time*			-0.0158	-6.4
Overtime days			-0.2857	-5.9
Work Home days			0.2778	5.58
Van Atmosphere			0.8195	6.86
Confidence in Van Driving	-1.0087	-9.38	-1.8457	-12.12
Van Comfort	0.303 1	8.98		
Van Driveability	-0.2017	-5		
Rider Activities - Work	0.0147	7.65	0.0033	1.1
Rider Activities - Necessary	0.0176	15.9	0.0075	4.16
Rider Activities - Other	0.0096	6.68	0.0037	1.41
Rider Activities - Conversation	0.0049	3.03	0.0034	1.2
Driver Duties	0.0016	4.56		
Out-of-veh time			0.0012	0.83
In-van Time	-0.019	-14.46	-0.0027	-1.29
Round trip cost/Household wage rate	-0.019	-4.73	-0.0046	-1.54
# respondents	5952		4114	
# parameters	17		20	
$\mathcal{L}(0)$	-2700.62		-1798.75	
$\mathcal{L}(c)$	-2560.935		-1379.945	
$\mathcal{L}(B)$	-2134.04		-1065.879	
$2[\mathcal{L}(0)-\mathcal{L}(B)]$*	-1133.16		-1465.742	
$2[\mathcal{L}(c)-\mathcal{L}(B)]$*	-853.79		-628.132	
ρ^2	0.209796269		0.407433495	
$\bar{\rho}^2$	0.203501418		0.396314663	

Notes
1. When reading the results of dummy variables, it should be remembered that the category which is not stated is the base dummy, with which all other dummy categories should be compared within that variable set. For example, all household type variables should be compared to the Married No Children category, for both males and females.
* These variables were treated as continuous variables, with the estimated data value being the midpoint of the category stated by the respondent.

CASE 1: IDENTICAL RIDE AND DRIVE TRAVEL TIMES

Alternative-Specific Constant

The alternative specific constant is only specified in the Ride Utility Function. It is statistically significant in models both for men and women. The positive sign for the constant in the models indicates, that other things being equal, there is a general preference for riding as opposed to driving.

User Attributes

Many forms of household size and marital status variables were considered before selecting a set of combined householod size - marital status dummy variables. Males and females seemed to react in opposite ways to being married. Single males were more likely to drive than married males while single females were less likely to drive than married females. Their reaction to having children was also opposite. While males with children were less likely to drive, females with children were more likely to drive.

Age was a factor in the choice of men but not of women, with older men being less likely to want to drive.

The effect of income on the drive/ride choice enters the models estimated separately for men and women through the ratio of the round-trip fare to wage rate. The ratio increases as cost increases and as income decreases. It is a measure of the financial burden of riding. When income decreases, the ratio increases, and the respondent is more likely to choose a higher proportion of driving days. The effect is stronger among men than women.

None of the occupation dummy variables were statistically significant or robust at the initial stages of variable selection in the male data set. On the other hand, occupation was a statistically significant choice variable for women. Women with professional and administrative occupations are almost equally likely to drive, but women in managerial occupations are more likely to drive than administrative workers.

This is contrary to what we expect if we assume traditional income and occupation correlations. We should expect those in managerial occupations with traditionally higher incomes to be more likely to want to avoid driving. Possible reasons for the contrary result could be correlations with sociability, marginal **utilty** of income and sense of responsibility.

(i) Sociability: administrative workers may work in more social settings, be more likely to travel with fellow workers and enjoy extending these relationships, while managers may work more independently, and so may find it more difficult to derive the social benefits of vanpooling.

(ii) Marginal Utility of income: Managers may be more likely than administrative workers to come from larger households, and therefore have greater need for additional income. We earlier noted that many administrative workers were single. Also, a worker's occupation may not reflect total household income since her spouse may have a very different income; i.e. in some instances a female administrative worker may come from a household with a higher total income than a female managerial worker.

(iii) Responsibility: Females in managerial occupations may also be more likely to want to drive due to a customary sense of responsibility and a greater confidence in adopting a role of active participant. In fact, proportionate to their occupation group size, the highest number of current drive-only users are managers while they are the lowest in ride-only users.

Trip Characteristics

Round-Trip Travel Cost

Some **vanpools** gave small fare discounts that primarily affected out-of-pocket costs. But others offered high rates of driver pay. For both men and women, the higher the cost of riding, the more likely they are to choose to drive more days, although for women the coefficient is only statistically **significant** at the 10% level.
Those **vanpools** that offered relatively high driver pay rates introduced an additional financial consideration. Depending on the relative rates between driver pay and fare, a user who drove more than he rode, could sometimes earn extra income; and then, depending on the user's economic circumstances, this extra income might be perceived differently than an equal lowering of out-of-pocket cost. Therefore although we used a common modelling simplification of assuming equal coefficients for driver and rider 'cost', the **coefficients** could in actual fact be different.

Round-Trip Travel Time

As in-van travel time increases, men are more likely to choose to drive. The coefficient for women is only significant at the 10% level. The negative relationship between in-van travel time and the choice to ride could be due to the correlation between time and cost; because both driver pay and rider cost increase with trip length (across the sample). Similarly for women, the correlation between time and cost makes it hard to elicit the individual explanatory power of this travel time. The appropriate substantive interpretation in this case is that as in-vehicle time increases, women do not show as clear a preference for driving as men do.

Out-of-Van Time

Gut-of-van time is not a statistically significant explanatory factor in the decision to drive or ride. This may be because out-of-van-time or access time may be correlated with in-van time. That is, because the longer the in-van trip segment, the longer maybe the access time.

Geographical Region

Location was a statistically significant explanatory variable only for females. Females who live in Southern California are more likely to choose to ride than their counterparts in Northern California. Average travel times and distances are longer in southern California, and thus we would expect vanpool users there to be more inclined to drive based on the results reported above for travel time. However, since the region variable gives exactly the opposite result, it indicates that there may be other issues apart from issues of travel time. The worse traffic conditions in southern California may be the reason why women respondents from southern California show a stronger preference for riding than do their northern California counterparts.

Overtime and Davs Work Taken Home

Work taken home

Table 5.2 shows that 23% of women and 33% of men took work home at least 1 day per week. The percentage of males who took work home 4 or more days per week was also higher than the corresponding percentage for females (8.3% versus 4.6%). However, "Number of Days the User took Work Home" was absent from the model for men. For women, on the other hand, the number of days the user took work home was a significant explanatory factor. However, this variable is correlated with occupation and rider work activity. This may explain:

(i) the insignificant coefficient for rider work activity in the female model because the occupation and take-work-home variables are already present.

(ii) the absence of take-work-home in the male model, because the rider work activity variable is highly statistically significant.

Table 5.2 Days Work Is Taken Home Per Week, Number (Row Percent)

Number of Days	0	1	2	3	4	5	Total
Male	203 (67.4)	0 (0.0)	61 (20.3)	12 (4.0)	23 (7.6)	2 (0.7)	301 (100)
Female	168 (77.4)	1 (0.5)	31 (14.3)	7 (3.2)	9 (4.1)	1 (0.5)	217 (100)
Total	371 (71.6)	1 (0.2)	92 (17.8)	19 (3.7)	32 (6.2)	3 (0.6)	518 (100)

The importance of the number of days work is taken home increases in occupations where: 1) work is not physically linked to a specific work location and 2) work cannot be completed in an eight hour work day. Primarily these occupations are professional and managerial, but could include others which include some "paper work" responsibilities. Most of these take-home work tasks are not prescribed by the employer, but rather chosen by the individual. The travel time spent on work activities rather than on driving can have three types of benefits:

(i) it can reduce the amount of time spent on office work while at home, thus leaving time for leisure activities **and/or** home care activities;

(ii) it can improve the person's performance on existing projects thus earning employer recognition and future benefits, or immediate earning increases; and

(iii) it can allow the person to increase his/her task load to earn extra income, and/or improve job status

Overtime

The number of days a respondent did overtime at work was obtained in addition to information about the number of days work was taken home. The modal and median values for overtime at work and taking work home are both zero. Nevertheless there are some small differences in the pattern of distribution. While the next most common overtime rate is 1 day per week those who take work home are unlikely to do so only 1 day a week. Taking work home is next most likely to occur 2 or 4 days per week. In addition, a sampled vanpooler is on average more likely to be a take-home-worker than an overtime worker.

Table 5.3 Overtime Days at Work, Number (Row Percent)

Number of Davs	0	1	2	3	4	5	Total
Male	244 (81.1)	23 (7.6)	5 (1.7)	4 (1.3)	23 (7.6)	2 (0.7)	301 (100)
Female	184 (84.4)	17 (7.8)	5 (2.3)	3 (1.4)	9 (4.1)	0 (0.0)	218 (100)
Total	428 (82.5)	40 (7.7)	10 (1.9)	7 (1.3)	32 (6.2)	2 (0.4)	519 (100)

For males again, the best models do not contain the overtime variable, and it should again be remembered that on the other hand the rider work activity variable for men is very highly statistically significant. For females only, models containing the variable for the number of overtime days have higher explanatory power than those that exclude the variable. Unexpectedly, the coefficient has a negative sign, indicating that the probability of wanting to ride decreases with the number of days needed to do overtime at work. One would think that doing overtime would make it difficult for one to be a driver. But since our question was worded in hypothetical terms, respondents may have been reflecting their desires rather than the practicality of driving. Another reason could be that overtime at work, (to the extent that it represents *paid* overtime), is often done voluntarily by those who are trying to earn more money, and that since driving gives the opportunity of saving money, and in some cases even earning extra income, those who work overtime may also be those users more likely to want to drive.

Vanvool Organization

Expected Driver Tasks

Among men, the amount of time they expect to spend on driver-related tasks (other than driving) is a statistically significant factor in choosing to ride -- the higher the expected task time, the greater the probability of riding. This is not true for women -- the time they expect to spend on driver tasks plays no role in their choice whether to ride or drive.

Rider Activities

Extensive use of travel time for non-driving activities caused users, particularly men, to choose higher proportions of riding days. The importance of various rider activities differed between males and females. The more time women spent on essential activities (eating, sleeping, preparing for work), the more likely they were to choose to ride. "Other" activities (such as recreational reading, hobbies, etc) were only statistically significant at the 10% level, so may not be a primary choice factor for women Work and Conversation are activities that were shown to be choice factors of very little importance for females.

For males, all rider activities were statistically significant and had positive signs. Thus the more time spent in all rider activities, the more likely men are to choose more riding days. With the exception of conversation, the magnitude of the rider activity coefficients is between two and three times larger for men, indicating that the drive/ride choice for men may be more affected by the time they spend in non-driving activities.

Stated Van Driving Confidence

Table 5.4 shows that men are more likely than women to feel as confident driving a van as driving a car. 54% of females said they felt, or would feel, less confident driving a van as opposed to a car. In contrast, 32% of male respondents indicated a similar difference in confidence. It should be noted that actual operator risk may not be absolutely correlated with stated vehicle operating confidence, since people's perception of and attitudes towards potential risk will be different.

Table 5.4 Confidence Driving Van, Number (Row Percent)

	Less Confident	As Confident	Total
Male	90 (31.5)	196 (68.5)	286 (100)
Female	102 (54.0)	87 (46.0)	189 (100)
TOTAL	192 (40.4)	283 (59.6)	475 (100)

Notes: Categories are defined as:
- the **vanpool** user feels less confident driving a van than driving an auto.
- the **vanpool** user feels as confident driving a van as driving an auto;

Stated van driving confidence was statistically significant in the model for males and females. Due to the definition of the variable, it seems reasonable to suppose that relative confidence driving the van is related to vehicle size. Van size could be a cause of higher stress among drivers who are in fact generally less confident about driving. Therefore, the confidence factor could be reflecting a user's general attitudes about driving.

Another aspect of riding and driving confidence has not been discussed here. Since our discussions have focused around the choice between two modes, what we should also consider is relative confidence between one mode and another. Confidence about being the driver oneself should be compared with confidence being driven by another vanpooler. The latter aspect was not analyzed in the survey. In a parallel automated choice situation, the question would be "do you feel more confident with the automated machine's driving capabilities or do you feel more confident driving yourself?"

Ridesharing Familiarity / Commitment

Table 5.5 shows that approximately 60% of users sampled have been ridesharing for 3 or more years. Differences between sex groups are not large nor are they statistically significant.

Table 5.5 Total Rideshare Experience, Number (Row Percent)

	<1Month	I-3M	4-6M	7-11M	1-2Years	3-5Y	>5Y	Total
Male	3 (1.0)	13 (4.2)	12 (3.9)	19 (6.2)	60 (19.5)	76 (24.7)	124 (40.3)	307 (100)
Female	2 (0.9)	15 (6.8)	11 (5.0)	13 (5.9)	51 (23.3)	49 (22.4)	78 (35.6)	219 (100)
TOTAL	5 (0.9)	28 (5.5)	23 (4.3)	32 (6.0)	111 (21.1)	125 (23.7)	202 (38.0)	526 (100)

Note: M stands for months. Y stands for years.
The table reflects total ridesharing time up to the survey date.

Table 5.6 Experience Riding Current Vanpool, Number (Row Percent)

	<1 Month	1-3M	4-6M	7-11M	1-2Y	3-5Y	>5Y	Total
Male	8(2.6)	25(8.1)	25(8.1)	34(11.1)	90(29.3)	65(21.2)	60(19.5)	307(100)
Female	4(1.8)	29(13.2)	27(12.3)	16(7.3)	51(23.2)	56(25.5)	37(16.8)	220(100)
Total	12(2.3)	54(10.2)	52(9.9)	50(9.5)	141(26.8)	121(23.0)	97(18.5)	527(100)

Two different rideshare experience measures were available. Total length of time spent ridesharing was not an important determinant of men's' choices to ride or drive, but was important for women, while the length of time in the current vanpool was a choice determinant for men. Some possible reasons why rideshare experience would be a drive-ride choice factor are suggested below:

(i) Someone unsure about driving a large van may find an increased confidence after he or she has been able to observe other drivers for a while;
(ii) Familiarity with the operation of vanpools, its available driver benefits and driver-associated tasks, as well as familiarity with fellow riders, increase over time and may play a role in the decision to drive;
(iii) Length of time ridesharing may also be connected with a user's commitment to the mode, both on a moral and practical level, that may give her a stronger desire to ensure the vanpool's continued operation by choosing to drive more;

Time in the current vanpool and total time ridesharing are choice factors for males and females respectively. They are similar, in that both represent familiarity with vanpool operation characteristics, and riding with others.

However, riding in one's own vanpool also allows one to attain a more specific impression of vanpool driving. For example, it gives one a chance to assess the driving pay schedules, exact driving arrangements, driver associated tasks and benefits and the driving ability of fellow commuters. We may conclude, that these aspects of vanpool driving are considered important by males, and not as important to females. To corroborate this evidence we find that Van Comfort and Van Drivability are also factors that only affect mens' drive-ride choice. On the other hand, the ability to make use of ride time for rider activities may be somewhat dependent on specific vanpool companions but should be possible in most cases, to be determined after any rideshare experience.

Van Atmosphere

Table 5.7 Van Atmosphere, Number (Row Percent)

	1	2	3	Total
Male	4 (1.3)	109 (36.5)	186 (62.2)	299 (100)
Female	2 (0.9)	89 (42.0)	121 (57.1)	212 (100)
TOTAL	6 (1.2)	198 (38.7)	307 (60.1)	511 (100)

Note: 1 = atmosphere not relaxed
2 = atmosphere reasonably relaxed
3 = atmosphere very relaxed.

Most respondents considered the atmosphere in their van to be very relaxed. Only a few people considered van atmosphere to be not relaxed. There is no statistical difference between the distribution of men and women on their perception of vanpool atmosphere.

Somewhat surprisingly then, van atmosphere is a statistically significant choice factor for females but not for males. As perceived van atmosphere becomes more relaxed, women are more likely to choose to an increased proportion of riding days. One interpretation is that women are more attuned to the vanpool as a social setting. In fact we find that on average women state that they spend approximately 50% more time in "conversation" than men. The mean values are approximately 16 and 24 minutess for men and women respectively. The median values are 10 and 15 minutes respectively. We do not find "conversation" to be an explanatory choice factor in the best available statistical models for females however.

The greater time spent on social rider activities and the importance of van atmosphere as a choice factor for women still adds up to our interpretation that women may, in general, be more influenced by the vanpool as a social unit rather than a mere mode of transportation.

Van Driveability and Van Comfort

The van driveability and comfort indices are constructed from a number of van attributes and amenities. (The exact construction of the indices is contained in section 3). Both van driveability and van comfort were statistically significant choice factors for men but not for women. Both these results may be due to the smaller relative number of women who currently drive the van. Lacking direct driving experience, women may not consider these attributes as important to their drive/ride choices.

SUMMARY

The model with the most robust statistics includes the assumptions that models should be estimated separately for women and men and that driving time is considered equal to riding time by the respondents. Under these assumptions, the most influential factors explaining men's ride/drive choices are the time they spend on rider activities, in-vehicle travel time, their confidence driving the van, and their assessment of the van's driver amenities. The largest influence on women's ride/drive choice was van driving confidence. This was followed by the region they lived in; northern or southern California, their assessment of the vanpool atmosphere, their rideshare experience and workplace and out of workplace overtime requirements. Both men and women tend to place greater importance on activities essential to prepare for work in choosing to ride or drive. In addition, men who use travel time to accomplish specific work-related tasks and other miscellaneous activities are also shown to have a higher probability of choosing to be driven.

The case 2 model in which we assume respondents do not consider driving time to be equal to riding time yields non-robust results. This could be due to multi-collinearity between the measures of time The case 2 results are not presented.

6 CONCLUSIONS AND EXTENSIONS TO AUTOMATED VEHICLE TECHNOLOGY

VANPOOL USERS CHOICE TO RIDE OR DRIVE

This study demonstrates that the majority of vanpool users would prefer not to drive, if given a free choice. Their reasons for doing so may, however, be different. In particular, men and women differ in their motivations; and men and women in different lifecycle stages and with different income, occupations and geographical locations may react differently.

For women, the primary motivation to ride rather than drive, may be their lack of confidence driving; evidenced by the importance of the stated van driving confidence variable in the model and the importance of regional differences perhaps due to traffic conditions. Familiarity with ridesharing increase their chances of driving perhaps because it improves their confidence. Although the link is somewhat more tenuous, one reason why women managers seem to want to drive more may be because they are more confident due to age and occupation features.

Reasons why women in managerial occupations may want to drive were discussed before; such as a possible lower valuation of the social benefits of vanpooling, a higher sense of responsibility towards the vanpool and a greater sense of driving confidence.

Women seem also to weigh social aspects highly, in that a more pleasant van atmosphere is more likely to make women wish to ride.

For men, the primary motivation to ride rather than drive, may be the ability to rest, relax and finish small acts such as eating and dressing up. Men may in fact be using ride time as respite and thinking time away from family or work stresses, because older, married men with children are more likely to want to ride. As a result too, perhaps, van comfort is shown to be a significant explanatory factor. Ability to work while riding is of slightly less importance in their drive ride choice. Driving confidence is also important for men, evidenced by the variable measuring stated driving confidence, and the fact that older men prefer not to drive.

Travel cost was an explanatory factor for both men and women. Men and women may also indirectly indicate financial concerns. For instance, men are more likely to drive if the trip is long and this could be due to additional income they could earn by driving. Women who are married with children and who may thus have greater financial burdens are more likely to want to drive. Women who do more overtime (perhaps to increase income), are also more likely to want to drive.

The only factor left in common between vanpools and automated vehicles is the substitution of non-travel activity during travel time,

EXTENSIONS TO AUTOMATED VEHICLES

These results may be extended to the automated vehicle case. To do so requires we return to the questions raised in the Introduction:

1) What factors will play a part in vanpoolers' decisions?
2) How are these choice factors related to observable user characteristics?
3) Do the factors important in the vanpool choice situation differ from the factors important in the automated vehicle choice situation?
4) Are these differences significant to predictions about automated vehicle choice behavior?
5) What are the differences between our actual sample of vanpoolers and the target sample of potential automated vehicle buyers?

The answers to the first two questions are complicated by the fact that men and women respond to different aspects of their vanpools in making their drive/ride choice. Because different explanatory factors affect women and men's choice to ride or drive, our results clearly indicate that extensions to the automated vehicle should be made separately for men and women.

There are some statistically significant demographic variables in both male and female models. However, many of the important explanatory variables for both men and women are specific to the vanpool choice setting -- van driving confidence, vanpool atmosphere and ridesharing experience. These two facts together-- the few socio-demographic descriptors and the choice setting specific factors -- imply that conceptual extensions to the automated vehicle choice are appropriate, but specific numerical results will not apply to automated vehicles.

Therefore, to summarize, our inferences regarding extension of the vanpool results to the case of automated vehicles are:

> Van driving confidence is important to both men's and women's choices whether to ride or drive. We expect that the perceived safety of turning the vehicle over to the automated system will affect both groups.
>
> Women appear to be more inclined to base their choice on their evaluation of the vanpool as a social setting. One implication of this may be that women who currnetly travel in vanpools or other non drive-alone modes, may be less attracted to a single passenger automated mode. Therefore estimating female ridership on automated modes may depend on the type of automated mode being considered. Furthermore, if the automated mode is multi-passenger, possible rider activities will yet depend on who one's fellow commuters are. Sleeping and work activities, which are possible in a vanpool where fellow travellers are not family members, may be less likely in an automated private vehicle, if a household member travels with them. On the other hand many people who currently do not value their riding time much, may value it more if they can ride in private, if they are better able to read or sleep in these surroundings. In

general, preference for a single or multi passenger mode will depend on one's preference for rider activities.

The available rider activities may be in general, somewhat different in an automated mode than in a vanpool. Some new activities will be created and some activities eliminated in an automated mode. For example, an activity such as reading, or activities requiring tine writing skills may not be an option for many people in current vanpools; but may be possible in automated vehicles if they operate more smoothly. Therefore our numerical result on the value of substituting non-travel activities during travel time is not directly transferable to the automated mode, because of potential differences in privacy and smoothness of vehicle operation.

Vehicle atmosphere will also not have the same interpretation in an automated vehicle model. As discussed, the importance of vehicle atmosphere is related to rider activity choices. Comparing general commuters and vanpoolers, there will be differences in company and differences in activity availability. Therefore in the automated vehicle, vehicle atmosphere may not be a factor at all or may have a different impact than indicated in the vanpool model.

Although respondents were asked to state how confident they felt driving a van as opposed to an automobile, this outcome is likely to be an extension of their general attitude towards driving. Confidence should also not be thought of as simply a "self' attribute, but involves evaluations of others in the vanpool. The rider must place confidence in the driver. In the automated choice situation, the rider must place confidence in the automated machine's driving capabilities. The implications for automation are that women and men will be happy to transfer the driving task to an automated control, as long as they view it as being safe.

The proportion of professional and managerial workers may be higher in the vanpool population than amongst commuters in general. Therefore the proportion of commuters who place importance on being able to use travel time to accomplish non-travel activity, and who may therefore be more likely to purchase automated vehicles, may be less than indicated by our vanpool sample.

The comparative role of travel costs in the vanpool and automated vehicle choice setting are not easily assessed for several reasons. The higher costs of riding as opposed to driving, caused vanpoolers to choose to drive more often as a way to reduce those costs. However, operating costs in an automated travel choice may be in a different price range than current vanpooler fares. The choice between using an automated or non-automated vehicle may be perceived to be a one-time choice in which consumers may buy an automated vehicle without already having made the decision to use the automated capability for specific travel. Thus purchase costs may be more important than per trip costs. Most importantly, the possibility of earning extra income will not be available in the automated vehicle choice situation. Thus, it is possible that the impact of mode cost will not be the same as it is in the vanpool model.

Finally, a note on automation for vanpools. In the Introduction we speculated on the value of automated vehicle technologies to vanpools. We would caution against overcounting the benefits of **vanpool** automation. The potential exists to multiply the value of vehicle automation by the number of **vanpool** users, all for the same investment in automation per vehicle. The multiplicative value will apply to any *absolute* travel time savings but not to the freeing of travel time from the travel activity itself In the case of an automated **vanpool** vehicle, only the drivers ability to free travel time from driving may be counted as a travel time *re-allocation* benefit. The dynamic is further complicated by the new role of the **vanpool** 'driver", since the driver would probably perform other **vanpool** organization functions and must actually drive the automated van for some portion of the trip.

The previously unexplored aspect of travel time -- the ability to accomplish non-travel activities while travelling -- has yielded promising prospects. These prospects are supported by other burgeoning new technology such as cellular telephones and faxes. If automated vehicles can free drivers for other valued activities, while creating improved safety for the user and other motorists, then vehicle automation technology will be perceived as more valuable by consumers than simple travel-time savings analysis might suggest.

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APPENDIX 1: PILOT SURVEY

We initially sent questionnaires to 10 vanpools. 7 vanpools returned a total of 75 surveys. As a test of our intended distribution method, the questionnaires were mailed to the driver of the vanpool and the driver was asked to distribute the surveys to the other riders. 15 Rider Surveys and one General Survey were enclosed. The rider surveys were to'be completed by the driver and all riders who agreed to it. The General Survey was to be completed by the driver. These ten pilot vanpools were selected from two sources: 5 each from Commuter Transportation Services (CTS) and Caltrans ridesharing agency in Sacramento. The latter were all ridden by Caltrans employees.

An 1 lth vanpool was selected in which to conduct personal rider interviews after completion of the questionnaire. This vanpool was registered with the University of California Davis (UCD) Transportation Services. The riders were all UCD employees traveling between Woodland and Davis. The interviews probed how well the respondents had understood the questionnaire.

After these 11 evaluations of the pilot survey the survey was slightly modified. The new survey was tested on a 12th vanpool; another UCD vanpool operating between Berkeley and Davis. Based on the response from this survey, some further minor adjustments were made before the full survey.

Past vanpool surveys were consulted to improve questionnaire construction. (In particular, CALTRANS 1989. Also Kumar and Moilov 1990, RIDES 1991, Ferguson 1989 and CTS 1989.)