DCT 183

# Estimating Current Modal Splits

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# Project Report for

# "Estimating Modal Splits"

**prepared for**

**Delaware Transportation Institute**

**and**

**The State of Delaware Department of Transportation**

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# Introduction

This project is the second part in a two part modeling effort. In previous work*, mode choice was modeled by examining characteristics of individuals and the trips they make. A study of the choices of individuals is necessary for a fundamental understanding of travel mode choice. Models were built to estimate mode split at the State and County level. 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. The modeling difficulty becomes greater as estimates of mode split are desired for smaller levels of geography, such as for a traffic zone, rather than a County.

For use in travel demand forecasting and examination of transit markets, almost all mode choice models used by transportation agencies 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. The reason for this is that aggregate data, such as provided by the U.S. Census, is typically more available. For the most part, estimates of travel mode split used in travel demand models are not very sophisticated and often consist of an estimate based on fixed percentage of trips (e.g. 1% of trips in a zone will be accomplished by using transit) rather than a model considering a number of factors.

This project investigates how travel mode split can be modeled using aggregate data at smaller levels of geography like traffic zones for use in route planning and travel demand forecasting. It starts with models based on individual data developed at the county level and investigates the applicability of these models at smaller levels of geography where aggregate estimates of the factors are available.

* Factors That Can Affect and/or Alter Mode Choice, David Racca, Delaware Transportation Institute, March 2004

# 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**
**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 (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.

**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.

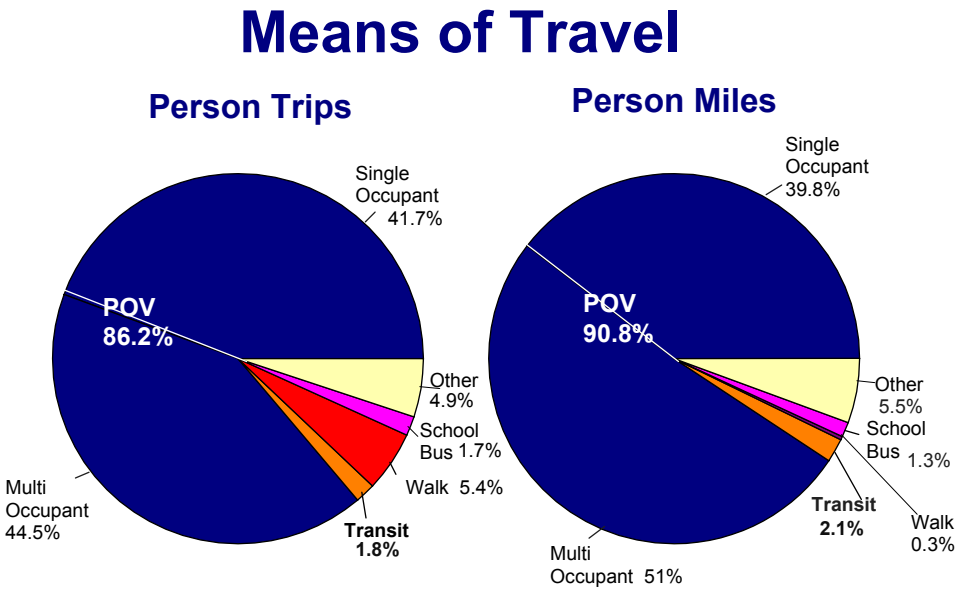
As part of a first look at appropriate factors for mode choice modeling, several descriptive views from the DelDOT Household Survey and other sources were compiled and are presented in the rest of this chapter.

**Mode Split**

Figure 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.

**FIGURE 2**




Walk accounts for 5% of trips, but less than 1% of miles. Air travel accounts for less than 1% of trips, but 3% of miles.

**Source: 1995 Nationwide Personal Transportation Survey**

The DelDOT Household Survey provides a view of mode split over the last seven years as shown in Figure 3 below.

**Figure 3**
**Travel Mode Share(%)**

**Weekday travel, age sixteen years and older**

| Mode | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Total |
|---|---|---|---|---|---|---|---|---|
| **Auto** | 94.7 | 95.5 | 96.6 | 96.5 | 97 | 94.5 | 95.8 | 96.0 |
| **Public Bus** | 1.0 | 1.2 | 0.9 | 1.1 | 1.1 | 1.4 | 1.2 | 1.1 |
| **Walked** | 1.4 | 1.8 | 1.6 | 1.4 | 0.9 | 2.5 | 1.8 | 1.6 |
| **School Bus** | 2.6 | 0.7 | 0.4 | 0.4 | 0.4 | 1.2 | 0.7 | 0.7 |
| **Bike** | 0.2 | 0.3 | 0.1 | 0.1 | 0.2 | 0.3 | 0.2 | 0.2 |
| **Other** | 0.2 | 0.5 | 0.3 | 0.4 | 0.3 | 0.1 | 0.3 | 0.3 |

**Source: DelDOT Household Survey**

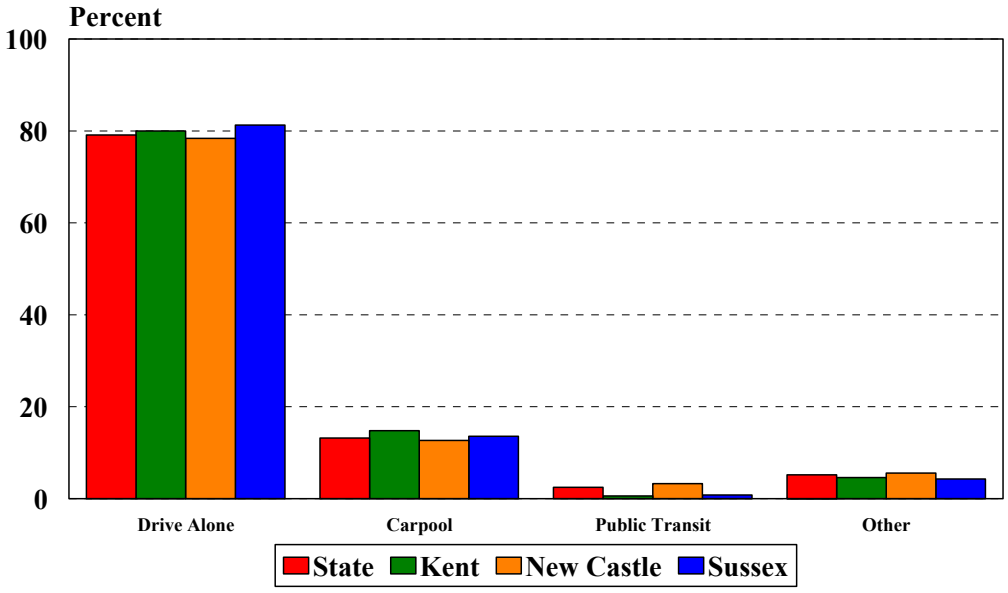
There is also data about travel mode split data that is available for the Journey to Work as tracked by the Census Bureau. Figures 4 and 5 below show year 1990 figures for Delaware.

**Figure 4**
**Employees by Travel Mode**
**State of Delaware - 1990**

| Travel Mode | State | Percent | Kent | Percent | New Castle | Percent | Sussex | Percent |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Drive Alone | 258,087 | 79.1 | 42,492 | 80.0 | 175,198 | 78.4 | 40,397 | 81.3 |
| Carpool | 42,968 | 13.2 | 7,881 | 14.8 | 28,370 | 12.7 | 6,717 | 13.6 |
| Public Transit | 8,069 | 2.5 | 329 | 0.6 | 7,327 | 3.3 | 413 | 0.8 |
| Other | 17,022 | 5.2 | 2,442 | 4.6 | 12,436 | 5.6 | 2,144 | 4.3 |
| Work at Home | 7,980 | | 1,553 | | 4,313 | | 2,114 | |

**Source: Center for Applied Demography and Survey Research, University of Delaware**
**US Bureau of Census**

**Figure 5**
**Percent of Employees by Travel Mode**
**State of Delaware - 1990**




**Source: Center for Applied Demography and Survey Research, University of Delaware**
**US Bureau of Census, 1990 Census Transportation Planning Package**

**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 6 and 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.

**Figure 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 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 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 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 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 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 10 below presents mode split by purpose for Delaware trips.

**Figure 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 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 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 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 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 14 below.

**Figure 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 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 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 17 below by ethnicity, and focusing on this one factor of ethnicity one might think that ethnicity was a factor in mode split.

**Figure 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 as a driver in the 65 years and older category.

**Figure 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 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 |

**Transit Service Level Factors**

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. In previous modeling work variables as shown in figure 26 below were estimated. In that case however, the origin and destination and other characteristics of the trip were known.

**Figure 26**
**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

In previous work where specific trips were identified a method was developed to estimate the factors in figure 26 on the previous page. Based on those estimates classifications of the level of service were developed as in figure 27 below.

**Figure 27**
**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 28 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 28**
**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 29**
**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 30**
**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 31**
**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 | | |

**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)

Level of transit service and trip distance definitely influence mode split.

## MODE SPLIT MODELS AT THE COUNTY AND STATE LEVEL

In a previous Delaware Center for Transportation study entitled "Factors That Can Affect And/Or Alter Mode Choice, models were developed for Delaware that could best predict mode choice ( car, transit, walking, carpool) at a county and State level. Many factors were examined including:

- Age
- Employment status
- Gender
- Ethnicity
- Number of vehicles in the household
- Household income
- Level of transit service
- Trip method
- Type of area (urban, suburban, rural, density
- Travel to the central business district

Models for mode split were created from the DelDOT Trip Monitoring System Survey (DTMS) data. Since 1995 with this 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 data collected is on an individual basis. Factors associated with the individual and the trips taken are used in models to predict the mode of travel that will be used.

The conclusions of the modeling work done at the State and County level follow:

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 the City of 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. 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.

The previous 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 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 hoped 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 was indicated.

**Figure 32, Summary of Variables Used In Mode Choice Model**

TDAP – Time of day is afternoon peak
TDMD – Time of day is midday
TDEM – Time of day is early morning before morning peak
TDMP – Time of day is morning peak
TDNT – Time of day night (missing variable, others relative to this)
SERVG – Good Transit Service (Direct service route, Good park and ride service, or total transit trip time less than 35 minutes)
WORK – Trip is a work trip
EMP – Individual is employed
VEH – One or more vehicles available in the household
CBDO – Origin is the central business district
CBDD – Destination is the central business district
INCLT30K – Household Income less than $30K (missing variable, others relative to this)
INC30K – HH Income $20,000 to $30,000
INC50K – HH Income $30,000 to $75,000
INC75K – HH Income $75,000 to $150,000
INC150K – HH Income greater than $150,000
INCRF – HH Income refused
INCDK – HH Income don't know
AGE17 – Age 16 to 17
AGE29 – Age 18 to Age 29
AGE49 – Age 30 to Age 49
AGE64 – Age 50 to Age 64
AGE65 – Age 65 or greater, (missing variable, others relative to this)
AGEDK – Age don't know.
TRANTIME – Ratio of transit trip time to drive time
TTIMEUK – Missing, unknown, or not computable transit time

**Figure 33**
**Individual Based Model For Transit Choice**

| | 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

# ESTIMATING MODE CHOICE USING AGGREGATE DATA

The investigation of factors that affect mode choice and the establishment of models at the county and State level were the first steps toward developing a predictive tool. The next effort was how travel mode split can be modeled at smaller levels of geography (such as at the traffic zone level) for use in planning and travel demand forecasting. Travel demand forecasting requires data at a more detailed level and a big difference is that instead of modeling the behavior of individuals as was done in the first part of the research, the form of the information is aggregate data at the traffic zone level. To be more useful, any mode choice model created would have to include factors that could be generated at the aggregate level of a traffic zone or other demographic unit below the level of county.

## Approach

In the models previously generated the leading factors were:

- purpose of trip (work /nonwork)
- number of vehicles
- destination or origin to the Central Business District (CBD)
- transit level of service, either Direct-Indirect-NoService or the transit time to drive time ratio
- income, (a strong factor but left out of models that used number of vehicles instead)

The approach was to use these same factors at the aggregate level as percentages for a smaller unit of geography than the county level. Two data sources for Delaware are available for this analysis, the DelDOT Trip Monitoring System Survey (DTMS) data and the U.S. Bureau of the Census, Census Transportation Planning Package (CTPP) data from the year 2000. The DTMS data is a sampling of individuals across Delaware for all types of trip purposes (i.e. work, shopping, school etc). The CTPP data is only available for the journey to work as tabulated from the Census 14% sample (the long form).

The trip mode variable in its aggregate form becomes the percentage of trips in the zone or census tract that are done by transit. The number of vehicles factor becomes the percentage of trips from people who had zero trips. The CBD destination factor becomes the percentage of trips that are to the CBD. The income variable could be the mean household income of the traffic zone or tract.

When the percentage of trips that would be accomplished using transit for a small geographic unit like a traffic zone is considered, a transit service factor is desired but it has to be aggregate in form as well and a property of the zone. Examples would be “the percentage of trips in the zone where direct transit service is available” or “the mean trip distance of trips from the zone”. What is commonly done in travel demand forecasting models is to determine whether a zone is adjacent to a bus stop(s) or to estimate the

percentage of households in the zone that are within a quarter mile to a bus stop. While this is certainly an indication of some type of transit service at the origin of a trip, it says nothing about whether destinations are actually served by transit or the difficulty that a transit route might present in comparison to using a personal vehicle. The service factor chosen for use in this modeling effort is the mean estimated ratio of the transit trip time to drive time for trips in the zone or tract. From previous research the relative trip time between the transit and personal auto modes would seem to be the most important level of service factor. It is a competition in terms of time. The reported trip times in the data available are expected to be door to door times that factor in proximity to transit entry points and wait times. Certainly hours and frequency of service, perceived safety, and other level of transit service factors have an effect but these are extremely difficult to estimate and are considered secondary. For a person who is not dependent on transit the first consideration is whether the trip would be practical in terms of travel time.

Data from the Delaware Trip Monitoring System (DTMS) and from the U.S. Bureau of the Census- Census Transportation Planning Package (CTPP) data were prepared with the variables shown in figure 34

**Figure 34 Variables used in aggregate models**

pertran - percentage trips that are transit, all trip types.
percbd - percentage of trips to the CBD
perzero - percentage of workers who made work trips and had zero vehicles
perwork - percentage of trips that were work trips
tran2dr - mean estimated ratio transit trip time to drive time for trips in the tract

In phase one of this research, the relationship between personal characteristics and the choice of transit was established. This analysis used individuals as the unit of analysis and included everyone interviewed in New Castle County over the past five years. The objective of the current research is to establish whether or not similar models can predict the mode split in disaggregated spatial areas in the county and using aggregated data rather than individual results.

DelDOT does its transportation planning using transportation analysis zones. That planning utilizes aggregated measures such as average household size, average household income, and average number of vehicles available, among others, to generate the number of trips likely to be produced from that zone. Transit trips are then estimated using a fixed fraction of that estimated total. If this research is successful, it should be possible to significantly improve the quality of the transit estimates. In addition, the results should improve the confidence in the behavioral model produced in the first phase.

The data used in the trip generation models presented here are derived from the Delaware Trip Monitoring System (DTMS). The DTMS measures trip activity for a random set of

individuals throughout the State of Delaware. For this effort, 17,604 respondents were included in the study. The data were drawn from surveys conducted 1995-2003.

The data includes information on the respondent, the respondent's household, and the trip activity. The modeling deals with individuals rather than households as is common for many trip studies that use household diaries. The focus is on individual behavior as opposed to household behavior. At the root, individuals make trips not households. However, individual behavior is influenced by the environment in which they live. If there is another adult in the household, the possibility for trip sharing/splitting exists in contrast with a single person household. Children in the household also have an impact on the number of trips required of an individual. One of the key variables affecting trip generation is the number of vehicles. The absence of a vehicle or even a single vehicle when it's shared among adults reduces the trip possibilities. Labor market activity has an immediate impact since work trips are going to be required. Higher incomes to some extent open the possibilities for more trips, more dining out for example or trips to the ball park.

The data from the Census Transportation Planning Package (CTPP) is aggregate data built from a sample of the 2000 Census participants. It involves only journey to work information and the information is aggregated to the census tract of the origin with reference to the census tract of the destination.

This research focuses on work trips for two reasons. First, work trips are the focal point during peak use of the roadways. Clearly a reduction in work trips creates capacity on the network. Second, work trip data are available from both DTMS and from CTPP by sub-county spatial areas. Thus, the basic models can be validated with independent data.

The structure of the presentation which follows includes a description of the model and its components, results from a base and extended model using the DTMS data, and presentation of the results using the CTPP data. The presentation concludes with a discussion of the policy and planning implications of these results as well as some suggestions for future research.

The dependent variable for all of these models is the percentage of work trips that are taken within each of the 127 census tract in New Castle County . Seventy eight tracts had a positive percentage and those values ranged from 1% to 22%. The median value including 0% was 2%.

In the earlier analysis using individual observations, one of the key independent variables was having a destination of the Wilmington central business district. This certainly makes a great deal of sense given the layout of the transit system in New Castle County. In this model, the variable is formed by determining the percentage of work trips in the census tract. Only eight of the 127 census tracts were without a work trip to the Wilmington CBD. Those with positive values ranged from 1% to 23% and the median value was 7%.

The second most important variable in the phase one analysis was the availability of a vehicle. Obviously a person who does not have access to a vehicle is more likely to use transit. Almost half of the census tracts (65) have at least one person who is without a vehicle and is taking a work trip. The positive values range from 1% to 40% and the median value is 1%.

Figure 35 below contains the coefficients for the most compact form of the model where percwcbd is the percentage with the CBD as a destination, and percwnoveh is the percentage of the population with no vehicle.

**Figure 35, Coefficients of Aggragate Model Using CBD and No Vehicle Variables**

| | B | Std. Error | Beta | t-statistic | Significance |
|---|---|---|---|---|---|
| Constant | .001 | .004 | | .246 | .806 |
| Percwcbd | .168 | .044 | .193 | 3.844 | .000 |
| percwnoveh | .52 | .037 | .742 | 13.983 | .000 |

R-square = .682 F(2,123)=132.077 Significance .000

First of all, this simple model explains 67.3% of the variance of the dependent variable. (The relative high value of R-square is attributable to the fact that this is aggregated data as opposed to individual data.) The equation is statistically significant as is indicated by the significance of the F-statistic. An examination of the variance inflation factors and the eigen values of the matrix show no evidence of collinearity that would threaten the interpretation of the equation. An analysis of the residuals shows no major departure from normality although the distribution is shifted slightly to the left of zero.

The coefficient of .168 on the variable indicating the percentage heading to the Wilmington CBD is significant. The coefficient suggests that over the range of the variable (0% to 23%) the percentage taking transit can move at most by 3.9%. This may seem small however it is significant if one considers the fact that only 2.6% in the sample are taking transit to work. At the median (7%), transit use is increased by 1% by this variable.

The coefficient on the second variable, percent with no vehicle available, is also statistically significant. The coefficient suggests that over the range of the variable (1% to 40%) the percentage taking transit can move at most by 20.8%. It is substantively significant if one considers the fact that only 2.6% in the sample are taking transit to work. At the median (1%), transit use is increased by .5% by this variable.

This compact model, which will be used to compare with another data source, was extended to include a few additional variables that played a role in the person based

model. These new variables include the percentage of people with incomes below the median income in Delaware, the percentage of adults in the census tract who were employed, and the ratio of trip time by transit to trip time by automobile. The results are found in Figure 36, below.

**Figure 36, Coefficients of Aggregate Model Using CBD, No Vehicles, Income, Employment, and Service Variables**

| | B | Std. Error | Beta | t-statistic | Significance |
|---|---|---|---|---|---|
| Constant | .001 | .022 | | 1.901 | .060 |
| Percwcbd | .166 | .042 | .202 | 3.927 | .000 |
| percwnoveh | .480 | .041 | .686 | 11.812 | .000 |
| Incomelt50k | .031 | .018 | .098 | 1.741 | .084 |
| Employed | -.042 | .023 | -.094 | -1.828 | .070 |
| Service | -.006 | .003 | -.082 | -1.639 | .104 |

R-Square = .711 F(5,120)=59.046 Significance .000

The introduction of the three new variables, namely income, employment, and service level predictably lowered the magnitude of both variables in the compact model. The reduction in the size of those coefficients is minimal and does not alter their statistical significance or substantive significance and the earlier interpretation.

The three new variables are all marginally significant at the .10 level. The income variable has the proper sign, positive, and indicates that a household in the lower half of the household income distribution are more likely to use transit, holding other variables constant. This is consistent with the model developed with disaggregated data. The range of this variable is from 7% to 100% thus it can shift the percent using transit by up to 2.8%. At the mean, this variable makes a positive contribution of about 1%.

The second variable, percentage of people working in the census tract, has a negative sign which is also consistent with the disaggregated model. In general one would expect the percentage taking transit to decrease because substitutes i.e. carpooling and riding with another family member are more available. This variable varies between 34% and 87%. At the most it could shift the percent riding transit by a negative 2.2% as the variable increases from its lowest value to its highest. At the mean it contributes a negative 2.9% to the percent riding transit.

The service variable, the ratio of transit time and automobile time, is also negative as it was in the disaggregated model. As the penalty (time) for riding transit increases, individuals will choose other modes and the percent using transit will fall. Service varies between 2.3 and 6.73 with a mean of 3.59. The variable can shift the percentage using transit by -2.7% over its range and contributes a negative 2.2% at the mean.

Some might be tempted to exclude the three variables added at this stage since their significance falls below the traditional acceptance level of .05. However, based on the

results from the individual model, this model would be considered mis-specified, i.e. variables with an expected relationship have been omitted. The omission of variables with potential influence on the dependent variable and potential correlation with included variables can bias the coefficients of the included variables either positively or negatively. This can be understood better by observing the changes in the coefficients in the simple model with the more robust equation. From a predictive standpoint however, it matters little whether we include or exclude them.

Replication generally serves to strengthen confidence in the results of any research. In this case, the 2000 Census provides data that can help corroborate the findings from the DTMS aggregate data set. In the long form for the 2000 Census (15% sample), respondents were asked to provide a specific location for their place of work. The Bureau of the Census in preparing the CTPP product coded these locations to the census tract in Delaware. There are 127 census tracts that cover New Castle County although only 126 contain housing units. All 126 tracts contained at least one work trip by transit. This is substantially larger than the 78 tracts in the DTMS data that had at least one work trip by transit. However, the median value for percent using transit was about 2% for both samples. The median percentage going to the CBD was somewhat higher for the DTMS data (7%) compared with 4% for the CTPP data. The reverse held for percentage with no vehicle where the median was 1% for the DTMS sample and 3% for the CTPP data. Figure 37 below contains the coefficients for the CTPP census tract form of the model.

**Figure 37 CTPP Transit Model Using CBD and No Vehicle**

| | B | Std. Error | Beta | t-statistic | Significance |
|---|---|---|---|---|---|
| Constant | -.006 | .009 | | -.663 | .508 |
| To-CBD | .321 | .126 | .132 | 2.544 | .000 |
| No vehicle | .565 | .043 | .761 | 12.995 | .000 |
| Walk | .063 | .056 | .058 | 1.135 | .259 |
| Carpool | .068 | .061 | .052 | 1.116 | .267 |

R-square = .780 F(4,121)=113.980 Significance .000

Both variables that were the principal drivers in the DTMS models, namely percentage going to the CBD and the percentage with no vehicle in the household, are also significant in the CTPP tract model. The coefficients are of the same relative magnitude and are not significantly different from those observed in the DTMS sample. Two variables intended to account for the ability to walk to work or to carpool were not significant in this model.

Deldot made the decision to use census block groups as a surrogate for the traffic analysis zones in generating the CTPP data. This offers the opportunity to compare the results at a more disaggregated level than census tracts. There are 347 census block groups in New Castle County in comparison to 126 census tracts. To the extent that higher levels of

aggregation reduce the amount of variance in the data, it is possible that the models may differ. Figure 38 below contains the coefficients for the census block group form of the mode

**Figure 38, CTPP Transit Model At the Census Block Group Level**

| | B | Std. Error | Beta | t-statistic | Significance |
|---|---|---|---|---|---|
| Constant | -.001 | .006 | | -.153 | .878 |
| To-CBD | .171 | .036 | .190 | 4.733 | .000 |
| No vehicle | .495 | .034 | .653 | 14.648 | .000 |
| Walk | -.050 | .046 | -.044 | -1.069 | .286 |
| Carpool | .012 | .036 | .013 | .348 | .728 |

R-square = .535 F(4,342)=98.368 Significance .000

The results from this more disaggregated model are consistent with both the earlier DTMS model and the census tract version of the CTPP model. While the size of the CBD coefficient was reduced somewhat, its standard error was also significantly reduced, yielding a more precise result.

These results derived from different data sets and using two levels of data aggregation give some confidence that it is reasonable to forecast the mode split for transit use at sub-areas of the county.

The most logical sub-area to use for forecasting the percentage of work trips is the traffic analysis zone. First, projections of population and housing are produced at regular intervals for the TAZ's. Second, the DTMS data is collected annually and can be aggregated as needed to produce estimates for the percentage of households without cars and the percentage going to the CBD. Third, Deldot's traffic model also produces work trip rates by TAZ's on a regular basis. Using all or some combination of this dataset, estimates of work trips by transit can be generated as needed.

# 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.

Ben-Akiva, M. and Bierlaire, M. (1999), *Discrete choice methods and their applications to short-term travel decisions*, in R.Hall, Handbook of Transportation Science, International Series in Operations Research and Management Science, Vol 23 Kluwer.
(A good presentation of travel behavior modeling.)

Nerhagen, Lena, February 2000, Mode Choice Behavior, *Travel Mode Choice Models and Value of Time Estimation – A Literature Review*, T&S Dalarna University, Borlange.
(A very good literature review particularly addressing past research and theories about how travel choices are made by individuals)

Polzin, Steven, Xuehao, Chu, Rey, Joel R., *Mobility and Mode Choice of People of Color for Non-Work Travel*, Center for Urban Transportation Research, University of South Florida.

Purvis, Charles L., June 1997, *Travel Demand Models for the San Francisco Bay Area (BAYCAST-90),* Metropolitan Transportation Commission, Oakland, California.
(Traditional travel demand modeling application)

Zhao, Fang, Gan, Albert, Min-Tang Li, Shen, L. David, July 2002, *FSUTMS Mode Choice Modeling: Factors Affecting Transit Use and Access,* National Center for Transit Research, University of South Florida, Tampa, Florida.
(This is a substantial modeling effort using aggregate data that includes a comprehensive literature review and numerous references)

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