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Factors That Affect and/or Can Alter Mode Choice

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Project Report for

"Factors That Affect and/or Can Alter Mode Choice"

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and

The State of Delaware Department of Transportation

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

Figure **Page**

INTRODUCTION

This project uses data about individuals, their characteristics, the trips they make, and the costs and benefits of travel modes, to identify factors that can be used in models for travel mode choice. For use in travel demand forecasting and examination of transit markets, almost all mode choice models are developed using aggregate level data, typically at the level of a traffic zone, such as population totals, mean incomes, average household characteristics, and other summary data. Perhaps the reason for this is that aggregate data is typically more available such as provided by the U.S. Census data. These aggregate models, though they may be useful and have some predictive value for a given area, do not address the choices of individuals or develop a fundamental understanding of travel mode choice as may be indicated by the many conflicting results seen in the literature concerning factors that influence mode choice. This project addresses mode choice using data about individuals.

Where transit or walk trips often account for only 1 to 5% of all trips, the main problem in modeling the use of other choices of travel besides the personal auto is that there is very little data available. Individual level data is most commonly available where locales have issued trip diaries to a sample population. For a period of time, individuals log information about every trip they make, and this information is combined with socio-economic information about the individual. In Delaware, for the past eight years, the Delaware Department of Transportation (DelDOT) has sponsored the DelDOT Household Survey. Approximately 200 people of the age of 16 or older are called on the telephone and asked to describe the trips they have taken in the previous day. Trip origins and destinations are geo-coded to a small geographic unit (modified grid), and information is obtained for trip time, purpose, incidental stops, travel preferences, demographic data, vehicle occupancy, travel mode, and other information. This is a wealth of information very suited to the modeling goals of this project.

The modeling of transit use was a focus in this project. Automobiles offer large advantages over transit in convenience, flexibility, and travel time. A particular level of service of transit is necessary to have people choose to use transit over a car when they have the choice. Factors that reflect the transit level of service are necessary in any model, and level of service factors certainly significantly influence mode choice. A review of the literature indicates many types of service factors that have been used in mode choice models. Level of service is often very difficult to quantify. This project employed road network models and optimum routing algorithms as available in geographical information systems to estimate travel times and service factors for trips taken by individuals.

This project is the first part in a two part modeling effort. Once mode choice is modeled at the individual and trip level, a study will be done on how travel mode split can be modeled at the smaller levels of geography like traffic zones for use in route planning and travel demand forecasting.

Factors Influencing Mode Choice

Introduction

Numerous factors used for model mode choice were found in the literature. A study by members of the National Center for Transit Research (CTR) at the University of South Florida entitled "FSUTMS:Mode Choice Modeling: Factors Affecting Transit Use and Access" (Fang Zhao 2002) included an identification of many of the factors that have been used in modeling is modal split. In that work, factors affecting transit usage are classified into the first four categories below:

(1) Travel mode level of service (LOS)
(2) Accessibility
(3) Land use/urban design; and
(4) Transit users' socioeconomic/demographic characteristics
(5) Characteristics of the trip

Characteristics of a trip may affect the mode of travel, and the fifth category above was added. For instance the trip purpose, whether it is travel for work, recreation, shopping, school, or other purpose is a factor. The trip distance can play a role in mode choice. Shorter trips may be done by walking or bicycling. Figure 1-1 on the next page provides examples of factors that have been identified in the literature by these categories. These many factors and others can be involved in a person's travel mode choice.

Modeling mode choice when there are so many factors that come into play is very challenging. The main difficulty is the availability of data. Even when large travel data sets are available, the relatively very small fraction of trips that are made by modes other than personal vehicle, often does not provide enough data to establish significant results.

Factors most used to understand mode choice as referenced in the literature are the following:

- Mode travel time
- Mode costs
- Income
- Availability of a personal vehicle
- Parking availability and costs
- Access to alternative modes
- Time of day of transit service and service frequencies
- Population densities
- Land use variables (retail, commercial, manufacturing, etc. densities)
- Transit service factors

Figure 1-1
Examples of Factors Used for Mode Choice Modeling

Transit Level of Service

Transit travel time (including transfer time, wait time, etc. walk time)
Highway travel time
Out of vehicle travel time
Presence of a transit, bicycle or walk route
Direct service or not, transfer costs
Hours of operation
Costs, fares
Comfort/security variables
Time of year, season
Total number of bus runs
Average bus runs per stop
Average daily headways
Peak headways
Revenue vehicle hours, revenue vehicle distance
Service offered by park and rides and multi-modal facilities

Accessibility

Walk time involved in trip
% of people in an area that are within a certain distance to transit facilities
Time it takes to drive to a park and ride, (dist <= 10 miles)
Regional accessibility (see pg 65 for forms)
Often arrayed by different types of employment (service, commercial)
Kinds of accessibility

- Modal – degree of connectivity of two places by mode available
- Temporal – variation in time of day
- Legal- legal/regulatory restrictions
- Relative – Ease of travel between two points based on time and cost
- Integral – Ease of travel between one point and many, time and cost
- Place – just spatial separation between two places
- Activity – activities at destinations accounted for explicitly
- Cumulative opportunity index-#opportunities reachable within defined cost/or time
- Gravity type measures- sum of opportunities weighted by travel time/cost

(figure continued on next page)

Figure 1-1 (continued)
Examples of Factors Used for Mode Choice Modeling

Land use / urban design

Land use mix, entropy (single family multi, retail, office entertainment, institutional, industrial, manufacturing)
Sidewalks
Population density
Employment density
Parking fees / parking availability
Availability of parking
Average commute time
Housing density
Retail, commercial, service, industrial, employment density
Average parcel size
Pedestrian environment factors

Transit users socioeconomic/demographic characteristics

Gender
Age
Ethnicity
Income
Child in the household
Proportion of population 16 yrs and younger
Proportion of population 65 and older
Household structure, HH size
Average housing value
Average commercial, industrial, service, nonresidential, property value
Vehicle availability, % of household without car
Total number of vehicles per hh, #vehicles/licensed driver, #vehic/worker
Avg number of cars owned by households with children
Avg number of cars owned by households without children
Race, percentages for white, black, Asian, Hispanic, Foreign
Average workers in HH with and without children
Average person in HH with and without children
% HH without children
Number of persons in household who can drive
Origin and/or destination

Characteristics of the trip

Trip purpose (work, school, shopping, recreation, or others)
Trip distance
Origin and destination information

Available data can be seen as either at the level of the individual or as aggregate data. For instance, population densities, employment densities and mode choice data by census tract are examples of aggregate data. Most data that is available about transit is aggregate, summary level data. Individual level data is where information is available about a particular individual's characteristics. For a given trip you may know a person's income, age, race, whether a car is available, the purpose, length, and time of a trip and other data about an individual, on a trip by trip basis. This allows for modeling of a person's travel choice. This project is mostly concerned with individual level data and modeling the choices of individuals.

The DelDOT Household Survey

The DelDOT Household Telephone Survey, as part of the Delaware Statewide Model Improvement Project, is an ongoing survey since 1995 that gathers information about the weekday travel behaviors and preferences of drivers, 16 years and older, across the State. It began initially to update DelDOT trip generation models and takes the place of trip diaries used by other States. In a random process, respondents are selected and asked to list the origin, destination, time, and trip method (mode) of every trip made in the preceding day. Demographic data is compiled for each respondent. Public opinion on transportation issues is also surveyed. Since the start of the survey there have been over 12,000 people surveyed, and over 35,000 trips have been documented. This represents a continually growing body of knowledge specific to Delaware and has yet to be fully taken advantage of for planning. The DelDOT Household Survey is the data that was used to study factors related to travel mode choice.

As part of a first look at appropriate factors for mode choice modeling, several descriptive views from the DelDOT Household Survey and other sources were compiled and are presented in the rest of this chapter.

Mode Split

Figure 1-2 summarizes information from the 1995 Nationwide Personal Transportation Survey (NPTS) for means of travel. Nationwide, travel by private auto accounts for 86% of all person trips. Walking is the next most used mode with 5.4% of all trips. Transit accounts for 1.8% of all trips. School bus trips account for 1.7% of all trips.

By NPTS, walk trips were mainly for family and personal business (43% of walk trips) and for social and recreational purposes (22% of walk trips). Seven percent of work trips were made by walking. Social and recreational purposes accounted for 60% of trips by bicycle, and family and personal business accounted for 22% of bicycle trips. Transit captured 3.1% of the trips for work, and 44% of all transit trips took place during peak times.

Public Opinion On Travel Modes

One way of identifying factors that influence transit use is through a survey. The DelDOT Household Survey includes questions about transit and carpooling. Results of two questions are shown in Figures 1-6 and 1-7. The availability or unavailability of a car clearly is the most influential factor. Of those riding transit, most other factors for increased usage are related to higher levels of service.

Table 1-6
If You Ride Transit,
What Would Make You Ride Transit More Frequently?
Source: DelDOT Household Survey 1995-2001, N=3009 of 13622

Reason to use transit more	% responding
Unavailability of a car	40
More routes	31
Weekend service	27
Better information about service	26
Night service	26
More Frequent Service	25
Lower Fares	12

As shown in Figure 1-7 on the next page, about 14% of those who don't use transit, see transit as inconvenient. Convenience is related to a level of transit service. Convenience is also related to travel patterns. The DelDOT Household Survey data in years 1995 thru 1999 showed that about 1/3 of all trips could be considered as part of a chain of trips. A trip chain, while difficult to exactly define is where, for instance, someone stops to go shopping or pick up their children on the way to or from work. Or a chain could be a tour of errands from the grocery store, to the cleaners, to the mall, and then to a recreational activity. Transit cannot compete with a private auto in these cases (and certainly not walking or bicycling in a low density area). With the inconvenience, the impracticality of fixed transit to serve low density areas, and much of today's travel patterns and fast paced life styles, it's not surprising that over 90% of respondents gave their reason for not using transit as simply "A car is always available". From this question it appears that for most respondents, transit is not considered a viable alternative to the personal vehicle. Other responses mostly relate to the level of service provided by transit or a lack of knowledge of the services that are available. Eighteen percent of those who don't use transit said there was no service ("No public transit in area" "Hours of service are not appropriate").

Figure 1-7
If You Don't Use Transit,
What are the Reasons these Services are Not Used?
Source: DelDOT Household Survey 1995-2001, N=10,613 of 13,622

Reason for not using transit	% responding
Car is always available	92
Inconvenient	14
Unaware of routes or schedules	13
No public transit in area	11
Hours of service are not appropriate	7
Do not like buses	6
Want privacy	3
Health problems	1

So for those who now use transit and to a lesser extent those who don't use transit, the level of transit service is an important factor. The percentage of people using transit is available for aggregate level data as with the Census Transportation Planning Package, but data that includes transit level of service is difficult to find. This project estimated factors for transit LOS as explained in the next chapter.

Close to 70% of those interviewed were not interested in carpooling to work. Those that might consider it sited flexible work hours, a free ride home in an emergency, and easy to find car pool partners as factors that might influence them to car pool.

Figure 1-8
Which of the Following Might Influence
You to Car/Vanpool to Work?

Near-the-door parking	1.8
Flexible work hours	8.7
Easy to find carpool partners	9.2
Free ride home in emergency	5.1
Reserved near-the-door	1.8
Priority highway lane	2.2
Already car/van pool	12.2
Not interested in car pooling	68.5

Availability of Vehicles

Figure 1-9 below clearly shows that the availability of vehicles in the household is a factor in mode choice. About forty two percent of transit trips and a fifth of walking and bicycling trips are from households with no vehicles.

Figure 1-9
Mode Split Versus Vehicle Availability, Number of Cars/Vans/Pickups

Number of Vehicles In The Household

	0	1	2	3	4
Driver of car	27.5	80.2	87.4	87.8	93.3
Passenger of car	21.6	12.8	9.3	9.6	5.6
Public Bus	26.7	2.6	0.7	0.3	
Walked	20.0	3.0	1.5	1.1	0.5
School Bus	0.8	0.9	0.9	0.9	0.6
Rode Bike	1.1	0.4	0.2		

Source: DelDOT Household Survey 1995 to 2001

Further examination of DelDOT Household Survey Data reveals that those in households with one or no vehicle use transit at three times the rate and walk or use bicycles at twice the rate as those households with two or more vehicles in New Castle County. About ¾ of all transit trips, and over half of all walking trips and bike trips are from those in households with one or no vehicle, though this represents only about a quarter of the population.

Trip Purpose

The purpose of a trip is an important factor related to travel mode. Certain types of trips are more easily accomplished using transit or an alternative other than a personal vehicle. Different trip purposes will show different mode splits. The journey to work in general shows the most use of public transit and carpooling. Very few people would use transit as part of a childcare trip. Bicycling and walking are often related to travel to school activities. Walking appears more dependent on trip distance and exhibits a significant share across trip purposes. Figure 1-10 below presents mode split by purpose for Delaware trips.

Figure 1-10
Percentage Persons Using Particular Modes by Purpose
DelDOT Household Survey 1995-1999

	Driver	Passenger	Public Bus	Walk	Sch. Bus	Bike	Other
Childcare	96.9	1.0	0	2.1	0	0	0
Work	92.6	3.6	1.9	1.3	0.1	0.1	0.4
Drop/Pickup	91.9	6.0	0.4	0.6	0.4	0.0	0.7
Other	85.7	9.4	1.0	1.4	0.7	0.2	0.2
Shop	85.1	13.3	0.4	1.1	0	0.1	0.1
Social	80.7	16.1	0.6	1.8	0	0.4	0.3
Recreation	79.5	16.5	0.6	1.7	0.2	0	1.7
School	71.0	12.9	0.8	3.4	10.6	1.2	0.2
Eat Out	70.2	26.8	0.5	2.3	0	0	0.2

Figure 1-11 shows results of a 1997 on-board survey for the Delaware Administration For Regional Transit (DART First State) and provides a view of trip purpose for transit riders.

Figure 1-11
What is the Purpose of this Transit Trip?
DART 1997 On-Board Survey, Ilium Associates, Inc.

	New Castle	**Kent**	**Sussex**	**Inter-county**
Work	60.8 %	33.3 %	50 %	50 %
Other	7.1	7.5	11.1	5.6
Shopping	5.7	15.8	5.6	1.9
School	4.4	11.7	11.1	12
Social/Recreational	4.1	7.5	16.7	7.4
Medical/Dental	3.5	5	0	3.7

Central Business District

Transit service can be highest where there are focused destinations and high employment and population densities as in the City of Wilmington. Historically and now, Wilmington is the major hub for transit lines. A primary incentive for transit use and other alternatives to the private vehicle, is the cost of parking. A factor to consider in modeling would be those trips to and from the Central Business District. This is a large portion of the transit market. Trips to or from the Wilmington CBD are 55% of the transit trips surveyed. Trips to or from Wilmington zip codes are 85% of the transit trips surveyed.

Figure 1-12
Mode Split Where Trip Origin or
Destination is the Wilmington Central Business District

	Trip includes CBD	Trip does not include CBD
Driver	72.4	85.5
Passenger	9.5	10.3
Public Bus	13.2	0.9
Walked	4.6	2.1
Bicycled	0	0.2

Travel Time

Travel time by transit and travel time by car are factors that have been used in other research and efforts to model travel mode choice. It was expected that the choice between using transit or a car would be somewhat dependent on the relative time between transit and personal vehicle trip time and this was incorporated into a service factor as explained in the next chapter.

Figure 1-13
Median and Mean Travel Time by Travel Mode
Reported Times for Trips from the DELDOT HH Survey 1995-2001

Mode	**Median Time**	**Mean Reported Trip Time in Minutes**
Driver of car	15	18.5
Passenger in car	15	21.1
Public Bus	30	34.2
Walked	10	13.6
School Bus	25	27.3
Bicycle	15	18.7
All modes	15	19.0

While the median transit trip distance is less than for travel by car, median trip time for transit is twice that for car. Walk trips are generally around 10 minutes and the percentage of walk trips drops off rapidly as walk time goes beyond 15 minutes.

Travel Distance

Trip distance, particularly for walking and bicycling is a big factor for travel mode choice. Distances were estimated for the DelDOT Household data using a road network model of Delaware and minimum path algorithms. In terms of mode choice, results are shown in Figure 1-14 below.

Figure 1-14
Mean and Median Trip Distances by Travel Mode
Source: DELDOT HH Survey 1995-2001

Mode	Median Distance	Mean Distance in Miles
Driver of car	5.2	6.5
Passenger in car	4.7	5.7
Public Bus	2.9	5.0
Walked	1.0	1.1
School Bus	14.7	5.1
Bicycle	1.2	1.4
All modes	5.0	6.3

Most trips by transit involve a shorter distance than those taken by car. There are a large number of trips from areas in Wilmington going to other areas in Wilmington. Across all other factors, whenever there are shorter trip distances, a few percent or more are walk trips. The estimation of trip distance shows the most error when trip distances are small. In particular for walking, any type of path or short cut or positioning within the origin or destination modified grid could effect the calculation by as much as 50% at least. As the median time for walk trips is ten minutes, it is guessed that the median distance is closer to a half of a mile.

Gender

Gender does not seem to be a big factor in estimating mode choice, though certainly females are more often the passenger than the driver

Figure 1-15
Travel Mode by Gender
Source: DelDOT Household Survey 1995-2001

	Male	Female	Total
Driver	88.4	80.6	84.3
Passenger	7.6	15.4	11.7
Public Bus	1.0	1.2	1.1
Walked	1.7	1.5	1.6
Rode Bike	0.2	0.1	0.2

Income

As would be expected, those from the lowest income brackets use transit, walk, and bicycle more. In New Castle County they also tend to live more in urban areas where trips are generally shorter in distance and where transit service is better. Once household income reaches the $15,000 to $20,000 per year range though, mode split begins to look more like the rest of the population. It's not thought that the poorest people like walking or transit more (though they may be more familiar with its benefits) but rather that they do not have a vehicle available.

Figure 1-16
Income (x $1000) by Mode Split
Source: DelDOT Household Survey 1995-2001

	< 10k	10 - 14.9	15- 19.9	20 - 24.9	25 – 29.9	30 – 34.9	35 – 39.9	40 – 49,9	50 – 74.9	75 – 99.9	100 – 149.9	150 +
Driver	57.7	70.3	82.1	81.8	82.6	86.3	84.5	87.3	90.0	91.0	92.4	87.2
Passenger	16.0	12.3	14.1	13.3	13.0	9.3	11.6	10.1	7.7	7.0	5.4	10.9
Public Bus	6.2	8.1	1.2	1.6	1.9	0.9	2.5	0.8	0.4	0.9	0.5	1.5
Walked	13.7	6.2	2.2	2.7	1.3	1.5	0.9	1.0	0.6	0.7	0.6	
School Bus	1.3		0.2		0.6	0.8	0.4	0.5	0.9	0.2	0.4	
Bike	3.4	2.3		0.2	0.2	0.5				0.1	0.2	
Other	1.8	0.4	0.3	0.4	0.4	0.1	0.1	0.4	0.3	0.2	0.3	0.4

Ethnicity

Mode choice is shown in Figure 1-17 below by ethnicity, and focusing on this one factor of ethnicity one might think that ethnicity was a factor in mode split.

Figure 1-17
Mode Split Versus Race
Source: DelDOT Household Survey 1995-2001

	Latino/Hisp Mex Amer	Black/African American	White	All
Driver of car	73.3	73.3	86.6	84.3
Passenger in car	15.8	15.8	10.8	11.8
Public Bus	2.9	4.5	0.5	1.1
Walked	4.3	3.7	1.2	1.6
School Bus	1.5	2.0	0.5	0.7
Rode Bike	0.2	0.2	0.1	0.2

There are other related variables to consider though. For instance, the average household income between blacks and whites is lower. More minorities live in urban areas better served by transit. The City of Wilmington is the focus of the transit system and has many more minorities than any other area. While to some extent there may be cultural arguments around a historically greater familiarity with transit and its benefits, race was not considered as a good factor for modeling mode choice.

Polzin, Chu , and Rey produced an interesting study of mode choice of people of color in an analysis of 1983, 1990 and 1995 NPTS data. A principle finding was that non-work travel behavior for the various racial/ethnic groups has changed dramatically over time with minority travel behavior now more closely matching majority behaviors.

Age

Age was thought to be a possible factor affecting mode choice. Walk trips were generally by younger people. There is a greater likelihood of taking a trip as a passenger than a drive in the 65 years and older category.

Figure 1-18
Mode Split Versus Mean Age
Source: DelDOT Household Survey 1995-2001

Mode	Mean Age
Driver	42
Passenger	41
Public Bus	40
Walked	34
School Bus	18
Bike	37
All modes	42

Figure 1-19
Mode Split by Three Age Groups
Source: DelDOT Household Survey 1995-2001

Mode	16 to 39	40 to 64	65 and over
Driver	85.5	90.3	81.1
Passenger	9.8	7.1	16.7
Public Bus	1.1	1.0	0.7
Walked	1.9	0.9	0.8
School Bus	1.1	0.2	0
Bike	0.2	0	0.2
Other	0.3	0.3	0.5

Household Structure

Some household structure variables may be of interest for modeling travel mode choice. For instance, whether or not children are in the household as shown in Figure 20, though this does not seem to be a major factor.

Figure 20
Mode Split for Households With and Without Children
SOURCE: DELDOT HOUSEHOLD SURVEY 1995-2001

	No Children	One or more children
Driver	83.0	87.1
Passenger	12.9	9.2
Public Bus	1.2	1.0
Walked	1.8	1.3
School Bus	0.6	1.1
Rode Bike	0.2	0.1
Other	0.4	0.1

The number of people in a household might also be of interest. Figure 21 shows the number of people in the survey respondent's household and mode split. No major differences are seen with respect to household size.

Figure 21
Household Size and Mode Choice in Delaware

	1	2	3	4	5	6	7
Driver of car	87.4	83.4	85.3	85.3	82.3	76.6	85.9
Passenger-car	7.4	13.6	10.7	13.0	13.0	16.2	10.2
Public Bus	1.8	0.8	1.0	1.2	1.2	1.6	1.7
Walked	2.5	1.3	1.5	2.0	2.0	3.1	1.7
School	0.1	0.2	1.0	1.2	1.2	2.0	0.6
Bicycle	0.3	0.2	0.2	0.2	0.2	0.4	-

SOURCE: DELDOT HOUSEHOLD SURVEY 1995-2001

For households with no vehicle available as shown in Figure 22, there also doesn't seem to be a particular trend related to household size.

Figure 22
Household Size and Mode Choice in Delaware
Where No Vehicle is Available.
SOURCE: DELDOT HOUSEHOLD SURVEY 1995-2001

	1	2	3	4	5	6
Driver	32.6	33.3	41.7	28.9	28.6	26.9
Passenger	28.0	19.2	28.7	12.0	42.9	46.2
Public Bus	18.6	19.8	13.0	39.8	23.8	23.1
Walked	17.4	21.5	12.0	19.3	-	-

Time of Day

Time of day is a factor as it relates to mode choice is shown in Figure 23. Public transit's percentage is about 50% greater during peak times, though this reflects the large use of transit for work trips. Transit would of course be low during night hours, as there is generally no fixed transit service. Whether a trip occurs at night or not would be included in models as it indicates a time of no transit service.

Figure 23
TRAVEL MODE SPLIT BY TIME OF DAY

TIME OF DAY

	5-7am	7-9am	9am-4pm	4pm –6pm	6pm – 5am
Driver	87.7	86.4	83.9	85.7	81.6
Passenger	3.7	7.4	10.8	9.2	15.5
Public Bus	1.6	2.3	1.6	2.2	0.5
Walked	1.4	2.2	2.4	2.6	2.0
School	3.2	1.4	0.9	0.1	0.2
Bike	-	0.2	0.3	0.1	0.1

SOURCE: DELDOT HOUSEHOLD SURVEY 1995-2001

Figure 24
Trip Purpose by Time of Day
(Row Percentages)

TIME OF DAY

	5-7am	7-9am	9am-4pm	4pm –6pm	6pm – 5am
Other	1.7	10.4	45.8	15.1	27.0
School-DC	4.1	33.2	43.0	11.7	8.0
Shop	0.1	3.1	64.0	14.4	18.4
Work	12.7	28.0	25.9	23.0	10.4
All Trips	5.9	17.3	41.5	17.8	17.5

SOURCE: DELDOT HOUSEHOLD SURVEY 1995-2001

Figure 25
Trip Purpose By Time of Day
(column percentages)

TIME OF DAY

	5-7am	7-9am	9am-4pm	4pm –6pm	6pm – 5am
Other	9.9	20.4	37.3	28.6	52.2
School-DC	4.5	12.4	6.7	4.2	2.9
Shop	0.2	3.7	31.6	16.5	21.6
Work	85.5	63.6	24.5	50.7	23.3

Summary

A number of factors were reviewed that may influence mode choice. The following factors would appear to have the strongest effect.

- Vehicle availability (related to income)
- Trip distance
- Parking incentives as where origin and/or destination is the Wilmington CBD

Vehicle availability certainly seems to be the most powerful factor. Those with no personal vehicle use transit, walk, and bike considerably more than those who have vehicles. Travel distance is an important factor in that as soon as trip distances become small there are more walking and bicycling trips taken for all trip purposes. Trip purpose showed differences in mode choice. People are much more likely to use transit for a work trip than a shopping trip.

Prior to modeling work, differences in mode choice associated with factors such as age, race, household structure, and gender are thought to be more related to income and level of service variations in certain locales, rather than a specific preferences for other travel means than by car. In the research there are conflicting findings in regards to socioeconomic/demographic characteristics and their influence on transit ridership. Often these characteristics are also highly correlated with each other. (Zhao pg3)

What has not been presented is factors associated with transit level of service which are expected to have strong effects based on previous research, opinion polls, and reasoning along the lines of costs and benefits. The next chapter describes transit level of service and trip time and distance estimates that can be used in modeling.

Transit Service Level Factors

Introduction

Transit level of service (LOS) can be described in terms of hours of service, headway, pedestrian environment (sidewalks, lights, shelters), safety, rider comfort, appearance, reliability, transfer, costs, and transit travel time, to name a few of the more common factors. Most modeling efforts are focused on generating mode split approaches that can be used in travel demand forecasting models. Most of the data employed is at an aggregate level, typically a traffic zone. LOS Measures of Effectiveness (MOEs) are typically developed such as the Persons Per Minute Served, Average Bus Headway, or total number of bus runs in a census tract. In a survey done by Cleland etal (1997) that included 14,500 surveys collected in six urban areas in Florida, transit users identified hours of service, location of routes and headways as the biggest concerns.

The literature generally supports the ability of transit systems with high-quality services to attract more users, as well as for poor services to encourage more automobile use. (Zhao pgs 2,13). Public opinion indicated increases in level of service as important factors for using transit. The availability of direct service from origin to destination, transit travel times that are not much greater than travel times by private automobile, more frequent service, and service on nights and weekends are the types of service that are expected to encourage transit use. Those who have access to a personal vehicle are expected to weigh the benefits of taking transit relative to the convenience of driving. The use of the transit system by those who have no private vehicles and to a much larger extent those who have vehicles, does depend on the level of service. Many of the LOS factors affecting transit use however cannot be easily quantified and there is always the problem of generally not having data available. It is still difficult to formulate LOS variables in models for estimating transit share.

The approach in this project is to model the travel choice of the individual using nonaggregate data as available from the DelDOT Household Survey. The DelDOT Household Survey has data on over 40,000 trips over the last 7 years and includes a range of socioeconomic data about respondents. The survey captured the travel mode of each trip and the trip time from the respondent. Otherwise, nothing is known about the transit service for trips. For the purposes of modeling and better understanding travel mode choice, estimates of transit service level for surveyed trips were derived. Figure 2-1 shows the variables that were estimated.

Figure 2-1
Factors Estimated to Include Level of Service in Mode Choice Models

Type of service: Direct, Indirect, No service
Trips modeled as Walk
Trip distance
Trip time by car
Total transit time
Walk time to and from bus stops at origin and destination
Ratio of transit time to reported trip time

Addressing transit service for each trip and for each individual allows a much more accurate view of information for mode choice modeling.

Trip distance is also an important factor. Whenever trip distances become shorter, there are more walking and bicycle trips across all purposes and factors. The median walk trip distance estimated for the DelDOT household data is about 0.9 mile or less and the average bicycle distance is about a mile and a third. (As only the trip time was asked for in the DelDOT Survey, it was necessary to estimate trip distance and the estimates were least accurate for smaller trips. Actual average distances for walking and bike are expected to be a bit less.)

A factor used in many travel choice models is accessibility to transit. Often, analysts have estimated in various ways the percentage of persons that are within a particular walking distance from transit stops or other facilities. This will generally tell the number of people in aggregate that could use transit for a trip, however it usually does not take into account the destination of the trip or whether or not transit can effectively serve the trips that population wishes to make. Accessibility to the transit system was estimated in this project in terms of proximity to transit facilities but also in terms of the routes serving various destinations.

Development of a Road Network Model for Analyzing Service

Using geographical information systems and routing software, a road network model of New Castle County was developed for analyzing accessibility, travel time by personal vehicle, travel time by transit, and travel distance. The New Castle County Road Centerline file as maintained by and available through the New Castle County Department of Land Use was used as a starting point. The Centerline file has accurate representation of all roads in New Castle County (and municipalities) including highways, major and minor roads, and subdivision roads. The GIS software used was ARC/INFO from Environmental Systems Research Institute, and network modeling extensions to this software (NETWORK) for determination of optimum path through the road network from specified origin and destination points. An optimum path is determined based on the sum of impedances of the portions of roads or transit routes that make up the path. Impedance can be in terms of length along the roadway minimizing path length, or as a time associated with traversing each segment, or as any other cost or impedance function that is desired. For this project, three networks were used, one modeling transit routes and times, one for walking, and one for driving, each mode with different travel times (impedances) associated with each segment.

The transit network model was constructed by referencing GIS representations of transit routes from DART First State and from time schedules for each route. Time points available on the schedules were used to develop the time that transit took between each stop on each route. Representations of each route were then joined together to form the entire transit network. Connectivity between routes existed where routes shared the same stop allowing transfers to be modeled.

A walking network was developed allowing for travel time along road segments at three miles per hour. The walking network was then connected to the transit network.

Using ARC/INFO's Network module it is possible to find the minimum path through the network based on the impedances that have been defined. An important feature of the software that allows for the modeling to be done correctly is the ability to add a turn impedance. A turn impedance is an impedance associated with going from one segment to another, and it's primary use is to model intersections. For instance, it would take less time to make a right turn at an intersection with a yield sign than if one had to wait for a traffic light, or as another example there may be a situation where roads are connected but a particular turn is illegal so a turn impedance can be used to not allow path building that included the illegal turn. Turn tables were used in this project's model in two ways. During path building whenever the path went from a walk segment to a transit segment (a "turn" onto a transit segment), there was a 10 minute penalty as a way to account for waiting times and differences in headways. Leaving a transit segment to a walk segment did not involve a penalty. Going from a transit segment to another transit segment where the route designation is not the same is a transfer and a 10 minute transfer penalty was added to the path. Adding turn impedances then made sure that the paths that were determined by the computer did not unrealistically include numerous changes of route or getting off and on the bus routes without some penalty.

One other important adjustment had to be made. Since minimum path was calculated as that path with the minimum time, in some cases the computer would determine that it was quicker to take long walks (30 or 40 minutes or more) rather than take transit. As the purpose of the network modeling was primarily to develop a level of service for transit and the average walk trip was about 10 minutes, the impedances were inflated by a factor of 10 on the walking network to be able to determine a minimum transit path that involved less walking. Once the paths were determined, the walking portions of the trips were divided by 10 to get a realistic total trip time. There were still cases where trips were not served well or at all by transit but rather by a short or long (> 15 minutes) walk.

Trip origins and destinations were coded to the nearest modified grid (average size about 280 acres). Centroids of each modified grid were associated with the nearest point in the walking/transit network. On average, this positional uncertainty was estimated at plus or minus 5 minutes on the walk time to transit facilities. There might be extreme cases where a person could live right next to a bus stop and access times would be overestimated or the person could start from the furthest point away from the stop, underestimating the access time. Ideally, if an address were available, the origin and destination points could be specified very accurately.

With origins, destinations, and a walk and transit network specified, the optimum path algorithms can determine the least cost path, to minimize time for the trip. The best transit route is selected. Walking time to and from transit stops and transfers are well modeled and travelers do not enter the transit network at an arbitrary point in the transit network but rather to a place/route that best serves the trip. The optimum path can be displayed in the GIS, the transit route(s) involved in the trip are known, the access (walk) time are estimated, and the total transit time for the trip can be estimated.

Throughout the analysis several of the paths that were derived were checked and the path and travel times by transit appeared to be reasonable.

About 70% of the suburban transit market is served by Park & Ride facilities. A full picture of transit service must include service at Park & Ride facilities. The technique was first to develop a road network that would model drive time by personal vehicle to the Park and Rides. Then the driving distance to each Park and Ride and the estimated transit time on the transit network from the Park and Ride to the destination was calculated. The process determined the optimum Park and Ride to use to minimize total door to door travel time. Park and Rides are used predominantly for the journey to work, and it was not expected that someone would drive to a Park and Ride and leave their car to go on a shopping trip for instance. A total transit trip time using Park and Rides was only estimated for the journey to work.

The construction of the road network models to estimate transit service involved a great deal of effort, about 200 hours of technical staff time. Developing computer programs and testing to process 15,000 trips surveyed in New Castle County took about 80 hours of professional staff time. The process is very computer intensive. Running batch jobs day and night on very fast personal computers and University main frames to determine optimum paths and to process all of the information took about 150 hours.

Classifying Transit Service

The results of the travel network modeling were examined and categorized based on whether the service was direct, and transit time relative to estimated drive time of service as shown below in figures 2-2 and 2-3 where "T/D" is the ratio of estimated transit trip time to drive time.

Figure 2.2
Park and Ride Service Categories

"G": Good service, ratio of P&R trip time to drive time <=1.5
"B: Bad Service, ratio of P&R trip time to drive time 1.5 to 2.0
"N": Not served

Figure 2-3
Service Classifications for Fixed Transit
(T/D = ratio of estimated transit trip time to car drive time)

Class "D": Good direct service. Direct service and T/D <= 2, and/or transit trip time less than 35 minutes.
Class "DB": Not so good direct service. Direct service and T/D > 2
Class "DP": Good fixed service and good Park and Ride Service
Class "BP": Served good by Park and Ride but otherwise not so good service or not served
Class " I": Good indirect service. Indirect service and transit time <= 35 minutes
Class "IB": Not so good indirect service. Indirect and T/D > 2
Class "B": Bad service. (direct and T/D >=4) or indirect and T/D>=4
Class "N": Not served by transit.
Class "W": Trip modeled as a 15 minute or less walk, very bad or no transit service
Class "LW: Trip modeled as a long walk > 15 min, very bad or no transit service
Class "S": Origin and destination was the same modified grid. No path developed. Many of these trips turned out to be walk trips, none were transit.

Figures 2-4 below shows a view of these service classifications versus travel mode split. When a trip is estimated as having good transit service of some kind, transit share was 4% or more. Trips where origin and destination were the same modified grid showed the highest percentages of walking trips. Direct service included shorter trips that sometimes would be done by walking. As expected, bad service and no service saw as expected very low percentage of transit trips.

Figure 2-4
Mode Split Versus Service Quality
DelDOT Household Survey Data 1995-2001 for New Castle County

	D	DP	DB	BP	I	IB	B	N	S	W	LW
Personal auto	*87.1*	*93.4*	*96.5*	*97*	*90.2*	*97.3*	*88.6*	*98.6*	*81.3*	*91.5*	*100*
Public Bus	*4.7*	*6.6*	*2.3*	*2.9*	*5.6*	*1.4*	*0.9*		*0.3*		
Walked	*6.5*		*0.3*	*0.1*	*3.8*	*0.3*	*8.1*	*0.2*	*16.5*	*8.5*	
Bike	*0.6*		*0.8*			*0.1*	*0.7*		*1.1*		

As there is not a large amount of transit data the classification was narrowed to three categories, Good service (D,BP,DP), Low service (B,DB,I,IB), and No service. Collapsing the transit service categories provides a bit clearer first view as shown in the next three tables. Level of service does seem to be a factor for populations that have no car and for those who have a car in the household.

Figure 2-5
Mode Split Versus Service Quality, All Trips
DelDOT Household Survey Data 1995-2001 for New Castle County

	Good	Low	No	Samegrid	Walk	Lwalk
Personal auto	90.6	96.4	98.6	81.3	91.5	100
Public Bus	4.2	1.6		.3		
Walked	4.2	1.0	0.2	16.5	8.5	
Rode Bike	0.4	0.1		1.1		

Figure 2-6
Mode Split Versus Service Quality
Those from Zero Car Households
DelDOT Household Survey Data 1995-2001 for New Castle County

	Good	Low	No	Samegrid	Walk	Lwalk
Personal auto	35.5	54.2	97.4	20.0	0	
Public Bus	36.7	27.8		5.0		
Walked	24.9	13.9	2.6	60.0	100	
Rode Bike		0.7		12.5		

Figure 2-7
Mode Split Versus Service Quality
Those from One or More Car Households
DelDOT Household Survey Data 1995-2001 for New Castle County

	Good	Low	No	Samegrid	Walk	Lwalk
Personal auto	92.8	97.5	100	84.6	91.9	100
Public Bus	2.8	0.8		.3		
Walked	3.3	0.6	0.2	16.5	8.5	
Rode Bike	0.4	0.1		1.1		

Modeling Mode Choice

Introduction

Much of the research on the particular mode of travel a person chooses has relied on aggregate data. That is, the dependent variable tends to be the percentage of people in some spatial area that are using transit. The independent variables are also aggregations, e.g. average income or average number of vehicles. This means that the models do not really reflect individual behavior and in fact wash out much of the variation between travelers in the aggregation process.

The data used in this study allow the construction of models that are based on individual decisions. The individual observation is a trip made by an individual in Delaware. There are 14,617 un-weighted trips available for this analysis drawn exclusively from New Castle County. While data is available statewide, almost all transit trips are made in New Castle County.

The models presented here are drawn from the logistic regression family using a binary dependent variable at this stage. The three areas of interest are factors affecting transit trips (n=277), passenger trips (n=1436), and walking trips (n=320). The use of these three modes obviously pales in comparison with trips made as the driver of a vehicle (n=12450) and that influences the selection of the binary logistic regression instead of the multinomial approach.

The independent variables have already been addressed in this paper, but their specification for the model has not. With the exception of the trip length in time, all other variables are treated as categorical. For example, the age variable, which has 6 categories are treated as 6 different design variables coded 1 if a member of the category or 0 if not. The household income variable has 7 categories, and that includes separate categories for "refused" and "don't know". The time of day variable has 5 categories that were selected based on transit activity. These include "early morning", "morning peak", "midday", "afternoon peak", and "night". Two variables were included to capture activity in Wilmington's central business district. Trips that originate or have the CBD as a destination are captured through those two variables. The level of transit service available at the trip origin is a complex variable but is reduced to a single variable for the model. The included variable is coded 1 if there is good service and 0 otherwise. The final three variables included a variable that indicated a work trip, a variable that indicated the person was employed, and a variable that indicated if the household had a vehicle.

Transit Choice Model

The results for the transit model are found in Figure 3-1, below. The second column of the table contains the logistic regression coefficient. The standard error of the coefficient is found in the third column. In linear regression models, the significance of a particular variable is judged by the ratio of the coefficient to its standard error, which follows the t-distribution. In this case the Wald statistic (column 4), which is the square of that same ratio and is distributed chi-square with 1 degree of freedom is used. The significance of that test is shown in column 5. A factor can be significant but not have a strong influence. In this case a Wald statistic of about 15 or greater is considered to be a stronger factor. The last column, the exponentiation of the logistic regression coefficient, represents the odds ratio and that allows interpretation of the coefficient in probability terms.

The first four variables in the table relate to the time of day of the trip. They are all interpreted relative to an omitted variable TDNT or "night time". First, all four of the variables are significant which is hardly surprising since transit rides throughout the county fall rapidly after the afternoon peak. The largest difference is TDEM, "early morning" which is 663% (Exp(B) –1)*100) more likely to occur than a nighttime transit trip. It is interesting to see that the coefficients for afternoon peak (TDAP) and morning peak (TDMP) are very similar with a drop in the midday (TDMD).

The City of Wilmington has the most well developed transit network and also has a much more transit dependent population. In addition, more than 60,000 commuters enter the city each day to work. For that reason, the two variables that indicate whether a trip originated in the central business district (CBDO) or had as its destination the central business (CBDD) have two of the largest coefficients. People with trips originating in the CBD as measured by CBDO are nearly 740% more likely to choose transit as a mode than those outside the CBD. Similarly, those that have a destination in the CBD as measured by CBDD are 462% more likely to use transit than those with destinations outside the CBD.

The VEH factor indicating whether there are one or more vehicles available in the household is a very strong factor for transit choice. If the respondent had at least one vehicle in the household, they were 98% less likely to use transit than those that had no vehicles available. Obviously, the person without a vehicle has a more limited set of choices for making a trip.

The service variable (SERVG) that represents good service at the point of origin has a predictable positive sign and shows a 56% higher probability of a transit trip relative to no service or some restricted service category. Level of service expressed in these simple terms (good or bad/none) is significant though not the strongest factor in the model. In terms of the best model, the CBD factors and Vehicle factor very much dominate. The CBD has the highest level of transit service Transit service and SERVG would be a more influential variable (Wald statistics >30) if the CBD factors were removed, though the model overall would not be as good.

Figure 3-1
Factors Affecting the Selection of Transit

	B	S.E.	Wald	Sig.	Exp(B)
TDAP	1.409	.320	19.419	.000	4.090
TDEM	2.033	.355	32.745	.000	7.635
TDMD	1.111	.307	13.063	.000	3.037
TDMP	1.475	.324	20.738	.000	4.371
SERVG	.447	.150	8.848	.003	1.564
WORK	.573	.182	9.884	.002	1.773
EMP	-.413	.206	4.038	.044	.662
VEH	-3.769	.188	400.180	.000	.023
CBDO	2.128	.176	145.595	.000	8.396
CBDD	1.727	.174	99.010	.000	5.625
INC30K	.943	.320	8.663	.003	2.567
INC50K	.784	.281	7.755	.005	2.189
INC75K	-.467	.366	1.627	.202	.627
INC150K	.276	.313	.779	.378	1.318
INCRF	-.552	.325	2.894	.089	.576
INCDK	.843	.273	9.526	.002	2.324
AGE17	.954	.467	4.178	.041	2.597
AGE29	1.008	.367	7.554	.006	2.740
AGE49	1.093	.360	9.202	.002	2.983
AGE64	1.392	.363	14.715	.000	4.024
AGEUK	-5.698	7.302	.609	.435	.003
TRANTIME	-.008	.003	7.502	.006	.992
TTIMEUK	-2.799	.739	14.342	.000	.061
Constant	-3.572	.497	51.690	.000	.028

Source: Center for Applied Demography & Survey Research, University of Delaware

A person making a work trip (WORK) is 77% more likely to use transit than a person taking a trip for some other purpose. This is consistent with the overall use of transit as well. Employed persons are 34% less likely than people who are not working to make a trip by transit. Remember that work trips have been included separately. If only the employment variable is included, then employed persons are only 15% less likely to use transit for a trip than all other employment statuses.

The income design variables are measured relative to household incomes of under $20,000. The variable INC30K is the $20,000 to $30,000, etc. There are significant differences between those variables as measured against that omitted group. Persons from households with incomes under $50,000 designated by the variables INC30K and INC50K both show a positive relationship with the choice of transit when compared to the lowest income group. Both groups are more than 118% more likely to take transit. The results for the higher income groups INC75K and INC150K are not significantly different from the lowest income group with respect to transit use. These results are not unexpected. As incomes rise trips should increase. At the same time available alternatives to transit also increase.

Finally, a series of age design variables is included with the over 65 age group being the omitted group, against which each of the series are measured. All of the coefficients are positive except for the unknown age category, which is insignificant. Though the 65 and older age group uses transit less than all others, the probability of choosing transit increases with age.

The overall fit of the model as measured by the Hosmer-Lemeshow test is significant at the .011 level with a chi-square of 19.8 and 8 degrees of freedom. The Nagelkerke pseudo R-square was .391.

Walking

The second model developed examined the relationship between the selected factors and a dependent variable coded 1 if the person chose to walk and 0 otherwise. The results are found in Figure 3-2 on the next page.

This model has a much more compact specification that that for transit. The time of day variables are not included and neither is the employment variable. Instead of the transit time variable, the estimated trip distance variable TOTMILE has been substituted. The central business district variables are also not included.

The service variable (SERVG) that represents good service at the point of origin does have a significant effect on walking trips. One might find this surprising since transit would be a good substitute for walking. More likely this suggests that the person lives in a more urbanized environment where there are more destinations reachable by walking.

A person making a work trip (WORK) is more likely to walk than to use another mode of travel. However although the coefficient is significant, it is not particularly strong.

If the respondent had at least one vehicle in the household (VEH), they were 85% less likely to walk than those that had no vehicles available. A person without a vehicle has a more limited set of choices for making a trip. This is a very strong variable as it was for transit.

Figure 3-2
Factors Affecting the Choice to Walk

	B	S.E.	Wald	Sig.	Exp(B)
SERVG	.593	.128	21.575	.000	1.810
WORK	.373	.118	9.976	.002	1.451
VEH	-1.881	.174	116.265	.000	.152
INC30K	-.284	.270	1.104	.293	.753
INC50K	-.809	.215	14.170	.000	.445
INC75K	-1.333	.279	22.860	.000	.264
INC150K	-1.029	.278	13.660	.000	.357
INCRF	-.988	.239	17.107	.000	.372
INCDK	-.314	.193	2.647	.104	.730
AGE17	1.159	.294	15.566	.000	3.185
AGE29	1.049	.224	21.856	.000	2.855
AGE49	.201	.234	.738	.390	1.222
AGE64	.276	.255	1.170	.279	1.318
AGEUK	-7.797	15.871	.241	.623	.000
TOTMILE	-1.218	.064	360.602	.000	.296
Constant	.568	.261	4.725	.030	1.764

Source: Center for Applied Demography & Survey Research, University of Delaware

The income design variables are measured relative to household incomes of under $20,000. There are significant differences between those variables as measured against that omitted group. Persons from households with incomes over $30,000 designated by the variables INC50K, INC75K, INC150K all show a negative relationship with the choice of walking when compared to the lowest income group. Both groups are more than 40% less likely to take a walk. As incomes rise trips should increase. At the same time available alternatives also increase.

Finally, a series of age design variables is included with the over 65 age group being the omitted group, against which each of the series are measured. All of the coefficients are positive except for the unknown age category, which is insignificant. The probability of choosing to walk decreases with age relative to the omitted group. In fact there is a fairly significant drop off after the age of 30. Keep in mind that the effects of both income and having a vehicle have already been accounted for.

Finally, the effect of trip distance is both strong and negative. Each additional tenth of a mile reduces the probability of walking by .3%. While this seems small, only 2.2% of trips in the study were by walking. Thus, at .75 mile, the probability of walking falls to about zero.

The overall fit of the model as measured by the Hosmer-Lemeshow test is significant at the .000 level with a chi-square of 172.7 and 8 degrees of freedom. The Nagelkerke pseudo R-square was 43.6%.

Passengers

This model was the most difficult to specify since there are relatively few variables that are clearly related to the decision to make a trip as a passenger. Age is the most obvious choice but the other variables are more problematic. It was essentially modeled with the variables from the transit model with the exception of transit time, level of transit services, and the central business district variables.

The first four variables in the table relate to the time of day of the trip. They are all interpreted relative to an omitted variable TDNT or "night time". First, all four of the variables are strongly significant with Wald statistics over 19. All of the coefficients are negative which means that one is more likely to be a passenger in the evening hours. This would seem reasonable, since many if not most shopping trips and most social and entertainment trips are made after work hours.

A person making a work trip (WORK) is less likely to be a passenger than to use another mode of travel. Most work trips are made as the driver of the vehicle or with public transit. This finding is consistent with the fact that a person who is employed is also less likely to be a passenger. Both of these variables confirm the findings for time of day.

If the respondent had at least one vehicle in the household (VEH), they were 70% less likely to be a passenger than those that had no vehicles available. While a person can be a passenger in a motor vehicle of a person from outside the household they are more likely to be a passenger with another family member. This is a very strong variable as it was for transit and for walking.

The income variables, which are measured relative to a household income below $20,000, are marginally significant and are without strength as indicated by Wald statistics less than 11 for all but the undefined categories of INCDK and INCRF. This contrasts with the other two models that showed strong relationships within this set of variables.

The age variables, which are measured relative to 65 years old and up, exhibit an understandable pattern. The members of the 17 and under age group that make trips, are the most likely to be passengers and the relationship is strong. Those in the 30-49 age group are by far the least likely to be passengers although the negative relationship is not as strong as that for the youngest age groups positive relationship.

Figure 3-3
Factors Affecting the Selection of Passenger Mode

	B	S.E.	Wald	Sig.	Exp(B)
TDAP	-.418	.082	26.148	.000	.658
TDEM	-1.064	.181	34.392	.000	.345
TDMD	-.635	.066	91.968	.000	.530
TDMP	-.685	.089	59.0002	.000	.504
WORK	-.530	.072	54.503	.000	.588
EMP	-.697	.064	118.025	.000	2.133
VEH	-1.268	.132	91.620	.000	.281
INC30K	.403	.160	6.305	.012	1.496
INC50K	.343	.135	6.445	.011	1.409
INC75K	.301	.140	4.664	.031	1.352
INC150K	.202	.140	2.085	.149	1.224
INCRF	.521	.133	15.241	.000	1.683
INCDK	.704	.131	29.088	.000	2.022
AGE17	.501	.113	19.542	.000	1.650
AGE29	.257	.089	8.338	.004	1.293
AGE49	-.337	.091	13.814	.000	.714
AGE64	-.091	.095	.918	.338	.913
AGEUK	-1.789	.672	7.089	.008	.167
FEMALE	.757	.055	186.324	.000	2.133
Constant	-.757	.168	29.221	.000	.469

Source: Center for Applied Demography & Survey Research, University of Delaware

While gender (FEMALE) has not been a part of the model specification in the other two cases, this variable was introduced to see if women were more likely to be passengers. This is the case as indicated by a positive coefficient (.757) and a very strong relationship as indicated by the large Wald statistic. In general, women are more than twice as likely to be passengers than men.

The overall fit of the model as measured by the Hosmer-Lemeshow test is significant at the .012 level with a chi-square of 19.6 and 8 degrees of freedom. The Nagelkerke pseudo R-square was 13.7%. This model is considerably less robust than the transit and walking models. A better understanding as to the factors that go into this decision is needed. It may be that passenger trips are frequently incidental in nature i.e. ride-along and are not really a definitive mode. If this is in fact the case, there will be a tremendous amount of noise in the data.

Conclusions

Not having a vehicle is the most influential factor affecting the selection of transit. The next most important factor shown by modeling is where the trip originates or is destined for the Central Business District in Wilmington. Eighty five percent of the transit trips surveyed in the DelDOT Household Survey were trips to or from City of Wilmington zip codes. In the model constructed, level of service is significant though not the strongest factor in the model. The CBD and Wilmington in general have the highest level of transit service so there is certainly correlation between CBD and Service factors and in this type of model the influence shifts to the CBD factor rather than the good/bad service factor. When the CBD factors are removed, the service factor is shown as much more influential. In terms of modeling the CBD factors produce better models than service variables which would make sense considering the other features of Wilmington including parking costs and an urban environment.

A similar competition between factors is seen also with income and vehicle availability. When the vehicle availability factor is removed, income becomes a very influential factor (particularly low income) in the model. Vehicle availability from the models though is a more accurate predictor of transit use than income. It is not income that is the driving factor but the availability of a car (though there is a high correlation) .

A person making a work trip is 77% more likely to use transit than a person taking a trip for some other purpose. Early morning hours (5 to 7AM) see more transit trips than other times of the day. The probability of using transit increases with age up to the 65 and older category that uses transit less than any other age group.

Trip distance is the most influential factor affecting the selection of walking for a trip. Each additional tenth of a mile reduces the probability of walking by 0.3%. At ¾ of a mile the probability of walking falls to about zero. The probability of walking decreases with age, with a fairly significant drop off after the age of 30. As incomes rise the probability of walking decreases. The availability of direct transit service was an influential factor in walking trips which is thought to be a reflection of the urban environment and densities.

The model for travel as a passenger was significant but considerably less robust than the transit and walking models. A better understanding as to the factors that go into this decision is needed. Females are more than twice as likely to be passengers than men. Being a passenger is much more likely in the evening. Those 65 years and older are more likely to be passengers and the 30 to 49 year age group least likely. A person making a work trip is less likely to be a passenger. Not having a vehicle certainly increases the likelihood of being a passenger.

This project developed a methodology to quantify service for each trip by estimating trip times for each mode, and for transit whether service was direct or indirect. Accessibility to transit was estimated not just as the walking time to the nearest stop but to the stop that would best serve the intended destination. Network modeling predicted the optimum transit path. Transit time versus travel by personal auto and the type of transit service are thought of as important factors influencing travel mode choice as is indicated in the literature. The quality of service as measured in this project was a significant factor in mode choice models though overshadowed by the dominance of vehicle availability and trips to or from the Central Business District in the data. It was hope that a better indication of the effects of various levels of transit service for "choice riders" and to travel to other areas besides the CBD would be demonstrated, but the primary difficulty is always getting enough data to establish significant results. At a descriptive level, the importance of good service is indicated.

This project will form an adequate foundation for the next portion of the work involving the adaptation of mode choice models to models that can be used at the traffic zone level for travel demand forecasting.

Bibliography

A number of articles were reviewed, most of which involved models using aggregate data, such as income, population density, etc. Below are a view references to literature that has been specifically referenced or is particularly relevant.

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