77-12,741

JOHANNING, James Joseph, 1946-
POLICY MAKING IMPLICATIONS OF DISAGGREGATE
MODAL CHOICE MODELS.

The University of Oklahoma, Ph.D., 1976
Transportation

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

POLICY MAKING IMPLICATIONS OF DISAGGREGATE MODAL CHOICE MODELS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1976

POLICY MAKING IMPLICATIONS OF DISAGGREGATE MODAL CHOICE MODELS

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGMENTS

I wish to thank Dr. Antti Talvitie for his assistance and helpful comments while serving as my major professor; also thanks to Dr. Larry Canter, Dr. Robert Nelson and Professor Robert Goins for serving on the dissertation committee. A special thanks to my wife, Margaret, for interpreting my poor handwriting in preparation of the first draft and for her assistance in proofreading throughout. Thank you, Kerry Sullivan, for typing the final draft including all those tables.

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POLICY MAKING IMPLICATIONS OF DISAGGREGATE MODAL CHOICE MODELS

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ABSTRACT

In this study, the usefulness of standard transport policies in affecting work trip vehicle miles traveled (VMT) under various conditions is investigated. The models used to form a basis for the policy analyses are conditional multinomial logit modal choice models. Twenty different models, possessing the same utility specifications, are calibrated with a maximum likelihood technique using home interview data from the Minneapolis-St. Paul region.

Two sets of choices are modelled--drive alone, car pool and bus; and drive alone, shared ride and bus. The difference between the car pool and shared ride alternatives is that travelers choosing car pool indicated so in home interviews; whereas any evidence of the use of a mode of multiple car occupancy is considered to be a choice of shared ride. To facilitate the analysis of the differential effectiveness of policies across age and marital status market segments, separate models are calibrated for each market segment. Models pertaining to the general population are calibrated with data drawn from all segments of the population.

The technique used to test each of the policies is a disaggregate sampling method that predicted estimates of total work trips and VMT for the region under study. Trips are randomly sampled from the population being analyzed. The choice probabilities of the individual sampled are predicted by an appropriate modal choice model and weighted by the

screenline count and sample expansion factors. Resultant trip totals and VMTs are then cumulated to form estimates of population trips and VMTs. Changes in VMTs from base estimates as a result of the simulation of a policy are used as measures of the effectiveness of that policy.

The results indicate that the effectiveness of standard transport policies in changing the aggregated work trip VMT is minimal given that the initial population makeup remains invariant. Some policies do exhibit differential effectiveness between age and marital status market segments when the differences are based on VMTs generated separately from distinct market segments. However, the low-level of policy effectiveness is stable under a change of the age and marital status makeup of a population.

POLICY MAKING IMPLICATIONS OF DISAGGREGATE MODAL CHOICE MODELS

CHAPTER I

INTRODUCTION

An important problem facing transportation planners today is how to predict the change in vehicle miles traveled (VMT) due to the imposition or occurrence of a given policy. VMT is an important indirect indicator of the amount of pollution and the level of energy consumption in the transportation sector that one can expect to observe in a future situation. In this study, a scheme is developed to estimate changes in VMT, person mile trips and total trips for work purposes in response to various policies.

Initially, disaggregate modal choice models are estimated. These models are all conditional multinomial logit models. Some of the models are calibrated with data that is stratified by age and marital status while others are calibrated with unstratified data.

Using the choice probabilities given by the logit models with data such as screenline counts, trip lengths and vehicle occupancy factors, a program is developed to generate VMT, person miles traveled, and total trips for each mode. This information is generated for each policy scenario.

There are three main objectives in this study. The first is to determine if there are significant differences in responses to policy initiatives between people of different lifestyles. For example, do older people react differently than younger ones to a given policy change.

The second objective is to determine how a change in the demographic makeup of a population will affect the effectiveness of a policy. Recent trends in the distribution of ages, such as the increase in the proportion of elderly in this country, make this problem serious.

Last, and perhaps the most important objective of this study, is to determine if various standard policies (such as parking taxes, auto free zones or increased frequency of bus service) have a significant possibility of reducing VMT.

CHAPTER II

LITERATURE REVIEW

In general, travel behavior has been analyzed in two separate ways. The traditional method involved the use of data which was aggregated to the zonal level (Richards 1974). Models describing travel behavior were then calibrated with variables that represented a zone, not an individual. A typical dependent variable was the number of trips between two zones on a given mode, while independent variables were usually zonal means of such variables as income, travel times and travel costs (Stopher and Meyburg 1975). More recently, travel behavior analysis has been based upon data at the individual, disaggregated level.

One of the foremost reasons for analysis at the level of the individual was proffered by Fleet and Robertson (1968). They showed that with typical travel data an appreciable amount of information is lost when that data is aggregated to the traffic zonal level. The amount of variability lost can be up to 80 percent. Another reason for using disaggregate data is that behavioral models developed with it have a great potential for multiple applications (Reichman and Stopher 1971). That is, they should be usable in more than one situation.

The initial work with disaggregate data was with formulating stochastic binary choice models. These models are stochastic in that they estimate the probability of a choice and binary in that only two choices are available to the traveler.

Warner (1962) did some of the earliest work with binary stochastic choice models. He used both discriminant analysis and nonlinear regression analysis approaches to analyze elasticities of work trip modal choice. A logit curve was approximated with the nonlinear regression in a sequence of iterative steps. The time and cost elasticities of auto choice given by the two methods were of the same order, so he concluded that there was little difference between the two approaches. McGillivray (1970) also used discriminant analysis to estimate binary choice elasticities. Although his work was done at a much later date with different data, the results were quite similar to Warner's.

The major tools used to estimate binary stochastic choice models have been logit, probit and discriminant analysis. Various studies were made to determine if any of these techniques were statistically better than the others for estimation of modal choice. Talvitie (1972) performed a series of rank tests on binary modal choice models calibrated with Chicago data. The conclusion was that all three methods gave similar results and that they should be equally usable. Reichman and Stopher (1971) also concluded that on an operational basis, probit and logit analysis yield like results. However, McFadden (1974a) showed that under certain theoretical conditions discriminant analysis can produce estimates that are biased downwards in comparison with logit analysis. So, although it is generally concluded that the different estimation procedures give similar results with operational data, cases can arise where differences would be significant.

Because logit models which involve multiple choices can be readily calibrated, the binary logit model will be discussed in more detail. In logit analysis, the utility of a choice is formulated as a linear combination of the attributes of that choice. Typical attributes of modal choice are variables such as access time, travel time and out-of-pocket costs. If V_i is the utility associated with choice, i, and V_k is the utility of the other choice, then equation (2-1) is the binary logit model describing the probability, P_i, of choosing i.

$$P_i = (e^{V_i - V_k})/(1+e^{V_i - V_k}) \qquad (2\text{-}1)$$

Attempts have been made to estimate binary modal split probabilities at the disaggregate level with ordinary least squares regression analysis (OLS). Stopher (1969) used data collected at University College, London for this type of study. He admitted that the OLS procedure gave biased results because the dependent variable, which was the probability of using automobile, could take on values greater than one or less than zero. Secondly, the probabilities used to calibrate the model were determined from classes of individuals while the values of the independent variables were determined at the disaggregate level.

In more recent work, the binary logit model has been expanded to handle more than two alternatives. This model is termed the multinomial logit model. The multinomial logit model has been used quite frequently because in addition to its ability to digest multiple alternatives, it does not require an excessive amount of processing time for typical applications (Richards 1974).

Characteristics of the Multinomial Logit Model

An interesting consequence was derived by Domencich and McFadden (1975). They showed that the multinomial logit model resulted from a utility maximizing decision process when the utility function, U_i, is a random variable where unobserved attributes are distributed independent Weibull. This random utility function can be considered as the sum of two terms, one nonstochastic, V_i, the other stochastic, η_i,

$$U_i = V_i + \eta_i \tag{2-2}$$

The nonstochastic term represents those characteristics one would expect to observe if the traveler behaved according to the characteristics of the general population. The stochastic term is indicative of the unobserved attributes of choice.

The probability, P_i, of a rational consumer choosing alternative, i, is the same as the probability that U_i is greater than the utilities of all the other alternatives simultaneously.

$$P_i = P\{U_i > U_j\} \quad \text{for every } j \neq i \quad j=1,2,\ldots,J \tag{2-3}$$

Now by substituting equation (2-2) into equation (2-3) and rearranging, the resultant expression shows the relationship between the stochastic and nonstochastic terms.

$$P_i = P\{\eta_j - \eta_i < V_i - V_j\} \tag{2-4}$$

If the cumulative distribution $\Psi(t+V_i-V_1,\ldots,t+V_i-V_j)$ of $\{\eta_1,\eta_2,\ldots,\eta_J\}$ is independent Weibull, then

$$\Psi = \prod_{J=1}^{J} \exp(-\exp-(t+V_i-V_j)). \tag{2-5}$$

The partial of Ψ with respect to the i^{th} element, Ψ_i, is

$$\Psi_i = \exp(-t+V_i-V_i) \prod_{j=1}^{J} \exp(-\exp-(t+V_i-V_j)) \qquad (2\text{-}6)$$

$$\Psi_i = \exp(-t)+\exp((-\exp(-t))* \sum_{j=1}^{J} \exp-(V_i-V_j)). \qquad (2\text{-}7)$$

The probability, P_i, of choosing an alternative, i, is

$$P_i = \int_{-\infty}^{\infty} \Psi_i(t+V_i-V_1,\ldots,t+V_i-V_j)dt. \qquad (2\text{-}8)$$

When equation (2-7) is substituted in equation (2-8), the result is a closed integral that is solvable.

$$P_i = \int_{-\infty}^{\infty} (\exp(-t)*\exp((-\exp(-t)* \sum_{j=1}^{J} \exp-(V_i-V_j)))dt \qquad (2\text{-}9)$$

The solution becomes evident when equation (2-9) is simplified by letting $\varepsilon = \exp(-t)$

$$P_i = \int_{0}^{\infty} \exp(-\varepsilon* \sum_{j=1}^{J} \exp(V_i-V_j))d\varepsilon \qquad (2\text{-}10)$$

$$P_i = (e^{V_i})/ \sum_{j=1}^{J} e^{V_j}) \qquad (2\text{-}11)$$

Equation (2-11) is the multinomial logit form of the choice probability for the i^{th} choice.

Rassam, et al, (1971) developed a multilogit model to study the modal split associated with airport access. They calibrated their model with a maximum likelihood technique and also attempted to use least squares. The maximum likelihood method gave results that were considered acceptable because coefficients had correct signs and were of a reasonable magnitude.

The least squares approach was not as straightforward in that the dependent variables had to be the natural logs of the ratios of choice probabilities. A given choice, i, was singled out and its probability formed the denominator in ratios with each of the other choice probabilities. Consequently, with J choices they had to calibrate J-1 equations like equation (2-12).

$$\ln (P_k/P_i) = V_k - V_i \quad i \neq k \tag{2-12}$$

The least squares method had two deficiencies. It yielded coefficients of incorrect sign and it also had to be calibrated with aggregate probabilities.

Later applications of multinomial logit models have involved more complicated decision processes. Because of the ability of the multilogit models to handle large numbers of alternatives, studies have been conducted in which more than a single type of decision is taken into consideration. Such applications are discussed next.

Joint and Recursive Models

If it is posited that a given set of travel decisions are made at the same time, then the model will have to account for the choices jointly. That is, the joint probability of a decision is modelled. The utilities of the choices will be composed of variables that reflect the characteristics of elements of the choice jointly and separately. For example, if the joint probability of choosing mode and destination P(m,d) is calibrated, the utilities, V_{md}, in the model could each have a joint attribute, such as travel time on that mode to that destination, and a separate attribute like employment at that destination. The model to be calibrated would be represented by equation (2-13) where M is the set of modes and D is the set of destinations.

$$P(M,D) = (e^{V_{md}}) / \sum_{M} \sum_{D} e^{V_{md}}) \qquad (2\text{-}13)$$

The total number of alternatives in the system could be as large as the product of the number of modes with the number of destinations. However, the number of alternatives available to any individual could be much smaller. The other approach is to assume that decisions have been made sequentially. That is, one was made before the others.

In the case of sequential decisions a recursive model is formulated. Conditional and marginal probabilities have to be calibrated. The structural form will be dependent upon the sequence of choice. Staying with the previous example, if a modal choice is assumed to precede the destination choice, then the conditional probability, P(d|m), is calibrated first. The next procedure is usually to construct a weighted generalized price using the probabilities and coefficients calibrated in the conditional model (Ben-Akiva 1974; Liou and

Talvitie 1974). Then using the generalized price and other modal attributes, the marginal probability, P(m), is calibrated. The resultant joint probability would be given by equation (2-14).

$$P(m,d) = P(d|m) * P(m) \tag{2-14}$$

Two of the first studies involving multiple decisions did indeed concern mode and destination choices.

Ben-Akiva (1974) developed a model which estimated the probability of choosing the mode and destination of a shopping trip jointly. The data used was from the Washington, D.C. metropolitan area. The number of alternatives available to the traveler ranged from two to 16. He found his results acceptable both from the standpoints of the statistics involved and from value of time considerations. He also developed two recursive schemes in the same study.

With the recursive setups, different generalized price schemes were employed. It was discovered that the composition of the generalized price and the order in which the sequence of decisions was modelled would affect the results. That is, mode then destination gave different results than the reverse order. The joint model was favored on theoretical grounds, however, it was admitted that the information gathered from the study itself did not show which of the three methods, the simultaneous or the two recursive structures was correct.

At about the same time, Liou and Talvitie (1974) calibrated models for decisions involving which models and which stations a rail traveler would choose for access. They used the joint approach and the recursive in both sequences, calibrating the models with Chicago data. However, they favored the recursive model in which the sequence was station (destination) followed by mode. This sequence gave the most reasonable and acceptable results in their study.

Some of the most recent models which have concerned multiple decisions have adhered to the joint approach. In one study, the joint choice of mode and auto ownership was modelled for work trips (Ben-Akiva and Lerman 1974). The primary assumption made in that study was that the household made two decisions simultaneously; how many cars they would own and which mode would be taken to work. The choice set contained five alternatives which were not always available to individual households. Low income households were not given a choice involving multiple car ownership. Households which were located an appreciable distance from transit lines were denied choices involving transit (Ben-Akiva and Lerman 1974). This study gave reasonable results from a statistical standpoint but one wonders if the simultaneity of the modal choice-auto ownership decision is valid.

For the worker who is new in the job market, the assumption of simultaneity appears valid. Prior to holding a job, he may not have been able to own the number or type of cars he wanted or needed. Given the ability to purchase a car because of the initial employment it is reasonable to assume the trip maker would make the auto purchase with the mode of travel to work in mind. But if a person has been employed and consequently has had the ability to own a car or cars, it is also reasonable to assume that the choice of mode to work is conditioned upon auto ownership. That is, he has already determined how many cars he wishes to own and this determination subsequently affects his choice of mode to work. In any event it is generally agreed that car ownership should somehow be taken into account in models which involve modal choice (McFadden 1974b).

All of the choice models discussed in this paper have a common principle in that they all are subject to the axiom of independence of irrelevant alternatives. Models which possess this characteristic have certain distinct advantages over other types of models but are susceptible to the drawbacks associated with it. For these reasons, it is important to discuss what is meant by the term independence of irrelevant alternatives and what are the consequences when models possess this feature.

Independence of Irrelevant Alternatives

The principle of independence of irrelevant alternatives was first investigated by Luce (1959). It means that the ratios of the probabilities of existing choices remain invariant when an additional alternative is added to the choice set. The multinomial logit model possesses this characteristic as can be readily shown.

Let ℓ and m be any two alternatives in $i=1,2,\ldots,J$. The ratio of the probabilities of choosing ℓ to choosing m is given by equation (2-15).

$$P_\ell/P_m = (e^{V_\ell}/\sum_{j=1}^{J+1} e^{V_j})/(e^{V_m}/\sum_{j=1}^{J} e^{V_j}) = e^{V_\ell}/e^{V_m} \qquad (2\text{-}15)$$

To show the ratio remains invariant, an alternative J+1 is added to the existing set. Because this new term appears in the denominators of both P_ℓ and P_m, the ratio remains constant as can be seen in equation (2-16).

$$P_\ell/P_m = (e^{V_\ell}/\sum_{j=1}^{J+1} e^{V_j})/(e^{V_m}/\sum_{j=1}^{J+1} e^{V_j}) = e^{V_\ell}/e^{V_m} \qquad (2\text{-}16)$$

One of the most powerful consequences of this property is that choice probabilities can be estimated at the individual level for alternatives not presently available to that individual. McFadden (1974b) expanded a binary modal split model to estimate the patronage of the then proposed Bay Area Rapid Transit (BART) system. The coefficients of generic variables previously calibrated were used as weights in the utility function characterizing BART. Probabilities and demand elasticities of auto, bus and BART choices were then generated with a weighted sample. Using this information, resultant patronage was predicted. A comparison was made between the predicted BART patronage and some adjusted patronage values which were available at that time. The conclusion was that the predicted values were low because of the model and because the data used for forecasting did not reflect subsequent population growth.

Elasticities, however, were considered to be quite reasonable.

Although models which possess the property of independence of irrelevant alternatives have the advantage of ease of expansion to accomodate new choices, this property can cause problems if alternatives are not carefully chosen. If the choice alternatives are highly related, the classical red bus-blue problem arises (Mayberry 1970). To illustrate the problem consider the following example.

Posit a system which offers to alternatives, auto and red bus. And further, assume that for some individual in the population the choice probabilities, P(choice), are equal. Thus, P(auto) = 0.5 and P(red bus) = 0.5 because no other alternatives are available. Now suppose the bus operator paints half his buses blue. If blue bus is entered into the multinomial logit model, then the independence of irrelevant alternatives axiom will insure that the ratio P(auto)/P(red bus) = 1.0 remains invariant. The characteristics of the bus alternatives are identical so that P(red bus) = P(blue bus). Thus P(auto) = P(red bus) = P(blue bus) = 0.33 instead of the expected P(auto) = 0.5, P(red bus) = 0.25 and P(blue bus) = 0.25. Although this is an extreme example, it does show that one must be careful to choose alternatives that are as distinct as possible.

A recent study by McFadden, et al, (1976) tends to suggest that the independence of irrelevance property does not present serious drawbacks if models are calibrated with typical transportation data. They developed a series of diagnostic tests and performed those tests on models which had alternatives similar to those used in this study. Thus, the alternatives used in this study should be sufficiently distinct to avoid major problems of bias.

Choice Elasticities

Another way of examining the independence of irrelevant alternatives property is by way of choice elasticities. The elasticity, ${}_{X_{jk}}E_{P_i}$, of a choice probability, P_i, with respect to an attribute, X_{jk}, of that choice or any choice in the choice set $\{j=1,2,...,J\}$ is defined mathematically as

$$ {}_{X_{jk}}E_{P_i} = \frac{\partial P_i}{\partial X_{jk}} * \frac{X_{jk}}{P_i} \qquad (2\text{-}17) $$

where X_{jk} is the k^{th} attribute of choice, j. This elasticity is an indicator of the magnitude and direction of the change one would expect to observe in the choice probability in response to a one percent change in the attribute.

The elasticity in equation (2-17) is a direct elasticity if $j=i$ and is a cross elasticity if $j \neq i$. Using the functional form of the multinomial logit model as in equation (2-11), one can show that the direct and cross choice elasticities are given by equations (2-18) and (2-19) respectively, where b_{jk} is the coefficient of X_{jk} (Reichman and Stopher 1971).

$$X_{ik}{}^{E}P_i = b_{ik}X_{ik}(1-P_i) \qquad (2\text{-}18)$$

$$X_{jk}\ {}^{E}P_i = -b_{jk}\ X_{jk}\ P_j \qquad j \neq i \qquad (2\text{-}19)$$

Upon combining equations (2-18) and (2-19), a more general expression results.

$$X_{jk}{}^{E}P_i = b_{jk}X_{jk}(\sigma-P_j) \qquad (2\text{-}20)$$

$$\sigma = \begin{cases} 1 & \text{if } i=j \\ 0 & \text{if } i \neq j \end{cases}$$

Calculations of choice elasticities will help to determine the plausibility of the models estimated in this study by comparing them to the changes observed when changes have been made in the real world. They are also useful in pointing out possibly important or effective transport policies.

Policy Analysis

Various attempts have been made to determine the effectiveness of different transport policies. Kulash (1974) speculated that central business district (CBD) traffic counts would be reduced from 3.6 to 8.7 percent if a 100 percent parking tax was implemented. His results were based on the normal proportion of parking exempt from charges and on parking cost elasticities. These elasticities were estimated by directly interviewing travelers and noting how the respondents said they would react to various parking costs.

Lutin (1976) speculated that the imposition of physical parking restraints in CBD zones is counter productive in the long-run. He reasoned that the restraints would give an added incentive to the trip makers to secure employment in suburban areas.

An interesting piece of work on policy analysis was recently performed by Atherton, et al, (1975). They used three different types of disaggregate demand models to form the modelling system. One model was for shopping trips, one was for work trips and the last was used to determine automobile ownership. A fairly structured decision process, not probably found in the real world, was modelled. Very specific interrelationships between shopping trips, work trips and automobile ownership were assumed.

Policies were tested with data from Washington, D.C. The effectiveness of the policies in providing incentives for car pooling were analyzed. The authors did discover that most policies resulted in modest reductions of work trip VMT. They did not consider, however, changes in population attributes, such as changes in lifestyle makeup which will occur regardless of which policies are implemented.

The changing lifestyle phenomenon and its influence on policy effectiveness is analyzed in this study. The next chapter contains a description of the data used and a discussion of the models calibrated from that data.

CHAPTER III

DATA AND MODELS

Introduction

The main purposes of this study are threefold. The first and primary objective is to determine if upon the application of standard transportation policies one could reasonably expect to observe a significant reduction in vehicular travel. The second is to see if various classes of people would react differently to such policies and the third is to see how a change in the age distribution of a population could alter the effectiveness of policies. As an initial step toward achieving these ends, modal choice models which embody characteristics of proposed policies have to be developed. The calibration of these models is dependent upon the data used and the sampling from that data. These are explained next.

Data Base

The data used in this study was based on a home interview survey conducted in the Minneapolis-St. Paul area. This data, compiled in 1972, contains two files of variables. The first set contains numerical values of transport system performances which are both observed in the home interview and calculated via network analysis. The remaining ones are dummy variables and indicate the characteristics of the trips.

The data is disaggregate in that it consists of observations at the individual level. The number of modes present in the original data set include auto drive, auto passenger, car pool, public bus, school bus, taxi passenger and motorcycle. The choice of a mode by an individual is given as an absolute. That is, the data set does not give the frequency of a person choosing a given mode but indicates which mode was chosen. The trip purposes in the data set were varied. Home based trips, i.e., trips originating at a household, were for purposes of work, personal business, medical matters, outdoor recreation, other social recreation, shopping and school. Nonhome based trips were grouped together but not identified by purpose.

For this study, only home based work trips between traffic zones were needed for modelling purposes. Secondly, because some of the modes in the choice set (such as school bus) were inapplicable for work trips, the choice set was narrowed to auto type trips and public bus trips. After processing, there were 6042 work trips usable for model calibration.

Although the number of observations was quite large, a visual inspection of the data was made to insure that variables were coded properly. For example, there were two different sources for parking costs, 1) the home interview survey and 2) a parking cost survey. The home interview set appeared to have many omissions, so parking costs were taken from the parking cost survey.

Another difficulty arose in that one of the objectives of the study concerned classes of people. Individuals had to be identified by life cycle. A person with a given age and marital status was assigned a life cycle code by the planners who compiled the data set. The age of the individual was also coded in a separate set of variables. The problem was that in many cases there was a conflict between the age code and the life cycle code. Data in which the two sets of variables were in agreement were used for model calibration. However, the base set of 6042 observations was used as a benchmark for VMT calculations.

Choice Alternatives

Choice Sets

Two general sets of alternatives were chosen for calibration. The first set was drive alone, car pool and bus transit. The distinction between car pool and shared ride lay in the way the data was coded. The general rule for the coding of a characteristic was that if the value was one, the characteristic applied to the individual, otherwise the characteristic did not apply to that individual.

In the case of car pool, the individual was considered to be car pooling if that is what he reported in his interview. The determination of shared ride was more indirect. The individual was classified as sharing a ride if he was an auto driver and there was more than one occupant in the car, or if he was an auto passenger. The difference should be slight but there may be behavioral ramifications.

The person who indicates in a home interview that he car pools is probably quite serious about saving fuel and money in his work trips. It would also imply that some preliminary planning went into the trip and that car pooling is a fairly permanent choice for this person, given his present situation. Shared ride, on the other hand, includes all auto trips which involve multiple occupancy. So in addition to car poolers, shared ride would encompass those individuals who had any reason to be riding together in an automobile.

One would expect that the number of observations of shared ride choices would be greater than car pool from the same type of sample. This is reflected in the information given in Table 1. In order to read Table 1 a short digression is necessary for the discussion of what is meant by sample type as used in this study.

TABLE 1

Total Sample Observations

Modes	Sample Type: All Alternatives Available	Sample Type: Alternatives Restricted
Choice Set 1		
Drive Alone	1696	1667
Car Pool	325	317
Bus	387	387
Choice Set 2		
Drive Alone	1696	1667
Shared Ride	542	521
Bus	395	395

Sample Types

The first sample type is a sample in which the individual is considered to have all alternatives available in making his choice for mode of travel to work. For example, even if the individual owns no cars, the alternative of drive alone is made available. This sample type will be used to test various policies. The other sample type is a sample in which normal restrictions are placed upon individuals. That is, if an alternative cannot under usual circumstances be a reasonable choice for an individual, that choice is denied the individual when the models are calibrated. Table 1 indicates that the number of observations of a given mode in a restricted drawing is less than or equal to the number in an unrestricted drawing.

In the multinomial logit models, the dependent variables are the probabilities, P_j, of the individual choosing each of the j=1,2,...,J choices. The data set in this study only indicates what was chosen. So, for calibration purposes, the probability of the chosen mode will be one. Consequently, the probabilities of the other modes will be input as zero.

Variables in Model Calibration

The independent variables used in the calibration of the models were of three general types. The first type characterizes the system which is being modelled. These are sometimes known as level-of-service variables. The next set of variables is indicative of an individual's social and economic status. Variables of this type are known as socio-economic variables. The last group is dummy variables. Dummy variables are two valued (0,1) which are used for various purposes.

Level-of-Service Variables

The level-of-service variables used in the models include cost/income, walk time, initial bus headway and secondary bus headway. These are defined next.

Cost/Income. The cost/income variable is actually a combination of a level-of-service variable, cost, and a socioeconomic variable, income. It is discussed here because pure income effects will be embodied in the income variable itself. That variable will be input as a socioeconomic variable. The purpose for dividing cost by income was to account for inflationary trends and to achieve a real price effect. It is reasonable to assume that, under normal conditions, an individual in a high income bracket will be less sensitive to a cost increase than someone who is less wealthy.

Cost/income was calculated for each of the modes, regardless of which was chosen. Derivations of income values will be discussed in the section of the paper concerning socioeconomic variables. An explanation of the assessment of costs for each mode will be presented here.

Auto drive alone cost was the sum of the out-of-pocket operating cost and the parking cost. The out-of-pocket cost was computed at the rate of $.06/mile with the auto distance given by the highway network skim tree distance. Skim tree distances were used so that the expected auto costs of bus riders could be calculated. Parking costs were from the parking cost survey. This meant that the parking cost was an average value which was linked to the trip destination traffic zone. Unfortunately, the home interview parking costs in the data set were unreliable.

Shared ride and car pool costs were computed as the auto drive alone cost divided by the number of car occupants. If the traveler did not choose shared ride or car pool, it was estimated that car occupancy would have been two occupants. This value is the lower bound of multiple occupancy. It ensured that car pool and shared ride costs were a conservative reduction of drive alone costs if occupancy was unknown.

Bus costs were computed from a sum of the bus fare and an estimate of the out-of-pocket cost of auto access for bus. The bus fares were taken from a network fare matrix. Therefore, regardless of the mode chosen, a bus fare could be assigned to the traveler. The auto access portion of bus fare was computed from network zonal auto access times. An average speed of 15 miles/hour was assumed and the out-of-pocket cost rate was $.06/mile.

Walk Time. Walk time is the amount of time one could expect a traveler to spend walking during the access, transfer and egress portions of a work trip. Because of the high sensitivity of many travelers to walk time, it can have a significant influence on the choice of mode.

Walk times for drive alone, car pool and shared ride choices were computed as the sum of the terminal times at the origin zone and at the destination zone. These values were aggregate estimates, but they facilitated the estimation of walk times for these modes when bus was not chosen.

Transit network access times for the walk mode summed with network transfer times provided a means of estimating bus walk times.

Bus Headway. Bus headway is a measure of the frequency of bus service. The mathematical relationship is quite simple. A uniform headway, H, in minutes can be calculated using equation (3-1) where, f, is the uniform frequency of bus service in buses/hour.

$$H = 60/f \qquad (3\text{-}1)$$

It is logical to assume that the more frequent the bus service the more likely one is to ride a bus.

The effect of bus headways on traveler choice was separated into two components. This was the result of an assumption that the effect of headway on choice is not linear. If the frequency of service is high, it is reasonable to assume that the average traveler is not aware of scheduled arrival times. When he wishes to board he goes to the nearest stop and waits an average of half the headway. But, if service is infrequent, say once an hour, the frequent bus traveler would consciously take into account the schedule. He would probably wait much less than half the headway.

After some experimentation with different configurations, it was determined that an acceptable point at which to separate these effects was at a headway of 16 minutes. For example, if the headway was 10 minutes, then the initial headway variable was assigned the value of 10 minutes and the secondary headway variable was zero. If the headway was

20 minutes, the initial headway was 16 minutes and the secondary headway was four minutes.

Splitting the effects at 16 minutes was necessary for two reasons, both of which were dependent upon the data chosen for model calibration. When the split was made at values less than 16 minutes, there was insufficient variation in the value of the initial headway variable. That is, too many of the values were equal to the maximum allowed. An excessively high value of the split caused most of the observations of the secondary headway to be zero, resulting in insufficient variation in its values. In either case, the models could not be calibrated because of a high correlation between one of the headway variables and the mode specific constant.

The calculation of the actual headway had to be made indirectly as the frequency of service was not included in the data set used for calibration. The headway value was set equal to twice the sum of the transit network wait time and transfer time.

Socioeconomic Variables

The socioeconomic variables used for calibration purposes were income and automobile ownership/household size.

Income. A dollar value estimate of the individual trip makers yearly income was input as a socioeconomic variable and as the denominator of the cost/income variable.

An estimate of the income had to be used since the data set indicated income with a sequence of dummy variables. The median of the income range of the appropriate income dummy was used to determine the dollar value. For instance, if the income dummy indicating an income of $12,000 to $14,999 was equal to one, that individual was assigned an income of $13,500. The open ended dummy representing an income of $25,000 or more was given the value $30,000. As Table 2 shows, the mean incomes of the four samples in Table 1 are reasonable for 1972 data.

TABLE 2

Mean Incomes of Samples

	Sample Type	
Choice Sets	All Alternatives Available	Alternatives Restricted
1*	$12,108	$12,109
2**	$12,143	$12,173

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

<u>Automobile Ownership/Household Size</u>. Many studies indicate a high correlation between auto ownership levels and the tendency to choose the auto mode for a given trip (McFadden 1974b). But as the household size increases, it

is reasonable to assume that each car available to that household would be subject to more usage. Therefore, the number of cars/person was considered to be a realistic indicator of auto availability.

This variable is also a good indicator of the socioeconomic status of the household. Larger families will have less money to spend per person than smaller families of equal income. Also, families in higher income brackets are likely to own a greater number of automobiles than those families in low income brackets. The variable cars/person, then, should provide information about the status and the automobile usage of the individual.

Other Variables

The remaining variables used in this study are dummy variables. These are the alternative specific constants and the head of household dummy variables.

Alternative Specific Constants. These variables are used to facilitate the inclusion of mode specific but unobservable effects in the utility functions of the choice alternatives. If there are J choices, only J-1 terms can be used in the models. In the models calibrated in this study, constant terms are input in the auto drive alone and the shared ride-car pool choice utility functions.

Head of Household. The head of household dummy variable is equal to one if the trip maker is the head of the household and equal to zero otherwise. This variable is also mode specific and is included in the drive alone utility function.

Model Specifications

Two groups of models were calibrated for the study. The first group was calibrated with the four samples whose modal breakdowns are given in Table 1. The second group was calibrated with four demographically distinct subsets of each of those four samples. Thus, four models were calibrated in the first group and 16 were calibrated in the second group. In order to insure some consistency of models within groups and between groups, all models were calibrated with the same specification of utility functions.

The final specification was determined experimentally. Working within a theoretical framework, the specification that gave the best results for all 20 models was chosen. Variables were input in both a generic and mode specific manner. A variable is generic if it and its corresponding variables are constrained to have equal coefficients. For example, in this study the cost/income variables are generic. The coefficient of drive alone cost/income in the drive alone utility function will equal the coefficients of shared ride cost/income and bus cost/income in their respective utility functions. A mode specific variable appears only in the utility function of the alternative of which it is an attribute. For instance, the drive alone constant is in the drive alone utility function and has no constraints on its coefficient.

The utility function specifications, U, for choice set 1 (Table 1) are illustrated by equations (3-2) through (3-4). The cost/income coefficients and the walk time coefficients are equal in all three equations. The specifications for choice set 2 are identical except that car pool is replaced by shared ride.

$$\begin{aligned} U(\text{drive alone}) = \alpha_0 &+ \beta_1 \text{ (drive alone/cost income)} \\ &+ \beta_2 \text{ (drive alone walk time)} \\ &+ \beta_3 \text{ (head of household dummy)} \\ &+ \beta_4 \text{ (autos/household size)} \\ &+ \beta_5 \text{ (income)} \end{aligned} \qquad (3\text{-}2)$$

$$\begin{aligned} U(\text{car pool}) = \alpha_1 &+ \beta_1 \text{ (car pool cost/income)} \\ &+ \beta_2 \text{ (car pool walk time)} \\ &+ \beta_6 \text{ (autos/household size)} \end{aligned} \qquad (3\text{-}3)$$

$$\begin{aligned} U(\text{bus}) = \quad & \beta_1 \text{ (bus cost/income} \\ &+ \beta_2 \text{ (bus walk time)} \\ &+ \beta_7 \text{ (initial headway)} \\ &+ \beta_8 \text{ (secondary headway)} \end{aligned} \qquad (3\text{-}4)$$

where:

α_0 = drive alone constant

α_1 = car pool constant

β_1 = cost/income coefficient

β_2 = walk time coefficient

β_3 = head of household coefficient

β_4 = autos/household size coefficient no.1

β_5 = income coefficient

β_6 = autos/household size coefficient no. 2

β_7 = initial headway coefficient

β_8 = secondary headway coefficient

Note that the cost/income and walk time variables are generic and that the remainder are mode specific.

The level-of-service variable linehaul time was not included in the utility functions used in this study.[1] This is unfortunate because linehaul time is normally found in modal choice models. This variable was eliminated because of the simultaneous requirements of having uniform utility specifications and of achieving logical calibration results for all 20 models used in the study. The logical sign for a linehaul time coefficient is negative because one would expect to observe a decrease in a given choice probability if the corresponding linehaul time increased.

The problem arose when the coefficient of linehaul time was of the incorrect sign in some of the models calibrated with data from specific market segments. For example, the coefficients for a model in which linehaul time was

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[1] Linehaul time is that portion of the total door-to door trip time that is spent using the mode characterizing the modal choice. It does not include access, egress or transfer times.

added to the existing utility specifications used in this study are given in Table A-1 in Appendix A. In this model the choice set was drive alone, shared ride and bus. All alternatives were available to all individuals and the market segment was single people over 45 years of age. The line-haul time coefficient was positive, and although it was statistically insignificant, the model was invalid.

Model Evaluation

Coefficients of the Model

The sign of a coefficient is an important factor in determining the validity of that coefficient. The coefficient sign will determine the direction of change of the probability of choice with a given change in the value of the corresponding attribute. For instance, if the drive alone cost/income experienced an increase, one would expect a corresponding decrease in the probability of the traveler choosing the alternative auto drive alone. Thus, one would expect the sign of the drive alone coefficient to be negative. In addition one could expect the coefficients of walk time, initial headway and secondary headway to be negative.

The signs of the autos/household size coefficients should be positive. As the number of cars/person increases, one would expect an increase in the probability of a choice which involves an automobile for the major portion of the trip.

The signs of the income and head of household coefficients are not so straightforward. One could argue that if a person was the head of a household he would be inclined to drive alone. However, there might also be reasons that would sway him toward other modes. The head of a household could have a greater probability of having a job in an area of high employment density than the other family members. Areas of high employment often have more transit facilities than areas of low employment. For these reasons, the head of the household may have a greater opportunity to use transit for work trips while his family members would not. The head of the household might also be better acquainted with fellow workers and, therefore, have an inherent greater probability of choosing a car pool alternative. Similarly, it could be argued that income should have a positive coefficient because those of higher income levels have an increased economic ability to drive alone. But the more wealthy could be better informed than the average person and might be more aware of the possibility of car pooling. The proper signs of these two variables are not so obvious as the signs of the preceding ones and could well be indeterminant.

There is no reason to be concerned about the signs of the alternative specific constants.

The statistical significance of the coefficients is also an important determinant of the usefulness of coefficients. One standard test that can be performed is the t-test. The usual procedure is to test whether the coefficient is significantly different from zero at a 95 percent level of confidence. Caution must be taken with these tests because the assumption made is that the true value of the variable is, indeed, not zero.

Another commonly employed technique used to analyze coefficients is the calculation of elasticities. Normally mean values of the coefficients and sample choice probabilities are used in the calculations. Equations (2-18) and (2-19) are employed to determine the values. The magnitudes and signs of the choice elasticities reflect the appropriateness of the magnitudes and signs of the corresponding independent variables.

Coefficients can also yield additional information such as the implied value of time. The implied value of walk time of all modes for the models in this study is directly proportional to the income of the individual. The proportionality constant is the product of a conversion factor for units of measure and the ratio of the walk time coefficient over the cost/income coefficient. For the purposes of analyzing differences in walk time values for individuals from different market segments, an income of $12,000 was used to calculate all time values. This income figure was used instead of the mean incomes of the market segments because it enabled meaningful comparisons to be made between market segments and the population as a whole.

Model as a Whole

A statistic can be computed to determine the significance of each of the models. This statistic is $-2\ell n\lambda$, where λ is the ratio of the value of the likelihood function of the initial model over the value of the likelihood function of the final model. If L is the number of nonzero parameters in the final model and, K, is the number of nonzero parameters in the initial model, then $-2\ell n\lambda$ is distributed χ^2 with L-K degrees of freedom.

To test the significance of the models in this study, the log likelihood functions are evaluated with the coefficients set to zero and also set to the final values for computation of $-2\ell n\lambda$. The number of nonzero coefficients in the final model is equal to the degrees of freedom. The relationship used for calculations is given in equation (3-5) where $L(0)$ is the log likelihood using coefficients equal to 0 and $L(\hat{\beta})$ is the log likelihood of the model with the final calibrated coefficients.

$$-2\ell n\lambda = -2(L(0) - L(\hat{\beta})) \qquad (3\text{-}5)$$

An empirical test that can be performed on the models is to determine the percentage of individuals whose behavior the model correctly predicts. This is done by going through the disaggregate data using the final model to calculate the probabilities of each individual choosing each one of the alternatives that is available to him. If the probability of choosing the alternative he actually chose is greater than the probabilities of each of the other choices, then, this is counted as a correct prediction. Although there is no statistical threshold to work with, one would expect a good model to have a high percentage of correct predictions.

Model Calibration Results Using Combined Data Sets

In this study, combined data sets will be those data sets referred to in Table 1. The models discussed here make no distinctions regarding market segments, the market segments being defined on the basis of age and marital status. One of the main reasons the combined models have been calibrated is to be able to check the results of models calibrated with market segment specific data.

Four models were calibrated, one for each of the combined data sets. Specific numerical information about these models is included in Tables 3, A-2 and A-3.[1]

The coefficients, t-values of coefficients, values of $-2\ell n\lambda$ and percentage of individuals classified correctly for the combined models are given in Table 3. The signs of the coefficients of all the models are correct, i.e., they are logical. Most of the coefficients are significantly different from zero as indicated by their t-values. Because

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[1]Tables A-1 through A-16 are in Appendix A. These tables contain information pertaining to all the modal choice models discussed in this study.

TABLE 3

Coefficients, t-values (in parentheses)
and Other Statistical Measures of Models

Combined Data Sets

Coefficients	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Cost/Income	-15.57 (-2.50)	-15.35 (-2.58)	-24.08 (-2.87)	-20.85 (-2.78)
Walk Time	-0.062 (-3.92)	-0.065 (-4.25)	-0.063 (-2.94)	-0.069 (-3.45)
Initial Headway	-0.11 (-4.66)	-0.106 (-4.85)	-0.086 (-2.96)	-0.09 (-3.31)
Secondary Headway	-0.039 (-8.85)	-0.038 (-9.04)	-0.015 (-2.97)	-0.013 (-2.77)
Head of Household	0.094 (0.78)	0.042 (0.38)	-0.070 (-0.44)	-0.097 (-0.74)
Autos/Household Size #1	2.91 (13.12)	2.95 (13.55)	2.07 (7.13)	2.19 (8.19)
Autos/Household Size #2	1.49 (5.77)	1.74 (7.46)	0.91 (3.74)	1.197 (5.10)
Income	0.00006 (6.21)	0.00004 (-4.98)	0.00002 (1.56)	0.000003 (0.36)
Drive Alone Constant	-3.29 (-9.09)	-3.098 (-8.96)	-2.01 (-4.15)	-2.16 (-4.81)
Car pool--Shared Ride Constant	-3.36 (-9.67)	-3.02 (-9.14)	-3.12 (-7.06)	-2.98 (-7.15)
$-2\ell n\lambda$	2066.7	1752.8	1465.4	1022.0
% Correct	75%	69%	83%	76%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

of the large number of observations and relatively small number of parameters, the 95 percentile t-value for the models is ± 1.96. When the absolute values of the t-values exceed 1.96, the coefficient is significant.

The head of household coefficients are all insignificant so the sign change from the unrestricted to the restricted set is not alarming. The income variables in the restricted set are also insignificant but are still consistent with those in the unrestricted set.

The values of $-2\ln\lambda$ are all quite large. There are 10 degrees of freedom for this statistic in these models. The models will be considered significantly different from the null model at the 99 percentile level if $-2\ln\lambda > 23.2$. All the combined models exceed this so they are significant.

The models utilizing choice set 1 (drive alone, car pool and bus) have a higher percentage of correct predictions than those of the other set. A possible explanation could be that shared ride is not as definitive a mode as car pool. People who indicate in a home interview that they car pool may be more sensitive to car pool characteristics than those who just happen to be sharing rides.

The models in which the alternatives are restricted have a greater proportion of correct predictions. This is to be expected because more information has been provided in the calibration of the models. By keeping impossible choices from entering the estimation procedure, one should receive results which will more closely reflect the data input.

Table A-2 lists direct choice elasticities of some important coefficients of the combined models. These elasticities were determined at the sample means given in Table A-3 and at the sample multinomial choice probabilities. These probabilities are calculated by using the actual choices taken from the sample. For instance, if a sample had 10 observations and four individuals chose alternative A, then the sample choice probability for choosing A would be 0.4. The sample choice probabilities for these models can be calculated from the information in Table 1.

All the choice elasticities are inelastic except for those of initial headway. If the choice elasticity, $X_{jk}{}^{E}P_i$, is of the correct sign, then the following three relations determine if the k^{th} attribute of alternative, j, is elastic, unitary elastic or inelastic with respect to the choice probability, P_i.

$$\text{If } |X_{jk}{}^{E}P_i| > 1.0, \quad X_{jk} \text{ is elastic} \qquad (3\text{-}6)$$

$$|X_{jk}{}^{E}P_i| = 1.0, \quad X_{jk} \text{ is unitary elastic} \qquad (3\text{-}7)$$

$$|X_{jk}{}^{E}P_i| < 1.0, \quad X_{jk} \text{ is inelastic} \qquad (3\text{-}8)$$

Because the choice elasticities of initial headways are elastic, one can surmise that the population sampled is quite sensitive to a change in headway if the headway is initially of small magnitude. However, the average values of initial headways for this group of combined models ranged from 15.19 minutes to 15.22 minutes (from Table A-3) which is very close to the maximum of 16 minutes. Standard deviations of the values of initial headway were on the order of 2.3. Therefore, there was not an appreciable amount of deviation from near the maximum in the values of initial headways in the data.

The conclusion, i.e., a heightened sensitivity to a change in an initially low magnitude headway, must be qualified. The headway under consideration has to be within a reasonable range of that experienced in this study. One would expect a lessening of sensitivity to headway changes if headway values were, say, less than five minutes. The corresponding levels of frequency of service are extremely high. It would be reasonable to assume that in this situation the normal traveler would not be able to detect small changes in service frequency.

The implied values of walk times (at an income level of $12,000) for all the models used in this study are given in Table A-16. The implied values for the models calibrated with combined data sets are quite high. They are in excess of 500 percent of the before tax wage rate. This indicates that the average traveler has a great aversion to the walking portion of his work trip. The walk time values of these models were used as benchmarks for comparisons with the walk time values implied by the models calibrated with market segment specific data.

Model Calibration Results Using Market Segment Specific Data Sets

Purpose for Market Segment Separation

In order to facilitate an analysis of the effects of a changing demographic makeup on different policy scenarios, sets of models were calibrated with different market segment characteristics. The observations were separated into four groups of individuals. The groups or market segments were formed by taking into account the age and marital status of each of the individual travelers sampled. The four market segments identified by age and marital status are: 1) married and younger than 45 years, 2) married and older than 45 years, 3) unmarried and younger than 45 years and, 4) unmarried and older than 45 years. The calibration results of each of these groups are discussed below.

Married and Younger than 45 Years Market Segment

The data sets used to calibrate this group of models are quite reduced in size from those used to calibrate the combined models. This is evident by comparing Table 1 with Table 4 on the following page.

TABLE 4

Sample Observations of Individuals Married and Younger than 45 Years

Modes	Sample Type: All Alternatives Available	Sample Type: Alternatives Restricted
Choice Set 1		
Drive Alone	405	398
Car Pool	84	84
Bus	73	73
Choice Set 2		
Drive Alone	405	398
Shared Ride	171	166
Bus	74	74

Because these models were calibrated with subsets of data used to calibrate the combined models, one would expect that the resultant coefficients would not be as significant from a standard error viewpoint as those of the combined models. This is, in fact, evident if Table A-4 is compared with Table 3. The cost/income and initial headway coefficients all have t-values indicating a less than 90 percent confidence of being significantly different from zero. This is unfortunate but not disastrous because the signs and magnitudes appear to reasonably reflect the expected behavior of individuals in this group.

All the models in Table A-4 are, on the whole, significant because values of $-2\ell n\lambda$ range from 204.3 to 502.4. The proportions of observations predicted correctly are also high. With this group, as with the combined group, models using choice set 1 (drive alone, car pool and bus) are consistently better when used to simulate the predictions of input data.

The elasticities of all the cost/income variables (Table A-5) are uniformly reduced from those in the combined group. Although calculated at different means and probabilities, the reduction points to a reduced sensitivity to costs by those married and less than 45 years in comparison with the general population. However, the trend with respect to walk times appears to be less distinct.

The implied values of walk time given in Table A-16 show that the young marrieds have an increased sensitivity to walk times when choices are restricted but decreased sensitivity when all alternatives are available. The values of walk times for this market segment are nearly triple those for the general population when choices are restricted. The young marrieds have an inordinate aversion to walking under the initial conditions. The ultimate consequences of this will not be evident until the policy analyses are made.

The average value of secondary headway for the young married data sets is approximately 35 minutes which is roughly five minutes more than in the combined data sets

(Table A-6). Because of the 16 minute restriction on initial headway, the average value of total headway for the young marrieds' market segment is greater than total headway for the combined group. Therefore, headways of less than 16 minutes are not as frequent for the young marrieds as for the general population. The young marrieds probably have a greater proclivity for living in suburban neighborhoods than the average individual. These types of neighborhoods generally have a low population density. As a result, they quite often have poorer transit service than older neighborhoods which are closer to the CBD.

The group of models calibrated with data from the young married sample is, on the whole, quite acceptable. The group is less sensitive to modal costs and to headways less than 16 minutes than the general population. The next group of models reflects work trip behavior of older married individuals.

Married and Older than 45 Years Market Segment

The samples used to calibrate the models for the married and older group are slightly larger than those in the married and younger group (Table 4 and Table 5). This would imply that, in the population sampled, the median age of married trip makers is slightly more than 45 years.

TABLE 5

Sample Observations of Individuals
Married and Older than 45 Years

Modes	Sample Type: All Alternatives Available	Sample Type: Alternatives Restricted
Choice Set 1		
Drive Alone	486	472
Car Pool	83	83
Bus	96	96
Choice Set 2		
Drive Alone	486	472
Shared Ride	116	115
Bus	98	98

When the characteristics of the two different sets of models for the married groups are analyzed, there are significant differences between the older and younger than 45 years samples. As the married and older than 45 years models are discussed, some of the differences will be pointed out.

Information concerning coefficients and statistical sets for the models calibrated for individuals who are married and older than 45 years is presented in Table A-7. The cost/income variables in the married, older than 45 years group are significant at the 95 percent level for models using the choice set drive alone, car pool and bus. These variables were significant at the 90 percent level for the model calibrated with the unrestricted choices of drive alone, shared ride and bus. The head of household coefficients are insignificant as they have been for all the models discussed previously. The signs of all the coefficients are logical from a behavioral veiwpoint.

All of the models calibrated with observations of individuals married, older than 45 years are, on the whole, significant because values of $-2\ell n\lambda$ range from 587.0 to 349.0. The percentages of correct predictions determined from the input data are comparable with the group of combined models even though the data sets used for calibration are much smaller. Differences between the married, older than 45 years group and the rest of the population become evident when the elasticities in Table A-8 and the implied walk time values in Table A-16 are analyzed.

The absolute values of the elasticities of all the cost/income variables are greater than the corresponding values for the married, younger than 45 years group and the combined group. This indicates that members of the married, older than 45 years market segment are definitely more sensitive to cost changes than an average individual.

The walk time values are slightly less than those of the combined population values taken from models using restricted choice sets. This indicates that travelers in the older married market segment have nearly the same sensitivity to walk time changes as the average traveler when incomes are equal. The average income of the older married market segment is higher than the population average income, however, so the walk time elasticities indicate a slight increase in walk time sensitivity. The result is that one cannot find a definite trend in the walk time sensitivity of the older married individuals in comparison with the general population.

Unmarried and Younger than 45 Years Market Segment

The unmarried and younger than 45 years group formed the largest samples of the market segment specific data sets (Table 6).

TABLE 6

Sample Observations of Individuals
Unmarried and Younger than 45 Years

	Sample Type	
Modes	All Alternatives Available	Alternatives Restricted
<u>Choice Set 1</u>		
Drive Alone	673	667
Car Pool	127	124
Bus	157	157
<u>Choice Set 2</u>		
Drive Alone	673	667
Shared Ride	208	202
Bus	161	161

Many of the characteristics of this group are shared by the married and younger than 45 years group.

In both groups the cost/income variables are insignificant. An inspection of Table A-10 shows that all signs are correct except for the income coefficient of the model in which elements of the choice set drive alone, shared ride and bus are restricted to eligible individuals. This sign problem is not serious, however, for two reasons. Income is a socioeconomic variable; the sign convention for such a variable cannot be argued from an irrevocably logical standpoint as it can be for a level-of-service variable. The second reason is that the coefficient involved is insignificant.

These models, like the preceding ones, are all significant at the 99 percent level with values of $-2\ell n\lambda$ ranging from 857.6 to 425.7. The percentage correctly predicted is actually improved over the combined samples.

As in the models developed for the younger married individuals, direct elasticities of the cost/income variables for the unmarried and younger than 45 years group (Table A-11) show a decreased sensitivity to a cost change in comparison with the general population. Implied values of time for the young singles are much lower than those of the general population (Table A-16). A stark contrast is evident when these walk time values are compared to those of the young marrieds whose modal choices have remained restricted. This is the main difference between the two younger market segments.

Although both groups of younger individuals evince a lessened sensitivity to initial headway changes than the combined groups, the reduction exhibited by the unmarried, younger than 45 years group is not quite as great as that of the married and younger than 45 years group. There are differences between the two groups of young individuals, but both have the same tendencies of decreased sensitivities to changes in costs and headways less than 16 minutes.

Unmarried and Older than 45 Years Market Segment

The last of the specific market segments studied is the unmarried and older than 45 years group. The data sets used to calibrate the models for this group are smaller than the sets used for the other groups (Table 7).

TABLE 7

Sample Observations of Individuals
Unmarried and Older than 45 Years

Modes	Sample Type: All Alternatives Available	Sample Type: Alternatives Restricted
Choice Set 1		
Drive Alone	132	130
Car Pool	31	26
Bus	61	61
Choice Set 2		
Drive Alone	132	130
Shared Ride	47	38
Bus	62	62

Even though the number of observations was small, nearly all of the resulting coefficients were acceptable (Table A-13). The signs of all coefficients except for one were acceptable. The exception was the coefficient of autos/household size for drive alone in the model in which each of the choices of drive alone, car pool and bus were not always available to all individuals. This coefficient was insignificant which reduces the importance of the incorrect sign. The income coefficients in the models with restricted alternatives were negative, but this is not overly objectionable. The reasons for this argument were presented in the section concerning models calibrated with unmarried and younger than 45 years travelers. The models calibrated for the single older group are presented in a more favorable light by their statistical measures rather than their coefficients.

The t-values in the models with restricted alternatives were, in general, not as favorable as those in the other models. The values of $-2\ell n\lambda$ ranged from 168.4 to 111.7 for the models. These values are smaller than those of the other model groups but still indicate the models are significant at the 99 percent level. The proportion of observations classified correctly are comparable to the combined models for the restricted set but are not as good for the unrestricted models. Thus, the restricted models in the unmarried and older than 45 years group which are hampered by insignificant coefficients are as viable as the unrestricted ones.

When one looks at the direct elasticities of the variables in the models for the unmarried and older than 45 years individuals in Table A-13, similarities crop up with the trends exhibited in the models applied to the married and older than 45 years individuals. All the cost/income variables have absolute values greater than corresponding variables in the combined models. This indicates that individuals in this group are more sensitive to cost changes than the general population. The same trend was noted with the other group of older individuals.

The implied value of walk time, at an income of $12,000, for the older single group was generally the lowest observed in the set of market segments studied (Table A-16). It was on the order of $17.00/hour for the models in which modal choices were restricted to initial availability. This indicates a lower reluctance to walking for these people than the general population.

The characteristics of the models discussed in this chapter do indicate possible mode choice changes resulting from given policies. However, the ultimate results of these policies expressed in vehicular miles traveled are not evident. In the next chapter, a method will be devised to estimate VMT changes due to the imposition of different policies.

CHAPTER IV

METHODOLOGY AND POLICY RESULTS

Introduction

An important result of the implementation of a transportation policy is how that policy will affect VMT. A change in VMT can have far reaching consequences. The estimation of future pollution and energy consumption problems, in the transportation sector, is dependent upon some knowledge of expected VMT. In this chapter a methodology is developed to estimate changes in VMT that will result if standard transportation policies are implemented. The differential effects of policies on market segments is analyzed in terms of the percentage changes of VMT each market segment could expect to observe. The latter portion of the chapter contains an analysis of the demographic sensitivity of standard policies.

Method

The bases of the method used to estimate VMT and total trips are the group of modal choice models developed in the study, the screenline estimates in the Minneapolis data set and the characteristics of the standard policies to be tested. The data used in the method is the same disaggregate trip data used to estimate the models. However, disaggregate data from other sources would be acceptable if the necessary trip characteristics used by the modal split models were present in the data.

A program was written to perform the necessary calculations to facilitate final estimates of total VMT and total trips. To achieve the total values, partial sums have to be calculated for each observation. The calculation of a partial sum due to a given observation will be discussed next.

The initial task is to read and store the attributes of an individual trip observation. These attributes are then modified to simulate the new attributes which will result if the standard policy in question is implemented. For instance, if the policy is to increase auto costs by $.10, this sum is added to the auto cost attribute. No policy modifications are performed when base values of total VMT and total trips are being estimated.

The modal choice model coefficients, which were previously input, are used with the modified attributes to calculate the expected probabilities of modal choice for the individual observation being analyzed. Alternatives not available to that individual are assigned a probability of zero. The next step is to determine the partial sums of trips and VMT to be assigned to the observation.

Each observation is considered to be a member of a random sample of a segment of the general population. The primary link between the observation and its corresponding population segment is the screenline count. Screenline counts are used to correlate home interview observations with actual traffic counts. Thus, the number of individuals making similar trips in the general population from which the sample was taken can be estimated by the screenline count. Another method that can be used to link each trip to the actual number of trips made is the sampling rate. The reciprocal of the sampling rate provides the link. For example, if the sampling rate is five percent then each trip could be considered to be representative of 20 trips.

In this study, the screenline count was used to link each observation to its corresponding population segment. The total number of travelers using a given mode to make a work trip was estimated by multiplying the probability of the individual choosing that mode by the screenline count for that individual.

The total number of home based work trip observations could not be used because of coding conflicts between life cycle variables and age variables. An expansion factor was calculated for each of the market segment data sets so that resultant trips and VMT would be representative of the general population. The previous trip totals were then multiplied by the expansion factor to achieve the partial sums of trips due to each observation. If T_j^{mA} is the partial sums of trips by mode j due to observation, m, for market segment A, then equation (4-1) expresses how the sum is determined.

$$T_j^{mA} = P_j^{mA} * SC_m * NT_m * EP_A \tag{4-1}$$

Where P_j^{mA} = The probability of individual m in market segment A choosing mode j

SC_m = The screenline count for individual, m

NT_m = The number of trips made by individual, m

EP_A = The work trip expansion factor for market segment A

The partial trip sums, T_j^{mA}, were used with the highway distances to calculate partial sums of VMTs for each mode. The drive alone VMT partial sum was the product of T^{mA}(drive alone) and the highway skim tree distance. Car pool and shared ride VMT partial sums were calculated by finding the product of T^{mA}(car pool) or T^{mA} (shared ride) and an equivalent per person highway distance. This per person highway distance was determined by dividing the highway distance by the number of occupants. The number of occupants was determined in the same manner as it was for calibration of the modal choice models. Occupancy was no less than two if the individual actually chose a different mode. If car pool or shared ride was actually chosen, then the occupancy was the number of car occupants.

Bus VMT partial sums were calculated in terms that were roughly equivalent to the drive alone, car pool and shared ride VMT partial sums. The equivalency was made from the energy consumption standpoint. Average bus occupancy is approximately 30 passengers and, considering energy differences between gasoline and diesel fuel, a bus consumes roughly three times more fuel per mile than a typical automobile (American Public Transit Association 1975). The equivalent occupancy was, therefore, set at 10 passengers for calculations of the partial sums of VMT for the linehaul portion of bus trips. The calculation of the partial sums of VMT due to the use of automobiles to access bus trips was determined by calculating an auto distance from the auto access times with an assumption of an average speed of 15 miles/hour. The bus VMT partial sum for observation, m, and market segment, A, was then the sum of the linehaul VMT partial sum and the access VMT partial sum.

On each iteration of the program, partial sums of mode specific trips and VMTs were cumulated with previous partial sums. The final results were mode specific estimates of the total number of work trips made by the general population in a 24 hour period and the resultant VMT. A run was made for each policy to be analyzed including the null policy for comparison purposes. The policies tested will be discussed next.

Policies

Because of the large number of policies tested, the policies will be numbered for identification purposes. A description of the policies and the way in which they were simulated in the estimation method will be discussed in this section.

Policy No. 1--Central Business District Parking Tax

Parking restrictions, whether economic or physical, are considered to be a class of short range transportation options commonly available to the planner (Schoefer 1973). In order to analyze the effects of an economic parking restriction, the first policy tested is the imposition of a $2.00 tax on parking in the central business district (CBD). The obvious intent of such a policy is to provide economic incentives for use of modes other than drive alone. Parking is not physically banned but will be indirectly discouraged for some individuals.

The coding of this policy into the VMT estimation program is straightforward. Two dollars is added to the parking cost portion of the cost/income attributes of all input observations which have a CBD destination. The ultimate usefulness of this policy will be analyzed in the latter sections of this chapter.

Policy No. 2--Auto Free CBD Zone

The creation of an auto free CBD zone is in effect the implementation of a physical parking restriction along with a reduction in the size of the highway network available to auto drivers and passengers. The purpose of this policy, like the previous one, is to reduce total VMT.

To simulate the presence of an auto free CBD zone, the walk times for drive alone, car pool and shared ride choices were increased five minutes. This increase may seem to be on the low side, but it was assumed that the auto traveler would try to find a different means of egress such as bus if CBD walk times exceeded five minutes. An additional assumption was made that the amount of time taken to find a parking place would not increase. Work trips are made often enough for the driver to become quickly familiar with a new parking situation. If shopping trips were being studied, the extra time spent searching for parking would have to be organized.

Policy No. 3--No More than One Car Per Household

The placement of an upper limit on the number of cars a household would be allowed to own is a rather drastic policy. This policy is one of the most forceful policies analyzed in the study. The legal feasibility of implementing this type of policy directly is questionable. Some device, such as the assessment of a luxury tax on additional cars might be used to legally accomplish the same results as an outright ban. It is the travel consequences that are of interest here, however, not the legal ramifications.

Logically, one would expect a reduction in VMT due to the reduction of auto accessibility and to the smaller number of cars in general. To simulate the implementation of this policy, the numerator of the number of autos/household size attribute of each individual trip observation was given an upper bound of 1.0. If there were no autos or one auto owned by the household, no changes were made in the number of autos/household size attribute of that particular observation.

Policy No. 4--Standard of Living Improvement

To capture the effects of a general improvement of living standards, a policy of across-the-board income increases was tested. This is what one would expect with a standard of living improvement. Income is included in the cost/income level-of-service attributes and is an attribute itself in all the modal choice models estimated.

In a purely inflationary situation, both modal costs and income will increase, though not necessarily concurrently. The change in cost/income would be indeterminant. Since in this study the cost will remain constant, the cost/income values will be reduced. The simulation of this policy was accomplished by increasing the calculated income in each observation 30 percent before cost/income and income attributes were used to calculate choice probabilities.

Policy No. 5--Doubling of Modal Costs

The trend in increasing fuel prices will directly affect out-of-pocket costs for travelers choosing drive alone, car pool and shared ride modes. Lagged fare increases for bus riders would also be expected unless subsidation was allowed to grow. This policy was used to test the steady state results of a significant increase of operating costs of all modes.

The models used in the policy estimation method did not indicate a decrease in total trips because they were mode choice models. However, that was not a serious drawback because the movements being analyzed were work trips. One would expect work trip frequency to be fairly insensitive to modal cost increases as long as the increases did not make travel costs prohibitive. All modal costs were doubled, after they were calculated, to simulate this policy.

Policy No. 6--High Bus Frequency

It is logical to assume that if the average wait times for bus service could be reduced, there should be a resultant increase in ridership. This policy explored the possible effects of placing an upper bound of 10 minutes on bus headways while maintaining existing bus route coverage. From the viewpoint of the operator, the consequences of adding buses to existing routes in such numbers as to insure that the headway at any point in the system would not exceed 10 minutes was analyzed.

To simulate this policy in the estimation method, the initial and secondary headway attributes were modified. The value of initial headway was set equal to the actual observed headway or to 10 minutes, whichever was less. Secondary headway values were constrained to be equal to zero for all observations.

Policy No. 7--Reduce Walk Times to Less Than 10 Minutes

Many travelers have an aversion to walking. It is not unusual for an excessive walk time to preclude the choice of a mode even though it is technically accessible to the traveler involved. Longer walk times are normally associated with transit type modes. This can be illustrated if the average values of drive alone and bus walk times are compared (Table A-3).

Therefore, implementation of the policy will result in a limited expansion of the coverage of bus routes. Expansion is limited in that if a person indicated a given mode was not available, it remained unavailable. Policy simulation was accomplished by setting an upper bound of 10 minutes for calculated walk times for all available modes in each observation.

Policy No. 8--All Modes Made Available

One step toward a balanced transportation system would be to implement a policy of making all modes available to all individuals. This would be a radical policy from a cost standpoint. Implementation would entail extreme expansion of most existing transit systems. Making cars available to all travelers would probably involve some type of negative income tax. The political feasibility of making all alternatives available to all individuals is questionable, but the travel implications are still of interest.

The simulation of this policy was accomplished by using the modal choice models calibrated with data which was unrestricted in individual choice selection. Coefficients of models used in this simulation are contained in the first two columns of Tables 3, A-4, A-7, A-10 and A-13. Coefficients used for the simulation of the first seven policies are in the last two columns of those tables. In addition to using different coefficients, the calculation of choice probabilities in the policy method program is not the same for the policy of making all alternatives available to all individuals as it is for the other policies. No prior restrictions are placed on the final choice probabilities of any given individual.

Some of the preceding sections of this chapter have included speculations as to the logical trends in ridership and resultant VMT. These trends are what one would expect to observe as a result of the implementation of various standard policies. The next sections concern the validity of those suspected trends and numerical estimates of the magnitude of ridership and VMT.

Policy Consequences for the Entire Population

Background

A set of base trips and VMTs was generated with combined population trip samples and the models were calibrated with combined samples in which alternatives were restricted to eligible individuals. The program used was described in the method section of this chapter. The results are in Tables 8 and 9. Base trips and VMTs resulted when the null policy was simulated in the program. That is, the choice attributes were not altered before choice probabilities were calculated. The restricted models were used to develop base data because they reflected the status quo of choices available to the trip makers.

The relative difference between total trips generated by the model using the choices of drive alone, car pool and bus and the model using choices of drive alone, shared ride and bus was only 0.8 percent. Total relative VMT difference was 4.6 percent. Thus, the use of expansion factors to relate the partial work trip data sets used in the study to the original 6042 work trip sample and

TABLE 8

Base Data Trips

	Drive Alone	Car Pool--Shared Ride	Bus
Choice Set 1 Models:*			
Combined	1994198	347171	381600
Married and Younger than 45	524783	103702	80216
Married and Older than 45	517015	85233	84818
Unmarried and Younger than 45	849612	144111	161944
Unmarried and Older than 45	163512	28471	60693
Choice Set 2 Models:**			
Combined	1814148	530491	356927
Married and Younger than 45	458501	181183	72497
Married and Older than 45	457968	105944	76761
Unmarried and Younger than 45	750435	213137	147825
Unmarried and Older than 45	144562	37765	54931

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE 9

Base Data VMT

	Total	Drive Alone	Car Pool--Shared Ride	Bus
Choice Set 1 Models: *				
Combined	13526455	12328757	989442	208257
Married and Younger than 45	3493432	2924074	526544	42814
Married and Older than 45	3243252	2883180	309967	50105
Unmarried and Younger than 45	5165656	4481901	611041	72716
Unmarried and Older than 45	980272	845718	101796	32758
Choice Set 2 Models:**				
Combined	12898920	11167637	1531156	200128
Married and Younger than 45	3790232	3441013	302842	46379
Married and Older than 45	3580012	3274832	251090	54090
Unmarried and Younger than 45	5488023	5013483	398554	75987
Unmarried and Older than 45	1068797	955188	77708	35902

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

resultant general population values for trips and VMTs was fairly successful. The value of roughly 13 million vehicle miles/day for work trips in the Minneapolis-St. Paul area at the time of sampling should be of reasonable accuracy. In any event, it did form a usable basis for comparative purposes in the testing of the standard policies.

The data which indicates the effectiveness of the eight policies studied based on the combined models is in Tables 10 and 11. This information will be considered in more detail in the following section.

Results

Policy No. 1--CBD Parking Tax. The policy of instituting a parking tax is the most effective in reducing the total amount of VMT. This can be seen from the results in Table 11. The relative reduction of total VMT was in the range of 3.3 to 3.4 percent regardless of whether the multiple car occupancy alternative was defined as car pool or shared ride. Parking costs were increased over 100 percent for most individuals who were already paying CBD parking charges. A moderate parking charge was levied on those who had previously parked free in the CBD. Yet, the VMT reduction was only on the order of three percent. Considering the magnitude of the parking tax, $2.00, and the scope of its application, the anticipated reduction is diminutive.

TABLE 10

Absolute and Percentage Changes in Trips for the Entire Population

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-115614 -5.80%	42976 12.4%	72687 19.1%	-119363 -6.58%	55889 10.5%	63534 17.8%
2	-27214 -1.4%	-19875 -5.7%	47112 12.4%	-28484 -1.6%	-25733 -4.9%	54226 15.2%
3	-89833 -4.5%	49616 14.3%	40243 10.6%	-107921 -6.0%	62346 11.8%	45620 12.8%
4	23145 1.2%	-18099 -5.2%	-5037 -1.3%	10372 0.6%	-9310 -1.8%	-1061 -0.3%
5	-23056 -1.2%	22176 6.4%	884 0.2%	-25095 -1.4%	24667 4.7%	426 0.1%
6	-12611 -0.6%	-9175 -2.6%	21796 5.7%	-10290 -0.6%	-8326 -1.6%	18631 5.2%
7	-22019 -1.1%	-14483 -4.2%	36516 9.6%	-23123 -1.3%	-19058 -3.6%	42188 11.8%
8	-35142 -1.8%	10824 3.1%	24788 6.5%	-35230 -1.9%	15653 3.0%	18615 5.2%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE 11

Absolute and Percentage Changes
in VMT for the Entire Population

Policy Number	Choice Set 1* Total	Drive Alone	Car Pool	Bus	Choice Set 2** Total	Drive Alone	Shared Ride	Bus
1	-439340 -3.3%	-632898 -5.1%	148658 15.0%	44899 21.6%	441196 -3.4%	662920 -5.9%	182738 11.9%	38985 19.5%
2	-134153 -1.0%	-121234 -1.0%	-42322 -4.3%	29402 14.1%	-150461 -1.2%	-130273 -1.2%	-54471 -3.6%	34283 17.1%
3	-319977 -2.4%	-515087 -4.2%	166892 16.9%	28217 13.6%	388216 -3.0%	-633659 -5.7%	213179 13.9%	32264 16.1%
4	81386 0.6%	143464 1.2%	-58855 -6.0%	-3223 -1.6%	37900 0.3%	69704 0.6%	-31293 -2.0%	-512 -0.3%
5	-88166 -0.7%	-163543 -1.3%	75558 7.6%	-182 -0.1%	-96990 -0.8%	-182107 -1.6%	85646 5.6%	-529 -0.3%
6	-106460 -0.8%	-96510 -0.8%	-36634 -3.7%	26683 12.8%	-93595 -0.7%	-83012 -0.7%	-35162 -2.3%	24578 12.3%
7	-101907 -0.8%	-89277 -0.7%	-28252 -2.9%	15622 7.5%	-113503 -0.9%	-94603 -0.9%	-36823 -2.4%	17923 9.0%
8	-157404 -1.2%	-290908 -2.4%	61260 6.2%	72243 34.7%	-159161 -1.2%	-294869 -2.6%	69414 4.5%	66294 33.1%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

Bus ridership increased approximately 18 percent (Table 10). One could argue that if this increase did not cause the bus system to exceed its present capacity, the approximate 20 percent increase in VMT of buses due to bus riders would be much reduced. Even if this increase is eliminated, the total VMT reduction is still only 3.6 to 3.7 percent.

This result of the ineffectiveness of a CBD parking tax is not unreasonable. Other studies, based on different assumptions and using different methods of measuring results, indicated similar conclusions (Kulash 1974).

Policy No. 2--Auto Free CBD Zone. Unlike the previous policy in which car pool and shared ride alternatives had increased patronage, the policy of an automobile free CBD zone decreased use of these type of modes on the order of five percent (Table 10). This was to be expected because multiple occupancy cars were excluded along with those of single occupancy. The overall reduction of VMT, using either the choice set of drive alone, car pool and bus or the choice set drive alone, shared ride and bus was approximately one percent (Table 11).

Such a small reduction in VMT would hardly justify the establishment of an auto free zone considering associated drawbacks. Vehicles such as buses would still be using the affected streets, minimizing aesthetic improvements anticipated. Car poolers, who can be considered conscientious in their efforts to improve the urban environment, would be subjected to additional egress times that could make their total trip times unreasonable. The problem of enforcing an auto free zone would be difficult both physically and economically. One must conclude that the ultimate success of an auto free CBD zone is questionable at best.

Policy No. 3--No More Than One Car Per Household. This policy is second only to the policy of imposing a CBD parking tax in its effectiveness in reducing total VMT. The reduction in VMT one would expect to observe would be on the order of 2.4 to 3.0 percent (Table 11). This, as in the previous policies, is disappointingly low. The feasibility of imposing a car ownership limit was discussed earlier, and it was concluded that it was doubtful. It was interesting to note, however, the changes in ridership that resulted when implementation was considered possible.

There was an increase in the expected number of travelers choosing car pool or shared ride. It appeared that even though there was a reduction in the total number of automobiles available for work trips, these travelers would still manage to commute in automobiles.

Policy No. 4--Standard of Living Improvement. The increase in total VMT due to a standard of living improvement expressed as a 30 percent rise in income was 0.3 and 0.6 percent in the two choice sets, respectively (Table 11).

This is the most insensitive response observed in the policies tested. As expected, a small increase was observed in the auto drive alone VMT. Small increases were also evident in car pool, shared ride and bus VMTs. An overall income increase will not, of itself, alter total VMT of work trips appreciably. However, one has to point out that this conclusion is based on income change only. Changes in other attributes, such as car ownership, residential location, etc., which might accompany an income increase, are not considered here.

Policy No. 5--Doubling of Modal Costs. The simulation of this policy resulted in a slight decrease in total VMT (Table 11). There was a decrease of approximately one percent in the VMT due to travelers driving alone, while there was virtually no change in VMT generated by bus travelers. Only the car pool and corresponding shared ride choices experienced increases of patronage and VMT of notable magnitude. Yet the increase in VMT of those modes was only in the 6 to 8 percent range. If one considers the present demographic makeup, then a doubling of all modal costs will have little effect on the whole transportation system as far as VMT is concerned. Only a slight increase in car pooling will result.

Policy No. 6--High Bus Frequency. Setting the bus headways at less than 10 minutes did increase bus ridership, as one would expect, but only slightly more than 5.0 percent (Table 10). However, both car pool and shared ride trips decreased on the order of 2.0 percent. Apparently the added attractiveness of the bus system lured some riders who would otherwise have car pooled.

The overall effect on VMT was minimal. The decrease in VMT of the automobile oriented alternatives was not enough to offset the increase in bus VMT. The result was that the ultimate total VMT was only reduced by approximately 0.8 percent.

Policy No. 7--Reduce Walk Times to Less Than 10 Minutes. Decreasing walk times to less than 10 minutes did switch some riders to the bus mode, but as in the case of high bus frequencies, one would expect this at the expense of car pool and shared ride modes. The expected shift in travelers using auto type modes to transit occurred, but it was only a small shift. The bus ridership increase was approximately 10.0 percent (Table 10). The car pool and shared ride decrease was about 4.0 percent and drive alone trips decreased 1.0 percent. One could not expect, therefore, that a ceiling on walk time would, by itself, appreciably alter total VMT. This was reflected in the actual results. The ultimate relative decrease in total VMT was only approximately 0.8 percent (Table 11).

Policy No. 8--All Modes Made Available. The policy of making all modes available to all travelers had, like all of the other policies, only a small effect on total VMT. Notice that although cars were available to all travelers, the drive alone VMT was reduced approximately 2.5 percent (Table 11). This was reasonable because bus was now available to all travelers. The other curious fact was that car pool and its counterpart shared ride VMT's have increased. This could be because cars were now available to bus riders who previously had no vehicles. So it appeared that travelers switched to preferred modes, whatever they may be, whenever all modes became available. The end result, however, is a change of total VMT of only 1.2 percent which is negligible.

The eight policies tested all showed a minimal ability to change the ultimate total VMT for work trip purposes when combined models, representative of the general population, were used in the process of calculating the expected number of trips and VMT by mode. In this section the differences between policies based on models pertaining to the entire population were analyzed. In the next section the differences within policies based on the four specific market segment classifications are considered.

Comparative Analysis of Policy Consequences by Market Segments

Background

The modal choice models developed for each market segment in this study were used to generate total trips and VMT's by the method described in the second section of this chapter. The base trips and VMT's for the different market segments are given in Tables 8 and 9. The results of total trip and VMT changes by market segment due to policy implementation are given in Tables B-1 through B-8.[1] Since the base trips and VMT's will be different for each market segment, comparisons of the effective policies will have to be limited to relative (percentage) differences.

The results are discussed in two sections. The first concerns those policies in which there appeared to be a significant difference between responses to policy implementations on the basis of age and marital status. The other concerns those policies that elicit similar responses from different market segments.

Policies Sensitive to Age and Marital Status

The policies of placing a $2.00 CBD tax on parking and of imposing an upper bound of one car per household were the only policies that showed an appreciable difference

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[1] Because of their size, these tables are in Appendix B. Summary tables are provided in the text for purposes of analysis.

in relative VMT changes using information specific to each market segment. The policy of making all alternatives available was also included because a trend was evident, but not as clearly as with the two previous policies. Table 12 contains summary results from Tables B-2, B-4, B-6 and B-8 for the three policies discussed here.

TABLE 12

Relative Total VMT Changes for Policies Sensitive to Age and Marital Status

Market Segments	CBD Parking Tax Choice Set 1*	CBD Parking Tax Choice Set 2**	≥ 1 Car/ Household Choice Set 1	≥ 1 Car/ Household Choice Set 2	All Alternatives Available Choice Set 1	All Alternatives Available Choice Set 2
Married, younger than 45	-1.9%	-2.0%	-4.6%	-7.1%	-5.0%	-1.6%
Married, older than 45	-5.5%	-4.7%	-1.6%	-2.5%	-1.1%	1.3%
Unmarried, younger than 45	-2.3%	-2.7%	-2.7%	-2.6%	-4.8%	-2.3%
Unmarried, older than 45	-11.0%	-12.2%	0.1%	-0.05%	-6.6%	-2.3%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

The $2.00 parking tax stimulated more of a reaction from the two older groups than from the younger ones. Marital status did not appear to be as important a differentiating factor as age. The unmarried groups, however, tended to be slightly more sensitive to parking costs than the others. Again, one must be cautious in interpreting these results because the value differences were generated from different sets of base data. The results indicated a trend to support the conclusion that the older groups were indeed more responsive to parking taxes than their younger cohorts. This appears to be reasonable because of the higher sensitivities to costs exhibited by the older groups when the modal choice model results were analyzed.

The placement of a limit on car ownership yielded logical results. The group of older, single travelers exhibited little reaction, with respect to total VMT, to the implementation of this policy. This is as expected. It would not be unusual for an older, single person to need only one vehicle for work purposes.

The young married individuals showed the greatest relative reduction in VMT. The higher incidence of working spouses and, consequently, a higher average number of individuals per household employed over the other groups would be one possible driving force for the reduction. The higher number of employed individuals would place a greater reliance on multiple car usage for work trips for this group in comparison to the other market segments. Secondly, the preferences of young marrieds to live in suburban areas would be an additional reason for having high car ownership levels. It is reasonable that individuals of this market segment would be highly sensitive to an upper bound on car ownership.

The assessment of a market segment trend for the policy of making all alternatives available to all individuals is more difficult than for the other two policies previously considered in this section. Apparently the older marrieds are scarcely affected by increasing the availability of all modes. It may be that older married individuals are more intransigent than the general population; they are more insensitive than other market segments to the availability of previously inaccessible modes.

The remaining groups showed reductions of total VMT. One would expect this because, as was discussed in a previous section of the study, making all alternatives available to all members of the general population did decrease total VMT. These remaining groups, however, could not be differentiated by their reactions to this policy.

Policies Insensitive to Age and Marital Status

The determination of whether a policy was considered to be sensitive or insensitive to a change in age and marital status was based on the variation between market segments of relative VMT changes observed for that policy. This determination was rather arbitrary; it was for discussion purposes only. The policies discussed in this section and the resultant relative market segment specific changes in VMT upon implementation of these policies are given in Table 13. The results in Table 13 are derived from Tables B-2, B-4, B-6 and B-8.

In Table 13 the least amount of variation in relative VMT changes between market segments was when the policy of high bus frequencies was simulated given that the choices of drive alone, shared ride and bus were available. A difference of only 0.4 percent was noted between the older single and younger married groups. The greatest market segment difference found for the policies discussed in this section was the result of an income increase of 30 percent. A 2.0 percent difference between the older single and older married group was noted for the choice set of drive alone, car pool and bus. All other differences between market segments in Table 13 were between those two extremes.

Since these relative differences were so minor, considering the absolute differences involved, one has to conclude that the policies of an auto free CBD zone, standard of living improvement, modal cost increase, high bus frequency and reduced walk times do not exhibit appreciable differential changes in VMTs with respect to the age and marital status of the traveler.

It was noted that only three of the tested policies, a CBD parking tax, a ceiling of one automobile per household and making all alternatives available produced noticeably different relative changes in total VMTs when distinct market

TABLE 13

Relative Total VMT Changes for Policies
Insensitive to Age and Marital Status

Market Segments	Auto Free CBD Zone Choice Set		Income Increase Choice Set		Modal Cost Increase Choice Set		High Bus Frequency Choice Set		Reduce Walk Times Choice Set	
	1*	2**	1	2	1	2	1	2	1	2
Married, younger than 45	-1.6%	-1.4%	0.6%	-0.1%	-0.4%	-0.5%	-0.4%	-0.5%	-1.5%	-1.3%
Married, older than 45	-1.6%	-1.9%	0.7%	0.7%	-1.1%	-1.0%	0.8%	-0.8%	-0.9%	-1.3%
Unmarried, younger than 45	-0.3%	-0.5%	0.5%	-0.3%	-0.5%	-0.6%	-0.9%	-0.8%	-0.2%	-0.4%
Unmarried, older than 45	-1.8%	-1.7%	-1.3%	-0.2%	-1.7%	-2.1%	-1.0%	-0.9%	-1.3%	-1.2%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

segments were used to generate these VMTs. This does not show, however, that these differences will be manifested in the end results of population total VMTs if the distributions of age and marital status in the population are changed. This sensitivity to demographic change is discussed next.

Demographic Sensitivity of Policy Results

Background

The first step in developing a method to test demographic sensitivity of the different policies was to determine a reasonably interesting demographic change for experimentation. Recently there has been a trend toward zero population growth in the United States (Hoch 1975). Considering the age breakdown limitations of the data used in this study, this points toward an upward shift in the fraction of the population over 45 years of age. Secondly, it can be anticipated that the fraction of the population which is married will become smaller due to the increasing popularity of nontraditional living arrangements. For these reasons, the demographic change decided on was an increase in the fraction of older, single individuals with corresponding decreases in the other groups. The method used to generate the final VMTs for testing demographic sensitivity of policy effectiveness is discussed in more detail on the following page.

Procedure for Generation of VMTs

The procedure used to generate the base future VMTs for both initial and altered demographic makeups was similar to that used to generate the preceding combined base VMTs in Table 9. The models illustrated in Table 3 (calibrated with combined market segment data in which choices were restricted to eligible individuals) were used for generation of base trips and VMTs for both initial and altered demographic makeup populations. The difference was that a growth expansion factor was incorporated. The altered demographic base VMTs were generated with demographically altered data sets. Construction of the demographically altered data sets is discussed first.

The four combined data sets illustrated in Table 1 are composed of the market segment specific data sets in Tables 4 through 7. To form the four combined data sets that were demographically altered, the market segment specific data sets were first modified and then summed. These modifications were accomplished by randomly enlarging the older, single data sets and randomly decreasing the size of the other market segment specific data sets.

The magnitude of increase of the older, single data sets tested was set at 50 percent. This was achieved by using a program, which incorporated a random number generator, to randomly duplicate 50 percent of the observations of the older, single data sets. These altered older, single data sets, therefore, contained 50 percent more observations than the previous ones. The other data sets were each reduced in size by randomly eliminating a fraction of the observations. The fractions were proportional to the original sizes. They were also calculated so that the total number of observations eliminated in the three groups would equal the number duplicated in the older, single group. Table 14 shows the percentage changes input to the program that randomly formed the demographically altered data sets.

TABLE 14

Percentage Changes in Data Set Observations Used to Form Altered Data Sets

Market Segment	Percent Change
Married, younger than 45	-6.18
Married, older than 45	-5.74
Unmarried, younger than 45	-3.85
Unmarried, older than 45	50.0

The growth expansion factor was incorporated into the total trip and VMT generation program. The expression in equation (4-1) was multiplied by this factor to get a simulated number of trips for a possible future situation. This growth expansion factor was randomly generated with a uniform distribution ranging from 1.0 to 2.0. The same set of random expansion factors used with the base runs were used with the policy runs so that results were calculated from similar populations.

Results

The base run results of expanded trips and VMTs are given in Tables 15 and 16. These tables contain results generated from data sets which have the initial demographic makeup and from those which have the altered demographic makeup. The values in Tables 15 and 16, representative of initial demographic makeup, are greater than the corresponding combined values in Tables 8 and 9. This is only because of the inclusion of the expansion factors.

These increased values are, however, in the same range as those values representative of altered demographic makeup. This indicates that there is a fair stability of future VMT, with respect to age and marital status makeup of the population, if initial base policies are unchanged.

TABLE 15

Base Expanded Trips for the Entire Population

	Drive Alone	Car Pool--Shared Ride	Bus
Initial Demographic Makeup			
Choice Set 1*	3004348	522104	573037
Choice Set 2**	2733298	798964	541179
Altered Demographic Makeup			
Choice Set 1	3009800	527137	575635
Choice Set 2	2734474	802155	534910

TABLE 16

Base Expanded VMT for the Entire Population

	Total	Drive Alone	Car Pool--Shared Ride	Bus
Initial Demographic Makeup				
Choice Set 1*	203392264	18547104	1480296	311885
Choice Set 2**	19408784	16803796	2303922	301570
Altered Demographic Makeup				
Choice Set 1	20438704	18624976	1497387	316356
Choice Set 2	19383808	16790848	2295335	297645

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

The main interest here, however, is to test the change in the effectiveness of policies analyzed in this study in response to a demographic change in the population. Tables B-9 and B-10 contain the changes in trips and VMTs associated with the population having the initial demographic makeup.[1] The corresponding information for the population with the altered demographic makeup is in Tables B-11 and B-12. Table 17 contains summary information from Tables B-10 and B-12.

TABLE 17

Relative Changes in
Total VMT Using Expanded Data

Policy Number	Initial Demographic Makeup		Altered Demographic Makeup	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
1	-3.2%	-3.5%	-3.2%	-3.4%
2	-1.0%	-1.2%	-1.0%	-1.2%
3	-2.4%	-3.0%	-2.3%	-2.9%
4	0.6%	0.3%	0.6%	0.3%
5	-0.6%	-0.8%	-0.7%	-0.8%
6	-0.8%	-0.7%	-0.7%	-0.7%
7	-0.7%	-0.9%	0.7%	-0.9%
8	-1.2%	-1.2%	-1.0%	-1.1%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

[1]Tables B-9 through B-12, from which the information in the section is derived, are in Appendix B.

One can see, that on the basis of the relative VMT changes in Table 17, there is virtually no difference in the effectiveness of policies tested using observations drawn from two demographically distinct populations. This implies that the policy effectiveness conclusions, discussed earlier in this chapter, remain valid even if the population undergoes a fairly drastic demographic change.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The main purpose of this study was to investigate the usefulness of standard transport policies in effecting work trip VMT under various conditions. This investigation involved three objectives. The first objective was to see if implementation of standard policies was effective in reducing VMT conditioned upon initial population attributes. The second was to find out if various classes of travelers would have differential responses to such policies. The last objective was to discover if a significant change in the age and marital status makeup of the population studied would alter the effectiveness of standard policies.

The models used to form a basis for the policy analysis were multinomial logit modal choice models. Twenty different models, possessing the same utility specifications, were calibrated with home interview data from the Minneapolis-St. Paul region. These models encompassed differences in age and marital status attributes, alternative selection methods and choice set compositions.

Half the models used the choice set of drive alone, car pool and bus. The other half used the choice set of drive alone, shared ride and bus. Both the car pool and shared ride alternatives were of multiple automobile occupancy. The difference was that travelers choosing car pool indicated so in the home interviews; whereas, only an indication of multiple car occupancy was deemed sufficient to assign an individual's choice as shared ride.

Two types of alternative selection schemes were investigated. One half of the models were calibrated in such a way as to reflect the actual choices available to each traveler. These were classified as restricted models. To facilitate the analysis of the policy of making all alternatives available to all individuals, the remainder of the models were calibrated to simulate this policy. Thus, for each of the four market segments and for the entire population, four models were calibrated reflecting the combination of two choice sets and two methods of selecting alternatives.

The population attributes used to distinguish the four market segments were marital status (single or married) and age (younger than 45 years or older than 45 years). Each model in a market segment specific group was calibrated with data drawn from the population having the attributes of age and marital status representative of that specific market segment. Models pertaining to the entire population were calibrated with data possessing attributes of all four market segments. All model results were reasonable.

The models for the entire population indicated walk time values on the order of 500 percent of the before tax wage rate. These values are high, but walking is an especially onerous portion of a work trip for the average American traveler. These models possessed coefficients of reasonable sign and the models, as a whole, were statistically significant.

The models representing individuals with attributes of being married and under 45 years of age indicated walk time values much higher than the other specific groups or the population as a whole. The wage rate for individuals who were married and under 45 years of age was not above average, so their high time valuation does not appear to be linked to their income. It is possible that the high value of time is a result of prior conditioning. That is, people in this market segment may have acquired a propensity for high time valuation from parental and peer influences unrelated to the work trip. In that case, success in altering the walking portion of work trip patterns for these individuals would have to involve measures normally considered to be outside the domain of transportation planners.

The remaining market segment specific groups exhibited characteristics that were not as extreme as those of the married and younger than 45 years group. The two groups of models calibrated with data drawn from the unmarried portion of the population, showed implied walk time values slightly less than the entire population. The older married group had walk times that were in the same range as those in the general population. A reasonable conclusion (based on this evidence and additional evidence in the study) is that, in general, the younger married individuals as a group were less sensitive to cost changes and more sensitive to walking time changes than other segments of the traveling population.

The effectiveness of each of the policies was tested using a disaggregate sampling method to predict total trips and VMTs. Trips were randomly sampled from the population. Attributes of those samples were modified to simulate the policy being tested. The probabilistic choice behavior of the individual represented by a given observation was predicted by an appropriate modal choice model and weighted by the screenline count and sample expansion factors. The weighted mode specific trip totals and resultant VMTs were then cumulated to form an estimate of the population trips and VMTs. Changes in the VMTs as a result of implementation of a policy were used as a measure of the effectiveness of that policy. The results of the effectiveness of standard transport policies, based on the modal choice models, were not as distinct as the characteristics of the models themselves.

The policies studied were, as a whole, fairly ineffective in altering total work trip VMT based upon the initial population attributes. This ineffectiveness was nearly uniform across age and marital status groups for the policies of implementing an auto free CBD zone, improving the standard of living, doubling modal costs, placing an upper bound of 10 minutes on bus headways and decreasing walk time to a maximum of 10 minutes.

The other three policies, although showing an overall ineffectiveness as the preceding policies, showed differential effectiveness across market segments. The policy of instituting a $2.00 CBD parking tax was significantly more effective in reducing total VMT in the older single group than in the other groups. Placing a ceiling of one car per household hardly affected the older single group, but did show a slight reduction of VMT for the other groups. This was a reasonable result because older single people would, in many cases, have little need for more than one car. Making all alternatives available did not alter the total VMT for the older married group, but small reductions were noted for the other groups. These differences in policy responses, however, did not manifest themselves in the aggregate responses when the demographic makeup of the population was altered by changing the percentage composition by market segment of the population.

The change in aggregate responses to standard transportation policies due to an alteration in the demographic makeup of the population was determined by making a comparison between two sets of aggregate responses to those policies. The initial aggregate responses to standard policies were estimated using samples with existing demographic attributes. These samples were expanded to simulate random growth before responses were estimated.

This process was repeated using samples in which the proportion of the population composed of single individuals older than 45 years was increased 50 percent. The outcome was that policy effectiveness, expressed as a relative (percentage) change in total VMT, was virtually unchanged when market segment proportions were altered.

The study supports three general conclusions:

1. The effectiveness of standard transport policies in changing the aggregated work trip VMT is minimal.

2. Some policies do exhibit differential effectiveness between age and marital status market segments when the differences are based on VMTs generated separately from the different market segments.

3. The low-level of aggregate policy effectiveness is extremely stable under a change in the age and marital status makeup of a population.

Extension of the Research

The present study gives expected relative changes in VMTs due to the implementation of standard transport policies. A rough estimation of the relative changes in fuel consumption, as a result of these policies, can be obtained by using average fuel consumption rates with the predicted VMTs. Since average rates are used in this type of estimation procedure, the relative changes in fuel consumption will be similar to the relative changes in VMTs.

A technical extension of the research in this study would be to obtain fuel consumption rates at the disaggregate level. For example, home interview respondents could be asked pertinent questions about the characteristics of their automobile(s) and their driving habits. Fuel consumption is a function of vehicle characteristics and driving habits of the operator. It is entirely possible that the variation in fuel consumption due to driving habits is as large as that due to a characteristic such as vehicle weight. For this reason, a disaggregate automobile fuel consumption rate would be a useful and interesting addition to the usual inventory of trip attributes. Fuel consumption changes resulting from transport policy impositions could be estimated with the same cumulative process used to determine VMTs in this study. These fuel consumption changes, in contrast to those based on average rates, could possibly differ significantly from the VMT changes.

A more general impetus for future research as a result of this study is based on the ineffectiveness of various transport policies in significantly reducing VMTs. If the main objective in future transportation planning remains the reduction of VMT, then approaches other than standard transport policies may prove more successful. One possibility is the reeducation of the public in an effort to change inherent values and, ultimately, transportation decisions based on those values. The maintenance of an individual's value system has normally been treated as a constraint in transportation planning. The relaxation of this constraint, although objectionable to some, could provide a passive means of reducing VMTs. In conclusion, innovative and possibly controversial approaches will have to be explored if future transportation problems are to be ameliorated.

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APPENDIX A

TABLES OF THE MODAL CHOICE MODEL CHARACTERISTICS

TABLE A-1

Typical Model in which the
Linehaul Time Coefficient was Positive*

Coefficient Name	Value	t-Value
Cost/Income	-35.425	-1.92
Linehaul Time	0.158	0.35
Walk Time	-0.081	-1.72
Initial Headway	-0.232	-3.06
Secondary Headway	-0.248	-2.30
Head of Household	-0.547	-0.14
Autos/Household Size #1	3.468	6.63
Autos/Household Size #2	1.140	2.13
Income	0.00006	2.09
Drive Alone Constant	-5.853	-4.41
Shared Ride Constant	-5.116	-4.12

*These model results were obtained by using the unmarried and older than 45 years of age data set. All alternatives were available and the choice set was Drive Alone, Shared Ride, and Bus.

TABLE A-2

Direct Elasticities of Selected Variables at Sample Means and Probabilities

Combined Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	-0.03	-0.04	-0.05	-0.05
Car pool--Shared Ride Cost/Income	-0.04	-0.04	-0.07	-0.05
Bus Cost/Income	-0.07	-0.07	-0.11	-0.09
Drive Alone Walk Time	-0.07	-0.09	-0.07	-0.09
Car pool--Shared Ride Walk Time	-0.21	-0.20	-0.21	-0.21
Bus Walk Time	-0.42	-0.44	-0.42	-0.46
Initial Headway	-1.34	-1.37	-1.09	-1.16
Secondary Headway	-0.97	-0.96	-0.38	-0.33

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-3

Sample Mean Values

Combined Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	.0066	.0066	.0066	.0065
Car pool--Shared Ride Cost/Income	.0032	.0032	.0032	.0032
Bus Cost/Income	.0053	.0053	.0053	.0053
Drive Alone Walk Time	3.83	3.82	3.83	3.82
Car pool--Shared Ride Walk Time	3.83	3.82	3.83	3.82
Bus Walk Time	7.97	7.97	7.93	7.93
Initial Headway	15.20	15.22	15.19	15.22
Secondary Headway	29.50	29.77	29.64	29.84

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-4

Coefficients, t-values and Other Statistical Measures of Models

Married and Younger than 45 Years Data Sets

Coefficients	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Cost/Income	-8.98 (-0.67)	-12.18 (-0.98)	-15.06 (-0.74)	-11.98 (-0.75)
Walk Time	-0.022 (-0.59)	-0.032 (-0.90)	-0.121 (-2.08)	-0.097 (1.90)
Initial Headway	-0.046 (1.04)	-0.055 (-1.30)	-0.032 (0.601)	-0.020 (-1.41)
Secondary Headway	-0.046 (-4.51)	-0.043 (-4.50)	-0.0074 (-0.71)	-0.008 (-0.81)
Head of Household	0.316 (0.42)	0.209 (0.33)	-0.568 (-0.50)	-0.09 (-0.12)
Autos/Household Size #1	3.53 (6.05)	3.69 (6.49)	3.44 (4.51)	3.79 (5.51)
Autos/Household Size #2	1.79 (2.78)	1.85 (3.22)	1.31 (1.92)	1.56 (2.49)
Income	0.00005 (2.14)	0.00002 (1.31)	0.00002 (0.70)	-0.00001 (-0.24)
Drive Alone Constant	-2.85 (-2.92)	-2.67 (-3.03)	-1.72 (-1.18)	-2.13 (-1.96)
Car pool--Shared Constant	-2.41 (-3.50)	-1.85 (2.92)	-2.45 (-2.93)	-1.84 (-2.45)
$-2\ell n\lambda$	502.4	425.9	334.1	204.3
% Correct	76%	65%	83%	70%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-5

Direct Elasticities of Selected Variables
at Sample Means and Probabilities

Married and Younger than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	-0.02	-0.03	-0.03	-0.03
Car Pool-- Shared Ride Cost/Income	-0.02	-0.03	-0.04	-0.03
Bus Cost/Income	-0.04	-0.06	-0.07	-0.06
Drive Alone Walk Time	-0.02	-0.05	-0.13	-0.14
Car Pool-- Shared Ride Walk Time	-0.07	-0.09	-0.40	-0.28
Bus Walk Time	-0.15	-0.22	-0.82	-0.68
Initial Headway	-0.16	-0.74	-0.42	-0.27
Secondary Headway	-1.42	-1.31	-0.22	-0.25

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-6

Sample Mean Values

Married and Younger than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	0.0066	0.0067	0.0066	0.0066
Car Pool--Shared Ride Cost/Income	0.0032	0.0033	0.0032	0.0032
Bus Cost/Income	0.0054	0.0055	0.0054	0.0054
Drive Alone Walk Time	3.897	3.90	3.90	3.89
Car Pool--Shared Ride Walk Time	3.897	3.90	3.90	3.89
Bus Walk Time	7.74	7.84	7.80	7.90
Initial Headway	15.10	15.14	15.1	15.13
Secondary Headway	35.03	34.70	35.0	34.63

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-7

Coefficients, t-values and Other Statistical Measures of Models

Married and Older than 45 Years Data Sets

	All Alternatives Available		Alternatives Restricted	
Coefficients	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Cost/Income	-38.70 (2.17)	-32.35 (-1.91)	-43.71 (1.96)	-32.51 (-1.54)
Walk Time	-0.125 (3.86)	-0.127 (-3.99)	-0.079 (-1.96)	-0.0969 (-2.50)
Initial Headway	-0.193 (-3.61)	-0.195 (-3.74)	-0.295 (-3.39)	-0.298 (-3.48)
Secondary Headway	-0.032 (-4.07)	-0.03 (-4.07)	-0.0133 (-1.34)	-0.0118 (-1.31)
Head of Household	0.396 (0.98)	0.200 (0.50)	0.621 (1.19)	0.276 (0.54)
Autos/Household Size #1	2.20 (3.83)	2.29 (4.02)	2.17 (3.04)	2.67 (3.92)
Autos/Household Size #2	1.42 (2.14)	1.28 (2.03)	1.05 (1.95)	1.07 (2.08)
Income	0.00005 (2.71)	0.00005 (2.93)	0.00002 (0.74)	0.00001 (0.74)
Drive Alone Constant	-4.53 (-4.80)	-4.43 (4.80)	-5.87 (-3.82)	-6.05 (-3.97)
Car Pool--Shared Ride Constant	-4.93 (-5.60)	-4.53 (-5.35)	-6.49 (-4.50)	-6.33 (-4.45)
$-2\ln\lambda$	587.0	532.2	419.5	349.0
% Correct	74%	70%	83%	79%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-8

Direct Elasticities of Selected Variables at Sample Means and Probabilities

Married and Older than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	-0.06	-0.06	-0.07	-0.06
Car Pool--Shared Ride Cost/Income	-0.09	-0.07	-0.11	-0.07
Bus Cost/Income	-0.15	-0.13	-0.17	-0.13
Drive Alone Walk Time	-0.13	-0.15	-0.08	-0.11
Car Pool--Shared Ride Walk Time	-0.41	-0.40	-0.26	-0.30
Bus Walk Time	-0.88	-0.89	-0.54	-0.66
Initial Headway	-2.55	-2.59	-3.88	-3.94
Secondary Headway	-0.84	-0.80	-0.34	-0.31

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-9

Sample Mean Values

Married and Older than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	0.0058	0.0057	0.0058	0.0057
Car Pool--Shared Ride Cost/Income	0.0028	0.0028	0.0028	0.0028
Bus Cost/Income	0.0046	0.0046	0.0046	0.0046
Drive Alone Walk Time	3.74	3.75	3.76	3.76
Car Pool--Shared Ride Walk Time	3.74	3.75	3.76	3.76
Bus Walk Time	8.20	8.16	8.02	7.99
Initial Headway	15.44	15.45	15.43	15.44
Secondary Headway	30.20	30.38	30.39	30.61

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-10

Coefficients, t-values and Other Statistical Measures of Models

Unmarried and Younger than 45 Years Data Sets

Coefficients	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Cost/Income	-10.75 (-1.22)	-11.77 (1.34)	-19.10 (-1.60)	-18.16 (-1.68)
Walk Time	-0.0274 (-1.08)	-0.032 (-1.32)	-0.020 (-0.59)	-0.346 (-1.10)
Initial Headway	-0.0765 (-2.16)	-0.086 (-2.52)	-0.058 (-1.30)	-0.0790 (-1.84)
Secondary Headway	-0.051 (-6.0)	-0.48 (-6.01)	-0.023 (-2.68)	-0.0184 (-2.34)
Head of Household	0.076 (4.70)	0.065 (0.45)	-0.125 (-0.61)	-0.057 (-0.342)
Autos/Household Size #1	3.05 (8.86)	2.95 (8.91)	2.25 (4.87)	2.13 (5.07)
Autos/Household Size #2	1.85 (4.65)	2.139 (6.00)	1.386 (3.32)	1.688 (4.32)
Income	0.00006 (4.40)	0.00003 (2.56)	0.00002 (1.03)	-0.00001 (-0.85)
Drive Alone Constant	-2.84 (-5.30)	-2.57 (-5.03)	-1.508 (-2.09)	-1.645 (-2.41)
Car Pool--Shared Ride Constant	-3.03 (-5.83)	-2.86 (-5.76)	-2.831 (-4.30)	-2.964 (4.63)
$-2\ell n\lambda$	857.6	717.3	602.7	425.7
% Correct	77%	70%	84%	77%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-11

Direct Elasticities of Selected Variables
at Sample Means and Probabilities

Unmarried and Younger than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	-0.02	-0.03	-0.04	-0.04
Car Pool--Shared Ride Cost/Income	-0.03	-0.03	-0.06	-0.05
Bus Cost/Income	-0.05	-0.05	-0.08	-0.08
Drive Alone Walk Time	-0.03	-0.04	-0.02	-0.05
Car Pool--Shared Ride Walk Time	-0.09	-0.10	-0.07	-0.10
Bus Walk Time	-0.18	-0.21	-0.13	-0.23
Initial Headway	-0.97	-1.10	-0.73	-1.01
Secondary Headway	-1.18	-1.13	-0.53	-0.44

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-12

Sample Mean Values

Unmarried and Younger than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	0.0069	0.0068	0.0068	0.0067
Car Pool--Shared Ride Cost/Income	0.0034	0.0033	0.0034	0.0033
Bus Cost/Income	0.0053	0.0052	0.0053	0.0052
Drive Alone Walk Time	3.79	3.78	3.79	3.77
Car Pool--Shared Ride Walk Time	3.79	3.78	3.79	3.77
Bus Walk Time	7.86	7.84	7.85	7.82
Initial Headway	15.11	15.15	15.11	15.16
Secondary Headway	27.76	27.86	27.87	20.04

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-13

Coefficients, t-values and Other Statistical Measures of Models

Unmarried and Older than 45 Years Data Sets

Coefficients	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Cost/Income	-32.21 (-1.71)	-35.55 (-1.93)	-53.09 (-2.40)	-50.38 (-2.53)
Walk Time	-0.0767 (-1.70)	-0.0847 (-1.85)	-0.078 (-1.30)	-0.0712 (-1.23)
Initial Headway	-0.251 (-3.18)	-0.231 (-3.05)	-0.0342 (-0.30)	-0.0581 (-0.682)
Secondary Headway	-0.0177 (-1.66)	-0.0231 (-2.41)	-0.015 (-0.88)	-0.013 (-0.803)
Head of Household	0.101 (0.24)	-0.051 (-0.13)	0.488 (0.74)	0.220 (0.38)
Autos/Household Size #1	3.33 (6.46)	3.45 (6.64)	-0.0186 (-0.02)	0.658 (0.79)
Autos/Household Size #2	0.603 (1.02)	1.12 (2.11)	0.237 (0.39)	0.739 (1.30)
Income	0.00005 (1.80)	0.00006 (2.11)	-0.00006 (-1.46)	-0.00002 (-0.060)
Drive Alone Constant	-6.05 (-4.51)	-5.99 (-4.55)	0.368 (0.216)	-0.857 (-0.55)
Car Pool--Shared Ride Constant	-5.43 (-4.24)	-5.14 (-4.14)	-2.70 (-1.95)	-2.93 (-2.22)
$-2\ell n\lambda$	168.4	151.22	146.9	111.7
% Correct	60%	69%	83%	78%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-14

Direct Elasticities of Selected Variables at Sample Means and Probabilities

Unmarried and Older than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	-0.11	-0.13	-0.17	-0.17
Car Pool--Shared Ride Cost/Income	-0.11	-0.11	-0.18	-0.16
Bus Cost/Income	-0.18	-0.21	-0.28	-0.28
Drive Alone Walk Time	-0.13	-0.15	-0.13	-0.12
Car Pool--Shared Ride Walk Time	-0.27	-0.27	-0.28	-0.24
Bus Walk Time	-0.47	-0.53	-0.28	-0.43
Initial Headway	-2.76	-2.60	-0.37	-0.64
Secondary Headway	-0.27	-0.40	-0.23	-0.21

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-15

Sample Mean Values

Unmarried and Older than 45 Years Data Sets

Variables	All Alternatives Available		Alternatives Restricted	
	Choice Set 1*	Choice Set 2**	Choice Set 1	Choice Set 2
Drive Alone Cost/Income	0.0081	0.0081	0.0080	0.0080
Car Pool--Shared Ride Cost/Income	0.0039	0.0038	0.0038	0.0038
Bus Cost/Income	0.0076	0.0078	0.0075	0.0076
Drive Alone Walk Time	4.03	3.98	4.02	4.00
Car Pool--Shared Ride Walk Time	4.03	3.98	4.02	4.00
Bus Walk Time	8.36	8.36	8.29	8.34
Initial Headway	15.08	15.10	15.06	15.07
Secondary Headway	21.01	22.99	21.43	22.30

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE A-16

Implied Walk Time Values*

Market Segments	All Alternatives Available		Alternatives Restricted	
	Choice Set 1** ($/hour)	Choice Set 2*** ($/hour)	Choice Set 1 ($/hour)	Choice Set 2 ($/hour)
Combined	47.78	50.81	31.39	39.71
Married and Younger than 45	29.39	31.52	96.41	97.61
Married and Older than 45	38.75	47.11	21.68	35.76
Unmarried and Younger than 45	30.58	32.63	12.57	22.86
Unmarried and Older than 45	28.57	28.59	17.63	16.95

*These values of time were calculated for individuals with an income of $12,000.

**{Drive Alone, Car Pool, Bus}

***{Drive Alone, Shared Ride, Bus}

APPENDIX B

TABLES OF WORK TRIPS AND VMTS

TABLE B-1

Absolute and Percentage Changes in Trips for Married and Younger than 45 Years Market Segments

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-19360 -3.7%	8153 7.9%	11206 14.0%	-19604 -4.3%	10850 6.0%	8754 12.1%
2	-14262 -2.7%	-9578 -9.2%	23840 29.7%	-9625 -2.1%	-10077 -5.6%	19702 27.2%
3	-46512 -8.9%	28111 27.1%	18399 22.9%	-68451 -14.9%	48124 26.6%	20325 28.0%
4	6814 1.3%	-5422 -5.2%	-1390 -1.7%	-1275 -0.3%	976 0.5%	300 0.4%
5	-3710 -0.7%	3783 3.7%	-73 -0.1%	-4253 -0.9%	4226 2.3%	27 0.04%
6	-1743 -0.3%	-428 -0.4%	2171 2.7%	-2001 -0.4%	-1051 -0.6%	3052 4.2%
7	-12625 -2.4%	-8339 -8.0%	20965 26.1%	-8616 -1.9%	-8707 -4.8%	17327 23.9%
8	-12906 -2.5%	-1759 -2.1%	5018 5.9%	-5115 -1.1%	3064 1.7%	2728 3.8%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-2

Absolute and Percentage Changes in VMT
for Married and Younger than 45 Years Market Segments

	Choice Set 1*				Choice Set 2**			
Policy Number	Total	Drive Alone	Car Pool	Bus	Total	Drive Alone	Shared Ride	Bus
1	-71410	-11804	31366	8026	-69655	-112323	36768	5900
	-1.9%	-3.2%	10.4%	17.3%	-2.0%	-3.8%	7.0%	13.8%
2	-61988	-59330	-18172	15513	-48910	-42161	-19431	12682
	-1.6%	-1.7%	-6.0%	33.5%	-1.4%	-1.4%	-3.7%	29.6%
3	-174173	-293415	104488	14754	-248827	-434780	169910	16043
	-4.6%	-8.5%	34.5%	31.8%	-7.1%	-14.9%	32.3%	37.5%
4	23411	42225	-17859	-956	-3681	-6535	2603	252
	0.6%	1.2%	-5.9%	-2.1%	-0.1%	-0.2%	0.5%	0.6%
5	-15089	-28877	13910	-124	-17042	-32473	15521	-90
	-0.4%	-0.8%	4.6%	-0.3%	-0.5%	-1.1%	3.0%	-0.2%
6	-13800	-14874	-2851	3925	-16042	-15746	-4804	4509
	-0.4%	-0.4%	-0.9%	8.5%	-0.5%	-0.5%	-0.9%	10.5%
7	-56800	-51657	-15911	10767	-43854	-35755	-16816	8719
	-1.5%	-1.5%	-5.3%	23.2%	-1.3%	-1.2%	-3.2%	20.4%
8	-189674	-218262	9911	18677	-54280	-95173	26538	14897
	-5.0%	-6.3%	3.3%	40.2%	-1.6%	-3.3%	5.0%	34.8%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-3

Absolute and Percentage Changes in Trips
for Married and Older than 45 Years Market Segments

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-47010 -9.1%	19291 22.6%	27716 32.7%	-36649 -8.0%	16722 15.8%	19925 26.0%
2	-8691 -1.7%	-5361 -6.3%	14052 16.6%	-9964 -2.2%	-7021 -6.6%	16986 22.1%
3	-15032 -2.9%	8290 9.7%	6741 8.0%	-21670 -4.7%	14252 13.5%	7417 9.7%
4	6743 1.3%	-5353 -6.3%	-1388 -1.6%	6430 1.4%	-5367 -5.1%	-1060 -1.4%
5	-9599 -1.9%	8744 10.3%	853 1.0%	-7575 -1.7%	7143 6.7%	432 0.6%
6	-3430 -0.7%	-2275 -2.7%	5704 6.7%	-3027 -0.7%	-2068 -2.0%	5095 6.6%
7	-6303 -1.2%	-3617 -4.2%	9920 11.7%	-7597 -1.7%	-4292 -4.7%	12521 16.3%
8	-12906 -2.5%	-1759 -2.1%	5018 5.9%	496 0.1%	152 0.1%	6265 8.2%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-4

Absolute and Percentage Changes in VMT
for Married and Older than 45 Years Market Segments

Policy Number	Choice Set 1* Total	Choice Set 1* Drive Alone	Choice Set 1* Car Pool	Choice Set 1* Bus	Choice Set 2** Total	Choice Set 2** Drive Alone	Choice Set 2** Shared Ride	Choice Set 2** Bus
1	-197898	-277675	60283	19494	-151806	-217299	51417	14077
	-5.5%	-8.5%	24.0%	36.0%	-4.7%	-7.5%	16.6%	28.1%
2	-51759	-28204	-14013	10458	-61901	-56353	-18285	12737
	-1.5%	-1.5%	-5.6%	19.3%	-1.9%	-2.0%	-5.9%	25.4%
3	-56803	-91027	29808	4416	-80730	-135898	50275	4891
	-1.6%	-2.8%	11.9%	8.2%	-2.5%	-4.7%	16.2%	9.8%
4	26190	44604	-17191	-1222	24375	42442	-17134	-932
	0.7%	1.4%	-6.9%	-2.3%	0.7%	1.5%	-5.5%	-1.9%
5	-39882	-70268	29290	1097	-31226	-55924	24118	580
	-1.1%	-2.2%	11.7%	2.0%	-1.0%	-1.9%	7.8%	1.2%
6	-29794	-27400	-9230	6836	-25809	-23698	-8466	6355
	-0.8%	-0.8%	-3.7%	12.6%	-0.8%	-0.8%	-2.7%	12.7%
7	-32533	-29476	-7928	4871	-40414	-35778	-10761	6126
	-0.9%	-0.9%	-3.2%	9.0%	-1.3%	-1.2%	-3.5%	12.2%
8	-39629	-57748	2859	15260	42421	17776	9621	15024
	-1.1%	-1.8%	1.1%	28.2%	1.3%	0.6%	3.1%	30.0%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-5

Absolute and Percentage Changes in Trips
for Unmarried and Younger than 45 Years Market Segments

Policy Number	Choice Set 1* Drive Alone	Car Pool	Bus	Choice Set 2** Drive Alone	Shared Ride	Bus
1	-37109 -4.4%	15168 10.5%	21938 13.6%	-40623 -5.4%	20294 9.5%	20329 13.8%
2	-3103 -0.4%	-2564 -1.8%	5667 3.5%	-5077 -0.7%	-4833 -2.3%	9910 6.7%
3	-41922 -4.9%	17933 12.4%	23988 14.8%	-35116 -4.7%	10563 5.0%	24551 16.6%
4	9190 1.1%	-7068 -4.9%	-2123 -1.3%	-4657 -0.6%	3905 1.8%	752 0.5%
5	-8282 -1.0%	6982 4.8%	1299 0.8%	-9345 -1.3%	8277 3.9%	1066 0.7%
6	-6489 -0.8%	-6124 -4.3%	12615 7.8%	-4636 -0.6%	-4748 -2.2%	9384 6.4%
7	-2689 -0.3%	-1481 -1.0%	4171 2.6%	-4235 -0.6%	-2946 -1.4%	7182 4.9%
8	-44177 -5.2%	-1597 -1.1%	3391 2.1%	-20842 -2.8%	3046 1.4%	5818 3.9%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-6

Absolute and Percentage Changes in VMT
for Unmarried and Younger than 45 Years Market Segments

Policy Number	Choice Set 1*				Choice Set 2**			
	Total	Drive Alone	Car Pool	Bus	Total	Drive Alone	Shared Ride	Bus
1	-127615	-188152	48836	11701	-137693	-212972	64428	10851
	-2.3%	-3.8%	12.3%	15.4%	-2.7%	-4.8%	10.5%	14.9%
2	-14214	-12201	-5054	3041	-24689	-20653	-9576	5539
	-0.3%	-0.2%	-1.3%	4.0%	-0.5%	-0.5%	-1.5%	7.6%
3	-147841	-221685	58153	15690	-132105	-188958	40126	16727
	-2.7%	-4.4%	14.6%	20.7%	-2.6%	-4.2%	6.6%	23.0%
4	29846	53201	-22381	-974	-15368	-28229	12140	719
	0.5%	1.1%	-5.6%	-1.3%	-0.3%	-0.6%	2.0%	1.0%
5	-27906	-51216	23562	-252	-32474	-61035	28825	-264
	-0.5%	-1.0%	5.9%	-0.3%	-0.6%	-1.4%	4.7%	-0.4%
6	-48986	-39211	-23295	13520	-38771	-31057	-18777	11063
	-0.9%	-0.8%	-5.8%	17.8%	-0.8%	-0.7%	-3.1%	15.2%
7	-11016	-9704	-2673	1361	-18320	-15365	-5287	2330
	-0.2%	-0.2%	-0.7%	1.8%	-0.4%	-0.3%	-0.9%	3.2%
8	-264680	-287822	1968	211173	-120953	-155100	9763	24383
	-4.8%	-5.7%	0.5%	27.9%	-2.3%	-3.5%	1.6%	33.5%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-7

Absolute and Percentage Changes in Trips for Unmarried and Older than 45 Years Market Segments

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-26773	2974	23799	-28914	7247	21667
	-16.4%	10.5%	39.2%	-20.0%	19.2%	39.4%
2	-3310	-3743	7054	-2824	-3577	6401
	-2.0%	-13.2%	11.6%	-2.0%	-9.5%	11.7%
3	262	-302	40	-119	-256	375
	0.1%	-1.0%	0.1%	-0.1%	-0.7%	0.7%
4	-3414	1543	1871	-645	-402	1047
	-2.1%	5.4%	3.1%	-0.5%	-1.1%	1.9%
5	-4315	7247	-2932	-4837	7760	-2923
	-2.6%	25.5%	-4.8%	-3.4%	20.6%	-5.3%
6	-1305	-1859	3164	-1050	-1551	2602
	-0.8%	-6.5%	5.2%	-0.7%	-4.1%	4.7%
7	-1968	-3412	5381	-1661	-3123	4758
	-1.2%	-12.0%	8.9%	-1.2%	-8.3%	8.7%
8	-11826	5712	2676	-7664	9320	3488
	-7.2%	20.1%	4.4%	-5.3%	24.7%	6.4%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-8

Absolute and Percentage Changes in VMT
for Unmarried and Older than 45 Years Market Segments

Policy Number	Choice Set 1*				Choice Set 2**			
	Total	Drive Alone	Car Pool	Bus	Total	Drive Alone	Shared Ride	Bus
1	-117861 -11.0%	-150100 -15.7%	17320 22.3%	15099 42.1%	-119457 -12.2%	-159774 -18.9%	26664 26.2%	13653 41.7%
2	-19074 -1.8%	-15898 -1.7%	-7820 -10.1%	4654 12.9%	-16475 -1.7%	-13252 -1.6%	-7390 -7.3%	4166 12.7%
3	798 0.1%	1687 0.2%	-901 -1.2%	13 0.04%	-444 -0.05%	-56 -0.01%	-542 -0.5%	153 0.5%
4	-13509 -1.3%	-22061 -2.3%	7253 9.3%	1299 3.6%	-1705 -0.2%	-1912 -0.2%	-468 -0.5%	675 2.1%
5	-18597 -1.7%	-38250 -4.0%	21255 27.4%	-1601 -4.4%	-20763 -2.1%	-41698 -4.9%	22615 22.2%	-1680 -5.1%
6	-11137 -1.0%	-8382 -0.9%	-5250 -6.8%	2494 7.0%	-9098 -0.9%	-6707 -0.8%	-4490 -4.4%	2098 6.4%
7	-13876 -1.3%	-9533 -1.0%	-6616 -8.5%	2273 6.3%	-11793 -1.2%	-7782 -0.9%	-6014 -5.9%	2004 6.1%
8	-70539 -6.6%	-95014 -10.1%	14319 18.4%	10156 28.3%	-22545 -2.3%	-57922 -6.9%	26715 26.2%	8661 26.4%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-9

Absolute and Percentage Changes in Trips for Combined Models Using Expanded Data with Initial Demographic Makeup

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-173113 -5.8%	64543 12.4%	108553 18.9%	-180760 -6.6%	85198 10.7%	95591 17.7%
2	-40622 -1.4%	-29823 -5.7%	70443 12.3%	-42820 -1.6%	-38877 -4.9%	81709 15.1%
3	-134259 -4.5%	74377 14.3%	59884 10.5%	-162561 -6.0%	94813 11.9%	67777 12.5%
4	34579 1.2%	-27241 -5.2%	-7358 -1.3%	15627 0.6%	-14024 -1.8%	-1620 -0.3%
5	-33906 -1.1%	33272 6.4%	632 0.1%	-38109 -1.4%	37226 4.7%	889 0.2%
6	-19010 -0.63%	-13621 -2.6%	32628 5.7%	-15167 -0.6%	-12396 -1.6%	27561 5.1%
7	-32810 -1.1%	-21597 -4.1%	54412 9.5%	-35062 -1.3%	-28902 -3.6%	63984 11.8%
8	-52756 -1.8%	15584 3.0%	38767 6.8%	-54088 -2.0%	24763 3.1%	28003 5.2%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-10

Absolute and Percentage Changes in VMT for
Combined Models Using Expanded Data with Initial Demographic Makeup

Policy Number	Choice Set 1* Total	Choice Set 1* Drive Alone	Choice Set 1* Car Pool	Choice Set 1* Bus	Choice Set 2** Total	Choice Set 2** Drive Alone	Choice Set 2** Shared Ride	Choice Set 2** Bus
1	-654512 -3.2%	-944416 -5.1%	222333 15.0%	67559 21.7%	-669376 -3.5%	-1006338 -6.0%	278062 12.1%	58916 19.5%
2	-200112 -1.0%	-181296 -1.0%	-62918 -4.3%	44095 14.1%	-227392 -1.2%	-196309 -1.2%	-82439 -3.6%	51369 17.0%
3	-479744 -2.4%	-772816 -4.2%	251050 17.0%	42007 13.5%	-582192 -3.0%	-951043 -5.7%	320981 13.9%	47886 15.9%
4	121440 0.6%	214432 1.16%	-88176 -6.0%	-4822 -1.6%	57024 0.3%	104976 0.6%	-47234 -2.1%	-718 -0.3%
5	-128544 -0.6%	-240528 -1.3%	112433 7.6%	-449 -0.1%	-147024 -0.8%	-275969 -1.6%	129883 5.6%	-927 -0.3%
6	-161136 -0.8%	-147792 -0.8%	-53912 -3.6%	40562 13.0%	-139744 -0.7%	-123755 -0.7%	-52848 -2.3%	36872 12.2%
7	-151248 -0.7%	-123496 -0.7%	-42017 -2.8%	23252 7.46%	-171888 -0.9%	-142735 -0.9%	-56096 -2.4%	26954 8.9%
8	-224576 -1.2%	-435543 -2.6%	112772 4.9%	98208 32.6%	-232976 -1.2%	-435040 -2.4%	91786 6.2%	110272 35.4%

* {Drive Alone, Car pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-11

Absolute and Percentage Changes in Trips for Combined Models Using Expanded Data and Altered Demographic Makeup

	Choice Set 1*			Choice Set 2**		
Policy Number	Drive Alone	Car Pool	Bus	Drive Alone	Shared Ride	Bus
1	-174268 -5.8%	64058 12.2%	110233 19.2%	-180037 -6.6%	83503 10.4%	96576 18.1%
2	-40197 -1.3%	-30654 -5.8%	70861 12.3%	-42262 -1.6%	-39322 -4.9%	81600 15.3%
3	-132653 -4.4%	72877 13.8%	59798 10.4%	-157655 -5.8%	91007 11.4%	66674 12.5%
4	34664 1.2%	-27328 -5.2%	-7343 -1.3%	15567 0.6%	-14154 -1.8%	-1399 -0.3%
5	-34900 -1.2%	34233 6.5%	664 0.1%	-37588 -1.4%	37810 4.7%	-233 -0.04%
6	-17468 -0.6%	-14329 -2.7%	31806 5.5%	-14730 -0.5%	-12700 -1.6%	27429 5.1%
7	-31614 -1.1%	-22969 -4.4%	54586 9.5%	-33681 -1.2%	-29983 -3.7%	63671 11.9%
8	-42825 -1.4%	17603 3.3%	34133 5.9%	-49852 -1.8%	25961 3.2%	27632 5.2%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}

TABLE B-12

Absolute and Percentage Changes in VMT
for Combined Models Using Expanded Data with Altered Demographic Makeup

	Choice Set 1*				Choice Set 2**			
Policy Number	Total	Drive Alone	Car Pool	Bus	Total	Drive Alone	Shared Ride	Bus
1	-658112	-946629	223267	65254	-663568	-993480	273524	56381
	-3.2%	-5.1%	14.9%	20.6%	-3.4%	-5.9%	11.9%	18.9%
2	-198704	-178032	-64914	44236	-224832	-193698	-82100	50956
	-1.0%	-1.0%	-4.3%	14.0%	-1.2%	-1.2%	-3.6%	17.1%
3	-472608	-761328	246230	42482	-570096	-930105	311722	48279
	-2.3%	-4.1%	16.4%	13.4%	-2.9%	-5.5%	13.6%	16.2%
4	121376	214976	-88791	-4808	56848	104544	-46969	-722
	0.6%	1.2%	-5.9%	-1.5%	0.3%	0.6%	-2.1%	-0.2%
5	-131856	-247248	115807	-407	-145968	-273628	128700	-1040
	-0.7%	-1.3%	7.7%	-0.1%	-0.8%	-1.6%	5.6%	-0.4%
6	-152096	-133120	-56999	38018	-133264	-116102	-51087	33919
	-0.7%	-0.7%	-3.8%	12.0%	-0.7%	-0.7%	-2.2%	11.4%
7	-145888	-124592	-44251	22948	-165712	-135715	-56763	26768
	-0.7%	-0.7%	-3.0%	7.3%	-0.9%	-0.8%	-2.5%	9.0%
8	-207776	-411872	96121	107975	-215632	-427777	111246	100894
	-1.0%	-2.2%	6.4%	34.1%	-1.1%	-2.6%	4.9%	33.9%

* {Drive Alone, Car Pool, Bus}

** {Drive Alone, Shared Ride, Bus}