# INNOVATIVE APPROACH TO ESTIMATING DEMAND FOR INTERCITY BUS SERVICES IN A RURAL ENVIRONMENT

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Innovative Approach to Estimating Demand for Intercity Bus Services in a Rural Environment

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

**DOCTOR OF PHILOSOPHY**

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# ABSTRACT

Because existing models have their limitations, there is a significant need for a model to estimate demand for intercity bus services, especially in rural areas. The general objective of this research was to develop an intercity mode choice model that can be incorporated into a statewide travel demand model to estimate demand for rural intercity bus services. Four intercity transportation modes were considered in the study: automobile, bus, rail, and air. A stated preference survey was conducted of individuals across the state of North Dakota, and a mixed logit model was developed to estimate a mode choice model. Results from the mode choice model showed the significant impacts of individual, trip, and mode characteristics on choice of mode. Gender, age, income, disability, trip purpose, party size, travel time, travel cost, and access distance were all found to have significant impacts on mode choice, and traveler attitudes were also found to be important. The study demonstrated how the mode choice model can be incorporated into a statewide travel demand model, and intercity bus mode shares were estimated for origin-destination pairs within the state. Alternative scenarios were analyzed to show how mode shares would change under different conditions or service characteristics. This study was conducted in the largely rural state of North Dakota, but results could be transferable to other areas with similar geographic characteristics.

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# 1. INTRODUCTION

A significant need exists for a model to estimate demand for intercity bus services, especially in rural areas. Many states and rural operators are unsure about the potential demand for rural intercity bus service, and many existing models are unreliable due to poor data (Fravel et al. 2011). Numerous types of intercity demand models have been estimated over the past few decades, but these models have their limitations, and intercity modeling remains less developed than urban travel demand modeling.

To address the need for rural intercity bus demand modeling, a TCRP project by Fravel et al. (2011) developed a sketch-planning guide that could be used by state transportation department program managers and both public and private rural intercity bus service providers to forecast demand for rural intercity bus services. The route-level modeling techniques used in this TCRP report provide a useful tool for estimating ridership on rural intercity routes, but it has some limitations. It does not account for through passengers using the service, and it is not sensitive to changes in fares or frequency.

Many previous demand models are route-level, corridor-level, or city-pair models. While these models can be useful, they ignore the effects of existing within a larger network, and they rely on aggregate data. Disaggregate data, or data at the level of the individual or household, can be more useful in developing travel demand models (Koppelman and Hirsch 1986). Intercity mode choice models have been developed using disaggregate data, but there are many variables that could influence mode choice which are often not included in these models.

Demand for intercity transit services can be estimated within the framework of a statewide intercity travel demand model that has a mode choice component. A number of states have operational statewide travel demand models, but they are often rudimentary or lacking in necessary detail. Many are partial models or focus on freight. Miller (2004) argued that many passenger models do not pay sufficient attention to access and egress when estimating mode choice splits. Access and egress refer to the distance to and from the long-distance mode at either end of the trip.

Previous research by Mattson et al. (2010a,b) estimated a mode choice model for regional intercity travel for residents of North Dakota and western Minnesota. The study used a stated preference survey and a multinomial logit model to estimate the impacts of mode characteristics, including travel time, cost, and frequency, and individual characteristics, including age, income, etc., as well as trip characteristics, including distance and trip purpose, on choice of mode. The model did not consider issues of access and egress but assumed respondents had easy access to each of the modes. In reality, of course, many travelers in rural areas need to travel considerable distance to reach a transit station. Information is needed on how far travelers are willing to drive to a bus station. Adding stops along a route would increase the number of potential users with access to the service, but it could also have a negative impact on ridership as it increases travel time on the route. The impacts of both of these factors need to be considered.

### 1.1. Research Objectives

The general objective of this research is to develop an intercity mode choice model that can be incorporated into a statewide travel demand model to estimate demand for rural intercity bus services. Four intercity transportation modes are considered in the study: automobile, bus, rail, and air. Specific objectives are to:

- Estimate impacts of mode characteristics, such as cost, in-vehicle travel time, access and egress times, and service frequency on intercity mode shares.
- Estimate impacts of individual characteristics, such as age, income, gender, and disability on intercity mode shares.
- Estimate impacts of trip characteristics, such as travel distance, trip purpose, and party size on intercity mode shares.
- Estimate impacts of attitudes on intercity mode shares.
- Examine changes in attitudes regarding intercity travel.

- Develop a mode choice model that can be incorporated into a North Dakota statewide travel demand model to estimate demand for intercity bus services.
- Conduct scenario analysis to estimate the effects of possible service changes or other changes.

This study develops a mode choice model that can be used to estimate the percentage of trips used by each mode for each origin-destination (O-D) pair throughout the state of North Dakota given the current intercity transit network and hypothetical changes to the network. This model is developed so that it can be incorporated into a statewide travel demand model under development. The number of trips by each mode between each O-D pair could then be estimated using results from the mode choice model, with data for travel time by each mode and access and egress times for rail and bus.

Mode shares are first estimated using current conditions, including demographic data, gasoline prices, and service conditions. Then additional scenarios are run under different mode characteristics. The model can be used to estimate the demand for potential new transit services, new transit stops, reduced travel time, or other service changes, as well as impacts from demographic changes or changes in competing modes such as rising gasoline prices.

### 1.2. Organization

Previous research on intercity bus demand modeling is presented in Section 2. This includes a discussion of basic and modified gravity models; route-level, corridor-level, and city-pair models; mode choice models; statewide travel demand models; and other approaches. This study employs a mode choice model estimated with a mixed logit model using data collected from a statewide stated preference survey. The methodology and development of the survey are detailed in Section 3. Survey results are presented in Section 4. In Section 5, the final mode choice model specification is described. Results are provided in Section 6. Section 7 details how the mode choice model can be incorporated into a statewide travel demand model, and shows estimated mode shares for intercity bus within the state. This section also includes a series of alternative scenarios showing how mode shares would change under different conditions or service characteristics. The final section provides a summary, a discussion of implications and limitations, and conclusions.

# 2. LITERATURE REVIEW

Most previous research on intercity bus demand consists of corridor or route studies and mode choice studies. Researchers began developing intercity corridor models in the 1960s, motivated largely by a need to evaluate investment alternatives for improving travel in the northeast corridor (Washington-New York-Boston). These models have evolved, and different approaches for studying intercity passenger travel have emerged, but these models lack the complexity of urban travel demand models (Miller 2004).

## 2.1. Basic Structure of Existing Models

As Fravel et al. (2011) explained, intercity demand studies often start with the basic gravity model, which generally states that demand for travel between two places is proportional to the populations and inversely proportional to the distance between them. This relationship can generally be formulated as the population of one urban area times the population of the second, divided by the distance between them squared. The simplest gravity models use city population to measure attractiveness and distance as the measure of impedance. Some basic gravity models also include income. Modified gravity models include measures of impedance such as travel time, travel cost, service frequency, and generalized cost of travel, as well as a more extensive list of city attractiveness variables.

### 2.1.1. Major ridership generators

Studies of intercity bus demand need to go beyond the simple gravity model to include places that are potential attractors of intercity bus ridership. Previous studies have included colleges and universities, major military bases, hospitals and major medical facilities, regional correctional facilities, recreation areas, and major intermodal connections at airports as facilities that would attract ridership (Utah Department of Transportation 2010, KFH Group 2003, Yang and Cherry 2012). Yao and Morikawa (2005) calculated attractiveness using factors such as number of headquarters, number of international conferences, and other business-relevant factors for business trips. For non-business travel, they used factors capturing suitability for leisure activities, such as number of resorts, sport centers, museums, cinemas, shopping centers, etc.

### 2.1.2. Characteristics of population

The demand model can be revised to account for both total population served as well as the characteristics of that population. Studies have shown that certain populations have a greater likelihood of using intercity bus services (Yang and Cherry 2012; KFH Group 2001, 2003; Fravel et al. 2011, Al-Sahili and Sadeq 2003, Kack et al. 2011, Sperry et al. 2014). These populations may include older adults, youth (aged 18-24), low-income persons, people with mobility limitations, and people without access to an automobile. In a survey of intercity bus riders in Montana, Kack et al. (2011) found the 18-24 age group most likely to use the bus, and half of all respondents were from a household with income of less than $15,000 per year. Sperry et al. (2014) found similar results in a survey of intercity bus riders in Michigan.

## 2.2. Route, Corridor, and City-Pair Models

Many previous studies estimate ridership along a route or corridor or between two cities. Fravel et al. (2011) discussed demand models for boardings at a stop, route-level demand models, and city-pair demand models. A demand model for boardings at each stop, or a point demand model, could be estimated as a function of population and demographic data for the bus stop location and characteristics of the service. This demand model uses demographic and service data to estimate the number of persons boarding at a particular stop, similar to models estimated by KFH Group (2001, 2003). Such a model would require data on boardings or ticket sales from intercity bus carriers, service data (e.g., frequency, fares) from the intercity bus carriers, and population and demographic data from the Census.

A route-level demand model is a similar model that could be used when there are several stops along a route that generate ridership. Calibrating such a model would require ridership for the entire route or route segments, fare and frequency data, and demographic data. Both the point demand model and the route-level demand model lack the ability to estimate potential overhead traffic. A city-pair demand model can be used to estimate ridership between a particular pair of cities. Many previous studies, including most of those reviewed by Koppelman et al. (1984), used city-pair demand models.

### 2.2.1. Overview of early research efforts

Koppelman et al. (1984) reviewed the development of intercity passenger demand models from the 1960s through the early 1980s. Many of these models were corridor models using aggregate travel data. They described five groups of aggregate corridor models developed during this period: direct origin-destination (O-D) mode volume models, total O-D volume (all modes) models, mode share models, sequential models of total intercity demand and mode share, and direct demand models for a single intercity mode.

The direct O-D mode volume models predict travel demand for each O-D pair separately for each mode using one or a set of equations. These models use variables to describe the city pair, including population, per capita income, and employment, and variables to describe the modes, including travel time, travel cost, and service frequency. According to Koppelman et al. (1984), these models made a number of contributions but contain a number of weaknesses, such as the exclusion of a number of important travel service variables (e.g., comfort, convenience, reliability, safety), inadequate representation of population distribution characteristics (e.g., income segmentation), lack of access times and costs to intercity terminals, no clear basis to define market area for the city or terminal, and other failings.

The total O-D volume models estimate total demand between city pairs using a single equation with a gravity-type formulation. These models do not predict mode volumes or mode splits, and they typically do not include mode characteristics or important policy variables.

Mode share models predict mode splits and can be used to predict mode volumes when combined with total intercity travel volume. Sequential models of total intercity demand and mode share are two-stage models that combine the total volume models with mode share models. These are similar to the sequential model system used in urban travel demand modeling, and the main advantage of such an approach is that it estimates the effects of policy changes separately on city-pair trip volume and intermodal competition (Koppelman et al. 1984).

Some direct-demand, non-sequential models estimate demand for a single mode. These generally are formulated using a simple or modified gravity model. Population, income, and distance between cities are used in the most basic gravity models. While modified gravity models can estimate impacts of policy changes and are an improvement over simple gravity models, the models reviewed by Koppelman et al. (1984) do not account for intermodal competition.

Some time-series analysis has also been conducted to capture time trends, seasonal variations, period-to-period correlations, and lagged response in ridership in response to changes in service characteristics or other variables. These single-mode models, according to Koppelman et al. (1984), are designed to be used in cases where there is a particular interest in only one of the modes in a corridor. One advantage to using such a model is the reduced requirements for data, but these models suffer from a lack of intermodal competition in the formulation.

### 2.2.2. Route-level research for rural intercity bus service

Burkhardt and Riese (1982) developed a model to estimate ridership on rural intercity bus routes as a function of route length, the frequency of service, and the population served. The population data used in the model included the total population of each city, town, or village lying adjacent to the route, or adjacent to a town served. Population data for the central city or town center served were used, rather than for the entire metropolitan area. The model used least squares regression and was developed using data from Greyhound for 89 routes in 17 states. As KFH Group (2001) noted, this research was published in 1982, and estimates from a model developed this long ago may no longer be relevant. The overall level of intercity bus ridership has changed over time, so estimates from old data would not be reliable.

Because of the age of this model, KFH Group (2001) developed a new model to estimate demand for a new route between Macon, GA, and Brunswick, GA. They developed a linear regression model to estimate passenger revenue as a function of the attributes of the location. To estimate the model they obtained passenger revenue and passengers by stop for all Georgia locations for 1999 and 2000, and used data for 18 small towns similar to the ones along the proposed route. They hypothesized that the following would affect intercity bus revenue: the 10- and 20-mile market area population; the percentage of the population with incomes below the poverty line; the percentage of households with no vehicle; the percentage of the population with incomes under $25,000; the frequency of bus service, measured in departures per week; and a dummy variable for Greyhound service within 10 miles. However, only total population and frequency were found to be statistically significant.

KFH Group (2003) followed this study with a similar analysis to examine the feasibility of implementing intercity bus service between the cities of Hampton, VA, and Fredericksburg, VA. To do so, they developed a model using data from Greyhound for passenger revenue for all Greyhound stops in eastern North Carolina, Virginia, and Maryland. A linear regression model was developed that estimated revenue as a function of attributes of the location. Data were restricted to stops in towns with a population of less than 20,000, so that it would be more useful for predicting revenue to the small towns along the proposed route.

The following factors were hypothesized to affect intercity bus ridership: the population within the town's boundaries, the 10-mile population around the stop, the percentage of the population with income below the poverty level, the percentage of households that rent, the percentage of the population older than age 60, the percentage of the population aged 18-24, the frequency of bus service, measured in departures per week, and the presence of a four-year residential college, major medical facility (more than 150 beds), military installation, state or federal level correctional institution, or a locally operated transit system. Dummy variables were included for the presence of these special generators.

Results showed that population within 10 miles of the stop, the percentage of population below the poverty line, the presence of a medical facility, and service frequency all had a significant positive effect on annual revenue. A drawback of this model is that it only estimates revenue generated en-route, and it does not include any "overhead" traffic revenue, or traffic generated by those traveling beyond these points.

More recently, Fravel et al. (2011) developed a route-level model based on the theory that rural intercity demand is a function of the following: overall population levels of origin points, population of the destination city, population characteristics, length of the route or service, basic service characteristics (frequency, fare level, etc.), impact of key institutions that are likely to concentrate demand, and connectivity of the service. These factors were used to build upon the basic gravity model, where the friction factor includes actual distance, the fare level, and the frequency. This work was published as part of a TCRP project described in TCRP Report 147.

Fravel et al. (2011) developed a regression model to predict ridership as a function of the populations served and the service characteristics. They found that using corridor population alone provides poor estimates. Separate models were estimated for regional providers and intercity bus providers. Population was divided into urbanized and non-urbanized. The final model estimated ridership on a route (annual one-way passenger boardings) as a function of origin population (sum of populations of origin points along the route, excluding the point with the largest population which is referred to as the destination population), the number of stops on the route, whether it provides a connection to an airport, and whether service is operated by a carrier meeting the definition of an intercity carrier. This model provided much greater predictive power, and it showed that ridership along the route increased with an increase in origin population, number of stops on the route, and the presence of an airport connection. Ridership was also found to be greater for providers defined as intercity carriers. The impact of the airport connection and intercity bus carrier demonstrate the advantages of connectivity. An intercity bus provider, as opposed to a regional transit provider, provides the advantages of interlining, allowing greater connectivity to the intercity bus network.

Fravel et al. (2011) also examined long-distance trip rate data from the 2001 National Household Travel Survey (NHTS). They obtained trip rates categorized by urbanized and non-urbanized, region, and income. A problem with using the NHTS data is too few trips reported by intercity bus. Therefore, they used overall trip rates for long-distance travel and applied a mode split factor, which they assumed to be 0.09% for bus. This trip rate method, however, was found to be less accurate than the regression model.

### 2.2.3. Other studies

Al-Sahili and Sadeq (2003) studied intercity bus ridership in Palestine using ridership data obtained from bus operators there. Their model predicted ridership between city pairs, and five independent variables were examined: origin city population, destination city population, bus fare, percentage of population in origin city consisting of students attending secondary schools or universities, and percentage of population in origin city consisting of people older than 15 years who are employed. The study found that origin and destination city population, percentages of employees and students, and bus fare all significantly influenced ridership between city pairs.

Wirasinghe and Kumarage (1998) developed an intercity demand model for use in a developing country. The model form was calibrated for Sri Lanka, but can be applied to other countries. Their model formulation for total trips between districts is a modified gravity model, including socioeconomic variables and impedance variables. Impedance variables include wait time, transfers, service frequency, and generalized cost of travel (which is a composite cost variable of minimum travel time and minimum fare). Wirasinghe and Kumarage (1998) used the following socioeconomic variables in developing a model appropriate for Sri Lanka: the product of origin and destination populations, the product of urban population proportions (based on the assumption that urban areas generate more travel than rural areas), and the difference of urban population proportions (based on the assumption that there would be less need to seek services outside the district in districts with a large urban center).

Pagano et al. (2001, 2003) estimated demand between city pairs in Illinois using a gravity-type formula. Their rationale was that the level of demand for intercity bus service between two places, excluding intermediate stops, would be proportional to the population masses of the terminal places and inversely proportional to the squared distance between places. For their study, they did not have data on the number of trips between city pairs, so they developed a scoring function to determine the interactivity potential between city pairs, which was equal to the product of the populations divided by squared distance. The method then assigned a score to each O-D pair and sorted the pairs in descending order. This method is useful for identifying the greatest need for service, but it does not provide ridership estimates and is limited in that it only accounts for population and distance.

Yao and Morikawa (2005) developed an intercity travel demand model to account for induced travel. As they note, ridership is determined by both exogenous factors that determine the location of the demand curve, such as population and economic development, and endogenous factors that determine the point along the demand curve, such as changes in travel time and travel cost. Reducing travel time and cost will lead to increased travel, and this induced travel may include shifts between alternative routes, modes, destinations, times of day, or new trips not previously made (Yao and Morikawa 2005). To capture induced travel, Yao and Morikawa (2005) developed an integrated model including trip generation, destination choice, mode choice, and route choice. As they noted, the destination choice utility function is generally specified using variables to describe the city’s characteristics and a measure of impedance between cities.

## 2.3. Intercity Bus Network Model

Fravel et al. (2011) proposed a network model that would follow the structure of the urban travel demand model and apply it to the intercity bus network. They described a single-mode bus model that would include trip generation and trip distribution to a network but would not include mode split. As they described, such a network could be used by bus companies and state DOTs to evaluate network impacts of adding links to the network or bypassing congested stops, and a national intercity bus network model could be developed which could estimate impacts from service changes, such as rerouting service, adding new links, or eliminating routes or links. The network model would describe the initial network in terms of the routes, bus stops, frequencies, and travel times between stops.

In this framework, a point demand model would be used to estimate the number of intercity bus trips generated at each stop. The point demand model would be used for the trip generation step. Once the number of boardings at each stop has been estimated, trip distribution and assignment would place the trips onto the links, resulting in the overall ridership on each link. A type of gravity model could be used for calculating trip distribution, and O-D data or data on the distribution of trip distances for intercity bus trips would be needed to calibrate the model.

There are advantages to analyzing the intercity bus network from a statewide or regional level rather than at the corridor level. Because each individual route operates within a larger network, its performance is likely to depend on the other parts of the network. Because of the substitutive and complementary effects among intercity bus routes, Guo et al. (2008) argued that analyses that focus only on the individual corridor would lead to erroneous conclusions.

## 2.4. Disaggregate vs. Aggregate Models

The models previously described are aggregate models that rely on total ridership numbers. Disaggregate models differ from aggregate models in that they use data at the level of the individual or household. These models are used widely in urban travel analysis, and according to Koppelman et al. (1984), they provide better results and are preferred because of their ability to represent the individual traveler’s decision process. These models require data describing the travel behavior of a set of individuals, their individual characteristics, and the attributes of the travel services available to each of them.

As described by Koppelman et al. (1984) the use of aggregate data results in parameter estimation bias. Other weaknesses they describe are that the formulation of the models is correlative rather than causal, the selection of variables is generally based on statistical results and may not represent the true determinants, limitations on data availability and measurement problems may undermine the quality of the models, the models are not able to consider the relationship between intercity travel decisions and related travel decisions, and the validation of the models has been limited, partially due to lack of data.

Because of the problems with existing models using aggregate data, Koppelman and Hirsh (1986) recommended a disaggregate approach. Their study presented a conceptual structure of the intercity passenger decision process. They recommended using a fully disaggregate dataset, with data gathered at the individual or household level, compatible with a behavioral framework. The recommended dataset would include individual characteristics, actual intercity travel behavior over a substantial period of time, full description of all of the intercity trips undertaken during this period (purpose, party size, time of year), relevant information about the destinations visited (city, specific areas visited, number of stops, trip duration), attributes of the modes chosen for the trips as well as the corresponding attributes of the non-chosen modes, and description of the local activity pattern at the destination (length of stay, accommodations, and transportation arrangements). Koppelman and Hirsh (1986) noted that no existing datasets included all the desired information.

Most of the early research reviewed by Koppelman et al. (1984) used aggregate data, but they also described a few disaggregate intercity travel models that included binary mode choice, multinomial mode choice, and destination-mode choice models. More recently, a number of disaggregate intercity mode choice models have been developed.

## 2.5. Mode Choice Models

Mode choice models predict the likelihood of an individual choosing a given mode for a given trip based on individual, mode, and trip characteristics, using a discrete choice modeling technique. These models are used to estimate mode splits and can be used to predict mode volumes when used with known or estimated total trip volume.

Factors affecting mode choice can be organized into three categories: the characteristics of the different transportation modes, the characteristics of the individual making the trip, and the characteristics of the trip itself. Mode characteristics that could potentially affect mode choice include cost, travel time, comfort and convenience, service frequency, need for transfer, and access. The trip-maker characteristics include income, age, gender, car-ownership, ability to drive, and preferences and attitudes. Trip characteristics include trip purpose, trip length, and size of party.

Most studies find that cost and time are important determinants of intercity mode choice. Cost is commonly regarded as one of the main factors, and a variety of intercity and mode choice studies over the last several years have demonstrated the importance of travel time (Kumar et al. 2004, Ashiabor et al. 2007, Proussaloglou et al. 2007, Andrade et al. 2006). Studies also include other mode characteristics such as service frequency. Access, egress, and transfer times and costs should also be accounted for to compare door-to-door travel costs (Zhang et al. 2012).

Most studies include some socioeconomic variables as predictors of mode choice. Many include income (Kumar et al. 2004, Ashiabor et al. 2007, Proussaloglou et al. 2007), while age, gender, education, and profession have also been considered (Kumar et al. 2004). Socioeconomic factors can affect how sensitive travelers are to travel time and cost. For example, some research has shown that high-income travelers are less sensitive to travel cost (Ashiabor et al. 2007). The habits and attitudes of individuals can also be important. A number of studies have investigated the effects of habit on mode choice (Aarts et al. 1997, Verplanken et al. 1997, Garvill et al. 2003), while others have asked respondents a series of attitudinal questions and analyzed how different attitudes influenced choice of mode (Gilbert and Foerster 1977, Golob and Recker 1977, Outwater et al. 2003, Mattson et al. 2010b, Ripplinger et al. 2011).

Finally, the characteristics of the trip itself can influence the choice of mode. Research has shown that transit is a closer substitute to the automobile for commuter or business trips than for leisure travel (Storchmann 2001). Business travelers may be motivated differently than those traveling for personal reasons. Also, as the trip distance increases, the substitutability between the different modes may also change. For example, motorists may be more likely to switch to bus or rail in response to higher gas prices as the length of the trip increases (Wallis and Schmidt 2003, Currie and Phung 2008), which could be due to an increase in the cost difference at greater trip distances. The size of the travel party could also be an important variable that is commonly ignored in mode choice studies (Miller 2004). As the size of the travel party increases, the automobile becomes more cost-effective.

Mode choice models are often estimated using data collected from stated preference (SP) surveys. SP surveys, also referred to as stated choice experiments, are widely used in areas such as marketing and transportation. A number of transportation studies have utilized an SP survey to analyze transportation alternatives (Mattson et al. 2010a,b, Kumar et al. 2004, Andrade et al. 2006, Dehghani et al. 2002, Mehndiratta and Hansen 1997, Pinjari and Bhat 2006, Richardson 2002, Richardson 2006). These studies analyze the SP survey data using a discrete choice modeling technique. Discrete choice modeling is popular in transportation and marketing research for understanding an individual's stated choice among alternatives (Kuhfeld 2010). The multinomial logit model, which is a type of random utility choice model, has been traditionally used to model the choice among alternative modes in intercity travel demand modeling (Koppelman and Sethi 2005). The nested logit model has been shown to be superior to the traditional multinomial logit model for intercity model choice studies (Forinash and Koppelman 1993), as has the mixed logit model (Hensher and Greene 2003). Use of these more advanced models has increased in recent years.

### 2.6. Statewide Travel Demand Models

Intercity mode choice can be included as part of a statewide travel demand model. Some states have travel demand models that include intercity bus as one of the modes. Statewide travel demand models follow the same basic four-step process as the more common urban travel demand model and are run using GIS. A statewide travel demand model divides the state into a number of traffic analysis zones (TAZs). Population, employment, and other characteristics of each TAZ are used to estimate the number of trips produced and attracted by each zone. Trips between zones are distributed using a gravity model and assigned to the transportation network based on minimizing travel times. Some of these models also include the intercity bus network and a mode choice component that assigns a certain percentage of the trips to the bus network.

The direct demand model is an alternative to the four-step process. In a typical direct demand model, the aggregate passenger travel demand between an O-D pair by each transportation mode is expressed as a function of economic, land use, and socio-economic characteristics of the origin and destination, as well as the attributes of the particular mode and its competing modes (e.g., travel time, cost, other level of service factors) (Zhang et al. 2012).

Statewide travel demand models, though, have typically been motivated by freight concerns and model truck traffic (Giaimo and Schiffer 2005). These models are not as advanced as urban models in terms of data collection and modeling (Zhang et al. 2012). Not all states have statewide travel demand models, and many of the existing models have been developed within the last couple of decades. One of the biggest problems with these models is a lack of data on how and why U.S. travelers choose different long-distance modes, destinations, and routes (Zhang et al. 2012).

A NCHRP project, NCHRP Synthesis 358 conducted by Horowitz (2006), described the state of statewide travel demand models. Horowitz (2006) noted that the state of practice had been maturing over the previous 10 years and, at the time of his publication, approximately half of the states had functional models. Most states tend to rely on secondary data sources, such as the National Household Travel Survey or the Census Transportation Planning Package.

One of the more advanced statewide travel demand models that incorporates the intercity transit network is one developed for the Wisconsin Department of Transportation (WisDOT) by Proussaloglou et al. (2007). Their passenger model was estimated using Wisconsin add-on data for the 2001 National Household Travel Survey (NHTS), and model validation relied on the NHTS data, statewide traffic counts, intercity transit ridership estimates, and 2000 U.S. Census data including the Census Transportation Planning Package. The model divided the state into 1,642 zones, derived the highway network from WisDOT databases, and developed the intercity transit network to reflect all the existing intercity rail and bus services serving Wisconsin. Their mode choice model included in-vehicle travel times, access and egress travel times, walk access to existing intercity services, frequency of service, transit fares, vehicle availability, household income, the size of traveling party, and the need for transfers as factors that would impact choice of mode.

## 2.7. Other Approaches

Fravel et al. (2011) also described a few different approaches for estimating rural intercity bus demand: per capita intercity trip generation rates, use of comparable services, and use of historical data. The per capita intercity trip generation rate approach estimates the number of trips per year per capita for a given town and multiplies it by population to get an estimate of total annual ridership. The model is developed based on existing ridership data. This is a very basic model that does not consider service characteristics, demographic differences, travel patterns, or other factors that would influence use of intercity bus service. Another approach is to compare the service being studied with similar routes or services and use data from the similar services to develop ridership estimates. There are many factors that can influence ridership, however, so an accurate comparison could be difficult. Using historical data from previous services may be possible in some cases, but as Fravel et al. (2011) noted, there are several significant issues with this approach.

Koppelman et al. (1984) described aggregate regional intercity demand models that estimate total intercity travel volume, usually for a single mode, for all the intercity corridors in a selected region. These models can be used to estimate the impact of service changes, price changes, or regional economic changes on total regional ridership, but they cannot be applied to specific corridors.

## 2.8. Conclusions

Important determinants of intercity bus demand include population, demographics, location of major trip generators, and service characteristics, such as travel time, service frequency, fares, and transfers. Proper analysis should also consider competition between modes, and to be useful, demand models need to consider issues relevant to decision-makers. Models can be evaluated based on their policy relevance, effectiveness in providing useful forecasts, and ease of implementation (Koppelman et al. 1984).

A modified gravity model with attractiveness and impedance factors can be used to estimate demand between city pairs. Attractiveness variables should include population, demographics, and major trip generators; and measures of impedance should include travel time and level of service. However, the gravity model approach becomes more complicated once a route has numerous intermediate stops that offer alternative destinations (Fravel et al. 2011, Cook and Lawrie 2008). Previous studies have commonly developed gravity-type models to estimate demand for a single mode or all modes between city-pairs, while other studies have focused on mode choice modeling.

The Fravel et al. (2011) model and the previous models used by KFH Group are useful for estimating demand on proposed feeder routes, but one of the major drawbacks of these models is that they only take into account characteristics along the route itself while not factoring in how the route fits into a larger network. As a result, predicted ridership does not account for through traffic, or trips that begin or end elsewhere on the network. The new route may simply be filling a gap in the network. Predicting ridership on the route, therefore, requires not just population and service information for that route but also information about how the route fits into the larger network. Therefore, a network model would be more useful than a route-level model for predicting demand.

Ideally, demand for intercity bus service could be estimated within a statewide travel demand model with a mode choice component. Such a model would benefit from the use of disaggregate data. As Koppelman and Hirsh (1986) argued, a disaggregate model with data gathered at the individual or household level is the preferred approach for estimating demand for intercity bus services. Koppelman and Bhat (2006) also noted that disaggregate models are more likely to be transferable to different points in time and different locations. Previous mode choice models have used data at the level of the individual to estimate mode shares for intercity bus and other modes. However, as Miller (2004) showed, there is a wide set of explanatory variables needed for modeling mode choice, and most studies at the time had used a fairly limited set of variables.

# 3. METHODS

Applying an intercity mode choice model, with disaggregate data, within a statewide travel demand model provides an attractive approach for estimating demand for intercity bus services. As previously noted, however, not all states have statewide travel demand models, and many existing models have been motivated by freight concerns and are not as advanced as urban models.

This study aims to improve upon previous mode choice models by developing a model focusing on passenger travel that can be incorporated into a statewide travel demand model for the state of North Dakota. Unlike a previous mode choice model developed in North Dakota and Minnesota by Mattson et al. (2010a,b), this model includes access and egress distance, which are important determinants of intercity bus use. The model can be used to determine how far travelers are willing to travel to and from intercity bus stops, and by incorporating it into a statewide travel demand model, it can be used to estimate demand throughout the state. The model can be used to estimate ridership on proposed services or the impacts of potential service changes, changes in fares or travel times, rising gasoline prices, or other factors on the use of intercity bus.

To obtain the data needed for the mode choice model, a stated preference survey was conducted of individuals across North Dakota. Then, a discrete choice model was used to estimate the mode share model.

The model includes four modes: air, automobile, bus, and rail. Choice of mode is hypothesized to be affected by different mode-specific factors, generic trip attributes that do not depend on the mode, and individual characteristics. Mode-specific factors include price (the explicit financial cost), travel time, frequency of service, and access and egress distances. Generic trip attributes include trip type (personal or business) and party type (traveling alone or in a group). Individual characteristics include age, income, gender, disability, and personal attitudes. Information for each of these variables was collected through the survey.

## 3.1. Survey Development

The survey included four sections: a general demographic information section, a section on transportation experience, a stated preference section, and a section on travel attitudes.

### 3.1.1. Demographic characteristics

The first two sections of the survey collected demographic information about the respondents, including age, gender, household income, disability, and whether they have access to an automobile and are able to drive. It is expected that these factors may influence mode choice. The survey also asked respondents if they have ever traveled by intercity bus or rail or by airplane. Research has shown that habit plays a role in mode choice (Garvill et al. 2003, Verplanken et al. 1997, Aarts et al. 1997). The survey also asked for the respondents' zip code, so that the geographic distribution of survey respondents could be documented.

### 3.1.2. Stated preference survey

The next part of the survey was a stated preference (SP) survey. SP surveys, also referred to as stated choice experiments, are widely used in areas such as marketing and transportation. In such a survey, the respondent is shown a number of choice sets. Each choice set consists of two or more options, or alternatives, that are described by a set of attributes with varying levels. The survey respondent is asked to choose his or her preferred option. In this survey, each choice set described a hypothetical intercity trip, and the respondent was asked to choose between four options for taking the trip: air, automobile, bus, or train.

SP surveys have gained popularity for use in travel behavior research due to their ability to accommodate hypothetical alternatives and identify behavioral responses to choice situations that are not revealed in the market (Hensher 1994 and Kumar et al. 2004). An SP survey is useful for this study because it allows for attributes to be varied to levels not yet observed in the market and for individuals to be surveyed who do not currently have access to each of the modes of travel. Furthermore, real-world collection of all the necessary variables could prove to be difficult. Hess et al. (2007) argued that revealed preference (RP) survey data, which attempts to collect information about actual travel behavior, suffers due to the low quality of data relating to un-chosen alternatives. SP surveys also have their disadvantages, one being that actual behavior does not always match what people say they would do (Murphy et al. 2005). However, because of the advantages, a number of transportation studies have utilized an SP survey to analyze transportation alternatives (Andrade et al. 2006, Dehghani et al. 2002, Haghani et al. 2015, Hess et al. 2007, Jiang and Zhang 2014, Kumar et al. 2004, Mattson et al. 2010a,b, Mehndiratta et al. 1997, Pinjari et al. 2006, Richardson 2002, Richardson 2006, and Srinivasan et al. 2006).

Hensher (1994) identified the following key steps to designing a stated choice experiment: 1) identify the set of attributes, or factors; 2) select the measurement unit for each attribute; 3) specify the number and magnitude of attribute levels; 4) create the statistical design, combining the attribute levels into an experiment; 5) translate the design into a set of questions; 6) select an appropriate estimation procedure; and 7) use the estimated parameters to obtain choice probabilities for each alternative. Each of these steps will be described in the following sections.

#### *3.1.2.1. Mode alternatives, attributes, and levels*

The survey included four mode alternatives for respondents to choose among: air, automobile, bus, and train. These alternatives were described by a set of mode-specific attributes, and survey respondents also had to consider a set of generic trip attributes that did not depend on the mode.

Generic trip attributes included trip distance, trip type, and party type. One-way trip distances of 50 miles, 100 miles, 250 miles, and 400 miles were used. Trip type was categorized as either personal or business, and the party type indicated if the individual was traveling alone or with a group of either family and friends or co-workers.

Mode-specific attributes included price (the explicit financial cost, which was the price of gasoline for automobile travel or the fare for other modes), travel time, access distance (travel distance from origin to bus stop, train station, or airport), egress distance (travel distance from bus stop, train station, or airport to final destination), and service frequency. Different levels for each factor were used and varied between the choice sets. The factors and their relative levels are presented in Table 3.1.

**Table 3.1.** Factors, Modes, and Levels for Stated Preference Questions

| Factor | Modes | Levels |
|---|---|---|
| Price | Air, automobile, bus, train | Low, medium, high |
| Travel time/speed | Air<br>Bus, train | Slow (with transfer), Fast (direct flight)<br>Slow, medium, fast |
| Access distance | Air, bus, train | Short, medium, long |
| Egress distance | Air, bus, train | Short, medium, long |
| Frequency | Air, bus, train | Three times per week, once per day, twice per day |

Each mode had three relative price levels: low, medium, and high (Table 3.2). Automobile costs included just the price of gasoline at the following levels: $2.00 per gallon, $3.50 per gallon, and $5.00 per gallon. Automobile costs were presented in the survey in dollars per gallon rather than cost per mile or total cost per trip because this is the information travelers would encounter in the real world when making a decision. The range of intercity bus and rail prices were determined by reviewing fares charged by Jefferson Lines and Amtrak for trips in North Dakota. Intercity bus fares tend to vary by distance, day of the week, and proximity to travel date. Fares generally are lower on weekdays and if they are purchased further in advance, and fares tend to be higher on a per mile basis for shorter trips.

**Table 3.2.** Price Levels by Mode

| Mode | Low | Medium | High |
|---|---|---|---|
| Air | \$300/trip | \$600/trip | \$900/trip |
| Automobile | \$2.00/gallon | \$3.50/gallon | \$5.00/gallon |
| Bus | \$0.15/mile | \$0.20/mile | \$0.25/mile |
| Train | \$0.15/mile | \$0.20/mile | \$0.25/mile |

Bus and train modes each had three speed levels: slow, medium, and fast. Slow travel was defined as 45 miles per hour, medium speed was 55 miles per hour, and fast travel was 65 miles per hour. Slower travel occurs when there are multiple stops along the route or buses travel along routes with lower speed limits. Automobile speed was assumed to be 65 miles per hour. Air had two speed levels based on if a transfer was required (slow) or if it was a direct flight (fast). Table 3.3 presents travel time by air as a function of trip distance.

**Table 3.3.** Travel Time by Air

| Miles | Slow | Fast |
|---|---|---|
| 50 | 2 hours | 30 minutes |
| 100 | 3 hours | 45 minutes |
| 250 | 4 hours | 60 minutes |
| 400 | 4 hours | 75 minutes |

Three levels were considered for access and egress distances for air, bus, and train, as shown in Table 3.4. The access distance is the distance from the traveler’s home to the airport, bus station, or rail station. The egress distance is the distance from the destination airport, bus station, or rail station to the traveler’s final destination.

**Table 3.4.** Access and Egress Distance for Air, Bus, and Train

| Factor | Short | Medium | Long |
|---|---|---|---|
| Access Distance | 2 miles | 10 miles | 20 miles |
| Egress Distance | 1 mile | 5 miles | 10 miles |

While some other factors may also influence mode choice, such as transfer requirements, the number of factors included in the choice sets was limited to avoid over-burdening survey respondents. As the number of alternatives, attributes, and attribute levels increase, the choice experiment becomes increasingly complex, and the cognitive burden for participants increases. As a result, participants may have difficulty processing all the information and may ignore some attributes, providing less useful results (Hensher 2006, Caussade et al. 2005).

Caussade et al. (2005) found that the two most critical design dimensions were the number of attributes and the number of alternatives. This study and others found a significant negative effect on data quality resulting from an increase in the number of attributes (DeShazo and Fermo 2002, Arentze et al. 2003). Because of the impact of survey complexity on the reliability of results, the number of attributes was limited to those considered most important. Caussade et al. (2005) also found that four alternatives are optimum.

The impact of survey fatigue, resulting from too many choice sets to consider, on data quality is also a potential concern. However, Arentze et al. (2003) did not find any fatigue effect for transportation SP surveys. Caussade et al. (2005) did not find the number of choice sets in the survey to be as important as other design dimensions, but they found that experiments with 9 or 10 choice sets were optimal, minimizing any fatigue effect.

#### *3.1.2.2. Statistical design*

The stated choice experiment consisted of 19 factors with varying levels, as shown in Table 3.5. Three of the factors had two levels, one had four, and the remainder all consisted of three levels. After identifying the factors, selecting the measurement units, and specifying the number and magnitude of factor levels, the next step, following Hensher (1994), was to create the statistical design of the experiment.

**Table 3.5.** Stated Choice Experiment Factors and Levels

| Factor | Number of Levels | Levels |
|---|---|---|
| Distance | 4 | 50 miles, 100 miles, 250 miles, 400 miles |
| Trip type | 2 | Business, personal |
| Party size | 2 | Alone, with a group |
| Air price | 3 | \$300/trip, \$600/trip, \$900/trip |
| Automobile price | 3 | \$2.00/gallon, \$3.50/gallon, \$5.00/gallon |
| Bus price | 3 | \$0.15/mile, \$0.20/mile, \$0.25/mile |
| Train price | 3 | \$0.15/mile, \$0.20/mile, \$0.25/mile |
| Air travel speed | 2 | Slow, fast |
| Bus travel speed | 3 | 45 mph, 55 mph, 65 mph |
| Train travel speed | 3 | 45 mph, 55 mph, 65 mph |
| Air access distance | 3 | 2 miles, 10 miles, 20 miles |
| Bus access distance | 3 | 2 miles, 10 miles, 20 miles |
| Rail access distance | 3 | 2 miles, 10 miles, 20 miles |
| Air egress distance | 3 | 1 mile, 5 miles, 10 miles |
| Bus egress distance | 3 | 1 mile, 5 miles, 10 miles |
| Rail egress distance | 3 | 1 mile, 5 miles, 10 miles |
| Air frequency | 3 | Three times per week, once per day, twice per day |
| Bus frequency | 3 | Three times per week, once per day, twice per day |
| Train frequency | 3 | Three times per week, once per day, twice per day |

Methods from the field of experimental design were used to develop the stated preference questions. Experimental design is a field of statistics concerned with the proper construction of experiments to ensure the preservation of necessary properties. It is often used in marketing research to assist in the investigation of consumer choices. Experimental design methods were used to identify the minimum number of choice sets needed and to construct the individual choice sets.

A full-factorial design consists of all possible combinations of the factor levels. Such a design allows the estimation of main effects – simple effects such as the effects of price or travel time – and interactions between variables. A full-factorial design was not feasible for this study, however, as it would result in millions of unique choice sets. To reduce the number of combinations considered, researchers often use fractional-factorial designs. The cost of a fractional-factorial design is that some effects become confounded, or not distinguishable from each other.

Fractional-factorial designs are categorized by their resolution, as explained by Kuhfeld (2010) and shown below:

- Resolution III – All main effects can be estimated free of each other, but some are confounded with two-factor interactions.
- Resolution IV – All main effects can be estimated free of each other and free of all two-factor interactions, but some two-factor interactions are confounded with other two-factor interactions.
- Resolution V – All main effects and two-factor interactions can be estimated free of each other.

Higher resolutions require larger designs, which are often impractical in marketing or transportation research. As noted by Kuhfeld (2010), Hensher (1994), and Sanko (2001), Resolution III fractional-factorial designs, also referred to as main-effects designs, are commonly used in marketing and transportation research. These designs assume there are no significant interactions between attributes. Main effects and other fractional factorial designs have been shown to be valid, explaining the largest amount of variance in response data, but care should be taken to avoid confounding interaction effects with main effects (Sanko 2001).

Fractional-factorial designs that are both orthogonal and balanced are preferred. A design is balanced when each level occurs equally often within each factor, and a design is orthogonal when every pair of levels occurs equally often across all pairs of factors. Orthogonality is important because it ensures that there is no correlation between attributes. While this is a desirable property, it is not a necessary condition (Hensher 1994).

As Kuhfeld (2010) explained, the efficiency of an experimental design can be quantified, and the two most prominent efficiency measures are referred to as the A-efficiency and the D-efficiency. A-efficiency is a function of the arithmetic mean of the eigenvalues, which is also the arithmetic mean of the variances, and D-efficiency is a function of the geometric mean of the eigenvalues. A third efficiency measure, the G-efficiency, is based on the maximum standard error for prediction over the candidate set. The three criteria are usually highly correlated, and they can be scaled to range from 0 to 100. A more efficient design has greater balance and orthogonality. If the design is balanced and orthogonal, then is has optimum efficiency.

According to Kuhfeld (2010), D-efficiency is usually used because it is easier and faster for a computer program to optimize, and the ratio of two D-efficiencies for two competing designs does not vary under different coding schemes, unlike the A-efficiency. Carlsson and Martinsson (2003) also strongly recommend that researchers use a D-optimal design.

Even when not using a full-factorial design, the number of choice sets in the design could be too many for the survey respondent. To reduce the choice sets to a reasonable number for the survey participant, the survey questions can be broken into subsets or blocks, which is common in transportation studies (Hensher 1994). Blocking can be successful if the preferences across the samples of respondents receiving different subsets of questions are sufficiently homogenous (Sanko 2001).

The statistical design for the SP survey was created with SAS 9.3, using a set of macros described by Kuhfeld (2010). First, the %MktRuns macro was used to choose the number of choice sets. It was found that a balanced and orthogonal design, with optimal D-efficiency, could be achieved with 72 choice sets.

After identifying the optimal number of choice sets, the %MktEx macro was used to efficiently create the choice sets. This macro, which attempts to optimize D-efficiency and provide balanced and orthogonal designs, was created to produce the types of designs that marketing researchers need for choice experiments (Kuhfeld 2010). The resulting design, with 72 choice sets, was found to be sufficient for estimating main effects.

Next, because 72 choice sets are still far too many for an individual survey respondent to complete, the choice sets were assigned to eight blocks, using the %MktBlock macro in SAS, with each block consisting of nine choice sets. The %MktBlock macro attempts to create a blocking factor, which is an additional factor that is uncorrelated with all existing factors and ensures orthogonality within each block.

Eight different versions of the stated preference survey were then created with each including a single block of nine choice sets. Each survey respondent, therefore, received nine stated preference questions.

Appendix A shows the resulting survey design. The first table provides the coded survey design, which shows the level for each factor in each of 72 choice sets, as well as the block to which each choice set was assigned. The second table in Appendix A shows the actual factor values for each choice set.

In preparing the survey, prices for bus and train travel were converted from cost per mile to total cost by multiplying the cost per mile by trip distance. Similarly, travel time for automobile, bus, and train were calculated by dividing trip distance by travel speed.

After creating the statistical design, the next step, according to Hensher (1994), was to translate the design into a set of questions. Appendix B provides a final survey design with one of the eight SP blocks.

The final steps outlined by Hensher (1994), selecting an appropriate estimation procedure and using the estimated parameters to obtain choice probabilities, will be discussed in Section 3.3.

### 3.1.3. Attitudinal questions

The last section of the survey presented a number of statements about travel, and the respondent was asked to respond on a Likert-type scale the degree to which he or she agreed or disagreed with the statement. These statements, which were used in a previous study by Mattson et al. (2010) and were derived from those used by Outwater et al. (2004), described a number of attitudes regarding the traveler's sensitivity to the environment, time, flexibility, safety, stress, comfort, reliability, privacy, convenience, and other elements of the travel experience. The full set of attitudinal questions is shown in Appendix B. As shown by Mattson et al. (2010b), an individual's attitude regarding these aspects of travel can influence choice of mode. Comparing results to previous research will also show if traveler attitudes have changed over time.

## 3.2. Survey Administration

### 3.2.1. Study population, sample frame, and drawing the sample

The target population for the survey was adults aged 18 or older living in North Dakota. The survey sample was generated from a list of names and addresses obtained from AccuData Integrated Marketing, a marketing firm that sells mailing lists. AccuData maintains frequently updated databases of individual records compiled from property data, public records, transactional data, consumer surveys, etc. Most of the records include the age of the individual, as well as a number of different variables. The database from which the sample was drawn contained approximately 220,000 individual records for the state of North Dakota. This represented the sample frame, from which the sample was drawn.

It is desirable for the age and geographic distribution of the sample to resemble those of the study population. The geographic distribution of the sample frame closely resembled the geographic distribution of the study population, as determined by comparing the number of individuals per county. The age distribution of the sample frame, however, was not representative of the study population, as younger adults were underrepresented in the AccuData database. Therefore, a stratified sampling technique was used, where the sample frame was divided into subsets, based on age, and a random sample was drawn from each subset. When purchasing the records, a specific number of records was requested from each age group, so the age distribution of the sample resembled that of the study population. Because these records were randomly chosen, the geographic distribution of the sample should be similar to that of the study population.

The sample frame was divided into two-year age bands. Table 3.6 shows the percentage of the North Dakota population belonging to each of these age bands (according to 2014 population estimates from the Census), the number of individual records purchased from each age band, and the percentage of the sample belonging to each age band. Because of the very low number of individuals aged 18-19 in the AccuLeads database, it was not possible to obtain proportional representation of this age group in the sample. All other age groups, however, were represented appropriately.

### 3.2.2. Sample size

Suzuki et al. (2002) studied design issues in a stated preference survey for a light rail project in Japan, including the effects of sample size on mode split models, and they found that it is possible to estimate a well-behaved model from 100-300 samples if the survey instrument is well designed and administered. Other transportation studies have estimated models using SP survey data with a similar number of responses, such as Kumar et al. (2004), Andrade et al. (2006), and Srinivasen et al. (2006). While 100-300 usable SP responses appears sufficient and consistent with other published transportation research, a review of stated preference methods published by Accent and RAND Europe (2010) recommended a minimum of 400 survey responses for market research. Therefore, the goal for the survey was 400-500 responses. This number of responses would provide a 5% sampling error with a 95% confidence level.

**Table 3.6.** Age Distribution of Survey Sample and North Dakota Population

| Age | Number in Sample | Percentage of Sample | Percentage of North Dakota Population |
|---|---|---|---|
| 18-19 | 114 | 2.3% | 4.0% |
| 20-21 | 244 | 4.9% | 4.8% |
| 22-23 | 269 | 5.4% | 5.3% |
| 24-25 | 232 | 4.6% | 4.5% |
| 26-27 | 194 | 3.9% | 3.8% |
| 28-29 | 197 | 3.9% | 3.9% |
| 30-31 | 190 | 3.8% | 3.7% |
| 32-33 | 184 | 3.7% | 3.6% |
| 34-35 | 171 | 3.4% | 3.4% |
| 36-37 | 156 | 3.1% | 3.1% |
| 38-39 | 144 | 2.9% | 2.8% |
| 40-41 | 136 | 2.7% | 2.7% |
| 42-43 | 142 | 2.8% | 2.8% |
| 44-45 | 145 | 2.9% | 2.8% |
| 46-47 | 140 | 2.8% | 2.7% |
| 48-49 | 151 | 3.0% | 3.0% |
| 50-51 | 168 | 3.4% | 3.3% |
| 52-53 | 179 | 3.6% | 3.5% |
| 54-55 | 184 | 3.7% | 3.6% |
| 56-57 | 180 | 3.6% | 3.5% |
| 58-59 | 175 | 3.5% | 3.4% |
| 60-61 | 163 | 3.3% | 3.2% |
| 62-63 | 149 | 3.0% | 2.9% |
| 64-65 | 132 | 2.6% | 2.6% |
| 66-67 | 125 | 2.5% | 2.4% |
| 68-69 | 94 | 1.9% | 1.8% |
| 70-71 | 91 | 1.8% | 1.8% |
| 72-73 | 77 | 1.5% | 1.5% |
| 74-75 | 68 | 1.4% | 1.3% |
| 76-77 | 65 | 1.3% | 1.3% |
| 78-79 | 61 | 1.2% | 1.2% |
| 80-81 | 56 | 1.1% | 1.1% |
| 82-83 | 52 | 1.0% | 1.0% |
| 84+ | 172 | 3.4% | 3.6% |

The study employed a combination of mail and online surveys and, based on expected response rates for these types of surveys, a sample of 5,000 individuals was determined adequate for obtaining 400-500 responses (assuming that about 5% of individual records would be outdated, that the response rate for mail surveys would be about 12%-20%, and that the response rate for online surveys would be even lower).

### 3.3.3. Survey distribution

To reduce costs, half of the surveys were administered online. Individuals in the sample were randomly assigned to either the mail survey or the online survey, while maintaining a similar age distribution between the two groups. When assigning individuals to the mail or online survey, potential survey participants were categorized into four age groups: 18-29, 30-49, 50-69, and 70 or older. In each of these four age groups, half of the individuals were randomly chosen to receive the paper survey, and the other half received the online survey. This procedure allowed for a similar age distribution between recipients of the two types of surveys.

Since the SP questions were blocked into eight groups, there were eight different versions of the survey instrument. Those selected to receive the mail survey were randomly assigned to receive one of the eight versions, with an equal number of recipients of each (four versions of the survey each had 313 recipients and the other four versions each had 312 recipients, totaling 2,500 recipients). The online survey was developed so that participants would randomly be given one of the eight SP blocks.

Recipients of the mail survey received a mailing consisting of a cover letter, the survey, and a postage-paid return envelope. Recipients of the online survey received a postcard in the mail with information about the survey and a web address where they can access and participate in the survey. Recipients of the mail survey were also given the web address so they could take the survey online if they preferred.

One to two weeks after the initial mailing, a postcard reminder was sent to all potential survey participants. To boost the response rate further, a cash incentive was used.

All survey participants who provided their name and contact information were entered into a drawing to win a $300 cash prize. While research tends to show that these types of lottery incentives are not effective for increasing response rates for mail surveys, some studies have found that they can be quite effective for web-based surveys (Heerwegh 2006, Laguilles et al. 2011).

## 3.3. Discrete Choice Modeling

The survey data were analyzed with a discrete choice model. Factors affecting mode choice can be organized into three categories: the characteristics of the different transportation modes, the characteristics of the individual making the trip, and the characteristics of the trip itself. A type of discrete choice model was developed based on this framework, using data collected from the survey. The model estimated the probability of a survey respondent choosing a given mode as a function of the mode characteristics (e.g., cost, travel time, service frequency, etc.), trip characteristics (e.g., trip purpose, party size), and individual characteristics (e.g., age, income, gender, etc.). Results from the model can be used to predict the probability that an individual with a given set of characteristics will choose a certain mode with given mode attributes for a certain type of trip.

### 3.3.1. Multinomial logit model

Discrete choice modeling is popular in transportation and marketing research for understanding an individual's stated choice among alternatives (Kuhfeld 2010). The multinomial logit model, which is a type of random utility choice model, has been traditionally used to model the choice among alternative modes in intercity travel demand modeling (Koppelman and Sethi 2005).

The basic assumption in such a model is that decision makers are utility maximizers. Therefore, given a set of alternatives, the decision maker will select the one that maximizes his or her utility, $U_{jk}$. The utility of an alternative $k$ for decision maker $j$ is assumed to consist of a deterministic part that can be estimated, $V_{jk}$, and a random portion called the error term, $\varepsilon_{jk}$, as follows:

$$U_{jk} = V_{jk} + \varepsilon_{jk} \tag{1}$$

The deterministic part of the utility function includes characteristics of the decision maker, trip characteristics, and characteristics of the alternatives. Different assumptions about the distribution of the error component result in different choice models. The simplest and most widely used among the multinomial discrete choice models is the conditional logit, which is often what is being referred to as the multinomial logit model (Koppelman and Sethi 2005).

The deterministic portion of the utility from Equation 1 can be written as follows:

$$V_{jk} = \beta' X_j + \gamma' Y_j + \theta' Z_{jk} \tag{2}$$

where $X_j$ are the characteristics of individual $j$; $Y_j$ are the trip characteristics for individual $j$; $Z_{jk}$ are the attributes of alternative $k$ for individual $j$; and $\beta'$, $\gamma'$, and $\theta'$ are the parameter vectors associated with the vectors $X_j$, $Y_j$, and $Z_{jk}$, respectively. The probability that individual $j$ would choose mode $k$ among $m$ alternatives is as follows:

$$P_{jk} = \frac{\exp(\beta'_k X_j + \gamma'_k Y_j + \theta' Z_{jk})}{\sum_{l=1}^{m} \exp(\beta'_l X_j + \gamma'_l Y_j + \theta' Z_{jl})}. \tag{3}$$

The data collected from the stated preference survey were used to estimate $\beta'$, $\gamma'$, and $\theta'$. Discrete choice models usually use Maximum Likelihood Estimation (MLE) to estimate these values. Each choice set completed by a survey participant is represented in the data by a block of four rows (one for each mode), columns for each observable characteristic ($X_j$, $Y_j$, and $Z_{jk}$), and a column indicating if the mode was chosen. MLE is used to estimate values of $\beta'$, $\gamma'$, and $\theta'$ that make the observed choices have the highest probability. As described by Ortuzar and Willumsen (2001), maximum likelihood estimates are the set of parameters which will generate the observed sample most often.

A problem with the multinomial logit model is that it suffers from the Independence from Irrelevant Alternatives (IIA) property, which makes the model inappropriate for situations where some pairs of alternatives are more substitutable than others (Koppelman and Sethi 2005). The restriction imposed by the IIA property implies equal competition between all pairs of alternatives. Therefore, the introduction of a new mode or improvements to an existing mode will reduce the probabilities for existing modes in proportion to their probabilities before the change (Koppelman and Bhat 2006). In reality, some modes are more similar to each other than they are to other alternatives. For example, for intercity travel, bus and rail modes have shared attributes which are not included in the measured portion of the utility function, as they are both forms of public transportation with lack of privacy, lack of control of the environment, etc. As a result, they may be more substitutable than others, so improvements to bus service would disproportionately affect the rail mode share.

### 3.3.2. Nested logit model

Hensher and Greene (2002) argued that the nested logit model is the preferred specification of a discrete choice model when moving beyond the multinomial logit model, and Forinash and Koppelman (1993) found nested logit structures for intercity mode choice modeling to be superior to the multinomial logit model. As Wen and Koppelman (2001) noted, the nested logit model is the most widely known relaxation of the multinomial logit model. An advantage of the nested model is that similar modes can be grouped as a subset.

Figure 3.1 is an example of a two-level nest structure that could be used for modeling intercity mode choice. The figure depicts an upper-level choice among automobile, air, and public transit and a lower-level choice between bus and rail, given that public transit is chosen.

Nested logit probabilities can be expressed as the product of two simple logits (UC Berkeley 2000).

$$P = \text{Prob (nest containing i) x Prob (i, given nest containing i)} \tag{4}$$

So,

$$P(Bus) = \text{Prob (PT) x Prob (Bus|PT)} \tag{5}$$

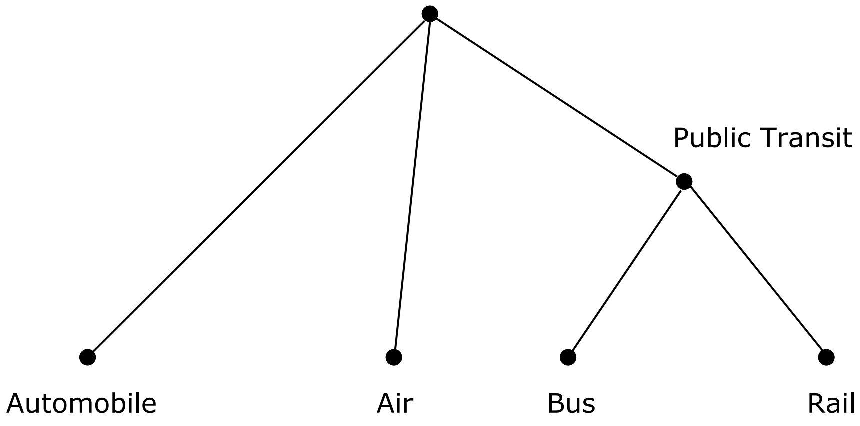

**Figure 3.1.** Two-Level Nest Structure

Following Koppelman and Bhat (2006), the choice probabilities for the lower-level nested alternatives (bus or rail), conditional on choice of these alternatives, are given by:

$$\Pr(Bus|PT) = \frac{exp\left(\frac{V_{Bus}}{\theta_{PT}}\right)}{exp\left(\frac{V_{Bus}}{\theta_{PT}}\right) + exp\left(\frac{V_{Rail}}{\theta_{PT}}\right)} \tag{6}$$

$$\Pr(Rail|PT) = \frac{exp\left(\frac{V_{Rail}}{\theta_{PT}}\right)}{exp\left(\frac{V_{Rail}}{\theta_{PT}}\right) + exp\left(\frac{V_{Bus}}{\theta_{PT}}\right)} \tag{7}$$

$\theta_{PT}$ is the logsum parameter, bounded by zero and one. The logsum parameter measures how similar items are within a nest. The marginal choice probabilities for the automobile, air, and public transit alternatives are:

$$\Pr(Auto) = \frac{\exp(V_{Auto})}{\exp(V_{Auto}) + \exp(V_{Air}) + \exp(V_{PT} + \theta_{PT}\Gamma_{PT})} \tag{8}$$

$$\Pr(Air) = \frac{\exp(V_{Air})}{\exp(V_{Auto}) + \exp(V_{Air}) + \exp(V_{PT} + \theta_{PT}\Gamma_{PT})} \tag{9}$$

$$\Pr(PT) = \frac{\exp(V_{PT} + \theta_{PT}\Gamma_{PT})}{\exp(V_{Auto}) + \exp(V_{Air}) + \exp(V_{PT} + \theta_{PT}\Gamma_{PT})} \tag{10}$$

$\Gamma_{PT}$ represents the expected value of the maximum of the bus and rail utility and is computed as follows:

$$\Gamma_{PT} = log \left| exp\left(\frac{V_{Bus}}{\theta_{PT}}\right) + exp\left(\frac{V_{Rail}}{\theta_{PT}}\right) \right| \tag{11}$$

### 3.3.3. Mixed logit model

The mixed logit model is another alternative to the multinomial logit model. Like the nested logit model, the mixed logit model does not suffer from the IIA property (Hensher and Greene 2003). With improvements in software packages and the development of simulation methods, the mixed logit model became more popular in the 1990s and 2000s, when it became considered one of the more promising state-of-the-art discrete choice models available (Hensher and Greene 2003).

The mixed logit model models heterogeneity of multiple choices, with the probability of choosing alternative j written as

$$P_i(j) = \frac{\exp(x'_{ij}\beta)}{\sum_{k=1}^{J} \exp(x'_{ik}\beta)} \tag{12}$$

where $\beta$ is allowed to vary randomly (SAS 2010). This model uses a Monte Carlo simulation method to estimate the probabilities of each choice. The mixed logit model takes into account that the error components of different alternatives could be correlated by partitioning the stochastic component into two parts

$$U_{ij} = x'_{ij}\beta + [\eta_{ij} + \varepsilon_{ij}] \tag{13}$$

where $\eta_{iq}$ can be correlated among alternatives and heteroscedastic for each individual while $\varepsilon_{ij}$ is independently and identically distributed.

### 3.3.4. Determining appropriate model

The multinomial logit model can be used if the IIA property is not problematic. The Hausman specification test can be conducted to analyze the IIA assumption (SAS 2010). If this test rejects the null hypothesis that the IIA property holds, then a different model that does not assume the IIA property would be more appropriate. The appropriateness of the nested logit model can be determined based on the estimate of the logsum parameters ($\theta$), which measure how similar items are within a nest. If the estimated logsum parameter is statistically insignificant, then the nest is not necessary.

To estimate the mixed logit model, the random parameters must be selected. One method for selecting random parameters, as suggested by Hensher and Greene (2003) is to first assume all parameters are random and then examine their estimated standard deviations using a t-test. Mariel et al. (2011) noted that this is a common procedure for most applications of discrete choice experiments in the literature.

### 3.4. Statewide Travel Demand Model

The estimated mode choice model can be incorporated into a statewide travel demand model to estimate demand for each mode. Such a model estimates an origin-destination (O-D) matrix of trips across the state. By adding the intercity bus network to the model and including data for travel time, access and egress distances, fares, and service frequency, as well as data for other modes, the number of trips taken by bus for each O-D pair can be estimated.

Mode shares for each O-D pair were estimated using travel time for each mode; access and egress distances for bus, rail, and air; current costs for each mode; and service frequency for bus, rail, and air. To account for demographic impacts on mode choice, demographic data for each TAZ were obtained from the American Community Survey.

This model could then be used to estimate the impact of hypothetical changes to the intercity bus network, changes in the service characteristics of intercity bus, changes in the attributes of competing modes, or demographic changes in the state.

# 4. SURVEY RESPONSE AND SUMMARY STATISTICS

This section describes the survey response rate and provides a summary of survey responses, including demographic and transportation characteristics of respondents. Responses to the attitudinal questions and stated preference survey are summarized.

## 4.1. Response Rate

Among the 2,500 paper surveys sent by mail, 226 were returned undeliverable due to incorrect addresses, which left 2,274 surveys that were presumably delivered. A total of 393 responses were received, yielding a response rate of 17.3% (Table 4.1). Recipients of the paper survey had the option of completing the paper survey and returning it by mail or completing it online. Among the 393 responses, 52 were completed online, and 341 were paper responses delivered by mail.

**Table 4.1.** Survey Response Rate

| | Paper + Online | Online Only | Total |
|---|---|---|---|
| Sample | 2,274 | 2,489 | 4,763 |
| Responses* | 393 | 148 | 541 |
| Response Rate | 17.3% | 5.9% | 11.4% |

*For the paper+online survey, 341 paper surveys were completed, and 52 were received online

A second group of 2,500 potential participants received a postcard informing them of the survey with instructions on how to complete the survey online. Recipients were directed to a website where they could participate. Among the 2,500 postcards sent, 11 were returned undeliverable. A total of 148 online responses were received, yielding a 5.9% response rate.

Combined, 541 responses were received from the 4,763 paper surveys or postcards that were delivered. The overall response rate was 11.4%. The response rates were within the range of expectations. The number of responses received per block ranged from 56 to 76.

## 4.2. Summary Statistics

### 4.2.1. Demographic characteristics of respondents

Table 4.2 shows the demographic characteristics of survey respondents. Differences are shown between the paper survey and online survey respondents, and the demographic characteristics of the target population, which is North Dakota adults aged 18 or older, is also presented. Overall, the survey respondents were fairly representative of the North Dakota population. Men were slightly overrepresented, as 55% of respondents were male, compared to 51% of the target population. Young adults under age 25 were underrepresented, while the 25-69 age groups were slightly overrepresented, and adults 80 or older were underrepresented. The gender and age distributions of the survey respondents appear reasonable, though, as men tend to drive more miles per year than women, and those aged 25-69 also drive more miles (Mattson 2012).

Two measures of geographic distribution are illustrated in Table 4.2. First, the state was divided into nine regions based on the first three digits of the zip code, as shown in Figure 4.1. The percentage of respondents from each of these regions closely matched the percentage of the state's population in each region, showing that all regions of the state were adequately represented.

Second, based on respondent zip codes, each individual was classified as living in a metropolitan city, a micropolitan city, a town with population of 2,500 to 10,000, or a rural area, as shown in Table 4.3. There are three metropolitan areas in North Dakota and five micropolitan areas. A respondent was classified as living in a metropolitan city, micropolitan city, or town with a population of 2,500 to 10,000 if his or her zip code belonged to one of the cities shown in Table 4.3.[1] All other zip codes were classified as rural.

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[1] Metropolitan areas are defined as having an urban core area population of 50,000 or more, and micropolitan areas are defined as having an urban core population of 10,000 to 50,000. While Wahpeton has a population of less than 10,000, it combines with Breckinridge, MN, to have an urban core population greater than 10,000. For the classification purposes of this study, only the urban core cities are classified as metropolitan or micropolitan.

**Table 4.2.** Demographic Characteristics of Survey Respondents and Target Population

| Demographic Characteristic | Paper Survey Respondents (No.) | Paper Survey Respondents (%) | Online Survey Respondents (No.) | Online Survey Respondents (%) | Total Survey Respondents (No.) | Total Survey Respondents (%) | Target Population* (%) |
|---|---|---|---|---|---|---|---|
| Gender | | | | | | | |
| Male | 195 | 58 | 102 | 51 | 297 | 55 | 51 |
| Female | 144 | 42 | 98 | 49 | 242 | 45 | 49 |
| No response | 2 | | 0 | | 2 | | |
| Age | | | | | | | |
| <25 | 29 | 9 | 23 | 12 | 52 | 10 | 16 |
| 25-29 | 31 | 9 | 39 | 20 | 70 | 13 | 10 |
| 30-39 | 56 | 17 | 50 | 25 | 106 | 20 | 16 |
| 40-49 | 34 | 10 | 29 | 15 | 63 | 12 | 14 |
| 50-59 | 70 | 21 | 31 | 16 | 101 | 19 | 17 |
| 60-69 | 67 | 20 | 23 | 12 | 90 | 17 | 13 |
| 70-79 | 37 | 11 | 4 | 2 | 41 | 8 | 7 |
| 80+ | 14 | 4 | 1 | 1 | 15 | 3 | 6 |
| No response | 3 | | 0 | | 3 | | |
| 3-Digit Zip Code | | | | | | | |
| 580 | 56 | 16 | 31 | 16 | 87 | 16 | 12 |
| 581 | 52 | 15 | 33 | 17 | 85 | 16 | 16 |
| 582 | 45 | 13 | 35 | 18 | 80 | 15 | 14 |
| 583 | 22 | 6 | 8 | 4 | 30 | 6 | 7 |
| 584 | 24 | 7 | 13 | 7 | 37 | 7 | 7 |
| 585 | 61 | 18 | 48 | 24 | 109 | 20 | 20 |
| 586 | 18 | 5 | 7 | 4 | 25 | 5 | 6 |
| 587 | 35 | 10 | 18 | 9 | 53 | 10 | 13 |
| 588 | 7 | 2 | 3 | 2 | 10 | 2 | 4 |
| No response | 21 | | 4 | | 25 | | |
| Urban/Rural | | | | | | | |
| Metropolitan City | 140 | 44 | 112 | 57 | 252 | 49 | 44 |
| Micropolitan City | 49 | 15 | 27 | 14 | 76 | 15 | 18 |
| Towns 2,500-10,000 | 22 | 7 | 9 | 5 | 31 | 6 | 5 |
| Rural Areas <2,500 | 109 | 34 | 49 | 25 | 158 | 31 | 32 |
| No response | 21 | | 3 | | 24 | | |
| Household Income | | | | | | | |
| < $25,000 | 44 | 13 | 21 | 11 | 65 | 12 | 22 |
| $25,000-$49,999 | 69 | 21 | 42 | 22 | 111 | 21 | 25 |
| $50,000-$74,999 | 84 | 25 | 34 | 17 | 118 | 22 | 19 |
| $75,000-$99,999 | 56 | 17 | 33 | 17 | 89 | 17 | 14 |
| $100,000+ | 80 | 24 | 65 | 33 | 145 | 27 | 20 |
| No response | 8 | | 5 | | 13 | | |

*Sources: American Community Survey 2014 1-Year Estimate, 2009-2013 5-Year Estimates

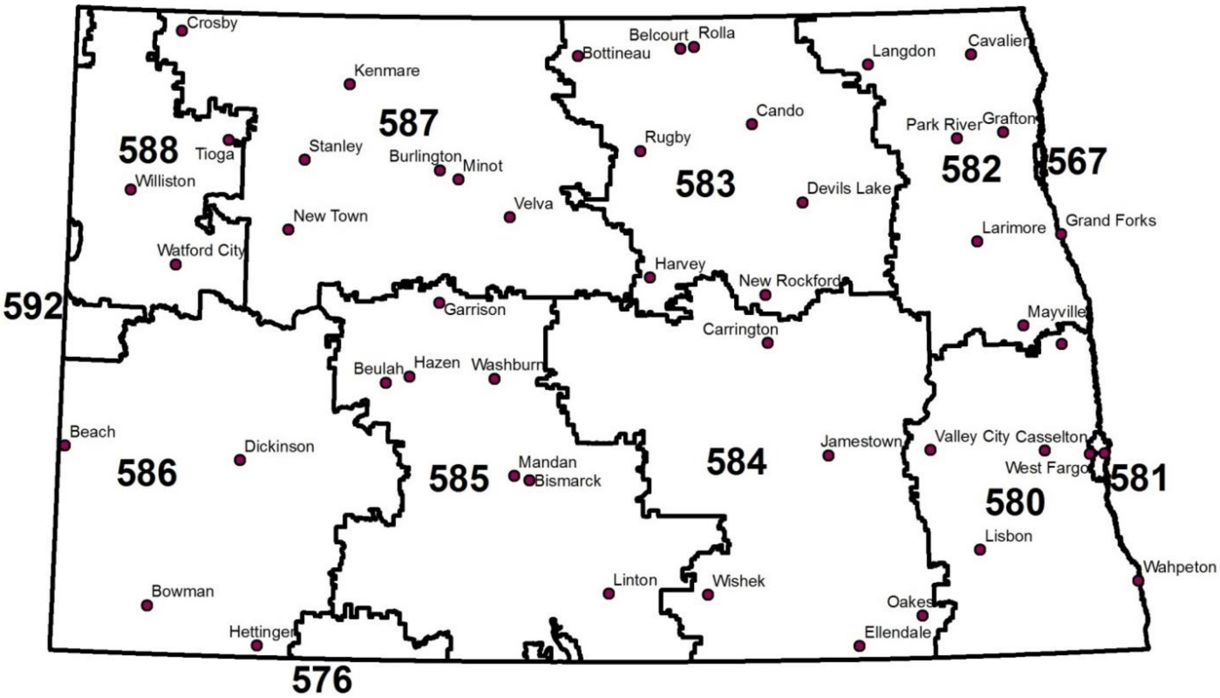


**Figure 4.1.** North Dakota Regions based on Three-Digit Zip Codes

Based on these classifications, 49% of respondents were from a metropolitan city, 15% were from a micropolitan city, 6% were from a town with a population of 2,500 to 10,000, and 31% were from rural areas. This again shows a good geographic distribution of survey respondents, similar to the statewide population distribution, though residents of metropolitan cities were somewhat overrepresented.

**Table 4.3.** Geographic Classification of North Dakota Areas

| Metropolitan City | Micropolitan City | Town 2,500 to 10,000 Population | Rural |
|---|---|---|---|
| Fargo | Minot | Devils Lake | All others |
| West Fargo | Williston | Valley City | |
| Horace | Dickinson | Grafton | |
| Bismarck | Jamestown | Watford City | |
| Mandan | Wahpeton | Beulah | |
| Lincoln | | Rugby | |
| Grand Forks | | Casselton | |

Lastly, Table 4.1 shows the income distribution of survey respondents. While middle-income residents tended to be fairly adequately represented, low-income residents were underrepresented in the survey and high-income residents were overrepresented (12% of respondents had a household income of less than $25,000, compared to the statewide total of 22%). Again, this may be reasonable as higher-income individuals tend to make more trips overall (Mattson 2012).

There are some demographic differences between the paper survey respondents and the online survey respondents. Notably, the online respondents skewed younger, as might be expected. Fifty-six percent of online respondents were younger than 40, and just 14% were 60 or older. Conversely, 34% of paper survey respondents were under the age of 40 and 35% were 60 or older. In addition to being younger, online respondents were more likely to be from a metropolitan area and to have a higher income.

### 4.2.2. Transportation characteristics of respondents

Nearly all survey respondents reported being able to operate an automobile, and just a small percentage reported having a medical condition or disability that makes it difficult to travel (Figure 4.2). More precisely, 34 out of 540 respondents, or 6%, reported having a medical condition or disability that makes it difficult to travel, and just eight respondents, or 1.5%, reported being unable to drive an automobile. Only 1% of respondents were from households without any automobile, while close to four out of five had two or more automobiles in their household. Most respondents (91%) had made a long-distance trip of 100 miles or more one-way within the previous year, though 9%had not taken any such trips. Most respondents were not recent users of intercity bus or rail services, but many had traveled by airplane. Within the previous five years, 15% had traveled by intercity rail, 13% had traveled by intercity bus, and 79% had traveled by airplane.

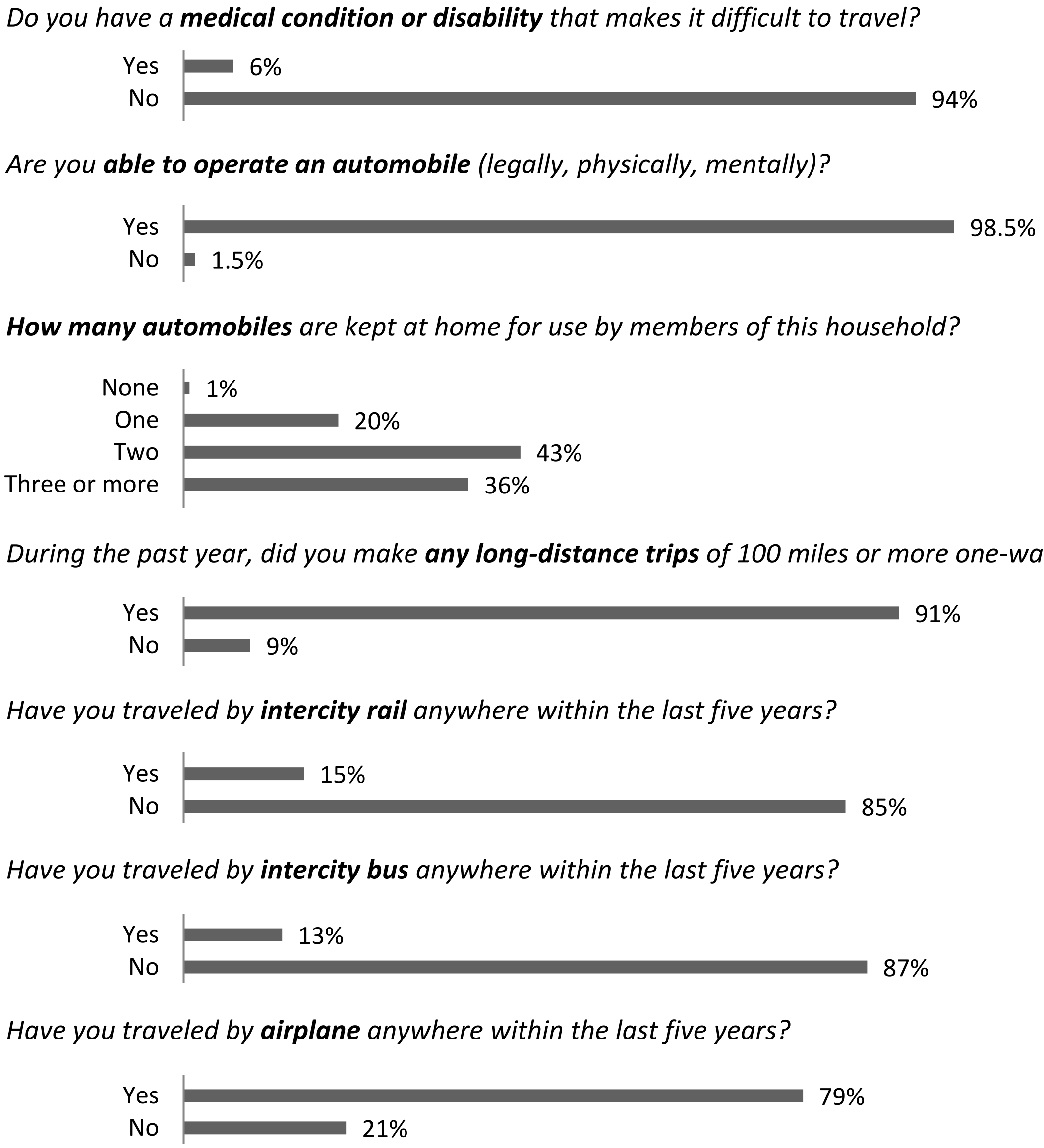


**Figure 4.2.** Transportation Characteristics of Survey Respondents

### 4.2.3. Opinions on ease of travel and need for improvements

Most respondents reported that it was easy for them to travel to other cities in North Dakota. Of 539 responses, 73% answered that it was either easy or very easy (Figure 4.3). Ten percent reported that it was either somewhat difficult, difficult, or very difficult.

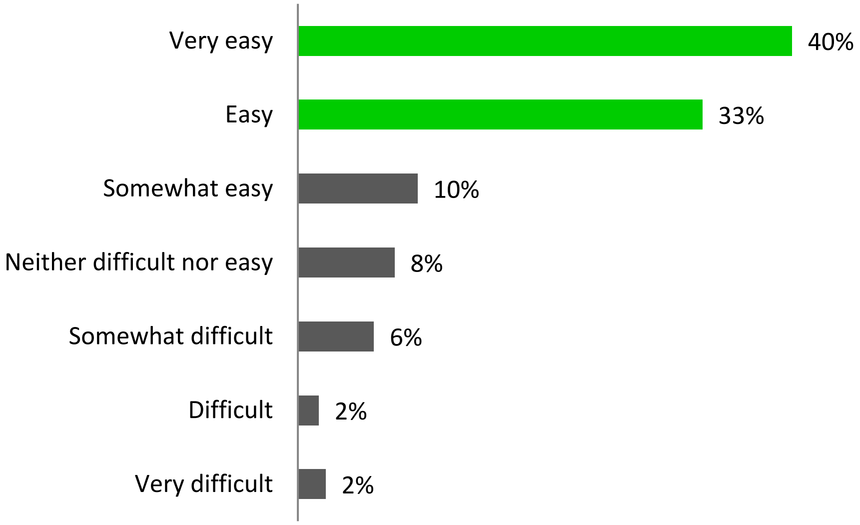
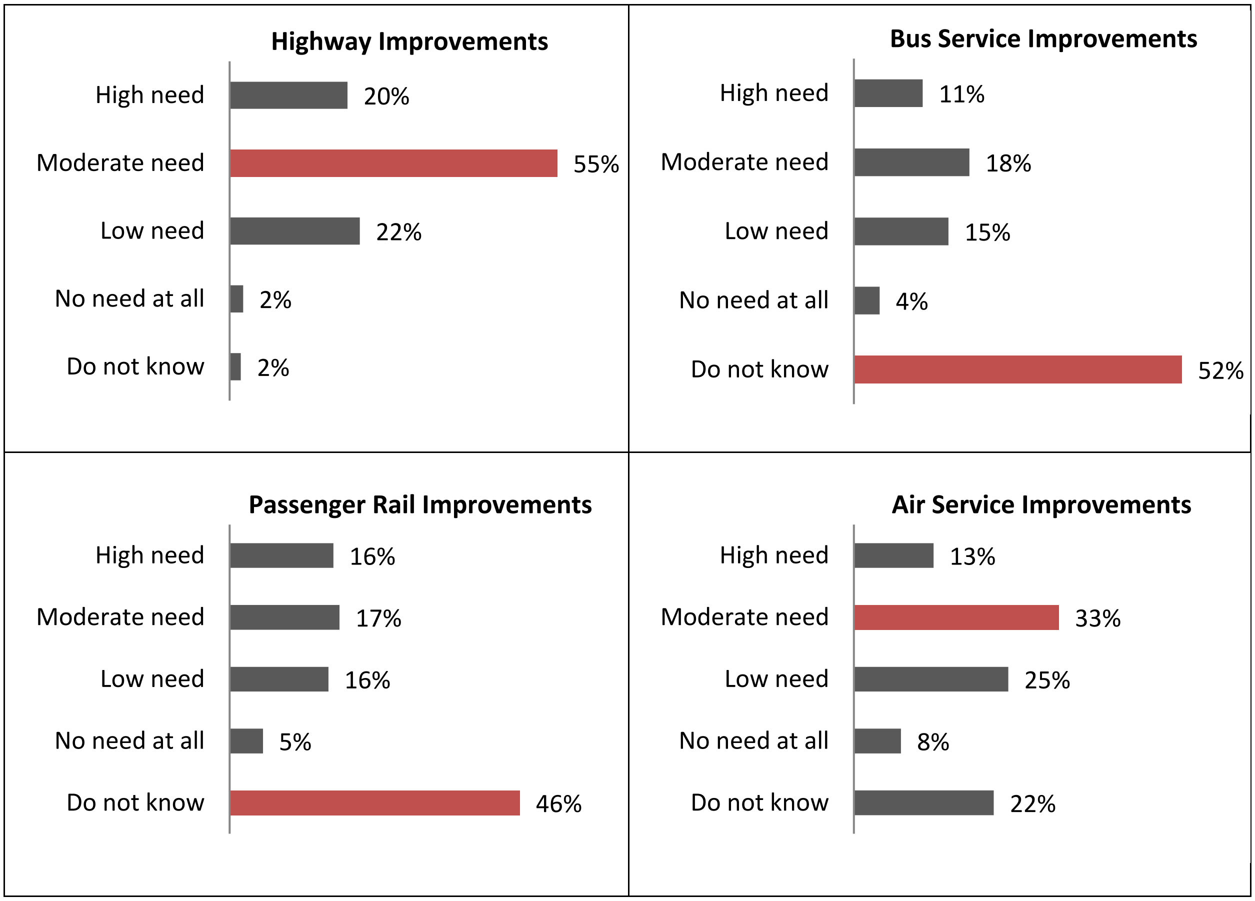


**Figure 4.3.** Survey Responses on How Easy it is to Travel to Other Cities in North Dakota

Survey respondents were then asked, regarding travel between towns and cities in North Dakota, how much there is a need for highway improvements, bus service improvements, passenger rail service improvements, and air service improvements (Figure 4.4). Respondents were most likely to indicate a need for highway improvements, which was not surprising given that the automobile was the predominant mode of travel within the state. Twenty percent indicated a high need for highway improvements, and 55% answered there is a moderate need.

Many answered (about half of respondents) that they do not know if there is a need for bus or rail service improvements, which again was not surprising given the lower usage of these modes. Despite the low use of bus and rail services by these respondents, many indicated a need for service improvements. Twenty-nine percent said there was a high or moderate need for bus service improvements, and 34% answered the same for rail service improvements. Very few answered that there was no need for improvements of bus or rail. Regarding air service, 46% answered there was a high or moderate need for improvements.


Highway Improvements

Bus Service Improvements

Passenger Rail Improvements

Air Service Improvements

**Figure 4.4.** Survey Responses on Need for Intercity Transportation Improvements in North Dakota

### 4.2.4. Opinions on travel

The average responses from the opinion questions on travel preferences and attitudes are shown in Table 4.4. Responses were given on a 1-10 scale, with a higher number indicating greater agreement. The highest rated statement, with an average response of 8.4, was, "If my travel options are delayed, I want to know the cause and length of the delay." In fact, 42% of respondents answered with a 10 on this statement. The next highest rated statements were regarding timeliness, comfort, predictability, and cleanliness.

**Table 4.4.** Response to Opinion Questions

| Average Score | Statement |
|---|---|
| 8.4 | If my travel options are delayed, I want to know the cause and length of the delay. |
| 8.1 | When traveling, I like to keep as close as possible to my departure and arrival schedules. |
| 8.0 | It is important to have comfortable seats when I travel. |
| 8.0 | I prefer a travel option that has a predictable travel time. |
| 7.8 | A clean vehicle is important to me. |
| 7.0 | I would like to make productive use of my time when traveling. |
| 6.8 | I would change my form of travel if it would save me some time. |
| 6.8 | Having a stress-free trip is more important than reaching my destination quickly. |
| 6.2 | I would rather do something else with the time that I spend traveling. |
| 5.9 | Having privacy is important to me when I travel. |
| 5.7 | It’s important to be able to change my travel plans at a moment’s notice. |
| 5.6 | I need to make trips according to a fixed schedule. |
| 5.6 | I avoid traveling at certain times because it is too stressful. |
| 5.6 | The people who fly are like me. |
| 5.5 | I prefer to make trips alone, because I like the time to myself. |
| 5.5 | When traveling, I like to talk and visit with other people. |
| 5.4 | I’m willing to pay more for a ticket if it allows me to re-book my trip later for free. |
| 5.0 | I use the most convenient form of transportation regardless of cost. |
| 5.0 | I always take the fastest route to my destination even if I have a cheaper alternative. |
| 4.7 | I don’t mind traveling with strangers. |
| 4.5 | The people who use intercity rail service are like me. |
| 4.5 | I would switch to a different form of transportation if it would help the environment. |
| 4.4 | I worry about getting in an accident when I travel. |
| 4.4 | I don’t mind long delays as long as I’m comfortable. |
| 4.1 | The people who ride intercity bus are like me. |
| 4.1 | I would be willing to pay more when I travel if it would help the environment. |
| 2.7 | People who travel alone should pay more to help improve the environment. |

Environmental issues were not a primary concern for survey respondents. The lowest-rated statement, with an average score of 2.7, was, "People who travel alone should pay more to help improve the environment." In fact, 45% gave a response of 1 to this statement. Statements regarding the willingness to pay more or to switch to a different form of transportation if it would help improve the environment also received among the lowest scores.

The average response to the statements that people who fly, ride intercity rail, or use intercity bus services are "like me" were 5.6, 4.5, and 4.1, respectively. The lower responses for intercity rail and, especially, bus suggest that people perceive users of these services to be different from them.

Other statements receiving low ratings regarded concerns about getting into an accident (respondents tended to be not too worried) and long delays (although they valued comfortable seats, the statement "I don't mind long delays as long as I'm comfortable" received a low score).

Responses to these attitudinal questions were very similar to those from a previous survey conducted in 2009 (Mattson et al. 2010b). This survey asked the same attitudinal questions of residents from North Dakota and western Minnesota. The differences in responses between the two surveys are largely negligible, as shown in Table 4.5. A t test was conducted to measure the statistical significance of the differences. Most differences were found to be statistically insignificant. A few were found to be statistically significant, but these differences are small in magnitude. There does not appear to be any trend or change in traveler attitudes in North Dakota during this period.

**Table 4.5.** Differences in Traveler Attitudes from 2009 to 2015

| Average Score | | Difference | Statement |
|---|---|---|---|
| 2015 | 2009 | | |
| 5.6 | 5.0 | 0.6** | The people who fly are like me. |
| 6.8 | 6.3 | 0.5** | I would change my form of travel if it would save me some time. |
| 7.0 | 6.5 | 0.5** | I would like to make productive use of my time when traveling. |
| 4.5 | 4.1 | 0.4* | The people who use intercity rail service are like me. |
| 4.4 | 4.0 | 0.4* | I worry about getting in an accident when I travel. |
| 6.2 | 5.8 | 0.4 | I would rather do something else with the time that I spend traveling. |
| 8.0 | 7.6 | 0.4* | I prefer a travel option that has a predictable travel time. |
| 4.1 | 3.8 | 0.3 | The people who ride intercity bus are like me. |
| 5.6 | 5.4 | 0.2 | I need to make trips according to a fixed schedule. |
| 8.4 | 8.2 | 0.2 | If my travel options are delayed, I want to know the cause and length of the delay. |
| 8.1 | 7.9 | 0.2 | When traveling, I like to keep as close as possible to my departure and arrival schedules. |
| 5.4 | 5.2 | 0.2 | I'm willing to pay more for a ticket if it allows me to re-book my trip later for free. |
| 5.5 | 5.4 | 0.1 | I prefer to make trips alone, because I like the time to myself. |
| 4.5 | 4.4 | 0.1 | I would switch to a different form of transportation if it would help the environment. |
| 6.8 | 6.7 | 0.1 | Having a stress-free trip is more important than reaching my destination quickly. |
| 4.4 | 4.3 | 0.1 | I don't mind long delays as long as I'm comfortable. |
| 7.8 | 7.7 | 0.1 | A clean vehicle is important to me. |
| 5.0 | 5.0 | 0.0 | I always take the fastest route to my destination even if I have a cheaper alternative. |
| 5.7 | 5.7 | 0.0 | It's important to be able to change my travel plans at a moment's notice. |
| 4.1 | 4.1 | 0.0 | I would be willing to pay more when I travel if it would help the environment. |
| 8.0 | 8.1 | -0.1 | It is important to have comfortable seats when I travel. |
| 5.9 | 6.0 | -0.1 | Having privacy is important to me when I travel. |
| 5.5 | 5.6 | -0.1 | When traveling, I like to talk and visit with other people. |
| 5.0 | 5.2 | -0.2 | I use the most convenient form of transportation regardless of cost. |
| 4.7 | 4.9 | -0.2 | I don't mind traveling with strangers. |
| 5.6 | 6.0 | -0.4 | I avoid traveling at certain times because it is too stressful. |
| 2.7 | 3.1 | -0.4 | People who travel alone should pay more to help improve the environment. |

* denotes difference is statistically significant at $p<0.05$
** denotes difference is statistically significant at $p<0.01$

### 4.2.5. Stated preference response

With each survey respondent given nine different SP questions to answer, there were a total of 4,724 responses received. The automobile was the mode of choice in 73% of these responses, while air, rail, and bus accounted for 13%, 10%, and 4% of responses, respectively (Figure 4.5). While it was expected that the automobile would be the dominant mode of choice, the results also revealed a clear preference for rail travel over bus travel. More interesting than the overall mode shares is how mode shares change with changes in demographic, trip, and mode characteristics.

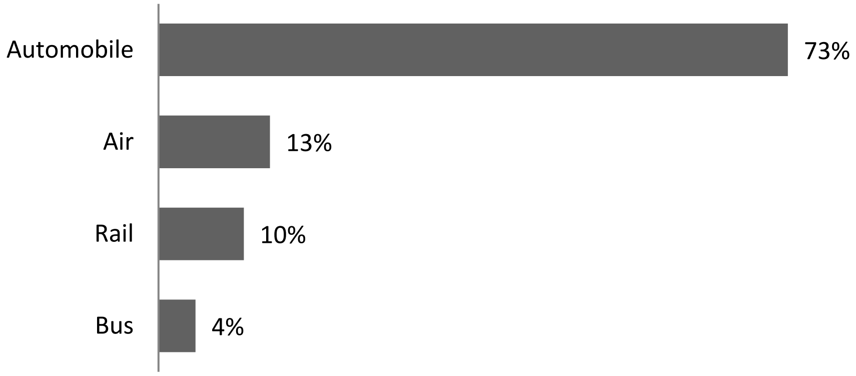


**Figure 4.5.** Mode Choice Responses from Stated Preference Survey

Table 4.6 shows changes in mode choices with changes in demographic characteristics. Men were more likely than women to choose automobile, and a greater percentage of women chose rail travel. Older adults (age 70 or older) and younger adults (age 18-24) were more likely to choose bus travel. Older adults tended to be less likely to choose air travel, choosing automobile travel instead. Those from lower income households tended to be less likely than others to choose automobile or air travel and more likely to choose bus or rail travel. For example, bus travel was chosen 6% of the time by those with income below $50,000 but just 3% of the time by those with income of $75,000 or more. Similar differences were found for rail travel.

**Table 4.6.** Mode Choice Data from the Stated Preference Survey by Individual Characteristics

| Characteristic | Auto (%) | Air (%) | Bus (%) | Rail (%) |
|---|---|---|---|---|
| Gender | | | | |
| Male | 75 | 12 | 4 | 8 |
| Female | 70 | 14 | 4 | 12 |
| Age | | | | |
| < 25 | 71 | 13 | 6 | 10 |
| 25-49 | 70 | 16 | 4 | 10 |
| 50-69 | 77 | 11 | 4 | 9 |
| 70+ | 76 | 7 | 6 | 11 |
| Household Income | | | | |
| <$25,000 | 69 | 11 | 6 | 14 |
| $25,000-$49,999 | 67 | 14 | 6 | 12 |
| $50,000-$74,999 | 78 | 10 | 4 | 8 |
| $75,000-$99,999 | 74 | 14 | 3 | 9 |
| $100,000+ | 74 | 14 | 3 | 9 |

The age composition of respondents who chose each mode is presented in Table 4.7. Among those who chose the bus, 13.8% were aged 18-24 and 14.3% were aged 70 or older. Comparatively, among all SP survey responses, 9.7% were from those aged 18-24 and 10.4% were from those 70 or older. This result shows bus travel having a larger share of young users and old users, compared to other modes, though the difference may not be as great as shown in some surveys of intercity bus users. The table also shows that just 5.9% of those who chose bus were 70 or older.

**Table 4.7.** Age Composition by Mode Chosen in Stated Preference Survey

| | Age | | |
|---|---|---|---|
| | <25 (%) | 25-69 (%) | 70+ (%) |
| Mode chosen | | | |
| Automobile | 9.5 | 79.6 | 10.9 |
| Air | 9.8 | 84.3 | 5.9 |
| Bus | 13.8 | 71.9 | 14.3 |
| Rail | 10.1 | 78.5 | 11.4 |
| All respondents | 9.7 | 79.9 | 10.4 |

Mode choice percentages changed significantly for automobile, air, and rail travel based on the length of the trip, as shown in Table 4.8. Auto shares decreased with increases in travel distance, while air and rail shares increased. While air travel was rarely chosen for 50- or 100-mile trips, it was chosen 12% of the time for 250-mile trips and 37% of the time for 400-mile trips. Meanwhile, rail shares increased from 6% for 50-mile trips to 14% for 400-mile trips. Bus shares, on the other hand, were consistently 4-5%, regardless of trip distance.

Respondents were more likely to choose automobile travel for personal trips than for business trips, while air, bus, and rail travel were chosen more often for business trips. These results are consistent with previous findings by Mattson et al. (2010b). Survey findings also showed that those traveling alone were less likely to choose the automobile and more likely to choose bus and rail travel. This finding is reasonable as there is more of a cost disadvantage for groups to travel by bus or rail (as well as air) because each traveler would need to purchase a ticket, whereas they could share the cost of automobile travel.

**Table 4.8.** Mode Choice Data from the Stated Preference Survey by Trip Characteristics

| Characteristic | Auto (%) | Air (%) | Bus (%) | Rail (%) |
|---|---|---|---|---|
| Trip distance | | | | |
| 50 miles | 89 | 1 | 4 | 6 |
| 100 miles | 85 | 2 | 4 | 8 |
| 250 miles | 71 | 12 | 4 | 12 |
| 400 miles | 45 | 37 | 5 | 14 |
| Trip purpose | | | | |
| Personal | 77 | 11 | 3 | 9 |
| Business | 69 | 15 | 5 | 11 |
| Party Size | | | | |
| Alone | 71 | 13 | 5 | 11 |
| Group | 75 | 13 | 3 | 8 |

The impacts of mode characteristics on mode choices are shown in Table 4.9. Of note are the changes in mode choices as the price of gasoline changes. As the price of gasoline increases from $2.00 to $5.00, the auto share decreases from 79% to 65%, while the bus share increases from 3% to 6% and the rail share increases from 6% to 15%. The most significant impacts occur as the price of gasoline increases from $3.50 to $5.00. The impacts on mode shares are much smaller when the gasoline price varies between $2.00 and $3.50.

The impact of trip cost demonstrates the changes in mode shares for each mode as the cost of that mode changes from low to medium to high. For example, bus travel was chosen 5% of the time when the bus price was low and 3% of the time when the bus price was high. Three price levels were surveyed for each mode, as shown previously in Table 3.2. The results are as expected, with each mode being chosen less often as its cost increases.

**Table 4.9.** Mode Choice Data from the Stated Preference Survey by Mode Characteristics

| Characteristic | Auto (%) | Air (%) | Bus (%) | Rail (%) |
|---|---|---|---|---|
| Price of gasoline | | | | |
| $2.00/gallon | 79 | 12 | 3 | 6 |
| $3.50/gallon | 75 | 14 | 3 | 8 |
| $5.00/gallon | 65 | 14 | 6 | 15 |
| Trip cost | | | | |
| Low | 79 | 16 | 5 | 13 |
| Medium | 75 | 13 | 5 | 9 |
| High | 65 | 10 | 3 | 8 |
| Speed | | | | |
| Slow | na | 10 | 4 | 7 |
| Medium | na | na | 4 | 11 |
| Fast | na | 16 | 5 | 11 |
| Access distance | | | | |
| 2 miles | na | 12 | 5 | 11 |
| 10 miles | na | 13 | 4 | 10 |
| 20 miles | na | 13 | 4 | 8 |
| Egress distance | | | | |
| 1 mile | na | 13 | 5 | 11 |
| 5 miles | na | 12 | 5 | 9 |
| 10 miles | na | 14 | 3 | 10 |
| Frequency | | | | |
| Three times per week | na | 14 | 4 | 10 |
| Once per day | na | 12 | 5 | 10 |
| Twice per day | na | 13 | 5 | 9 |

na = not applicable

Similarly, Table 4.9 shows changes in mode shares for each mode with changes in its own speed, access and egress distance, and service frequency. As expected, each mode is chosen more often when it travels at a higher speed. Respondents tended to be more likely to choose bus and rail travel as access and egress distances for those modes decreased, though access and egress distances do not appear to have any impact on choice of air travel. Lastly, service frequency did not appear to influence choice of air or rail travel, while there was a slight increase in bus shares as bus frequency increased.

These statistics are based on the raw survey data and are presented to illustrate correlations found in the survey responses. To determine the statistical significance of these relationships and disentangle the various factors that could be impacting mode choice, these data are analyzed using a discrete choice mode choice model, as described in Section 3.3. The model specification is detailed in Section 5 and results are presented in Section 6.

Further, the results from the survey are all based on the hypothetical conditions presented in the stated choice experiments and may not be representative of real-world conditions present to North Dakota travelers. For example, many North Dakotans do not live within 20 miles of a rail or bus station, so the actual, real-world mode share for bus and rail travel are expected to be smaller. Real-world conditions will be considered when the mode choice model is incorporated into a statewide travel demand model, which will estimate actual access and egress distances and travel times for each mode. This incorporation into the statewide model is presented in Section 7.

# 5. MODEL SPECIFICATION

Two models were estimated. The first was a mixed logit mode choice model designed to be incorporated into a statewide travel demand model. The second was a binary logit model used to examine the impacts of attitudes on choice of mode.

## 5.1. Mixed Logit Mode Choice Model

As discussed in Section 3, the deterministic portion of the utility is written as follows:

$$V_{jk} = \beta' X_j + \gamma' Y_j + \theta' Z_{jk} \tag{14}$$

where $X_j$ are the characteristics of individual $j$; $Y_j$ are the trip characteristics for individual $j$; $Z_{jk}$ are the attributes of alternative $k$ for individual $j$; and $\beta'$, $\gamma'$, and $\theta'$ are the parameter vectors associated with the vectors $X_j$, $Y_j$, and $Z_{jk}$, respectively. More specifically, utility for each mode is specified as follows:

$$\begin{aligned} V_{auto} = {} & \beta_{1auto} \cdot x_{1auto} + \beta_{2auto} \cdot x_{2auto} + \beta_{3auto} \cdot x_{3auto} + \beta_{4auto} \cdot x_{4auto} + \beta_{5auto} \cdot x_{5auto} \\ & + \gamma_{1auto} \cdot y_{1auto} + \gamma_{2auto} \cdot y_{2auto} + \theta_{1auto} \cdot z_{1auto} + \theta_2 \cdot z_{2auto} + \theta_{3m} \cdot z_{3auto} \end{aligned} \tag{15}$$

$$\begin{aligned} V_{air} = {} & \beta_{1air} \cdot x_{1air} + \beta_{2air} \cdot x_{2air} + \beta_{3air} \cdot x_{3air} + \beta_{4air} \cdot x_{4air} + \beta_{5air} \cdot x_{5air} + \gamma_{1air} \cdot y_{1air} \\ & + \gamma_{2air} \cdot y_{2air} + \theta_{1air} \cdot z_{1air} + \theta_2 \cdot z_{2air} + \theta_3 \cdot z_{3air} + \theta_4 \cdot z_{4air} + \theta_5 \cdot z_{5air} + \theta_6 \cdot z_{6air} + \theta_7 \cdot z_{7air} \end{aligned} \tag{16}$$

$$\begin{aligned} V_{bus} = {} & \beta_{1bus} \cdot x_{1bus} + \beta_{2bus} \cdot x_{2bus} + \beta_{3bus} \cdot x_{3bus} + \beta_{4bus} \cdot x_{4bus} + \beta_{5bus} \cdot x_{5bus} + \gamma_{1bus} \cdot y_{1bus} \\ & + \gamma_{2bus} \cdot y_{2bus} + \theta_{1bus} \cdot z_{1bus} + \theta_2 \cdot z_{2bus} + \theta_3 \cdot z_{3bus} + \theta_4 \cdot z_{4bus} + \theta_5 \cdot z_{5bus} + \theta_6 \cdot z_{6bus} + \theta_7 \cdot z_{7bus} \end{aligned} \tag{17}$$

$$V_{rail} = \theta_2 \cdot z_{2rail} + \theta_3 \cdot z_{3rail} + \theta_4 \cdot z_{4rail} + \theta_5 \cdot z_{5rail} + \theta_6 \cdot z_{6rail} + \theta_7 \cdot z_{7rail} \tag{18}$$

where

$x_{1auto}$ = male dummy variable times automobile dummy variable

$x_{1air}$ = male dummy variable times air dummy variable

$x_{1bus}$ = male dummy variable times bus dummy variable

$x_{2auto}$ = dummy variable for age $18 - 24$ age group times automobile dummy variable

$x_{2air}$ = dummy variable for age $18 - 24$ age group times air dummy variable

$x_{2bus}$ = dummy variable for age $18 - 24$ age group times bus dummy variable

$x_{3auto}$ = dummy variable for age 70 or older age group times automobile dummy variable

$x_{3air}$ = dummy variable for age 70 or older age group times air dummy variable

$x_{3bus}$ = dummy variable for age 70 or older age group times bus dummy variable

$x_{4auto}$ = income times automobile dummy variable

$x_{4air}$ = income times air dummy variable

$x_{4bus}$ = income times bus dummy variable

$x_{5auto}$ = dummy variable for disability times automobile dummy variable

$x_{5air}$ = dummy variable for disability times air dummy variable

$x_{5bus}$ = dummy variable for disability times bus dummy variable

$y_{1auto}$ = dummy variable for traveling alone times automobile dummy variable

$y_{1air}$ = dummy variable for traveling alone times air dummy variable

$y_{1bus}$ = dummy variable for traveling alone times bus dummy variable

$y_{2auto}$ = dummy variable for personal trip times automobile dummy variable

$y_{2air}$ = dummy variable for personal trip times air dummy variable

$y_{2bus}$ = dummy variable for personal trip times bus dummy variable

$z_{1auto}$ = automobile dummy variable

$z_{1air}$ = air dummy variable

$z_{1bus}$ = bus dummy variable

$z_{2auto}$ = automible travel time

$z_{2air}$ = air travel time

$z_{2bus}$ = bus travel time

$z_{3auto}$ = automobile travel cost

$z_{3air}$ = air travel cost

$z_{3bus}$ = bus travel cost

$z_{4air}$ = air access distance

$z_{4bus}$ = bus access distance

$z_{4rail}$ = rail access distance

$z_{5air}$ = air egress distance

$z_{5air}$ = bus egress distance

$z_{5air}$ = rail egress distance

$z_{6air}$ = air frequency dummy variable for lowest frequency

$z_{6bus}$ = bus frequency dummy variable for lowest frequency

$z_{6rail}$ = rail frequency dummy variable for lowest frequency

$z_{7air}$ = air frequency dummy variable for highest frequency

$z_{7bus}$ = bus frequency dummy variable for highest frequency

$z_{7rail}$ = rail frequency dummy variable for highest frequency

In this model, the characteristics of the individual included age, gender, income, and if they have a disability. Interaction terms between these variables and mode-specific dummy variables were included in the model to show the effect of individual characteristics on choice of specific modes.

Age was categorized into three groups: 18-24, 25-69, and 70 and older. Travel behavior may differ between these three age groups. The 18-24 age group, which consists of college students and younger adults, has been shown in some research to be more likely to use intercity bus services. The 25-69 age group consists of working-age individuals who, on average, drive more and may be more likely to choose automobile travel. The 70 and older group consists of older adults who may have reduced driving abilities and may be less inclined to drive long distances or travel by air. The model includes dummy variables for the 18-24 age group and 70+ age group, with the middle age group used as the reference.

Income was measured with a 1-5 scale, with 1 = less than \$25,000, 2 = \$25,000 to \$49,999, 3 = \$50,000 to \$74,999, 4 = \$75,000 to \$99,999, and 5 = \$100,000 or more. Disability was measured with a dummy variable equal to 1 if the individual answered that they have a medical condition or disability that makes it difficult to travel, and 0 otherwise.

Trip-specific characteristics included party size (traveling alone vs. in a group) and trip purpose (business or personal). Again, interaction terms between these variables and mode-specific dummy variables were included in the model to show the effect of trip characteristics on choice of specific modes.

Lastly, mode attributes included travel time, price, access distance, egress distance, and service frequency. Travel time was measured in hours, price in dollars per mile, access and egress distance in miles, and service frequency with dummy variables indicating the lowest and highest levels of frequency. Mode-specific dummy variables were also included in the model to account for mode preferences not accounted for by other variables in the model. The rail dummy variable was excluded from the model, so rail is considered the base or reference mode.

The model tests the following hypotheses, which were developed based on theory, findings from previous research, and survey results:

- Gender influences mode choice; men are more likely than women to drive.
- Younger adults (aged 18-24) are more likely than others to choose intercity bus.
- Older adults (aged 70 or older) are more likely than others to choose intercity bus.
- Those with higher income are less likely to choose bus and more likely to choose automobile or air.
- People with a disability are less likely to drive and more likely to choose bus.
- People traveling alone are more likely to choose bus than those traveling in a group.
- Those traveling for personal reasons are more likely to choose the automobile than those traveling for business.
- Travel time negatively impacts choice of mode.
- Travel cost negatively impacts choice of mode.
- Access distance negatively impacts choice of mode.
- Egress distance negatively impacts choice of mode.
- Service frequency positively impacts choice of mode.
- Everything else equal, travelers are less likely to choose bus than other modes.

Multinomial logit, nested logit, and mixed logit specifications of the model were all attempted. First, a multinomial logit model was estimated, and a Hausman specification test was conducted to analyze the IIA assumption (SAS 2010). Under the null hypothesis, the

IIA property holds. Based on the test, which was run using the %IIA macro in SAS, the null hypothesis was rejected (p-value <0.01), indicating that an alternative model could be more appropriate.

Next, a nested logit model was estimated, as specified in section 3.3.3, with bus and rail nested together as an upper level choice. However, the logsum parameter for the public transit nest was not found to be statistically significant, indicating that the nest was not necessary.

A mixed logit model, therefore, was specified, based on it being a state-of-the-art model that does not rely on the IIA assumption. To select random parameters, following Hensher and Greene (2003), all parameters were first assumed to be random and then their estimated standard deviations were examined using a t-test. This approach was conducted, and two variables were found to have statistically significant standard deviations (travel time and price). These variables were then selected to be random in the final model. The random parameters were assumed to take a normal distribution.

The use of stated preference data with multiple SP responses from individual respondents results in repeated observations, or multiple observations from the same individual. Mehndiratta and Hansen (1997) noted that analysis of such data is complicated by the correlation of responses across the choices made by a single individual. They found that random parameter models offer advantages over standard logit models when repeated choice data are used. Further, Rose et al. (2011) argued that large improvements have been made with the use of the mixed multinomial logit model in cases where datasets contain multiple observations per respondent.

The analyses were conducted using SAS 9.3. Appendix C shows SAS code that was used, and SAS printouts of each of the models are provided in Appendix D. SAS code was developed with guidance from the SAS User’s Guide (SAS 2010).

## 5.2. Binary Logit Models to Estimate Effects of Attitudes on Mode Choice

In addition to the individual, trip, and mode characteristics included in the mode choice model, individuals have their own beliefs and attitudes about travel that are not directly observable but influence mode choice. As shown in section 4.2.4, the survey asked respondents a series of opinion questions regarding travel preferences and attitudes. These attitudinal variables were not included in the mixed logit model because doing so would have required adding numerous variables. Further, because attitudinal characteristics are not directly observable, including them in a mode choice model is not as useful for predicting ridership. Some of those attitudes may also be correlated to demographic characteristics already included in the model.

However, examining the influence of attitudes is important for understanding why some people choose a particular mode of travel. Knowledge about how attitudes influence mode choice can be used by intercity bus and rail companies for improving and marketing their services to attract new customers.

To examine the impact of attitudes on mode choice, separate binary logit models were estimated for each of the four modes. In these models, the dependent variable was equal to 1 if the mode was chosen and 0 if not. Mode characteristics (travel time and cost for the mode and competing modes) and trip characteristics (trip purpose, and party size) were included as explanatory variables with the addition of the 27 attitudinal responses given by the individual. These attitudinal variables were measures on a scale from 1 to 10, with a higher number indicating greater agreement with the attitude statement.

The binary logit models test the following hypotheses:

- Those with greater concern for the environment would be more likely to choose bus or rail travel and less likely to choose automobile travel.
- Those who want to make more productive use or their time or who want to do something else while traveling would be less likely to choose auto and more likely to choose the alternatives.

- Those who are more sensitive to travel time would be more likely to choose air and less likely to choose bus or rail.
- Those who value flexibility would be more likely to travel by automobile.
- Those concerned about privacy would be more likely to choose the automobile and less likely to choose air, bus, or rail.
- Those concerned about safety and stress would be more likely to travel by bus or rail.
- Individuals are more likely to choose a given mode if they perceive other users of that mode to be similar to them.

# 6. MODE CHOICE MODEL RESULTS

## 6.1. Mixed Logit Model Results

A total of 4,607 observations were used to estimate the model. Estimated results are shown in Table 6.1. The table also shows odds ratios for the statistically significant variables. The odds ratio is a way of comparing whether the probability of an event is the same for two groups of people. The odds of an event happening is equal to the probability of it happening divided by the probability of it not happening. An odds ratio is calculated by dividing the odds in group 1 by the odds in group 2. An odds ratio of 1 indicates the event is equally probable for the two groups, while an odds ratio greater than 1 indicates the event is more likely among the first group. An odds ratio less than 1 indicates the event is less likely among the first group. For variables not represented by a dummy variable, such as income (which is measured on a scale), travel time, price, and access and egress distance, the odds ratio is the estimated change in the odds of choosing a mode with a one unit increase in the variable.

### 6.1.1. Impacts of individual characteristics

Among the individual characteristics, gender, age, income, and disability were all found to have some effect on mode choice. Men were found to have greater odds of choosing automobile or bus travel.

Regarding age, adults aged 70 or older were found to be less likely to choose air travel. Odds of choosing air travel decreased by 54% for older adults. Younger adults, aged 18-24, were found to be more likely to choose bus travel. The odds of choosing bus travel increased 61% for younger adults. This finding is consistent with other research showing younger adults being more likely to choose bus travel. The negative impact of age on choice of air travel was also found in previous research by Mattson et al. (2010a,b).

**Table 6.1.** Estimated Mixed Logit Mode Choice Model

| Variable | Variable description | Parameter Estimate | t value | Odds Ratio |
|---|---|---|---|---|
| Individual characteristics | | | | |
| $x_{1auto}$ | Male x Auto | 0.4425 | 3.98*** | 1.56 |
| $x_{1air}$ | Male x Air | 0.0871 | 0.46 | |
| $x_{1bus}$ | Male x Bus | 0.508 | 2.76*** | 1.66 |
| $x_{2auto}$ | Age 18-24 x Auto | 0.1778 | 0.97 | |
| $x_{2air}$ | Age 18-24 x Air | 0.123 | 0.39 | |
| $x_{2bus}$ | Age 18-24 x Bus | 0.4762 | 1.68* | 1.61 |
| $x_{3auto}$ | Age 70+ x Auto | 0.135 | 0.73 | |
| $x_{3air}$ | Age 70+ x Air | -0.7658 | -2.29** | 0.46 |
| $x_{3bus}$ | Age 70+ x Bus | 0.0712 | 0.25 | |
| $x_{4auto}$ | Income x Auto | 0.096 | 2.22** | 1.10 |
| $x_{4air}$ | Income x Air | 0.1905 | 2.63*** | 1.21 |
| $x_{4bus}$ | Income x Bus | -0.1167 | -1.57 | |
| $x_{5auto}$ | Disability x Auto | -0.8052 | -4.3*** | 0.45 |
| $x_{5air}$ | Disability x Air | -1.4034 | -3.16*** | 0.25 |
| $x_{5bus}$ | Disability x Bus | 0.2571 | 0.91 | |
| Trip characteristics | | | | |
| $y_{1auto}$ | Travel alone x Auto | -0.3531 | -3.28*** | 0.70 |
| $y_{1air}$ | Travel alone x Air | -0.2013 | -1.11 | |
| $y_{1bus}$ | Travel alone x Bus | 0.1236 | 0.69 | |
| $y_{2auto}$ | Personal trip x Auto | 0.3108 | 2.88*** | 1.36 |
| $y_{2air}$ | Personal trip x Air | -0.4977 | -2.67*** | 0.61 |
| $y_{2bus}$ | Personal trip x Bus | -0.1997 | -1.1 | |
| Mode characteristics | | | | |
| $z_{1auto}$ | Auto dummy | 1.1581 | 5.87*** | 3.18 |
| $z_{1air}$ | Air dummy | 0.9613 | 2.95*** | 2.62 |
| $z_{1bus}$ | Bus dummy | -0.8797 | -2.9*** | 0.41 |
| $z_{2m}$ | Travel time mean | -0.2706 | -6.21*** | 0.76 |
| $z_{2s}$ | Travel time st. dev. | -0.6322 | -10.16*** | 0.53 |
| $z_{3m}$ | Price mean | -5.4204 | -11.04*** | 0.00 |
| $z_{3s}$ | Price st. dev. | -2.4231 | -8.49*** | 0.09 |
| $z_4$ | Access distance | -0.0189 | -3.57*** | 0.98 |
| $z_5$ | Egress distance | -0.005461 | -0.53 | |
| $z_6$ | Frequency level 1 | -0.0149 | -0.16 | |
| $z_7$ | Frequency level 3 | 0.0197 | 0.22 | |

Goodness of fit measures

| | | | |
|---|---|---|---|
| Cragg-Uhler 1 | 0.7296 | Adjusted Estrella | 0.8253 |
| Cragg-Uhler 2 | 0.7783 | McFadden's LRI | 0.4717 |
| Estrella | 0.8296 | Veall-Zimmermann | 0.7711 |

*,**,*** denote significance at the 10%, 5%, and 1% levels, respectively

Income was found to have a statistically significant impact on mode choice. As income increased, individuals were more likely to choose automobile and air travel.

The impact of having a disability on mode choice was also found to be statistically significant and large in magnitude. People with a disability were much less likely to choose automobile or air travel and, therefore, more likely to choose bus and rail travel, compared to those without a disability.

### 6.1.2. Impacts of trip characteristics

The results show that party size and trip purpose have some significant effects on mode choice. Individuals traveling alone were found to be less likely to choose automobile travel, and, therefore, more likely to choose air, bus, or rail travel. In other words, respondents were more likely to choose automobile travel if they were traveling with a group of people. This result makes sense, because automobile travel becomes more cost effective as the size of the travel group increases (travel by other modes would require multiple fare payments).

Those taking personal trips were found to be more likely to choose automobile travel and less likely to choose air travel. The odds of choosing the automobile increased 36% if it was a personal trip, while the odds of choosing air decreased 39% for personal trips. Conversely, if the person was asked to take a business trip, the probability of choosing air increased and the probability of choosing automobile decreased. This result also makes sense, because business travelers may place a higher value on time and could be less sensitive to trip cost.

### 6.1.3. Impacts of mode characteristics

Travel time and travel price (consisting of fares and price of gasoline) were found to have negative and statistically significant impacts on mode choice, as expected. Access distances for bus, rail, and air travel were found to have negative and statistically significant impacts on mode choice, also as expected, but the impact of egress distance, while shown to also be negative, was not found to be statistically significant. Service frequency was not found to have a statistically significant effect.

The insignificant impacts of egress distance and service frequency may indicate that these variables are less important, or not important, but the complexity of the survey may have led respondents to focus on the factors they deemed most important, such as travel time and cost, while paying less attention to the other factors. In the real world, individuals may consider a wider range of variables. Another possible explanation for the insignificant impact of frequency is that individuals who do not typically use transit may not appreciate the importance of frequency and, therefore, may not consider it when evaluating options.

Finally, the estimates for the mode-specific dummy variables show that, all other variables equal, respondents were significantly more likely to choose automobile travel (in comparison to all other modes) and air travel (in comparison to bus and rail), and were least likely to choose bus.

## 6.2. Attitudes and Mode Choice Results

Table 6.2 shows the odds ratios for each of the attitudes estimated from the binary logit model for each of the four modes. An odds ratio greater than 1 indicates an increased probability of choosing that mode if the respondent rated a higher agreement with the statement, and an odds ratio less than 1 indicates a decreased probability. (Estimated results for the mode and trip characteristics are not shown in the table but can be found in Appendix D.) A number of the results are statistically significant, as indicated by the asterisks. Many of the results are as expected, though some are unexpected.

The first three attitudes regard the environment. Respondents who gave higher scores tended to be more likely to choose bus and rail services, except for two results that were counter-intuitive: those who would be willing to pay more if it would help the environment were more likely to choose automobile and less likely to choose rail. The results suggest environmental concerns may play a role in supporting intercity bus and rail travel, but the results are inconsistent, and some results are not statistically significant.

**Table 6.2.** Impacts of Attitudes on Mode Choice, Results from Binary Logit Model

| Opinion Statement | Auto | Air | Bus | Rail |
|---|---|---|---|---|
| | ---------------Odds Ratios--------------- | | | |
| People who travel alone should pay more to help improve the environment. | 0.95** | 0.97 | 1.01 | 1.11*** |
| I would be willing to pay more when I travel if it would help the environment. | 1.09*** | 0.90*** | 1.09* | 0.93** |
| I would switch to a different form of transportation if it would help the environment. | 0.92*** | 1.05 | 1.02 | 1.10*** |
| I would rather do something else with the time that I spend traveling. | 0.94*** | 1.13 | 0.95 | 1.02 |
| I would like to make productive use of my time when traveling. | 0.99 | 0.93* | 1.06 | 1.09** |
| I prefer a travel option that has a predictable travel time. | 1.08** | 0.97 | 0.91 | 0.93 |
| When traveling, I like to keep as close as possible to my departure and arrival schedules. | 1.01 | 1.00 | 0.97 | 1.03 |
| If my travel options are delayed, I want to know the cause and length of the delay. | 1.00 | 0.88*** | 1.06 | 1.09* |
| I would change my form of travel if it would save me some time. | 0.87*** | 1.19*** | 1.10** | 1.06* |
| I always take the fastest route to my destination even if I have a cheaper alternative. | 0.98 | 0.97 | 1.03 | 1.05* |
| I don’t mind traveling with strangers. | 0.92*** | 1.00 | 1.13*** | 1.08*** |
| When traveling, I like to talk and visit with other people. | 1.10*** | 0.98 | 0.96 | 0.87*** |
| I prefer to make trips alone, because I like the time to myself. | 1.04* | 0.99 | 0.91** | 0.97 |
| I worry about getting in an accident when I travel. | 0.95*** | 1.06** | 1.05 | 1.00 |
| Having privacy is important to me when I travel. | 1.03 | 1.00 | 0.97 | 0.97 |
| I need to make trips according to a fixed schedule. | 0.98 | 1.06** | 1.03 | 0.96 |
| It’s important to be able to change my travel plans at a moment’s notice. | 1.04** | 0.98 | 0.97 | 0.99 |
| Having a stress-free trip is more important than reaching my destination quickly. | 1.02 | 0.87*** | 1.14** | 1.05 |
| I don’t mind long delays as long as I’m comfortable. | 0.94*** | 1.08*** | 0.91** | 1.08*** |
| It is important to have comfortable seats when I travel. | 0.99 | 1.02 | 0.96 | 1.01 |
| I avoid traveling at certain times because it is too stressful. | 1.01 | 0.98 | 1.03 | 1.00 |
| A clean vehicle is important to me. | 1.08*** | 0.92*** | 0.96 | 0.94** |
| I use the most convenient form of transportation regardless of cost. | 1.04** | 1.05** | 0.93** | 0.91*** |
| The people who ride intercity bus are like me. | 0.99 | 1.02 | 1.12* | 0.98 |
| The people who fly are like me. | 1.03 | 1.09*** | 0.90** | 0.88*** |
| The people who use intercity rail service are like me. | 0.89*** | 0.95 | 0.98 | 1.33*** |
| I’m willing to pay more for a ticket if it allows me to re-book my trip later for free. | 0.97* | 1.03 | 1.09** | 0.99 |

*,**,*** denote significance at the 10%, 5%, and 1% levels, respectively

Those who would rather do something else with the time spent traveling were found to be less likely to choose automobile, which makes sense because unlike driving, other modes allow the individual to do other things while traveling. Similarly, those who would like to make productive use of their time when traveling were more likely to choose rail travel.

Those who placed a higher value on a predictable travel time were more likely to choose the automobile. This result suggests the other modes are not viewed as being as predictable.

Regarding travel time, those who would change their form of travel if it would save time were more likely to choose air travel, as expected. On the other hand, those more sensitive to time also had higher likelihoods of choosing bus and rail travel, though these effects were smaller in size.

Travelers who do not mind traveling with strangers were more likely to choose bus and rail travel and less likely to travel by automobile, which makes sense. Similarly, those who prefer to make trips alone were more likely to choose automobile and less likely to choose bus.

Those more concerned about getting into an accident were less likely to choose automobile and more likely to choose air travel, and those more concerned about having a stress-free trip than reaching their destination quickly were less likely to choose air travel and more likely to choose bus travel. These results suggest that the automobile is viewed as being less safe and air travel as safer. Further, bus travel is perceived as being less stressful. Intercity bus services could market their services to those more concerned about having a safe and stress-free trip.

Results showed that those who place a higher value on cleanliness were more likely to choose automobile travel, suggesting there may be negative perceptions regarding the cleanliness of the alternative modes, whether warranted or not.

Sensitivity to cost, as well as the value of convenience, was also shown to have an effect, with bus and rail users being more sensitive to cost. Those who were more likely to use the most convenient form of transportation, regardless of cost, were more likely to choose auto and air travel and less likely to choose bus or rail.

Lastly, the results suggest that individuals are more likely to choose a mode of travel if they feel that the people who use that mode are similar to them. Similar results were found by Mattson et al. (2010b). This effect was found to exist for intercity bus, rail, and air.

# 7. APPLYING THE RESULTS FROM THE MODE CHOICE MODEL

Results from the mixed logit model can be used to estimate mode shares between origins and destinations, and it can be incorporated into a statewide travel demand model to estimate mode volumes. Section 7.1 provides a description of a statewide travel demand model, and Section 7.2 describes how mode shares were estimated for each origin-destination (OD) pair. To help understand how the results from the mode choice model can be applied to estimate mode shares, Section 7.3 provides an example calculation. A number of alternative scenarios were then analyzed, with the results presented in Section 7.4.

## 7.1. North Dakota Statewide Passenger Travel Demand Model

North Dakota does not currently have a statewide travel demand model for passenger travel, but this study shows how the mode choice results could be incorporated into such a model. The state was divided into traffic analysis zones (TAZs) based on census block groups. The model has 572 TAZs in North Dakota, following the 572 census block groups in the state, and 96 out-of-state TAZs, for a total of 668 TAZs, (Figure 7.1).

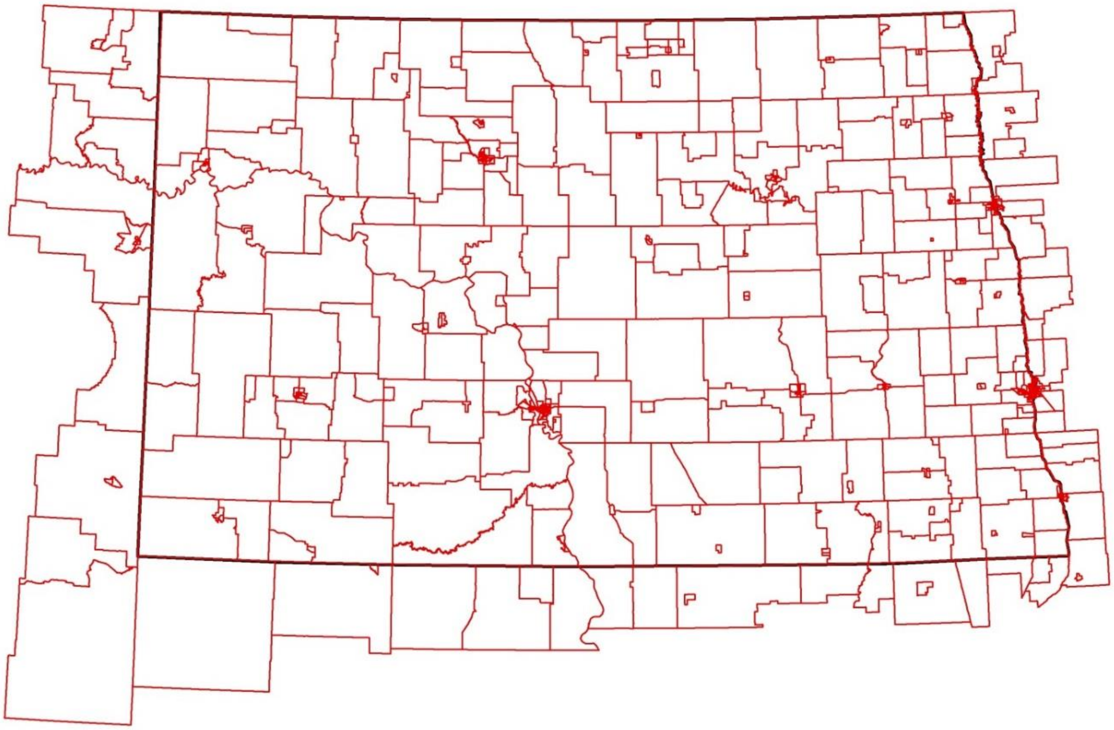


**Figure 7.1.** Traffic Analysis Zones for North Dakota Travel Demand Model

A road network for the state and external TAZs was developed consisting of all U.S., state, and local roadways. Speed limits were also estimated for each roadway segment to estimate travel times between points. Next, the intercity bus and rail networks were created, as shown in Figures 7.2 and 7.3.

The intercity bus network depicted in Figure 7.2 was the existing network as of February 2016. There have been regular changes to the network, including changes later in 2016, so this network is not current as of publication. However, for the sake of this study, it will be referred to as the current network. The objective of this demonstration is to show how the results from this study can be used with a given intercity bus network. The network shown in Figure 7.2 includes nine bus stops in North Dakota, including two different stops in Grand Forks, and stops in Sidney, Montana, and Sisseton, South Dakota. The Sidney and Sisseton stops were included because they are the closest bus stops for some North Dakota residents.

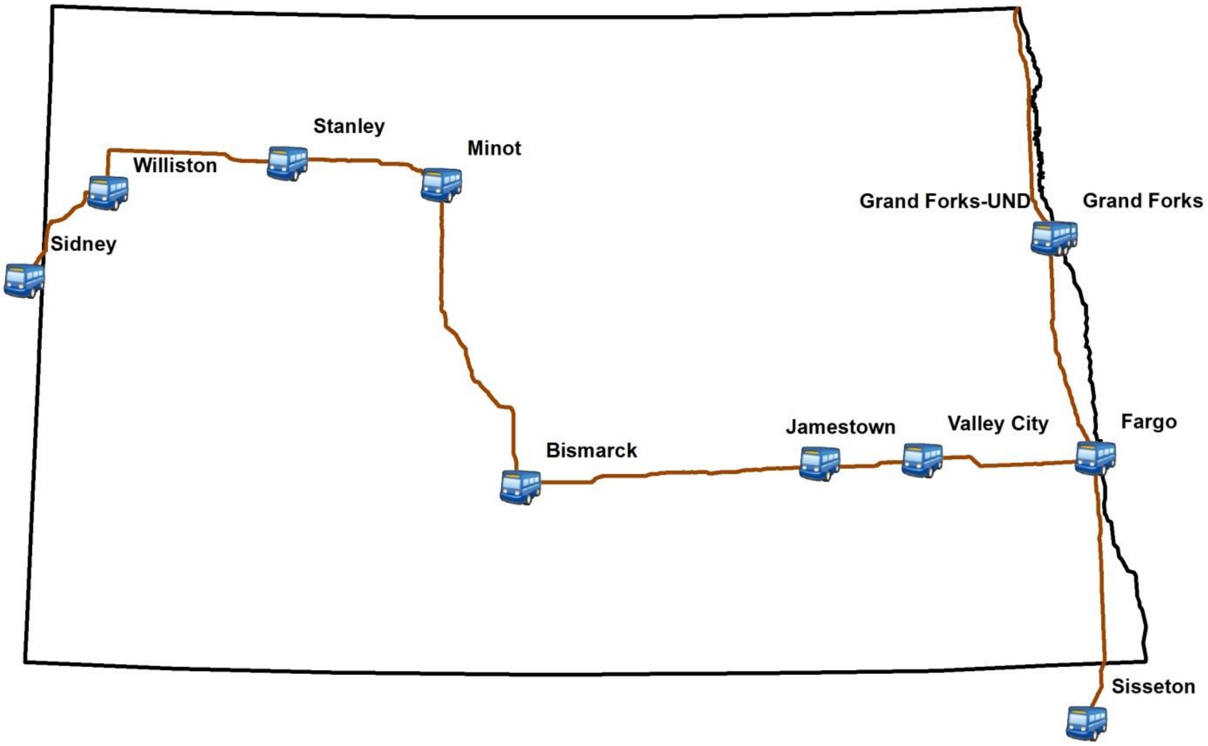


**Figure 7.2.** North Dakota Intercity Bus Network, February 2016

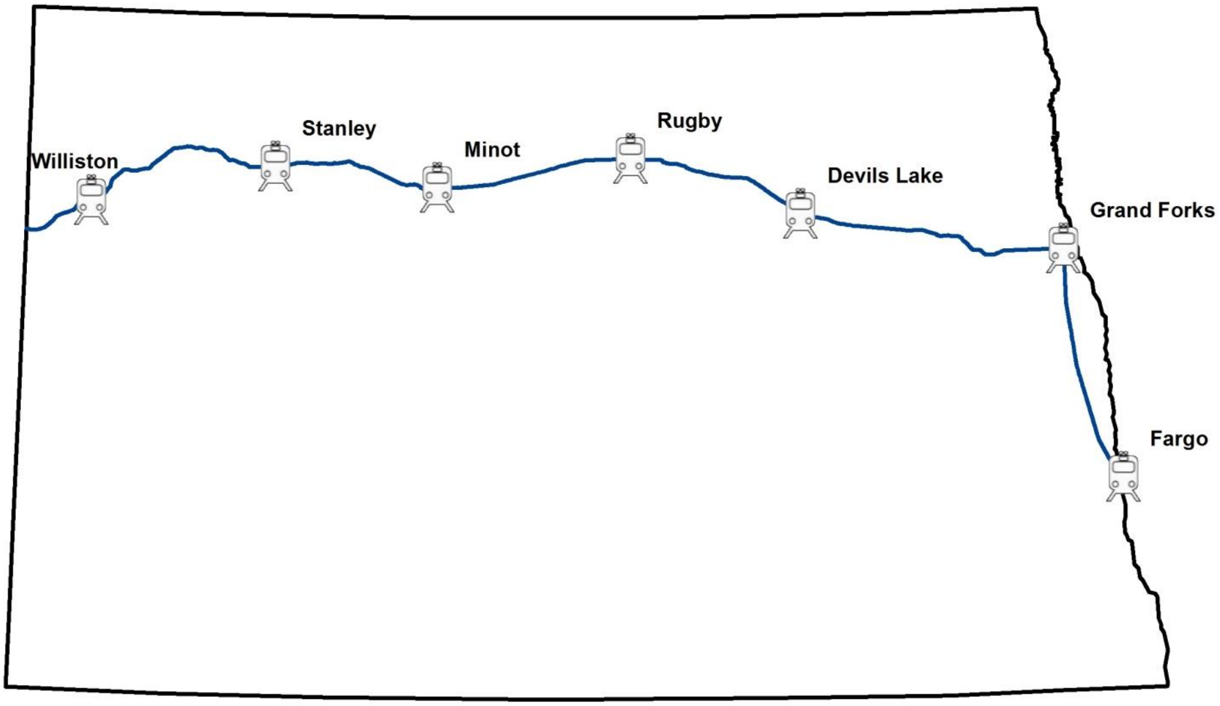


**Figure 7.3.** North Dakota Intercity Rail Network

The bus network consists of three routes (with service in both directions), all operated by Jefferson Lines. Each route terminates or originates in Fargo. One route travels east-west across the state connecting Fargo to Williston, by way of Bismarck and Minot. The route also travels into Montana, on its way to Billings. Two north-south routes are also provided (in addition to the north-south service between Bismarck and Minot on the previously described route). One provides service between Fargo and Sioux Falls, South Dakota, and the other provides service between Fargo and Grand Forks.

Although each route connects to Fargo, each route provides just one trip per day, and the schedules, in many cases, do not provide meaningful connections that would allow for same-day transfers. For example, service from Grand Forks to Fargo arrives in Fargo at 9:00 p.m., but services that depart Fargo to the west or south leave much earlier in the day, so residents in Grand Forks cannot travel elsewhere on the network without spending a night in Fargo. Similarly, service into Fargo from South Dakota arrives late at night. The current schedules allow for one relatively easy transfer. Service from the west into Fargo arrives at 11:55 a.m., while service into South Dakota departs Fargo at 1:00 p.m. These routes, therefore, were considered to be connected in the network, while the other routes were considered to be disconnected. When estimating travel times by bus between different origins and destinations, it was assumed that transfers would not be made between the disconnected routes.

The intercity rail network consists of one route connecting Fargo and Williston, with service provided once per day in each direction. This is part of Amtrak's Empire Builder route, which provides service between Seattle and Chicago.

Bus and rail travel times between stops were calculated based on schedules given on the Jefferson Lines and Amtrak websites as of February 2016, as shown in Tables 7.1 and 7.2.

**Table 7.1.** Travel Time between Intercity Bus Stops

| | Destination | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Origin | Grand Forks | Fargo | Valley City | James -town | Bismarck | Minot | Stanley | Williston | Sidney | Sisseton |
| | minutes | | | | | | | | | |
| Grand Forks | 0 | 85 | - | - | - | - | - | - | - | - |
| Fargo | 80 | 0 | 65 | 105 | 210 | 315 | 415 | 490 | 566 | 65 |
| Valley City | - | 55 | 0 | 40 | 145 | 250 | 350 | 425 | 501 | 185 |
| Jamestown | - | 105 | 35 | 0 | 105 | 210 | 310 | 385 | 461 | 235 |
| Bismarck | - | 210 | 140 | 105 | 0 | 105 | 205 | 280 | 356 | 340 |
| Minot | - | 330 | 260 | 225 | 105 | 0 | 75 | 150 | 226 | 460 |
| Stanley | - | 450 | 380 | 345 | 225 | 65 | 0 | 75 | 151 | 580 |
| Williston | - | 530 | 450 | 425 | 305 | 145 | 80 | 0 | 61 | 660 |
| Sidney | - | 605 | 525 | 500 | 380 | 220 | 155 | 60 | 0 | 735 |
| Sisseton | - | 75 | - | - | - | - | - | - | - | - |

**Table 7.2.** Travel Time between Intercity Rail Stations

| Origin | Destination<br>Fargo | Grand Forks | Devils Lake | Rugby | Minot | Stanley | Williston |
|---|---|---|---|---|---|---|---|
| | --minutes-- | | | | | | |
| Fargo | 0 | 77 | 158 | 212 | 299 | 387 | 457 |
| Grand Forks | 76 | 0 | 81 | 135 | 222 | 310 | 380 |
| Devils Lake | 161 | 85 | 0 | 54 | 141 | 229 | 299 |
| Rugby | 215 | 139 | 54 | 0 | 87 | 175 | 245 |
| Minot | 271 | 195 | 110 | 56 | 0 | 51 | 121 |
| Stanley | 362 | 286 | 201 | 147 | 71 | 0 | 70 |
| Williston | 424 | 348 | 263 | 209 | 133 | 62 | 0 |

Travel times between each pair of TAZs were calculated for automobile, bus, and rail travel based on road, bus, and rail networks. Centroids were created for each TAZ, and travel times between centroids were estimated.

First, travel times between TAZ centroids for automobile travel were estimated by finding paths with the shortest travel time (based on travel distance and speed). Bus and rail travel included both in-vehicle travel time and access and egress travel. For each O-D pair, access distance was found by calculating the distance on the road network to the nearest bus or rail station. Similarly, egress distance was calculated as the distance on the road network from the final destination to the bus or rail station closest to the final destination. In-vehicle travel times were then calculated based on the travel times shown in Tables 6.1 and 6.2. These calculations were made for every O-D pair, though in many cases, bus or rail travel would be impractical or unrealistic because of very long access or egress distances.

## 7.2. Estimating Mode Shares

Mode shares for automobile, bus, and rail travel were calculated for each O-D pair using the calculated travel times for each mode, access distances for bus and rail, given gas prices and fares for bus and rail, income levels for the origin zone, and the percentage of population in the origin zone aged 18-24. Air travel was not considered in this analysis because in-state intercity trips by air are rare given current service levels.

Average income levels and percentage of population aged 18-24 for each origin TAZ were calculated using data from the ACS. Because the ACS does not include disability data at the block group level, the analysis assumed that in each TAZ, 6% of the population has a medical condition or disability that makes it difficult to travel. This estimate is based on the results from the survey. It was also assumed that travelers were evenly split between males and females in each zone.

Separate mode shares were calculated for personal trips and business trips. It was assumed that most business trips would be made alone, and that personal trips would include a greater percentage of group trips. Data from the 2009 National Household Travel Survey showed that the average vehicle occupancy was 1.13 for work trips, 1.78 for shopping trips, and 2.20 for social and recreational trips (Santos et al. 2011). A rough estimate was made that 90% of business trips and 20% of personal trips would be made alone.

While the mode choice model did not show egress distance having a significant effect on mode share, it can reasonably be expected that bus and rail are not an option when access or egress distance is greater than a certain distance. In this analysis, is assumed that trips would not be made by bus or rail if access or egress distance is greater than 25 miles. Previous research tends to suggest catchment areas of 10 to 20 miles, though it could be somewhat higher in North Dakota, where travel distances are generally greater. Figures 7.4 and 7.5 highlight TAZs within 25 miles of a bus stop or rail station.

Mode shares were then estimated for each OD pair. Because bus and rail are not an option for many trips, due to long access or egress distance, the automobile mode share is 100% for many OD pairs. Some OD pairs also represents trips that are not intercity, since most cities contain multiple TAZs, and intercity bus and rail are therefore not an option.

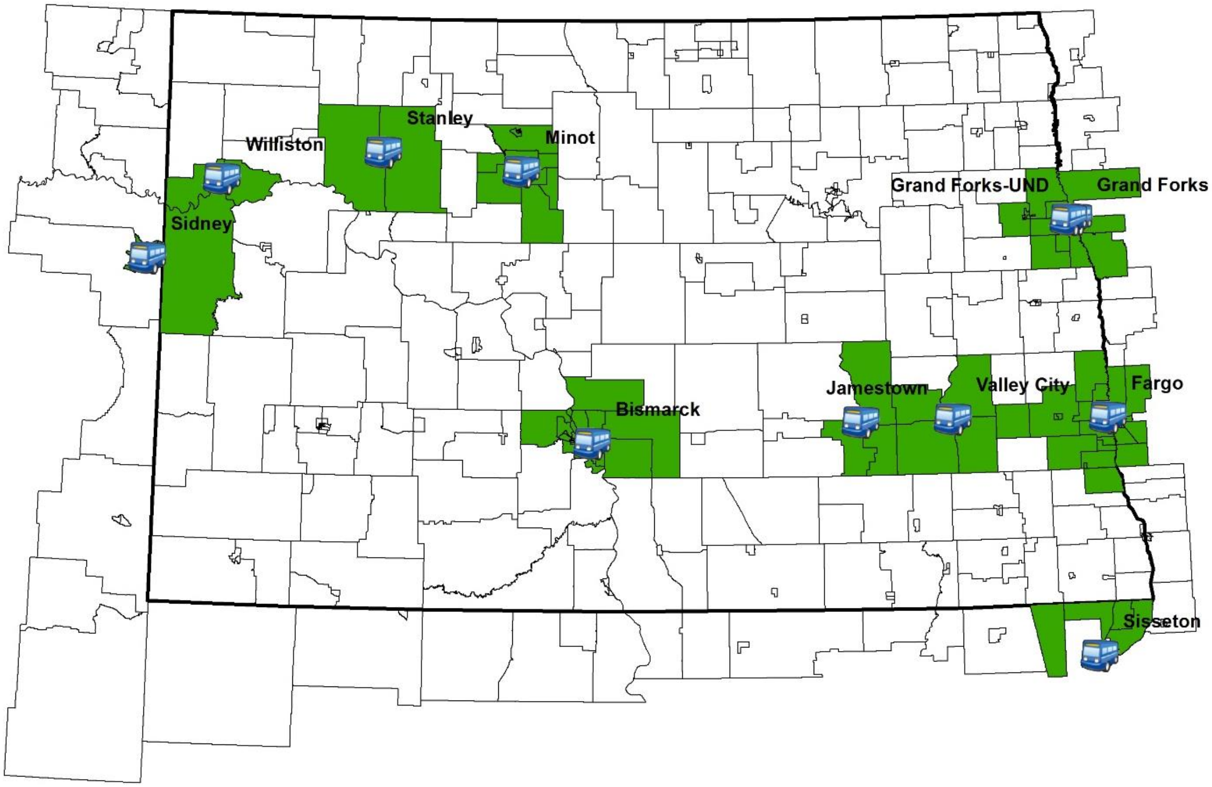


**Figure 7.4.** TAZs within 25 Miles of Intercity Bus Stop

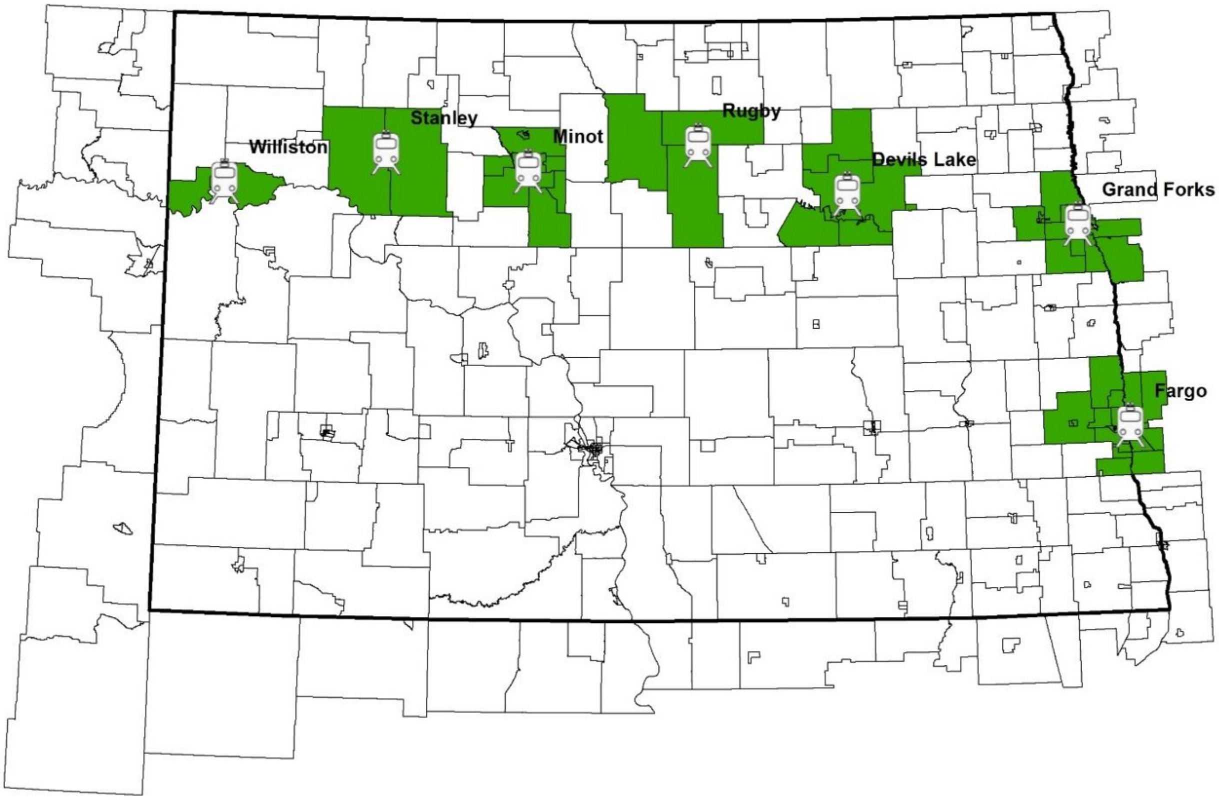


**Figure 7.5.** TAZs within 25 Miles of Intercity Rail Station

To illustrate intercity mode shares between the main cities across the state, the 30 largest cities or metro areas were identified, and a matrix of mode shares was calculated for these cities. Figure 7.6 shows these cities and the TAZs that intersect or are contained within them. A significant majority of intercity trips originate or terminate in these TAZs. Because most of these cities contain multiple TAZs, calculating mode shares between cities required taking a weighted average of mode shares between TAZs based on the number of households in each TAZ. The cites of Fargo, West Fargo, and Horace were combined into one metro area, and the cities of Bismarck, Mandan, and Lincoln were similarly combined.

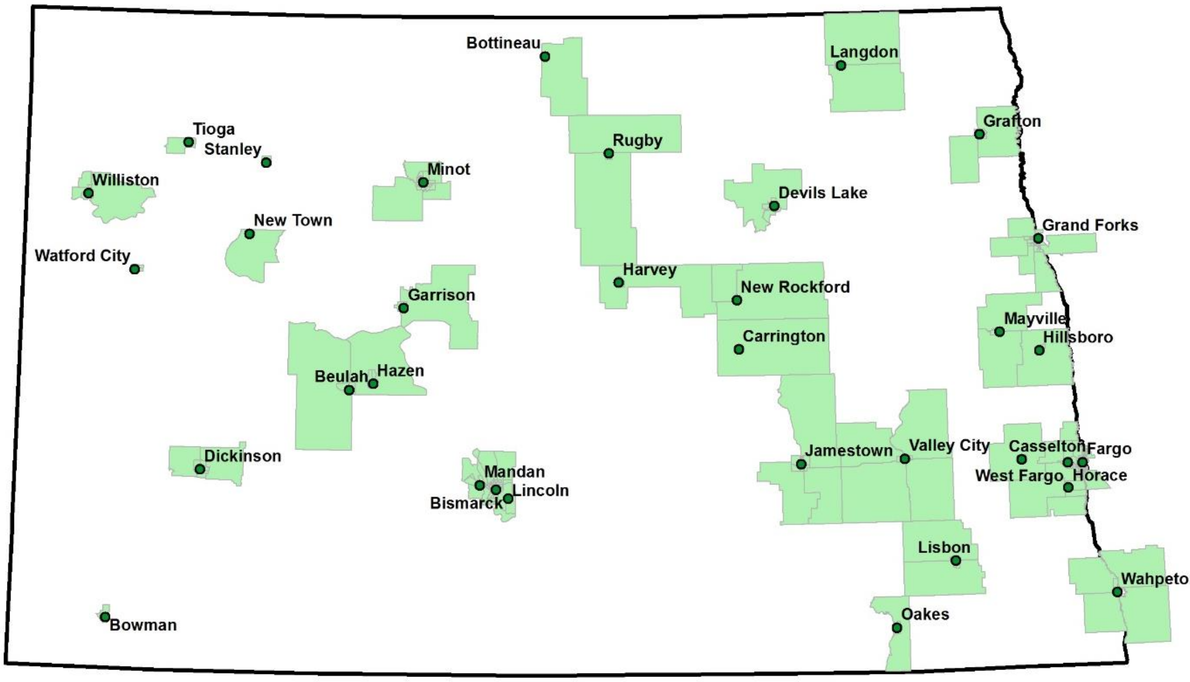


**Figure 7.6.** Most Populated Cities in North Dakota and Corresponding TAZs

Table 7.3 shows the estimated bus mode shares between the 17 most populated cities/metro areas for personal trips, and Table 7.4 shows the same for business trips. The remaining cities are excluded because none of them have access to intercity bus. These estimates are based on a gas price of $2.00 per gallon and intercity bus and rail fares at $0.20 per mile. Among these cities, eight are served by a bus station, and a ninth, Casselton, is within 25 miles of the Fargo bus station.

**Table 7.3.** Estimated Bus Mode Shares for Personal Trips

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | **3.2** | **4.1** | **3.0** | **2.2** | 0.0 | **3.5** | 0.0 | 0.0 | **4.3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **2.4** |
| Bismarck | **3.4** | - | 0.0 | **4.2** | **2.9** | 0.0 | **4.0** | 0.0 | 0.0 | **3.9** | 0.0 | 0.0 | 0.0 | 0.0 | **3.2** | 0.0 | **3.3** |
| Grand Forks | **4.6** | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **4.7** | 0.0 | 0.0 |
| Minot | **2.9** | **4.4** | 0.0 | - | **3.9** | 0.0 | **2.6** | 0.0 | 0.0 | **2.8** | 0.0 | 0.0 | 0.0 | 0.0 | **2.7** | 0.0 | **4.1** |
| Williston | **1.8** | **2.0** | 0.0 | **3.7** | - | 0.0 | **1.7** | 0.0 | 0.0 | **1.9** | 0.0 | 0.0 | 0.0 | 0.0 | **1.7** | 0.0 | **4.0** |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | **4.0** | **4.2** | 0.0 | **3.5** | **2.6** | 0.0 | - | 0.0 | 0.0 | **4.5** | 0.0 | 0.0 | 0.0 | 0.0 | **3.8** | 0.0 | **2.7** |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | **4.2** | **3.7** | 0.0 | **3.1** | **2.3** | 0.0 | **4.1** | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | **3.9** | 0.0 | **2.5** |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | **2.2** | **2.9** | **2.0** | **1.4** | 0.0 | **2.4** | 0.0 | 0.0 | **2.8** | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | **1.5** |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | **2.0** | **2.3** | 0.0 | **4.0** | **4.1** | 0.0 | **1.8** | 0.0 | 0.0 | **2.0** | 0.0 | 0.0 | 0.0 | 0.0 | **1.8** | 0.0 | - |

**Table 7.4.** Estimated Bus Mode Shares for Business Trips

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | **5.1** | **6.9** | **5.2** | **3.8** | 0.0 | **5.4** | 0.0 | 0.0 | **7.3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **4.1** |
| Bismarck | **5.8** | - | 0.0 | **7.0** | **5.0** | 0.0 | **6.7** | 0.0 | 0.0 | **6.5** | 0.0 | 0.0 | 0.0 | 0.0 | **5.5** | 0.0 | **5.6** |
| Grand Forks | **7.7** | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **7.9** | 0.0 | 0.0 |
| Minot | **4.9** | **7.5** | 0.0 | - | **6.5** | 0.0 | **3.9** | 0.0 | 0.0 | **4.4** | 0.0 | 0.0 | 0.0 | 0.0 | **4.7** | 0.0 | **6.9** |
| Williston | **3.1** | **3.0** | 0.0 | **6.2** | - | 0.0 | **2.6** | 0.0 | 0.0 | **3.0** | 0.0 | 0.0 | 0.0 | 0.0 | **2.9** | 0.0 | **6.7** |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | **6.8** | **7.1** | 0.0 | **5.9** | **4.4** | 0.0 | - | 0.0 | 0.0 | **7.6** | 0.0 | 0.0 | 0.0 | 0.0 | **6.4** | 0.0 | **4.7** |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | **7.1** | **6.3** | 0.0 | **5.3** | **4.0** | 0.0 | **7.0** | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | **6.7** | 0.0 | **4.2** |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | **3.5** | **4.9** | **3.4** | **2.5** | 0.0 | **3.8** | 0.0 | 0.0 | **4.8** | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | **2.7** |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | **3.4** | **3.3** | 0.0 | **6.9** | **7.0** | 0.0 | **2.8** | 0.0 | 0.0 | **3.1** | 0.0 | 0.0 | 0.0 | 0.0 | **3.2** | 0.0 | - |

The five largest cities or metro areas are all served by intercity bus. Among the 10 largest, Dickinson, Wahpeton, and Devils Lake are not served by intercity bus as of the time of this analysis (recent changes have added service to Dickinson).

### 7.3. Example Mode Share Calculation

The model estimates mode shares between all 668 TAZs in the model. To demonstrate how these mode shares are calculated, this section walks through an example calculation. In this example, mode shares will be estimated for trips originating in TAZ 33 and ending in TAZ 41, which are highlighted in Figure 7.7. TAZ 33 is on the west side of the Bismarck-Mandan metropolitan area, and TAZ 41 is southwest of Valley City. The red dots within the TAZs represent the TAZ centroids, which are used to calculate distances and travel times.

**Figure 7.7.** TAZs Highlighted for Example Calculation

These two TAZs are within 25 miles of an intercity bus stop, so trips between them can be served by bus. There is no intercity rail serving these TAZs, however. Data for this example calculation are based on the base case scenario, using the intercity bus network shown in the Figure 7.7. These data are shown in Table 7.5. Demographic data from the origin TAZ were obtained from the ACS. A description for how to obtain ACS demographic data in GIS is provided in Appendix E. This particular example estimates mode shares for personal trips, so it is assumed that all trips are personal trips, and it is estimated that 20% of trips are made alone. Separate estimates could be made for business trips.

**Table 7.5.** Data for Personal Trips Originating in TAZ 33 and Ending in TAZ 41

| Variable | Variable description | Value | Data source |
|---|---|---|---|
| $x_1$ | Origin TAZ percentage of population male (decimal) | 0.47 | ACS |
| $x_2$ | Origin TAZ percentage of population aged 18-24 (decimal) | 0.047 | ACS |
| $x_3$ | Origin TAZ percentage of population 70+ (decimal) | 0.071 | ACS |
| $x_4$ | Origin TAZ average income segment (1-5 scale) | 3.6 | ACS |
| $x_5$ | Origin TAZ percentage of population with disability (decimal) | 0.06 | Survey data for state of North Dakota |
| $y_1$ | Percentage of trips made alone (decimal) | 0.2 | Estimate |
| $y_2$ | Percentage of personal trips (decimal) | 1 | Given |
| $z_{2auto}$ | Auto travel time (hours) | 2.2 | GIS estimate based on travel distance and speed limits |
| $z_{2bus}$ | Bus in-vehicle travel time (hours) | 2.33 | Jefferson Lines travel schedule |
| $z_{2rail}$ | Rail in-vehicle travel time (hours) | 4.52 | Amtrak travel schedule |
| $z_{3auto}$ | Automobile travel cost ($ per mile) | 0.09 | Includes only price of gasoline, calculated at $2/gallon and 21.6 miles per gallon |
| $z_{3bus}$ | Bus travel cost ($ per mile) | 0.2 | Estimate based on bus fares posted on Jefferson Lines website |
| $z_{3rail}$ | Rail travel cost ($ per mile) | 0.2 | Estimate based on rail fares posted on Amtrak website |
| $z_{4bus}$ | Bus access distance (miles) | 22 | Calculated in GIS using locations of bus stops given in Jefferson Lines website |
| $z_{4rail}$ | Rail access distance (miles) | 132 | Calculated in GIS using locations of rail stops given in Amtrak website |
| $z_{5bus}$ | Bus egress distance (miles) | 20 | Calculated in GIS using locations of bus stops given in Jefferson Lines website |
| $z_{5rail}$ | Rail egress distance (miles) | 96 | Calculated in GIS using locations of rail stops given in Amtrak website |

Automobile travel times were estimated based on travel distances and estimated roadway speeds. In-vehicle travel time by bus and rail were determined based on the information in Tables 7.1 and 7.2. Access distance for bus and rail was calculated in GIS as the distance on the road network from the origin TAZ centroid to the nearest bus or rail station. Egress distance is the distance on the road network from the destination TAZ centroid to the bus or rail station. Travel costs for each mode were estimates that could be varied to analyze alternative scenarios.

In this example, the rail access and egress distances far exceed the 25-mile cut-offs used in the model. Therefore, it is not considered an option. Automobile and bus are the only realistic options for this example.

To calculate automobile and bus mode shares, first determine utility for each mode, using Equations 15 and 17. These equations can be modified to remove variables found to be statistically insignificant, as follows:

$$V_{auto} = \beta_{1auto} \cdot x_1 + \beta_{4auto} \cdot x_4 + \beta_{5auto} \cdot x_5 + \gamma_{1auto} \cdot y_1 + \gamma_{2auto} \cdot y_2 + \theta_{1auto} + \theta_{2m} \cdot z_{2auto} + \theta_{3m} \cdot z_{3auto} \tag{19}$$

$$V_{bus} = \beta_{1bus} \cdot x_1 + \beta_{2bus} \cdot x_2 + \theta_{1bus} + \theta_{2m} \cdot z_{2bus} + \theta_{3m} \cdot z_{3bus} + \theta_4 \cdot z_{4bus} \tag{20}$$

Utility can be calculated using the data in Table 7.5 and the estimated coefficients in Table 6.1.

$$V_{auto} = 0.4425 \cdot 0.47 + 0.096 \cdot 3.6 - 0.8052 \cdot 0.06 - 0.3531 \cdot 0.2 + 0.3108 \cdot 1 + 1.1581 - 0.2706 \cdot 2.2 - 5.4204 \cdot 0.09$$

$$V_{auto} = 0.82$$

$$V_{bus} = 0.508 \cdot 0.47 + 0.4762 \cdot 0.047 - 0.8797 - 0.2706 \cdot 2.33 - 5.4204 \cdot 0.2 - 0.0189 \cdot 22$$

$$V_{bus} = -2.75$$

The probably that mode *k* would be chosen among *m* alternatives is estimated as follows:

$$P_k = \frac{e^{V_k}}{\sum_{l=1}^{m} e^{V_m}}. \tag{21}$$

Probabilities for automobile and bus travel are then estimated.

$$P_{auto} = \frac{e^{V_{auto}}}{e^{V_{auto}} + e^{V_{bus}}} = \frac{2.27}{2.27 + 0.06} = 0.97$$

$$P_{bus} = \frac{e^{V_{bus}}}{e^{V_{auto}} + e^{V_{bus}}} = \frac{0.06}{2.27 + 0.06} = 0.03$$

Therefore, the estimated mode shares from TAZ 33 to TAZ 41 are 97% automobile and 3% bus.

## 7.4. Scenario Analysis

The mode shares presented in the previous sections represent the base scenario. The model can be used to estimate changes in mode shares under different scenarios, including changes in service characteristics, demographic characteristics, or costs of competing modes. This study evaluates the following scenarios

1) The addition of a new route between Grand Forks and Minot, with a stop in Devils Lake.
2) The addition of a new route between Bismarck and Williston, with intermediate stops in Dickinson and Watford City.
3) Adding a stop in Wahpeton on the existing route between Fargo and Sioux Falls, SD.
4) Providing express service between Fargo and Bismarck with no intermediate stops.
5) Gas prices increasing to $5.00 per gallon.

### 7.4.1. Scenario 1: New route between Grand Forks and Minot

The first scenario is the addition of a new route connecting Grand Forks and Minot. This route would provide a connection between two of the four largest cities in the state, and it would include an intermediate stop in Devils Lake, which is one of the largest cities in the state to not currently have intercity bus service. The timing of the route would allow for the following transfers:

- Passengers traveling west from Grand Forks or Devils Lake into Minot could transfer onto the route traveling farther west to Stanley and Williston

- Passengers traveling east from Stanley, Williston, or points farther west could transfer in Minot to the new route to travel to Devils Lake or Grand Forks.

This new route, therefore, would provide connections along the Highway 2 corridor in northern North Dakota where there is currently intercity rail service, but it would not provide connections to Fargo or Bismarck.

Based on current travel speeds on existing routes, travel times on this new route are estimated to be 105 minutes between Grand Forks and Devils Lake, 145 minutes between Devils Lake and Minot, and 250 minutes between Grand Forks and Minot. With the addition of a new stop in Devils Lake, access distance to the nearest bus stop was re-calculated. Mode shares were then re-estimated, taking into account the travel times for the new route and the new access that it provides.

Table 7.6 provides the estimated mode shares for personal trips between the 17 largest cities under this scenario. Mode shares that differ from those in the base scenario are highlighted. In the base scenario there were no trips beginning or ending in Devils Lake that used intercity bus, and regarding trips beginning or ending in Grand Forks, intercity bus was used only for trips beginning or ending in Fargo or Casselton. In this scenario, among trips originating in Grand Forks, intercity bus is used for 4.3% of trips to Devils Lake, 3.6% of trips to Minot, 2.9% of trips to Stanley, and 2.7% of trips to Williston. Among trips originating in Devils Lake, 4.2% trips to Grand Forks, 4.0% of trips to Minot, 3.1% of trips to Stanley, and 2.9% of trips to Williston are now made by intercity bus.

**Table 7.6.** Estimated Bus Mode Shares for Personal Trips, Scenario 1

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | 3.2 | 4.1 | 3.0 | 2.2 | 0.0 | 3.5 | 0.0 | 0.0 | 4.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 |
| Bismarck | 3.4 | - | 0.0 | 4.2 | 2.9 | 0.0 | 4.0 | 0.0 | 0.0 | 3.9 | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 | 0.0 | 3.3 |
| Grand Forks | 4.6 | 0.0 | - | **3.6** | **2.7** | 0.0 | 0.0 | 0.0 | **4.3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | **2.9** |
| Minot | 2.9 | 4.4 | **3.4** | - | 3.9 | 0.0 | 2.6 | 0.0 | **3.9** | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 4.1 |
| Williston | 1.8 | 2.0 | **2.4** | 3.7 | - | 0.0 | 1.7 | 0.0 | **2.7** | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 4.0 |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | 4.0 | 4.2 | 0.0 | 3.5 | 2.6 | 0.0 | - | 0.0 | 0.0 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 | 0.0 | 2.7 |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | **4.2** | **4.0** | **2.9** | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **3.1** |
| Valley City | 4.2 | 3.7 | 0.0 | 3.1 | 2.3 | 0.0 | 4.1 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 3.9 | 0.0 | 2.5 |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | 2.2 | 2.9 | 2.0 | 1.4 | 0.0 | 2.4 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 1.5 |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | 2.0 | 2.3 | **2.6** | 4.0 | 4.1 | 0.0 | 1.8 | 0.0 | **2.9** | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.0 | - |

### 7.4.2. Scenario 2: New route between Bismarck and Williston via Dickinson

Scenario 2 is the addition of a new route between Bismarck and Williston that travels through Dickinson and Watford City. Figure 7.8 shows the location of the new stops. Dickinson is the largest city in North Dakota without access to intercity bus, and Watford City is one of the fastest growing cities in the state. The route would be timed such that those traveling from the east on the route into Bismarck would be able to transfer to the new route and continue west to Dickinson, Watford City, or Williston. Those traveling from the west on the new route would also be able to transfer at Bismarck and continue east on the existing route.

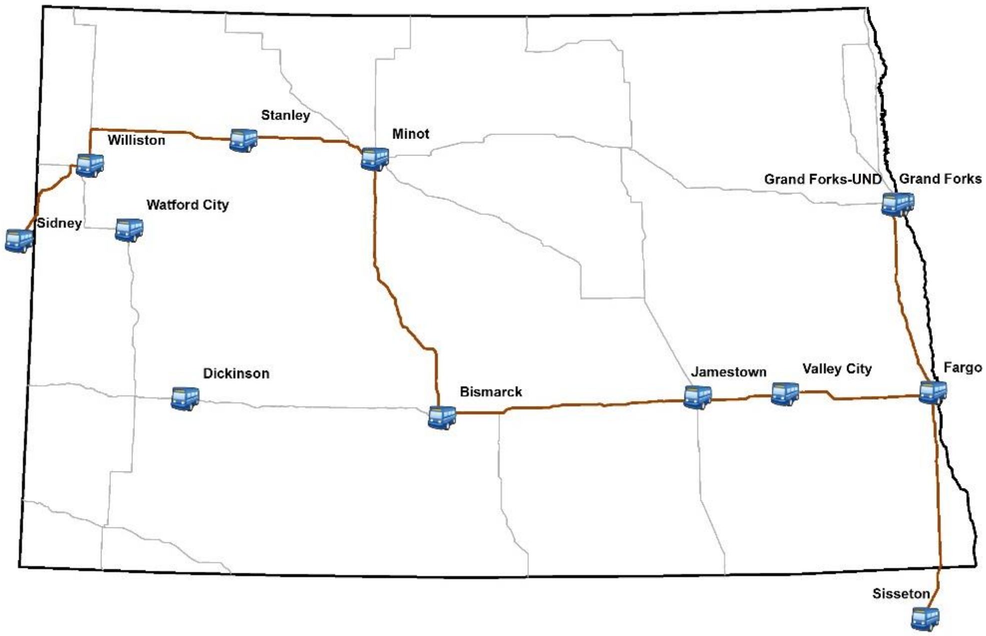


**Figure 7.8.** New Service to Dickinson and Watford City Provided in Scenario 2

Based on current travel speeds on existing routes, travel times on this new route are estimated to be 110 minutes between Bismarck and Dickinson, 100 minutes between Dickinson and Watford City, and 60 minutes between Watford City and Williston. The new route reduces travel time between Bismarck and Williston by 10 minutes, compared to the existing route, thereby diverted ridership from the old route to the new one. With the addition of new stops in Dickinson and Watford City, access distance to the nearest bus stop was re-calculated. Mode shares were then re-estimated, taking into account the travel times for the new route and the new access that it provides.

Table 7.7 provides the estimated mode shares for personal trips between the 17 largest cities under Scenario 2. Mode shares that differ from those in the base scenario are highlighted. In the base scenario there were no bus trips beginning or ending in Dickinson or Watford City. Because the new scenario reduced travel time between Bismarck and Williston by 10 minutes, there were slight increases in bus mode shares on trips to and from Williston. For example, the bus mode share for trips from Fargo to Williston increased from 2.2% to 2.3%.

**Table 7.7.** Estimated Bus Mode Shares for Personal Trips, Scenario 2

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | 3.2 | 4.1 | 3.0 | **2.3** | **2.8** | 3.5 | 0.0 | 0.0 | 4.3 | 0.0 | **2.4** | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 |
| Bismarck | 3.4 | - | 0.0 | 4.2 | **3.0** | **3.8** | 4.0 | 0.0 | 0.0 | 3.9 | 0.0 | **3.3** | 0.0 | 0.0 | 3.2 | 0.0 | 3.3 |
| Grand Forks | 4.6 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | 0.0 |
| Minot | 2.9 | 4.4 | 0.0 | - | 3.9 | 0.0 | 2.6 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 4.1 |
| Williston | 1.8 | 2.0 | 0.0 | 3.7 | - | **2.8** | 1.7 | 0.0 | 0.0 | 1.9 | 0.0 | **4.0** | 0.0 | 0.0 | 1.7 | 0.0 | 4.0 |
| Dickinson | **3.1** | **4.0** | 0.0 | 0.0 | **3.7** | - | **3.6** | 0.0 | 0.0 | **3.4** | 0.0 | **4.1** | 0.0 | 0.0 | **2.9** | 0.0 | 0.0 |
| Jamestown | 4.0 | 4.2 | 0.0 | 3.5 | **2.7** | **3.6** | - | 0.0 | 0.0 | 4.5 | 0.0 | **3.2** | 0.0 | 0.0 | 3.8 | 0.0 | 2.7 |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | 4.2 | 3.7 | 0.0 | 3.1 | **2.4** | **3.2** | 4.1 | 0.0 | 0.0 | - | 0.0 | **2.8** | 0.0 | 0.0 | 3.9 | 0.0 | 2.5 |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | **2.7** | **3.4** | 0.0 | 0.0 | **4.1** | **3.9** | **3.1** | 0.0 | 0.0 | **3.0** | 0.0 | - | 0.0 | 0.0 | **2.5** | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | 2.2 | 2.9 | 2.0 | **1.5** | **1.9** | 2.4 | 0.0 | 0.0 | 2.8 | 0.0 | **1.6** | 0.0 | 0.0 | - | 0.0 | 1.5 |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | 2.0 | 2.3 | 0.0 | 4.0 | 4.1 | 0.0 | 1.8 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.0 | - |

### 7.4.3. Scenario 3: Add a stop in Wahpeton

Scenario 3 would alter the existing route between Fargo and South Dakota so that it would deviate to serve the city of Wahpeton, as shown in Figure 7.9. Wahpeton is one of the largest cities in the state without intercity bus service. The city is located about ten miles from Interstate-29, where the route currently runs. Deviating the route, therefore, would cause travel times between Fargo and cities in South Dakota to increase. The estimated travel time from Wahpeton to Fargo is 60 minutes. This scenario assumes riders on this route would not transfer to other routes. While it is possible to transfer from the route that travels into Fargo from the west onto the route traveling south to Wahpeton, a timed transfer in the reverse direction is not possible, so round trips could not be made, which makes use of intercity bus less likely.

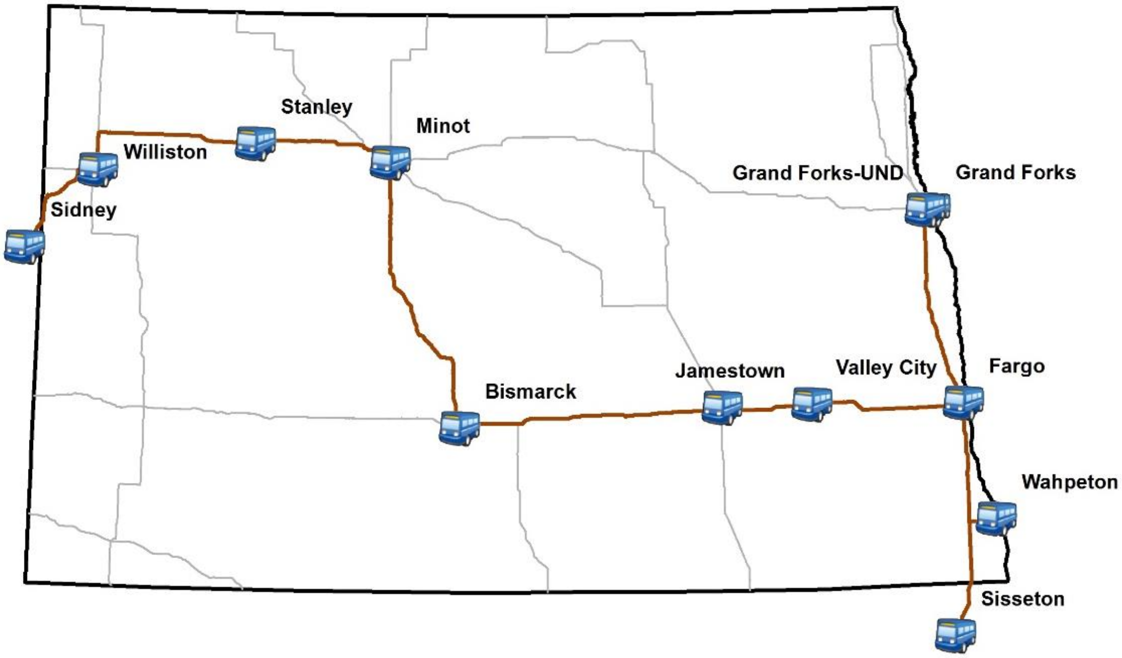


**Figure 7.9.** New Service to Wahpeton Provided in Scenario 3

Table 7.8 provides the estimated mode shares for personal trips under this scenario. Mode shares that differ from those in the base scenario are highlighted. In the base scenario, there were no bus trips beginning or ending in Wahpeton. In Scenario 3, 4.2% of trips between Fargo and Wahpeton are made by intercity bus. Some trips between Casselton and Wahpeton are also made by bus, as Casselton is close enough to the Fargo bus station.  Mode shares for all other O-D pairs remain the same. Because the route deviation to Wahpeton causes increased travel time from Fargo to South Dakota locations, there would likely be a decrease in bus mode shares for those trips, but that is not shown in this model.

**Table 7.8.** Estimated Bus Mode Shares for Personal Trips, Scenario 3

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | 3.2 | 4.1 | 3.0 | 2.2 | 0.0 | 3.5 | **4.2** | 0.0 | 4.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 |
| Bismarck | 3.4 | - | 0.0 | 4.2 | 2.9 | 0.0 | 4.0 | 0.0 | 0.0 | 3.9 | 0.0 | 0.0 | 0.0 | 0.0 | 3.2 | 0.0 | 3.3 |
| Grand Forks | 4.6 | 0.0 | - | 3.6 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | 2.9 |
| Minot | 2.9 | 4.4 | 3.4 | - | 3.9 | 0.0 | 2.6 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 4.1 |
| Williston | 1.8 | 2.0 | 2.4 | 3.7 | - | 0.0 | 1.7 | 0.0 | 0.0 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 4.0 |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | 4.0 | 4.2 | 0.0 | 3.5 | 2.6 | 0.0 | - | 0.0 | 0.0 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 | 0.0 | 2.7 |
| Wahpeton | **4.2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **4.5** | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | 4.2 | 3.7 | 0.0 | 3.1 | 2.3 | 0.0 | 4.1 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 3.9 | 0.0 | 2.5 |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | 2.2 | 2.9 | 2.0 | 1.4 | 0.0 | 2.4 | **3.1** | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 1.5 |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | 2.0 | 2.3 | 2.6 | 4.0 | 4.1 | 0.0 | 1.8 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 | 0.0 | - |

### 7.4.4. Scenario 4: Express service between Fargo and Bismarck

The next scenario eliminated the stops in Valley City and Jamestown so that a faster service could be provided between Fargo and Bismarck, the two largest cities in the state. In this scenario, travel time between Fargo and Bismarck was reduced by 30 minutes. Travel times between Fargo and other stations on the route beyond Bismarck were also reduced by 30 minutes. Estimated mode shares for personal trips are shown in Table 7.9, with the differences from the base scenario highlighted.

Because of reduced travel times, the share of trips made by intercity bus from Fargo to Bismarck increased from 3.2% to 3.6%, and similar increases were observed for trips from Fargo to Minot, Stanley, and Williston. However, because bus stops were eliminated in Jamestown and Valley City , intercity bus was no longer used for any trips beginning or ending in these two cities. To determine the net effect on the number of bus trips made requires information from the statewide travel demand model regarding the total number of trips made for each O-D pair.

**Table 7.9.** Estimated Bus Mode Shares for Personal Trips, Scenario 4

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | **3.6** | 4.1 | **3.5** | **2.6** | 0.0 | **0.0** | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **2.7** |
| Bismarck | **3.9** | - | 0.0 | 4.2 | 2.9 | 0.0 | **0.0** | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 0.0 | 3.3 |
| Grand Forks | 4.6 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 0.0 | 0.0 |
| Minot | **3.3** | 4.4 | 0.0 | - | 3.9 | 0.0 | **0.0** | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 0.0 | 4.1 |
| Williston | **2.0** | 2.0 | 0.0 | 3.7 | - | 0.0 | **0.0** | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | 4.0 |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | **0.0** | **0.0** | 0.0 | **0.0** | **0.0** | 0.0 | - | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** | 0.0 | **0.0** |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | **0.0** | **0.0** | 0.0 | **0.0** | **0.0** | 0.0 | **0.0** | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | **0.0** | 0.0 | **0.0** |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | 2.5 | 2.9 | 2.2 | 1.7 | 0.0 | **0.0** | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 1.8 |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | **2.2** | 2.3 | 0.0 | 4.0 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | - |

### 7.4.5. Scenario 5: Gasoline prices increase to $5.00 per gallon

The base case and all previous scenarios assumed that the price of gasoline was $2.00 per gallon. Scenario 5 assumed gasoline prices increase to $5.00 per gallon. All other variables were the same as in the base case. Estimated mode shares for personal trips are shown in Table 7.10. Bus mode shares are shown to increase significantly with such a price increase. For example, the share of trips from Fargo to Bismarck made by intercity bus increased from 3.2% to 5.9%, and the share of trips from Fargo to Grand Forks made by intercity bus increased from 4.1% to 8.3%. Table 7.10 shows increased bus shares for all O-D pairs served by intercity bus in the base case, but mode shares remained at 0% for all other O-D pairs. These results assumed that bus fares do not change, but in reality, there may be a correlation between gasoline prices and bus fares. Bus operators may be forced to increase bus fares following increased fuel costs, thereby reducing the mode shift.

**Table 7.10.** Estimated Bus Mode Shares for Personal Trips, Scenario 5

| Destination →<br>Origin | Fargo | Bismarck | Grand Forks | Minot | Williston | Dickinson | Jamestown | Wahpeton | Devils Lake | Valley City | Grafton | Watford City | Beulah | Rugby | Casselton | Hazen | Stanley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fargo | - | **5.9** | **8.3** | **6.2** | **4.6** | 0.0 | **6.3** | 0.0 | 0.0 | **8.7** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **4.9** |
| Bismarck | **7.0** | - | 0.0 | **8.4** | **6.0** | 0.0 | **8.1** | 0.0 | 0.0 | **7.8** | 0.0 | 0.0 | 0.0 | 0.0 | **6.6** | 0.0 | **6.7** |
| Grand Forks | **9.2** | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **9.4** | 0.0 | 0.0 |
| Minot | **5.9** | **9.0** | 0.0 | - | **7.8** | 0.0 | **4.3** | 0.0 | 0.0 | **5.0** | 0.0 | 0.0 | 0.0 | 0.0 | **5.6** | 0.0 | **8.3** |
| Williston | **3.7** | **3.3** | 0.0 | **7.5** | - | 0.0 | **2.9** | 0.0 | 0.0 | **3.5** | 0.0 | 0.0 | 0.0 | 0.0 | **3.5** | 0.0 | **8.1** |
| Dickinson | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Jamestown | **8.1** | **8.4** | 0.0 | **7.1** | **5.3** | 0.0 | - | 0.0 | 0.0 | **9.1** | 0.0 | 0.0 | 0.0 | 0.0 | **7.7** | 0.0 | **5.6** |
| Wahpeton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Devils Lake | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Valley City | **8.5** | **7.6** | 0.0 | **6.4** | **4.8** | 0.0 | **8.4** | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | **8.0** | 0.0 | **5.1** |
| Grafton | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Watford City | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beulah | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 |
| Rugby | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| Casselton | 0.0 | **4.1** | **5.9** | **4.1** | **3.0** | 0.0 | **4.5** | 0.0 | 0.0 | **5.8** | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | **3.2** |
| Hazen | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| Stanley | **4.1** | **3.7** | 0.0 | **8.2** | **8.3** | 0.0 | **3.2** | 0.0 | 0.0 | **3.6** | 0.0 | 0.0 | 0.0 | 0.0 | **3.8** | 0.0 | - |

# 8. SUMMARY AND CONCLUSIONS

Existing models for estimating demand for rural intercity bus services have their limitations. Many previous demand models are route-level, corridor-level, or city-pair models. While these models can be useful, they ignore the effects of existing within a larger network, and they rely on aggregate data. Using disaggregate data, or data at the level of the individual or household, are more useful in developing travel demand models.

Ideally, demand for intercity bus services could be estimated within a statewide travel demand model with a mode choice component. Such a model would benefit from the use of disaggregate data, while also accounting for competition between modes. Mode choice models predict the likelihood of an individual choosing a given mode for a given trip based on individual, mode, and trip characteristics, using a discrete choice modeling technique. These models are used to estimate mode splits and can be used to predict mode volumes when used with known or estimated total trip volume. Intercity mode choice models have been developed, but there are many variables that could influence mode choice which are often not included in these models.

The general objective of this research was to develop an intercity mode choice model that could be incorporated into a statewide travel demand model to estimate demand for rural intercity bus services. Four intercity transportation modes were considered in the study: automobile, bus, rail, and air. Specific objectives were to estimate the impacts of mode, trip, and individual characteristics on mode choice; estimate the impacts of attitudes on mode choice; examine changes in attitudes regarding intercity travel; and conduct scenario analyses to demonstrate how the model could be used to estimate the possible impacts of service changes or changes in other variables.

The model was applied to the state of North Dakota. To obtain the data needed for the mode choice model, a stated preference survey was conducted of individuals across the state. Then, a mixed logit model was used to estimate the mode share model.

The survey included four sections: a general demographic information section, a section on transportation experience, a stated preference section, and a section on travel attitudes. The stated preference section of the survey presented a series of choice sets to survey participants, where they were asked to identify their mode of choice given varying levels of price, travel time, access distance, egress distance, and frequency of service for each mode, while also considering trip distance, trip purpose, and whether they were traveling alone or in a group.

The target population for the survey was adults aged 18 or older living in North Dakota. Surveys were distributed to a random sample of 5,000 residents. Half of these residents received a paper survey in the mail, and the other half received a postcard by mail with a web address for where they could complete the survey online. A total of 541 responses were received. The paper survey had a 17% response rate, while the online-only survey had a 6% response rate, yielding an overall response rate of 11%.

With each survey respondent given nine different SP questions to answer, there were a total of 4,724 SP responses received. The automobile was the mode of choice in 73% of these responses, while air, rail, and bus accounted for 13%, 10%, and 4% of responses, respectively. The raw data showed differences in mode shares based on gender, age, income, trip distance, trip purpose, party size, travel costs, travel speeds, and access distances.

A mixed logit model was developed to estimate the impacts of individual, trip, and mode characteristics on choice of mode. Among the individual characteristics, gender, age, income, and disability were all found to have some effect on mode choice. Men were found to have greater odds of choosing automobile or bus travel. Older adults aged 70 or older were found to be less likely to choose air travel, and younger adults, aged 18-24, were found to be more likely to choose bus travel. As income increased, individuals were more likely to choose automobile and air travel. The impact of having a disability on mode choice was also found to be statistically significant and large in magnitude. People with a disability were much less likely to choose automobile or air travel and, therefore, more likely to choose bus and rail travel, compared to those without a disability.

The results showed that party size and trip purpose have some significant effects on mode choice. Individuals traveling alone were found to be less likely to choose automobile travel, and those traveling for business purposes were more likely to choose air and less likely to choose automobile. Travel time and travel price (consisting of fares and price of gasoline) were found to have negative and statistically significant impacts on mode choice, as did access distances for bus, rail, and air travel. However, the impacts of egress distance and service frequency,  were not found to be statistically significant. Finally, all other variables equal, respondents were significantly more likely to choose automobile travel (in comparison to all other modes) and air travel (in comparison to bus and rail), and they were least likely to choose bus.

Comparing responses to the survey's attitudinal questions to those from a similar survey conducted in 2009 showed little change in traveler attitudes. Modeling the impacts of traveler attitudes on mode choice showed that attitudes play a role. For example, individuals more likely to choose bus than the automobile included those who do not mind traveling with strangers, those more concerned about getting into an accident, those more concerned about having a stress-free trip than reaching their destination quickly, those more sensitive to cost, and those who feel that people who use intercity bus are like them. On the other hand, people who value a more predictable travel time or who place a higher value on cleanliness were more likely to choose the automobile.

## 8.1. Implications

By including access and egress distance in the mode choice model, it could be incorporated into a statewide travel demand model. The study demonstrated how the model could be used to estimate mode shares between origin-destination pairs after calculating in-vehicle travel times for each mode and access and egress distances to intercity bus and rail stations. When combined with travel volume estimates from a statewide travel demand model, this model would provide estimates for travel volume by intercity bus or rail.

The model could be used to estimate changes in mode shares and travel volume by each mode under different scenarios, including changes in service characteristics, demographic characteristics, or costs of competing modes. The model could be used to estimate demand for a new route, and the feasibility of the route could be analyzed by comparing the estimated ridership and fare revenue with the expected costs, allowing for a cost-benefit analysis.

Similarly, the model could be used to estimate the impact of adding a new stop along an existing route. The new stop would provide access to more potential users, but it would also increase travel time along the route. On the other hand, a low-usage stop could be removed to increase travel time along a route. This model could be used to evaluate the tradeoff between providing access to more potential users or increasing travel time. Two of the scenarios analyzed in this study evaluated such a tradeoff.

The model also takes into account how individual routes fit into a larger network. Ridership on an individual route can affect or be affected by ridership on another route. One of the scenarios analyzed in this study demonstrated this effect. This scenario proposed a new route between Bismarck and Williston via Dickinson and Watford City. Meanwhile, an existing route provides service between Bismarck and Williston via Minot. The new route would provide intercity bus access to two of the larger cities in the western part of the state while also providing a slightly faster service between Bismarck and Williston. Because of the faster travel time, intercity bus trips between Williston and Bismarck would be diverted to the new route. The model would show how many trips are generated with the new route and also how many are lost on the existing route. The new route, in this scenario, would also complement the existing route by allowing transfers at Bismarck. Those traveling from Watford City or Dickinson could transfer at Bismarck and continue east on the existing route, thereby increasing ridership on the existing route between Bismarck and Fargo. The model would be able to determine the overall net effect on ridership from the addition of the route, and its feasibility could be assessed. Policy makers would be able to use the tool to determine if the additional ridership could justify public investment.

In addition to changes in service characteristics, the model could be used to analyze impacts of demographic changes or changes regarding the characteristics of competing modes. Notably, the price of gasoline can have a significant impact on the demand for intercity bus service. One of the scenarios in this study analyzed the impact of higher gasoline prices. Bus mode shares approximately doubled when the price of gasoline increased from $2.00 per gallon to $5.00 per gallon, although this scenario did not consider a corresponding increase in bus fares.

With an aging population in North Dakota and across the county, consideration of demographics is important. The results showed that adults aged 70 and older are much less likely to travel by air, and given that driving rates tend to decrease for older adults, demand for intercity bus could increase as the elderly population continues to increase. The results did not specifically show that older adults are more likely to choose intercity bus, compared to those who are younger, but it did show that people with disabilities are much more likely to choose bus or rail. Given that disability rates increase significantly with age, an aging population would lead to increased demand for intercity bus or rail services.

The analysis of attitudes and mode choice provides some insight into how intercity bus services are perceived by the public and how they could be marketed. Bus services tend to be perceived as less stressful than automobile or air services and safer than the automobile. Intercity bus companies could market their services to those more concerned about having a safe and stress-free trip, those who want to make a more productive use of their time when traveling, or those who like to visit with others when traveling. Results also suggest intercity bus service is perceived as less predictable and less clean than traveling by automobile, whether warranted or not, and that individuals would be more likely to travel by bus if they were made to feel like they are similar to other bus users.

## 8.2. Limitations and Further Research

While the model developed in this study provides an improvement over previous models, it has its limitations, including limitations of the mode choice model, the stated preference survey, and the transferability of the results.

First, while the mode choice model can be used to estimate mode shares, estimating the number of bus trips requires an estimate of total travel volume, which could be obtained through the use of a statewide travel demand model. Even without an estimate of total travel volume, the model could be used to estimate changes in mode shares following service changes or changes in other factors, which could be used to predict changes in bus ridership on existing routes.

Second, due to limitations of the SP survey, some variables which could further influence mode choice are not accounted for in the model. While the model includes access distance as an important determinant of mode choice, the impacts of egress distance and frequency were not statistically significant. In reality, it is expected that these variables may impact mode choice, but their effects were not captured in the model (to partially capture the impact of egress distance, this study imposed a maximum egress distance of 25 miles, after which no intercity bus trips would be made). The nature of the SP survey limits the number of factors that can be used, because the inclusion of too many variables in the survey increases the cognitive burden to survey respondents and leads to inconsistent or useless results, which may explain why egress distance and frequency were not statistically significant.

This limitation also precluded the inclusion of other factors which may further influence mode choice, such as the time of day that service is provided. For example, Amtrak intercity rail currently provides service to the city of Fargo once a day in each direction, but eastbound trains depart at 2:18 am and westbound trains depart at 3:24 am. These inconvenient service times could have a negative impact on ridership, which is not accounted for in the model. However, intercity bus services are provided at reasonable times throughout the state, so the impact on bus ridership may not be great. Other factors, such as the availability of wi-fi or power outlets onboard buses could also have an impact.

Another limitation is that the mode choice model was incorporated into a statewide model, while many intercity bus routes travel multiple states. Statewide travel demand models include external TAZs to account for traffic originating or terminating outside the state, but it would be useful to have a larger regional model to show how routes in different states interact. The mode choice model developed in this study could be applied to a larger regional travel demand model if such a model existed.

Last is the question of the model's transferability to other states or regions outside of North Dakota. The model was developed for the state of North Dakota, but it would be useful to know if it could be applied elsewhere. Generally, models developed with disaggregate data such as this are more transferable than those using aggregate data (Koppelman and Bhat 2006). The one component of the model that makes it specific to North Dakota is that it was developed using data collected through a SP survey of North Dakota residents. The model could be applied in other areas if residents in those areas have similar travel preferences and similar sensitivities to cost, travel time, and other factors as do North Dakota residents.

The model is most likely to be transferable to other states or regions consisting of largely rural and small urban areas where travel behavior is similar. Residents in larger metropolitan areas or those with different cultural backgrounds may have different travel preferences and may respond differently to the SP questions. Further research would be needed to test these differences. In those areas, the same model structure could be used, but a separate SP survey may need to be conducted of residents in that area, and the data from that survey could be used to estimate the mode choice model using the same framework developed in this study.

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# APPENDIX A. STATED CHOICE EXPERIMENT DESIGN

**Table A.1.** Coded Survey Design

| Choice Set | Block | SPD AIR | TRIP TYPE | PARTY | PR AIR | PR AUTO | PR BUS | PR RAIL | SPD BUS | SPD RAIL | ACS AIR | ACS BUS | ACS RAIL | EGS AIR | EGS BUS | EGS RAIL | FREQ AIR | FREQ BUS | FREQ RAIL | DIST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 3 |
| 2 | 1 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 2 | 1 | 2 | 3 | 2 |
| 3 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 3 | 1 | 3 | 2 | 3 | 2 | 1 | 4 |
| 4 | 1 | 2 | 1 | 2 | 2 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 3 | 2 | 2 | 2 | 3 |
| 5 | 1 | 1 | 1 | 2 | 1 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 1 |
| 6 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 2 | 1 | 3 | 3 | 1 | 2 | 1 | 2 | 1 | 1 | 3 |
| 7 | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 3 | 4 |
| 8 | 1 | 1 | 1 | 2 | 3 | 1 | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 3 | 1 |
| 9 | 1 | 2 | 1 | 1 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 2 | 2 | 1 | 3 | 3 | 1 | 3 | 2 | 2 |
| 10 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 3 | 1 | 3 | 2 | 3 | 2 | 1 | 3 |
| 11 | 2 | 2 | 2 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 |
| 12 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 2 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 1 |
| 13 | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 1 | 2 | 2 | 3 | 1 |
| 14 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 3 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 3 |
| 15 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 1 | 3 | 2 | 1 | 3 | 3 | 3 | 1 | 3 | 4 |
| 16 | 2 | 1 | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 2 | 4 |
| 17 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 1 | 2 | 3 | 2 | 3 | 2 | 1 | 3 | 4 |
| 18 | 2 | 1 | 1 | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | 3 |
| 19 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | 4 |
| 20 | 3 | 2 | 1 | 1 | 3 | 3 | 3 | 1 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 3 | 3 |
| 21 | 3 | 1 | 2 | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 2 |
| 22 | 3 | 2 | 2 | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 1 |
| 23 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 3 | 3 | 1 | 3 | 1 | 2 | 1 | 3 | 3 | 3 | 1 | 3 | 3 |
| 24 | 3 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 |
| 25 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| 26 | 3 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 1 | 3 | 2 | 1 | 2 | 3 | 2 | 3 |
| 27 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 2 |
| 28 | 4 | 1 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 3 |
| 29 | 4 | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 4 |
| 30 | 4 | 2 | 1 | 1 | 3 | 1 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| 31 | 4 | 1 | 2 | 2 | 3 | 2 | 2 | 1 | 1 | 2 | 1 | 3 | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 4 |
| 32 | 4 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 1 |
| 33 | 4 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3 |
| 34 | 4 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 3 | 1 | 2 | 1 | 1 | 2 | 3 | 2 |
| 35 | 4 | 1 | 2 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 2 | 2 | 3 | 3 |
| 36 | 4 | 2 | 1 | 1 | 1 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 3 | 2 | 2 | 2 | 1 |
| 37 | 5 | 2 | 1 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 1 | 2 | 1 | 3 | 3 | 2 |
| 38 | 5 | 2 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 3 |

**Table A.1.** Coded Survey Design (continued)

| Choice Set | Block | SPD AIR | TRIP TYPE | PARTY | PR AIR | PR AUTO | PR BUS | PR RAIL | SPD BUS | SPD RAIL | ACS AIR | ACS BUS | ACS RAIL | EGS AIR | EGS BUS | EGS RAIL | FREQ AIR | FREQ BUS | FREQ RAIL | DIST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 5 | 1 | 1 | 2 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 2 | 1 | 2 |
| 40 | 5 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 2 |
| 41 | 5 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 2 | 3 |
| 42 | 5 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 3 | 3 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 3 | 4 |
| 43 | 5 | 2 | 2 | 1 | 1 | 2 | 3 | 3 | 3 | 3 | 1 | 2 | 3 | 1 | 2 | 1 | 1 | 2 | 3 | 4 |
| 44 | 5 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 |
| 45 | 5 | 2 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 3 | 1 | 3 | 2 | 2 | 3 | 2 | 4 |
| 46 | 6 | 1 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 |
| 47 | 6 | 2 | 1 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 1 | 3 | 2 |
| 48 | 6 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 3 | 1 | 1 | 3 | 3 | 2 | 2 | 3 | 1 | 3 | 3 | 2 |
| 49 | 6 | 1 | 2 | 1 | 3 | 3 | 3 | 1 | 3 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 3 |
| 50 | 6 | 1 | 2 | 2 | 3 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 1 |
| 51 | 6 | 1 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 1 | 2 | 2 | 3 | 1 |
| 52 | 6 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| 53 | 6 | 2 | 2 | 1 | 3 | 3 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 4 |
| 54 | 6 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 1 | 2 | 1 | 4 |
| 55 | 7 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 4 |
| 56 | 7 | 2 | 2 | 2 | 3 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 2 | 3 | 3 | 2 | 3 | 1 | 2 |
| 57 | 7 | 1 | 2 | 1 | 3 | 1 | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 3 |
| 58 | 7 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 3 | 2 | 2 | 3 | 1 | 2 | 1 | 3 | 3 | 3 |
| 59 | 7 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 |
| 60 | 7 | 1 | 1 | 2 | 3 | 3 | 1 | 2 | 3 | 1 | 1 | 3 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 4 |
| 61 | 7 | 1 | 2 | 1 | 2 | 3 | 3 | 3 | 1 | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 1 | 2 | 2 |
| 62 | 7 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 1 |
| 63 | 7 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 3 | 1 | 3 | 2 | 2 | 3 | 2 | 2 |
| 64 | 8 | 1 | 1 | 1 | 3 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| 65 | 8 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 3 | 1 | 1 | 3 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 2 |
| 66 | 8 | 2 | 1 | 2 | 3 | 2 | 2 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 2 | 1 | 2 | 1 | 1 | 2 |
| 67 | 8 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 1 |
| 68 | 8 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 3 | 2 | 3 | 1 | 4 |
| 69 | 8 | 2 | 2 | 2 | 3 | 3 | 1 | 2 | 1 | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 1 | 3 | 3 | 4 |
| 70 | 8 | 1 | 2 | 1 | 2 | 1 | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 2 | 3 | 3 |
| 71 | 8 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 1 | 2 | 1 | 2 | 1 | 1 | 3 | 1 | 3 | 2 |
| 72 | 8 | 1 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 1 | 3 | 2 | 4 |

**Table A.2.** Uncoded Survey Design

| Choice Set | Block | SPD AIR | TRIP TYPE | PARTY | PR AIR | PR AUTO | PR BUS | PR RAIL | SPD BUS | SPD RAIL | ACS AIR | ACS BUS | ACS RAIL | EGS AIR | EGS BUS | EGS RAIL | FREQ AIR | FREQ BUS | FREQ RAIL | DIST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Fast | Personal | Group | 150 | 0.2 | 0.15 | 0.15 | 55 | 65 | 20 | 20 | 10 | 5 | 10 | 1 | 3 times per week | 3 times per week | 3 times per week | 250 |
| 2 | 1 | Slow | Business | Alone | 450 | 0.16 | 0.2 | 0.15 | 65 | 45 | 20 | 2 | 2 | 10 | 10 | 5 | 3 times per week | Once per day | Twice per day | 100 |
| 3 | 1 | Slow | Business | Group | 300 | 0.2 | 0.25 | 0.25 | 55 | 45 | 20 | 10 | 20 | 1 | 10 | 5 | Twice per day | Once per day | 3 times per week | 400 |
| 4 | 1 | Fast | Personal | Group | 300 | 0.16 | 0.25 | 0.2 | 45 | 45 | 2 | 2 | 20 | 10 | 1 | 10 | Once per day | Once per day | Once per day | 250 |
| 5 | 1 | Slow | Personal | Group | 150 | 0.2 | 0.2 | 0.25 | 65 | 55 | 20 | 20 | 10 | 5 | 5 | 5 | Twice per day | Twice per day | 3 times per week | 50 |
| 6 | 1 | Fast | Business | Group | 300 | 0.11 | 0.15 | 0.25 | 45 | 55 | 2 | 20 | 20 | 1 | 5 | 1 | Once per day | 3 times per week | 3 times per week | 250 |
| 7 | 1 | Fast | Personal | Alone | 150 | 0.16 | 0.25 | 0.25 | 55 | 55 | 10 | 2 | 2 | 5 | 1 | 1 | Twice per day | 3 times per week | Twice per day | 400 |
| 8 | 1 | Slow | Personal | Group | 450 | 0.11 | 0.25 | 0.2 | 45 | 45 | 10 | 10 | 2 | 1 | 1 | 10 | Once per day | Once per day | Twice per day | 50 |
| 9 | 1 | Fast | Personal | Alone | 300 | 0.2 | 0.2 | 0.2 | 65 | 65 | 2 | 10 | 10 | 1 | 10 | 10 | 3 times per week | Twice per day | Once per day | 100 |
| 10 | 2 | Fast | Personal | Alone | 150 | 0.16 | 0.2 | 0.2 | 45 | 65 | 10 | 20 | 20 | 1 | 10 | 5 | Twice per day | Once per day | 3 times per week | 250 |
| 11 | 2 | Fast | Business | Alone | 450 | 0.11 | 0.25 | 0.2 | 55 | 65 | 20 | 20 | 2 | 1 | 5 | 5 | 3 times per week | 3 times per week | Once per day | 50 |
| 12 | 2 | Fast | Business | Alone | 300 | 0.16 | 0.15 | 0.15 | 65 | 55 | 10 | 10 | 20 | 10 | 1 | 10 | Twice per day | Twice per day | 3 times per week | 50 |
| 13 | 2 | Fast | Business | Alone | 150 | 0.2 | 0.2 | 0.25 | 45 | 45 | 2 | 2 | 10 | 5 | 10 | 1 | Once per day | Once per day | Twice per day | 50 |
| 14 | 2 | Fast | Personal | Alone | 300 | 0.11 | 0.15 | 0.25 | 65 | 45 | 20 | 2 | 2 | 5 | 1 | 1 | 3 times per week | Twice per day | Once per day | 250 |
| 15 | 2 | Slow | Personal | Alone | 450 | 0.16 | 0.2 | 0.15 | 45 | 55 | 2 | 20 | 10 | 1 | 10 | 10 | Twice per day | 3 times per week | Twice per day | 400 |
| 16 | 2 | Slow | Personal | Alone | 300 | 0.2 | 0.25 | 0.25 | 55 | 45 | 20 | 10 | 2 | 10 | 5 | 1 | Once per day | Twice per day | Once per day | 400 |
| 17 | 2 | Slow | Business | Group | 150 | 0.11 | 0.15 | 0.2 | 65 | 65 | 10 | 2 | 10 | 10 | 5 | 10 | Once per day | 3 times per week | Twice per day | 400 |
| 18 | 2 | Slow | Personal | Group | 450 | 0.2 | 0.25 | 0.15 | 55 | 55 | 2 | 10 | 20 | 5 | 1 | 5 | 3 times per week | Once per day | 3 times per week | 250 |
| 19 | 3 | Slow | Personal | Alone | 150 | 0.11 | 0.15 | 0.2 | 65 | 65 | 10 | 2 | 20 | 5 | 1 | 5 | 3 times per week | Once per day | 3 times per week | 400 |
| 20 | 3 | Fast | Personal | Alone | 450 | 0.2 | 0.25 | 0.15 | 55 | 55 | 2 | 10 | 10 | 10 | 5 | 10 | Once per day | 3 times per week | Twice per day | 250 |
| 21 | 3 | Slow | Business | Alone | 450 | 0.16 | 0.15 | 0.25 | 45 | 65 | 20 | 10 | 10 | 1 | 1 | 1 | Twice per day | Once per day | Once per day | 100 |
| 22 | 3 | Fast | Business | Group | 450 | 0.11 | 0.25 | 0.2 | 55 | 65 | 20 | 20 | 20 | 10 | 10 | 1 | Twice per day | Twice per day | Twice per day | 50 |
| 23 | 3 | Slow | Personal | Group | 300 | 0.11 | 0.15 | 0.25 | 65 | 45 | 20 | 2 | 10 | 1 | 10 | 10 | Twice per day | 3 times per week | Twice per day | 250 |
| 24 | 3 | Fast | Business | Group | 150 | 0.2 | 0.2 | 0.25 | 45 | 45 | 2 | 2 | 2 | 1 | 1 | 10 | 3 times per week | 3 times per week | 3 times per week | 50 |
| 25 | 3 | Fast | Business | Group | 300 | 0.16 | 0.15 | 0.15 | 65 | 55 | 10 | 10 | 10 | 5 | 5 | 5 | Once per day | Once per day | Once per day | 50 |
| 26 | 3 | Slow | Personal | Group | 150 | 0.16 | 0.2 | 0.2 | 45 | 65 | 10 | 20 | 2 | 10 | 5 | 1 | Once per day | Twice per day | Once per day | 250 |

**Table A.2.** Uncoded Survey Design (continued)

| Choice Set | Block | SPD AIR | TRIP TYPE | PARTY | PR AIR | PR AUTO | PR BUS | PR RAIL | SPD BUS | SPD RAIL | ACS AIR | ACS BUS | ACS RAIL | EGS AIR | EGS BUS | EGS RAIL | FREQ AIR | FREQ BUS | FREQ RAIL | DIST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 3 | Slow | Business | Alone | 300 | 0.2 | 0.2 | 0.2 | 55 | 55 | 10 | 2 | 2 | 10 | 10 | 5 | Once per day | 3 times per week | 3 times per week | 100 |
| 28 | 4 | Slow | Business | Alone | 300 | 0.16 | 0.25 | 0.2 | 45 | 45 | 2 | 2 | 10 | 5 | 5 | 5 | Twice per day | Twice per day | 3 times per week | 250 |
| 29 | 4 | Fast | Business | Group | 150 | 0.16 | 0.25 | 0.25 | 65 | 65 | 2 | 10 | 2 | 10 | 10 | 5 | Once per day | 3 times per week | 3 times per week | 400 |
| 30 | 4 | Fast | Personal | Alone | 450 | 0.11 | 0.25 | 0.2 | 45 | 45 | 10 | 10 | 10 | 5 | 10 | 1 | 3 times per week | 3 times per week | 3 times per week | 50 |
| 31 | 4 | Slow | Business | Group | 450 | 0.16 | 0.2 | 0.15 | 45 | 55 | 2 | 20 | 2 | 5 | 1 | 1 | 3 times per week | Twice per day | Once per day | 400 |
| 32 | 4 | Slow | Personal | Group | 300 | 0.16 | 0.15 | 0.15 | 55 | 65 | 2 | 2 | 20 | 10 | 10 | 1 | 3 times per week | 3 times per week | Once per day | 50 |
| 33 | 4 | Fast | Personal | Group | 450 | 0.11 | 0.2 | 0.25 | 65 | 55 | 10 | 10 | 2 | 1 | 5 | 5 | Twice per day | Twice per day | Twice per day | 250 |
| 34 | 4 | Fast | Business | Group | 300 | 0.2 | 0.2 | 0.2 | 55 | 55 | 10 | 2 | 20 | 1 | 5 | 1 | 3 times per week | Once per day | Twice per day | 100 |
| 35 | 4 | Slow | Business | Alone | 150 | 0.2 | 0.15 | 0.15 | 55 | 65 | 20 | 20 | 2 | 1 | 1 | 10 | Once per day | Once per day | Twice per day | 250 |
| 36 | 4 | Fast | Personal | Alone | 150 | 0.2 | 0.2 | 0.25 | 65 | 55 | 20 | 20 | 20 | 10 | 1 | 10 | Once per day | Once per day | Once per day | 50 |
| 37 | 5 | Fast | Personal | Group | 300 | 0.2 | 0.25 | 0.25 | 45 | 65 | 10 | 20 | 10 | 10 | 1 | 5 | 3 times per week | Twice per day | Twice per day | 100 |
| 38 | 5 | Fast | Business | Group | 450 | 0.2 | 0.25 | 0.15 | 65 | 65 | 10 | 2 | 2 | 5 | 10 | 10 | Twice per day | Once per day | Once per day | 250 |
| 39 | 5 | Slow | Personal | Group | 450 | 0.16 | 0.15 | 0.25 | 55 | 45 | 10 | 20 | 10 | 10 | 5 | 10 | 3 times per week | Once per day | 3 times per week | 100 |
| 40 | 5 | Slow | Business | Alone | 150 | 0.11 | 0.15 | 0.2 | 55 | 55 | 2 | 10 | 10 | 1 | 1 | 1 | Once per day | Twice per day | 3 times per week | 100 |
| 41 | 5 | Slow | Business | Alone | 150 | 0.16 | 0.2 | 0.2 | 55 | 45 | 20 | 10 | 20 | 5 | 5 | 10 | Twice per day | 3 times per week | Once per day | 250 |
| 42 | 5 | Slow | Personal | Group | 300 | 0.11 | 0.2 | 0.15 | 45 | 65 | 20 | 10 | 20 | 5 | 1 | 5 | Once per day | 3 times per week | Twice per day | 400 |
| 43 | 5 | Fast | Business | Alone | 150 | 0.16 | 0.25 | 0.25 | 65 | 65 | 2 | 10 | 20 | 1 | 5 | 1 | 3 times per week | Once per day | Twice per day | 400 |
| 44 | 5 | Fast | Personal | Alone | 150 | 0.11 | 0.25 | 0.15 | 45 | 55 | 20 | 2 | 2 | 10 | 5 | 1 | Twice per day | Once per day | 3 times per week | 100 |
| 45 | 5 | Fast | Personal | Alone | 450 | 0.2 | 0.15 | 0.2 | 65 | 45 | 2 | 20 | 20 | 1 | 10 | 5 | Once per day | Twice per day | Once per day | 400 |
| 46 | 6 | Slow | Business | Group | 150 | 0.2 | 0.15 | 0.15 | 45 | 45 | 10 | 10 | 2 | 1 | 5 | 5 | 3 times per week | 3 times per week | Once per day | 50 |
| 47 | 6 | Fast | Personal | Alone | 450 | 0.16 | 0.15 | 0.25 | 55 | 45 | 10 | 20 | 20 | 5 | 1 | 5 | Once per day | 3 times per week | Twice per day | 100 |
| 48 | 6 | Slow | Business | Alone | 150 | 0.11 | 0.25 | 0.15 | 65 | 45 | 2 | 20 | 20 | 5 | 5 | 10 | 3 times per week | Twice per day | Twice per day | 100 |
| 49 | 6 | Slow | Business | Alone | 450 | 0.2 | 0.25 | 0.15 | 65 | 65 | 10 | 2 | 10 | 1 | 1 | 1 | Once per day | Twice per day | 3 times per week | 250 |
| 50 | 6 | Slow | Business | Group | 450 | 0.11 | 0.2 | 0.25 | 55 | 65 | 2 | 2 | 20 | 10 | 1 | 10 | Twice per day | Twice per day | 3 times per week | 50 |
| 51 | 6 | Slow | Business | Group | 300 | 0.16 | 0.25 | 0.2 | 65 | 55 | 20 | 20 | 10 | 5 | 10 | 1 | Once per day | Once per day | Twice per day | 50 |
| 52 | 6 | Fast | Personal | Group | 150 | 0.11 | 0.15 | 0.2 | 55 | 55 | 2 | 10 | 2 | 5 | 10 | 10 | Twice per day | Once per day | Once per day | 100 |

**Table A.2.** Uncoded Survey Design (continued)

| Choice Set | Block | SPD AIR | TRIP TYPE | PARTY | PR AIR | PR AUTO | PR BUS | PR RAIL | SPD BUS | SPD RAIL | ACS AIR | ACS BUS | ACS RAIL | EGS AIR | EGS BUS | EGS RAIL | FREQ AIR | FREQ BUS | FREQ RAIL | DIST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53 | 6 | Fast | Business | Alone | 450 | 0.2 | 0.15 | 0.2 | 45 | 55 | 20 | 2 | 10 | 10 | 1 | 5 | Twice per day | 3 times per week | Once per day | 400 |
| 54 | 6 | Fast | Personal | Alone | 300 | 0.11 | 0.2 | 0.15 | 45 | 65 | 20 | 10 | 10 | 10 | 5 | 10 | 3 times per week | Once per day | 3 times per week | 400 |
| 55 | 7 | Fast | Business | Group | 300 | 0.11 | 0.2 | 0.15 | 55 | 45 | 10 | 20 | 10 | 1 | 1 | 1 | Twice per day | Once per day | Once per day | 400 |
| 56 | 7 | Fast | Business | Group | 450 | 0.16 | 0.15 | 0.25 | 45 | 65 | 20 | 10 | 2 | 5 | 10 | 10 | Once per day | Twice per day | 3 times per week | 100 |
| 57 | 7 | Slow | Business | Alone | 450 | 0.11 | 0.2 | 0.25 | 65 | 55 | 10 | 10 | 20 | 10 | 10 | 1 | 3 times per week | 3 times per week | Once per day | 250 |
| 58 | 7 | Fast | Business | Group | 150 | 0.16 | 0.2 | 0.2 | 55 | 45 | 20 | 10 | 10 | 10 | 1 | 5 | 3 times per week | Twice per day | Twice per day | 250 |
| 59 | 7 | Slow | Personal | Alone | 300 | 0.16 | 0.25 | 0.2 | 65 | 55 | 20 | 20 | 2 | 1 | 1 | 10 | 3 times per week | 3 times per week | 3 times per week | 50 |
| 60 | 7 | Slow | Personal | Group | 450 | 0.2 | 0.15 | 0.2 | 65 | 45 | 2 | 20 | 2 | 10 | 5 | 1 | Twice per day | Once per day | 3 times per week | 400 |
| 61 | 7 | Slow | Business | Alone | 300 | 0.2 | 0.25 | 0.25 | 45 | 65 | 10 | 20 | 20 | 5 | 5 | 10 | Twice per day | 3 times per week | Once per day | 100 |
| 62 | 7 | Fast | Personal | Alone | 300 | 0.16 | 0.15 | 0.15 | 55 | 65 | 2 | 2 | 2 | 1 | 5 | 5 | Twice per day | Twice per day | Twice per day | 50 |
| 63 | 7 | Slow | Personal | Group | 150 | 0.11 | 0.25 | 0.15 | 45 | 55 | 20 | 2 | 20 | 1 | 10 | 5 | Once per day | Twice per day | Once per day | 100 |
| 64 | 8 | Slow | Personal | Alone | 450 | 0.11 | 0.2 | 0.25 | 55 | 65 | 2 | 2 | 10 | 5 | 5 | 5 | Once per day | Once per day | Once per day | 50 |
| 65 | 8 | Fast | Business | Group | 150 | 0.11 | 0.25 | 0.15 | 65 | 45 | 2 | 20 | 10 | 10 | 1 | 5 | Twice per day | 3 times per week | Once per day | 100 |
| 66 | 8 | Fast | Personal | Group | 450 | 0.16 | 0.2 | 0.15 | 65 | 45 | 20 | 2 | 20 | 1 | 5 | 1 | Once per day | 3 times per week | 3 times per week | 100 |
| 67 | 8 | Slow | Personal | Alone | 150 | 0.2 | 0.15 | 0.15 | 45 | 45 | 10 | 10 | 20 | 10 | 10 | 1 | Twice per day | Twice per day | Twice per day | 50 |
| 68 | 8 | Fast | Business | Alone | 300 | 0.11 | 0.2 | 0.15 | 55 | 45 | 10 | 20 | 2 | 5 | 10 | 10 | Once per day | Twice per day | 3 times per week | 400 |
| 69 | 8 | Fast | Business | Group | 450 | 0.2 | 0.15 | 0.2 | 45 | 55 | 20 | 2 | 20 | 5 | 5 | 10 | 3 times per week | Twice per day | Twice per day | 400 |
| 70 | 8 | Slow | Business | Alone | 300 | 0.11 | 0.15 | 0.25 | 45 | 55 | 2 | 20 | 2 | 10 | 10 | 5 | 3 times per week | Once per day | Twice per day | 250 |
| 71 | 8 | Slow | Personal | Group | 300 | 0.2 | 0.2 | 0.2 | 65 | 65 | 2 | 10 | 2 | 5 | 1 | 1 | Twice per day | 3 times per week | Twice per day | 100 |
| 72 | 8 | Slow | Personal | Group | 150 | 0.16 | 0.25 | 0.25 | 55 | 55 | 10 | 2 | 10 | 1 | 10 | 10 | 3 times per week | Twice per day | Once per day | 400 |

# APPENDIX B. SURVEY

NDSU
UPPER GREAT PLAINS TRANSPORTATION INSTITUTE
SMALL URBAN AND RURAL TRANSIT CENTER
NDSU Dept. 2880 · PO Box 6050 · Fargo, ND 58108-6050

Dear North Dakota resident:

You have been selected to give your opinions about city-to-city travel in North Dakota. By participating, you have the opportunity to win a $300 cash prize, as well as to influence future transportation improvements. The Upper Great Plains Transportation Institute at North Dakota State University is conducting a study on city-to-city travel in North Dakota, and the results will help us learn more about the need for transportation improvements, including city-to-city bus and rail services.

You are invited to participate in this research study and answer questions regarding attitudes toward and use of transportation. It should take about 15-20 minutes to complete the survey. When you have completed the survey, please return it using the envelope provided. **Please complete the enclosed drawing entry slip with your completed survey if you would like to enter a drawing for a $300 cash prize.** If you prefer, you can take the survey and enter the drawing online by going to www.tinyurl.com/ugpti.

Your participation is entirely voluntary, and you may decline or withdraw from participation at any time. Neither your name nor any other personal identifier will be collected for the survey and your responses will remain confidential. The only linkage will be with the drawing entry slip which will only be used to manage the drawing process. Your information will be combined with information from other people taking part in the study.

If you have any questions about this project, please contact Jeremy Mattson by phone at 701-231-5496 or by email at jeremy.w.mattson@ndsu.edu. If you have questions about the rights of human participants in research, or to report a problem, contact the NDSU IRB Office toll free at 1-855-800-6717 or ndsu.irb@ndsu.edu.

Thank you for your participation in this research.

Sincerely,

Jeremy Mattson

North Dakota State University

# North Dakota Intercity Transportation Survey

## Mode of Transportation Descriptions

This survey is about four different kinds of transportation:

| | |
|---|---|
| **Automobile** | Personal car, sport-utility vehicle, light-duty truck, van or other vehicle that is driven by you or a member of your party. |
| **Air** | Commercial or private airplane. |
| **Bus** | Bus that provides passenger service **between cities**, such as Greyhound or Jefferson Lines. |
| **Train** | Passenger train such as Amtrak. |

## Part A. General Information

First, please provide some general information about yourself. Your responses in this section allow us to project the results to the population as a whole. **Your answers will be kept entirely confidential**.

1. What is your gender? ☐ Male ☐ Female

2. What is your age?

   ☐ <25 ☐ 25-29 ☐ 30-39 ☐ 40-49
   ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐ 80 or older

3. What is your 5-digit zip code? __ __ __ __ __

4. What is your household income?

   ☐ Less than $25,000 ☐ $25,000-$49,999 ☐ $50,000-$74,999
   ☐ $75,000-$99,999 ☐ $100,000 or more

5. Do you have a medical condition or disability that makes it difficult to travel?

   ☐ Yes ☐ No

## Part B. Transportation

1. Are you able to operate an automobile (legally, physically, mentally)?

   ☐ Yes ☐ No

2. How many automobiles are kept at home for use by members of this household?

   ☐ None ☐ 1 ☐ 2 ☐ 3 or more

3. During the past year, did you make any long-distance trips of 100 miles or more one-way?

☐ Yes ☐ No

4. Have you traveled by intercity rail, such as Amtrak, anywhere within the last five years?

☐ Yes ☐ No

5. Have you traveled by **intercity bus**, such as Greyhound, Jefferson Lines, Rimrock Trailways, etc., anywhere within the last five years?

☐ Yes ☐ No

6. Have you traveled by airplane anywhere within the last five years?

☐ Yes ☐ No

7. In general, how easy is it for you to travel to other cities in North Dakota?

☐ Very difficult
☐ Difficult
☐ Somewhat difficult
☐ Neither difficult nor easy
☐ Somewhat easy
☐ Easy
☐ Very easy

8. Regarding travel between towns and cities in North Dakota, how much is there a need for the following improvements?

| | High Need | Moderate Need | Low Need | No Need at All | Do Not Know |
|---|---|---|---|---|---|
| Highway improvements | ☐ | ☐ | ☐ | ☐ | ☐ |
| Bus service improvements | ☐ | ☐ | ☐ | ☐ | ☐ |
| Passenger rail service improvements | ☐ | ☐ | ☐ | ☐ | ☐ |
| Air service improvements | ☐ | ☐ | ☐ | ☐ | ☐ |

9. Please describe the types of improvements you would make:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

## Part C. Hypothetical Trips

In this section, you are given nine hypothetical situations. In each situation, imagine that you are taking a trip and are asked to choose which mode of travel you would use. These trips are 50-400 miles long, beginning at home and ending in either North Dakota or another state.

Factors that you will need to consider include:

- Travel distance
- Type of trip (business or personal)
- Whether you are traveling alone or in a group
- Travel cost
- Travel time

For air, bus, and train travel, you also need to consider:

- How frequently the service is offered
- The distance from your home to the airport, bus station, or rail station
- The distance from the airport, bus station, or rail station at your destination to where you are going (your final destination)

The cost refers to the fares for air, bus, and train travel and the cost of gasoline for automobile travel. The travel time and cost are calculated based on a one-way trip. Take your time and consider each situation carefully.

For each trip, please consider the alternatives and select either automobile, air, bus, or train. Choose one of the options for each question, even if you don't make the type of trip being described.

**Trip #1: How would you get there?**

Distance: <u>50 miles</u> Type of trip: <u>Personal</u> Traveling with: <u>Friends or family</u>

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | **Automobile** | **Air** | **Bus** | **Train** |
| Cost: | \$5.00 per gallon | \$150/person | \$10/person | \$12.50/person |
| Frequency: | - | Twice per day | Twice per day | 3 times per week |
| Distance from home to bus/rail station or airport: | - | 20 miles | 20 miles | 10 miles |
| Travel time: | 45 minutes | 2 hours | 46 minutes | 55 minutes |
| Distance from bus/rail station or airport to final destination: | - | 5 miles | 5 miles | 5 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #2: How would you get there?**

Distance: 50 miles  Type of trip: Personal  Traveling with: Friends or family

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $2.00 per gallon | $450/person | $12.50/person | $10/person |
| Frequency: | - | Once per day | Once per day | Twice per day |
| Distance from home to bus/rail station or airport: | - | 10 miles | 10 miles | 2 miles |
| Travel time: | 45 minutes | 2 hours | 1 hour 7 minutes | 1 hour 7 minutes |
| Distance from bus/rail station or airport to final destination: | - | 1 miles | 1 miles | 10 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #3: How would you get there?**

Distance: 100 miles  Type of trip: Business  Traveling with: Alone

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $3.50 per gallon | $450 | $20/person | $15/person |
| Frequency: | - | 3 times per week | Once per day | Twice per day |
| Distance from home to bus/rail station or airport: | - | 20 miles | 2 miles | 2 miles |
| Travel time: | 1 hour 32 minutes | 3 hours | 1 hour 33 minutes | 2 hours 13 minutes |
| Distance from bus/rail station or airport to final destination: | - | 10 miles | 10 miles | 5 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #4: How would you get there?**

Distance: 100 miles  Type of trip: Personal  Traveling with: Alone

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $5.00 per gallon | $300 | $20/person | $20/person |
| Frequency: | - | 3 times per week | Twice per day | Once per day |
| Distance from home to bus/rail station or airport: | - | 2 miles | 10 miles | 10 miles |
| Travel time: | 1 hour 32 minutes | 45 minutes | 1 hour 33 minutes | 1 hour 33 minutes |
| Distance from bus/rail station or airport to final destination: | - | 1 miles | 10 miles | 10 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #5: How would you get there?**

Distance: 250 miles Type of trip: Personal Traveling with: Friends or family

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $5.00 per gallon | $150/person | $37.50/person | $37.50/person |
| Frequency: | - | 3 times per week | 3 times per week | 3 times per week |
| Distance from home to bus/rail station or airport: | - | 20 miles | 20 miles | 10 miles |
| Travel time: | 3 hours 50 minutes | 1 hour | 4 hours 33 minutes | 3 hours 50 minutes |
| Distance from bus/rail station or airport to final destination: | - | 5 miles | 10 miles | 1 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #6: How would you get there?**

Distance: 250 miles Type of trip: Personal Traveling with: Friends or family

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $3.50 per gallon | $300/person | $62.50/person | $50/person |
| Frequency: | - | Once per day | Once per day | Once per day |
| Distance from home to bus/rail station or airport: | - | 2 miles | 2 miles | 20 miles |
| Travel time: | 3 hours 50 minutes | 1 hour | 5 hours 33 minutes | 5 hours 33 minutes |
| Distance from bus/rail station or airport to final destination: | - | 10 miles | 1 miles | 10 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #7: How would you get there?**

Distance: 250 miles Type of trip: Business Traveling with: Co-workers

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $2.00 per gallon | $300/person | $37.50/person | $62.50/person |
| Frequency: | - | Once per day | 3 times per week | 3 times per week |
| Distance from home to bus/rail station or airport: | - | 2 miles | 20 miles | 20 miles |
| Travel time: | 3 hours 50 minutes | 1 hour | 5 hours 33 minutes | 4 hours 33 minutes |
| Distance from bus/rail station or airport to final destination: | - | 1 miles | 5 miles | 1 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #8: How would you get there?**

Distance: 400 miles Type of trip: Business Traveling with: Co-workers

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $5.00 per gallon | $300/person | $100/person | $100/person |
| Frequency: | - | Twice per day | Once per day | 3 times per week |
| Distance from home to bus/rail station or airport: | - | 20 miles | 10 miles | 20 miles |
| Travel time: | 6 hours 9 minutes | 4 hours | 7 hours 16 minutes | 8 hours 53 minutes |
| Distance from bus/rail station or airport to final destination: | - | 1 miles | 10 miles | 5 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

**Trip #9: How would you get there?**

Distance: 400 miles Type of trip: Personal Traveling with: Alone

| | Possible Modes of Travel | | | |
|---|---|---|---|---|
| | Automobile | Air | Bus | Train |
| Cost: | $3.50 per gallon | $150 | $100/person | $100/person |
| Frequency: | - | Twice per day | 3 times per week | Twice per day |
| Distance from home to bus/rail station or airport: | - | 10 miles | 2 miles | 2 miles |
| Travel time: | 6 hours 9 minutes | 75 minutes | 7 hours 16 minutes | 7 hours 16 minutes |
| Distance from bus/rail station or airport to final destination: | - | 5 miles | 1 miles | 1 miles |
| **CHOOSE ONE OPTION** | ☐ | ☐ | ☐ | ☐ |

## Part D. Your Opinion about Travel

Lastly, for each of the following statements, circle the number on the scale indicating how much you agree or disagree.

| | | Strongly Disagree ← | | | | | | → Strongly Agree | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | People who travel alone should pay more to help improve the environment. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2. | I would be willing to pay more when I travel if it would help the environment. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 3. | I would switch to a different form of transportation if it would help the environment. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 4. | I would rather do something else with the time that I spend traveling. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5. | I would like to make productive use of my time when traveling. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 6. | I prefer a travel option that has a predictable travel time. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 7. | When traveling, I like to keep as close as possible to my departure and arrival schedules. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 8. | If my travel options are delayed, I want to know the cause and length of the delay. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 9. | I would change my form of travel if it would save me some time. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 10. | I always take the fastest route to my destination even if I have a cheaper alternative. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11. | I don't mind traveling with strangers. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 12. | When traveling, I like to talk and visit with other people. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 13. | I prefer to make trips alone, because I like the time to myself. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 14. | I worry about getting in an accident when I travel. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 15. | Having privacy is important to me when I travel. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 16. | I need to make trips according to a fixed schedule. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 17. | It's important to be able to change my travel plans at a moment's notice. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 18. | Having a stress-free trip is more important than reaching my destination quickly. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 19. | I don't mind long delays as long as I'm comfortable. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 20. | It is important to have comfortable seats when I travel. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 21. | I avoid traveling at certain times because it is too stressful. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 22. | A clean vehicle is important to me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 23. | I use the most convenient form of transportation regardless of cost. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 24. | The people who ride intercity bus are like me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 25. | The people who fly are like me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 26. | The people who use intercity rail service are like me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 27. | I'm willing to pay more for a ticket if it allows me to re-book my trip later for free. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

**THANK YOU FOR YOUR HELP!**

# APPENDIX C. SAS CODE

```
PROC IMPORT OUT= WORK.modechoiceDATA
            DATAFILE= "C:\Users\user\Google
Drive\Dissertation\modechoicesasdata.xlsx"
            DBMS=EXCEL REPLACE;
     SHEET="Sheet1$";
data modechoicedata;
set modechoicedata;

if gender=1 then male=1; else male=0;

if modechoice="." then delete;

if age=1 then age1=1; else age1=0;
if age<2 then age2=0; else if age>6 then age2=0; else age2=1;
if age>6 then age3=1; else age3=0;
if income=1 then inc1=1; else inc1=0;
if income=2 then inc2=1; else inc2=0;
if income=3 then inc3=1; else if income=4 then inc3=1; else inc3=0;
if income=5 then inc4=1; else inc4=0;

acsauto=0;
egsauto=0;
freqauto=4;

if modechoice=1 then autochoice=1; else autochoice=0;
if modechoice=2 then airchoice=1; else airchoice=0;
if modechoice=3 then buschoice=1; else buschoice=0;
if modechoice=4 then railchoice=1; else railchoice=0;

prair2=0.5*prair/distance;
prauto2=prauto/21.6;

data newdata;
set modechoicedata;
array tvec{4} ttauto ttair ttbus ttrail;
array pvec{4} prauto2 prair2 prbus prrail;
array acsvec{4} acsauto acsair acsbus acsrail;
array egsvec{4} egsauto egsair egsbus egsrail;
array fvec{4} freqauto freqair freqbus freqrail;
retain pid 0;
pid+1;
do i = 1 to 4;
mode = i;
ttime = tvec{i};
price = pvec{i};
acs=acsvec{i};
egs=egsvec{i};
freq=fvec{i};
decision = (modechoice=i);
Auto=(i eq 1);
Air=(i eq 2);
Bus=(i eq 3);
Rail=(i eq 4);
```

```
AgeAuto=auto*age;
AgeAir=age*air;
AgeBus=age*bus;
AgeRail=age*rail;
MaleAuto=auto*male;
MaleAir=male*air;
MaleBus=male*bus;
MaleRail=male*rail;
if male=1 then female=0; else female=1;
femaleauto=female*auto;
femaleair=female*air;
femalebus=female*bus;
aloneauto=alone*auto;
aloneair=alone*air;
alonebus=alone*bus;
alonerail=alone*rail;
persauto=personal*auto;
persair=personal*air;
persbus=personal*bus;
persrail=personal*rail;
age1auto=age1*auto;
age1air=age1*air;
age1bus=age1*bus;
age1rail=age1*rail;
age3auto=age3*auto;
age3air=age3*air;
age3bus=age3*bus;
age3rail=age3*rail;
inc1auto=inc1*auto;
inc1air=inc1*air;
inc1bus=inc1*bus;
inc1rail=inc1*rail;
inc2auto=inc2*auto;
inc2air=inc2*air;
inc2bus=inc2*bus;
inc2rail=inc2*rail;
inc4auto=inc4*auto;
inc4air=inc4*air;
inc4bus=inc4*bus;
inc4rail=inc4*rail;
distauto=distance*auto;
distbus=distance*bus;
distair=distance*air;

if freq=1 then f1=1; else f1=0;
if freq=2 then f2=1; else f2=0;
if freq=3 then f3=1; else f3=0;

incauto=income*auto;
incbus=income*bus;
incair=income*air;
incrail=income*rail;

if dis=1 then disability=1; else disability=0;
disauto=disability*auto;
disair=disability*air;
disbus=disability*bus;
```

```
output;
end;
run;

*//Nested Logit Model//*;

proc mdc data=newdata outest=regout;
model decision = auto air bus ttime price acs egs f1 f3
maleauto maleair malebus aloneauto aloneair alonebus persauto persair persbus
age1auto age1air age1bus age3auto age3air age3bus inc1auto inc1air inc1bus
inc2auto inc2air inc2bus inc4auto inc4air inc4bus
disauto disair disbus distauto distbus distair/
      type=nlogit choice=(mode 1 2 3 4);
id pid;
utility u(1,)=auto air bus ttime price acs egs f1 f3
maleauto maleair malebus aloneauto aloneair alonebus persauto persair persbus
age1auto age1air age1bus age3auto age3air age3bus inc1auto inc1air inc1bus
inc2auto inc2air inc2bus inc4auto inc4air inc4bus
disauto disair disbus distauto distbus distair;
nest level(1)=(1 @ 1, 2 @ 2, 3 4 @ 3),
level(2)=(1 2 3 @1);
output out=choiceprob pred=p;

*//Multinomial Logit Model//*;

proc mdc data=newdata;
model decision = auto air bus ttime price acs egs f1 f3
maleauto maleair malebus aloneauto aloneair alonebus persauto persair persbus
age1auto age1air age1bus age3auto age3air age3bus incauto incair incbus
disauto disair disbus/
      type=clogit nchoice=4;
id pid;
run;

     /*-----------------------------------------------------------------
      * name: %IIA
      * note: This macro test the IIA hypothesis using the Hausman's
      *       specification test. Inputs into the macro are as follows:
      *       indata:    input data set
      *       varlist:   list of RHS variables
      *       nchoice:   number of choices for each individual
      *       choice:    list of choices
      *       nvar:      number of dependent variables
      *       nIIA:      number of choice alternatives used to test IIA
      *       IIA:       choice alternatives used to test IIA
      *       id:        ID variable
      *       decision:  0-1 LHS variable representing nchoice choices
      * purpose: Hausman's specification test
      *-----------------------------------------------------------------*/
```

```
%macro IIA(indata=, varlist=, nchoice=, choice= , nvar= , IIA= ,
               nIIA=, id= , decision=);

%let n=%eval(&nchoice-&nIIA);

    proc mdc data=&indata outest=cov covout ;
         model &decision = &varlist /
                 type=clogit
                  nchoice=&nchoice;
         id &id;
         run;

      data two;
         set &indata;
         if &choice in &IIA and &decision=1 then output;
      run;

      data two;
         set two;
         keep &id ind;
         ind=1;
      run;

      data merged;
         merge &indata two;
         by &id;
         if ind=1 or &choice in &IIA then delete;
      run;

      proc mdc data=merged outest=cov2 covout ;
         model &decision = &varlist /
                  type=clogit
                  nchoice=&n;
         id &id;
         run;

      proc IML;
         use cov var{_TYPE_ &varlist};
            read first into BetaU;
            read all into CovVarU where(_TYPE_='COV');
         close cov;

         use cov2 var{_TYPE_ &varlist};
            read first into BetaR;
            read all into CovVarR where(_TYPE_='COV');
         close cov;

         tmp = BetaU-BetaR;
         ChiSq=tmp*ginv(CovVarR-CovVarU)*tmp`;
         if ChiSq<0 then ChiSq=0;
         Prob=1-Probchi(ChiSq, &nvar);
         Print "Hausman Test for IIA for Variable &IIA";
         Print ChiSq Prob;
      run; quit;

   %mend IIA;
```

```
%IIA ( indata=newdata,
      varlist=auto air bus ttime price acs egs f1 f3
maleauto maleair malebus aloneauto aloneair alonebus persauto persair persbus
age1auto age1air age1bus age3auto age3air age3bus incauto incair incbus
disauto disair disbus,
      nchoice=4,
      choice=mode,
      nvar=1,
      nIIA=4,
      IIA=(1 2 3 4),
      id=pid,
      decision=decision );

run;

*//Mixed Logit Model//;

proc mdc data=newdata outest=regout;
model decision = auto air bus ttime price acs egs f1 f3
maleauto maleair malebus aloneauto aloneair alonebus persauto persair persbus
age1auto age1air age1bus age3auto age3air age3bus incauto incair incbus
disauto disair disbus/
      type=mixedlogit nchoice=4 mixed=(normalparm=ttime price incauto)
maxiter=1000;
id pid;

*//Binary Logit Models//;

proc logistic data=modechoicedata;
model autochoice(event='1')= att1 att2 att3 att4 att5 att6 att7 att8 att9
att10 att11 att12 att13 att14 att15 att16 att17 att18 att19 att20
att21 att22 att23 att24 att25 att26 att27 distance personal alone prauto
prair prbus prrail ttauto ttair ttbus ttrail;
proc logistic data=modechoicedata;
model airchoice(event='1')= att1 att2 att3 att4 att5 att6 att7 att8 att9
att10 att11 att12 att13 att14 att15 att16 att17 att18 att19 att20
att21 att22 att23 att24 att25 att26 att27 distance personal alone prauto
prair prbus prrail ttauto ttair ttbus ttrail;
proc logistic data=modechoicedata;
model buschoice(event='1')= att1 att2 att3 att4 att5 att6 att7 att8 att9
att10 att11 att12 att13 att14 att15 att16 att17 att18 att19 att20
att21 att22 att23 att24 att25 att26 att27 distance personal alone prauto
prair prbus prrail ttauto ttair ttbus ttrail;
proc logistic data=modechoicedata;
model railchoice(event='1')= att1 att2 att3 att4 att5 att6 att7 att8 att9
att10 att11 att12 att13 att14 att15 att16 att17 att18 att19 att20
att21 att22 att23 att24 att25 att26 att27 distance personal alone prauto
prair prbus prrail ttauto ttair ttbus ttrail;

run;
```

# APPENDIX D. SAS PRINTOUTS

## D.1. Nested Logit Results

The MDC Procedure

Nested Logit Estimates

ERROR: Convergence not attained in 100 iterations. Interpret the estimates with care.

| Model Fit Summary | |
|---|---|
| **Dependent Variable** | decision |
| **Number of Observations** | 4724 |
| **Number of Cases** | 18896 |
| **Log Likelihood** | -3375 |
| **Log Likelihood Null (LogL(0))** | -6549 |
| **Maximum Absolute Gradient** | 4124 |
| **Number of Iterations** | 100 |
| **Optimization Method** | Dual Quasi-Newton |
| **AIC** | 6834 |
| **Schwarz Criterion** | 7105 |

**Discrete Response Profile**

| Index | mode | Frequency | Percent |
|---|---|---|---|
| **0** | 1 | 3444 | 72.90 |
| **1** | 2 | 610 | 12.91 |
| **2** | 3 | 203 | 4.30 |
| **3** | 4 | 467 | 9.89 |

**Goodness-of-Fit Measures**

| Measure | Value | Formula |
|---|---|---|
| **Likelihood Ratio (R)** | 6348.1 | 2 * (LogL - LogL0) |
| **Upper Bound of R (U)** | 13098 | - 2 * LogL0 |
| **Aldrich-Nelson** | 0.5733 | R / (R+N) |

| Goodness-of-Fit Measures | | |
|---|---|---|
| **Measure** | **Value** | **Formula** |
| **Cragg-Uhler 1** | 0.7391 | 1 - exp(-R/N) |
| **Cragg-Uhler 2** | 0.7884 | (1-exp(-R/N)) / (1-exp(-U/N)) |
| **Estrella** | 0.8409 | 1 - (1-R/U)^(U/N) |
| **Adjusted Estrella** | 0.8357 | 1 - ((LogL-K)/LogL0)^(-2/N*LogL0) |
| **McFadden's LRI** | 0.4847 | R / U |
| **Veall-Zimmermann** | 0.7801 | (R * (U+N)) / (U * (R+N)) |
| **N = # of observations, K = # of regressors** | | |

The MDC Procedure

Nested Logit Estimates

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **t Value** | **Approx Pr > \|t\|** |
| **Auto_L1** | 1 | 2.4659 | 0.7992 | 3.09 | 0.0020 |
| **Air_L1** | 1 | -0.8470 | 0.9779 | -0.87 | 0.3864 |
| **Bus_L1** | 1 | -0.7332 | 0.2888 | -2.54 | 0.0111 |
| **ttime_L1** | 1 | -0.3753 | 0.0901 | -4.16 | <.0001 |
| **price_L1** | 1 | -3.0665 | 0.9042 | -3.39 | 0.0007 |
| **acs_L1** | 1 | -0.0298 | 0.008304 | -3.59 | 0.0003 |
| **egs_L1** | 1 | -0.0363 | 0.0168 | -2.16 | 0.0309 |
| **f1_L1** | 1 | 0.1119 | 0.1292 | 0.87 | 0.3866 |
| **f3_L1** | 1 | 0.0190 | 0.1345 | 0.14 | 0.8874 |
| **MaleAuto_L1** | 1 | 0.2768 | 0.1227 | 2.26 | 0.0241 |
| **MaleAir_L1** | 1 | 0.1114 | 0.3360 | 0.33 | 0.7402 |
| **MaleBus_L1** | 1 | 0.5157 | 0.1910 | 2.70 | 0.0070 |
| **aloneauto_L1** | 1 | -0.3078 | 0.1345 | -2.29 | 0.0221 |
| **aloneair_L1** | 1 | -0.5135 | 0.3542 | -1.45 | 0.1472 |
| **alonebus_L1** | 1 | 0.1797 | 0.1852 | 0.97 | 0.3319 |
| **persauto_L1** | 1 | 0.3320 | 0.1436 | 2.31 | 0.0208 |
| **persair_L1** | 1 | -0.3678 | 0.3406 | -1.08 | 0.2803 |
| **persbus_L1** | 1 | -0.2976 | 0.1903 | -1.56 | 0.1178 |
| **age1auto_L1** | 1 | 0.0554 | 0.1362 | 0.41 | 0.6841 |
| **age1air_L1** | 1 | 0.0224 | 0.5563 | 0.04 | 0.9679 |
| **age1bus_L1** | 1 | 0.2635 | 0.3075 | 0.86 | 0.3914 |
| **age3auto_L1** | 1 | 0.2909 | 0.1599 | 1.82 | 0.0688 |
| **age3air_L1** | 1 | -0.8551 | 0.6552 | -1.31 | 0.1918 |
| **age3bus_L1** | 1 | 0.2909 | 0.2761 | 1.05 | 0.2920 |
| **inc1auto_L1** | 1 | -0.3675 | 0.1795 | -2.05 | 0.0405 |

**Parameter Estimates**

| Parameter | DF | Estimate | Standard Error | t Value | Approx Pr > \|t\| |
|---|---|---|---|---|---|
| **inc1air_L1** | 1 | -0.5787 | 0.5874 | -0.99 | 0.3245 |
| **inc1bus_L1** | 1 | 0.0967 | 0.3034 | 0.32 | 0.7498 |
| **inc2auto_L1** | 1 | -0.4795 | 0.1968 | -2.44 | 0.0148 |
| **inc2air_L1** | 1 | -0.2434 | 0.4313 | -0.56 | 0.5725 |
| **inc2bus_L1** | 1 | 0.2795 | 0.2431 | 1.15 | 0.2501 |
| **inc4auto_L1** | 1 | -0.1689 | 0.1169 | -1.44 | 0.1488 |
| **inc4air_L1** | 1 | 0.6467 | 0.4542 | 1.42 | 0.1545 |
| **inc4bus_L1** | 1 | -0.3634 | 0.2550 | -1.43 | 0.1542 |
| **disauto_L1** | 1 | -0.6447 | 0.2654 | -2.43 | 0.0151 |
| **disair_L1** | 1 | -0.7447 | 0.7431 | -1.00 | 0.3162 |
| **disbus_L1** | 1 | 0.3792 | 0.2904 | 1.31 | 0.1917 |
| **distauto_L1** | 1 | 0.001111 | 0.001649 | 0.67 | 0.5003 |
| **distbus_L1** | 1 | -0.002285 | 0.000666 | -3.43 | 0.0006 |
| **distair_L1** | 1 | 0.008623 | 0.004116 | 2.09 | 0.0362 |
| **INC_L2G1C1** | 1 | 1.1773 | 0.4104 | 2.87 | 0.0041 |
| **INC_L2G1C2** | 1 | 0.3828 | 0.1096 | 3.49 | 0.0005 |
| **INC_L2G1C3** | 1 | 0.2344 | 0.1427 | 1.64 | 0.1005 |

### D.2. Multinomial Logit Results

The MDC Procedure

Conditional Logit Estimates

Algorithm converged.

**Model Fit Summary**

| | |
|---|---|
| **Dependent Variable** | decision |
| **Number of Observations** | 4607 |
| **Number of Cases** | 18428 |
| **Log Likelihood** | -3443 |

| Model Fit Summary | |
|---|---|
| **Log Likelihood Null (LogL(0))** | -6387 |
| **Maximum Absolute Gradient** | 4.64088E-7 |
| **Number of Iterations** | 7 |
| **Optimization Method** | Newton-Raphson |
| **AIC** | 6946 |
| **Schwarz Criterion** | 7139 |

**Discrete Response Profile**

| Index | CHOICE | Frequency | Percent |
|---|---|---|---|
| **0** | 1 | 3353 | 72.78 |
| **1** | 2 | 596 | 12.94 |
| **2** | 3 | 197 | 4.28 |
| **3** | 4 | 461 | 10.01 |

**Goodness-of-Fit Measures**

| Measure | Value | Formula |
|---|---|---|
| **Likelihood Ratio (R)** | 5887 | 2 * (LogL - LogL0) |
| **Upper Bound of R (U)** | 12773 | - 2 * LogL0 |
| **Aldrich-Nelson** | 0.561 | R / (R+N) |
| **Cragg-Uhler 1** | 0.7214 | 1 - exp(-R/N) |
| **Cragg-Uhler 2** | 0.7695 | (1-exp(-R/N)) / (1-exp(-U/N)) |
| **Estrella** | 0.8197 | 1 - (1-R/U)^(U/N) |
| **Adjusted Estrella** | 0.8153 | 1 - ((LogL-K)/LogL0)^(-2/N*LogL0) |
| **McFadden's LRI** | 0.4609 | R / U |
| **Veall-Zimmermann** | 0.7633 | (R * (U+N)) / (U * (R+N)) |
| **N = # of observations, K = # of regressors** | | |

The MDC Procedure

Conditional Logit Estimates

**Parameter Estimates**

| Parameter | DF | Estimate | Standard Error | t Value | Approx Pr > \|t\| |
|---|---|---|---|---|---|
| **Auto** | 1 | 1.1828 | 0.1838 | 6.44 | <.0001 |
| **Air** | 1 | 0.7314 | 0.2456 | 2.98 | 0.0029 |
| **Bus** | 1 | -0.7986 | 0.2831 | -2.82 | 0.0048 |
| **ttime** | 1 | -0.2018 | 0.0250 | -8.07 | <.0001 |
| **price** | 1 | -2.3017 | 0.1758 | -13.09 | <.0001 |
| **acs** | 1 | -0.0124 | 0.004340 | -2.86 | 0.0042 |
| **egs** | 1 | -0.008264 | 0.008596 | -0.96 | 0.3363 |
| **f1** | 1 | 0.0329 | 0.0776 | 0.42 | 0.6721 |
| **f3** | 1 | 0.003172 | 0.0771 | 0.04 | 0.9672 |
| **MaleAuto** | 1 | 0.4059 | 0.1053 | 3.85 | 0.0001 |
| **MaleAir** | 1 | 0.1615 | 0.1394 | 1.16 | 0.2467 |
| **MaleBus** | 1 | 0.5059 | 0.1807 | 2.80 | 0.0051 |
| **aloneauto** | 1 | -0.3214 | 0.1012 | -3.18 | 0.0015 |
| **aloneair** | 1 | -0.2244 | 0.1335 | -1.68 | 0.0928 |
| **alonebus** | 1 | 0.1159 | 0.1733 | 0.67 | 0.5038 |
| **persauto** | 1 | 0.3010 | 0.1009 | 2.98 | 0.0029 |
| **persair** | 1 | -0.2360 | 0.1340 | -1.76 | 0.0781 |
| **persbus** | 1 | -0.2559 | 0.1741 | -1.47 | 0.1415 |
| **age1auto** | 1 | 0.1781 | 0.1780 | 1.00 | 0.3170 |
| **age1air** | 1 | 0.2177 | 0.2338 | 0.93 | 0.3516 |
| **age1bus** | 1 | 0.4383 | 0.2779 | 1.58 | 0.1147 |
| **age3auto** | 1 | 0.1105 | 0.1679 | 0.66 | 0.5105 |
| **age3air** | 1 | -0.5820 | 0.2466 | -2.36 | 0.0183 |
| **age3bus** | 1 | 0.0755 | 0.2711 | 0.28 | 0.7806 |
| **incauto** | 1 | 0.0924 | 0.0411 | 2.25 | 0.0244 |
| **incair** | 1 | 0.1480 | 0.0540 | 2.74 | 0.0061 |

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **t Value** | **Approx Pr > \|t\|** |
| **incbus** | 1 | -0.1229 | 0.0711 | -1.73 | 0.0839 |
| **disauto** | 1 | -0.7624 | 0.1759 | -4.33 | <.0001 |
| **disair** | 1 | -1.0384 | 0.2918 | -3.56 | 0.0004 |
| **disbus** | 1 | 0.2029 | 0.2639 | 0.77 | 0.4420 |

Hausman Test for IIA for Variable (1 2 3 4)

| ChiSq | Prob |
|---|---|
| 41.900294 | 9.605E-11 |

### D.3. Mixed Multinomial Logit Results

The MDC Procedure

Mixed Multinomial Logit Estimates

Algorithm converged.

| Model Fit Summary | |
|---|---|
| **Dependent Variable** | decision |
| **Number of Observations** | 4607 |
| **Number of Cases** | 18428 |
| **Log Likelihood** | -3374 |
| **Log Likelihood Null (LogL(0))** | -6387 |
| **Maximum Absolute Gradient** | 0.40325 |
| **Number of Iterations** | 93 |
| **Optimization Method** | Dual Quasi-Newton |
| **AIC** | 6814 |
| **Schwarz Criterion** | 7026 |
| **Number of Simulations** | 100 |
| **Starting Point of Halton Sequence** | 11 |

**Discrete Response Profile**

| Index | CHOICE | Frequency | Percent |
|---|---|---|---|
| **0** | 1 | 3353 | 72.78 |
| **1** | 2 | 596 | 12.94 |
| **2** | 3 | 197 | 4.28 |
| **3** | 4 | 461 | 10.01 |

**Goodness-of-Fit Measures**

| Measure | Value | Formula |
|---|---|---|
| **Likelihood Ratio (R)** | 6025.7 | 2 * (LogL - LogL0) |
| **Upper Bound of R (U)** | 12773 | - 2 * LogL0 |
| **Aldrich-Nelson** | 0.5667 | R / (R+N) |
| **Cragg-Uhler 1** | 0.7296 | 1 - exp(-R/N) |
| **Cragg-Uhler 2** | 0.7783 | (1-exp(-R/N)) / (1-exp(-U/N)) |
| **Estrella** | 0.8296 | 1 - (1-R/U)^(U/N) |
| **Adjusted Estrella** | 0.8253 | 1 - ((LogL-K)/LogL0)^(-2/N*LogL0) |
| **McFadden's LRI** | 0.4717 | R / U |
| **Veall-Zimmermann** | 0.7711 | (R * (U+N)) / (U * (R+N)) |

**N = # of observations, K = # of regressors**

The MDC Procedure

Mixed Multinomial Logit Estimates

**Parameter Estimates**

| Parameter | DF | Estimate | Standard Error | t Value | Approx Pr > \|t\| |
|---|---|---|---|---|---|
| **Auto** | 1 | 1.1581 | 0.1971 | 5.87 | <.0001 |
| **Air** | 1 | 0.9613 | 0.3263 | 2.95 | 0.0032 |
| **Bus** | 1 | -0.8797 | 0.3031 | -2.90 | 0.0037 |
| **ttime_M** | 1 | -0.2706 | 0.0436 | -6.21 | <.0001 |
| **ttime_S** | 1 | -0.6322 | 0.0622 | -10.16 | <.0001 |
| **price_M** | 1 | -5.4204 | 0.4909 | -11.04 | <.0001 |
| **price_S** | 1 | -2.4231 | 0.2855 | -8.49 | <.0001 |
| **acs** | 1 | -0.0189 | 0.005288 | -3.57 | 0.0004 |
| **egs** | 1 | -0.005461 | 0.0103 | -0.53 | 0.5960 |
| **f1** | 1 | -0.0149 | 0.0923 | -0.16 | 0.8720 |
| **f3** | 1 | 0.0197 | 0.0907 | 0.22 | 0.8284 |
| **MaleAuto** | 1 | 0.4425 | 0.1111 | 3.98 | <.0001 |
| **MaleAir** | 1 | 0.0871 | 0.1902 | 0.46 | 0.6469 |
| **MaleBus** | 1 | 0.5080 | 0.1837 | 2.76 | 0.0057 |
| **aloneauto** | 1 | -0.3531 | 0.1078 | -3.28 | 0.0011 |
| **aloneair** | 1 | -0.2013 | 0.1820 | -1.11 | 0.2687 |
| **alonebus** | 1 | 0.1236 | 0.1792 | 0.69 | 0.4905 |
| **persauto** | 1 | 0.3108 | 0.1081 | 2.88 | 0.0040 |
| **persair** | 1 | -0.4977 | 0.1867 | -2.67 | 0.0077 |
| **persbus** | 1 | -0.1997 | 0.1818 | -1.10 | 0.2720 |
| **age1auto** | 1 | 0.1778 | 0.1834 | 0.97 | 0.3323 |
| **age1air** | 1 | 0.1230 | 0.3160 | 0.39 | 0.6971 |
| **age1bus** | 1 | 0.4762 | 0.2839 | 1.68 | 0.0935 |
| **age3auto** | 1 | 0.1350 | 0.1861 | 0.73 | 0.4681 |
| **age3air** | 1 | -0.7658 | 0.3341 | -2.29 | 0.0219 |
| **age3bus** | 1 | 0.0712 | 0.2878 | 0.25 | 0.8047 |

| Parameter Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **t Value** | **Approx Pr > \|t\|** |
| **incauto_M** | 1 | 0.0960 | 0.0433 | 2.22 | 0.0265 |
| **incauto_S** | 1 | 0.0108 | 0.3560 | 0.03 | 0.9759 |
| **incair** | 1 | 0.1905 | 0.0726 | 2.63 | 0.0087 |
| **incbus** | 1 | -0.1167 | 0.0745 | -1.57 | 0.1174 |
| **disauto** | 1 | -0.8052 | 0.1872 | -4.30 | <.0001 |
| **disair** | 1 | -1.4034 | 0.4445 | -3.16 | 0.0016 |
| **disbus** | 1 | 0.2571 | 0.2832 | 0.91 | 0.3639 |

### D.4. Binary Logit Results: Automobile Choice

The LOGISTIC Procedure

| Model Information | |
|---|---|
| **Data Set** | WORK.MODECHOICEDATA |
| **Response Variable** | autochoice |
| **Number of Response Levels** | 2 |
| **Model** | binary logit |
| **Optimization Technique** | Fisher's scoring |

| | |
|---|---|
| **Number of Observations Read** | 4724 |
| **Number of Observations Used** | 4303 |

| Response Profile | | |
|---|---|---|
| **Ordered Value** | **autochoice** | **Total Frequency** |
| **1** | 0 | 1159 |
| **2** | 1 | 3144 |

Probability modeled is autochoice=1.

**Note: 421 observations were deleted due to missing values for the response or explanatory variables.**

**Model Convergence Status**

Convergence criterion (GCONV=1E-8) satisfied.

**Model Fit Statistics**

| Criterion | Intercept Only | Intercept and Covariates |
|---|---|---|
| **AIC** | 5015.926 | 3947.379 |
| **SC** | 5022.294 | 4195.694 |
| **-2 Log L** | 5013.926 | 3869.379 |

**Testing Global Null Hypothesis: BETA=0**

| Test | Chi-Square | DF | Pr > ChiSq |
|---|---|---|---|
| **Likelihood Ratio** | 1144.5478 | 38 | <.0001 |
| **Score** | 1029.7899 | 38 | <.0001 |
| **Wald** | 785.9614 | 38 | <.0001 |

**Analysis of Maximum Likelihood Estimates**

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Intercept** | 1 | 3.4949 | 0.5027 | 48.3403 | <.0001 |
| **Att1** | 1 | -0.0554 | 0.0219 | 6.3958 | 0.0114 |
| **Att2** | 1 | 0.0823 | 0.0245 | 11.2744 | 0.0008 |
| **Att3** | 1 | -0.0859 | 0.0229 | 14.1246 | 0.0002 |
| **Att4** | 1 | -0.0598 | 0.0232 | 6.6598 | 0.0099 |
| **Att5** | 1 | -0.0100 | 0.0280 | 0.1280 | 0.7205 |
| **Att6** | 1 | 0.0730 | 0.0312 | 5.4606 | 0.0195 |
| **Att7** | 1 | 0.0128 | 0.0321 | 0.1602 | 0.6890 |
| **Att8** | 1 | 0.00410 | 0.0311 | 0.0174 | 0.8950 |
| **Att9** | 1 | -0.1433 | 0.0239 | 35.8571 | <.0001 |
| **Att10** | 1 | -0.0206 | 0.0190 | 1.1812 | 0.2771 |
| **Att11** | 1 | -0.0798 | 0.0188 | 18.0702 | <.0001 |

| Analysis of Maximum Likelihood Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Att12** | 1 | 0.0931 | 0.0199 | 22.0059 | <.0001 |
| **Att13** | 1 | 0.0381 | 0.0213 | 3.2035 | 0.0735 |
| **Att14** | 1 | -0.0541 | 0.0178 | 9.1738 | 0.0025 |
| **Att15** | 1 | 0.0331 | 0.0238 | 1.9426 | 0.1634 |
| **Att16** | 1 | -0.0174 | 0.0196 | 0.7937 | 0.3730 |
| **Att17** | 1 | 0.0376 | 0.0193 | 3.8158 | 0.0508 |
| **Att18** | 1 | 0.0194 | 0.0224 | 0.7480 | 0.3871 |
| **Att19** | 1 | -0.0594 | 0.0181 | 10.7986 | 0.0010 |
| **Att20** | 1 | -0.00866 | 0.0283 | 0.0938 | 0.7594 |
| **Att21** | 1 | 0.0103 | 0.0181 | 0.3206 | 0.5712 |
| **Att22** | 1 | 0.0752 | 0.0228 | 10.8837 | 0.0010 |
| **Att23** | 1 | 0.0368 | 0.0169 | 4.7556 | 0.0292 |
| **Att24** | 1 | -0.00943 | 0.0281 | 0.1126 | 0.7372 |
| **Att25** | 1 | 0.0324 | 0.0244 | 1.7573 | 0.1850 |
| **Att26** | 1 | -0.1184 | 0.0310 | 14.5800 | 0.0001 |
| **Att27** | 1 | -0.0334 | 0.0188 | 3.1623 | 0.0754 |
| **DISTANCE** | 1 | 0.0949 | 0.1391 | 0.4654 | 0.4951 |
| **Personal** | 1 | 0.5596 | 0.0813 | 47.4010 | <.0001 |
| **Alone** | 1 | -0.3776 | 0.0810 | 21.7545 | <.0001 |
| **PRAUTO** | 1 | -0.3487 | 0.0341 | 104.5450 | <.0001 |
| **PRAIR** | 1 | 0.000817 | 0.000351 | 5.4218 | 0.0199 |
| **PRBUS** | 1 | 0.9359 | 1.0033 | 0.8701 | 0.3509 |
| **PRRAIL** | 1 | 1.9731 | 1.0079 | 3.8325 | 0.0503 |
| **TTAuto** | 1 | -6.8493 | 9.0212 | 0.5765 | 0.4477 |
| **TTAir** | 1 | 0.0901 | 0.0307 | 8.6335 | 0.0033 |
| **TTBus** | 1 | 0.0166 | 0.0534 | 0.0970 | 0.7555 |
| **TTRail** | 1 | 0.1288 | 0.0527 | 5.9682 | 0.0146 |

**Odds Ratio Estimates**

| Effect | Point Estimate | 95% Wald Confidence Limits | |
|---|---|---|---|
| **Att1** | 0.946 | 0.906 | 0.988 |
| **Att2** | 1.086 | 1.035 | 1.139 |
| **Att3** | 0.918 | 0.877 | 0.960 |
| **Att4** | 0.942 | 0.900 | 0.986 |
| **Att5** | 0.990 | 0.937 | 1.046 |
| **Att6** | 1.076 | 1.012 | 1.144 |
| **Att7** | 1.013 | 0.951 | 1.079 |
| **Att8** | 1.004 | 0.945 | 1.067 |
| **Att9** | 0.867 | 0.827 | 0.908 |
| **Att10** | 0.980 | 0.944 | 1.017 |
| **Att11** | 0.923 | 0.890 | 0.958 |
| **Att12** | 1.098 | 1.056 | 1.141 |
| **Att13** | 1.039 | 0.996 | 1.083 |
| **Att14** | 0.947 | 0.915 | 0.981 |
| **Att15** | 1.034 | 0.987 | 1.083 |
| **Att16** | 0.983 | 0.946 | 1.021 |
| **Att17** | 1.038 | 1.000 | 1.078 |
| **Att18** | 1.020 | 0.976 | 1.065 |
| **Att19** | 0.942 | 0.909 | 0.976 |
| **Att20** | 0.991 | 0.938 | 1.048 |
| **Att21** | 1.010 | 0.975 | 1.047 |
| **Att22** | 1.078 | 1.031 | 1.127 |
| **Att23** | 1.038 | 1.004 | 1.072 |
| **Att24** | 0.991 | 0.938 | 1.047 |
| **Att25** | 1.033 | 0.985 | 1.084 |
| **Att26** | 0.888 | 0.836 | 0.944 |
| **Att27** | 0.967 | 0.932 | 1.003 |

| Odds Ratio Estimates | | | |
|---|---|---|---|
| **Effect** | **Point Estimate** | **95% Wald Confidence Limits** | |
| **DISTANCE** | 1.100 | 0.837 | 1.444 |
| **Personal** | 1.750 | 1.492 | 2.052 |
| **Alone** | 0.685 | 0.585 | 0.803 |
| **PRAUTO** | 0.706 | 0.660 | 0.754 |
| **PRAIR** | 1.001 | 1.000 | 1.002 |
| **PRBUS** | 2.549 | 0.357 | 18.215 |
| **PRRAIL** | 7.193 | 0.998 | 51.863 |
| **TTAuto** | 0.001 | <0.001 | >999.999 |
| **TTAir** | 1.094 | 1.030 | 1.162 |
| **TTBus** | 1.017 | 0.916 | 1.129 |
| **TTRail** | 1.137 | 1.026 | 1.261 |

| Association of Predicted Probabilities and Observed Responses | | | |
|---|---|---|---|
| **Percent Concordant** | 81.5 | **Somers' D** | 0.632 |
| **Percent Discordant** | 18.3 | **Gamma** | 0.633 |
| **Percent Tied** | 0.2 | **Tau-a** | 0.249 |
| **Pairs** | 3643896 | **c** | 0.816 |

### D.5. Binary Logit Results: Air Choice

The LOGISTIC Procedure

| Model Information | |
|---|---|
| **Data Set** | WORK.MODECHOICEDATA |
| **Response Variable** | airchoice |
| **Number of Response Levels** | 2 |
| **Model** | binary logit |
| **Optimization Technique** | Fisher's scoring |

| | |
|---|---|
| **Number of Observations Read** | 4724 |

| Number of Observations Used | 4303 |
|---|---|

**Response Profile**

| Ordered Value | airchoice | Total Frequency |
|---|---|---|
| **1** | 0 | 3755 |
| **2** | 1 | 548 |

Probability modeled is airchoice=1.

**Note: 421 observations were deleted due to missing values for the response or explanatory variables.**

**Model Convergence Status**

Convergence criterion (GCONV=1E-8) satisfied.

**Model Fit Statistics**

| Criterion | Intercept Only | Intercept and Covariates |
|---|---|---|
| **AIC** | 3283.672 | 2341.452 |
| **SC** | 3290.039 | 2589.767 |
| **-2 Log L** | 3281.672 | 2263.452 |

**Testing Global Null Hypothesis: BETA=0**

| Test | Chi-Square | DF | Pr > ChiSq |
|---|---|---|---|
| **Likelihood Ratio** | 1018.2205 | 38 | <.0001 |
| **Score** | 942.4408 | 38 | <.0001 |
| **Wald** | 584.7229 | 38 | <.0001 |

**Analysis of Maximum Likelihood Estimates**

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Intercept** | 1 | -3.9322 | 0.7428 | 28.0257 | <.0001 |
| **Att1** | 1 | -0.0278 | 0.0306 | 0.8246 | 0.3639 |

| Analysis of Maximum Likelihood Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Att2** | 1 | -0.1115 | 0.0334 | 11.1245 | 0.0009 |
| **Att3** | 1 | 0.0486 | 0.0312 | 2.4330 | 0.1188 |
| **Att4** | 1 | 0.1204 | 0.0327 | 13.5408 | 0.0002 |
| **Att5** | 1 | -0.0750 | 0.0388 | 3.7329 | 0.0534 |
| **Att6** | 1 | -0.0292 | 0.0416 | 0.4919 | 0.4831 |
| **Att7** | 1 | 0.00226 | 0.0436 | 0.0027 | 0.9587 |
| **Att8** | 1 | -0.1301 | 0.0409 | 10.1229 | 0.0015 |
| **Att9** | 1 | 0.1722 | 0.0323 | 28.4667 | <.0001 |
| **Att10** | 1 | -0.0269 | 0.0255 | 1.1120 | 0.2916 |
| **Att11** | 1 | 0.00237 | 0.0250 | 0.0090 | 0.9244 |
| **Att12** | 1 | -0.0176 | 0.0261 | 0.4531 | 0.5009 |
| **Att13** | 1 | -0.0101 | 0.0283 | 0.1274 | 0.7211 |
| **Att14** | 1 | 0.0614 | 0.0244 | 6.3465 | 0.0118 |
| **Att15** | 1 | 0.000424 | 0.0319 | 0.0002 | 0.9894 |
| **Att16** | 1 | 0.0619 | 0.0266 | 5.4100 | 0.0200 |
| **Att17** | 1 | -0.0235 | 0.0259 | 0.8232 | 0.3642 |
| **Att18** | 1 | -0.1392 | 0.0295 | 22.3230 | <.0001 |
| **Att19** | 1 | 0.0745 | 0.0242 | 9.5019 | 0.0021 |
| **Att20** | 1 | 0.0144 | 0.0375 | 0.1481 | 0.7004 |
| **Att21** | 1 | -0.0251 | 0.0246 | 1.0420 | 0.3074 |
| **Att22** | 1 | -0.0853 | 0.0297 | 8.2384 | 0.0041 |
| **Att23** | 1 | 0.0468 | 0.0229 | 4.1572 | 0.0415 |
| **Att24** | 1 | 0.0165 | 0.0383 | 0.1860 | 0.6663 |
| **Att25** | 1 | 0.0843 | 0.0322 | 6.8276 | 0.0090 |
| **Att26** | 1 | -0.0564 | 0.0411 | 1.8851 | 0.1698 |
| **Att27** | 1 | 0.0276 | 0.0251 | 1.2099 | 0.2714 |
| **DISTANCE** | 1 | 0.3269 | 0.2914 | 1.2587 | 0.2619 |

**Analysis of Maximum Likelihood Estimates**

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Personal** | 1 | -0.5893 | 0.1112 | 28.0876 | <.0001 |
| **Alone** | 1 | 0.1013 | 0.1103 | 0.8429 | 0.3586 |
| **PRAUTO** | 1 | 0.1584 | 0.0480 | 10.8729 | 0.0010 |
| **PRAIR** | 1 | -0.00285 | 0.000549 | 27.0086 | <.0001 |
| **PRBUS** | 1 | 0.3834 | 1.3742 | 0.0779 | 0.7802 |
| **PRRAIL** | 1 | -1.8286 | 1.4989 | 1.4883 | 0.2225 |
| **TTAuto** | 1 | -20.3484 | 18.8937 | 1.1599 | 0.2815 |
| **TTAir** | 1 | -0.2046 | 0.0395 | 26.7786 | <.0001 |
| **TTBus** | 1 | -0.0522 | 0.0641 | 0.6622 | 0.4158 |
| **TTRail** | 1 | 0.0136 | 0.0609 | 0.0502 | 0.8227 |

**Odds Ratio Estimates**

| Effect | Point Estimate | 95% Wald Confidence Limits | |
|---|---|---|---|
| **Att1** | 0.973 | 0.916 | 1.033 |
| **Att2** | 0.895 | 0.838 | 0.955 |
| **Att3** | 1.050 | 0.988 | 1.116 |
| **Att4** | 1.128 | 1.058 | 1.203 |
| **Att5** | 0.928 | 0.860 | 1.001 |
| **Att6** | 0.971 | 0.895 | 1.054 |
| **Att7** | 1.002 | 0.920 | 1.092 |
| **Att8** | 0.878 | 0.810 | 0.951 |
| **Att9** | 1.188 | 1.115 | 1.266 |
| **Att10** | 0.973 | 0.926 | 1.023 |
| **Att11** | 1.002 | 0.954 | 1.053 |
| **Att12** | 0.983 | 0.934 | 1.034 |
| **Att13** | 0.990 | 0.937 | 1.046 |
| **Att14** | 1.063 | 1.014 | 1.115 |

| Odds Ratio Estimates | | | |
|---|---|---|---|
| **Effect** | **Point Estimate** | **95% Wald Confidence Limits** | |
| **Att15** | 1.000 | 0.940 | 1.065 |
| **Att16** | 1.064 | 1.010 | 1.121 |
| **Att17** | 0.977 | 0.928 | 1.028 |
| **Att18** | 0.870 | 0.821 | 0.922 |
| **Att19** | 1.077 | 1.028 | 1.130 |
| **Att20** | 1.015 | 0.943 | 1.092 |
| **Att21** | 0.975 | 0.929 | 1.023 |
| **Att22** | 0.918 | 0.866 | 0.973 |
| **Att23** | 1.048 | 1.002 | 1.096 |
| **Att24** | 1.017 | 0.943 | 1.096 |
| **Att25** | 1.088 | 1.021 | 1.159 |
| **Att26** | 0.945 | 0.872 | 1.024 |
| **Att27** | 1.028 | 0.979 | 1.080 |
| **DISTANCE** | 1.387 | 0.783 | 2.455 |
| **Personal** | 0.555 | 0.446 | 0.690 |
| **Alone** | 1.107 | 0.891 | 1.374 |
| **PRAUTO** | 1.172 | 1.066 | 1.287 |
| **PRAIR** | 0.997 | 0.996 | 0.998 |
| **PRBUS** | 1.467 | 0.099 | 21.687 |
| **PRRAIL** | 0.161 | 0.009 | 3.032 |
| **TTAuto** | <0.001 | <0.001 | >999.999 |
| **TTAir** | 0.815 | 0.754 | 0.881 |
| **TTBus** | 0.949 | 0.837 | 1.076 |
| **TTRail** | 1.014 | 0.900 | 1.142 |

| Association of Predicted Probabilities and Observed Responses | | | |
|---|---|---|---|
| **Percent Concordant** | 87.8 | **Somers' D** | 0.758 |

| Association of Predicted Probabilities and Observed Responses | | | |
|---|---|---|---|
| **Percent Discordant** | 12.0 | **Gamma** | 0.760 |
| **Percent Tied** | 0.2 | **Tau-a** | 0.169 |
| **Pairs** | 2057740 | **c** | 0.879 |

## D.6. Binary Logit Results: Bus Choice

The LOGISTIC Procedure

| Model Information | |
|---|---|
| **Data Set** | WORK.MODECHOICEDATA |
| **Response Variable** | buschoice |
| **Number of Response Levels** | 2 |
| **Model** | binary logit |
| **Optimization Technique** | Fisher's scoring |

| | |
|---|---|
| **Number of Observations Read** | 4724 |
| **Number of Observations Used** | 4303 |

**Response Profile**

| Ordered Value | buschoice | Total Frequency |
|---|---|---|
| **1** | 0 | 4127 |
| **2** | 1 | 176 |

Probability modeled is buschoice=1.

**Note: 421 observations were deleted due to missing values for the response or explanatory variables.**

| Model Convergence Status |
|---|
| Convergence criterion (GCONV=1E-8) satisfied. |

**Model Fit Statistics**

| Criterion | Intercept Only | Intercept and Covariates |
|---|---|---|
| **AIC** | 1471.899 | 1397.779 |
| **SC** | 1478.266 | 1646.095 |
| **-2 Log L** | 1469.899 | 1319.779 |

**Testing Global Null Hypothesis: BETA=0**

| Test | Chi-Square | DF | Pr > ChiSq |
|---|---|---|---|
| **Likelihood Ratio** | 150.1192 | 38 | <.0001 |
| **Score** | 142.5132 | 38 | <.0001 |
| **Wald** | 130.5521 | 38 | <.0001 |

**Analysis of Maximum Likelihood Estimates**

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Intercept** | 1 | -5.3980 | 1.0247 | 27.7490 | <.0001 |
| **Att1** | 1 | 0.00775 | 0.0395 | 0.0385 | 0.8445 |
| **Att2** | 1 | 0.0875 | 0.0473 | 3.4191 | 0.0644 |
| **Att3** | 1 | 0.0218 | 0.0468 | 0.2180 | 0.6406 |
| **Att4** | 1 | -0.0489 | 0.0451 | 1.1748 | 0.2784 |
| **Att5** | 1 | 0.0563 | 0.0546 | 1.0620 | 0.3028 |
| **Att6** | 1 | -0.0937 | 0.0625 | 2.2486 | 0.1337 |
| **Att7** | 1 | -0.0359 | 0.0601 | 0.3569 | 0.5502 |
| **Att8** | 1 | 0.0584 | 0.0637 | 0.8414 | 0.3590 |
| **Att9** | 1 | 0.0978 | 0.0495 | 3.9010 | 0.0483 |
| **Att10** | 1 | 0.0272 | 0.0372 | 0.5352 | 0.4644 |
| **Att11** | 1 | 0.1225 | 0.0380 | 10.3694 | 0.0013 |
| **Att12** | 1 | -0.0464 | 0.0402 | 1.3329 | 0.2483 |
| **Att13** | 1 | -0.0958 | 0.0430 | 4.9609 | 0.0259 |
| **Att14** | 1 | 0.0521 | 0.0349 | 2.2230 | 0.1360 |

### Analysis of Maximum Likelihood Estimates

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Att15** | 1 | -0.0305 | 0.0463 | 0.4338 | 0.5101 |
| **Att16** | 1 | 0.0258 | 0.0407 | 0.4010 | 0.5266 |
| **Att17** | 1 | -0.0349 | 0.0393 | 0.7882 | 0.3747 |
| **Att18** | 1 | 0.1276 | 0.0496 | 6.6202 | 0.0101 |
| **Att19** | 1 | -0.0988 | 0.0391 | 6.3869 | 0.0115 |
| **Att20** | 1 | -0.0403 | 0.0569 | 0.5018 | 0.4787 |
| **Att21** | 1 | 0.0322 | 0.0372 | 0.7494 | 0.3867 |
| **Att22** | 1 | -0.0454 | 0.0489 | 0.8602 | 0.3537 |
| **Att23** | 1 | -0.0695 | 0.0348 | 3.9936 | 0.0457 |
| **Att24** | 1 | 0.1151 | 0.0589 | 3.8123 | 0.0509 |
| **Att25** | 1 | -0.1056 | 0.0498 | 4.4932 | 0.0340 |
| **Att26** | 1 | -0.0187 | 0.0658 | 0.0809 | 0.7760 |
| **Att27** | 1 | 0.0872 | 0.0385 | 5.1334 | 0.0235 |
| **DISTANCE** | 1 | 0.2365 | 0.2570 | 0.8466 | 0.3575 |
| **Personal** | 1 | -0.5329 | 0.1694 | 9.8983 | 0.0017 |
| **Alone** | 1 | 0.3876 | 0.1609 | 5.8018 | 0.0160 |
| **PRAUTO** | 1 | 0.3267 | 0.0682 | 22.9671 | <.0001 |
| **PRAIR** | 1 | 0.000352 | 0.000687 | 0.2625 | 0.6084 |
| **PRBUS** | 1 | -5.4435 | 2.0112 | 7.3256 | 0.0068 |
| **PRRAIL** | 1 | 5.5306 | 2.0135 | 7.5442 | 0.0060 |
| **TTAuto** | 1 | -15.1632 | 16.6643 | 0.8279 | 0.3629 |
| **TTAir** | 1 | -0.0461 | 0.0643 | 0.5133 | 0.4737 |
| **TTBus** | 1 | -0.2658 | 0.1249 | 4.5246 | 0.0334 |
| **TTRail** | 1 | 0.1187 | 0.1198 | 0.9812 | 0.3219 |

**Odds Ratio Estimates**

| Effect | Point Estimate | 95% Wald Confidence Limits | |
|---|---|---|---|
| **Att1** | 1.008 | 0.933 | 1.089 |
| **Att2** | 1.091 | 0.995 | 1.198 |
| **Att3** | 1.022 | 0.933 | 1.120 |
| **Att4** | 0.952 | 0.872 | 1.040 |
| **Att5** | 1.058 | 0.951 | 1.177 |
| **Att6** | 0.911 | 0.806 | 1.029 |
| **Att7** | 0.965 | 0.857 | 1.085 |
| **Att8** | 1.060 | 0.936 | 1.201 |
| **Att9** | 1.103 | 1.001 | 1.215 |
| **Att10** | 1.028 | 0.955 | 1.105 |
| **Att11** | 1.130 | 1.049 | 1.218 |
| **Att12** | 0.955 | 0.882 | 1.033 |
| **Att13** | 0.909 | 0.835 | 0.989 |
| **Att14** | 1.053 | 0.984 | 1.128 |
| **Att15** | 0.970 | 0.886 | 1.062 |
| **Att16** | 1.026 | 0.947 | 1.111 |
| **Att17** | 0.966 | 0.894 | 1.043 |
| **Att18** | 1.136 | 1.031 | 1.252 |
| **Att19** | 0.906 | 0.839 | 0.978 |
| **Att20** | 0.960 | 0.859 | 1.074 |
| **Att21** | 1.033 | 0.960 | 1.111 |
| **Att22** | 0.956 | 0.868 | 1.052 |
| **Att23** | 0.933 | 0.871 | 0.999 |
| **Att24** | 1.122 | 1.000 | 1.259 |
| **Att25** | 0.900 | 0.816 | 0.992 |
| **Att26** | 0.981 | 0.863 | 1.117 |
| **Att27** | 1.091 | 1.012 | 1.177 |

| Odds Ratio Estimates | | | |
|---|---|---|---|
| **Effect** | **Point Estimate** | **95% Wald Confidence Limits** | |
| **DISTANCE** | 1.267 | 0.765 | 2.096 |
| **Personal** | 0.587 | 0.421 | 0.818 |
| **Alone** | 1.473 | 1.075 | 2.020 |
| **PRAUTO** | 1.386 | 1.213 | 1.585 |
| **PRAIR** | 1.000 | 0.999 | 1.002 |
| **PRBUS** | 0.004 | <0.001 | 0.223 |
| **PRRAIL** | 252.284 | 4.875 | >999.999 |
| **TTAuto** | <0.001 | <0.001 | >999.999 |
| **TTAir** | 0.955 | 0.842 | 1.083 |
| **TTBus** | 0.767 | 0.600 | 0.979 |
| **TTRail** | 1.126 | 0.890 | 1.424 |

| Association of Predicted Probabilities and Observed Responses | | | |
|---|---|---|---|
| **Percent Concordant** | 74.8 | **Somers' D** | 0.510 |
| **Percent Discordant** | 23.8 | **Gamma** | 0.517 |
| **Percent Tied** | 1.3 | **Tau-a** | 0.040 |
| **Pairs** | 726352 | **c** | 0.755 |

### D.7. Binary Logit Results: Rail Choice

The LOGISTIC Procedure

| Model Information | |
|---|---|
| **Data Set** | WORK.MODECHOICEDATA |
| **Response Variable** | railchoice |
| **Number of Response Levels** | 2 |
| **Model** | binary logit |
| **Optimization Technique** | Fisher's scoring |

| | |
|---|---|
| **Number of Observations Read** | 4724 |

| **Number of Observations Used** | 4303 |
|---|---|

**Response Profile**

| Ordered Value | railchoice | Total Frequency |
|---|---|---|
| **1** | 0 | 3868 |
| **2** | 1 | 435 |

Probability modeled is railchoice=1.

**Note: 421 observations were deleted due to missing values for the response or explanatory variables.**

**Model Convergence Status**

Convergence criterion (GCONV=1E-8) satisfied.

**Model Fit Statistics**

| Criterion | Intercept Only | Intercept and Covariates |
|---|---|---|
| **AIC** | 2820.261 | 2457.037 |
| **SC** | 2826.628 | 2705.352 |
| **-2 Log L** | 2818.261 | 2379.037 |

**Testing Global Null Hypothesis: BETA=0**

| Test | Chi-Square | DF | Pr > ChiSq |
|---|---|---|---|
| **Likelihood Ratio** | 439.2245 | 38 | <.0001 |
| **Score** | 420.2185 | 38 | <.0001 |
| **Wald** | 345.8783 | 38 | <.0001 |

**Analysis of Maximum Likelihood Estimates**

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| **Intercept** | 1 | -5.1407 | 0.7029 | 53.4948 | <.0001 |
| **Att1** | 1 | 0.1012 | 0.0287 | 12.4127 | 0.0004 |

| Analysis of Maximum Likelihood Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Att2** | 1 | -0.0713 | 0.0331 | 4.6432 | 0.0312 |
| **Att3** | 1 | 0.0944 | 0.0304 | 9.6326 | 0.0019 |
| **Att4** | 1 | 0.0191 | 0.0320 | 0.3575 | 0.5499 |
| **Att5** | 1 | 0.0827 | 0.0382 | 4.6973 | 0.0302 |
| **Att6** | 1 | -0.0726 | 0.0450 | 2.6004 | 0.1068 |
| **Att7** | 1 | 0.0274 | 0.0447 | 0.3758 | 0.5398 |
| **Att8** | 1 | 0.0826 | 0.0455 | 3.2898 | 0.0697 |
| **Att9** | 1 | 0.0575 | 0.0332 | 2.9891 | 0.0838 |
| **Att10** | 1 | 0.0489 | 0.0261 | 3.5086 | 0.0611 |
| **Att11** | 1 | 0.0794 | 0.0260 | 9.3325 | 0.0023 |
| **Att12** | 1 | -0.1425 | 0.0271 | 27.6247 | <.0001 |
| **Att13** | 1 | -0.0359 | 0.0301 | 1.4171 | 0.2339 |
| **Att14** | 1 | 0.00444 | 0.0244 | 0.0332 | 0.8554 |
| **Att15** | 1 | -0.0350 | 0.0328 | 1.1407 | 0.2855 |
| **Att16** | 1 | -0.0399 | 0.0264 | 2.2844 | 0.1307 |
| **Att17** | 1 | -0.0129 | 0.0266 | 0.2360 | 0.6271 |
| **Att18** | 1 | 0.0487 | 0.0317 | 2.3512 | 0.1252 |
| **Att19** | 1 | 0.0808 | 0.0248 | 10.6446 | 0.0011 |
| **Att20** | 1 | 0.00893 | 0.0393 | 0.0517 | 0.8201 |
| **Att21** | 1 | -0.00110 | 0.0244 | 0.0020 | 0.9641 |
| **Att22** | 1 | -0.0664 | 0.0320 | 4.3004 | 0.0381 |
| **Att23** | 1 | -0.0915 | 0.0239 | 14.6465 | 0.0001 |
| **Att24** | 1 | -0.0208 | 0.0359 | 0.3359 | 0.5622 |
| **Att25** | 1 | -0.1312 | 0.0363 | 13.0628 | 0.0003 |
| **Att26** | 1 | 0.2850 | 0.0433 | 43.2550 | <.0001 |
| **Att27** | 1 | -0.00782 | 0.0261 | 0.0896 | 0.7647 |
| **DISTANCE** | 1 | -0.0912 | 0.1838 | 0.2461 | 0.6198 |

| Analysis of Maximum Likelihood Estimates | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **DF** | **Estimate** | **Standard Error** | **Wald Chi-Square** | **Pr > ChiSq** |
| **Personal** | 1 | -0.1718 | 0.1100 | 2.4403 | 0.1183 |
| **Alone** | 1 | 0.4001 | 0.1099 | 13.2472 | 0.0003 |
| **PRAUTO** | 1 | 0.4047 | 0.0475 | 72.6934 | <.0001 |
| **PRAIR** | 1 | 0.000937 | 0.000474 | 3.9163 | 0.0478 |
| **PRBUS** | 1 | -0.00550 | 1.3558 | 0.0000 | 0.9968 |
| **PRRAIL** | 1 | -6.0858 | 1.4274 | 18.1773 | <.0001 |
| **TTAuto** | 1 | 6.0461 | 11.9297 | 0.2569 | 0.6123 |
| **TTAir** | 1 | 0.1525 | 0.0425 | 12.8774 | 0.0003 |
| **TTBus** | 1 | 0.2180 | 0.0740 | 8.6860 | 0.0032 |
| **TTRail** | 1 | -0.2055 | 0.0791 | 6.7441 | 0.0094 |

| Odds Ratio Estimates | | | |
|---|---|---|---|
| **Effect** | **Point Estimate** | **95% Wald Confidence Limits** | |
| **Att1** | 1.106 | 1.046 | 1.171 |
| **Att2** | 0.931 | 0.873 | 0.994 |
| **Att3** | 1.099 | 1.035 | 1.167 |
| **Att4** | 1.019 | 0.957 | 1.085 |
| **Att5** | 1.086 | 1.008 | 1.171 |
| **Att6** | 0.930 | 0.851 | 1.016 |
| **Att7** | 1.028 | 0.942 | 1.122 |
| **Att8** | 1.086 | 0.993 | 1.188 |
| **Att9** | 1.059 | 0.992 | 1.130 |
| **Att10** | 1.050 | 0.998 | 1.105 |
| **Att11** | 1.083 | 1.029 | 1.139 |
| **Att12** | 0.867 | 0.822 | 0.915 |
| **Att13** | 0.965 | 0.909 | 1.023 |
| **Att14** | 1.004 | 0.958 | 1.054 |

| Odds Ratio Estimates | | | |
|---|---|---|---|
| **Effect** | **Point Estimate** | **95% Wald Confidence Limits** | |
| **Att15** | 0.966 | 0.906 | 1.030 |
| **Att16** | 0.961 | 0.913 | 1.012 |
| **Att17** | 0.987 | 0.937 | 1.040 |
| **Att18** | 1.050 | 0.987 | 1.117 |
| **Att19** | 1.084 | 1.033 | 1.138 |
| **Att20** | 1.009 | 0.934 | 1.090 |
| **Att21** | 0.999 | 0.952 | 1.048 |
| **Att22** | 0.936 | 0.879 | 0.996 |
| **Att23** | 0.913 | 0.871 | 0.956 |
| **Att24** | 0.979 | 0.913 | 1.051 |
| **Att25** | 0.877 | 0.817 | 0.942 |
| **Att26** | 1.330 | 1.221 | 1.448 |
| **Att27** | 0.992 | 0.943 | 1.044 |
| **DISTANCE** | 0.913 | 0.637 | 1.309 |
| **Personal** | 0.842 | 0.679 | 1.045 |
| **Alone** | 1.492 | 1.203 | 1.851 |
| **PRAUTO** | 1.499 | 1.366 | 1.645 |
| **PRAIR** | 1.001 | 1.000 | 1.002 |
| **PRBUS** | 0.995 | 0.070 | 14.180 |
| **PRRAIL** | 0.002 | <0.001 | 0.037 |
| **TTAuto** | 422.477 | <0.001 | >999.999 |
| **TTAir** | 1.165 | 1.072 | 1.266 |
| **TTBus** | 1.244 | 1.076 | 1.438 |
| **TTRail** | 0.814 | 0.697 | 0.951 |

| Association of Predicted Probabilities and Observed Responses | | | |
|---|---|---|---|
| **Percent Concordant** | 78.1 | **Somers' D** | 0.568 |

<table>
<tr><th colspan="4">Association of Predicted Probabilities and Observed Responses</th></tr>
<tr><td><b>Percent Discordant</b></td><td>21.4</td><td><b>Gamma</b></td><td>0.571</td></tr>
<tr><td><b>Percent Tied</b></td><td>0.5</td><td><b>Tau-a</b></td><td>0.103</td></tr>
<tr><td><b>Pairs</b></td><td>1682580</td><td><b>c</b></td><td>0.784</td></tr>
</table>

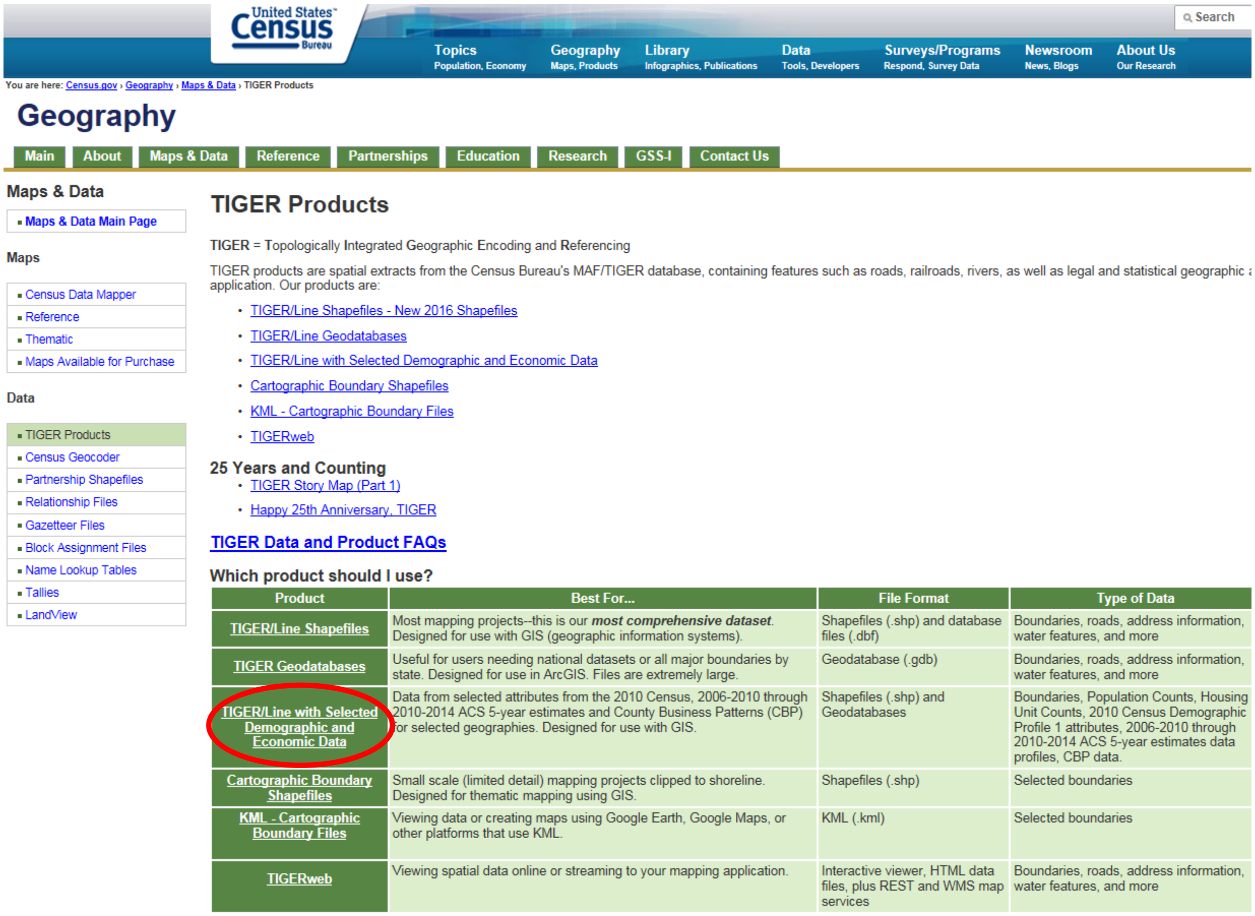
# APPENDIX E. OBTAINING DEMOGRAPHIC DATA IN GIS

The results from the mode choice model show that demographic factors, such as age, income, and disability, play a role in the choice of mode. Therefore, the demographics of a particular TAZ will have an effect on mode shares for trips originating from that TAZ. To account for this, demographic data at the level of the TAZ were obtained through the American Community Survey (ACS). The TAZs used in the statewide travel demand model described in Section 6 are census block groups. Age and income data at the block group level are available through the ACS, and GIS files containing these data can be obtained through the U.S. Census Bureau's TIGER products. This Appendix provides instruction for how to obtain these data in GIS.

As described by the U.S. Census Bureau, TIGER products are spatial extracts from the Census Bureau's MAF/TIGER database. Files can be obtained from the TIGER Products website: http://www.census.gov/geo/maps-data/data/tiger.html

A number of different file types are available. To obtain files designed for GIS containing demographic data, choose the product "TIGER/Line with Selected Demographic and Economic Data," as shown in Figure E.1.

After choosing this product, ACS 5-year estimates can be downloaded in geodatabase format. The ACS publishes 1-year estimates, 3-year estimates, and 5-year estimates, with the latter options based on 3 or 5 years of survey responses. Because the 5-year estimates are based on the largest number of responses, it has a smaller margin of error and is more appropriate for small geographic areas. The ACS publishes a new set of 5-year estimates each year. To obtain the 2010-2014 data, click on "2010-2014 Detailed Tables," as shown in Figure E.2.



You are here: Census.gov › Geography › Maps & Data › TIGER Products

Geography

TIGER Products

TIGER = Topologically Integrated Geographic Encoding and Referencing

TIGER products are spatial extracts from the Census Bureau's MAF/TIGER database, containing features such as roads, railroads, rivers, as well as legal and statistical geographic application. Our products are:

- TIGER/Line Shapefiles - New 2016 Shapefiles
- TIGER/Line Geodatabases
- TIGER/Line with Selected Demographic and Economic Data
- Cartographic Boundary Shapefiles
- KML - Cartographic Boundary Files
- TIGERweb

25 Years and Counting

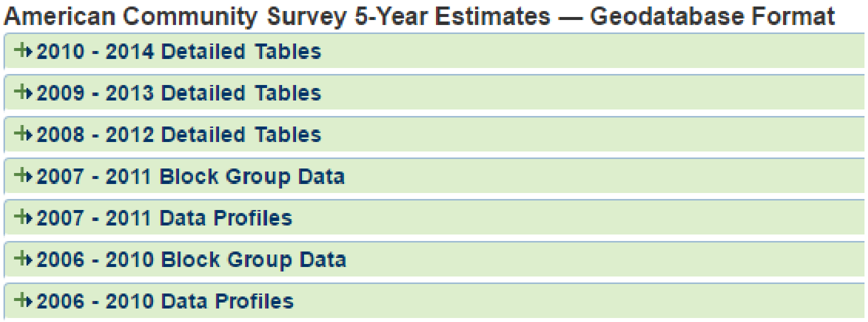
- TIGER Story Map (Part 1)
- Happy 25th Anniversary, TIGER

TIGER Data and Product FAQs

Which product should I use?

| Product | Best For... | File Format | Type of Data |
|---|---|---|---|
| TIGER/Line Shapefiles | Most mapping projects--this is our ***most comprehensive dataset***. Designed for use with GIS (geographic information systems). | Shapefiles (.shp) and database files (.dbf) | Boundaries, roads, address information, water features, and more |
| TIGER Geodatabases | Useful for users needing national datasets or all major boundaries by state. Designed for use in ArcGIS. Files are extremely large. | Geodatabase (.gdb) | Boundaries, roads, address information, water features, and more |
| TIGER/Line with Selected Demographic and Economic Data | Data from selected attributes from the 2010 Census, 2006-2010 through 2010-2014 ACS 5-year estimates and County Business Patterns (CBP) for selected geographies. Designed for use with GIS. | Shapefiles (.shp) and Geodatabases | Boundaries, Population Counts, Housing Unit Counts, 2010 Census Demographic Profile 1 attributes, 2006-2010 through 2010-2014 ACS 5-year estimates data profiles, CBP data. |
| Cartographic Boundary Shapefiles | Small scale (limited detail) mapping projects clipped to shoreline. Designed for thematic mapping using GIS. | Shapefiles (.shp) | Selected boundaries |
| KML - Cartographic Boundary Files | Viewing data or creating maps using Google Earth, Google Maps, or other platforms that use KML. | KML (.kml) | Selected boundaries |
| TIGERweb | Viewing spatial data online or streaming to your mapping application. | Interactive viewer, HTML data files, plus REST and WMS map services | Boundaries, roads, address information, water features, and more |

**Figure E.1.** Screenshot of TIGER Products from U.S. Census Bureau Website

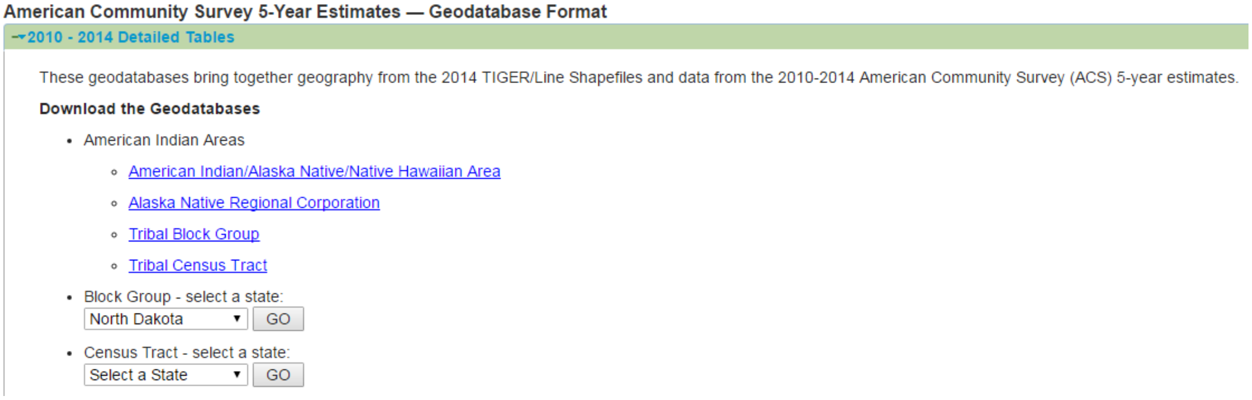

American Community Survey 5-Year Estimates — Geodatabase Format

- 2010 - 2014 Detailed Tables
- 2009 - 2013 Detailed Tables
- 2008 - 2012 Detailed Tables
- 2007 - 2011 Block Group Data
- 2007 - 2011 Data Profiles
- 2006 - 2010 Block Group Data
- 2006 - 2010 Data Profiles

**Figure E.2.** Screenshot of American Community Survey Data Options

As noted, these geodatabases bring together geography from the 2014 TIGER/Line Shapefiles and data from the ACS 5-year estimates. Geodatabases can be downloaded for a number of different geographies, including American Indian areas, block groups, census tracts, congressional districts, core based statistical areas, counties, county subdivisions, places, public use microdata areas (PUMAs), school districts, states, state legislative districts, urban areas, and zip codes. Not all data are available at every geographic level, as some data may be missing from small geographic areas. Data on disabilities, for example, are missing from the block group data. Age and income data, however, are available at the block group level.

To download the block group geodatabase, select the state for which you wish to obtain data from the drop-down menu, as shown in Figure E.3. A zip folder will then be downloaded and, after the files are extracted, they can be used in GIS.



**American Community Survey 5-Year Estimates — Geodatabase Format**

**2010 - 2014 Detailed Tables**

These geodatabases bring together geography from the 2014 TIGER/Line Shapefiles and data from the 2010-2014 American Community Survey (ACS) 5-year estimates.

**Download the Geodatabases**

- American Indian Areas
  - American Indian/Alaska Native/Native Hawaiian Area
  - Alaska Native Regional Corporation
  - Tribal Block Group
  - Tribal Census Tract
- Block Group - select a state: North Dakota
- Census Tract - select a state: Select a State

**Figure E.3.** Screenshot of How to Download American Community Survey Geodatabase

The downloaded geodatabase contains a feature class showing the block groups and multiple tables containing demographic information that can be joined to the feature class. Also included is a metadata table that defines all of the variables found in each table.

Figures E.4 and E.5 show some of the demographic data used in the study. The first shows population aged 18-24 in each census block group, and the second shows the number of households in each block group with income less than $25,000. These demographic groups were found to be more likely to use intercity bus. These maps were created using ACS 2009-2013 5-year estimates.

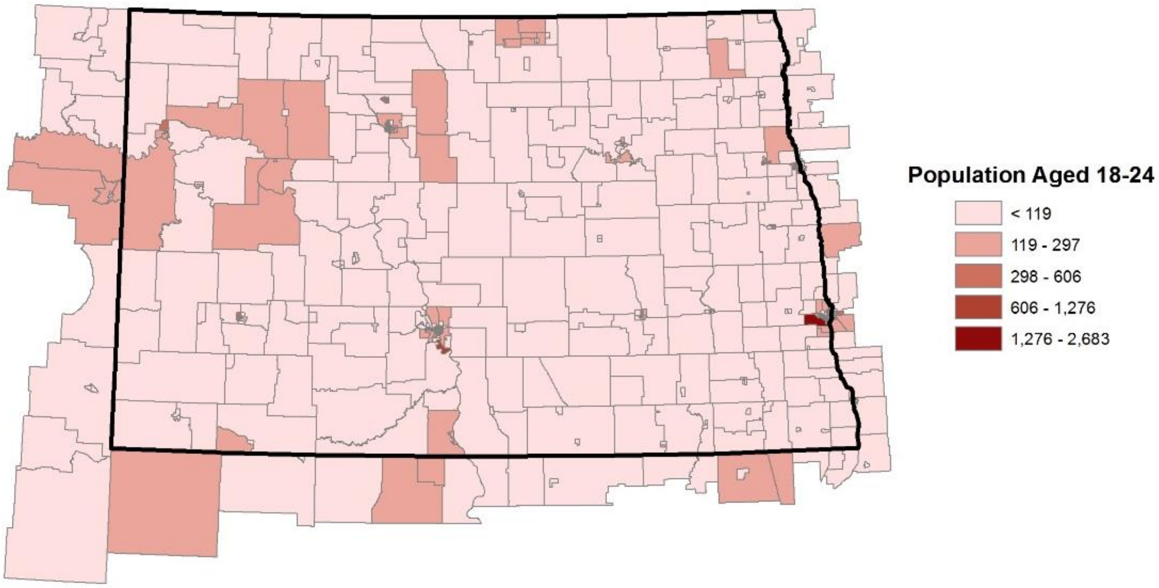


**Figure E.4.** North Dakota Population Aged 18-24, by Census Block Group

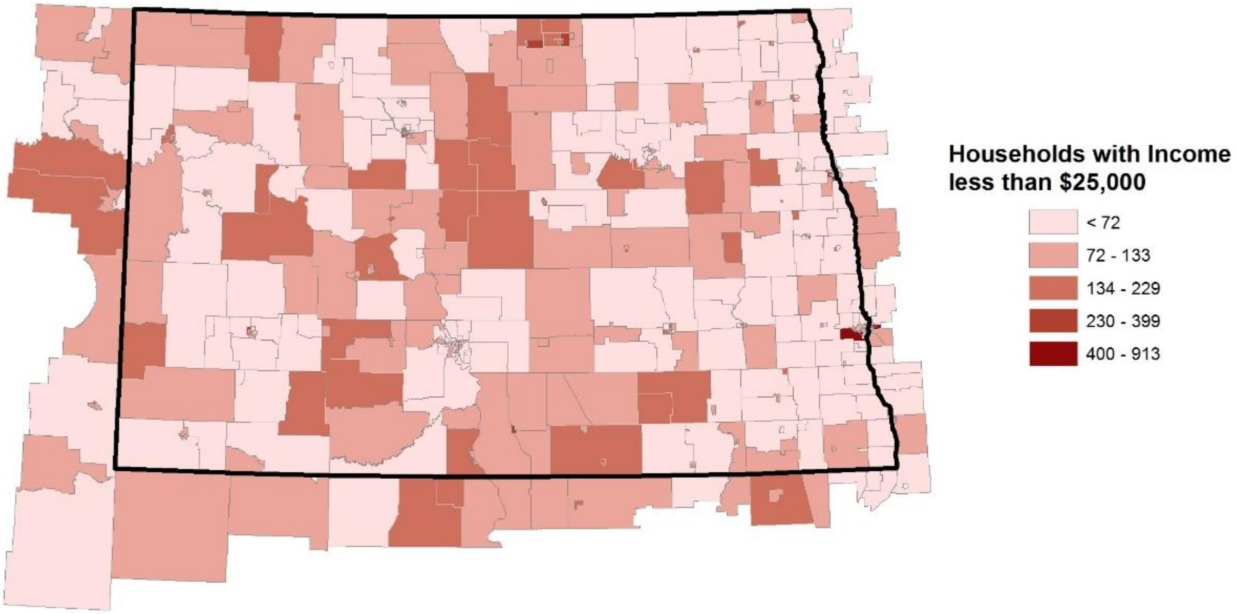


**Figure E.5.** North Dakota Households with Income less than $25,000, by Census Block Groups