FACTORS RELATED TO TRAVEL MODE CHOICES IN THE
DALLAS-FORT WORTH METROPOLITAN AREA

DISSERTATION

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This study examined the factors related to travel mode choices in the Dallas-Fort Worth Metropolitan Area. Changes in population, lifestyle and economy of the Dallas-Fort Worth region over the last few decades demand a careful re-examination of travel demand tools and methods. The purpose of the study was to provide an understanding of transportation modal choice in the region. Those demographic variables best predicting the choices were identified. The Home Interview Survey, a set of disaggregate data from the 1984 North Central Texas Council of Governments (NCTCOG) Regional Travel Survey, was analyzed using logistic regression.

The major findings of the research indicate that about 97 percent of the travelers in the study area used private cars and 3 percent used public transit. Household income and car-vans were significant explanatory variables. The impact of household income and number of car-vans available upon an individual's decision for travel mode choice were very important. The number of car-vans available in the household, and age of respondents were significant predictors in travel
mode. Household members with incomes of $30,000 to $39,000 and those with incomes of at least $50,000 tended to use more private cars than did other income groups. Also, household members with incomes below $9,000 used more public transportation. People reporting a lower preference for cars were younger than 26 years or older than 55 years of age.
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CHAPTER I

INTRODUCTION

In 1830 the United States entered an era of urban mass transportation. The first horse-drawn omnibus was developed in New York City at that time. The increased popularity of the horse-drawn omnibus gave New Yorkers a different kind of traffic congestion than they know today. Twenty-seven different routes had been established by 1885, and some 600 horse-drawn omnibuses were licensed to operate in the city (Mossman, 1951).

A more comfortable ride for an increased number of passengers was the contribution of the first urban transit vehicle. Horsecars had a major impact on American cities; more passengers were able to travel at one time because of the ability to pull larger cars at greater speeds. These improvements encouraged the development of horsecar systems in major cities throughout the United States. The terminal points for the horsecar line lay in the business districts. This allowed people who worked downtown to live farther from their work sites (Luna, 1971). In the early 1890s, 70 percent of the operating street railways still belonged to the horsecar (Mossman, 1971).

In 1868 elevated railways were built in major cities. The high cost of construction and their general unsightliness
made them unpopular (Mossman, 1951). In the early 1870s a cable car system was constructed in San Francisco. Between 1877 and 1890, there were 48 cable cars in operation (Mossman, 1951). The cable car reached the height of its popularity in 1890, when 375 million passengers rode 5000 cars (Mossman, 1951).

The first commercially operated electric railway in the United States began operation in Cleveland. Due to technical difficulties, the line was abandoned a few years later. However, across the nation other major city lines were soon in operation. By 1890 they constituted 30% of the operating railways in the United States (Mossman, 1951).

In the early 1900s the automobile was introduced in urban areas. In the same era, the motorbus was introduced in New York City. There were more than 60 of the early motorbuses in operation in the United States, most of them unreliable and extremely uncomfortable. Later redesigning improved comfort, which contributed to increased popularity (Mossman, 1951).

In the 1900s trolley coaches were introduced in California. This method of transportation operated with overhead wires. Sliding contacts on the overhead wires carried electric power to the trolley (Luna, 1971).

The flexibility of the motorbus and the difficulty and cost of maintaining an overhead power supply caused the decline of the trolley coach. The development of subways
superceded the elevated railways. Subways first appeared in larger American cities which did not have elevated trains (Luna, 1971).

The improvement of transportation over the years increased the mobility of people and goods. This encouraged people to settle in the metropolitan areas. By 1920 urban residents greatly outnumbered their rural counterpart. The newly developing areas were assured of receiving or acquiring food and other necessities not produced in their communities. Waterways, electric street cars, and railways helped to compress the urban centers into tightly packed clusters. Subway and elevated transit systems added to this clustering, in such major American cities as Chicago, Philadelphia, New York, and Boston (Luna, 1971).

Around 1950 commuter railroads were developed. This was a significant development for the major American metropolitan areas. Besides New York, Boston, Philadelphia, and Chicago, other cities like Baltimore, Pittsburgh, San Francisco, and Washington relied heavily on commuter rails. Steam-powered railroads initially offered commuter service from outlying communities to urban centers as a by-product of regular intercity passenger service (Luna, 1971).

The automobile was the most influential development in urban transportation. The automobile did not restrict the traveler in arrival or departure time. Nor did it restrict
the traveler's route. Public transportation systems were challenged to compete effectively with the automobile. Socially and economically, overuse of the vehicle burdened urban areas (Luna, 1971).

The growth and progress of cities prompted by improved transportation has already caused vast transportation problems and will continue to do so in the future. The automobile has facilitated the distribution of metropolitan populations, which strangled the capabilities of traditional mass transit facilities. No good travel pattern to and from central business districts has been developed. Now home-based trips are even more diverse in origin and destination. Mass transit is still unable to handle the increasing demands of metropolitan populations.

In the last few decades the bulk of the United States population has shifted from traditional urban centers toward suburban areas. Population growth and the domination of the automobile industry have been largely responsible for this shift. As the popularity of privately owned automobiles has grown, public transit has been left by the wayside. As with any commodity or service, the economic force of supply and demand will have a major influence on future urban transportation systems.

Concerning public transit in the Dallas-Fort Worth Metropolitan Area, the historical data are not encouraging.
Ridership on the existing transport system has fallen. Revenues have remained stable. Operation costs have risen steadily. However, the financial losses of the region's public transit systems do not necessarily provide a case for abandoning public transit (Richardson, 1975).

Study of the history of transportation identifies some of the problems which have existed since the beginning of urban mass transportation. The obvious goal of mass transit is access to activity centers, such as recreation facilities, shopping, medical care, and work (Hanson, 1986). Looking at the history of urban transportation has several advantages. First, modes of transportation suitable for present conditions may be identified, second, methods better suited for analyzing transit problems may be developed. Finally, modes of transportation are more useful and important for consumers under various conditions who may be isolated. The North Central Texas Council of Governments (NCTCOG) conducted a regional travel survey in 1984. The transportation study area included Dallas, Tarrant, Denton, and Collin Counties (Figure 1). The full survey consisted of three components: a home interview survey; an on-board transit survey; and a work place survey. The purpose of the overall survey was to obtain information on travel patterns and trip characteristics in the Dallas-Fort Worth Metropolitan Area. Dallas-Fort Worth Travel Patterns (1987), contains the following overview:
The survey was the first such comprehensive effort since the 1964 home interview survey conducted by the State Department of Highways and Public Transportation. This document summarizes the results of the 1984 Regional Travel Survey and, where possible, compares the data to results from the 1964 survey to examine the change in travel patterns over the past 20 years. (p. 1)

Of these components, only one will be used in the current study, the home interview survey, which gathered data on household travel patterns. The on-board transit survey contained redundant data, the work place survey data was inappropriate. This dissertation study used disaggregate data, but the work place survey was aggregate data.

Models of the binomial logist form were estimated on disaggregate data to predict the mode of travel of commuters in the Dallas-Fort Worth Metropolitan Area, given the age, gender, income, number of cars and vans available, number of household people age five and over, and occupation. The models predicted these choices from a set of alternative modes which included public-private mode, private modes, auto pool mode, and car-bus mode.

The aggregate and disaggregate models are commonly used for forecasting travel demand between locations. Aggregate models involve predicting the total trips between different zones. Disaggregate models call for predicting the model choice of the patronage with specific emphasis on predicating changes in mode used in response to changes in either the travel time or price of different modes. The traditional
Figure 1. Transportation Study Area.

aggregate forecasting models are based on "gravity models" of the physical sciences, and the disaggregate models are based on economic theory (Urban Travel Demand Forecasting, 1973).

Several attempts have been made to compare the aggregate and disaggregate choice models. Koppelman (1976) gives a good overview of the advantages of disaggregate choice models over aggregate demand models. Disaggregate choice models have made rapid progress in recent years. The improved understanding provided about the decision process influencing individual
behavior has contributed to the improvement and modification of theories of travel behavior. More recently, attention has been focused on the use of disaggregate models for the forecasting of aggregate travel demand behavior. This approach to obtaining aggregate predictions is based on the theory that the travel behavior of large groups is the manifestation of the travel decisions of numerous individuals or households. The problems associated with aggregate forecasting based on disaggregate models is the progress of a certain procedure for enlarging individual choice estimates over the population of interest to obtain a reliable, unbiased description of group behavior.

Sargious (1985) mentioned that disaggregate choice models have some advantages over aggregate models in that they are policy sensitive. They can be used in studying the effects of several strategies on the transportation system in order to achieve optimal results in the movement of goods and people.

Watson (1973) also argues that the structure of the models is different. The term "structure" may be interpreted in a number of ways; for example, the use of multiple regression or logistic analysis intrinsically imposes a structure on the models. In this sense, the structural difference between the aggregate and disaggregate models is self-evident. Also, the predictive power of the disaggregate model is much better than the aggregate model (Watson, 1973).
Statement of the Problem

The study was concerned with the characteristics of commuters and their choices of travel modes.

Purpose of the Study

The purpose of the study was to identify those demographic variables which best predict the travel mode choices of commuters in the Dallas-Fort Worth metropolitan area. The study used the Home Interview Survey from the 1984 NCTCOG Regional Travel Survey.

Hypothesis

The research hypothesis was that age, gender, income, number of cars, number of people age five and over, and occupation respectively and collectively, account for a significant proportion of any observed variance in mode of travel.

Significance of the Study

Changes in population, life style, and economy of the Dallas-Fort Worth region over the last two decades demand a careful re-examination of travel demand tools and methods. For example, the increase or decrease in car riders caused by traffic congestion and fare reductions will affect travelers mode choices.

Mode choice in transportation planning plays an important role. The importance of this function has been recognized in
the variety of travel behavior research at the disaggregate level. Data at the disaggregate level enables researchers to identify movements of people between zones and in understanding of the relations between travel mode choice and land use configurations (Hanson, 1986).

Definition of Terms

The following terms have been defined for this study. All were taken from the Urban Travel Demand Forecasting (1973).

**Aggregate model** is the terminology used when travel observations for individuals are combined into zones, geographically. These total observations combined are used to derive at an estimation of new flows when there is a change in service attributes or zone sizes.

**Assignment** is described when the time of day, point of origin, destination and mode of travel for trips are spread among the various routes available in a network.

**Behavioral pattern** is best described by the reaction of individuals or groups of individuals when they must choose from various transportation alternatives. Attitudinal modeling can be separated from behavioral modeling by the goal represented. Behavioral modeling has a goal represented by behavior patterns observed in a mathematical model in which forecast accuracy is improved.
Dallas-Fort Worth Metropolitan Area is a Consolidated Metropolitan Statistical Area (CMSA), made up of the Dallas area (Collin, Dallas, Denton, Coffman, and Rockwall counties), and the Fort Worth and Arlington areas (Johnson, Parker, and Tarrant counties).

Demand is the terminology based on a theory and characterized in an economic sense of the consumer's needs, the methodology of this consumer demand is timely report of the quantity of travel consumption at the different levels of service offered by the system of transportation and the various level of price in that system. However, the function of service is what demand describes rather than a certain amount of travel. Most of the forecasting methods of urban transportation and travel is based on the idea of the demand of travel and the facility service of transportation going between the transportation network as the avenue to obtain a balanced flow pattern.

Destination can be described as the specified area in which trips are made variously as a zone in the aggregate travel forecasting. Destination is also the desired location to be measured by an employee and his work or the area measured in square footage for shopping.

Disaggregate model whenever observations of travel use is obtained by choice behavior of an individual, this is known as an disaggregate model and is based usually on probability.
Distribution is the definition of the origin of trips to a variety of choices of destinations. Mostly used are the common distributions of the gravity and opportunity models.

Forecasting system to reach an outlook of travel flow for an area, set of computer programs are incorporated using all models and is known as a forecasting system. There are systems in existence maintained and developed by the Federal Highway Administration and the Urban Mass Transportation Administration. These systems are based on the components of deterministic, aggregate and sequential. The process for forecasting is generation, distribution modal split and the assignment.

Generation trips are defined by origin or destination, not both, but either one, are evaluated based on the character of the activity system and is the aggregate forecasting process step in sequential known as generation. A one dimensional array of trips into or out of a particular zone for the input to trips distribution models is the output of generation.

Logit model is a demand model suited to modeling of more than one choice of travel situation.

Modal split to predict how many travelers will use a special or available transportation model is the process of modal split. These models are usually either a pre- or post-
distributional models as applied to total trips between an origin and a destination.

**Probabilistic model** is the likelihood of a forecasted event in an disaggregate demand model. A probabilistic model is the probability of the choice of an alternative.

**Urban Transportation Modeling System** procedures were developed since the 1950s and used in all major metropolitan areas of the United States and in many foreign cities. Along with sequential, aggregate travel forecasting model is the Urban Transportation Modeling System, known as UMTS.

**Summary**

The purpose of this study was to determine the demographic and socioeconomic characteristics which predict the travel mode of commuters in the Dallas-Fort Worth metropolitan area. To achieve this purpose, the disaggregate travel demand model was used.

This chapter recalls the brief history of urban mass transit and the problems of urban transportation. The chapter attempts to summarize the research which the North Central Texas Council of Governments conducted. An overview of aggregate and disaggregate modeling, the purpose of the study, the hypothesis, and the significance of the study were also presented.
Organization of the Study

Chapter II describes a review of the literature related to transportation mode research and the nature of commuter travel in the Dallas-Fort Worth Metropolitan Area.

Chapter III presents the methodology and structure of the study.

Chapter IV reports the data analysis and includes a discussion of findings.

Chapter V suggests the impact of the study, discusses implications for urban transit planning in the survey area, and offers recommendations for future research.
CHAPTER BIBLIOGRAPHY


CHAPTER II

REVIEW OF THE RELATED LITERATURE

Introduction

This chapter describes the theoretical basis for a choice model calibrated on a regional scale. The review of the literature includes coverage of relevant topics and issues.

Travel in the United States' urban areas has increased dramatically in recent years. Rapid increases in the number of urban passengers and in freight transportation are a direct result of increases in population, income, automobile ownership, and suburbanization. Of course, the most obvious change has been a shift in popularity from mass transit before and just after World War II, to the private automobile today.

Urban transportation is a complex topic. The transportation system in a city affects every facet of urban life. It involves many considerations, approaches, and perspectives. An ever-growing body of literature frequently crosses disciplinary lines. Transportation researchers represent a wide variety of disciplines and professional practices, including traffic engineers, political scientists, urban planners, environmentalists, sociologists, and economists (Mills & Hamilton, 1981).
There are many perspectives but only one central question which applies to all cities in the United States. Why would people be willing to abandon their private automobiles to use mass transit in sufficiently large numbers to justify public expenditures? Transit ridership reached its peak just after World War II and has steadily declined. As recently as 1940, public transit was responsible for approximately 30% of all passenger miles in urban areas. In 1960 the figure fell to 12 percent, with 88% of the passenger miles attributed to automobiles. By 1970, the figures for public transit had fallen to nearly six percent, leaving 94% to the private automobile (Kemp & Cheslow, 1976).

That the automobile provides privacy, convenience, status, and comfort cannot be denied. Car ownership and operation have become affordable for almost everyone. In 1950, 41% of all families did not own a car. By 1970, cars were owned by all but seven percent. Most of the remaining carless families were concentrated among the very poor (Schmore, 1975).

Until the mid-1970s, the price of cars and car operation had fallen steadily in comparison to the rising purchasing power and the costs of most other goods and services. For instance, the real price of gasoline had actually declined 26% between 1950 and 1973. In 1978, gasoline cost about the
same as in 1950 (Meyer & Miller, 1984). The trend of the past two decades led to the conclusion that, in the absence of external constraints (i.e., costs, parking restrictions, congestion, the availability of alternative systems, and changing values), the public would continue to select the automobile. In fact, continual congestion on urban streets and highways was expected simply because of growing affluence and population. The level of congestion in suburban areas is already reaching that of the central cities. Major centers such as shopping malls and airports have been constructed primarily for automobile access. As central business districts have declined, suburban areas have been stricken with the noise, congestion, and various other difficulties of moving people and goods within large urban regions (Shank, 1976).

In the 1970s growing public concern began to support a revival of public transportation, although some attempts to strengthen it failed. A few new rail transit systems (e.g., Washington, San Francisco, and Atlanta) were opened. For the first time, efforts were made in some of the newer, growing cities to provide government-operated or subsidized public transit (Vernon, 1978). Federal subsidies for public transit increased markedly. But basic patterns changed very little. For instance, the number of bus passengers in 1977, although
increasing, remained significantly less than levels recorded as recently as 1965 (Mills & Hamilton, 1984). While the total number of people in urban areas has increased, the proportion of people relying on public transportation has still declined. According to a census bureau study from the 1970 to 1980 decade, the amount of commuting on public transportation had declined from 10% to 7% (Bureau of Census, 1980).

Lowering the transit fare or increasing service would increase ridership, but only that of existing transit users and non-travelers rather than converted auto users. Karft and Domenich (1970) pointed out that even free transit had not been successful because the price elasticity of demand was relatively low. The cross-elasticity of demand between modes is even lower (McGillivray, 1970). But McFadden (1974) has estimated this elasticity at 15% using a disaggregate model on data collected in Pittsburgh. He supported his argument with findings that a one percent increase in the price of the bus mode would result in an increase of 15% in the auto trip mode. Saltzman (1972) argued that:

Transit simultaneously lost its glamour and pervasiveness as it lost its patronage. Instead of serving all type of trips, transit became the preferred mode only for the journey to work, and then gradually even lost predominance in this area, being largely replaced by the private automobile for every type of trip. Transit rapidly became the conveyance only of those who had no other choice. (pp. 11-28)
Automobile users would only be persuaded to convert to mass transit by the idea of significantly reduced travel time for all road users. There will continue to be a growing concern to find a way to make urban transportation more efficient and effective for all groups in the population. As concern grows, a proliferation of literature on public transportation will occur.

Theoretical Frame of Reference

During the 1950s and 1960s, urban transportation planning developed as an independent discipline. The purpose process was to guide and predict future decisions and development in cities, metropolitan areas, regions, states, and the nation. Usually this kind of planning has been long-range.

In the decade of 1970, transportation planning assumed a new direction because of social changes. It became largely recognized as an activity which provides information to decision makers. At the present time transportation planning is still an important factor for decision makers.

The computer is a very important tool for transportation planning and in the analysis of urban travel patterns on a regional basis. Progress in computer use, encouraged planners to develop mathematical equations describing travel patterns. Early models were developed when highway planning was the
primary concern. The population was growing rapidly, and car ownership was increasing sharply (Foot, 1981).

In 1975, the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA) issued regulations containing major changes in planning regulations. Changes in urban transportation planning issues and concerns were important for the methods in the planning process to forecast travel demand. Also, the regulation required planners to use short-range planning in the forecasting process. Planners used the forecasting models for the assessment of impacts on specific population groups. The response to these regulations and changes was the development of travel analysis models (Pas, 1986).

By using mathematical equations, urban models endeavor to describe the urban system. The urban models provide a simplified and abstract view of some aspect of the urban system and deal with the allocation and interaction of land use activities in cities and regions. These urban models have been used for predicting future change and solving urban spatial problems. They were developed to find the various aspects of spatial distribution of land use activities within the urban system (Foot, 1981). Also, Foot argues that in the 1980s there is an increasing concern and interest among
planning agencies to use the models and find out that there are useful methods for analyzing and forecasting.

In general, there are two types of transportation modeling systems, aggregate and disaggregate. Large metropolitan transportation studies such as Washington Metropolitan Transportation and the North Central Texas Council of Governments have used models derived from a base-year data set identifying travel behavior by households within zones. These data are related to a representation of the transportation networks and geographical characteristics of the specific urban area. The models use four classical travel choices: trip generation, trip distribution, modal split, and trip assignment.

Disaggregate models were developed in the mid-1960s as transportation planners and geographers began studying travel behavior at a disaggregate level. In the 1970s transportation researchers had produced disaggregate, behavior travel demand models (Ben-Akiva, 1973; Domencich & McFadden, 1975).

The study of modal choice remains an important concern in transportation planning, often in conjunction with the work trip. Disaggregate models have different and more exacting data requirements than aggregate models (Pipkin, 1986). Disaggregate models analyze households or individuals but not zones. These models are concerned with movements of
various locations during the day, week, or month. The disaggregate approach is not concerned with activities between zones. The travel of individuals, a household, or a firm is the primary focus of disaggregate data analysis in the urban environment.

These types of data contain specific information about individuals or households making trips, household income, education, car ownership, and how the travel decisions are made. These data are collected in detail to describe the travel patterns of the households and individuals. Therefore, the picture of movement in the city provided by the disaggregate models is finer and more precise. These data are able to describe movement between zones. They are of interest to planners in understanding the relations between land use configurations and travel patterns (Hansom, 1986).

Recently, in terms of both the explanatory and the predictive powers of the models, there have been developments in the use of disaggregate, behavioral, and stochastic models in the area of transportation mode choice model. From a transportation planning point of view, however, the ability of the models to present the behavior of travelers is an important feature. The models are considered more realistic, because they are based on the observable behavior of the individual traveler.
To resolve mode choice models, transportation planners have developed a variety of statistical techniques. Choice is seen as a common feature of all models, a function of the utility gained from each alternative.

Interest in the urban transportation alternatives from which individuals make choices is becoming more common (Lave, 1969). From a rational point of view, the choice of one course of action over another can be predicted by understanding the perceptions and preferences individuals have of the available alternatives.

Transportation studies of discrete choice models were first used for binary choice of travel mode. For example, in 1962 Warner applied distinct choice models in transportation. In quick succession Lisco (1967), Lave (1969), Stopher (1969), de Donnea (1971), McGillivray (1972), Talvitie (1972), and Watson (1974), applied logit formulations. Further improvements followed in discrete choice modeling methods. Most of the reported studies of the 1970s involved application of mode choice models with more than two alternatives, and application of mode choice models toward trip destination, trip frequency, car ownership, residential location, and housing (Ben-Akiva & Lerman, 1985). Studies of this genre have been conducted by Rassan and Bennet (1971), Ben-Akiva (1973), Domencich and McFadden (1975), Train (1978), and Daly
and Zachary (1979). The home to work trip process has also been studied extensively (Atherton & Ben-Akiva, 1976; Train, 1978; Foot, 1981; Kanafani, 1983). Recent developments in the operation and refinement of the disaggregate travel demand models have been achieved by using behavioral constructs from psychology and microeconomics (Kanafani, 1983).

Discrete choice models are a class of statistical models applicable to the explanation and prediction of choices when the object choices are discrete. Such models attempt to measure in a useful way a relation between the discrete choice and a set of explanatory variables. The theoretical basis of discrete choice models is based largely on two behavioral disciplines, the economics of consumer behavior and the psychology of choice behavior.

Theory of Consumer Travel Behavior

The basic goal of the theory of consumer behavior is that an individual will choose his desire of goods or travel over what he can afford. An individual's desire will include the quantity and quality, but not necessarily his income. Meyer and Miller (1984) represented the theory of consumer behavior concisely. They argued that an individual's desire may not include the most for the money but the most satisfaction achieved. They wrote, "Formally, the individual's problem
consists of maximizing a utility function \( U \) subject to a budget constraint" (p. 168). They defined the function by the following formula:

\[
U = U(X_1, \ldots, X_n) \text{ subject to } Y = P_1X_1 + \ldots + P_nX_n
\]

where \( U \) = utility function

\( X_1, X_2, \ldots, X_n \) = goods consumed

\( P_1, P_2, \ldots, P_n \) = goods' prices

\( Y \) = income

The solution to this problem can be illustrated graphically by using an indifference curve and a budget line, an "indifference curve represented by various combinations of particular goods that will enable the individual to maintain a given level of utility" (p. 168). However, the case of two goods (Figure 2) characterizes the consumer's utility maximization consumption, \( X \) and \( X_2 \), given an income, \( Y \). Functional relationships of the utility maximizing values of \( X \) were provided in a set of formula.

\[
X_1 = F(P_1, \ldots, P_n, Y)
\]

\[
X_2 = F(P_1, \ldots, P_n, Y)
\]

\[
\vdots
\]

\[
X_n = F(P_1, \ldots, P_n, Y)
\]

These functions are known as demand functions, and they denote the utility maximizing quantity of a good that an individual
will purchase, given the price of goods consumed and that individual's income (Meyer & Miller, 1984, p. 168).

One must take into account the quantity an individual will purchase and consume given the price of the goods and the individual income. There is a balanced level of consumption obtained when the value of that consumption is the same as the market value of that same consumption (Meyer & Miller, 1984).

An individual may substitute one thing for another on a personal basis. But the market value of the consumption can only be represented by price. Therefore, consumed goods, including transportation, are chosen by satisfaction of the individual and not from economic considerations. Satisfaction is the demand for a particular good or service, depending on the quality and price and the individual purchasing the good or service.

Considering an individual tripmaker, one can reasonably hypothesize that the certainty of a decisions to make a trip, to use a particular mode, and to travel to a specific destination are made simultaneously rather than sequentially. Therefore, attempts have been made to develop models explaining individual mode choice behavior, known as discrete choice models or disaggregate models (Ben-Akiva & Lerman, 1985).

To test contemporary transportation policies, the logit formulation has been used increasingly in recent years. When
Figure 2. Consumer Utility Maximizing Behavior

\[ u = u(x_1, x_2) \]

\[ y = p_1 x_1 + p_2 x_2 \]

\[ x = \text{goods} \]
\[ p = \text{price of goods} \]
\[ u = \text{utility} \]
\[ y = \text{income} \]

traffic congestion and energy became big issues, the modal split modals were applied. Gas tax cost and parking cost policies were investigated in searches for alternative programs and facilities.
The logit formula is share modal, giving the total number of individuals selecting a particular travel alternative (Sheffi, 1985). This model divides the persons among the various modes depending on each mode's relative desirability for any given trip. If the modes are cheaper, faster, and have other features, they are relatively more desirable. The logit model recently has been used widely for study of modal split in transportation (Stopher & Lavender, 1972; Meyburge & Stopher, 1975; Sheffe, 1985). The term logit refers to the S-shaped logit curve (Figure 3) used to fit the model to the data (UMTA, 1977). When the mode is better it has more utility for the potential traveler.

Discrete choice models are using a form of regression to estimate the probability of a randomly selected traveler between two zones using one of two travel modes (car or bus). This hypothesis commonly takes the following form:

\[ P = \frac{\exp (\text{utility of mode } I)}{\sum \exp (\text{utility of } n)} \]

where \( P \) is the probability of using mode \( I \), the exponential function gives the characteristic logit curve as shown in Figure 3 for the two mode case.

Three common binary choice models have been extensively used: linear probability, the probit model and the logit
model. Perhaps the easiest model is the linear model, which uses cross-classification tables as the basis for forecasting mass transit. The logit model was developed by Adams (1959) to forecast the proportions of travel on different modes in an urban area. Other studies have used the logit model (Wilson, 1967; Ben-Akiva, 1974) in travel mode choice fields (McFadden, 1987; McCarthy, 1980) and in the area of shopping behavior. It has been shown that the logit model can be used to predict disaggregate mode choice behavior with a high degree of accuracy (Watson, 1973).

Comparisons between linear probability, logit and probit models have been repeatedly made (De Donnea, 1971; Talvitie, 1972; Stopher & Lavender, 1973; Watson, 1973). Talvitie (1972) argued that "the methods of estimation, commonly used in probabilistic modal choice models, probit, logit, and discriminant analysis all yielded comparable results. Any of them can be used with equal success." Stopher and Lavender (1972) and Watson (1973) concluded that discriminant analysis was inferior to the probit and logit analysis. The logit is better than probit analysis, because the logit calibration procedure is easier and yields a more useful model. Previous work with disaggregate travel demand models indicated that it was a feasible modeling approach (Charles River Associates, 1972).
Individual Behavior Theory

The theory of individual behavior is concerned with individual choice for a set of feasible alternatives. In transportation, individual behavior is seen as choice of transportation mode achieving that particular individual's greatest satisfaction. This theory cannot be proven. Any single individual's choice, demand, and satisfaction can only be dealt with as a probability. Although completely predictable, rational behavior should not be expected as an assumption of an individual's maximum satisfaction can be inferred from comparisons between choices and income or economic resources.

Choice is a fundamental component of the trip-making decision process. When the individual has to choose between transportation modes, mode choice models replicate the individual's decision-making process. Modeling travel choice is, therefore, an important function in transportation demand analysis and often a prerequisite to successful traffic estimation. Empirical evidence is scarce because the possibilities of controlled experimentation are limited. Nonetheless, simplifications are made to permit the analysis of travel choice using manageable quantitative models.

Models describing consumer behavior are based on the principle of utility maximization subject to resource
constraints. Traditional transportation modeling, however, is not suitable for deriving models describing a probabilistic choice from a qualitative or discrete set of alternatives. Watson (1974) has shown that the development of the theory of individual behavior is based on the theory of consumer demand. The theory of consumer demand is based on utility maximization. It is assumed that the decision maker is able to assign at least an ordinal ranking to the alternatives available in terms of relative desirability. The decision maker will then choose the alternative with the maximum utility (Ewing, 1974).

Summary

To predict how individuals and firms in a region will respond to changes in the transportation system, one must consider human behavior. An understanding of actual and potential behavior can be represented in the form of a demand function. In transportation it is important to emphasize that the factors a consumer considers are, first and foremost, important activities. For passenger travel these activity choices are about what to do, where and when to do it. For freight movements the choices are what products to sell in what places. Included in these activity choices are corresponding choices of transport (both mode and route).
Thus, the demand for transport is derived from a demand for activities (Manheim, 1984).

Several studies discussed the influences of different variables on an individual's behavior towards travel mode choices. These variables are age, gender, household income, number of cars available in the household, number of people age five and over (household size), time of travel day, and occupation. Age, gender, and income differences have shown to be important factors affecting travel mode choice of the people in the Dallas-Fort Worth metropolitan area.

The models that can be developed from individual behavior theory are probabilistic. They predict the probability of an individual making a specific choice where the probability is based on individual considerations, modified by personal characteristics. However, it is possible to apply the models of one area to another, because the basic attitudes of people regarding mode choice may not vary significantly. Therefore, the models could be geographically transferable.

The methodology of estimating the parameters and procedures used are discussed in detail in Chapter Three. These include preparatory steps, the data source, techniques for data collection, research design, and procedures for data analysis.
CHAPTER BIBLIOGRAPHY


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CHAPTER III

PROCEDURES OF THE STUDY

This study was conducted to identify those demographic variables which best predict the travel mode choices of commuters in the Dallas-Fort Worth Metropolitan Consolidated Area. This chapter presents 1) the study geography, 2) the methodology for conducting the research, 3) the data sources, 4) techniques for collecting the data, 5) design of the study, 6) the preparatory steps which made the study possible, and 7) methods of analyzing the data.

The study area included four counties: Collin, Dallas, Denton, and Tarrant counties. This area is known as the Dallas-Fort Worth Metropolitan Consolidated Area. This region covers about 12,789 square miles and includes a population of 3.8 million (Figure 1). A disaggregate travel demand model was used to predict changes in travel patterns which might result from various transportation options including car, bus, and car-van pool. These models are based on the binomial logit form.

Data Source

The data used in this study were obtained from a Regional Travel Survey, administered by North Central Texas
Council of Governments in 1984. The database included various socioeconomic and demographic characteristics and travel modes available to commuters in the Dallas-Fort Worth Metropolitan Area.

Techniques for Collecting the Data

The Regional Travel Survey included three parts: the Home Interview Survey, which contained data on individual households' travel patterns; the Work Place Survey, which gathered employee trip data at their work places; and the On-Board Transit Survey, which obtained information from bus passengers. These results were used by NCTCOG for traditional four-step travel forecasting. Only data from the Home Interview Survey (see Appendix) were used in this study. The on-board survey contained redundant data. The work place survey produced aggregate data, a form inappropriate for this study.

The Home Interview data were collected during the spring and summer of 1984. Members of 2,471 households were interviewed in their homes. Travel (trip record) and demographic information for household members over the age of four were collected.

According to the Dallas-Fort Worth Travel Patterns:

Approximately 20,200 person-trip records and walk to work trips were created for all vehicular trips made by 6,403 persons living in the survey households. All these trips were weighted by the total number of households in the NCTCOG transportation study area. The sample
represents over 1 million households and approximately 10 million trips in 1984.

(Dallas-Fort Worth Travel Patterns, 1987)

Research Design

The data-gathering procedure used by NCTCOG was a home interview conducted during individual household visits. Each household member age 16 or older was asked about travel performed on a specified day not more than three days ago. The prespecification of the travel day avoided bias in the travel patterns by day of the week. The immediacy of the interview schedule avoided loss of data caused by poor recall.

A quota sample was used rather than a pure random sample. Quota sampling estimated how many persons per household owning cars had home-based work trips; yielding a specific degree of travel for that area. To accomplish this statistic reliability, one must determine the area and household to be contacted through a telephone survey. This survey determined not only the socioeconomic characteristics of the household but also interest and willingness to participate. Recording data of these surveys determined a reliable estimate of travel demand for a specific area. This ensured that, for each stratum in the travel simulation modeling process, the number of completed home interviews would be statistically representative.
The strata were defined by four car ownership categories of zero, one, two and three or more cars owned; and by four family size categories of one, two, three, and four-plus person households. Taken together, these two variables defined sixteen possible combinations. However, three of these cells were unlikely to occur (two and three-plus cars within one person households and three or more cars within two person households) leaving only 13 actual strata for which quotas were to be set (Regional Travel Survey, 1984).

The objectives of the current research were 1) to use the NCTCOG database for calibration of travel mode choice in the study area, 2) to test the hypothesis that the travel mode selection process was sensitive to demographic variables, 3) to provide insight into the relative importance between socioeconomic and demographic groups, and 4) to determine the most frequently used alternative travel mode choice in the region. Because the current study was conducted ex post facto, the design of a separate research design was inappropriate. Therefore, the design of the NCTCOG Home Interview Study deserves separate description.

The Home Interview Study employed both a model and an evaluation framework for judging the relative performance of alternative travel mode choices. The questionnaire used consisted of two parts: demographic information and trip
information (Appendix A). The dependent variable (travel mode) of the study area was polytomous. Therefore, it was necessary to divide the dependent variable into a set of dichotomous variables. The first category was public versus private (Public-Private Model). In this category auto driver, auto passenger, motorcycle, car-van pool, and walk-bicycle were considered as private modes and bus-trolley, school bus, and taxi were labeled public transportation.

The second category, car-van pool versus motorcycle walk-bicycle, was created (Private Modes Model). The third model was auto driver and auto passenger versus car-van pool (Auto Pool Model). The final model was car versus bus (Car-Bus Model).

Validation and Reliability of the Data

The NCTCOG administered the Home Interview Survey three times to insure reliability of the data. A stratified sample was used in each case. For the validation and reliability of the instrument, NCTCOG used an alpha level of .05.

Analysis of Data

The data analysis techniques employed a logit model. This model is an analytical form for demand modeling suited to the modeling of multiple travel choice situations (Urban Travel Demand Forecasting, 1973).
Procedures for Data Analysis

The following steps were taken in analyzing the data:

1. The data obtained from NCTCOG were transferred from tape onto a computer at North Texas State University.


The procedure fit the logist multiple regression model to a single binary dependent variable. The SAS logit procedure is able to fit one model, or use either a backward or forward elimination procedure. In addition to the results of the logit model, the setwise procedure also calculates the mean, minimum and maximum values, and standard deviation of the set of variables. The hypothesis test assumes the estimators are asymptotically normally distributed. The model chi-square, its probability value, degrees of freedom, and standard error are calculated for each model (SAS Supplemental User's Guide, 1985).

The stepwise procedure progressively adds exogenous variables to the model. This procedure is able to determine the contribution of variables to observed variance. Maximum likelihood estimates (MLE) were computed using the Newton-Raphson method. Most computer packages for logit analysis employ a maximum likelihood estimation (MLE) technique. MLE
identifies the underlying parameters of a distribution. The likelihood of yielding the observed results from a general population are maximized.

Summary

This chapter described the study area, the methodology for conducting the research, the data source, techniques for collecting the data, design of the study, and the methods of data analysis. In addition, the survey instrument used by NCTCOG in gathering the data used in this study, were described.
CHAPTER BIBLIOGRAPHY


CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

Introduction

The purpose of this chapter is to report the results of a study of the determinants of travel mode choices in the Dallas-Fort Worth Metropolitan Area. To examine individual decisions about travel mode choices, the disaggregate modal choice model was used. Modal choice plays an important role in the process of forecasting and analyzing travel demand in an urban area. Choice of mode is a complex process and is central to achievement of efficient use of the existing facilities and capacity of an urban transportation system.

The data used in this study were from the 1984 NCTCOG Home Interview Survey. These data were collected during the spring and summer of 1984. Members of 2,471 households were interviewed in their homes. Travel (trip record) and demographic information for household members over the age of four were collected.

On these records a logist procedure in the SAS statistical package was used. A binomial logit model was used to predict individual travel mode choice in the Dallas-Fort Worth area. The research hypothesis was that age,
gender, income, number of cars in a household, number of people age five and over, and occupation would individually be statistically significant in explaining observed variance in mode of travel.

Characteristics of the Sample

Demographic characteristics of the sample are presented in Tables 1 and 2. Means, minimum and maximum values, and standard deviations are presented for the individual variables.

Demographic characteristics indicated that there was little variance in the sample, and that the sample was not normally distributed. Of the 20,203 observations, about 97 percent used private, and only three percent, public transportation. No matter how low the percentage in one category, logit regression would still identify the factors identified with a particular mode. In this case the low percentage of bus (or, in general, public transit) would not cause a statistical problem in explaining bus (or public transit) utilization. Income tended toward the high side and was slightly skewed from a normal distribution. Males and females were equally represented in the sample. The predominant mode of travel was the automobile. The number of people age five in a household had normal distribution. This number of family members suggests that the more people in the
household, the greater the use of cars. For clarity of presentation, occupations were regrouped. Group one included professional, semi-professional, proprietors, officials, self-employed, and traveling sales, persons or agents. Group two included store and office clerks, sales persons (excluding traveling), crafts people, forepeople, skilled laborers, operatives, semi-skilled workers, laborers and unskilled workers. Group three consisted of protective services and personal service workers. Group four included individuals not elsewhere classified, those unemployed but able to work; those not gainfully employed, retired or incapacitated persons; and students. The percentage of these groups using public transit was high. Store-office clerks and sales persons reported the highest usage (22%) of the occupational group. The results suggested females (10,588) used public transportation more than did males (9,622).

There was variance in the age category when distribution was normal. The age group of 21 to 25 and 36 to 45 reported greater use of public transit. Positive correlation was observed between the age and income of interviewees.

Data Analysis

The categorical dependent variables were dichotomous. Therefore, it was neccessary to successively divide the
### Table 1

Demographic Characteristics of the Sample

<table>
<thead>
<tr>
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<th>N</th>
<th>%</th>
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<th>MIN</th>
<th>MAX</th>
<th>S. D.</th>
</tr>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
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<td>n/a</td>
</tr>
<tr>
<td>Public</td>
<td>701</td>
<td>3.5</td>
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<td>n/a</td>
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<td>1155</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
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<td>n/a</td>
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<td>n/a</td>
<td>n/a</td>
</tr>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
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<td>Female</td>
<td>10588</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
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<td>n/a</td>
<td>n/a</td>
<td>1.2</td>
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<tr>
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<td>n/a</td>
<td>n/a</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td>21-25</td>
<td>1589</td>
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<td>n/a</td>
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<tr>
<td>36-45</td>
<td>4659</td>
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<td>n/a</td>
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<td>65-over</td>
<td>1243</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>NO REPORT</td>
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<td>0.4</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

dependent variable into a set of nested dichotomies. The eight modes of travel were grouped dichotomously. Auto
driver, auto passenger, motorcycle, car-van pool, and walk-bicycle were considered private; bus-trolley, school bus, and taxi were labeled public mode. The first category was public versus private (Public-Private Model). In this category auto driver, auto passenger, motorcycle, car-van pool, and walk-bicycle were considered as private modes and bus-trolley, school bus, and taxi were labeled public transit. The second category, car-van pool versus motorcycle and walk-bicycle, was created (Private Modes Model). The third model was auto driver and auto passenger versus car-van pool (Auto Pool Model). The final model was car versus bus (Car-Bus Model).

Table 2

<table>
<thead>
<tr>
<th>GROUP</th>
<th>N</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>5879</td>
<td>29.1</td>
</tr>
<tr>
<td>2</td>
<td>7004</td>
<td>34.6</td>
</tr>
<tr>
<td>3</td>
<td>133</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>7182</td>
<td>35.6</td>
</tr>
<tr>
<td>Total</td>
<td>20198</td>
<td>100</td>
</tr>
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</table>

The results of the analysis using the setwise procedure for public-private model are presented in Table 3. The analysis showed that number of passenger cars and vans
Table 3

Stepwise Logit Regression For Public-Private Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.126</td>
<td>18.63</td>
<td>-0.63</td>
<td>0.0000</td>
</tr>
<tr>
<td>Cars</td>
<td>-1.429</td>
<td>663.01</td>
<td>-0.349</td>
<td>0.0000</td>
</tr>
<tr>
<td>People5</td>
<td>0.409</td>
<td>236.31</td>
<td>0.213</td>
<td>0.0000</td>
</tr>
<tr>
<td>Age</td>
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</tr>
<tr>
<td>Income</td>
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<td>-0.093</td>
<td>0.0000</td>
</tr>
<tr>
<td>Occupation</td>
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<td>19.77</td>
<td>0.059</td>
<td>0.0000</td>
</tr>
<tr>
<td>Gender</td>
<td>0.213</td>
<td>5.33</td>
<td>0.025</td>
<td>0.0209</td>
</tr>
</tbody>
</table>

R = 0.487

available was a significant determinant of modal choice (B = -1.429, chi-square = 663, R = -0.349, p < 0.00001).

The household size (people age five and over) had a significant relation with choice of travel mode. The more people in the household, the more private cars and vans were used (B = .409, chi-square = 236.31, R = 0.213, p < 0.00001). The higher the income of the household the more cars and less public transit, were supported. Higher income was consistent with greater use of private cars and less support of public transportation. Income was also significant (B = -0.252, chi-square = 46.50, R = 0.093, p < 0.00001). Occupation was significant, the higher the level of job the less use of mass
transit ($B = 0.042$, chi-square = 19.77, $R = 0.059$, $p < 0.00001$).

Although estimation results indicate a systematic relationship between travel behavior and gender of the respondent, gender was observed to be a significant variable ($B = 0.213$, chi-square = 5.33, $R = 0.025$, $p < 0.02$). The $R$-value for this model was 0.487, explaining about half of the observed variance.

The results of setwise analysis of the private modes model are presented in Table 4. The analysis indicates that number of passenger cars and vans available were a significant determinant of modal choice in Dallas-Fort Worth Metropolitan Area ($B = -0.832$, chi-square = 41.60, $R = -0.194$, $p < 0.00001$). The age of respondents explained a sizable portion of the equation ($B$-value = -0.290, Chi-sq = 34.22, $R$-value = -0.175, $p$-value 0.0000). Figures for occupation showed that those having a higher level of income used less mass transportation. Occupation was also significant ($B = -0.148$, chi-square = 24.11, $R = -0.145$, $p < 0.00001$). A significant relation was observed between the gender and the dependent variable ($B = -0.972$, chi-square = 15.58, $R = -0.114$, $p < 0.0001$). Household income implied that a higher income would contribute to the decision to take a private or public transit mode ($B = -0.235$, chi-square = 6.42, $R = -0.065$, $p < 0.01$).
Table 4

Stepwise Logit Regression For Private Mode Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-square</th>
<th>R-value</th>
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</tr>
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<td>0.0000</td>
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<tr>
<td>Gender</td>
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<td>15.58</td>
<td>-0.114</td>
<td>0.0001</td>
</tr>
<tr>
<td>Income</td>
<td>-0.235</td>
<td>6.42</td>
<td>-0.065</td>
<td>0.0113</td>
</tr>
</tbody>
</table>

\[ R = 0.344 \]

Travel mode choice exhibited a positive relation with all independent variables, having R-values of 0.487, 0.344, 0.183, 0.586, 0.487, 0.342, 0.178, and 0.586.

The results of stepwise analysis of the auto pool model are presented in Table 5. The analysis shows that the age of the people in the household was a significant factor and indicated that the older the persons in the household the less use of the private car (\( B = -0.267 \), chi-square = 59.29, \( R = -0.17 \), \( p < 0.00001 \)). Although the analysis indicated that number of cars and vans available were a significant indicator of the modal choice (\( B = 0.250 \), chi-square = 11.84, \( R = -0.070 \), \( p < 0.0006 \)).
Table 5

**Stepwise Logit Regression For Auto-Pool Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-Value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.590</td>
<td>122.17</td>
<td></td>
<td>0.0000</td>
</tr>
<tr>
<td>Age</td>
<td>-0.267</td>
<td>59.29</td>
<td>-0.169</td>
<td>0.0000</td>
</tr>
<tr>
<td>Cars</td>
<td>-0.250</td>
<td>11.84</td>
<td>-0.070</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

R = 0.183

The results of stepwise analysis of the car-bus model are presented in Table 6. The number of cars and vans available was described as the most important factor in determining the travel mode choice in the study area (B = 1.463, chi-square = 118.93, R = 0.405, p < 0.00001). Household income indicated that the more income the household had the less use of public transit (B = 0.338, chi-square = 16.24, R = 0.141, P-value 0.00001). Occupation figures implied that the higher the level of the job, the greater number of cars and vans were used (B = 0.115, chi-square = 24.21, R = 0.176, p < 0.00001). The greater the number of people in the household may result in more use of the number of the cars and vans available (B = -0.167, chi-square = 4.29, R = -0.057, p < 0.0384). The age of the person's household was significant, indicating that the age was perhaps the important variable in determining the mode of travel (B = -0.171, chi-square = 6.59, R = 0.080, p < 0.0103).
Table 6

Stepwise Logit Regression For Car-Bus Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.401</td>
<td>12.73</td>
<td>0.0004</td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td>1.463</td>
<td>118.93</td>
<td>0.405</td>
<td>0.0000</td>
</tr>
<tr>
<td>Income</td>
<td>0.338</td>
<td>16.24</td>
<td>0.141</td>
<td>0.0001</td>
</tr>
<tr>
<td>Occupation</td>
<td>0.115</td>
<td>24.21</td>
<td>0.176</td>
<td>0.0000</td>
</tr>
<tr>
<td>People</td>
<td>-0.167</td>
<td>4.29</td>
<td>-0.057</td>
<td>0.0384</td>
</tr>
<tr>
<td>Age</td>
<td>-0.171</td>
<td>6.59</td>
<td>-0.080</td>
<td>0.0103</td>
</tr>
</tbody>
</table>

R = 0.586

There were two additional models comparing taxi with bus, and taxi with car. Neither were statistically significant. The number of observations indicating taxi travel was too small to permit any meaningful analysis.

The results of the setwise public-private model are presented in Table 7. Household income implied that the higher the income of the household the less use of public transportation (\(B = -0.222, \text{ chi-square} = 35.15, R = -0.08, p < 0.080\)). There was a slight difference in behavior between males and females in use of public-private transportation (\(B = 0.213, \text{ chi-square} = 5.33, R = 0.025, p < 0.0209\)). The results for the number of cars and vans available indicated that the more cars in the household the less use of the public
Table 7

Setwise Logit Regression For Public-Private Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.126</td>
<td>18.63</td>
<td>n/a</td>
<td>0.0000</td>
</tr>
<tr>
<td>Income</td>
<td>-0.222</td>
<td>35.15</td>
<td>-0.080</td>
<td>-0.080</td>
</tr>
<tr>
<td>Gender</td>
<td>0.213</td>
<td>5.33</td>
<td>0.025</td>
<td>0.0209</td>
</tr>
<tr>
<td>Cars</td>
<td>-1.366</td>
<td>379.98</td>
<td>-0.027</td>
<td>0.0000</td>
</tr>
<tr>
<td>People</td>
<td>0.307</td>
<td>108.94</td>
<td>0.144</td>
<td>0.0000</td>
</tr>
<tr>
<td>Occupation</td>
<td>0.041</td>
<td>18.71</td>
<td>-0.057</td>
<td>0.0000</td>
</tr>
<tr>
<td>Age</td>
<td>-0.156</td>
<td>49.74</td>
<td>-0.096</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R = 0.487

Transit ($B = -1.366$, chi-square = 379.98, $R = -0.027$, $p < 0.00001$). The number of household people age five and over implied that lower income families used more public transit than higher income families ($B = 0.307$, chi-square = 108.94, $R = 0.144$, $p < 0.00001$). Variance in the occupational group indicated that the higher the job position, the more private automobiles were used ($B = 0.041$, chi-square = 18.71, $R = 0.057$, $p < 0.00001$). The age of the respondents in this model showed that the older the household, the less mobile and the less use of the private automobile ($B = -0.156$, chi-square = 49.74, $R = 0.096$, $p < 0.00001$).

The results of setwise analysis of the car-van model are
## Table 8

**Setwise Logit Regression For Car-Van Model**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.422</td>
<td>5.12</td>
<td></td>
<td>0.0237</td>
</tr>
<tr>
<td>Income</td>
<td>-0.233</td>
<td>6.32</td>
<td>-0.064</td>
<td>0.0119</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.006</td>
<td>16.52</td>
<td>-0.117</td>
<td>0.00000</td>
</tr>
<tr>
<td>Cars</td>
<td>-0.717</td>
<td>21.32</td>
<td>-0.135</td>
<td>0.00000</td>
</tr>
<tr>
<td>People</td>
<td>0.038</td>
<td>0.20</td>
<td></td>
<td>0.6517</td>
</tr>
<tr>
<td>Occupation</td>
<td>-0.146</td>
<td>23.72</td>
<td>-0.144</td>
<td>0.00000</td>
</tr>
<tr>
<td>Age</td>
<td>-0.494</td>
<td>42.64</td>
<td>-0.196</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

R = 0.342

Presented in Table 8. Household income indicated that the higher the income, the less use of public transportation (B = -0.233, chi-square = 6.32, R = -0.064, p < 0.0237). There was a slight difference in the behavior of males and females in selection of travel mode choice (B = -1.006, chi-square = 16.52, R = -0.117, p < 0.00001). The results for the the cars and vans available in the household was the major factor in this model in determining mode of travel (B = -0.717, chi-square = 21.32, R = -0.135, p < 0.00001). Number of household people age five and over showed that it was not a significant variable (B = 0.038, chi-square = 0.20, R = 0.000, p < 0.6517).
### Table 9

**Setwise Logit Regression For Auto Pool Model**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>-3.023</td>
<td>47.77</td>
<td></td>
<td>0.0000</td>
</tr>
<tr>
<td>INCOME</td>
<td>-0.23</td>
<td>0.17</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>GENDER</td>
<td>-0.47</td>
<td>0.10</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>CARS</td>
<td>0.27</td>
<td>9.49</td>
<td>-0.061</td>
<td>0.0021</td>
</tr>
<tr>
<td>PEOPLE</td>
<td>0.081</td>
<td>1.83</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>OCCUPATION</td>
<td>0.022</td>
<td>1.69</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.229</td>
<td>29.75</td>
<td>-0.118</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

*R = 0.178*

Occupational group was the other major variable in the model and implied that the higher the job the greater likelihood of taking private transportation (\(B = -0.146\), chi-square = 23.72, \(R = -0.144\), \(p < 0.00001\)). The age of the respondents indicated that the older the household the less used was the private automobile (\(B = -0.494\), chi-square = 42.64, \(R = -0.196\), \(p < 0.00001\)).

The results of setwise analysis of the auto pool model are presented in Table 9. The analysis indicated that only the number of cars and vans available, and age were significant. The variable cars and vans available described the importance of the automobile in determining of the travel
Table 10

Setwise Logit Regression For Car-Bus Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B-value</th>
<th>Chi-sq</th>
<th>R-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.872</td>
<td>6.00</td>
<td>0.163</td>
<td>0.0143</td>
</tr>
<tr>
<td>Income</td>
<td>0.430</td>
<td>20.90</td>
<td>-0.015</td>
<td>0.0000</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.354</td>
<td>2.16</td>
<td>-0.094</td>
<td>0.0041</td>
</tr>
<tr>
<td>Cars</td>
<td>1.003</td>
<td>40.69</td>
<td>0.131</td>
<td>0.0002</td>
</tr>
<tr>
<td>People</td>
<td>-0.256</td>
<td>8.26</td>
<td>-0.073</td>
<td>0.0156</td>
</tr>
<tr>
<td>Occupation</td>
<td>0.103</td>
<td>14.21</td>
<td>-0.073</td>
<td>0.0156</td>
</tr>
<tr>
<td>Age</td>
<td>-0.162</td>
<td>5.84</td>
<td>-0.073</td>
<td>0.0156</td>
</tr>
</tbody>
</table>

\[ R = 0.586 \]

mode in the study area (\( B = -0.027, \) chi-square = 9.49, \( R = -0.061, p < 0.0021 \)). The age of the household was perhaps the most important variable in this model for determining travel mode choice in the Dallas-Fort Worth Metropolitan Area (\( B = -0.229, \) chi-square = 29.75, \( R = -0.118, p < 0.00001 \)).

The results of setwise analysis of the car-bus model are presented in Table 10. The analysis showed that household income was significant, and the more income the household had the higher the probability of using less the public transit (\( B = 0.430, \) chi-square = 20.90, \( R = 0.163, p < 0.00001 \)). The gender in this model was not significant and perhaps did not
have an impact on determining the travel mode choice in the study area \((B = -0.354, \chi^2 = 2.16, R = -0.015, p < 0.0001)\). The number of cars and vans available was the most important variable in determining travel mode choice in the Dallas-Fort Worth Metropolitan Area \((B = 1.033, \chi^2 = 40.69, R = 0.233, p < 0.00001)\). The results summarized in Table 10 described the setwise cases in the car-bus model indicate that the household size was significant, and contributed to the probability of using the private automobile more than public transportation \((B = -0.256, \chi^2 = 8.26, R = -0.094, p < 0.0041)\). The occupational group represented more use of the number of cars and vans available than mass transportation, because the higher the level of the job the more use of the private automobile \((B = 0.103, \chi^2 = 14.21, R = 0.131, p < 0.0002)\). The age of the household was the other variable in determining of the travel mode choice in the study area \((B = -0.162, \chi^2 = 5.84, R = -0.073, p < 0.0156)\).

In summary, several factors contributed to the likelihood of travel mode choice in the first three models. These variables are less in number in car-van and auto pool models than in the public-private model. The addition of the household people as a significant variable in public-private case can be explained by the fact that there have been
relatively fewer household people using mass transportation in the public-private model.

To view the results of including all the dependent variables in the model, a setwise model was analyzed. The setwise and stepwise models were almost identical. The only major difference was the variable gender which appeared only in the setwise model. As expected, gender was statistically insignificant. In general, however, the stepwise model proved more reliable for prediction travel mode choices in the study area.

Summary of Major Findings

The following findings were derived from the analysis of the data for study area. The investigation of travel mode choice in the study area indicate the following findings.

1. About 97 percent of the travelers used the private car and three percent used public transit.

2. The study suggested that the household income and number of cars and vans available were significant explanatory variables. The study also suggested the impact of household income and number of cars and vans available upon an individual's decision for travel mode choice is very important.

3. All independent variables were significant in explaining the effect of household income in travel mode
choice. Number of cars and vans and the ages in the household were also significant.

4. Household members with incomes of $30,000 to $39,000 and those with incomes of at least $50,000 tend to use more private cars than other income groups. Also, it was found that people with incomes below $9,000 used more public transportation. People representing lower preference for number of cars and vans available were younger than 26 years or older than 55 years of age. It was found that gender was a significant predictor in all setwise models, in public-private and private modes model stepwise models.
CHAPTER BIBLIOGRAPHY


CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to identify those demographic variables which best predicted the travel mode choices of commuters in the Dallas-Fort Worth Metropolitan Area. The data analyzed in this study was the Home Interview Survey of the 1984 Regional Travel Survey (NCTCOG, 1984). Household data included eleven variables addressing commuter behavior (see Appendix).

Summary

The summary of major findings from the research follows.

1. About 97 percent of the travelers in the study area used private cars and three percent used public transit.

2. The study suggested that household income and cars, vans were significant explanatory variables. The study also suggested that the impact of household income and number of cars and vans available upon an individual's decision for travel mode choice is very important.

3. The number of cars and vans available in the household was a significant predictor of travel mode.

4. Respondent's age was a significant predictor.

5. Household members with incomes of $30,000 to $39,000
and those with incomes of at least $50,000 tended to use more private cars than do other income groups. Also, it was found that household members with incomes below $9,000 used more public transportation. People representing lower preference for cars were younger than 26 years or older than 55 years of age.

6. Gender was a significant predictor in all setwise models and in public-private and car-van stepwise models.

Conclusions

The principal goal of this study was to establish the nature of the relation between demographic variables and modal choices. Binomial logit analysis was used to test models. The results substantiated the hypothesis that household income and number of cars and vans available in the household were most important factors in selecting the mode of travel in the study area.

During the period in which this survey was conducted, the economic situation in the Dallas-Fort Worth Metropolitan Area was at the peak of economic progress. People had a better income situation; therefore, they preferred to use private cars due to the greater comfort, convenience, and speed. These factors were obvious in the analysis done for this study. Travel distances may increase or decrease, public
transportation patronage may increase or decrease. The research results did not support the expectation that public transportation usage would be seen as a means of economizing on travel expenditures. On the contrary, the evidence shows that individual decisions regarding travel mode were predictable from knowledge of various demographic factors.

Another factor that may be discussed in this study is job position. This variable impacted the use of public transit. Household members in higher vocational positions could better afford to use private automobiles, choosing private transportation as often as possible. Overall, the research indicated the socioeconomic situation of people had a solid impact on the use of mass transportation.

From the comparison of all four models the conclusion may be drawn that people with the strongest preference for cars were from the middle-aged and the middle-income group. The people with the lowest preference for the car were people younger than 26 years or older than 55 years of age.

Recommendations for Further Research

The study leads to the following recommendations.

1. The questionnaire does not include any ethnic information. For further research, this should be added to the questionnaire.

2. There is a need for further research on the effects
of geographic income shifts.

3. Overall, a comparison is needed between household income and gender on the one hand and socioeconomic background on the other.
CHAPTER BIBLIOGRAPHY

### TRAVEL DIARY

**INSTRUCTIONS:**

Please carry this diary with you throughout the travel date shown at the left. Please use it to record each trip you make including the items specified below. Do not record walking or bicycle trips unless to go to work. Please leave the filled in card in a convenient place at home so it will be available when our interviewer calls. Use the back of this card and an extra card if necessary.

<table>
<thead>
<tr>
<th>SAMPLE NUMBER</th>
<th>I AM __ YEARS OLD</th>
<th>I AM ☐ MALE ☐ FEMALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WHERE DID THIS TRIP BEGIN?</th>
<th>WHERE DID THIS TRIP END?</th>
<th>TRIP PURPOSE (Enter Number)</th>
<th>DESTINATION ACTIVITY: Restaurant, Auto Repair, Office, etc.</th>
<th>TRIP TIME (Circle AM or PM BEGIN END)</th>
<th>MODE OF TRAVEL (Enter Number)</th>
<th>IF AUTO DRIVEN (No. in Car, Include Driver)</th>
<th>IF CAR OR VANPOOL (No. in Car, Include Driver)</th>
<th>IF BUS HOW DID YOU GET TO BUS STOP? (Enter Number)</th>
<th>TRANSIT PARKING COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>Address</td>
<td>1 Home</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>1 Auto Driver</td>
<td>1 Walk</td>
<td>2 Drive</td>
<td>$__</td>
<td></td>
</tr>
<tr>
<td>City Zip</td>
<td>City Zip</td>
<td>2 Work</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>2 Auto Passenger</td>
<td>2 Drive Auto and Parked</td>
<td>3 Auto Bus</td>
<td>$__</td>
<td></td>
</tr>
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<td>Address</td>
<td>Address</td>
<td>3 Shop</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
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<td>3 School Bus</td>
<td>4 Car Pool</td>
<td>$__</td>
<td></td>
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<td>City Zip</td>
<td>City Zip</td>
<td>4 Social Recreation</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>4 Tool</td>
<td>4 Motorcycle</td>
<td>5 Car Van Pool</td>
<td>$__</td>
<td></td>
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<td>Address</td>
<td>Address</td>
<td>5 Personal Business</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>5 Tool</td>
<td>5 Bicycle</td>
<td>6 Walker</td>
<td>$__</td>
<td></td>
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<td>City Zip</td>
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<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>6 Motorcycle</td>
<td>6 Walk or Walk by Bike</td>
<td>7 Car Van Pool</td>
<td>$__</td>
<td></td>
</tr>
<tr>
<td>Address</td>
<td>Address</td>
<td>7 Eat Meal</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>7 Car Van Pool</td>
<td>8 Car Pool</td>
<td>8 Other</td>
<td>$__</td>
<td></td>
</tr>
<tr>
<td>City Zip</td>
<td>City Zip</td>
<td>8 Serve Passenger</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM PM</td>
<td>8 Car Van Pool</td>
<td>9 Car Van Pool</td>
<td>9 Other</td>
<td>$__</td>
<td></td>
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<tr>
<td>Address</td>
<td>Address</td>
<td>9 Change Made in a Car to Bus</td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM AM AM</td>
<td>9 Change Made in a Car to Bus</td>
<td>10 Car Van Pool</td>
<td>10 Other</td>
<td>$__</td>
<td></td>
</tr>
<tr>
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<td>City Zip</td>
<td></td>
<td>Auto Repair, Office, etc.</td>
<td>AM PM AM AM AM</td>
<td>10 Change Made in a Car to Bus</td>
<td></td>
<td></td>
<td>$__</td>
<td></td>
</tr>
</tbody>
</table>

(NCTCOG HOME INTERVIEW SURVEY)
## Trip Report

### Section V: Trip Report

**NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS**

**NCTCOG HOME INTERVIEW SURVEY**

**TRIP REPORT**

*(Completed by Interviewer)*

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
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<th>J</th>
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<tbody>
<tr>
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<td>WHERE DID THIS TRIP BEGIN? (ORIGIN)</td>
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<td>TRIP PURPOSE</td>
<td>LAND USE (Type of Activity)</td>
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<td>CODE</td>
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**CONFIDENTIAL**

The information obtained in this survey will be accorded confidential treatment, and will not be used for statistical purposes only.
BIBLIOGRAPHY


Pas, E. I. (1986). *The urban transportation planning*


