MODE CHOICE MODELS FOR LONG DISTANCE TRAVEL IN USA

by

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ABSTRACT

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The influences of technology and economic development on human activity are increasingly taking place on larger spatial scales. As a consequence, complementary interactions between urban regions are getting stronger, which causes urban regions to change. In order to stimulate the integration between regions and states level, policy makers need increased knowledge of the factors that influence long distance travel. From an environmental perspective, long distance trips can be very important because most of the trips are made in personal vehicles or airplanes that affect emissions and fuel consumption. Mode choice alternatives for long distance travel include: personal vehicle, air, and ground. Trip purposes (business, personal business, and pleasure) are considered in modeling. Based on the research results, a household located in an urban area plays an important role in the mode choice decision. A traveler's occupation may affect the mode choice decision between personal vehicle and public carrier; a traveler in the sales, service, or other occupational categories tends to travel by a personal vehicle rather than a public carrier. A traveler who travels over long weekends, has a household income below $20,000, lives in an urban area, has many household members on the trip, or spends not many nights on the trip prefers to make a long distance trip by personal vehicle. Considering age, as the age of traveler increases, the traveler tends to travel by the air mode; this is the same as route distance increases. In this study, variables that are exclusive to specific trip purposes between business, personal business, and pleasure include the number of vehicles in a household, traveler occupation, and household income. The prediction results show that Neural Network models (piecewise linear network floating search) outperform the percent correct for two mode choice (personal vehicle and air mode) cases and nested logit models outperform the percent correct for three mode choice (personal vehicle, air, and ground) cases. The results indicate that Neural Networks are a possible model for estimating long distance travel mode choices; however, for data mining, logistic regression provides better explanations of the variables, especially, for independence of irrelevant alternatives.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Long distance travel is a greater concern than in the past due to its rapid increase over recent decades [10]. There are many reasons for the increase in long distance travel, for example, economic growth and car ownership. Economic growth and globalization factors tend to increase long distance business trips as well as private trips as disposable income increases [10]. Inexpensive automobiles may be another reason for the increase in long distance travel. Good highway, train, and airport infrastructure may encourage long distance travel because cost and travel time are reduced while safety is increased. According to the 2001 National Household Travel Survey (NHTS) [58], both car and air capture large market shares: more than ninety seven percent for long distance trips while train, bus, and other modes account for the remaining three percent.

Technological innovations in transportation and economic growth are the main factors contributing to an increase in mobility during in the last few decades [49]. High mobility brought about an increase in the number of long distance person trips. As mobility increases, long distance travel increases and urban areas expand. Long distance travel brings benefits to economic, and social factors and disbenefits for environmental factors. In additional to its economic benefit, long distance travel strengthens the links between different regions [57]. Each region has greater opportunities to become involved in the economic network and profit from the mutual exchange of knowledge and creativity [6]. Long distance travel enhances access to more facilities and services, such as health care, retail outlets, and social events, particularly in rural areas. Moreover, long distance travel is necessary for many recreational activities, such as vacation, day-trips, and other tourism [36]. With respect to environmental disbenefits, long distance travel is related to environmental problems because more long distance travel increases the level of energy consumption, emission of air pollutants, and noise [52].

Human activities are increasingly taking place on larger spatial scales because of the influence of technology and economic development. As a consequence, complementary interactions between urban regions are getting stronger [6].

Limtanakool et al. [32] give the definition of long distance travel as "*long distance travel refers to trips of a certain minimum distance.*" A benefit of using a distance threshold is that intra-urban trips can be excluded by defining the threshold based on the size of the urban area [47]. Many different threshold definitions have been used by various countries in their National Travel Surveys: one hundred miles for USA [57]; fifty miles for the UK [41]; one hundred kilometers for Sweden, Norway [53], [17], and fifty miles for another USA study [58]. In 1982, German residents made almost four long distance trips per year to destinations of at least fifty kilometers away from their homes [14]. The long distance trips (more than one hundred miles or 160 kilometers from home) explain only a few percent of all person trips.

From Table 1.1, vehicle miles traveled (automobiles, bus, train, and air) for long distance trips in the US were 1,360,679 millions miles, or 36% of total vehicle miles in year 2001. However, long distance trips only account for 0.7% of the total trips. The disproportionate percentage of vehicle miles traveled increase the impact of long distance trips on emissions, the environment, and economic policy.

Table 1.1 Total person trips and person miles traveled for long distance trips

	Number of trips (millions)	Miles (millions)
Total	384,489	3,783,975
Long distance only	2,611	1,360,679
Long distance percent	0.7%	36%

From NHTS [58], Americans took about 2.6 billion long distance trips, for over 1.3 trillion person miles. Ninety-eight percent of all long distance trips were for travel within the United States, with sixty-two percent of all long distance trips occurring within the traveler's home state. Fifty-seven percent of all long distance trips were made by men. Fifty-seven percent of all long distance trips were taken by persons living in households with total household income of $50,000 or more. Sixty-six percent of all long distance trips were made by persons aged twenty-five to sixty-four. Ninety percent of all long distance trips were taken by personal vehicle, while seven percent were taken by airplane. Only two percent of all long distance trips used bus, and train trips represented less than one percent of long distance trips. Personal vehicles were used for over ninety-seven percent of all trips of less than 300 roundtrip miles, while seventy-five percent of trips over 2,000 roundtrip miles were made by airplane. Fifty-six percent of all long distance trips taken in 2001 had a pleasure purpose, such as vacations, sightseeing trips, visiting friends and relatives, and outdoor recreation. Sixteen percent of long distance trips were taken for business trips to attend conferences or meetings. Thirteen percent of long distance trips were work commute trips. Personal reasons or family business purposes accounted for thirteen percent of long distance trips.

Most transportation-related research is concentrated on daily trip travel within urban areas. However, as new patterns of inter-regional travel and economic cooperation develop, policymakers will react to long distance travel needs by investing in transport infrastructure [5]. This research will analyze the influence of traveler's characteristics on long distance travel behavior (more than fifty miles from the home base, as defined by NHTS [58]).

1.2 Problem statement

In order to calibrate the models, factors that affect long distance trips need to be understood [4]. Factors that affect long distance trips are important for policy makers to meet long distance traveler needs. The microlevel socio-economic traveler characteristics that are expected to influence mode choice for long distance travel include age, income, race, and occupation. The impact of long distance travel may be realized in different ways. For a large country, like the USA, if people have to leave their own town, they most likely have to travel more than fifty miles. On the other hand, a larger country also means longer travel times, which can reduce individual motivation to travel long distances because travel has both high access times and cost.

For these reasons, the main goal for this research project is to develop a model to study the behavior of long distance travelers in the USA. From this model, a strategy can be developed that will result in improved infrastructure investments that satisfy traveler needs.

1.3 Purpose of the study

This research aims to enhance the understanding of the factors that affect mode choice decisions for long distance travel for different trip purposes. Mode choice alternatives for long distance travel include: personal vehicle, air, and ground (bus and train). Trip purposes (business, personal business, and pleasure) are considered.

The NHTS does not collect data related to the destination of long distance trips, travel times, and travel costs. However, it does include many factors that are important for developing a model. There are three sets of variables affecting mode choice for long distance trips: traveler socio-economic characteristics such as income, age, occupation and number of household (HH) members traveling; trip distance; and trip characteristics (short weekend, long weekend, and non weekend trip). A key assumption is that the differences in the decision situation for long distance travelers and differences in their motivation to start a long distance trip will have a critical impact on mode choice. For an example, the characteristics of the firm that employs business travelers are likely to be more important than household composition for the business trip mode choice.

Specially, the travel expense reimbursement policy of firms is an important determinant for business trip mode choice [33].

In this research, long distance travel in USA, Texas, and Wisconsin is analyzed and compared. The reason for including and comparing the two states is the assessment of differences in size, demographics, urbanization patterns, and data availability. Trips for each trip purpose, business, pleasure and personal business, are considered separately based on the assumption that each trip purpose may be affected by different variables for different reasons. The factors that influence mode choice for each purpose can be determined which can assist federal and state government in managing long distance travel and developing alternative modes.

The dissertation addresses the following objectives:

1. Identify the trip purposes, demographic characteristics, and trip characteristics that have significant effects on mode choice.
2. Identify any variables in demographic characteristics and trip characteristics that exclusive to the specific different trip purposes.
3. Develop and compare the logit and Neural Network models: usually the mode choice behavior is estimated by logistic regression based on random utility theory [19]: however: a different approach to mode choice behavior with a good prediction capability is Neural Network models proposed by Shmueli [50].
4. Develop recommendations for long distance travel modeling and interregional or statewide transportation planning.

1.4 Literature review

The lack of available data on long distance travel is the main hindrance to long distance travel research. As a result, not many people have conducted research on long distance travel; most of this limited research focuses on long distance travel impact on mode choice. A few exceptions have considered the influence of macrolevel factors, such as residential context and destination characteristics [40]. The existing literature about mode choice for long distance trips has mainly concentrated on the effect of factors at the microlevel, such as socio-demographics [40]. The most important factors of daily travel patterns are socio-demographic characteristics [18]. These factors also play a vital role in influencing long distance travel [35].

Algers [1] studied traveler socio-economic characteristics, travel cost, travel time, and some elements of destination land use attributes in Sweden. He found that the total number of long distance trips is sensitive to the size of the destination.

Bricka [13] analyzed variations in long distance trips in New York, Massachusetts and Oklahoma. In her opinion, the variations in mode, trip length and trip purposes between states can be explained by several differences between rural and urban areas, including dissimilar demographic profiles, availability of modes and urban form. She does not attempt to model the influence of these factors on mode choice, and her results are based only on descriptive cross-tabulation.

Bel [7] evaluated the impact of road network travel time changes on inter-city rail demand. He found that the addition of travel time considerations improves the explanatory power of an inter-city mode choice model, and concluded that these factors should be included in a model when studying the demand for inter-city travel.

Cervero [15] showed that land use diversity at the origin and destination tends to reduce driving alone; however, he indicates that this relationship is stronger for the destination. Many studies have shown population density to be an important predictor of mode choice [23]. In addition to population density, more diversity of mixed land uses increases the attractiveness of transit for both work trips and leisure trips [33].

Limtanakool et al. [33] discovered that the typical long distance trip maker is male with high-income, a high level of education, full-time employment, higher level job position, licensed driver, car owner, and married. Trip frequency increases with age, but decreases when age reaches 65 years [33].

Mallett [36] claims that families with children reduce the frequency of long distance trips for females more than males. However, O'Neill and Brown [40] found that children in households do not impact the average trip frequency, and the availability of a season ticket for travel does not show any significant effect [2].

In the USA, business and non-business trips affect mode choice, trip distance, number of people in a trip group, and travel duration differently [26], [47]. Choosing a more expensive mode depends on the work status and the economic strength of the company [1]. Moreover, car ownership increases the propensity to use a car for business trips [26].

Mallett [36] showed that elderly USA citizens have shorter trip distances and decreased business, recreational, and vacation trips; however, their trips for social visits and personal business increased. Similarly, low income households travel long distances less frequently for business, recreation, and vacation and more frequently for personal business and social visits than high income households. Also, males travel more frequently for business and outdoor recreation than females, but there are no statistical differences for other trip purposes [36].

Modal choice for long distance travel is also affected by trip purpose and socio-demographics. Air travel is predominant for business travel and car use for personal business or social purposes [26]. For elderly people, the airplane and the bus are used instead of the car more frequently. Females travel more frequently by bus than males and males travel more frequently by airplane than females [36].

In the USA, people who live in rural areas travel long distances more frequently than the people who live in urban areas [36]. However, longer working trips and urban dwellers use rail more often than others. There are several differences between rural and urban areas, including dissimilar demographic profiles, prices, accessibility, and availability of modes as well as urban form and potential destinations [13]. Algers [1] revealed that owners of a summer house travel long distances more frequently, and he also indicated that the total population, the number of employees, and the population density at the destination do not explain the number of trips taken for private purposes, but are proportional to the destination size for business purposes.

Based on previous research, the distinction between trip purposes for analyzing long distance trips is appropriate. Therefore this research will analyze business, pleasure and personal business trip separately. The study will identify the relationship between socio-demographic factors, such as income, age, occupation, and number of household member on travel period, and these trip purposes.

1.5 Significance of the study

The influences of technology and economic development on human activities are increasingly taking place on larger spatial scales. As a consequence, complementary interactions between urban regions are becoming stronger, which causes urban regions to change to meet emerging needs. Improved knowledge of various factors that affect the increase in long distance travel requires more understanding. In order to stimulate the traveling interaction between regions, state, and country level, policy makers need to know the factors that influence long distance traveling. From an environmental perspective, these trips can be very important because most long distance trips are made in personal vehicles or airplane, which may affect regional emissions and fuel consumption.

As a consequence of these changing relations between urban areas, the use of transport infrastructure can be improved, such as investing in high-speed railways and expanding airports. Policy makers need more information to anticipate the future demand for long distance travel. Also, the models can be used as a marketing tool for airlines and other transportation providers.

1.6 Expected contribution of the research

The models are expected to apply to transportation travel behavior to estimate long distance trip mode choices. The models will provide more reliable predictions of mode choices by identifying characteristics of the long distance traveler, which will assist planning activities based on the variables in the model that capture travel behavior. The models can be applied in regions to estimate the demand for different long distance mode choices. The models can help cities, MPOs, States, and the US plan to provide adequate supply to meet demand and promote the other modal alternatives.

1.7 Organization of dissertation

This dissertation has been organized into six chapters. Chapter one continues an introduction to long distance travel and previous research as well as the objectives and significance of the study. Chapter two provides information about the NHTS dataset, which is used in this research. Chapter three develops logistic regression models using both binary logit and nested logit structures. Chapter four develops Neural Network models using Neurosolutions and NuClass7 software. Chapter five provides analysis and compares results from the logistic regression and Neural Network models. Last, chapter six provides conclusions, and possibilities for future research.

CHAPTER 2

NATIONAL HOUSEHOLD TRAVEL SURVEY DATA (NHTS)

2.1 Introduction

In order to gain insight into the structure and characteristics of long distance trips within the USA, the analysis in this project uses existing databases.

This research will focus on the people who make a long distance trips for three purposes: business, pleasure, and personal business. The definition of long distance trips by NHTS is all trips with a distance longer than fifty miles from origin to destination.

2.2 The National Household Travel Survey (NHTS)

"*The National Household Travel Survey (NHTS) is the nation's inventory of daily and long distance travel. The survey includes demographic characteristics of households, people, vehicles, and detailed information on daily and longer-distance travel for all purposes by all modes. NHTS survey data are collected from a sample of U.S. households and expanded to provide national estimates of trips and miles by travel mode, trip purpose, and a host of household attributes.*" [58]

The daily travel surveys were conducted in 1969, 1977, 1983, 1990, 1995, and 2001 and US longer-distance travel was collected in 1977, 1995, and 2001. The NHTS provides the source of information at the national level on the relationships between the characteristics of personal travel and traveler demographics.

The NHTS collected travel data from a national sample of the civilian, non-institutionalized population of the United States. People living in college dormitories, nursing homes, other medical institutions, prisons, and military bases were excluded from the sample.

There were approximately 66,000 households in the final 2001 NHTS dataset. About 26,000 households were from the national sample, while the remaining 40,000 households were from nine add-on areas. There were 200,000 daily trips and 45,000 long distance trips.

Nine add-on areas are:

- Baltimore MPO, Maryland
- Des Moines MPO, Iowa
- Edmonson, Carter, Pulaski, and Scott Counties, Kentucky
- Lancaster MPO, Pennsylvania
- Oahu MPO, Hawaii
- State of Hawaii, except Oahu
- State of New York
- State of Texas
- State of Wisconsin

The NHTS obtained data by using Computer-Assisted Telephone Interviewing (CATI) technology. Each household was assigned a specific twenty-four-hour “Travel

Day" and kept diaries to record all travel by all household members for the assigned day. A twenty-eight-day "Travel Period" was assigned to collect longer-distance travel for each household member, and includes information on long commutes, airport access, and overnight stays. The NHTS interviews were conducted from April 2001 through May 2002.

The NHTS data was revealed preferences. Each traveler provided information about household characteristics and trip characteristics; however, many variables that may be important for mode choice decisions such as travel cost and travel time did not appear in the data set because of the cumbersome data collection.

Each traveler also provided information about the mode that they used but they did not provide information about other alternative modes because long distance travel did not usually happen frequently. People might travel long distances once in a while with a variety of constraints, such as time, cost, destination, and trip purpose; therefore people may not have many alternative mode choices and limited knowledge of those that exist.

Variables used in this research came from the NHTS, and Texas and Wisconsin additional data sets. There were many variables in the data set, but only the variables that were considered by the researcher and showed statistical significance were used for model development. The author excluded "other purpose," "other mode," and "ship mode" because their effect and number of data points were minimal. All travelers under age 18 were excluded because they cannot have a driver's license nor independently make mode choice decisions or initiate long distance travel. Missing values were also excluded, which reduced the dataset to 16,861 cases.

To strengthen the modeling process, the author divides the NHTS data into two sets of data by randomly shuffling the traveler records. The first set, which is eighty percent of the NHTS data, is used for calibration and the second set, which is twenty percent of the NHTS data, is used for validation.

2.3 Trip purpose, alternatives, and variables

2.3.1 Trip purpose

2.3.1.1 Business purpose

This trip purpose may be to attend a conference, meeting or other business purpose other than commuting to and from work [58]. The trip is considered to be for a business purpose as long as business is the primary purpose, even though travelers can participate in sightseeing, visiting friends, or other activities.

Travelers on business purpose trips may have to travel on duty for their organization. In this case, they can receive reimbursement from the organization for travel expense. As a result, income may not affect the mode choice decision.

2.3.1.2 Personal business purpose

This trip purpose includes trips for medical visits, shopping trips, and trips to attend weddings, funerals, and other events [58].

Travelers on personal business trips travel at their own expense; however, this kind of trip is required, which means that income and occupation may not have a significant impact on the model.

2.3.1.3 Pleasure purpose

This trip purpose includes trips for vacations, sightseeing trips, visiting friends and relatives, and outdoor recreation. The point of pleasure purpose is for rest and relaxation.

This trip purpose is based on the satisfaction of travelers; therefore, income and number of household members traveling on the trip may be important.

2.3.2 Alternatives

2.3.2.1 Personal vehicle

A personal vehicle represents a passenger car, sport utility vehicle (SUV), mini van, van, or other vehicle that the traveler's household owns. This alternative may be preferred for travelers due to:

- Travelers can travel from origin to destination and still have a vehicle to use at the destination,
- Travelers will have privacy in their own vehicle,
- Travelers can have a flexible schedule. Travelers can change time and they can visit any place at any time and location they want.
- In USA, almost every household owns a vehicle; therefore, travelers may prefer to use the vehicle they have.

However, this alternative will cost travelers gas and maintenance, and the time to drive from origin to destination. If the destination is very far from the origin, travelers need significant time to drive and travelers can become fatigued from travel.

2.3.2.2 Air mode

The air mode is a fast transportation alternative for delivering people from origin to destination. Travelers can travel with low travel time; however, the cost to travel using this alternative is high. Travelers have to travel with many people.

2.3.2.3 Ground mode

The ground mode represents both bus and train. Due to the small number of trips on bus and train, models cannot be developed for bus and train alternatives separately. Therefore, the author combined the two modes into ground. This alternative is a slower mode, which may need to stop at many stations before arriving at a destination. Travelers in this mode will not have privacy because they have to share a vehicle with many people.

2.3.3 Variables

2.3.3.1 Nights away on travel period trip

The number of nights away for a travel period is a variable that impacts which mode to select. An organization or family typically prefers to spend many nights at a destination rather than many nights en route. The sign of this variable should be to reduce the probability to travel with personal vehicle and ground transportation as the number of nights away increases.

2.3.3.2 Number of HH members on travel period trip

For this variable, the greater the number of household members on a trip, the greater the travel expense. Travelers may consider the privacy associated with their family. These two factors may decrease the attractiveness of a public carrier when traveling with many household members. The sign of this variable should reduce the probability to travel using air and ground due to privacy to travel with other people and expense.

2.3.3.3 Age of respondent

Age is a variable that may impact traveler mode choice. All trips for individuals under age 18 are excluded because these individuals cannot make decisions. Older travelers may not prefer to take much travel time to get to a destination. Therefore, this variable may decrease the probability to travel using slower modes such as personal vehicle and ground.

2.3.3.4 Route distance: origin to destination

Route distance is an important factor to determine mode choice. Very long distance travel will encourage a traveler to select a fast mode. Air mode will be preferred if travelers travel very long distanc; therefore, the sign of this variable should reduce the probability to travel on slow modes (personal vehicle and ground).

2.3.3.5 Number of vehicles in household

This variable shows the potential of a household to have variety of personal vehicles. These households can select a vehicle based on the trip purpose. For example, a household on pleasure trip that already owns a SUV or minivan may have a propensity to travel by personal vehicle rather than other modes.

2.3.3.6 Race of HH respondent

Differences in race may affect mode choices for long distance travel. Rosenbloom and Waldorf [48] mention that older people travel for long distances based on race and place. They found that culture differences, appropriate to traveling alone and safety risks during the travel would affect a race to select mode choices. Therefore, in this research, the author assumes that Rosenbloom and Waldorf's finding can apply to younger long distance travelers. White and African Americans may feel comfortable traveling by personal vehicle and ground mode due to the widespread population of both white and African Americans throughout USA. On the other hand, most of Asian people live in an urban area and a very small number live in non-urban areas, which may make the air mode more attractive.

2.3.3.7 Household in urban or rural area

Travelers who live in an urban area have a greater variety of alternative activities near the household to encourage the traveler to use personal vehicle more than a rural person. Route alternatives also would encourage personal vehicle. For travelers who live in rural area, all of those alternatives may not available in rural area.

2.3.3.8 Occupational category

NHTS does not provide the level of a job, such as high level, mid level, and low level; therefore, the occupational category variable may not correlate with the income variable. For business trip purposes, income may be insignificant due to reimbursement; however, the type of occupation may effect the decision of mode choices for business travelers. High revenue business organizations can provide more support for their employee to travel than low revenue organizations. Additionally, people in sales and service occupations may prefer to travel by personal vehicle for business trips.

2.3.3.9 Trip includes weekend

Travelers who travel not on weekends and short weekend trips may prefer a fast transportation mode such as air because they must come back to work. For long weekend trips, travelers can spend more time on travel with lower cost; therefore, a slower mode of transportation may be preferred.

2.3.3.10 Total income all HH members

Income is a very important variable for people who travel long distances. Low-income travelers should prefer inexpensive transportation modes such as personal vehicle or ground more than high-income travelers. In this research, the author separates income level to three levels. The first grouping is below poverty line income: the poverty line for this research is set below $20,000, which is the poverty line threshold between three and four family members in the 2002 census because the average family size in the US is 3.2 per family [56]. Second, the income between the national median and poverty line income: however, in 2002, national median income is $43,057 [56] and income in this research is catarical data. Therefore, $45,000 is approximately set for national median income in this research. The income in this level is from $20,000 to $44,999. The final grouping for above national median income contains families with incomes equal and greater than $45,000.

The models were developed from NHTS data and validated with the data from NHTS, Texas, and Wisconsin. However, the Texas data did not provide some variables, as shown in Table 2.1.

Table 2.1 The variables the for USA, Texas, and Wisconsin data file

Value Description	Provided Variables		
	USA	Texas	Wisconsin
Nights away on travel period trip	Yes	No	Yes
Number of HH members on travel period trip	Yes	Yes	Yes
Age of respondent	Yes	Yes	Yes
Route distance: origin to destination	Yes	Yes	Yes
Number of vehicles in HH	Yes	Yes	Yes
Race of HH respondent White (1 if yes, 0 otherwise) African American, Black (1 if yes, 0 otherwise) Asian Only (1 if yes, 0 otherwise) Other	Yes	Yes	Yes
Household in urban or rural area Urban (1 if yes, 0 otherwise) Rural	Yes	No	Yes
Occupational category Sales or Service (1 if yes, 0 otherwise) Clerical or administrative support (1 if yes, 0 otherwise) Manufacturing, construction, maintenance, or farming (1 if yes, 0 otherwise) Other	Yes	Yes	Yes
Trip includes weekend Short weekend (2-3 days incl FRI and-or SAT) no FRI return (1 if yes, 0 otherwise) Long weekend (4-6 days incl FRI and-or SAT) no FRI return (1 if yes, 0 otherwise) Not weekend trip (all other trips)	Yes	No	Yes
Total income all HH members < \$20,000 (1 if yes, 0 otherwise) \$20,000-\$44,999 (1 if yes, 0 otherwise) ≥ \$45000	Yes	Yes	Yes

As indicated in Table 2.1, the Texas dataset does not have a data for: "*nights away on travel period trip,*" "*household in urban or rural area,*" or "*trip includes weekend.*" Lack of these variables for the Texas data is a good opportunity to examine the performance of the models when a lack of variables is unavoidable; therefore, the unavailable data for Texas is filled with two substitution methods; zero and the US average value for continuous variable and 0.5 for category variable. However, both methods do not represent the actual travel behavior since they are defined as a presumption method.

Table 2.2 shows cross-tabulation of the USA dataset by mode choices and purposes.

Table 2.2 NHTS modal classification by trip purpose

	Personal Vehicle	Air	Ground	Total
Business	6,440	738	147	7,325
Personal Business	1,516	99	32	1,647
Pleasure	7,203	577	109	7,889
Total	15,159	1,414	288	16,861

From Table 2.2, it is obvious that personal vehicle was more preferred than other modes for each trip purpose, followed by the air mode and ground mode. According to Table 2.2, the number of pleasure purpose trips was higher than both business and personal business trips.

Table 2.3 shows cross-tabulation of Texas dataset by mode choices and purposes.

Table 2.3 Texas modal classification by trip purpose

	Personal Vehicle	Air	Ground	Total
Business	221	31	2	254
Personal Business	619	42	22	683
Pleasure	474	19	6	499
Total	1,314	92	30	1,436

From Table 2.3, similar to USA data, personal vehicle was more preferred than other modes for each trip purpose, followed by air mode and ground mode. However, the number of personal business purpose trips is higher than pleasure purpose trips and business purpose trips.

Table 2.4 shows cross-tabulation of Wisconsin dataset by mode choices and purposes.

Table 2.4 Wisconsin modal classification by trip purpose

	Personal Vehicle	Air	Ground	Total
Business	257	11	2	270
Personal Business	58	1	3	62
Pleasure	377	28	5	410
Total	692	40	10	742

From Table 2.4, similar to the national data, the personal vehicle was more preferred over other modes for each trip purpose, followed by the air mode and ground mode. Also, similar to the USA data, the number of pleasure trips is greater than business and personal business trips.

The previous research uses the data from the American Travel Survey (ATS) in 1995 for descriptive analysis, cross classification, the log-log demand model for the US and the logit model for Montgomery County, Maryland. In Europe, many researchers estimate logit models (binary and nested logit) using data from England, Netherlands, and Sweden. The NHTS dataset from 2001 is used in this research to calibrate binary logit, nested logit, and Neural Networks models that have never been developed before for a US long distance travel model; these models are validated using additional datasets from Texas and Wisconsin.

2.4 Descriptive Analysis

Long distance travel in the US accounts for 0.7% of total trips; however it accounts for 36% of the total travel distance. These proportions emphasize the important view that long distance travel has a disproportionate impact in terms of miles traveled, cost, and environment.

Tables 2.5 and 2.6 show the statistical summary of the US dataset. Tables 2.7 and 2.8 show the statistical summary of the Texas dataset. Tables 2.9 and 2.10 show the statistical summary of the Wisconsin dataset. The order of trips purpose based on frequency for the USA and Wisconsin data set is pleasure, business, and personal business trips; however, in Texas, personal business trips occur more frequently, followed by pleasure, and business. In the USA, personal vehicles are preferred for most long distance travel at 89.9%, while air and ground transportation account for a small part of long distance trips at 8.4% and 1.7%, respectively.

Travelers travel long distances during weekdays more than on weekends. Most business trips (92.6%) are non-weekend trips, which corresponds to the time periods when business activities are typically conducted. For personal business and pleasure trips, the percentage is slightly lower at 73.5% and 61.5%, respectively. The personal business trips show no significant preference for any day of the weekend because weekdays represent 71.43% of the week. On the other hand, pleasure trips seem to start a little more frequently on weekends. For nights away on the trip, Wisconsin travelers spent fewer nights than the US average. Wisconsin travelers also have fewer household members on the trips than the US average, but the number of household members on trips for Texas travelers is higher. Travelers with above $44,999 for household income travel long distances more than lower incomes. Though below $20,000 income individuals account for 22.1% of the US population, they only account for 4-6% of long distance travel. Between $20,000 and $44,999 household income travelers account for 21-30% of long distance trips, while above $44,999 household income travelers account for 63-73%; the population percentage of between $20,000 and $44,999 income and above $44,999 income households in the US are 31% and 46.9%, respectively. Total average age of travelers in the US is 43 years old, in Texas, 42.5 years old, and in Wisconsin, 47.2 years old: however, average age of USA population is 35.7 years old including citizens below eighteen years old. Average total distance traveled (origin to destination) is 257.9 miles for the US dataset, 203 miles for the Texas dataset, and 223.8 miles for the Wisconsin; however, with respect to each travel purpose, Wisconsin and Texas travelers travel shorter distances than the US average except Wisconsin pleasure trips. For occupation, the last category of occupation is the most selected by respondents. This may because the "other" category includes professional occupations and government service. Travelers in Texas and Wisconsin have the same average number of vehicles per household as the USA, at two or three vehicles (all of the averages are around 2.5 vehicles per household). For trip purpose, the averages of each variable are not different from the total average except for the nights away on the trip and number of household members on the trip, which are lower when the trip is for business.

Table 2.5 Statistical summary for the USA. (covariate variables)

	Min.	Max.	Mean	Std. Deviation
Business				
Nights away on travel period trip	0	55	0.761	2.260
Number of HH members on travel period trip	1	6	1.143	0.454
Age of respondent	18	89	43.684	11.549
Route distance: origin to destination	50	9968	237.06	559.19
Number of vehicles in HH	0	9	2.586	1.125
Personal Business				
Nights away on travel period trip	0	129	1.129	3.732
Number of HH members on travel period trip	1	10	2.005	1.047
Age of respondent	18	80	43.988	13.334
Route distance: origin to destination	50	5435	230.253	388.84
Number of vehicles in HH	0	10	2.541	1.217
Pleasure				
Nights away on travel period trip	0	120	1.804	3.602
Number of HH members on travel period trip	1	10	2.201	1.173
Age of respondent	18	88	42.381	12.996
Route distance: origin to destination	50	10763	283.09	557.26
Number of vehicles in HH	0	19	2.572	1.232
Total				
Nights away on travel period trip	0	129	1.285	3.146
Number of HH members on travel period trip	1	10	1.722	1.049
Age of respondent	18	89	43.104	12.441
Route distance: origin to destination	50	10763	257.93	544.47
Number of vehicles in HH	0	19	2.575	1.186

Table 2.6 Statistical summary for the USA. (category variables)

	Business	Personal Business	Pleasure	Total	Percent
Mode Choices					
Personal Vehicle	6440	1516	7203	15159	89.91%
Air	738	99	577	1414	8.39%
Ground	147	32	109	288	1.71%
Summary	7325	1647	7889	16861	100.00%
Race of HH respondent					
White	6378	1349	6939	14666	86.98%
African American, Black	299	99	274	672	3.99%
Asian Only	54	30	114	198	1.17%
Other	594	169	562	1325	7.86%
Summary	7325	1647	7889	16861	100.00%
Household in urban or rural area					
Urban	5006	1121	5710	11837	70.20%
Rural	2319	526	2179	5024	29.80%
Summary	7325	1647	7889	16861	100.00%
Occupational category					
Sales or Service	1764	425	2011	4200	24.91%
Clerical or administrative support	274	214	897	1385	8.21%
Manufacturing, construction	1735	303	1259	3297	19.55%
Other	3552	705	3722	7979	47.32%
Summary	7325	1647	7889	16861	100.00%
Trip includes weekend					
Short weekend	305	301	2094	2700	16.01%
Long weekend	240	135	942	1317	7.81%
Not weekend trip	6780	1211	4853	12844	76.18%
Summary	7325	1647	7889	16861	100.00%
Total income all HH members					
< $20,000	286	66	365	717	4.25%
$20,000 - $44,999	1599	364	1744	3707	21.99%
≥ $45,000	5440	1217	5780	12437	73.76%
Summary	7325	1647	7889	16861	100.00%

Table 2.7 Statistical summary for Texas (covariate variables)

	Min.	Max.	Mean	Std. Deviation
Business				
Nights away on travel period trip	N/A	N/A	N/A	N/A
Number of HH members on travel period trip	1	5	1.205	0.531
Age of respondent	18	81	44.614	11.494
Route distance: origin to destination	8.43	1893	207.55	286.56
Number of vehicles in HH	0	6	2.457	0.922
Personal Business				
Nights away on travel period trip	N/A	N/A	N/A	N/A
Number of HH members on travel period trip	1	7	2.212	1.076
Age of respondent	18	83	42.435	14.142
Route distance: origin to destination	4.28	1602	199.95	241.23
Number of vehicles in HH	0	7	2.530	0.978
Pleasure				
Nights away on travel period trip	N/A	N/A	N/A	N/A
Number of HH members on travel period trip	1	8	2.393	1.186
Age of respondent	18	85	41.583	13.249
Route distance: origin to destination	0.76	3301	205.45	361.03
Number of vehicles in HH	1	9	2.627	1.138
Total				
Nights away on travel period trip	N/A	N/A	N/A	N/A
Number of HH members on travel period trip	1	8	2.097	1.125
Age of respondent	18	85	42.524	13.429
Route distance: origin to destination	0.76	3301	203.21	295.60
Number of vehicles in HH	0	9	2.551	1.028

Table 2.8 Statistical summary for Texas (category variables)

	Business	Personal Business	Pleasure	Total	Percent
Mode Choices					
Personal Vehicle	221	619	474	1314	91.50%
Air	31	42	19	92	6.41%
Ground	2	22	6	30	2.09%
Summary	254	683	499	1436	100.00%
Race of HH respondent					
White	223	582	427	1232	85.79%
African American, Black	5	23	16	44	3.06%
Asian Only	2	0	5	7	0.49%
Other	24	78	51	153	10.65%
Summary	254	683	499	1436	100.00%
Household in urban or rural area					
Urban	N/A	N/A	N/A	N/A	N/A
Rural	N/A	N/A	N/A	N/A	N/A
Summary	N/A	N/A	N/A	N/A	N/A
Occupational category					
Sales or Service	73	157	99	329	22.91%
Clerical or administrative support	27	91	71	189	13.16%
Manufacturing, construction	28	112	92	232	16.16%
Other	126	323	237	686	47.77%
Summary	254	683	499	1436	100.00%
Trip includes weekend					
Short weekend	N/A	N/A	N/A	N/A	N/A
Long weekend	N/A	N/A	N/A	N/A	N/A
Not weekend trip	N/A	N/A	N/A	N/A	N/A
Summary	N/A	N/A	N/A	N/A	N/A
Total income all HH members					
< $20,000	9	51	26	86	5.99%
$20,000 - $44,999	53	167	114	334	23.26%
≥ $45,000	192	465	359	1016	70.75%
Summary	254	683	499	1436	100.00%

Table 2.9 Statistical summary for Wisconsin (covariate variables)

	Min.	Max.	Mean	Std. Deviation
Business				
Nights away on travel period trip	0	17	0.437	1.602
Number of HH members on travel period trip	1	5	1.074	0.398
Age of respondent	20	78	41.811	13.991
Route distance: origin to destination	50.6	9129.06	198.246	594.674
Number of vehicles in HH	1	6	2.656	0.935
Personal Business				
Nights away on travel period trip	0	6	0.774	1.431
Number of HH members on travel period trip	1	4	1.935	0.721
Age of respondent	18	66	44.081	12.128
Route distance: origin to destination	54.1	763	160.32	149.30
Number of vehicles in HH	1	6	2.484	1.036
Pleasure				
Nights away on travel period trip	0	49	1.554	3.483
Number of HH members on travel period trip	1	7	2.017	1.036
Age of respondent	16	87	42.312	13.107
Route distance: origin to destination	50.1	2724	250.27	410.93
Number of vehicles in HH	0	9	2.673	1.166
Total				
Nights away on travel period trip	0	49	1.082	2.842
Number of HH members on travel period trip	1	7	1.667	0.946
Age of respondent	16	87	42.278	13.355
Route distance: origin to destination	50.1	9129	223.82	473.69
Number of vehicles in HH	0	9	2.651	1.076

Table 2.10 Statistical summary for Wisconsin (category variables)

	Business	Personal Business	Pleasure	Total	Percent
Mode Choices					
Personal Vehicle	257	58	376	691	93.13%
Air	11	1	29	41	5.53%
Ground	2	3	5	10	1.35%
Summary	270	62	410	742	100.00%
Race of HH respondent					
White	239	59	385	683	92.05%
African American, Black	27	0	4	31	4.18%
Asian Only	0	1	1	2	0.27%
Other	4	2	20	26	3.50%
Summary	270	62	410	742	100.00%
Household in urban or rural area					
Urban	184	31	241	456	61.46%
Rural	86	31	169	286	38.54%
Summary	270	62	410	742	100.00%
Occupational category					
Sales or Service	84	22	97	203	27.36%
Clerical or administrative support	10	7	51	68	9.16%
Manufacturing, construction	63	14	83	160	21.56%
Other	113	19	179	311	41.91%
Summary	270	62	410	742	100.00%
Trip includes weekend					
Short weekend	9	14	99	122	16.44%
Long weekend	5	2	45	52	7.01%
Not weekend trip	256	46	266	568	76.55%
Summary	270	62	410	742	100.00%
Total income all HH members					
< $20,000	17	7	16	40	5.39%
$20,000 - $44,999	97	16	116	229	30.86%
≥ $45,000	156	39	278	473	63.74%
Summary	270	62	410	742	100.00%

CHAPTER 3

LOGISTIC REGRESSION

3.1 Introduction

3.1.1 Mode choice model

A mode choice model considers the travel mode that travelers chose for a particular trip. Utility theory is basis of many mode choice models, especially those that use logistic regression. Utility theory assumes that travelers prefer an alternative with the highest utility.

Random utility theory [19] is the framework for generating mode choice models. The basic assumptions of utility theory include:

1. Travelers in a given homogeneous population act rationally and possess perfect information.
2. A traveler's alternative set is predetermined. The effect of all constraints (legal, social, physical, and budgetary) has already been determined and it does not affect the process of selecting among alternatives.
3. The utility function (U) of each alternative is typically represented by a deterministic portion (V) and a random portion (ε) to capture the uncertainty. The function is represented as following:

$$U = V + \varepsilon \qquad (3.1)$$

The uncertainty originates from the following: [37]

- Unobserved alternative attributes
- Unobserved individual attributes
- Measurement errors
- Proxy or instrumental variables

4. Travelers always select the option which maximizes their net personal utility based on legal, social, physical, and budgetary constraints.

Ortuzar and Willumsen [42] describe a discrete choice model where *"the probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option."* The attractiveness of the alternatives can be represented by utility, which is derived from their characteristics and the individual [42].

3.2 Binary logit

Many problems require researchers to predict the value of a binary dependent variable from a set of independent variables. In this research, mode choices outcome will be obtained from analysis and used to predict the dependent variable. Logistic regression can be used when the dependent variable is a dichotomous variable and the independent variables are continuous, categorical, or both [43]. Logistic regression can be used to estimate the probability of an event occurring. The long distance travel model estimates the probability that a person makes a decision to travel by a particular mode for a specific travel reason. The dependent variables in this model are the personal vehicle and air modes. The independent variables consist of socio-demographic variables, such as economic status, age, total household members on trip, and number of vehicles in household. Logistic regression analysis is performed using SPSS for Windows 12.0.

In logistic regression, the relationship between the independent variables and the dependent variable is not assumed to be a linear relationship. Logistic regression also does not assume any distribution for the independent variables. They do not have to be normally distributed, linearly related, equal variance within each group or normally distributed in error terms [43]. However, the solution will be better if the independent variables have a normal distribution. Moreover, multicollinearity among the independent variables can lead to biased estimates and inflated standard errors [51].

Logistic regression requires the following assumptions: [39]

1. Observations are independent.
2. Variables are linearly related to the logarithm of the odds that an event occurs.

3.2.1 Odds and odds ratios

To understand the model, odds and odds ratios must be understood. Assume that the chance that an event will occur can range from 0 to 1, where 0 means that the event definitely will not occur and 1 means that the event will definitely occur. "Odds" is another method for presenting the chance of an event occurring [3].

The odds of an event is the ratio of the expected number of times that an event will occur to the expected number of times that the event will not occur. The relationship between probability and odds is;

$$O = \frac{P}{1-P} = \frac{\text{Probability of event}}{\text{Probability of no event}} \tag{3.2}$$

$$P = \frac{O}{1+O} \tag{3.3}$$

- P is the probability of an event
- O is the odds of the event

Odds ratios are used to measure the relationship between two dichotomous variables [3]. The odds ratio for an independent variable is the relative amount by which the odds of the outcome increase (odds ratios greater than 1.0) or decrease (odds ratios less than 1.0). The odds ratios depend on the categories that are compared; odds ratios can be greater than 1, while the corresponding reciprocal odds ratios are less than 1. Some simple algebra gives the result that *e* raised to the power B_i is the factor by which the odds change when the i^{th} independent variable increases by one unit and all other variables remain the same. This is known as the odds ratio.

The following statements relate B_i to the odds ratio:

- If B_i is positive, the odds ratio is greater than 1, which means that the odds of the event are increased (when attribute *i* increases).
- If B_i is negative, the odds ratio is less than 1, which means that the odds are decreased (when attribute *i* increases).
- If B_i is 0, the factor equals 1, and the odds are unchanged regardless of a change in attribute *i* (i.e. insignificance in the model).

3.2.2 Logistic regression model

For case of a single independent variable, the logistic regression model is:

$$\text{Probability of event} = \frac{1}{1+e^{-(B_0+B_1 x)}} \qquad (3.4)$$

$$\text{Ln}\left(\frac{P}{1-P}\right) = B_0+B_1X_1 \qquad (3.5)$$

- P is the probability of an event.
- B_0 and B_1 are coefficients estimated from the data.
- X is an independent variable.
- e is the base of the natural logarithm (2.718).
- Probability of an event is the predicted probability that an event occurs.
- Ln $\left(\frac{P}{1-P}\right)$ is known as the logit or log odds.

For a case with many independent variables, the logistic regression model is:

$$\text{Probability of event} = \frac{1}{1+e^{-Z}} \qquad (3.6)$$

$$\text{Ln}\left(\frac{P}{1-P}\right) = B_0+B_1X_1+B_2X_2+\ldots+B_nX_n \qquad (3.7)$$

- Z is a linear combination: $Z=B_0+B_1X_1+B_2X_2+\ldots+B_nX_n$
- n is the number of independent variables.

The values of Ln $(\frac{P}{1-P})$ are then transformed into probabilities by a logistic function. The function has the shape of an S (see Figure 3.1). With a S-Shaped curve, the probability approaches one as the log-odds become large and approaches zero as the log-odds become small. When the probability is near 0.5, the effect of a change on the log odds is large compared to the effect near 0 and 1. This S-shape shows that the curve can fit a dichotomous variable where most of the probability of outcomes scatters around 1 and 0. The horizontal axis shows the values of the independent variable, the log odds, and the vertical axis shows the probability of an outcome.

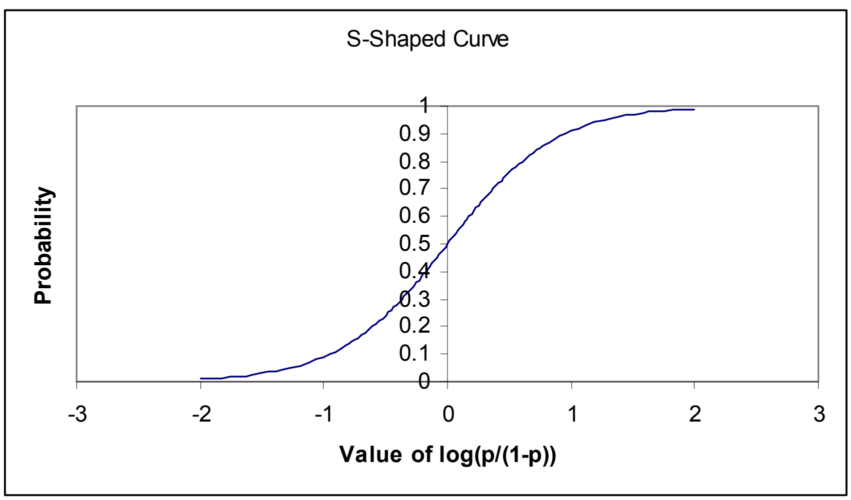

Figure 3.1 S-Shaped curve

Sample size of each independent variable is important calibrating the model. Research conducted by Peduzzi [44] did research on the number of events per variable in logistic regression analysis indicates that the overall sample size should be at least 10 times the number of independent variables to avoid an inaccurate estimation of regression coefficients. For this reason, a model cannot be calibrated for bus and train due to the small data set.

3.2.3 Estimation of the model fit

3.2.3.1 Maximum likelihood

Maximum likelihood is a statistical method to estimate the logistic regression model parameters (*B*). In the principle of maximum likelihood, the basic concept is to choose estimates of parameter values that maximize the likelihood function based on the probability density function for a given distribution of a sample [3]. The coefficients that make the observed result most likely are selected. The procedure begins with an expression for the likelihood of observing an event and characteristic in a given sample, such that an occurrence is 1 and a nonoccurrence is 0. However, this expression depends on unknown logistic regression parameters [43].

The parameters of the model are selected at random or by trial-and-error and the likelihood is computed. The selected parameters will have the result with the greatest likelihood computed. This estimation is called maximum likelihood because the parameters are chosen to maximize the likelihood of the sample data. Techniques to find the maximum likelihood come from general numerical analysis [12].

The estimation for maximum likelihood begins by constructing the likelihood function, and the computer picks some initial estimates of the parameters [12]. A binomial distribution presumes dichotomous dependent variables. The observations are assumed to be independent across the sample; then the likelihood is maximized. The likelihood of the data given these parameter estimates will be computed.

Maximizing log likelihood (LL) reflects how likely the odds are. The observed values of the dependent variable may be predicted from the observed values of the independent variables [25]. A Chi-square test is used to test the overall significance of the model. Based on the actual data, the model is assumed to have an accurate fit. The model Chi Square value is defined based on the likelihood of the actual data. It is convenient to use -2 to multiply the ln (natural logarithm) of this likelihood (-2LL), which is used to test the significance of the logistic model. The null hypothesis is that none of the independent variables are linearly related to the log odds of the dependent variable. Therefore, this is an overall model test which does not assure that every independent variable is significant [25]. A good model is one that results in a high likelihood of the observed results [22], which corresponds to a small value of -2LL.

3.2.3.2 Rho square: statistics

McFadden [38] suggests the following formation for ρ^2 for binary logit model.

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)} \tag{3.8}$$

The ρ^2 value lies between 0 and 1.

$L(0)$ is the value of the log likelihood function when all parameters are zero.

$L(\beta)$ is the value of the log likelihood function at its maximum with all the variables. $L(\beta)$ corresponds to a final state of information about the likelihood of alternatives when the information in V from equation (3.1) is fully known [42]. In order to obtain the improvement of ρ^2 based on the market share of mode choices, $L(C)$ is required. $L(C)$ is the log likelihood value at convergence; the equation follows:

$$L(C) = \sum_j Q_j \ln(\frac{Q_j}{Q}) \tag{3.9}$$

Where Q_j is the number of individuals choosing alternative j.

The Rho square for the improvement is:

$$\overline{\rho}^2 = 1 - \frac{L(\beta)}{L(C)} \tag{3.10}$$

The $\overline{\rho}^2$ value lies between 0 and 1. The $\overline{\rho}^2$ is better than the ρ^2 because $\overline{\rho}^2$ obtains $L(C)$ based on the market share of the alternative but ρ^2 obtains $L(0)$ based on the traveler have no knowledge of the alternative.

According to Hensher and Johnson [29], a ρ^2 for the logit model 0.2 is very good model and 0.4 is considered an extremely good fit.

3.2.4 The interpretation of coefficients

In logistic regression, instead of predicting the value of the dependent variable from the independent variables, the probability of the dependent variable occurring is predicted [22]. The change in the log odds can be addressed as one-unit change of the independent variable when all other independent variables are held constant [39]. With all other variables held constant, there is a constant increase of B in logit (P) for every 1-unit increase in X. For example, if B, a dummy variable, changes from 0 to 1 with other independent variables remaining the same, the log odds will increase by the coefficient of B. The resulting value from the equation is a probability value that varies between 0 and 1. A value close to zero means that dependent variable is very unlikely to have occurred, and a value close to 1 means that dependent variable is very likely to have occurred [22].

3.3 Multinomial logit model

The multinomial logit is preferred when more than two alternatives are available. The following equation shows the probability

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_{i=1}^{j} e^{V_{ij}}} \tag{3.11}$$

Where j is the set of available alternatives.

An important property of the logit model is independence from irrelevant alternatives (IIA). According to Train [55], the property of IIA can be stated as "*the ratio of the probabilities of any two alternatives is independent from the choice set*". Ben-Akiva and Lerman [8] give the definition as "*the ratio of the chosen probabilities of any two alternatives is entirely unaffected by the systematic utilities of any other alternatives.*"

3.3.1 Limitations of multinomial logit model

The IIA property of logit models is a limitation for some applications. The red bus and blue bus example can illustrate this limitation. First, consider a travel system that has two modes, car and bus service with red buses. They both have the same market shares.

$$P_{car} = P_{red\ bus} = 1/2$$

Then, assume half of the bus fleet changes the color to blue. If the system is considered as a three-mode system with the multinomial logit model, the market shares will be:

$P_{car} = P_{red\ bus} = P_{blue\ bus} = 1/3$ as shown in the Figure 3.2

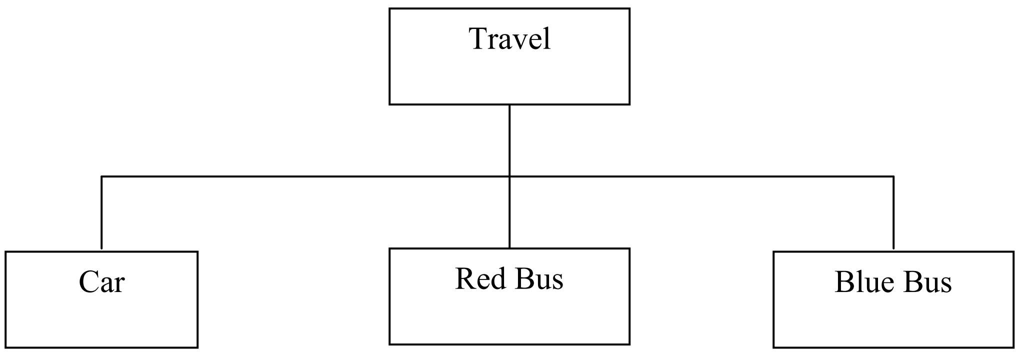

Figure 3.2 Multinomial logit decisions for car, red bus, and blue bus.

This idea will increase the market shares for bus mode from 1/2 to 2/3; however, this idea is unrealistic because the red bus blue bus alternatives are not independent. According to Ortuzar and Willumsen [42], people will consider car or public transit before selecting the red or blue bus. This decision making process is depicted in Figure 3.3.

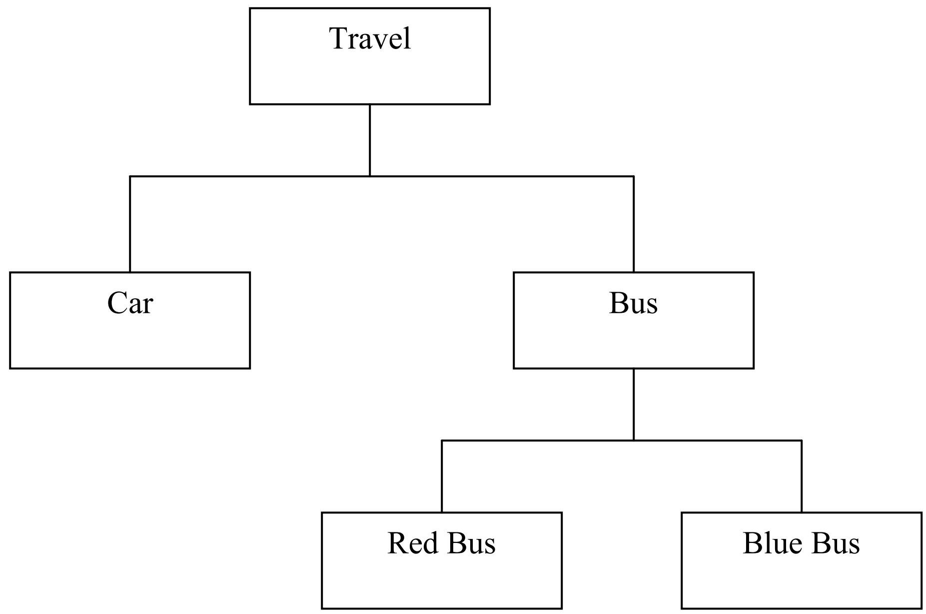

Figure 3.3 Nested logit decision for car, red bus, and blue bus

Using this structure, the correct probabilities for car, red bus, and blue bus are 1/2, 1/4, and 1/4, respectively. If there are reasons to believe that the alternatives are not completely independent, then a nested logit formulation is preferred.

3.4 Nested logit

Ben-Akiva [9] derived the nested logit model as an extension of the multinomial logit model to capture the correlation of alternatives when alternatives are not independent. In nested logit, the composite of the utility function on the lower level can be represented as a variable on the upper level called estimated maximized utility function (EMU) [42].

3.4.1 Nested logit in practice

1. Group the correlated (or more similar) alternatives in nests and each nest is represented by a composite alternative.
2. Estimate the logit model for the lowest level.
3. Introduce the lower nests in their upper levels by the utility of the composite alternative, which has two components, the EMU of the lower nest option and the vector Z of attributes, which are common to all members of the nest. According to Ortuzar and Willumsen [42], the EMU portion has the following expression:

$$EMU = \ln \sum_j \exp(W_j) \tag{3.12}$$

   Here, W_j is the utility of alternative A_j in the lower level. Therefore, the composite utility of the nest is $V_I = \phi EMU + \alpha Z$, where ϕ and α are parameters to be estimated.

4. Then, estimate a logit model for the higher nest that contains the composite alternatives representing lower nest(s) and the options, which are non-nested at that level.
5. Finally, the probability that travelers select an alternative may be computed as the product of the marginal probability of choosing the composite alternative in the higher nest and the conditional probability of choosing an option in the lower nest.

$$P_{\text{Personal Vehicle}} = P_{(\text{Personal Vehicle})} \tag{3.13}$$

$$P_{Air} = P_{(Air/PublicCarrier)}P_{(PublicCarrier)} \quad (3.14)$$

$$= P_{(Air/PublicCarrier)}(1 - P_{(Personal\ Vehicle)})$$

$$P_{Ground} = P_{(Ground/PublicCarrier)}P_{(PublicCarrier)} \quad (3.15)$$

$$= P(1 - P_{(Air/PublicCarrier)})(1 - P_{(Personal\ Vehicle)})$$

6. The important feature of the model concerns acceptable values for ϕ, the coefficient of the expected maximum utility of the nest. Ortuzar and Willumsen [42] suggest that ϕ must satisfy:

$$0 < \phi \leq 1 \quad (3.16)$$

If $\phi < 0$, an increase in the utility of an alternative in the nest will increase the value of EMU, which reduces the probability of selecting the nest. If $\phi = 0$, an increase of the utility would not effect the nest probability; therefore, the EMU would not affect the choice between air and ground transport. If $\phi = 1$, the nest will collapse to the multinomial logit case. If $\phi > 1$, it will increase the probability for selection on the level and also the probability of the alternatives in the nest.

In this research, this means that long distance mode choices consist of personal vehicle, air, and ground transport mode may not be well explained using a multinomial logit model because travel by personal vehicle has more privacy and does not follow a schedule during the journey. As a result, it will likely give an incorrect estimation and prediction for each mode. The nested logit model is considered to be a preferable structure in this research. The upper level considers the decision between personal vehicle and public carrier, and the lower level makes the choice of public carrier between air and ground transport.

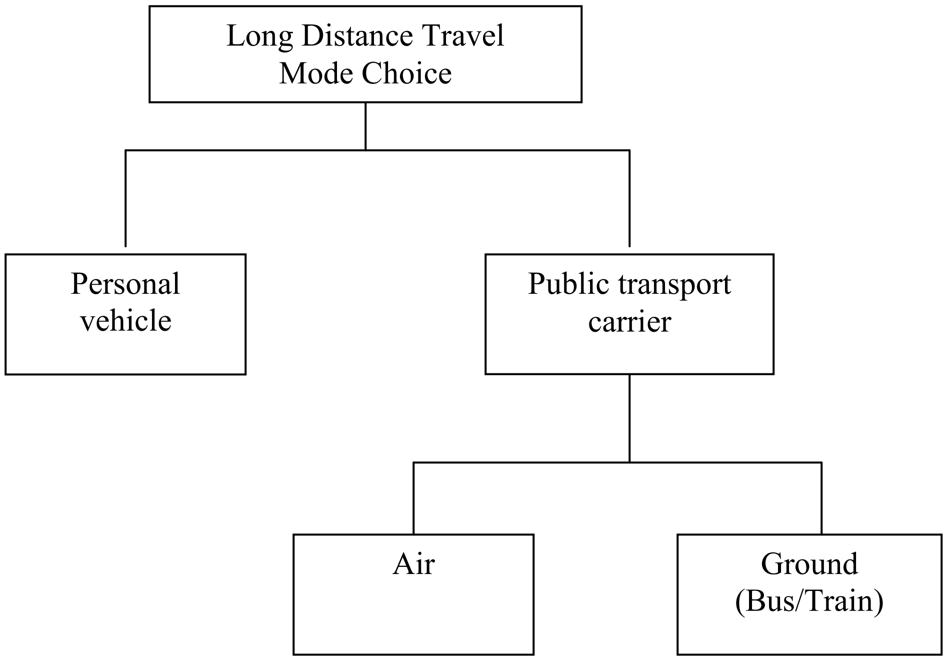

Figure 3.4 Nested logit decisions for long distance

3.4.2 Goodness of fit measure

The likelihood ratio index (ρ^2) is the value for goodness of fit measure to compare different specifications of the utility function.

3.4.2.1 Rho square: statistics

Suggested by McFadden [38] for nested logit, ρ^2, the following equation is used:

$$\rho^2 = 1 - \frac{L(\beta)_1 + L(\beta)_2 + \ldots\ldots\ldots + L(\beta)_j}{L(0)_1 + L(0)_2 + \ldots\ldots\ldots + L(0)_j} \tag{3.17}$$

In the nested logit model, $L(0)$ and $L(\beta)$ of the lower levels and the interested level are used to calculate ρ^2. The improved rho square is:

$$\bar{\rho}^2 = 1 - \frac{L(\beta)_1 + L(\beta)_2 + \dots\dots\dots + L(\beta)_j}{L(C)_1 + L(C)_2 + \dots\dots\dots + L(C)_j} \tag{3.18}$$

Where $L(C)$ is from the lower levels and the interested level of the nested logit model.

3.4.2.2 T-statistics

T-statistics help test whether a particular coefficient is statistically significantly different from zero. A t-statistic of 1.65 or -1.65 indicates that the variable has significance in the model at a 90 percent confidence level. A value 2.3 or -2.3 indicates that the variable has significance in the model at a 99 percent confidence level. All variables in the model should have t-statistic values that are 1.65 or greater. Some variables may be excluded from the model due to insignificance.

3.5 Result analysis

3.5.1 Analysis of the results binary logit models

The results from the binary logit model coefficient estimation are shown in Table 3.1 for three different long distance travel purposes.

Table 3.1 Binary results

Personal Vehicle(0)/Air(1)

Value Description	Business		Person Business		Pleasure	
	B	T-Stat	B	T-Stat	B	T-Stat
Constant	-1.264	-2.778	-3.350	-8.656	-6.396	-6.097
Nights away on travel period trip	0.056	2.240				
Number of HH members on travel period trip	-1.721	-5.199	-0.409	-2.223	-0.359	-5.056
Age of respondent						
Route distance: origin to destination	0.006	21.516	0.005	14.031	0.004	27.903
Number of vehicles in HH						
Race of HH respondent						
White			-2.275	-3.516		
African American, Black						
Asian Only					3.165	3.246
Other						
Household in urban or rural area						
Urban	-1.390	-6.915	-1.939	-3.558	-1.228	-5.293
Rural						
Occupational category						
Sales or Service						
Clerical or administrative support						
Manufacturing, construction						
Other						
Trip includes weekend						
Short weekend						
Long weekend	-0.956	-3.502				
Not weekend trip						
Total income all HH members						
< $20,000					-0.446	-1.697
$20,000-$44,999						
≥ $45000						
Number of Observation	5742		1292		6224	
-2LL only constant	3803.70		616.23		3261.42	
-2LL with variable	1644.12		303.71		1481.41	
ρ^2	0.567		0.507		0.546	
$\bar{\rho}^2$	0.566		0.506		0.545	
(Calibration) Percent Correct	95.30%		95.90%		95.90%	
(Validation) Percent Correct	94.56%		95.66%		93.76%	
Validation Texas Number of Observation	252		661		493	
Percent Correct (zero for missing variable)	89.68%		93.64%		96.75%	
Percent Correct (average for missing variable)	95.23%		93.64%		96.34%	
Validation Wisconsin Number of Observation	268		59		405	
Percent Correct	94.77%		98.30%		93.82%	

3.5.1.1 Binary logit for the business purpose

From Table 3.1, the variables included in the model are number of nights away on the trip, number of household members on the trip, route distance from origin to destination, household in urban area, and long weekend trip period.

- Number of nights away on the trip will increase the probability to travel by the air mode because travelers may need to save travel time and they will have more time for business activities.
- A longer travel distance will increase the probability to travel by the air mode. Travelers prefer air mode when they travel long distances because they can save travel time and they will not become fatigued if they do not have to drive.
- The number of household members on the trip will increase the probability of traveling by personal vehicle. This variable shows that some business trip travelers will take family members along on the trip, but most likely they will have to pay the extra cost for them. Therefore, if travelers travel with their family, the personal vehicle is preferable to the air mode because it reduces cost, provides more privacy and schedule flexibility. This variable can have a tremendous impact on the mode choice because each family member can counter act approximately 300 miles of travel distance.
- People who live in urban areas are more likely to travel by personal vehicle. This may convenient for travelers who live in an urban area

because they may be able to travel over fifty miles within the same urban area or have more business opportunities within a reasonable driving distance. Also, they may need to have a vehicle at the destination.

- People who travel for a long weekend will prefer to travel by personal vehicle because they want to have a vehicle to use at the destination. Furthermore, if they combine a vacation with the business trip, a personal vehicle makes it possible to bring along family members at no additional travel cost.

The ρ^2 of 0.567 and $\overline{\rho}^2$ of 0.566 indicate that the model is extremely good. The percent estimation of the model is 95.30 percent correct. For validation, the percent correct for the NHTS data is 94.56. The percent correct for the Texas data when zero is substituted for the missing variables (number of nights away on the trip, household in urban or rural area and trip includes a weekend) is 89.68 percent. For the Texas data with average values substituted for missing variables, the percent correct is 95.23 percent. Even though the average values substituted method produces a higher percentage of correct classification than the zero substituted method, both of them are a presumption method and they do not represent the actual travel behavior. The percent correct for the Wisconsin data is 94.77 percent. The insignificant variables are age, number of vehicles in household, race, household in rural area, occupation, short and non weekend trip, and income.

3.5.1.2 Binary logit for the personal business purpose

From Table 3.1, the variables included in the model are number of household members on the trip, route distance from origin to destination, race: white, and household in urban area.

- A higher number of household members on the trip will increase the probability to traveling by personal vehicle because the cost of travel by the air mode of higher than personal vehicle, especially when many household members travel together. Number of people on the trip is not as important for this mode choice; when compared to travel distance, each family member only accounts for approximately eighty miles.
- A longer travel distance will affect the mode choice decision. The sign for this variable is positive; therefore, a longer travel distance will increase the probability of traveling by air mode. Travelers prefer the air mode because the travel time may be greatly reduced, which will give them extra time for personal business.
- White people prefer to travel by personal vehicle, which may be affected by cultural differences where the appropriateness of traveling alone and safety risks associated with the travel affect the mode choice decision. White travelers may feel comfortable traveling by personal vehicle and ground mode due to the widespread population other white people throughout the USA.

- People who live in urban areas are more likely to select a personal vehicle for travel for the personal business purpose; as previously mentioned, a traveler who lives in an urban area has more alternatives (activities and routes) available than rural residents.

The ρ^2 of 0.507 and $\overline{\rho}^2$ of 506 indicate that the model is a very good model. The percent estimation for the model is 95.90 percent correct. For validation, the percent correct for the NHTS data is 95.66. The percent correct for the Texas data when zero is substituted for the missing variables (households in an urban or rural area) is 93.64 percent. For the Texas data with average values substituted for missing variables, the percent correct is 93.64 percent. The percent correct for the Wisconsin data is 98.30 percent. Insignificant variables are nights away on the trip, age, number of vehicles in household, race: African American, Asian, and other, household in rural area, occupation, trip includes weekend, and income.

3.5.1.3 Binary logit for the pleasure purpose

From Table 3.1, the variables included in the model are the number of household members on the trip, route distance, race: Asian, household in urban area, and below $20,000 for household income.

- A larger number of household members on the trip will increase the probability of traveling by personal vehicle because the cost of traveling by the air mode is high when many household members are traveling.
- The route distance variable shows that an increase in the travel distance will increase the probability of traveling by the air mode. Travel by air

mode greatly reduces travel time. The pleasure trips overall have a strong tendency towards personal vehicle, as evidenced by the constant. In fact, the travel distance must reach 1600 miles to cancel out this initial performance.

- Asian people prefer to travel by the air mode; this may be due to culture, comfort and safety.
- People who live in an urban area prefer to travel by personal vehicle because they have more access to activities and routes. Furthermore, most activities must be accessed using a personal vehicle even if another mode is used to reduce total travel time.
- Lower income people prefer to travel by personal vehicle more than higher income people because the cost to travel using a personal vehicle is lower than the air mode.

The ρ^2 of 0.546 and $\bar{\rho}^2$ of 0.545 indicate that the model is once again an extremely good model. The percent estimation for the model is 95.90 percent correct. For validation, the percent correct for the NHTS data is 93.76. The percent correct for the Texas data when zero is substituted for the missing variables (household in urban or rural area) is 96.75 percent. For the Texas data with average values substituted for missing variables, the percent correct is 96.34 percent. The percent correct for the Wisconsin data is 93.82 percent. The insignificant variables are nights away on the trip, age, number of vehicles in household, race: white, African Americans, and other, household in rural area, occupation, trip includes weekend, and the income below $20,000 and between $20,000 and $45,000.

3.5.1.4 Binary logit summary

In these models, the constant indicates an underlying preference for the personal vehicle based on conditions not captured by the variables included in the model. This preference is smallest for the business purpose and largest for the pleasure purpose. The probability of selecting air mode increases as the route distance increases. The probability for travel by personal vehicle increases when the number of household members on the trip increases. People who live in urban areas tend to select the personal vehicle mode over the air mode. For pleasure travel, Asian prefers to travel by the air mode. For the business purpose, race is insignificant due to the requirements of business travelers and the likely compensation provided by the employer irrespective of employee race. The business travelers seem to prefer to travel by personal vehicle during long weekend trips for business. People with household incomes lower than $20,000 prefer to travel by personal vehicle for the pleasure purpose; however, the income effect is not significant for the business purpose and personal business purpose. The Texas dataset with average for missing variables provides a higher percent correct than the Texas dataset with zero substituted for missing variables.

3.5.2 Analysis of the results nested logit model level 1

Nested logit models for each trip purpose for the lower level (level 1) are shown in Table 3.2. At this level, the maximum utility functions for the ground and air modes are obtained. Logit model from this level provides the utility function for the EMU in the upper level (level 2).

Table 3.2 The results of the model at level 1

Level 1 Ground (0)/Air (1)

Value Description	Business		Person Business		Pleasure	
	B	T-Stat	B	T-Stat	B	T-Stat
Constant	-0.979	-2.458	-4.629	-3.516	-2.206	-6.661
Nights away on travel period trip	0.287	3.302			0.225	1.927
Number of HH members on travel period trip						
Age of respondent			0.048	2.026		
Route distance: origin to destination	0.002	6.263	0.009	3.915	0.006	6.055
Number of vehicles in HH						
Race of HH respondent						
White						
African American, Black						
Asian Only						
Other						
Household in urban or rural area						
Urban						
Rural						
Occupational category						
Sales or Service						
Clerical or administrative support						
Manufacturing, construction						
Other						
Trip includes weekend						
Short weekend	0.765	2.052				
Long weekend						
Not weekend trip						
Total income all HH members						
< $20,000						
$20,000-$44,999						
≥ $45000						
Number of Observation	715		100		549	
-2LL only constant	634.10		114.63		489.93	
-2LL with variable	474.85		46.69		212.75	
ρ^2	0.251		0.593		0.566	
$\bar{\rho}^2$	0.250		0.592		0.565	
(Calibration) Percent Correct	88.88%		93.00%		92.90%	
(Validation) Percent Correct	88.82%		93.54%		94.89%	
Validation Texas Number of Observation	33		64		25	
Percent Correct (zero for missing variable)	81.81%		90.62%		100.00%	
Percent Correct (average for missing variable)	100.00%		100.00%		100.00%	
Validation Wisconsin Number of Observation	13		4		34	
Percent Correct	92.30%		75.00%		97.05%	

3.5.2.1 Nested logit for business purpose

From Table 3.2, the variables included in the model are number of nights away on the trip, route distance, and short weekend.

- Number of nights away on the trip appears to increase probability of traveling by the air mode as the number of nights away increase; as expected, travelers prefer to spend more time on business activities than travel time. The difficulties associated with accessing air travel, such as terminal and security delays, may also be mitigated by reducing their temporal proximity.
- The route distance variable shows that the distance increases the probability of traveling by the air mode because the travel time for most long distance trips is is shorter for air compared with automobile. As a result, they can save time for business activities.
- For the short weekend variable, as expected, traveler travels during short weekend prefer the air mode. This may because the traveler prefers to have short travel time and more time for business activities.

The ρ^2 of 0.251 and $\bar{\rho}^2$ of 0.250 indicate that the model is a good model. The percent estimation of the model is 88.88 percent correct. For validation, the percent correct for the NHTS is 88.82. The percent correct for the Texas data with a value of zero assigned for the missing variables (the number of nights away on the trip and short weekend) is 81.81 percent. For the Texas data with an average value assigned for missing variables, the percent correct is one hundred percent. The percent correct for the Wisconsin data is 92.30 percent. For the Wisconsin data, there is no lack of data for the model. The insignificant variables are number of household members on the trip, age, number of vehicles in household, race, household in urban or rural area, occupation, long and non weekend trip, and income.

3.5.2.2 Nested logit for personal business purpose

From Table 3.2, the variables included in the model are age and route distance.

- The probability of traveling by the air mode increases as the age increases. Older travelers may choose to travel this faster and more comfortable mode because they fatigue easier than younger travelers.
- For the route distance variable, as the distance increases, the probability of traveling by the air mode increases due to the travel time savings.

The ρ^2 of 0.593 and $\bar{\rho}^2$ of 0.592 indicate that the model is an extremely good model. The percent correct for estimation of the model is 93.00 percent. For validation, the percent correct for the NHTS data is 93.54. The percent correct for the Texas data with a value of zero given for the missing variables is 90.62 percent while the percent correct when an average value is assigned for the missing variables is one hundred percent. The percent correct for the Wisconsin data is 75.00 percent using all independent variables. The insignificant variables are nights away on the trip, number of household members on the trip, number of vehicles in household, race, household in rural area, occupation, trip includes weekend, and income.

3.5.2.3 Nested logit for pleasure purpose

From Table 3.2, the significant variables in the model are nights away on the trip and route distance.

- The probability of traveling by the air mode increases as the number of nights away on the trip increases. The trip length may be a partial determination because travelers may surrogate for income to spend more time at the destination than traveling.
- The route distance variable shows that as the distance increases, the probability of traveling by air mode increases in order to reduce travel time.

The ρ^2 of 0.566 and $\overline{\rho}^2$ of 0.565 indicate that the model is an extremely good model. The percent estimation of the model is 92.90 percent correct. For validation, the percent correct for the NHTS data is 94.89. The percent correct for the Texas data when zero is substituted for the missing variables (the number of nights away on the trip) is 100 percent. For the Texas data with average value substituted for the missing variables, the percent correct is one hundred percent. The percent correct for the Wisconsin data is 97.05 percent using all significant variables. The insignificant variables are number of household members on the trip, age, number of vehicles in household, race, household in rural area, occupation, trip includes weekend, and income.

3.5.2.4 Nested logit level 1 summary

In this level, the constant captures the variation not accounted for independent by the variables; the constant also indicates any preference given the absence of all predictor variables. The probability to select air mode will increase as the number of night away on the trip, age, and route distance increase. The impact of the route distance is highest for the personal business purpose, but the distance where the trip distances balances out the effect of the constant is approximately 500 miles for both business and personal business purposes. For the pleasure purpose, this distance is closer to 350 miles. The length of the trip has a lager impact for business purpose trips than pleasure purpose trips where each night for the business trip has the same impact as 150 miles of travel distance and for the pleasure purpose the equivalent distance is about thirty-five miles. The impact of age on personal business purpose affect for five miles per year. The short weekend has impact for business purpose trip as 350 miles. The percent correct for validation of this level is 100.00% for the pleasure purpose (Texas data with a zero value assigned for the missing variable), 100.00% for all three purposes of the Texas data with an average value given for the missing variable and 75.00% for Wisconsin. These may because of small dataset. The larger data set can provide more accuracy on validation.

3.5.3 Analysis of the results nested logit model level 2

The nested logit model analyses for each trip purpose for the upper level (level 2) are shown in Table 3.3. At this level, the EMU values are obtained from the lower level (Table 3.2).

Table 3.3 The results of the model at level 2

Level2 Personal Vehicle(0)/Public(1)

Value Description	Business		Person Business		Pleasure	
	B	T-Stat	B	T-Stat	B	T-Stat
Constant	-1.876	-6.902	-0.683	-1.816	-2.003	-2.770
EMU	0.134	1.895	0.344	9.862	0.478	25.414
Nights away on travel period trip						
Number of HH members on travel period trip			-0.481	-3.090	-0.484	-7.504
Age of respondent						
Route distance: origin to destination	0.005	15.281				
Number of vehicles in HH					-0.124	-2.230
Race of HH respondent						
White						
African American, Black						
Asian Only					1.499	2.277
Other						
Household in urban or rural area						
Urban			-0.932	-2.832	-0.665	-3.871
Rural						
Occupational category						
Sales or Service	-1.207	-4.901				
Clerical or administrative support						
Manufacturing, construction						
Other	-2.013	-9.058				
Trip includes weekend						
Short weekend						
Long weekend			-1.083	-3.588	-0.610	-4.540
Not weekend trip						
Total income all HH members						
< $20,000					-0.543	-2.272
$20,000-$44,999						
≥ $45000						
Number of Observation	5860		1318		6311	
-2LL only constant	4349.85		708.95		3734.05	
-2LL with variable	2211.99		49189		2116.06	
ρ^2	0.491		0.306		0.433	
$\bar{\rho}^2$	0.490		0.305		0.432	
(Calibration) Percent Correct	93.80%		93.60%		94.40%	
(Validation) Percent Correct	92.49%		93.00%		93.47%	
Validation Texas Number of Observation	254		683		499	
Percent Correct (zero for missing variable)	92.12%		92.24%		95.39%	
Percent Correct (average for missing variable)	99.21%		96.33%		95.79%	
Validation Wisconsin Number of Observation	270		62		410	
Percent Correct	94.07%		93.54%		93.65%	
Nested Logit Model						
ρ^2	0.461		0.346		0.448	
$\bar{\rho}^2$	0.460		0.345		0.447	

3.5.3.1 Nested logit for business purpose

From Table 3.3, the variables included in the model are route distance, and occupation (sales or service and other).

- The EMU is 0.134 with t-state 1.895. EMU is between 0 and 1. This means that the nest is valid for air and ground in the model with almost 95 percent confidence.
- For route distance variable, it shows that the distance will increase the probability of traveling by public mode and less likely to travel by personal vehicle. It is better to travel on public carrier than drive personal vehicle for long distance. A longer distance for the trip will cause more exhaustion for travelers who travel by personal vehicle than travel by public carrier. This variable also appears in the lower level, which increase its impact.
- The occupation category (sales or service and other) shows that travelers who work in sales or service and the other category tend to travel by personal vehicle rather than public carrier. The reason for the sales or service category is probably related to the need of the career for flexibility in these careers to sell merchandise and to service customer, and for the other category, which may represent a traveler in government service, professional career, or student in university, the propensity of

traveling by personal vehicle may be increased due to limited available funds or institutional guidelines.

The ρ^2 of 0.491 and $\overline{\rho}^2$ of 490 indicate that the model is a good model. The percent estimation of the model is 93.80 percent correct. For validation, the percent correct for the NHTS data is 92.49. The percent correct for the Texas data with a value of zero assigned for the missing variables is 92.12 percent. For the Texas data with an average value assigned for the missing variables, the percent correct is 99.21 percent. The percent correct for the Wisconsin data is 94.07 percent using all independent variables. The insignificant variables are nights away on the trip, number of household members on the trip, age, number of vehicles in household, race, household in urban or rural area, occupation: clerical, manufacturing and other, trip includes weekend, and income.

3.5.3.2 Nested logit for personal business purpose

From Table 3.3, the variables included in the model are number of household members on the trip, household located in urban area, and long weekend trip.

- The EMU is 0.344 with t-stat 9.862. The EMU is between 0 and 1. It shows that the nest for air and ground is valid in the model with 99 percent confidence.
- The more number of household members on the trip will increase probability of traveling by personal vehicle and less likely to travel by public mode. This variable will increase the cost of travel as number of number of household members on the trip increase. Traveling with

family, travelers might need flexibility on schedule and privacy during travel.

- If travelers live in an urban area, travelers appear more likely to travel by personal vehicle instead of public carrier; this may convenient for traveler who lives in urban area which has many alternatives to choose. Also, they may need to have a vehicle at the destination.
- Travelers who travel during long weekend are more likely to select personal vehicle and less likely to select public mode. In personal business purpose, travelers can have vehicle at destination to use with privacy and schedule flexibility.

The ρ^2 of 0.306 and $\overline{\rho}^2$ of 0.305 indicate that the model is a good model. The percent estimation of the model is 93.60 percent correct. For validation, the percent correct for the NHTS data is 93.00. The percent correct for the Texas data when zero is substituted for the missing variables (the household located in urban area and long weekend) is 92.24 percent. For the Texas data with an average given for the missing variables, the percent correct is 96.33 percent. The percent correct for the Wisconsin data is 93.54 percent using all independent variables. The insignificant variables are nights away on the trip, age, route distance, number of vehicles in household, race, household in rural area, occupation, short and non weekend, and income.

3.5.3.3 Nested logit for pleasure purpose

From Table 3.3, the variables included in the model are number of household members on travel period trip, number of vehicle in household, race (Asian), household located in urban area, long weekend trip, and below $20,000 household income.

- EMU is 0.478 with t-state 25.414. EMU is between 0 and 1. This means that the nest for air and ground is valid in the model with 99 percent confidence.
- The more number of household members on the trip will increase probability of traveling by personal vehicle mode and less likely to travel by public carrier. Cost of travel will increase as number of household members on travel period trip. Schedule flexibility and privacy are determined to select mode choices between personal vehicle and public carrier.
- Number of vehicles in household variable shows that travelers can select which vehicle properly based on the purpose such that if they have a pleasure trip and they already have SUV or minivan, they may select to travel my personal vehicle instead of travel by other modes.
- For race of household variable, Asian people prefer to travel by public mode instead of personal vehicle this may because of culture, comfortable and safety as mention above.
- For households located in an urban area, travelers appear more likely to travel by personal vehicle instead of public carrier; a traveler who lives

in urban area has more alternatives (activities and routes) than rural area residents.

- Travelers who travel during long weekend are more likely to select personal vehicle and less likely to select public carrier. Travelers may still have convenient transportation at destination.
- Below $20,000 household income people are more likely to select personal vehicle to travel. Personal vehicle travel cost is cheap and it is convenient, privacy, and flexible for people also many household members can participate on the trip.

The ρ^2 of 0.433 and $\overline{\rho}^2$ of 0.432 indicate that the model is an extremely good model. The percent estimation of the model is 94.40 percent correct. For validation, the percent correct for the NHTS data is 93.47. The percent correct for the Texas data with a value zero given for the missing variables (the household located in urban area and long weekend) is 95.39 percent. For the Texas data with an average substituted for the missing variables, the percent correct is 95.79 percent. The percent correct for the Wisconsin data is 93.65 percent using all independent variables. The insignificant variables are nights away on the trip, age, route distance, race: white, African Americans and other, household in rural area, occupation, short and non weekend trip, and income above $45,000 and income range from $20,000 to $45,000.

3.5.3.4 Nested logit level 2 summary

In this level, the constant captures the variation not accounted for independent by the variables; the constant also indicates any preference given the absence of all predictor variables. The EMU in the model are 0.134, 0.344, and 0.478 which are between 0 and 1 however; EMU for business, personal business, and pleasure purpose are significance at 95 percent and 99 percent level of confidence. The more number of household members on the trip increase probability of traveling by personal vehicle for personal business and pleasure purposes. In this level, route distance has impact only on business purpose with the balance out of the constant is approximately 370 miles. Also, number of vehicle in household has impact only on pleasure purpose. For pleasure purpose, race (Asian) is the only significant race variable on the model that Asian traveler prefer to travel by public carrier. Long weekend trip increases probability of traveling by personal vehicle for personal business and pleasure purposes. The below $20,000 household income people prefer to travel by personal vehicle but income variables are not significant for business purpose and personal business purpose. The Likelihood ratio index (ρ^2 and $\overline{\rho}^2$) of each nested logit model are extremely good as show on the Table 3.3. ρ^2 for business trip purpose is 0.461. ρ^2 for personal business trip is 0.346. ρ^2 for pleasure is 0.448. $\overline{\rho}^2$ for the business trip purpose mode is 0.460. $\overline{\rho}^2$ for the personal business trip model is 0.345, and $\overline{\rho}^2$ for the pleasure trip model is 0.447. According to $\rho^2, \overline{\rho}^2$, and percent correct on NHTS, Texas, and Wisconsin, all of those nested models are extremely good models.

3.6 Comparison between binary logit and nested logit

According to results based on percent correct, it show that binary logit for personal vehicle versus air mode give more accuracy on each purpose than nested logit for personal vehicle, air mode, and ground carrier. For ρ^2, again, binary logit show higher ρ^2 than nested logit. However, binary logit and nested logit model are very good model, although binary logit give the higher percent correct and ρ^2. It depends on how many mode choices are considered. Considering mode choice between personal vehicle and air mode, binary logit is suitable. Considering mode choice among personal vehicle, air mode, and ground mode, nested logit is suitable.

3.7 Distance boundary from models

Based on the Binary logit and Nested logit models, the distance boundary to determine which mode that travelers will prefer are obtained; since this boundary value changes based on other characteristics, a range of possible value between the maximum and minimum boundary distances is determined. If the route distance is longer than the maximum distance, a traveler prefers to travel using the mode that the sign of the route distance variable indicates, and if the route distance is shorter than minimum distance, traveler prefers to travel with the other mode.

3.7.1 Binary logit (personal vehicle versus air)

Table 3.4 show the maximum and minimum distance boundary derived from binary logit model for each three purposes.

Table 3.4 Distance boundary: binary logit (personal vehicle versus air)

	Business	Personal Business		Pleasure	
		White	Other	Asian	Other
Max (miles)	850	1600	1150	1300	2100
Min (miles)	500	1200	750	900	1700

In order to find the values for the business purpose, the number of nights away on the trip and other variables are set to zero, but the number of household members on the trip is set to one, as a result, 500 miles is the minimum preference boundary for a traveler to prefer the air mode. For the maximum boundary, the number of nights away on the trip and number of household members on travel period trip are still set to zero and one, respectively. The maximum preference boundary is 850 miles for a traveler that lives in an urban area taking a long weekend trip. The range between 850 to 500 miles is the range to consider which mode to travel but if traveler travel with the distance less than 500 miles, the more likely the traveler will travel by personal vehicle. If the traveler travel with the distance more than 850 miles, there are more likely for travel to travel with air mode. However, the number of nights away on the trip will decrease the boundary with an impact of approximately nine miles per night, but the number of household members on the trip will increase the boundary with an impact of approximately 280 miles per member.

In order to find the values for the personal business purpose, the number of household members on the trip is set to one. For this purpose, two separate boundary distances are calculated based on the race of the travelers.

- For White travelers, 1,600 is the maximum preference boundary when the traveler lives in an urban area, while 1,200 is the minimum preference boundary with hold all variables are zero.
- For other races, 1,150 is the maximum boundary when the traveler lives in an urban area, but 750 is the minimum preference boundary when all variables are zero.

For the personal business purpose, increasing the number of household members on the trip will increase the preference boundary with an impact of approximately 80 miles per member. A trip by a white person will increase the preference boundary by approximately 455 miles. If the household located in an urban area, the preference boundary increases by approximately 380 miles.

For the pleasure purpose, the number of household members on the trip is set to one. Once again, the boundary values are based on the race of the travelers.

- For Asian travelers, 1,300 is the maximum preference boundary when traveler lives in an urban area with a household income below $20,000. When all other variables are held to zero the minimum preference boundary is 900 miles.
- For other races, 2,100 is the maximum preference boundary when a traveler lives in an urban area with a household income below $20,000. The minimum preference boundary of 1,700 miles occurs when other variables are held to zero.

Increasing the number of household members on the trip will increase the boundary values by approximately ninety miles per member. If the household is located in an urban area will increase the boundary values by approximately 300 miles. A household income below $20,000 will increase the boundary values by approximately 110 miles. However; an Asian traveler decreases the boundary values by approximately 790 miles.

3.7.2 Nested logit level 1 (air versus ground)

Table 3.5 show the maximum and minimum distance boundary derived from nested logit model (level 1) for each three purposes.

Table 3.5 Distance boundary: nested logit level 1 (air versus ground)

Level 1	Business	Personal Business	Pleasure
Max (miles)	500	470	380
Min (miles)	105	Age.	Nights

Note: The minimum boundary value for personal business and pleasure trips is dependent on other characteristics:

- Age: age of traveler.
- Nights: number of nights away on the trip.

In order to determine the performance boundary value for the business purpose; the number of nights away on the trip and short weekend variables are set to zero; the resulting value is approximately 500 miles for the maximum preference boundary where the traveler's performance change to the air mode. For the minimum preference boundary, the number of nights away on the trip is set to zero but the short weekend is set to one; the resulting minimum preference distance is 105 miles. For all trips, of less than 105 miles, travelers definitely have a preference for ground mode, and for all trips of more than 500 miles, travelers definitely prefer the air mode. However, the number of nights away on the trip will decrease the preference boundaries by thirty seven miles per night.

Assessing the preference boundary for the personal business purpose requires setting the age of the traveler to eighteen years old. With this age of traveler, the maximum the preference boundary is 470 miles while the minimum preference boundary depends on the age of traveler such that it decreases five miles per year of age greater than eighteen. If the trip is less than 470 miles, the traveler is more likely to travel by the ground mode and if the trip is more than 470 miles, the traveler is more likely to travel by the air mode. However, as the age increases, the preference boundary will decrease by five miles per year.

The maximum preference boundary for pleasure trips is approximately 380 miles while the minimum preference boundary depends on the number of nights on the trip because each night reduces the boundary by thirty-seven miles. Once again, a distance of 380 miles or greater exceeds the boundary and indicates a preference for air travel. If the trip distance is less than the boundary, the traveler prefers a ground mode.

3.7.3 Nested logit level 2 (personal vehicle versus public)

Table 3.6 show the maximum and minimum distance boundary derived from nested logit model (level 2) for each three purposes.

Table 3.6 Distance boundary: nested logit level 2 (personal vehicle versus public)

Level 2	Business	Personal business	Pleasure	
			Asian	Others
Max (miles)	760	1600	1400	2000
Min (miles)	360	900	740	1280

In order to determine the performance boundary value for the business purpose; number of nights away on travel period trip and all occupational category variables are set to zero but short weekend variable is set to one; the resulting value is approximately 360 miles is the minimum preference boundary where the traveler's performance change to the public mode. For the maximum preference boundary, number of nights away on the trip, short weekend variable, and occupation 1 (sales or service) are set to zero, but the occupation 4 (others) is set to one; the resulting maximum preference distance is 760 miles. For all trips of less than 360 miles, travelers definitely have a preference for personal vehicle, and for all trips of more than 760 miles, travelers definitely prefer the public mode. Number of nights away on the trip increases the boundary value by approximately seven miles per night. Occupation 1 (sales or service) increases the boundary value by approximately 230 miles. Occupation 4 (Others) increases the boundary value by approximately 380 miles. However; short weekend variable decrease the boundary by approximately nineteen miles.

In order to determine the performance boundary value for the personal business purpose: Age of traveler is set to eighteen years old, number of household members on the trip (the traveler), household located in an urban area, and long weekend trip are set to one; the result maximum preference distance is 1,600. For minimum preference boundary; age of traveler and number of household members are still the same, eighteen and one, respectively, but household located in an urban area and long weekend trip are set to one. The resulting value is approximately 900 miles for minimum preference boundary. The trip is less than 900 miles; the traveler is more likely to travel by personal vehicle. If the trip is more than 1,600 miles, the traveler is more likely to travel with public mode. A household member on the trip increases the boundary value approximately 175 miles per person. Household located in an urban area increases the boundary value approximately 340 miles. A long weekend trip increases the boundary value approximately 400 miles. However; as the age increases, the preference boundary will decrease.

Assessing the preference boundary for the pleasure purpose requires setting nights away on travel period trip, number vehicle in household are set zero but number of household member on travel period trip is set to one (the traveler). For this level two separate boundary distance are calculated based on the race of the travelers.

- For Asian travelers, the maximum preference boundary is 1,400 miles when a household located in an urban area with a household income below $20,000 are set to one, and traveler has a long weekend trip. When all household located in an urban area, below $20,000 household income, and long weekend trip are held to zero, the minimum preference boundary is 740 miles.

- For other races, the maximum preference boundary is 2,000 miles when a household located in an urban area with a household income below $20,000 are set to one, and traveler has a long weekend trip. When all household located in an urban area, below $20,000 household income, and long weekend trip are held to zero, the minimum preference boundary is 1,280 miles.

Household members on the trip increase the boundary value by approximately 175 miles per person. A vehicle in a household increases the boundary value by approximately forty-five miles per vehicle. Household located in an urban area increase the boundary with impact of 240 miles. A long weekend trip increases the boundary value by approximately 220 miles. A below $20,000 household income person increases the boundary value by approximately 200 miles. However; a number of nights on the trip decrease the boundary value by approximately thirty-eight miles per years and an Asian traveler decrease the boundary value by approximately 540 miles.

3.8 Sensitivity analysis

Sensitivity analysis is an important technique for providing better understanding of the model and verify the potential effect of policy changes on travel behavior. The variables that are included in the previous models are analyzed to assess how changes in these variables may impact a traveler's mode choice. Sensitivity analysis is calculated by the difference in the probability to select a particular mode choice by increasing a unit of the subject variable value while holding all other variables constant. Binary logit and nested logit models are used to calculate probability when a variable change and hold other variable to be the same.

Table 3.7 shows the result of sensitivity analysis for binary logit models.

Table 3.7 Sensitivity analysis (binary logit)

Binary		Increased by	% changes in Air mode choice
Business purpose	Route distance	10%	7.80%
		20%	14.90%
		50%	32.00%
		100%	45.30%
	Nights away on the trip	1	1.80%
		2	3.20%
	HH members	2	-34.60%
		3	-46.90%
	HH located in an urban area		-29.80%
	Long weekend trip		-21.90%
Personal business purpose	Route distance	10%	9.00%
		20%	17.70%
		50%	36.60%
		100%	47.70%
	HH members	2	-10.30%
		3	-19.60%
	White traveler		-40.80%
	HH located in an urban area		-37.50%
Pleasure purpose	Route distance	10%	15.40%
		20%	28.70%
		50%	46.60%
		100%	49.90%
	HH members	2	-9.70%
		3	-18.00%
	Asian traveler		45.80%
	HH located in an urban area		-28.00%
	< $20,000 household income		-11.80%

For the business purpose, the results shown in Table 3.7 indicate that when route distance is increased by ten percent, a 7.8 percent increase in the air mode share occurs; however, when the number of household members is increased to two and three members on the trip, there is a corresponding 34.60% and 46.90% decrease in air mode share. The result indicates that the number of household members on the trip may play the most important role in the selection of air mode, but this depends on the increase in travel distance. On the other hand, increasing route distance by ten percent may not cause the traveler to select the air mode. For the long distance travel example, a traveler currently travels for 1,000 miles. If the traveler's trip length requirements increase by only 100 or 200 miles, this may not cause enough of a problem for the traveler to cause him to switch to air, but if this distance increased by fifty percent of route distance, the traveler may need to reconsider, again, 500 miles may require an additional day of travel by personal vehicle. The author recommends that long distance travel is different from daily travel trip; therefore, the standard sensitivity for distance should not be slightly increased by ten or twenty percent; but some higher value with regard to the mean and variance of a particular mode. The appropriate value of this change should be in future research; however, in this research, increasing the distance by ten percent is derived from Hickman and Blume research project [30]. They investigated integrated transit services and assumed that increasing the radius of proximity circles for a fixed-route bus stop about the origin and the destination by ten percent can change number of trips. Using existing guidelines the number of household members on the trip is the most important variable in the model. The second most important variable in the model is a household located in an urban area. The least important variable is nights away on the trip. For the personal business purpose, a white traveler is the most important variable for selecting the air mode choices while the second most important variable is household located in an urban area and the least important variable is route distance, if is only increased by ten percent. For the pleasure purpose, again, an Asian traveler has the most important effect on mode choice. The second important variable is, again, household located in urban area and the least important variable is the number of household members on the trip.

Table 3.8 shows the result of sensitivity analysis for nested logit (level 1).

Table 3.8 Sensitivity analysis (nested logit level 1)

Nested level 1		Increased by	% changes in Air mode choice
Business purpose	Route distance	10%	2.50%
		20%	4.90%
		50%	12.10%
		100%	22.80%
	Nights away on the trip	1	7.20%
		2	14.00%
	Short weekend trip		18.30%
Personal business purpose	Route distance	10%	9.40%
		20%	18.10%
		50%	36.90%
		100%	47.80%
	Age	28	11.60%
		38	21.90%
Pleasure purpose	Route distance	10%	5.40%
		20%	10.80%
		50%	25.00%
		100%	40.00%
	Nights away on the trip	1	5.60%
		2	11.00%

For the business purpose, the results in Table 3.8 indicate that a short weekend trip is the most important variable in the selection of the air mode. The second most important variable in the model is nights away on the trip. The least important variable is a ten percent increase in route distance. For the personal business purpose, age of traveler is the most important variable for selecting the air mode choices. The second most important variable is route distance increased by ten percent. For the pleasure purpose, one night away on the trip has the most significant effect to mode choice. The second most important variable is, again, ten percent increased in route distance.

The following table shows the sensitivity analysis for nested logit at level two.

Table 3.9 Sensitivity analysis (nested logit level 2)

Nested level 2		Increased by	% changes in Public mode choice
Business purpose	Route distance	10%	4.90%
		20%	9.80%
		50%	23.00%
		100%	38.00%
	Nights away on the trip	1	0.90%
		2	1.80%
	Short weekend trip		2.40%
	Sales or services occupation		-27.00%
	Other occupation		-38.30%
Personal business purpose	Route distance	10%	6.40%
		20%	12.30%
		50%	27.60%
		100%	42.30%
	HH member	2	-11.60%
		3	-22.10%
	Age	28	4.20%
		38	8.20%
	HH located in an urban area		-21.60%
	Long weekend		-24.50%
Pleasure purpose	Route distance	10%	8.90%
		20%	17.20%
		50%	35.60%
		100%	47.20%
	Nights aways on the trip	1	2.80%
		2	5.50%
	HH member	2	-11.70%
		3	-22.30%
	Number of vehicle	1	-2.90%
		2	-6.00%
	Asian traveler		31.80%
	HH located in an urban area		-15.90%
	Long weekend		-14.70%
	<$20,000 household income		-13.10%

For the business purpose, the results in Table 3.9 indicate that an other occupation is the most important variable in the selection of the public mode. The second most important variable is a sales or service occupation. The least important variable is one night away on the trip. For the personal business purpose, long weekend is the most important variable to select the public mode choice. The second most important variable is household located in an urban area and the least important variable is the age of traveler. For the pleasure purpose, an Asian traveler has the most significant effect on mode choice. The second most important variable is household located in an urban area and the least important variable is one night away on the trip.

Considering the results for both levels of the model (Table 3.8 and 3.9), the importance of the variables for each decision is compared. Route distance for business purpose has greater effect on selecting a public carrier in the upper level than for selecting the air mode in the lower level, but short weekend trip and night away on the trip have lesser effect for the public carrier choice. For the personal business purpose, route distance and age have greater effect on the selection of the air mode than the public carrier choice. Finally, for the pleasure purpose, nights away on the trip a smaller effect on the public carrier choice but it has a greater effect on the selection of air mode.

CHAPTER 4

NEURAL NETWORK

4.1 Introduction

Neural computing was first introduced in 1943 with a publication by the American scientists Warren McCulloch and Walter Pitts [28]. They studied the information processing capabilities of a Neural Network of simple processors, which were in some ways like the neurons of the human brain [54].

According to Principe [45], a Neural Network is a dynamic system consisting of processing units (neurons). The neurons interact with each other by using weighted connections. A Neural Network has an input layer, an output layer, and at least one hidden layer. Input and output neurons are connected by weights and passed to the hidden layers. The neurons have input and output connectors to connect with other neurons. Each neuron receives signals from the neurons of the previous layer. These signals are linearly weighted by the interconnecting values between neurons then transferred as an output by passing the sum through an activation function such as sigmoid, linear, or tanh, etc.

Neural Networks use training data to determine their parameters [45]. The results of a Neural Network are based on the desired input. The Neural Network updates its parameters through an iterative process as shown in Figure 4.1. This iterative process is called learning or training. In the first iteration of a Neural Network, the error may be large, but the process will seek to minimize the error during subsequent iterations until the parameters converge to acceptable level.

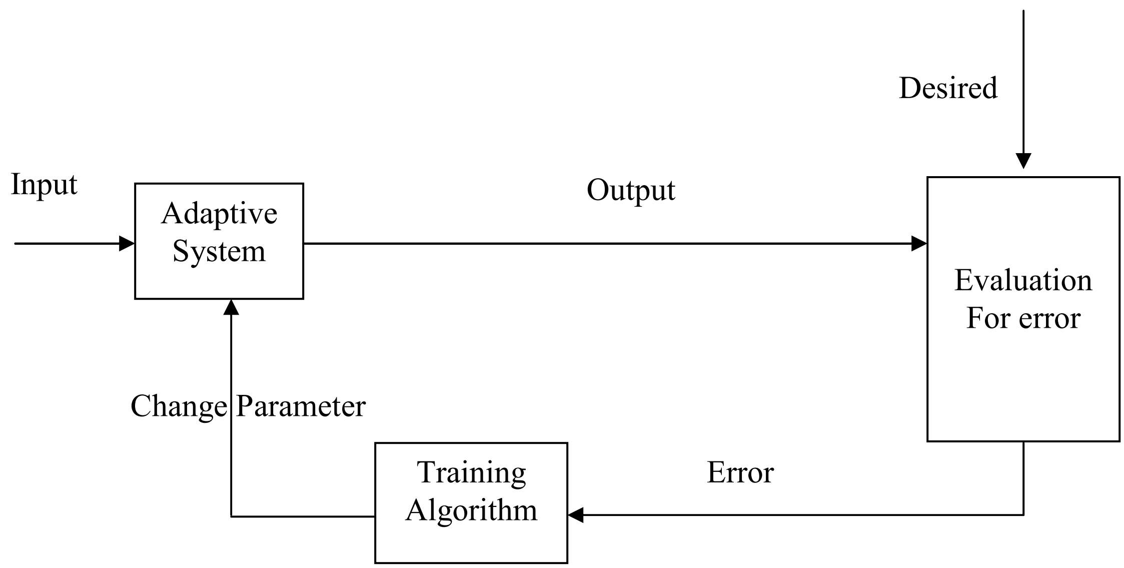

Figure 4.1 Basic Neural Network procedure

There are two phases in a Neural Network [45]

1. In the training or learning phase, the data is presented to the network repeatedly and the weights are updated to obtain the desired output.
2. In the recall or retrieval phase, the trained network with frozen weights is applied to a new data set (testing data set).

A Neural Network can be prepared using six steps:[27]

1. Define the problem to determine the relevent data and values to predict.
2. Represent the information to decide how many inputs will be fed to the network and what output will be predicted from the network.

3. Define the network by specifying how many neurons are in input, hidden and output layers. There is no exact rule to determine the number of hidden layers and hidden neurons; however, the rule of thumb is that the average number of input and output neurons equals the number of hidden neurons [34]. There is no theoretical limit for the number of hidden layers and no general statistical procedure to determine the optimal number of hidden layers nor number of neurons in the hidden layers [20]. Much empirical work shows that one hidden layer is sufficient for most problems.
4. Train the network; network training is accomplished by repeatedly presenting the data to the network until the network converges to the desired output. The Neural Network estimates its output, and compares this output with actual output. If the output is incorrect and the resulting error is more than the specificd mean square error, the Neural Network makes corrections to its internal weights. This process repeats until the error is within specified limits.
5. Test the network, where the network is presented with new data. If the network fails, there are no corrections to be made. The network is trained again with more data or in, this case, is redesigned untill the network produces desired results.
6. Run the network, after the network is trained and produces good results, the Neural Network is presented with new input data and the results are used for further analysis.

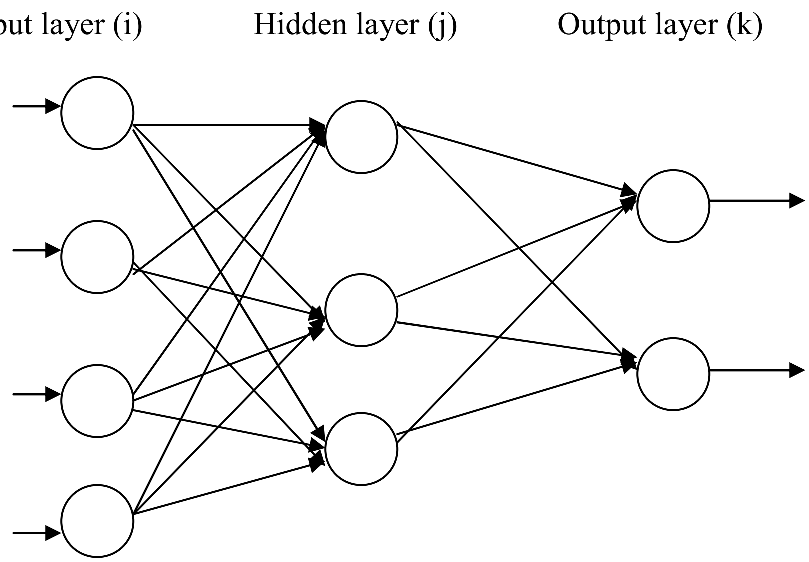

Figure 4.2 Multilayer perceptron (MLP)

From Figure 4.2, when a value is applied to each input node, each node then passes its given value to the connections, and at each connection the value is multiplied by the weight associated with that connection. Each node in the next layer receives a value, which is the sum of the values produced by the connections leading into it, and inside each node a simple computation, an activation function is typical, is performed on the value. These activities are shown in Figure 4.3. This process is then repeated, with the results being passed through subsequent layers of nodes until the output nodes are reached.

The values of the inputs use an internal activation function. In general terms, the relationship between the inputs $X_1,\ldots, X_n$ of neuron i and its output O_k are given by the following equation.

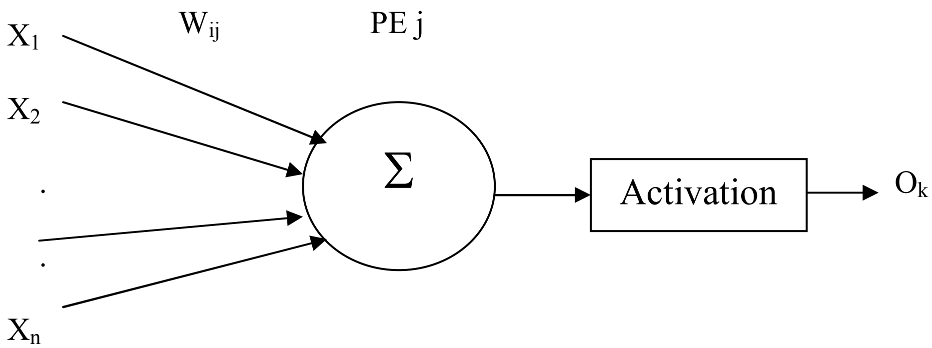

Figure 4.3 A neuron

$$Net_j = \Sigma W_{ij} X_i \quad (4.1)$$

$$O_{ki} = f(Net_j) \quad (4.2)$$

W_{ij} is the weight for the combination of processing units, i and j

X_i is the activation value of i-th processing units

The activation functions used in this research are:

1. Tanh function

$$O_k = \tanh(\Sigma W_{ij} X_i) \quad (4.3)$$

2. Sigmoid function

$$O_k = \frac{1}{1 + e^{-(\Sigma W_{ij} X_i)}} \quad (4.4)$$

3. Linear function

$$O_k = \begin{cases} 1 & 1 \leq (\Sigma W_{ij} Xi_j) \\ (\Sigma W_{ij} X_i) & 1 \leq (\Sigma W_{ij} X_i) \leq -1 \\ -1 & (\Sigma W_{ij} X_i) \leq -1 \end{cases} \qquad (4.5)$$

The initial weight for each connection is a random value. This represents the state where the network knows nothing. As the training process proceeds, these weights will converge to values that give the desired output. This means that a Neural Network learns from a state of no knowledge to gain more knowledge.

The operation of a Neural Network involves two main phases, training and testing. Training is the process that adjusts the connection weights to minimize the error in the Neural Network. This process continues until the error reduces to a level that the outputs from the Neural Network are close to the desired outputs. Testing is the process that monitors the training process so that overtraining does not occur.

4.1.1 Overtraining

Overtraining occurs when the Neural Network is trained too much and the model fits very well for the training data sets but not for other data set because of an excess number of layer and processing units. When this condition occurs, the model gives a very low percent error on the training data set but a high percent error on the other sets. The method used in this research to avoid overtraining is divining the data into two parts. The first part, the training set is used to obtain the weights (eighty percent NHTS dataset). The second part, the testing set is used to measure its performance (validation, twenty percent of NHTS dataset). After the network is trained with eighty percent of the data, the remaining twenty percent of data is tested using the network. If the percent errors are close to each other, then overtraining is not occurring.

4.2 Reason to choose Neural Network

Neural Networks are chosen as a mathematical tool to study the long distance travel behavior because a Neural Network can learn from experience and recognize new data from previous samples like humans. The advantage for a Neural Network is that there are no assumptions for the data and parameters. Neural Networks can handle both multi-collinearly and lack of correlation. Neural Networks can learn by themselves based on how the data is distributed [11]. The only data requirements are the input data and the researcher's determination of the number of hidden layers and number of neurons in each layer. The researcher's determination for the number of neurons and number of layers is reached through trial and error.

A Neural Network is a non-linear model. A Neural Network can solve problems like people naturally solve problems. A Neural Network learns to solve problems by being given data, examples of the problem, and its solution. The key benefit of a Neural Network is its ability to capture linear and non linear relationships between input and output data [31].

4.3 Learning

The learning process uses a search algorithm to minimize the error function. There are several types of search algorithms. In this research, backpropagation and hidden weight optimization (HWO) algorithms are used. This learning process is repeated until the average sum of squared errors are minimized and the network output values approximate the desired values. The Neural Network learns by adjusting these interconnection weights between neurons of two adjacent layers. The purpose of changing these weights is to lead to an improvement of the results.

Learning is iterative with the weights adjusting after each iteration. It will start with the calculation of the difference between the actual output and the desired output, which is the error. From this error, connection weights are increased or decreased in proportion to the error. The learning process allows the system to determine which inputs contributed the most to the desired output and how their weights should be changed to reduce the error.

After a Neural Network is trained, the network has learned and gained knowledge; it has stored values for the weights of its connections. In order to test the predictive potential of the Neural Network, the test data set (which is not used during the training process) is introduced to the trained network as input. The output is then generated at the output layer and compared with the actual desired response as a tool to evaluate the predictive potential of the trained network. Principe [45] recommends that the training set should be at least double the number of network weights.

A learning rule must be defined to determine how and when connection weights are updated [31].

The network adapts according to the following equation:

$$W_{ij(update)} \longleftarrow W_{ij\ (previous)} + \Delta\, W_{ij(calculate)} \tag{4.6}$$

The learning rate η can influence the weight changes in each epoch and the speed that the network learns; however, if the learning rate is too large it speeds up the rate of learning, the network will diverge.

In this research, two training algorithms are applied using two software package. For Neurosolutions, backpropagation is the training algorithm while for Nuclass7, hidden weight optimization is the training algorithm.

The percent correct is calculated to compare the result from Neurosolutions and NuClass7.

$$\text{Percent correct} = \left(\frac{\text{Number of correct prediction}}{\text{Number of sample}} \right) \times 100 \qquad (4.7)$$

4.4 Neurosolutions

Neurosolutions is an icon-based-oriented, window-based software package that is used for neurocomputing [21]. In this package, the Neural Network components are selected from palettes, and built in the breadboard. The Neural Network can be built using drag-drop components from palettes to the breadboard and connected to neurons. Neurosolutions uses two major families, axon and synapse, to construct the network topologies. An axon represents a layer of processing elements (PE), which may be linear or non linear. A synapse helps to connect the information flow between the processing elements of one axon (output) to another axon (input). The training algorithm that Neurosolutions uses is backpropagation.

4.4.1 Backpropagation

Backpropagation is a technique used for training a Neural Network.

There are two phases for backpropagation:

- A forward pass from the input layer through the hidden layer to the output layer the error term is calculated based on the output result compared to the desired output.
- The backward pass sends the error tern backward to each node with an adjustment for each weight based on the gradient descent method.

Procedure for backpropagation

1. Select the variables and randomly set the weights
2. Forward pass through the Neural Network for one iteration
3. Obtain weights
4. Obtain outputs
5. Backward pass and compare the output to the desired output

$$\delta_j = T_j - O_j \tag{4.8}$$

$$\delta_i = \sum_{j=1}^{j} W_{ij} \delta_j \tag{4.9}$$

$$\Delta W = \eta \delta_i \frac{df(Net_i)}{dNet_i} X_i \tag{4.10}$$

Where η is the learning rate, t is the desired output, and o is the actual output.

6. Adjust weights based on the impact of weights on the error term

$$W_{ij(update)} \longleftarrow W_{ij(previous)} + \Delta W_{ij(calculate)} \tag{4.11}$$

7. Repeat steps two through five until the errors are within acceptable limits.

The Means Square Error (MSE) for Neurosolutions software is

$$\text{MSE} = \frac{\sum_{j=0}^{P}\sum_{i=0}^{N}(T_{ij} - O_{ij})^2}{NP} \qquad (4.12)$$

Where N is number of sample and P is number of output neurons.

4.4.2 Momentum

When considering the learning rate, too large of a learning rate affects the minimum error; therefore, to reduce this limitation, the gradient descent method includes a term for the proportion of the last weight change. The previous weight change should influence the direction of weight space movement. It tends to smooth the gradient estimate and weight change. The momentum weight update equation is:

$$W_i(n+1) = W_i(n) + \eta\nabla W_i(n) + \rho\Delta W_i(n) \qquad (4.13)$$

Where η is learning rate

n is iteration number

ρ is momentum parameter

4.5 NuClass 7

NuClass7 is a different software package for classification of Neural Networks. The name NuClass stands for *Neural Network Classification*. NuClass7 is developed by the Image Processing and Neural Networks Lab, Department of Electrical Engineering, University of Texas at Arlington. The software is available at http://www-ee.uta.edu/eeweb/IP/.

NuClass7 has many tools for the user to select the number of inputs and processing units in the network. These tools include feature selection, network sizing, and pruning.

1. *Pruning* is a process that eliminates excess processing units from a large network to obtain an efficient number.
2. *Feature Selection*: or piecewise linear network floating search. A large number of inputs may result in slow network training, and too many operations required for applying the trained network. The feature selection can identify the importance of an input with respect to other inputs based on their usefulness. The feature selection tool can
    - find good subsets of the original N input features, for many subset sizes, and
    - estimate the classification error attainable for each subset.

    The feature selection tool plots the estimated classification error versus the number of inputs. The feature selection tool can also reduce the size of the training file and training times.
3. *Network sizing* is a process that predicts the number of processing units in a network based on the amount of classification error. This helps the user to select how many processing units to use in training.

4.5.1 Hidden weight optimization algorithm

The hidden weight optimization algorithm is developed by Dr. Michael T. Manry and team of other researchers from University of Texas at Arlington. The algorithm is described in this section [16]:

1. Initialize all weight and thresholds (Random numbers) and set the number of iterations
2. Increase the iteration number by 1. Stop if I > N.
3. Pass training data through the network. Calculate for f(Net_i),

$$\sum_{1}^{N_v} T_p(k) O_p(m) \tag{4.14}$$

$$\sum_{1}^{N_v} O_p(i) O_p(m) \tag{4.15}$$

   Where N_v is the training pattern $\{(x_p,T_p)\}$. x_p is an input vector and T_p is the desired output vector with dimension N and N_{out}. T(k) is the desired output. $O_p(m)$ is the actual output at unit m. $O_p(k)$ is the actual output at output unit k.

4. Solve for

$$\sum_{i=1} W(k,i) \sum_{1}^{N} O_p(i) O_p(m) = \sum_{1}^{N} T_p(k) O_p(m) \tag{4.16}$$

5. E and η are defined as the following:

$$E = \frac{1}{N_v} \sum_{k=1}^{N_{out}} \sum_{p=1}^{N_v} [T_p(k) - O_{op}(k)]^2 \tag{4.17}$$

   Where $O_{op}(k)$ is the net input at the k th output unit.

$$\eta = \frac{\eta' E}{\sum_{j}\left[\sum_{i}\left(\frac{\partial E}{\partial W(i,j)}\right)^2\right]} \qquad (4.18)$$

$$\eta' = (1 - \alpha) \qquad (4.19)$$

α is assumed to be close to but less than 1.

If E increases then reduce the value of η and reload the previous best hidden weights and go to step 9.

6. Make a second pass through the training data. Accumulate $\left(-\frac{\partial E}{\partial W(i,m)}\right)$, as the cross correlation
7. Solve for

$$\sum_{i} e(j,i)\sum_{p=1}^{N_v} O_p(i)O_p(m) = \left(-\frac{\partial E}{\partial W(i,m)}\right) \qquad (4.20)$$

8. Calculate for η
9. Update the hidden layer by

$$W(j,i) \longleftarrow W(j,i) + \eta e(j,i) \qquad (4.21)$$

10. Go to step 2

Means Square Error (MSE) for NuClass7 software is

$$\text{MSE} = \frac{1}{N_v}\sum_{p=0}^{N_v}\sum_{k=1}^{M}(T_{pk} - O_{ipk})^2 \qquad (4.22)$$

Where N_v is number of sample and M is number of output neurons.

4.6 Neural Networks result

4.6.1 Backpropagation results

4.6.1.1 Personal vehicle and air choices result

- Business purpose at 5000 iterations

Table 4.1 Percent correct for business purpose (personal vehicle and air)

	1 layer		2 layers	
Activation Function	Calibration	Validation	Calibration	Validation
Tanh	97.54%	96.37%	96.83%	96.58%
Sigmoid	92.98%	92.89%	89.72%	89.69%

Based on the results displayed in Table 4.1, using tanh activation function gives better percent correct than the sigmoid function and one layer gives a less complicated model than two layers. Therefore, the tanh activation function with one layer with ten neurons is selected for the hidden layer.

- For Personal business purpose at 5000 iterations

Table 4.2 Percent correct for personal business purpose (personal vehicle and air)

	1 layer		2 layers	
Activation Function	Calibration	Validation	Calibration	Validation
Tanh	98.06%	94.04%	98.68%	95.04%
Sigmoid	92.53%	92.45%	89.72%	89.54%

Based on the results displayed in Table 4.2, the tanh activation function with one layer with eight neurons is selected for the hidden layer.

- Pleasure purpose at 5000 iterations

Table 4.3 Percent correct for pleasure purpose (personal vehicle and air)

Activation Function	1 layer		2 layers	
	Calibration	Validation	Calibration	Validation
Tanh	96.64%	94.95%	96.81%	95.50%
Sigmoid	92.94%	92.54%	92.67%	92.22%

Based on the results displayed in Table 4.3, the tanh activation function with one layer with ten neurons is selected for the hidden layer.

The results for personal the vehicle and air choice cases indicate that the result using one hidden layer is not much different using two hidden layers. However one hidden layer provides a simpler model than two layers. Therefore, for the personal vehicle and air choice cases, one hidden layers with a tanh activation function are selected as the preferred model.

4.6.1.2 Personal vehicle, air, and ground choices result.

- Business purpose at 5000 iterations

Table 4.4 Percent correct for business purpose (personal vehicle, air, and ground)

Activation Function	1 layer		2 layers	
	Calibration	Validation	Calibration	Validation
Tanh	95.73%	94.74%	95.18%	94.11%
Sigmoid	88.19%	86.82%	88.19%	86.82%

Based on the results displayed in Table 4.4, the Neural network with a Tanh activation function and one layer with ten neurons is selected as the best network form.

- For Personal business purpose at 5000 iterations

Table 4.5 Percent correct for personal business purpose
(personal vehicle, air, and ground)

Activation Function	1 layer		2 layers	
	Calibration	Validation	Calibration	Validation
Tanh	97.04%	92.09%	96.99%	90.31%
Sigmoid	93.32%	91.48%	92.41%	90.57%

Based on the results displayed in Table 4.5, the Neural Network with a Tanh activation function and one layer with eight neurons is selected the best network structure.

- Pleasure purpose at 5000 iterations

Table 4.6 Percent correct for pleasure purpose (personal vehicle, air, and ground)

Activation Function	1 layer		2 layers	
	Calibration	Validation	Calibration	Validation
Tanh	95.62%	94.61%	95.70%	93.97%
Sigmoid	91.76%	91.44%	91.30%	91.32%

Based on the results displayed in Table 4.6, the neural network with a Tanh activation function and one layer with ten neurons outperforms selected the alternative network structure.

Once again, the results for the personal vehicle, air, and ground choice case indicate that the result for one hidden layer is not much different than from two hidden layers. However, one hidden layer provides more accuracy and the difference between the calibration percent correct and validation percent correct is smaller than the two hidden layer alternative. Therefore, for the personal vehicle, air, and ground choice case, one hidden layer with a tanh activation function is the preferred network form.

Through sensitivity analysis, the cause and effect relationship between the inputs and outputs of the network may be determined. Network learning is disabled during this operation so that the network weights are not affected. The equation 4.23 shows how much a change in x is reflected in y. This is how the sensitivity in y is to a change in x.

$$\frac{\partial y}{\partial w_i} = \frac{\partial y}{\partial Net_j}\frac{\partial Net_j}{\partial w_i} = f'(Net_j)x_i \tag{4.23}$$

4.6.1.3 Personal vehicle and air choices sensitivity:

- Business purpose with one hidden layer and Tanh activation function

Table 4.7 Sensitivity for business purpose (personal vehicle and air)

	Personal Vehicle	Air
Nights away on travel period trip	2.64%	2.69%
Number of HH members on travel period trip	2.64%	2.59%
Age of respondent	1.25%	1.25%
Route distance: origin to destination	61.81%	61.70%
Number of vehicles in HH	1.49%	1.50%
Race of HH respondent		
White	1.98%	1.97%
African American, Black	2.08%	2.08%
Asian Only	2.23%	2.20%
Other	2.36%	2.35%
Household in urban or rural area		
Urban	1.12%	1.12%
Rural	1.02%	1.09%
Occupational category		
Sales or Service	2.37%	2.35%
Clerical or administrative support	1.78%	1.71%
Manufacturing, construction	3.28%	3.32%
Other	2.01%	2.05%
Trip includes weekend		
Short weekend	2.18%	2.19%
Long weekend	1.67%	1.72%
Not weekend trip	1.55%	1.57%
Total income all HH members		
< $20,000	1.82%	1.83%
$20,000-$44,999	1.52%	1.51%
≥ $45000	1.21%	1.20%
Total percentage	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.7, route distance is the most influential variable on the mode choices; the second most influential is in occupational of manufacturing, construction, or farming. The least influential variable is for a household located in a rural area for both personal vehicle and air.

- Personal business purpose with one hidden layers and Tanh activation function

Table 4.8 Sensitivity for personal business purpose (personal vehicle and air)

	Personal Vehicle	Air
Nights away on travel period trip	6.80%	5.84%
Number of HH members on travel period trip	3.88%	3.39%
Age of respondent	1.86%	1.51%
Route distance: origin to destination	54.46%	53.69%
Number of vehicles in HH	2.50%	4.15%
Race of HH respondent		
White	2.18%	2.77%
African American, Black	2.06%	1.92%
Asian Only	3.53%	3.48%
Other	1.52%	2.18%
Household in urban or rural area		
Urban	1.46%	1.89%
Rural	1.46%	1.73%
Occupational category		
Sales or Service	2.58%	1.55%
Clerical or administrative support	2.15%	2.10%
Manufacturing, construction	2.10%	2.97%
Other	1.27%	1.55%
Trip includes weekend		
Short weekend	0.90%	0.85%
Long weekend	2.25%	1.38%
Not weekend trip	1.55%	1.27%
Total income all HH members		
< $20,000	2.11%	2.13%
$20,000-$44,999	1.70%	1.43%
≥ $45000	1.69%	2.22%
Total percentage	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.8, route distance is again the most influential variable for the mode choices. Night away on the trip is the second most influential variable. The least influential variable is short weekend trip for both personal vehicle and air.

- Pleasure purpose with one hidden layers and Tanh activation function

Table 4.9 Sensitivity for pleasure purpose (personal vehicle and air)

	Personal Vehicle	Air
Nights away on travel period trip	1.09%	1.10%
Number of HH members on travel period trip	2.28%	2.28%
Age of respondent	0.51%	0.51%
Route distance: origin to destination	70.37%	70.61%
Number of vehicles in HH	1.20%	1.22%
Race of HH respondent		
White	1.81%	1.78%
African American, Black	1.95%	1.93%
Asian Only	2.24%	2.21%
Other	1.77%	1.76%
Household in urban or rural area		
Urban	0.39%	0.43%
Rural	0.39%	0.36%
Occupational category		
Sales or Service	2.05%	2.01%
Clerical or administrative support	1.86%	1.85%
Manufacturing, construction	1.87%	1.86%
Other	1.75%	1.74%
Trip includes weekend		
Short weekend	1.45%	1.43%
Long weekend	1.51%	1.50%
Not weekend trip	1.38%	1.36%
Total income all HH members		
< $20,000	1.54%	1.52%
$20,000-$44,999	1.27%	1.25%
≥ $45000	1.30%	1.28%
Total percentage	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.9, route distance is again the most influential variable for the mode choices; the number of household members on the trip is second most influential. The least influential variable is the household location in rural area.

4.6.1.4 Personal vehicle, air, and ground choices sensitivity:

- Business purpose with one hidden layers and Tanh activation function

Table 4.10 Sensitivity for business purpose (personal vehicle, air, and ground)

	Personal Vehicle	Air	Ground
Nights away on travel period trip	1.64%	1.51%	4.08%
Number of HH members on travel period trip	2.37%	1.98%	6.35%
Age of respondent	1.28%	1.14%	8.13%
Route distance: origin to destination	66.73%	69.72%	30.53%
Number of vehicles in HH	1.23%	1.10%	9.13%
Race of HH respondent			
White	1.77%	1.53%	2.70%
African American, Black	2.65%	2.44%	3.72%
Asian Only	1.45%	1.29%	2.13%
Other	2.53%	2.35%	5.80%
Household in urban or rural area			
Urban	1.11%	1.05%	2.27%
Rural	1.12%	1.07%	2.34%
Occupational category			
Sales or Service	1.78%	1.63%	1.74%
Clerical or administrative support	1.93%	1.75%	2.70%
Manufacturing, construction	1.88%	1.71%	3.32%
Other	1.86%	1.73%	2.97%
Trip includes weekend			
Short weekend	1.31%	1.22%	1.26%
Long weekend	1.57%	1.44%	1.91%
Not weekend trip	1.15%	1.02%	2.28%
Total income all HH members			
< $20,000	1.80%	1.63%	2.94%
$20,000-$44,999	1.15%	1.11%	1.83%
≥ $45000	1.69%	1.59%	1.87%
Total percentage	100.00%	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.10, for the personal vehicle choice, route distance is the most influential and the least influential variable is a household located in an urban area. For the air choice, route distance is again the most influential variable and the least influential variable is for a non-weekend trip. For the ground choice, route distance is the most influential variable and the least influential variable is a short weekend trip. Overall, route distance has the greatest effect on all three mode choices; however, route distance is less influential for the ground choice because the relative importance of the following variables is higher than the air and personal vehicle choices: nights away on the trip, number of household members on the trip, age of respondent, and number of vehicles in household.

- Personal business purpose with one hidden layers and Tanh activation function

Table 4.11 Sensitivity for personal business purpose (personal vehicle, air, and ground)

	Personal Vehicle	Air	Ground
Nights away on travel period trip	7.59%	7.98%	11.27%
Number of HH members on travel period trip	6.92%	6.45%	8.34%
Age of respondent	3.44%	2.77%	11.71%
Route distance: origin to destination	47.90%	47.30%	16.87%
Number of vehicles in HH	2.04%	2.71%	1.83%
Race of HH respondent			
White	2.45%	2.61%	3.11%
African American, Black	2.87%	2.98%	4.71%
Asian Only	2.41%	2.21%	4.99%
Other	2.98%	2.92%	2.49%
Household in urban or rural area			
Urban	1.14%	1.32%	1.12%
Rural	0.98%	1.01%	1.54%
Occupational category			
Sales or Service	1.82%	1.73%	4.98%
Clerical or administrative support	1.59%	1.62%	1.75%
Manufacturing, construction	1.78%	1.78%	3.91%
Other	1.77%	1.78%	3.01%
Trip includes weekend			
Short weekend	3.21%	3.40%	4.27%
Long weekend	2.36%	2.42%	3.60%
Not weekend trip	2.31%	2.36%	2.83%
Total income all HH members			
< $20,000	2.70%	2.80%	3.53%
$20,000-$44,999	0.66%	0.82%	1.79%
≥ $45000	1.08%	1.03%	2.35%
Total percentage	100.00%	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.11, for the personal vehicle choice, route distance is the most influential variable; however, the nights away on the trip and the number of household members on the trip have both increased in relative importance compared to business purpose trips. For both the personal vehicle choice and air choice the least influential variable is between $20,000 and $44,999 income. For the air choice, route distance is the most influential variable, but the same variables, night away on the trip and the number of household members on the trip, have increase in relative importance compared to business purpose trips. For the ground choice, route distance remains the most influential variable, but age and the previously discussed variables continue to increase in importance. Route distance is the most influential variable for all three mode choices; however, route distance has less effect for the ground choice because the following variables have higher relative importance; nights away on the trip, number of household members on the trip, race, and occupational category.

- Pleasure purpose with one hidden layers and Tanh activation function

Table 4.12 Sensitivity for pleasure purpose (personal vehicle, air, and ground)

	Personal Vehicle	Air	Ground
Nights away on travel period trip	2.23%	2.16%	3.96%
Number of HH members on travel period trip	1.87%	1.62%	3.83%
Age of respondent	0.42%	0.39%	0.77%
Route distance: origin to destination	68.09%	69.63%	40.81%
Number of vehicles in HH	1.34%	1.16%	2.52%
Race of HH respondent			
White	1.76%	1.68%	3.10%
African American, Black	2.05%	1.88%	4.03%
Asian Only	2.90%	2.81%	5.13%
Other	1.93%	1.86%	3.58%
Household in urban or rural area			
Urban	0.28%	0.26%	0.24%
Rural	0.35%	0.33%	0.26%
Occupational category			
Sales or Service	2.02%	1.95%	3.99%
Clerical or administrative support	1.91%	1.86%	4.07%
Manufacturing, construction	2.29%	2.21%	3.81%
Other	1.90%	1.87%	3.75%
Trip includes weekend			
Short weekend	1.21%	1.12%	2.15%
Long weekend	1.72%	1.63%	3.29%
Not weekend trip	1.34%	1.33%	2.50%
Total income all HH members			
< $20,000	1.49%	1.39%	2.92%
$20,000-$44,999	1.42%	1.39%	2.65%
≥ $45000	1.49%	1.46%	2.64%
Total percentage	100.00%	100.00%	100.00%

Based on the sensitivity analysis results displayed in Table 4.12, for the personal vehicle choice, route distance returns to its dominant position as the most influential variable and the least influential variable is a household located in an urban area. For the air choice, route distance also returns to its dominant position as the most influential variable and the least influential variable is a household located in an urban area. For the ground choice, route distance is the most influential variable and the least influential variable is a household located in an urban area. Once again, route distance is the most influential variable for all three mode choices.

According to the results from the two mode choice and three mode choice models, the important variables are the same for both modes in the two mode choice model, but there are significant difference in some variables and their percentages for the three mode choice model. For this model, the personal vehicle and air choices show almost the same ranking for variable importance and percentage, but for the ground mode, these are different. Route distance percentage for the ground alternative is less influential than it is for the personal vehicle and air alternatives, but the rest of the variables' influence increase. As expected, the route distance is the most influential variable on output for the mode choice decision.

Based on percent correct for NHTS dataset in calibration and validation, Multilayer perceptron and backpropagation algorithm training give the best result. The number of neurons, momentum, and learning rate from the selected network are concluded below

- For Personal vehicle and air choices, one layer with twenty-one input neurons and two output neurons as shown in table 4.13.

Table 4.13 Neural Networks result for personal vehicle and air (backpropagation)

	Business	Person Business	Pleasure
Neurons in hidden layer	10	8	10
Momentum	0.7	0.7	0.7
Learning rate	0.1-0.02	0.1-0.02	0.1-0.02

The business travel model is composed of ten neurons for the hidden layer. For all models, the momentum used in the model is 0.7 by software default and the learning rate is 0.1 for the hidden layer and 0.02 for the output layer by software default. For the personal business purpose, the model is composed of eight neurons for the hidden layer. Lastly, pleasure travel model is composed of ten neurons for hidden layer.

- For Personal vehicle, air, and ground choices, one layer with twenty-one input neurons and three output neurons as shown in table 4.14.

Table 4.14 Neural Networks result for personal vehicle, air, and ground (backpropagation)

	Business	Person Business	Pleasure
Neurons in hidden layer	10	8	10
Momentum	0.7	0.7	0.7
Learning rate	0.1-0.02	0.1-0.02	0.1-0.02

The neural Network structure for the three mode case is identical to the two mode case for all trip purposes. However, each model will likely have different weight with the model.

4.6.1.5 Models evaluation on NHTS, Texas, and Wisconsin

Table 4.15 Percent correct for Neural Networks (backpropagation)

	Personal Vehicle and Air			Personal Vehicle, Air, and Ground		
	Business	**Personal Business**	**Pleasure**	**Business**	**Personal Business**	**Pleasure**
Calibration	97.54%	98.06%	96.64%	95.73%	97.04%	95.62%
Validation	96.37%	94.04%	94.95%	94.74%	92.09%	94.61%
Texas(zero)	22.61%	89.86%	86.00%	62.20%	90.48%	38.07%
Texas(avg)	88.09%	94.85%	96.95%	96.45%	91.65%	94.98%
Wisconsin	95.89%	96.61%	97.03%	96.29%	93.54%	96.09%

For the personal vehicle and air mode choice models, the percent correct are higher than ninety percent for the calibration, validation, and Wisconsin datasets. However, the Texas dataset percent correct with zero substituted for the missing variables for both the business trip purposes is very low because the dataset lacks the variables for nights away on the trip, household located in an urban or rural area, and trip includes a weekend. Even in the absence of these variables, the Neural Network is able to estimate the personal business and pleasure trip fairly accurately with 89.86 and 86.00 percent correct. However, the Texas data with an average value given for the missing variables provide high percent correct for two purposes.

For the personal vehicle, air, and ground mode choice model, the percent correct is still good, but overall, they are slightly lower than the personal vehicle and air mode choice model. Once again, Texas dataset with zero for missing variable performs poorly for the business and pleasure purposes, but its performance is improved over the simpler model. Also, it performs well for the personal business purpose. The Texas dataset with an average value given for the missing variable performs very well for each purpose.

4.6.2 Hidden weight optimization algorithm result

NuClass7 has one layer with a sigmoid function at the hidden layer and a linear function at output layer, it uses a hidden weight optimization (HWO) training algorithm.

Table 4.16 Feature number for NuClass7

Features	Description
1	**Nights away on travel period trip**
2	**Number of HH members on travel period trip**
3	**Age of respondent**
4	**Route distance: origin to destination**
5	**Number of vehicles in HH**
	Race of HH respondent
6	White (1 if yes, 0 otherwise)
7	African American, Black (1 if yes, 0 otherwise)
8	Asian Only (1 if yes, 0 otherwise)
9	Other (1 if yes, 0 otherwise)
	Household in urban or rural area
10	Urban (1 if yes, 0 otherwise)
11	Rural (1 if yes, 0 otherwise)
	Occupational category
12	Sales or Service (1 if yes, 0 otherwise)
13	Clerical or administrative support (1 if yes, 0 otherwise)
14	Manufacturing, construction, maintenance, or farming (1 if yes, 0 otherwise)
15	Other (1 if yes, 0 otherwise)
	Trip includes weekend
16	Short weekend (2-3 days incl FRI and-or SAT) no FRI return (1 if yes, 0 otherwise)
17	Long weekend (4-6 days incl FRI and-or SAT) no FRI return (1 if yes, 0 otherwise)
18	Not weekend trip (all other trips) (1 if yes, 0 otherwise)
	Total income all HH members
19	< $20,000
20	$20,000-$44,999
21	≥ $45000

Table 4.16 shows the features number used in the software package (hidden weight optimization) for subsetting selection tool.

NuClass7 uses the following steps to determine how many neurons are required in the network:

1. Feature subsetting: feature members (variables) are determined to include in the model.
2. Sizing: Estimated numbers of neurons in the model are determined.
3. Training: The network with result from previous steps is used to train the network. The result from this procedure is the weight of the network.
4. Pruning: after the network is trained, validation dataset is feed to the network with comparison how many neurons that provide the smallest error between both calibration and validation dataset.

The optimum number of neurons is selected and the network is saved for validation with the Texas and Wisconsin datasets.

4.6.2.1 Personal vehicle and air choices:

- Business purpose

Table 4.17 Feature subsetting with twenty-one features for business purpose (personal vehicle and air)

Error Percentage	Feature Subset Size	Feature Subset Members
4.95	21	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, 18, 16, 17, 12, 6, 11, 21}

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. The feature selection fit a piecewise linear mapping to the available training data. Candidate feature sets are found and evaluated by the MSE of that subset using the floating search [46], which finds near optimal feature subsets. The floating search is much faster than the optimal branch and bound approach [24]. All twenty-one features in the model may be considered a more complicated model than a model with fewer features model, but a Neural Network learns to solve problems by learning from the given data, examples of the problem, and solution. This means that a Neural Network requires a lot of information in order to obtain better results. Also, the difference in computational time for all twenty-one features and the three most important features is just thirty seconds from 1:20 minutes for the large model and 0:50 minutes for the smaller model, this is likely a minor coast of computational time in order to obtain a better result. A Neural Network, also, has the ability to learn complex patterns. Finally, it is easy to apply with a dataset, for example, a user can easier feed all features to the model rather than deleting some features, especially category variables such as using only one of the three weekend trip category variables. Feeding the entire weekend trip category to the network is easier than deleting a portion of a category and then feeding it to the model. The results in Table 4.17 show that route distance is the most influential feature followed by the nights away on the trip. The least influential feature is above $44,999 household income. The NuClass7 steps are applied to the dataset and the result shows that ten neurons are preferred for the business purpose (personal vehicle and air).

- Personal business purpose

Table 4.18 Feature subsetting with twenty-one features for personal business purpose (personal vehicle and air)

Error Percentage	Feature Subset Size	Feature Subset Members
2.32	21	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 19, 6, 17, 16, 9, 15, 20, 11 }

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. Route distance, again, is the most influential feature to select a mode followed by non-weekend trip. The least influential feature is household located in an urban area. The NuClass7 steps are applied to the dataset and the result show that two neurons are preferred for personal business purpose (personal vehicle and air).

- Pleasure purpose

Table 4.19 Feature subsetting with twenty-one features for pleasure purpose (personal vehicle and air)

Error Percentage	Feature Subset Size	Feature Subset Members
3.65	21	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, 19, 9, 8, 15, 11, 18, 21 }

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. Route distance is the most influential feature to select a mode followed by the nights away on the trip. The least influential feature is above $44,999 income. The NuClass7 steps are applied to the dataset and the result show that three neurons are preferred for pleasure purpose (personal vehicle and air).

4.6.2.2 Personal vehicle, air, and ground choices

- Business purpose

Table 4.20 Feature subsetting with twenty-one features for business purpose (personal vehicle, air, and ground)

Error Percentage	Feature Subset Size	Feature Subset Members
6.86	21	{4, 15, 1, 2, 5, 3, 14, 10, 9, 20, 13, 19, 18, 7, 17, 8, 16, 6, 12, 21, 11 }

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. Route distance is the most influential feature to select a mode followed by others occupational category. The least influential feature is household located in an urban area. The NuClass7 steps are applied to the dataset and the result show that ten neurons are preferred for business purpose (personal vehicle, air, and ground).

- Personal business purpose

Table 4.21 Feature subsetting with twenty-one features for personal business purpose (personal vehicle, air, and ground)

Error Percentage	Feature Subset Size	Feature Subset Members
4.55	21	{4, 18, 10, 3, 1, 12, 5, 14, 2, 7, 13, 9, 20, 17, 8, 19, 16, 21, 6, 15, 11 }

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. Route distance is the most influential feature to select a mode followed by non weekend trip. The least influential feature is rural area. The NuClass7 steps are applied to the dataset and the result shows that one neuron is preferred for personal business purpose (personal vehicle, air, and ground).

- Pleasure purpose

Table 4.22 Feature subsetting with twenty-one features for pleasure purpose (personal vehicle, air, and ground)

Error Percentage	Feature Subset Size	Feature Subset Members
5.02	21	{4, 2, 10, 1, 5, 12, 3, 21, 6, 14, 17, 13, 16, 9, 19, 8, 7, 20, 11, 18, 15 }

The feature subsetting tool indicates that including all twenty-one features (variables) in the network gives the lowest error percentage. Route distance is the most influential feature to select a mode followed by household members on the trip. The least influential feature is other occupational category. The NuClass7 steps are applied to the dataset and the result show that eight neurons are preferred for pleasure purpose (personal vehicle, air, and ground).

The numbers of neurons for each purpose are summarized in Table 4.23.

Table 4.23 Neural Networks result (hidden weight optimization)

	Personal Vehicle and Air			Personal Vehicle, Air, and Ground		
	Business	Personal Business	Pleasure	Business	Personal Business	Pleasure
Number of Processing Units	10	2	3	10	1	8

The numbers of neurons shown in the Table 4.23 are preferred for the long distance travel model based on the lowest error between the calibration and validation dataset. For two mode choices, ten neurons (number of processing units) are required for business model. The personal business model performs well with two neurons and the pleasure model requires three neurons. For three mode choices, the business model, once again, prefers ten neurons. Personal business model need just only one neuron for the model to perform and, lastly, the pleasure model requires eight neurons.

4.6.2.3 Models evaluation on NHTS, Texas, and Wisconsin

Table 4.24 Models evaluation on NHTS, Texas, and Wisconsin (hidden weight optimization)

	Personal Vehicle and Air			Personal Vehicle, Air, and Ground		
	Business	**Personal Business**	**Pleasure**	**Business**	**Personal Business**	**Pleasure**
Calibration	96.95%	96.90%	96.35%	94.88%	95.14%	95.04%
Validation	96.66%	96.59%	96.27%	94.74%	93.92%	94.99%
Texas(zero)	87.70%	94.70%	96.96%	76.38%	91.51%	95.59%
Texas(avg)	94.44%	95.16%	96.96%	96.45%	91.65%	94.98%
Wisconsin	95.90%	100.00%	96.79%	97.04%	95.16%	96.34%

For the Personal vehicle and air mode choices model the percent correct are higher than 95 percent for calibration, validation, and Wisconsin. Texas percent correct on business is lower but it is still a good percent correct. In the three mode choice model, the percent correct is still high for most cases, but it is slightly lower then the simpler two mode model.

The lack of variables for the Texas dataset had a reduced effect for these models compared to the backpropagation Neural Networks, the business purpose still has a lower percent correct, but it is not as large as the earlier models. The other trip purposes appear unaffected. The two mode choices (personal vehicle and air) model gives a better percent correct than the three mode choices (personal vehicle, air, and ground) model; however, both models still give a very good percent prediction.

CHAPTER 5

ANALYSIS AND RESULTS

In this study, the models from each method are compared based on percent correct. Comparison of percent correct for the two mode (personal vehicle and air) models logistic regression and Neural Networks are shown in Table 5.1.

The results shown in Table 5.1 indicate that the Neural Networks by backpropagation algorithm provide the highest percent correct for calibration dataset and the pleasure purpose validation with the Wisconsin dataset. Neural Networks by hidden weight optimization algorithm provide the highest percent correct for the US validation, Texas validation with zero assigned for missing variable for personal business and pleasure, and Wisconsin validation for business and personal business. As mentioned in chapters two and four, the Texas dataset does not have a variable for nights away on the trip, household located in an urban or rural area, and trip includes weekend, nevertheless the binary logit models and both Neural Networks software provide astonishing results for the Texas dataset (both zero and average value are assigned for the missing variable) with a high percent correct (more than eighty-five percent for business purpose and more than ninety percent for personal business and pleasure purposes). The only exception is the business purpose where validation with the backpropagation algorithm provides a low percent correct (twenty-two percent) for the Texas dataset with a zero value given for missing variable. Overall, hidden weight optimization models are slightly better than backpropagation models and the logit models. Hidden weight optimization and the logit models perform better than backpropagation models, when some variables are unavailable.

Table 5.1 Percent correct comparison: binary logit, backpropagation, and hidden weight optimization results (personal vehicle and air)

		Personal Vehicle and Air		
		Business	Personal Business	Pleasure
Calibration	Binary Logit	95.30%	95.90%	95.90%
	Backpropagation	97.54%	98.06%	96.64%
	Hidden weight optimization	96.95%	96.90%	96.35%
Validation	Binary Logit	94.56%	95.66%	93.76%
	Backpropagation	96.37%	94.04%	94.95%
	Hidden weight optimization	96.66%	96.59%	96.27%
Texas (zero)	Binary Logit	89.68%	93.64%	96.75%
	Backpropagation	22.61%	89.86%	86.00%
	Hidden weight optimization	87.70%	94.70%	96.96%
Texas (avg)	Binary Logit	95.23%	93.64%	96.34%
	Backpropagation	88.09%	94.85%	96.95%
	Hidden weight optimization	94.44%	95.16%	96.96%
Wisconsin	Binary Logit	94.77%	98.30%	93.82%
	Backpropagation	95.89%	96.61%	97.03%
	Hidden weight optimization	95.90%	100.00%	96.79%

Comparison of percent correct for the three mode (personal vehicle, air, and ground) models logistic regression and Neural Networks are shown in Table 5.2.

The results in Table 5.2, again, indicate that backpropagation algorithm provides the highest percent correct for calibration, but it is weak for validation when some variables are unavailable and filled with zero. However, for three mode choices, the nested logit model performs better than the Neural Networks when a lack of variable occurs; for the calibration and validation of the USA dataset, the nested logit model still provides good accuracy, although the Neural Networks provide better results. Overall, hidden weight optimization and nested logit models performance are not much different than the two mode case and they are slightly better than backpropagation algorithm for validation, but the nested logit provides a better result than hidden weight optimization when dealing with a lack of variables.

Table 5.2 Percent correct comparison between nested logit and Neural Networks (personal vehicle, air, and ground)

		Personal Vehicle, Air, and Ground		
		Business	Personal Business	Pleasure
Calibration	Nested logit			
	Level 1	88.88%	93.00%	92.90%
	Level 2	93.80%	93.60%	94.40%
	Backpropagation	95.73%	97.04%	95.62%
	Hidden weight optimization	94.88%	95.14%	95.04%
Validation	Nested logit			
	Level 1	88.82%	93.54%	94.89%
	Level 2	92.49%	93.00%	93.47%
	Backpropagation	94.74%	92.09%	94.61%
	Hidden weight optimization	94.74%	93.92%	94.99%
Texas (zero)	Nested logit			
	Level 1	81.81%	90.62%	100.00%
	Level 2	92.12%	92.24%	95.39%
	Backpropagation	62.20%	90.48%	38.07%
	Hidden weight optimization	76.38%	91.51%	95.59%
Texas (avg)	Nested logit			
	Level 1	100.00%	100.00%	100.00%
	Level 2	99.21%	96.33%	95.79%
	Backpropagation	96.45%	91.65%	94.98%
	Hidden weight optimization	83.07%	91.36%	95.99%
Wisconsin	Nested logit			
	Level 1	92.30%	75.00%	97.05%
	Level 2	94.07%	93.54%	93.65%
	Backpropagation	96.29%	93.54%	96.09%
	Hidden weight optimization	97.04%	95.16%	96.34%

5.1 Calibration with four most important variables

In this study, the four most important variables derived from sensitivity analysis and piecewise linear network floating search are modeled and compared with the twenty-one variable model in terms of percent correct. Table 5.3 shows how many neurons are required for each Neural Nework learning algorithm.

Table 5.3 Neural Networks result for two and three cases

Number of Processing Units	**Personal Vehicle and Air**			**Personal Vehicle, Air, and Ground**		
	Business	**Personal Business**	**Pleasure**	**Business**	**Personal Business**	**Pleasure**
Backpropagation	5	3	5	6	3	6
Hidden weight optimization	7	4	8	7	1	2

The results from Table 5.3 show that the backpropagation algorithm requires three to six neurons but, the hidden weight optimization algorithm requires one to eight neurons in order to model using the most four important variables in the model.

For two modes, the four most important variables in Neural Network models for the backpropagation algorithm are:

- Business purpose: route distance, manufacturing, nights away on the trip, and number of household members on the trip.
- Personal business purpose: route distance, nights away on the trip, number of household members on the trip, and race: Asian.

- Pleasure purpose: route distance, number of household members on the trip, race: Asian, and sales or service occupation.

The four most important variables in Neural Network models for hidden weight optimization algorithm are:

- Business purpose: route distance, nights away on the trip, occupation: other, and number of household members on the trip.
- Personal business purpose: route distance, non weekend trip, nights away on the trip, and number of household members on the trip.
- Pleasure purpose: route distance, nights away on the trip, number of household members on the trip, and number of vehicles in household.

Comparison of the percent correct for the two mode (personal vehicle and air) models between the process logistic regression and the Neural Networks with the four most important variables are shown in Table 5.4.

Comparing between the twenty-one variable model (Table 5.1) and the most four important variable model (Table 5.4), the twenty-one variable model provides a higher percent correct for calibration and validation; however, for the Texas (when either a zero or an average value is assigned for the missing variable) and Wisconsin dataset, the four most important variables provide a better percent correct, especially, for backpropagation with personal business for the Wisconsin dataset, it provide 100.00 percent correct. This may occur because the four most important variables do not include household located in an urban area and travel during weekend or non weekend trip.

Table 5.4 Percent correct comparison: binary logit, backpropagation, and hidden weight optimization results (personal vehicle and air)

		Personal Vehicle and Air		
		Business	Personal Business	Pleasure
Calibration	Binary Logit	95.30%	95.90%	95.90%
	Backpropagation	95.97%	95.74%	95.93%
	Hidden weight optimization	96.26%	95.59%	96.14%
Validation	Binary Logit	94.56%	95.66%	93.76%
	Backpropagation	95.75%	92.35%	92.64%
	Hidden weight optimization	96.24%	95.67%	96.02%
Texas (zero)	Binary Logit	89.68%	93.64%	96.75%
	Backpropagation	94.84%	95.76%	96.75%
	Hidden weight optimization	93.65%	94.40%	96.75%
Texas (avg)	Binary Logit	95.23%	93.64%	96.34%
	Backpropagation	94.84%	95.76%	96.95%
	Hidden weight optimization	94.65%	95.65%	96.96%
Wisconsin	Binary Logit	94.77%	98.30%	93.82%
	Backpropagation	96.64%	100.00%	97.08%
	Hidden weight optimization	96.64%	100.00%	97.04%

For, the three mode case, the four most important variables in the Neural Network models using the backpropagation algorithm are:

- Business purpose: route distance, race: African American, number of household members on the trip, and number of vehicles in the household.
- Personal business purpose: route distance, nights away on the trip, number of household members on the trip, and age.
- Pleasure purpose: route distance, race: Asian, nights away on the trip, and number of household members on the trip

The four most important variables in the Neural Network models using the hidden weight optimization algorithm are:

- Business purpose: route distance, occupation: other, nights away on the trip, and number of household members on the trip.
- Personal business purpose: route distance, non weekend trip, household located in an urban area, and age.
- Pleasure purpose: route distance, number of household members on the trip, household located in an urban area, and nights away on the trip.

Comparisons of the percent correct for the three mode (personal vehicle, air, and ground) models for both logistic regression and Neural Networks with the four most important variables are shown in Table 5.5.

Table 5.5 Percent correct comparison between nested logit and Neural Networks (personal vehicle, air, and ground)

		Personal Vehicle, Air, and Ground		
		Business	Personal Business	Pleasure
Calibration	Nested logit			
	Level 1	88.88%	93.00%	92.90%
	Level 2	93.80%	93.60%	94.40%
	Backpropagation	93.48%	93.39%	94.69%
	Hidden weight optimization	94.45%	94.23%	94.85%
Validation	Nested logit			
	Level 1	88.82%	93.54%	94.89%
	Level 2	92.49%	93.00%	93.47%
	Backpropagation	93.51%	91.22%	95.40%
	Hidden weight optimization	94.40%	93.01%	94.74%
Texas (zero)	Nested logit			
	Level 1	81.81%	90.62%	100.00%
	Level 2	92.12%	92.24%	95.39%
	Backpropagation	96.03%	92.09%	95.39%
	Hidden weight optimization	90.94%	91.65%	95.79%
Texas (avg)	Nested logit			
	Level 1	100.00%	100.00%	100.00%
	Level 2	99.21%	96.33%	95.79%
	Backpropagation	96.03%	92.09%	95.36%
	Hidden weight optimization	91.34%	92.48%	95.39%
Wisconsin	Nested logit			
	Level 1	92.30%	75.00%	97.05%
	Level 2	94.07%	93.54%	93.65%
	Backpropagation	95.14%	95.16%	96.58%
	Hidden weight optimization	97.93%	95.16%	95.85%

Comparing between the twenty-one variable model (Table 5.2) and the four most important variable model (Table 5.5), again, the twenty-one variable model provides higher percent correct for calibration and validation; however, for Texas (when either a zero and an average is assigned for the missing variable) and Wisconsin dataset, the four most important variables provide better percent correct. As mentioned for the two mode case, this may occur because the four most important variables do not include travel during weekend or non weekend trip variable.

5.2 Comparison between two mode choices and three mode choices models

In the USA, the personal vehicle and air modes dominate the long distance transportation choice, which affects this research because the data from ground transportation is very small (288 cases out of 16,861 cases); therefore, the three mode choice models may not accurately capture the characteristics of the ground transportation traveler. For the Neural Networks comparison, NuClass7 is much faster than Neurosolutions and the logit model because the pruning method and hidden weight optimization (HWO) are used to determine the number of neurons and learning rate instead of trial and error. Hidden weight optimization gives a better result when there may be missing or unavailable data for some variables to select two mode choices. On the other hand, for three mode choices, nested logit gives a better result than hidden weight optimization when some variables are unavailable, even though they have almost the same performance when all variables are present.

5.3 Comparison between Logistic regression and Neural Network

Logistic regression is better for interpreting each variable's effect on the output in terms of increasing and decreasing the value of each variable based on signs, magnitudes, and level of significance of the coefficients. Neural Networks lack the ability to provide for much interpretation of the variables; however, the importance of the variables can be identified by sensitivity analysis and piecewise linear network floating search. According to the results, for logit models, the most significant variables that influence a traveler's mode choice decision are shown in the model based on the t-statistic (significance). These variables are different from Neural Network models except for route distance; the reason for this result is probably related to multicollinearity between the variables. Logistic regression shows a high standard error when multicollinearity occurs in the model, which indicates that one of the variables must be dropped from the model. However, a Neural Network has the capability to handle multicollinearity; therefore, some of the important variables are not the same. The comparison in this research based on percent correct of model predictions; shows that the percent correct are very close for all of the models and the difference is less than 4%. According to the results, Neural Networks should be used to predict rather than explain behavior.

5.4 Sensitivity analysis and feature selection comparison

The sensitivity analysis of logit model is arc sensitivity analysis based on the difference between the range of a given value, but the sensitivity of Neural Network is point sensitivity obtained by differentiating the network function, $Net_j = \Sigma W_{ij}X_i$, with respect to a weight, W_{ij}. The sensitivity of the logit model and Neural Networks method are different; therefore, the results show a difference in ordering of important variables. In this section, Neural Network sensitivity represents sensitivity analysis from Neurosolutions software and piecewise linear network floating search represents feature selection from NuClass7.

For two choice models, Neural Network sensitivity and piecewise linear network floating search show that route distance is the most important for each purpose, but, for the business purpose, the logit model shows that the number of household numbers on the trip is the most important; however, it is ranked number four both in Neural Networks (Neural Network sensitivity and piecewise linear network floating search). Route distance is almost the least important in the logit model after nights away on the trip. When the household located in an urban area is the second most important variable in the logit but it has a less effect for both Neural Network sensitivity and piecewise linear network floating search.

For the personal business purpose, the logit model provides the different result from Neural Network sensitivity and piecewise linear network floating search, route distance is the least important for this purpose, and instead, white travelers have the most sensitive effect on the decision. For the logit model, the most important variable is the less important in Neural Network sensitivity and piecewise linear network floating search and the rest are also opposite.

Also, for the pleasure purpose, the logit model is most sensitive to Asian travelers; however, it is the third most important variable for Neural Network sensitivity and the less important for piecewise linear network floating search. Route distance is the third most important for the logit model, but it is the most important for both Neural Network sensitivity and piecewise linear network floating search. A household located in an urban area is the second most important variable for the logit model but it is the least important for Neural Network sensitivity and has a middle effect for piecewise linear network floating search.

For three mode choices, again, Neural Network sensitivity and piecewise linear network floating search provides different results from the logit model. Based on the logit model, the "other" occupation is the most important for business purpose, but it is the third and second most important for Neural Network sensitivity and piecewise linear network floating search, respectively. Nights away on the trip is the least important for the logit model and has the middle effect for Neurosolution, but it is the third most important for piecewise linear network floating search.

A Long weekend trip exerts the most influence on the logit model for the personal business purpose, but it is almost the least important for both Neural Network sensitivity and piecewise linear network floating search. The least important for Neural Network sensitivity is a household income from $20,000 to $44,999, but it is the middle important for piecewise linear network floating search.

For the pleasure purpose; Asian travelers continue to have the greatest effect on the logit model and second largest effect for Neural Network sensitivity, but they are the less important for piecewise linear network floating search. Route distance is the third least important for logit after nights away on the trip and number of vehicles in the household. Number of vehicles in the household has the less effect for both Neural Network sensitivity and piecewise linear network floating search and is the second least important for the logit model.

Interestingly, for the logit model results, all of the most important variables are categorical variables, but the most important variable for Neural Network sensitivity and piecewise linear network floating search is route distance (continuous variable). This seems to confirm the author's previous suggestion that for long distance travel, route distance should not be slightly increased for sensitivity analysis testing. Lastly, the most important for Neural Network sensitivity and piecewise linear network floating search is different from the logit model, but the lesser important variables are almost the same ranking.

5.5 Variable selection evaluation

In this section, logistic regression method, Neural Network sensitivity analysis, and piecewise linear network floating search (feature selection), are compared to determine the method that can identify the best variable set for prediction. A dataset was selected for the three approaches to determine which variables are important; the three approaches provided the important variables. Three calibration datasets with three validation datasets are obtained from the three variable selection methods using five variables. Each dataset is evaluated by the other two methods. For example, five variables are selected from Neural Network sensitivity, and then the calibration and validation datasets are obtained based on those five variables. The other two methods (logit and hidden weight optimization algorithm) are used to calculate percent correct of calibration and validation dataset. Finally, based on the lowest percent correct, the best method to select variable can be identified.

The author selected the dataset to test from the two choice case for pleasure trips. The most important variables selected from each method are:

- Logistic regression: number of household members on the trip, route distance, race: Asian, household located in an urban area, and below $20,000 household income traveler.
- Neural Network sensitivity: route distance, household members on the trip, race: Asian and African American, and occupation: sales or service.
- Piecewise linear network floating search: route distance, nights away on the trip, household members on the trip, number of vehicles in household, and long weekend trip.

Logistic regression is used to determine which variables appear significant for each dataset. The results are shown in Table 5.6.

Table 5.6 Selected variables that appear significant using logistic regression

Dataset	Significant variables for logistic regression
Logistic regression dataset	Number of household members on the trip Route distance Asian Household located in an urban area Below $20,000 household income
Neural Network sensitivity dataset	Number of household members on the trip Route distance Asian
Piecewise linear network floating search dataset	Nights away on the trip Number of household members on the trip Number of vehicles in a household Long weekend

For Neural Networks, numbers of neurons for each variable selection method are shown in Table 5.7.

Table 5.7 Number of required neurons

Variable selection method	Number of neurons	
	Backpropagation	Hidden weight optimization
Logistic regression method	4	6
Neural Network sensitivity	4	6
Piecewise linear network floating search	4	4

Table 5.8 shows the percent correct for the calibration dataset from each variable selection method that are evaluated with logistic regression, backpropagation algorithm, and hidden weight optimization algorithm.

Table 5.8 Calibration percent correct for three variable selection methods

Variable selection method	**Logistic regression model**	**Backpropagation**	**Hidden weight optimization**
Logistic regression method	95.90%	96.12%	96.19%
Neural Network sensitivity	95.80%	95.90%	96.08%
Piecewise linear network floating search	95.90%	96.12%	96.29%

Table 5.9 shows the percent correct for the validation dataset from each variable selection method that are evaluated with logistic regression, backpropagation algorithm, and hidden weight optimization algorithm.

Table 5.9 Validation percent correct for three variable selection methods

Variable selection method	**Logistic regression model**	**Backpropagation**	**Hidden weight optimization**
Logistic regression method	93.76%	96.20%	96.21%
Neural Network sensitivity	94.08%	95.95%	95.82%
Piecewise linear network floating search	95.37%	95.88%	96.27%

From Tables 5.8 and 5.9, based on the percent correct, the piecewise linear network floating search provides the highest percent correct using the hidden weight optimization algorithm. Also, when piecewise linear network floating search is used with the logistic regression model, it provides the highest percent correct. Therefore, the piecewise linear network floating search provides the best variable for prediction; however, the other two methods are still good variable selection methods because the differences of percent error are less than three percent.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This dissertation examined Neural Network models as an alternative to traditional logistic regression. The objectives of this dissertation were

1. Identify the purposes, demographic characteristics, and trip characteristics that have significant impacts on mode choice.
2. Identify variables in demographic characteristics and trip characteristics that is exclusive to the specific trip purposes.
3. Develop and compare the logit and Neural Network models: usually the mode choice behavior is estimated by logistic regression based on random utility theory [19]: however: a different approach to mode choice behavior with a good prediction capability is Neural Network models proposed by Shmueli [50].
4. Develop recommendations for long distance travel modeling and interregional or statewide transportation planning.

The Neural Network model used backpropagation and hidden weight optimization algorithms to predict long distance travel mode choices. Logistic regression (Binary logit and Nested logit) were compared with the Neural Network models. The predictive ability of the models was measured based on the percent correct in validation.

Both methods generated strong results, although Neural Networks yielded slightly better prediction. Neural Networks deliver a higher percent correct (greater than ninety percent) than logistic regression. However, nested logit models provided effectively capture the mode choice decision when dealing with a lack of variable.

Long distance models are developed to observe traveler behavior and to predict the mode choices using logistic regression and Neural Networks. However, Neural Networks are weak for interpreting the impact of individual variables; therefore, Neural Networks should be used to predict rather than explain behavior. The rest of this chapter focuses on the observations made during the research effort, summary of results and key findings.

6.1 Conclusions

In this research, the 2001 National Household Travel Survey is used to investigate three objectives and test the impact of three sets of variables affecting mode choice for long distance trips: traveler socio-economic characteristics such as income, age, occupation and number of household members traveling, etc., trip distance, and trip characteristics (short weekend, long weekend, and non weekend trip). Mode choice alternatives for long distance travel include: personal vehicle, air, and ground (bus and train). Additionally, three different trip purposes (business, personal business, and pleasure) are considered. Long distance travel brings the benefit people by providing opportunities for economic growth, social participation, and changes in environment.

The analysis has confirmed that nights away on the trip, household members on the trip, age, route distance, vehicles, race, household located in urban or rural area, a occupation, income, and trip characteristics have significant impact on mode choices for different purposes.

The summary of variables shown significant by the logit models:

Binary logit models:

- Business purpose; the variables included in the model are:
  - number of nights away on the trip,
  - number of household members on the trip,
  - route distance from origin to destination,
  - household in urban area, and
  - long weekend trip period
- Personal business purpose; the variables included in the model are:
  - number of household members on the trip,
  - route distance from origin to destination,
  - race: white, and
  - household in urban area
- Pleasure purpose; the variables included in the model are:
  - the number of household members on the trip,
  - route distance,
  - race: Asian,
  - household in urban area, and
  - below $20,000 for household income

Nested logit models level 1:

- Business purpose; the variables included in the model are:
    - number of nights away on the trip,
    - route distance, and
    - short weekend
- Personal business purpose; the variables included in the model are:
    - age, and
    - route distance
- Pleasure purpose; the significant variables in the model are:
    - nights away on the trip, and
    - route distance

Nested logit models level 2:

- Business purpose; the variables included in the model are:
    - route distance, and
    - occupation (sales or service and other)
- Personal business purpose; the variables included in the model are:
    - number of household members on the trip,
    - household located in urban area, and
    - long weekend trip
- Pleasure purpose; the variables included in the model are:
    - number of household members on travel period trip,
    - number of vehicles in household,

- race (Asian),
- household located in urban area,
- long weekend trip, and
- below $20,000 for household income

Based on the binary logit model results, route distance shows a strong influence on the mode choice for each purpose. Also, route distance appears to be a strong influence on the lower level of the nested logit models for determining the mode choice decision between the ground and air mode. For the upper level of the nested logit model, route distance appears to also influence the decision between personal vehicle and public carrier, but only for the business purpose.

A household located in an urban area appears in each logit model; therefore, it also plays an important role in the mode choice decision as the assumption that a traveler who lives in an urban area has more opportunities to travel and more variety of alternatives to use personal vehicle than a traveler who lives in a rural area.

A traveler's occupation may also affect the mode choice decision between personal vehicle and public carrier where a traveler in the sales, service, or other occupational categories tend to travel by personal vehicle rather than public carrier.

A traveler who travels over long weekends, has below $20,000 household income, lives in an urban area, has many household members on the trip, or spends few nights on the trip prefers to make a long distance trip by personal vehicle. Considering age and route distance, as the age of traveler increases, the traveler tends to travel by the air mode; this is the same as route distance increases, a traveler tends to travel by the air mode more.

In this research, distance boundaries for each purpose are obtained. Based on the logit models, a range of possible values between the maximum and minimum boundary distances is determined. These maximum and minimum levels indicate that if the route distance is longer than the maximum distance, a traveler definitely prefers to travel using the mode that the sign of the route distance variable indicates, and if the route distance is shorter than the minimum distance, traveler definitely prefers to travel with the other mode. The results show that the overall maximum is 2,100 miles for determining the mode choice boundary between the personal vehicle and the air mode for pleasure purpose and the overall minimum with regard to a specific number is 105 miles for determining the mode choice between ground transportation and the air mode for the business purpose. The results, for the two choice case, show that the business purpose provide lower boundary values for maximum and minimum preference boundaries than the personal business and pleasure purpose and the maximum and minimum preference boundaries for the pleasure purpose are higher than the personal business purpose. For the three choice case, the personal business purpose, in the lower level, has a higher maximum preference boundary than the pleasure purpose, but, for the upper level, the pleasure purpose has the higher maximum and the lower minimum preference boundary values.

Based on sensitivity analysis, households located in an urban area, occupation, and race are the most important variables for the logit models. For the Neural Network sensitivity analysis and piecewise linear network floating search, route distance is the most important variable, but it is almost the least important variable for logit model when a minimal increase in distance of ten percent is used. However, an increase of only ten percent for route distance on long distance trips is unlikely to a mode shift. The author recommends that long distance travel is different from daily travel trips; therefore, the sensitivity for distance should not be slightly increased by ten or twenty percent; but some higher value. The appropriate value of this change should investigate in the future.

The selection of variables between logistic regression model and Neural Networks model are different. The logistic regression selected significant variables based on statistical assessments. The Neural Networks selected the variables based on sensitivity for the networks; however, using all of the variables in the networks gives the lowest percent error and the computational time is not significantly different from models with fewer variables. For the Neural Networks models, route distance also shows the most influence on the network model. The analysis has suggested that route distance is the most important variable for making a long distance mode choice for both the two and three mode choice models based on the Neural Network sensitivity analysis and piecewise linear network floating search results.

In this study, variables that exclusive to specific trip purposes between business, personal business, and pleasure trip are the number of vehicles in a household, occupation, and income. As mentioned in Chapter two, income may not affect the mode choice decision for business and personal business purpose, but occupation may affect the business purpose trips. According to this research, the number of vehicles in a household increases the propensity to travel for the pleasure purpose, which is a different finding from Georggi and Pendyala's research [26], which is based on the business purpose for elderly and low income travelers. Based on the logit results, income is only significant for the pleasure purpose trips, but it is not significant for business and personal purposes. Occupation appears significant for the business purpose.

For prediction performance, the prediction results show that Neural Network models (hidden weight optimization) outperform for two mode choices (personal vehicle and air mode) and nested logit models outperform for three mode choices (personal vehicle, air, and ground). The results indicate that the Neural Networks are a possible model for estimating long distance travel mode choices; however, for data mining, logistic regression provides better explanations of the variables, especially, for independence from irrelevant alternatives (IIA).

Contributions of this research are:

- Development of long distance travel model by logistic regression and Neural Network.
- Comparison of performance among binary logit, nested logit, and Neural Network (both algorithms).
- Investigate the effect of household socioeconomics, route distance, and trip characteristic for long distance travel.

6.2 Implementation discussions

This dissertation has developed models to observe and predict long distance travel behavior. Also, the models can be used as a marketing tool for airlines and other transportation providers. This will benefit the state and region for determining demand on long distance transportation modes. Based on forecasts for particular modes, state and regional authorities can provide sufficient infrastructure for travelers and promote others alternative modes to reduce congestion.

Models for two mode choices and three mode choices can be used by a state or region to observe and predict mode choices for long distance travelers. The state may be able to provide these values as external input to the regional planning model.

In the future, the author expects that long distance trips will increase in the USA based on the large scale investment in transportation networks, such as the Trans Texas Corridor and low costs within the airline industry. Due to the uncertainty of gasoline prices, personal vehicle use may decrease its proportion of total person miles travel, which may affect access to facilities and services, such as health care, retail outlets, or social events, particularly in rural areas; therefore, economic and social benefits will be decreased. In order to provide the opportunities to maintain economic, social, and environment benefits, investment in a public carrier such as a high speed or Maglev train may need to be considered because these may prove to be an effective alternative in terms of low emissions and fuel consumption.

6.3 Future research

Future research to expand this dissertation includes:

- Race can be modeled separately to observe the travel behavior for each race, which may differ due to income level, cultural habits, and location.
- Travel behavior may be observed separately for urban and rural areas to obtain the behavior of travelers who may have different habits based on the location of household.
- A time dimension should be introduced in the choice problem. Month (season) can indicate what time of the year people prefer to travel and what mode choices travelers need under these different conditions.
- Access and egress mode, time, cost, and reliability should be considered in the model to assess their impact on traveler behavior.

The current data from the 2001 NHTS does not provide data about travel time, travel cost, destination, and destination characteristics requirements. In future data set, the NHTS should have data about travel time, travel cost, destination, and information on other mode choices for travelers to construct a more generic model.

APPENDIX A

LOGISTIC REGRESSION CROSS TABULATION RESULTS

A.1 Binary logit business purpose

Table A.1 Binary logit business purpose: mode frequency

	Frequency	Percent
Personal Vehicle	5152	89.7
Air	590	10.3
Total	5742	100

Table A.2 Binary logit business purpose: calibration: cross tabulation

Calibration	Predicted		
Observed	0	1	
0	5094	58	Percent Correct
1	210	380	95.3

Table A.3 Binary logit business purpose: validation: cross tabulation

Validation USA		CarAirPredicted		Total	
		0	1		
CarAir	0	1270	18	1288	
	1	60	88	148	Percent Correct
Total		1330	106	1436	94.56

Table A.4 Binary logit business purpose: Texas: cross tabulation

Texas		CarAirPredicted		Total	
		0	1		
CarAir	0	196	25	221	
	1	1	30	31	Percent Correct
Total		197	55	252	89.68

Table A.5 Binary logit business purpose: Wisconsin: cross tabulation

Wisconsin		CarAirPredicted		Total	
		0	1		
CarAir	0	248	9	257	
	1	5	6	11	Percent Correct
Total		253	15	268	94.77

A.2 Binary logit personal business purpose

Table A.6 Binary logit personal business purpose: mode frequency

	Frequency	Percent
Personal Vehicle	1209	93.6
Air	83	6.4
Total	1615	100

Table A.7 Binary logit personal business purpose: calibration: cross tabulation

Calibration	Predicted		
Observed	0	1	
0	1197	12	Percent Correct
1	41	42	95.9

Table A.8 Binary logit personal business purpose: validation: cross tabulation

Validation USA		CarAirPredicted		Total	
		0	1		
CarAir	0	306	1	307	
	1	13	3	16	Percent Correct
Total		319	4	323	95.66

Table A.9 Binary logit personal business purpose: Texas: cross tabulation

Texas		CarAirPredicted		Total	
		0	1		
CarAir	0	615	4	619	
	1	38	4	42	Percent Correct
Total		653	8	661	93.64

Table A.10 Binary logit personal business purpose: Wisconsin: cross tabulation

Wisconsin		CarAirPredicted	Total	
		0		
CarAir	0	58	58	
	1	1	1	Percent Correct
Total		59	59	98.30

A.3 Binary logit pleasure purpose

Table A.11 Binary logit pleasure purpose: mode frequency

	Frequency	Percent
Personal Vehicle	5768	92.7
Air	456	7.3
Total	6224	100

Table A.12 Binary logit pleasure purpose: calibration: cross tabulation

Calibration	Predicted		
Observed	0	1	
0	5709	59	Percent Correct
1	197	259	95.9

Table A.13 Binary logit pleasure purpose: validation: cross tabulation

Validation USA		CarAirPredicted		Total	
		0	1		
CarAir	0	1432	3	1435	
	1	94	27	121	Percent Correct
Total		1526	30	1556	93.76

Table A.14 Binary logit pleasure purpose: Texas: cross tabulation

Texas		CarAirPredicted		Total	
		0	1		
CarAir	0	473	1	474	
	1	15	4	19	Percent Correct
Total		488	5	493	96.75

Table A.15 Binary logit pleasure purpose: Wisconsin: cross tabulation

Wisconsin		CarAirPredicted		Total	
		0	1		
CarAir	0	375	2	377	
	1	23	5	28	Percent Correct
Total		398	7	405	93.82

A.4 Nested logit business purpose

Table A.16 Nested logit business purpose: mode frequency

	Frequency	Percent
Personal Vehicle	5145	87.8
Air	599	10.2
Ground	116	2
Total	5860	100

Table A.17 Nested logit business purpose: calibration: cross tabulation: level 1

Nested Level 1 Ground/Air

	Predicted		
Observed	0	1	
0	43	73	Percent Correct
1	7	592	88.80

Table A.18 Nested logit business purpose: calibration: cross tabulation: level 2

Nested Level2 Car/Public

	Predicted		
Observed	0	1	
0	5091	54	Percent Correct
1	308	407	93.8

Table A.19 Nested logit business purpose: validation: cross tabulation: level 1

Validation USA Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	21	10	31	
	1	9	130	139	Percent Correct
Total		30	140	170	88.82

Table A.20 Nested logit business purpose: validation: cross tabulation: level 2

Validation Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	1263	32	1295	
	1	78	92	170	Percent Correct
Total		1341	124	1465	92.49

Table A.21 Nested logit business purpose: Texas: cross tabulation: level 1

Texas Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	1	1	2	
	1	5	26	31	Percent Correct
Total		6	27	33	81.81

Table A.22 Nested logit business purpose: Texas: cross tabulation: level 2

Texas Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	216	5	221	
	1	15	18	33	Percent Correct
Total		231	23	254	92.12

Table A.23 Nested logit business purpose: Wisconsin: cross tabulation: level 1

Wisconsin Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	2	0	2	
	1	1	10	11	Percent Correct
Total		3	10	13	92.30

Table A.24 Nested logit business purpose: Wisconsin: cross tabulation: level 2

Wisconsin Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	248	9	257	
	1	7	6	13	Percent Correct
Total		255	15	270	94.07

A.5 Nested logit personal business purpose

Table A.25 Nested logit personal business purpose: mode frequency

	Frequency	Percent
Personal Vehicle	1218	92.4
Air	74	5.6
Ground	26	2
Total	1318	100

Table A.26 Nested logit personal business purpose: calibration: cross tabulation: level 1

Nested Level 1 Air/Ground

	Predicted		
Observed	0	1	
0	22	4	Percent Correct
1	3	71	93.00

Table A.27 Nested logit personal business purpose: calibration: cross tabulation: level 2

Nested Level2 Car/Public

	Predicted		
Observed	0	1	
0	1205	13	Percent Correct
1	71	29	93.60

Table A.27 Nested logit personal business purpose: validation: cross tabulation: level 1

Validation USA Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	4	2	6	
	1	0	25	25	Percent Correct
Total		4	27	31	93.54

Table A.29 Nested logit personal business purpose: validation: cross tabulation: level 2

Validation Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	293	5	298	
	1	18	13	31	Percent Correct
Total		311	18	329	93.00

Table A.30 Nested logit personal business purpose: Texas: cross tabulation: level 1

Texas Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	20	2	22	
	1	4	38	42	Percent Correct
Total		24	40	64	90.63

Table A.31 Nested logit personal business purpose: Texas: cross tabulation: level 2

Texas Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	603	16	619	
	1	37	27	64	Percent Correct
Total		640	43	683	92.24

Table A.32 Nested logit personal business purpose: Wisconsin: cross tabulation: level 1

Wisconsin Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	2	1	3	
	1	0	1	1	Percent Correct
Total		2	2	4	75.00

Table A.33 Nested logit personal business purpose: Wisconsin: cross tabulation: level 2

Wisconsin Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	58	0	58	
	1	4	0	4	Percent Correct
Total		62		62	93.54

A.6 Nested logit pleasure purpose

Table A.34 Nested logit pleasure purpose: mode frequency

	Frequency	Percent
Personal Vehicle	5762	91.3
Air	459	7.3
Ground	90	1.4
Total	6311	100

Table A.35 Nested logit pleasure purpose: calibration: cross tabulation: level 1

Nested Level 1 Air/Ground

	Predicted		
Observed	0	1	
0	68	22	Percent Correct
1	17	442	92.9

Table A.36 Nested logit pleasure purpose: calibration: cross tabulation: level 2

Nested Level2 Car/Public

	Predicted		
Observed	0	1	
0	5699	63	Percent Correct
1	290	259	94.4

Table A.37 Nested logit pleasure purpose: validation: cross tabulation: level 1

Validation
USA

Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	16	3	19	
	1	4	114	118	Percent Correct
Total		20	117	137	94.89

Table A.38 Nested logit pleasure purpose: validation: cross tabulation: level 2

Validation Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	1432	9	1441	
	1	94	43	137	Percent Correct
Total		1526	52	1578	93.47

Table A.39 Nested logit pleasure purpose: Texas: cross tabulation: level 1

Texas Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	6	0	6	
	1	0	19	19	Percent Correct
Total		6	19	25	100.00

Table A.40 Nested logit pleasure purpose: Texas: cross tabulation: level 2

Texas Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	470	4	474	
	1	19	6	25	Percent Correct
Total		489	10	499	95.39

Table A.41 Nested logit pleasure purpose: Wisconsin: cross tabulation: level 1

Wisconsin Level 1		AirGoundPredicted		Total	
		0	1		
AirGround	0	5	0	5	
	1	1	28	29	Percent Correct
Total		6	28	34	97.05

Table A.42 Nested logit pleasure purpose: Wisconsin: cross tabulation: level 2

Wisconsin Level 2		CarPublicPredicted		Total	
		0	1		
CarPublic	0	372	4	376	
	1	22	12	34	Percent Correct
Total		394	16	410	93.65

APPENDIX B

WEIGHT RESULTS FROM NEURAL NETWORKS BACKPROPAGATION

B.1Weight result for personal vehicle and air for business purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 5742.

#NSWeightFileVersion 225

#inputFile File
21
3.272727131843567e-002 -8.999999761581421e-001
3.599999845027924e-001 -1.259999990463257e+000
2.465753443539143e-002 -1.294520497322083e+000
1.952796592377126e-004 -9.097639322280884e-001
1.999999880790710e-001 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
10 1
1
10 -4.550007581710815e-001 -9.545778036117554e-001 -
2.801769733428955e+000 -1.992615222930908e+000 1.695468187332153e+000
5.617814064025879e-001 1.181109666824341e+000 -3.251133441925049e+000
3.360217511653900e-001 1.711189508438110e+000

#outputAxon TanhAxon
2 1
1
```

```
2 -2.864730730652809e-002 9.868446588516235e-001

#criterion L2Criterion
2 1
1
0

#hidden1Synapse FullSynapse
210 -9.666162729263306e-001 1.918311417102814e-001 -
6.914424300193787e-001 2.114627361297607e+000 3.003650605678558e-001
3.379695490002632e-002 -3.528567776083946e-002 8.143535852432251e-001
-3.805941641330719e-001 -3.664441704750061e-001 2.927210330963135e-001
1.302691578865051e+000 1.289058178663254e-001 -8.649754524230957e-001
-1.475114822387695e-001 -8.488003611564636e-001 1.459458112716675e+000
-4.689155519008637e-001 -7.790535092353821e-001 5.137180685997009e-001
5.444844365119934e-001 1.601726174354553e+000 3.233021736145020e+000
4.199409186840057e-001 -1.056539344787598e+001 -1.990342497825623e+000
3.426389396190643e-001 1.064973235130310e+000 -2.360738366842270e-001
1.350837826728821e+000 -8.948894739151001e-001 1.010893702507019e+000
1.721383452415466e+000 5.296640470623970e-002 -2.709047496318817e-001
1.037388682365418e+000 1.017449975013733e+000 6.398629546165466e-001 -
2.404033839702606e-001 -7.578970789909363e-001 1.960522979497910e-001
1.673031687736511e+000 -3.330952167510986e+000 -2.857394695281982e+000
6.274774670600891e-001 -1.962164402008057e+000 1.989631295204163e+000
7.596067786216736e-001 1.392757534980774e+000 1.664159774780273e+000
1.217907309532166e+000 1.182406902313232e+000 -1.270687341690064e+000
5.530751347541809e-001 2.065736293792725e+000 2.930259227752686e+000 -
3.600887358188629e-001 1.724758386611939e+000 -1.157635092735291e+000
2.050903797149658e+000 2.094137907028198e+000 9.206069111824036e-001 -
4.499183595180512e-001 -2.138410322368145e-002 -4.032859578728676e-002
-1.115646600723267e+000 -9.824437141418457e+000 -
1.769274830818176e+000 9.396024346351624e-001 8.098905086517334e-001
3.003393650054932e+000 -6.595366597175598e-001 8.547891974449158e-001
-6.906575560569763e-001 1.843643188476563e+000 -3.249289691448212e-001
3.748016595840454e+000 -1.149672985076904e+000 -1.082590818405151e+000
9.921252131462097e-001 2.029953241348267e+000 7.414295673370361e-001
7.706222534179688e-001 5.961183309555054e-001 3.956944465637207e+000 -
5.841621398925781e+000 3.682313919067383e+000 6.437494277954102e+000
3.782961368560791e+000 -8.816000819206238e-001 7.716684341430664e-001
-4.801712334156036e-001 -2.368723392486572e+000 2.806331634521484e+000
-2.848284244537354e+000 -5.753829479217529e-001 -
3.638134717941284e+000 4.360054492950440e+000 -2.677002429962158e+000
-1.096997022628784e+000 3.287924528121948e-001 -7.896124124526978e-001
-4.490016400814056e-002 -2.085647583007813e+000 8.511776328086853e-001
1.545975923538208e+000 8.892361819744110e-002 9.944005012512207e-001 -
4.156175613403320e+000 -4.988228380680084e-001 -9.764865972101688e-003
1.789464652538300e-001 -1.115909934043884e+000 7.243200540542603e-001
5.132631659507752e-001 -3.328151404857636e-001 -1.775198221206665e+000
-5.224234461784363e-001 1.588249683380127e+000 6.236625313758850e-001
1.446088075637817e+000 -2.300390720367432e+000 8.963499069213867e-001
1.442127585411072e+000 -7.230877280235291e-001 -8.179808259010315e-001
-2.645335197448731e+000 -2.086246490478516e+000 -8.203002810478210e-
001 1.459819984436035e+001 -9.935390949249268e-001 -
```

4.629020690917969e-001 -7.374179959297180e-001 -9.383911490440369e-001
-8.058135509490967e-001 -3.139557242393494e-001 3.660077452659607e-001
-4.741933569312096e-002 2.481552772223949e-002 -3.914751768112183e+000
9.904156327247620e-001 -9.775274991989136e-001 8.957248181104660e-002
-5.230983495712280e-001 -6.230674386024475e-001 -3.257925510406494e-001 -5.281250476837158e-001 -5.726162791252136e-001 -8.161112070083618e-001 -8.701348900794983e-001 -1.020288944244385e+001
1.631034493446350e+000 1.544632434844971e+000 1.338760375976563e+000
1.808866977691650e+000 1.115230917930603e+000 2.108087092638016e-001 -8.841849118471146e-002 1.828137397766113e+000 1.108337044715881e+000
1.359418511390686e+000 1.888807415962219e+000 8.984630703926086e-001
1.821403503417969e+000 2.956877946853638e-001 1.106171369552612e+000
8.786014318466187e-001 9.058265089988709e-001 4.198998510837555e-001 -3.491356670856476e-001 3.641261458396912e-001 -4.396439194679260e-001
-9.961203485727310e-002 -7.783023267984390e-002 -8.803430944681168e-002 -5.193485021591187e-001 5.027959868311882e-002 1.228372380137444e-001 -2.989776134490967e-001 -7.964035272598267e-001 -1.829414665699005e-001 3.251526355743408e-001 -1.578485667705536e-001
2.780018746852875e-001 -7.414717078208923e-001 9.440874308347702e-002
1.880802959203720e-001 -3.202932476997376e-001 -3.120992183685303e-001
-2.070697307586670e+000 8.822246640920639e-002 5.521582126617432e+000
-2.620082616806030e+000 1.575846791267395e+000 -7.341769337654114e-001
4.111110866069794e-001 -1.124431848526001e+000 -1.225465059280396e+000
-9.465464353561401e-001 1.059270262718201e+000 7.349936366081238e-001
-1.379810094833374e+000 -2.473100572824478e-001 -1.909114956855774e+000 -1.308511018753052e+000 4.272218793630600e-002
-2.193431407213211e-001 -1.744317114353180e-001 -1.411984860897064e-002 -1.185534596443176e+000

#hidden1SynapseBackprop BackFullSynapse
210 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
20 -2.260709285736084e+000 1.809480071067810e+000
1.667780518531799e+000 1.464226245880127e+000 -1.746698617935181e+000
6.478939056396484e-001 -1.181888818740845e+000 2.786669254302979e+000
```

```
-1.211609363555908e+000 1.446204900741577e+000 -1.059608101844788e+000
-1.851626873016357e+000 -1.701847434043884e+000 -
1.465036630630493e+000 1.779217720031738e+000 -2.415433883666992e+000
1.150111794471741e+000 -2.809538364410400e+000 -1.371208786964417e+000
-1.485395789146423e+000

#outputSynapseBackprop BackFullSynapse
20 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000

#outputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
210 -7.108991849236190e-004 -7.285434403456748e-004 -
3.380452399142087e-004 -7.081029471009970e-004 -4.202751151751727e-004
9.770060423761606e-004 -6.735218339599669e-004 -7.290508947335184e-004
-1.031063380651176e-003 7.067963015288115e-004 -7.067963015288115e-004
-2.158859388146084e-005 -7.241520797833800e-004 -7.270188652910292e-
004 1.612980304344092e-005 -7.348129875026643e-004 -
6.558556196978316e-005 7.208362512756139e-005 -7.314454414881766e-004
-9.065973572432995e-004 9.097277070395649e-004 6.624299567192793e-004
7.380772731266916e-004 3.086471115238965e-004 6.446268525905907e-004
1.968692085938528e-004 -1.072547747753561e-003 9.385237353853881e-004
7.475801976397634e-004 8.773735025897622e-004 -5.975959356874228e-004
5.975959356874228e-004 2.286183880642057e-003 2.298533654538915e-004
4.077475459780544e-004 -1.432855380699039e-003 8.089182083494961e-004
6.877482519485056e-004 -7.512015872634947e-004 5.833608447574079e-004
2.463214332237840e-003 -2.301110653206706e-003 -1.428819145075977e-003
-1.328129204921424e-003 6.703698891215026e-004 -1.173505326732993e-003
-7.114887703210115e-004 1.281204400584102e-003 -1.301263226196170e-003
```

-1.346047036349773e-003 -1.321146031841636e-003 9.308871813118458e-004
-9.308871813118458e-004 8.576254476793110e-004 -2.640463877469301e-003
-1.071996870450676e-003 1.675838575465605e-004 -1.275953487493098e-003
-1.346594071947038e-003 1.278921496123076e-003 8.749481639824808e-004
6.350026815198362e-004 -2.853576559573412e-003 8.992883522296324e-005
6.894457328598946e-005 -8.036763756535947e-005 1.536889758426696e-004
-1.927972189150751e-004 -2.520176058169454e-004 6.807308091083542e-005
1.687964395387098e-004 3.524930216372013e-004 -2.234620740637183e-003
2.234620740637183e-003 1.733940152917057e-004 1.492696610512212e-004
1.804689236450940e-004 -1.657874381635338e-004 2.049359754892066e-004
-1.850784989073873e-003 1.814521616324782e-003 2.572017547208816e-004
7.162828114815056e-004 -8.048121235333383e-004 -6.345783185679466e-005
-2.456913352943957e-005 -2.945292799267918e-004 -6.158333417261019e-005 -2.240248431917280e-005 1.878060284070671e-004 -1.134065096266568e-004 -9.089574450626969e-005 -1.561792741995305e-004
2.932445204351097e-004 -2.932445204351097e-004 -6.333942292258143e-004
1.348021214653272e-005 -1.703067246126011e-004 6.175450980663300e-004
-7.175353821367025e-004 1.669574849074706e-004 4.642401472665370e-004
-2.547818003222346e-004 -3.294388006906956e-004 4.978828947059810e-004
1.747467089444399e-003 1.818040153011680e-003 9.533228585496545e-004
1.745167654007673e-003 1.037913491018117e-003 -2.261470537632704e-003
1.735266996547580e-003 1.790594193153083e-003 2.317014615982771e-003 -1.964242197573185e-003 1.964242197573185e-003 -2.487238380126655e-004
1.778941717930138e-003 1.786445965990424e-003 2.647416258696467e-004
1.796745928004384e-003 2.916806261055172e-004 -2.977241820190102e-004
1.794104813598096e-003 2.210180275142193e-003 -2.213582396507263e-003
-2.244081348180771e-003 -2.185143297538161e-003 -1.786272041499615e-004 -2.246433403342962e-003 -6.544463103637099e-004
3.461974672973156e-003 -2.178338589146733e-003 -2.291791373863816e-003
-3.575713606551290e-003 2.119865268468857e-003 -2.119865268468857e-003
-3.851224202662706e-003 -2.230487996712327e-003 -2.310058334842324e-003 3.807901637628675e-003 -2.407510066404939e-003 -1.099102199077606e-003 1.214678632095456e-003 -2.794039668515325e-003
1.492502400651574e-003 -9.903974132612348e-004 2.290857955813408e-003
2.238159766420722e-003 1.047116355039179e-003 2.151671564206481e-003
7.004066719673574e-004 -2.112083137035370e-003 2.378496108576655e-003
2.352909883484244e-003 2.088893670588732e-003 -2.334164455533028e-003
2.334164455533028e-003 3.807794128078967e-004 2.288804622367024e-003
2.181275747716427e-003 -1.426437229383737e-004 3.457353450357914e-003
1.028632861562073e-003 -2.131877932697535e-003 3.497009165585041e-003
1.122179906815291e-003 -2.265080576762557e-003 6.460285658249632e-005
7.832398841856048e-005 1.805028114176821e-005 6.510411185445264e-005
5.275950024952181e-005 -1.021078860503621e-004 7.787536014802754e-005
6.932819087523967e-005 9.521403990220279e-005 -1.674596423981711e-004
1.674596423981711e-004 5.211342431721278e-005 6.806557939853519e-005
7.259631092892960e-005 -5.246559521765448e-005 5.623256220133044e-005
-1.233785878866911e-004 1.373008999507874e-004 7.531226583523676e-005
9.400607086718082e-005 -9.916348062688485e-005 5.075049120932818e-004
4.297005361877382e-004 2.775248140096664e-004 4.480757634155452e-004
2.550586359575391e-004 -4.182304546702653e-004 5.069772596471012e-004
5.067454767413437e-004 4.149012675043196e-004 -5.149235366843641e-004
5.149235366843641e-004 5.772038712166250e-004 3.539603203535080e-004
5.131596117280424e-004 -4.339302540756762e-004 6.646704277954996e-004

```
2.091231872327626e-004 -3.685967822093517e-004 5.292961141094565e-004
6.206419202499092e-004 -6.447411724366248e-004

#hidden1AxonBackpropGradient Momentum
10 8.092390489764512e-004 -8.282942580990493e-004 1.492918352596462e-
003 -1.874137669801712e-004 9.593104186933488e-005 -
1.989669166505337e-003 2.546594478189945e-003 -2.615675795823336e-003
-7.794983685016632e-005 -5.613297107629478e-004

#outputSynapseBackpropGradient Momentum
20 3.959369205404073e-004 -2.281907945871353e-004 5.496764788404107e-
004 -1.844915386755019e-004 9.667585254646838e-005 -
3.502559557091445e-004 -9.158483589999378e-005 3.479506704024971e-004
-4.500475188251585e-004 -5.184303154237568e-004 -3.780142869800329e-
004 2.351309958612546e-004 -5.560303688980639e-004 1.627211022423580e-
004 -9.671406587585807e-005 3.311220789328218e-004 1.137090439442545e-
004 -3.145925002172589e-004 4.362405161373317e-004 5.087670870125294e-
004

#outputAxonBackpropGradient Momentum
2 -5.148513591848314e-004 5.058468668721616e-004
```

B.2 Weight result for personal vehicle and air for personal business purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 1292.

#NSWeightFileVersion 225

#inputFile File
21
1.395348832011223e-002 -8.999999761581421e-001
1.999999880790710e-001 -1.100000023841858e+000
2.812499925494194e-002 -1.349999904632568e+000
3.342537675052881e-004 -9.167126417160034e-001
1.799999922513962e-001 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
8 1
1
8 1.770353168249130e-001 4.310241043567658e-001 -9.793550968170166e-
001 9.344794154167175e-001 8.149042725563049e-001 3.933012858033180e-
002 3.419184386730194e-001 3.548641502857208e-002

#outputAxon TanhAxon
2 1
1
```

```
2 -5.897756814956665e-001 1.080369710922241e+000

#criterion L2Criterion
2 1
1
0

#hidden1Synapse FullSynapse
168 -4.579196572303772e-001 2.077749729156494e+000 -
1.728377699851990e+000 6.335849165916443e-001 7.591116428375244e-001
5.467881560325623e-001 8.401803672313690e-002 -3.326781094074249e-001
-9.795491099357605e-001 1.290960013866425e-001 -1.346625685691834e-001
-1.777443438768387e-001 -1.703918218612671e+000 7.243813276290894e-001
5.501486063003540e-001 -3.354843854904175e-001 1.632439494132996e+000
-1.551692962646484e+000 -3.615230023860931e-001 8.432270884513855e-001
-8.852581977844238e-001 1.026675924658775e-001 9.151195883750916e-001
2.796579850837588e-003 -1.248008131980896e+000 -1.019920945167542e+000
-8.471763730049133e-001 -7.671217918395996e-001 -6.696183700114489e-
003 5.885078907012940e-001 -5.835218429565430e-001 5.680843591690064e-
001 4.320705235004425e-001 -3.677645325660706e-001 -
1.965071558952332e-001 -7.028917074203491e-001 -6.011691689491272e-002
-2.966438606381416e-002 -2.530038356781006e-001 5.769753456115723e-001
-3.626164793968201e-002 -1.051339030265808e+000 2.212507963180542e+000
1.290987730026245e+000 -2.215302437543869e-001 -6.976589202880859e+000
5.068985223770142e-001 4.722234979271889e-002 6.868981570005417e-002
1.100892305374146e+000 -4.741533696651459e-001 1.474131941795349e-001
-1.253633350133896e-001 -3.896805047988892e-001 3.898952007293701e-001
7.562035918235779e-001 1.401201933622360e-001 2.525691986083984e-001
3.366956114768982e-001 1.539801210165024e-001 -2.269941121339798e-001
4.552178382873535e-001 1.277280598878861e-001 3.251354694366455e-001
7.706740498542786e-001 2.384759187698364e-001 1.842669367790222e+000 -
3.104911744594574e-001 -1.450670212507248e-001 3.422374129295349e-001
-2.623092830181122e-001 -6.249738931655884e-001 4.962713122367859e-001
-5.110402703285217e-001 -1.243015885353088e+000 1.809357851743698e-001
-1.015199646353722e-001 1.883164346218109e-001 2.999944984912872e-001
-8.503334522247315e-001 1.364476084709168e-001 -1.239081144332886e+000
3.390896618366242e-001 5.107511878013611e-001 -5.870506763458252e-001
-4.709347784519196e-001 -2.876343019306660e-002 -6.011792421340942e-
001 -2.159091383218765e-001 2.049888819456101e-001 -
4.803179800510407e-001 -7.006708979606628e-001 -3.903077840805054e-001
1.912967562675476e-001 -2.664524018764496e-001 -1.938966810703278e-001
-4.144358932971954e-001 -3.746914863586426e-001 -1.195241808891296e-
001 -5.304694175720215e-001 -4.619742929935455e-001
3.581262528896332e-001 -5.481404066085815e-001 -1.690723896026611e-001
2.154474854469299e-001 -3.082893490791321e-001 9.775729179382324e-001
6.717303991317749e-001 8.351364731788635e-001 1.650375008583069e+000 -
1.632196158170700e-001 9.557538628578186e-001 -2.686711251735687e-001
-9.612878561019898e-001 1.927980482578278e-001 -2.092120051383972e-001
5.958903431892395e-001 5.779073834419251e-001 -6.707466840744019e-001
-8.710986971855164e-001 -1.447031497955322e-001 -3.264321386814117e-
001 2.915608584880829e-001 1.913819462060928e-001 4.292334616184235e-
001 -9.375365376472473e-001 -3.488850295543671e-001 -
9.560014605522156e-001 -5.759197473526001e-001 -1.185328722000122e+000
```

-1.536067724227905e+000 -1.126548171043396e+000 8.503892421722412e-001
-5.693277120590210e-001 -2.370013594627380e-001 -4.933942258358002e-
001 5.051411986351013e-001 -8.317191004753113e-001 -
1.080176115036011e+000 9.716296792030335e-001 -4.565186426043510e-002
-1.845881156623364e-002 -1.158921942114830e-001 -3.472701609134674e-
001 -9.787501394748688e-002 -8.602576851844788e-001
4.369499981403351e-001 1.157151699066162e+000 1.116472482681274e+000 -
2.091157883405685e-001 2.082738399505615e+000 -9.131417870521545e-001
3.302334547042847e-001 -6.275193691253662e-001 -6.869884580373764e-002
-2.083604782819748e-001 4.227375686168671e-001 -3.900778591632843e-001
-6.058108806610107e-001 -6.902550160884857e-002 -4.160462617874146e-
001 6.675958037376404e-001 3.138257861137390e-001 -4.175417423248291e-
001 -1.974418759346008e-001 -1.691677331924439e+000
5.622154474258423e-001 8.846163153648377e-001

#hidden1SynapseBackprop BackFullSynapse
168 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000

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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
16 -1.466638684272766e+000 8.558434844017029e-001
2.547664642333984e+000 -2.701228380203247e+000 1.981720328330994e+000
1.157916903495789e+000 2.508543252944946e+000 1.450467824935913e+000
6.559150815010071e-001 -1.612924098968506e+000 -1.648155212402344e+000
-2.884986698627472e-001 -1.498951911926270e+000 1.423521518707275e+000
-6.225336194038391e-001 8.560271859169006e-001

#outputSynapseBackprop BackFullSynapse
16 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000

#outputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
```

2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
168 -5.114806699566543e-004 -2.077714307233691e-004 -
2.516026725061238e-004 -4.113436443731189e-004 -1.461193751310930e-004
4.883814835920930e-004 -4.561226232908666e-004 -5.087114986963570e-004
-5.448916344903410e-004 6.371893687173724e-004 -6.371893687173724e-004
1.024081720970571e-003 -5.817584460601211e-004 -5.810034926980734e-004
-8.826640550978482e-004 -2.309680567122996e-004 -5.681403563357890e-
004 2.884364221245050e-004 -5.213480908423662e-004 4.355963610578328e-
004 -4.249204066582024e-004 1.710289972834289e-003 1.459302031435072e-
003 6.797484238632023e-004 1.495396951213479e-003 4.512215382419527e-
004 -1.279353862628341e-003 9.356213849969208e-004 1.630272250622511e-
003 1.976369414478540e-003 -1.472722738981247e-003 1.472722738981247e-
003 -1.324290875345469e-003 1.364450552500784e-003 1.231737434864044e-
003 1.991014229133725e-003 -1.159627208835445e-004 2.210799837484956e-
003 -4.633815551642329e-004 1.941885566338897e-003 7.130425656214356e-
004 -1.023473800159991e-003 3.706322559082764e-006 1.014816079987213e-
004 -1.687352196313441e-004 -2.140661672456190e-004 -
2.338024933123961e-004 -4.127645806875080e-004 2.262499328935519e-004
-1.219458499690518e-004 4.219088805257343e-005 -1.431472337571904e-004
1.431472337571904e-004 -4.013469442725182e-003 -3.741264517884702e-004
-2.213331317761913e-004 4.342658910900354e-003 -2.064974396489561e-004
2.221456263214350e-003 -2.148091793060303e-003 -3.513362753437832e-005
-3.084260504692793e-003 2.986259525641799e-003 -7.083315867930651e-004
-5.183255998417735e-004 4.198524038656615e-005 -6.445727776736021e-004
-1.970685407286510e-004 5.960565176792443e-004 -6.223431555554271e-004
-7.305832696147263e-004 -7.055245805531740e-004 1.381320878863335e-003
-1.381320878863335e-003 1.869678613729775e-003 -7.099744980223477e-004
-8.125425083562732e-004 -1.809556502848864e-003 -2.718188916333020e-
004 -1.939475419931114e-003 1.480096718296409e-003 -
8.705074433237314e-004 3.774960350710899e-004 -2.381853846600279e-004
-2.362580289627658e-006 -5.531060764951690e-007 -5.149643698132422e-
007 -9.610249662728165e-007 -2.379550551268039e-006 -
5.367548055801308e-006 2.610806404845789e-006 -2.950809175672475e-006
-1.672678138220363e-007 1.270700664690594e-007 -1.270700664690594e-007
-7.466508577635977e-006 -1.174515773527673e-006 -5.217292255110806e-
006 7.983499926922377e-006 -2.565591103120823e-006 4.881185304839164e-
006 -5.253001745586516e-006 2.955091986223124e-006 -
4.441116288944613e-006 -1.451383809580875e-006 -2.599517465569079e-004
-5.976366446702741e-005 -8.181186422007158e-005 -1.534605835331604e-
004 6.355794994306052e-006 1.098692882806063e-004 -9.914477413985878e-
005 -1.586254220455885e-004 -1.691374927759171e-004 -
8.011373574845493e-005 8.011373574845493e-005 3.011204244103283e-004 -
2.035889883700293e-005 -4.121427482459694e-004 -1.856573362601921e-004
-1.340101734967902e-004 -1.487620902480558e-004 1.242531143361703e-004
-1.537506177555770e-004 -5.064655561000109e-004 5.016969516873360e-004
7.988280849531293e-004 6.417725817300379e-004 -9.732096805237234e-005
7.379704038612545e-004 7.688695768592879e-005 -8.389972499571741e-004
8.384187822230160e-004 7.931424770504236e-004 7.960610673762858e-004 -
8.445982239209116e-004 8.445982239209116e-004 1.344269112451002e-004

```
9.203068329952657e-004 7.999284425750375e-004 -2.660371828824282e-004
5.346461548469961e-004 5.482745473273099e-004 -2.886086585931480e-004
8.250423707067967e-004 -5.661579780280590e-004 5.354282329790294e-004
2.265977382194251e-004 3.553965943865478e-004 4.956941847922280e-005
2.546637842897326e-004 8.705406798981130e-005 3.301614924566820e-005
1.561194803798571e-004 2.675029099918902e-004 8.074683864833787e-005 -
4.755237896461040e-004 4.755237896461040e-004 -1.514455652795732e-004
-4.701233410742134e-005 2.313625882379711e-004 5.044806166552007e-004
9.283945109928027e-005 5.530886701308191e-004 -3.772354975808412e-004
2.495942753739655e-004 -4.316447011660785e-004 4.507430712692440e-004

#hidden1AxonBackpropGradient Momentum
8 5.674129934050143e-004 -1.812728005461395e-003 1.479266647947952e-
004 8.124412270262837e-004 3.263788130425382e-006 1.761323510436341e-
004 -8.825688273645937e-004 -2.985472965519875e-004

#outputSynapseBackpropGradient Momentum
16 8.807506674202159e-005 -7.692007784498856e-005 -2.069326365017332e-
005 1.479088723499444e-006 -3.021442807948915e-006 -
1.712836237857118e-004 1.239687699126080e-004 2.428801526548341e-004 -
1.205426233354956e-004 9.866542677627876e-005 -1.989762095035985e-004
1.491856965003535e-004 7.264462328748778e-005 7.709833880653605e-005 -
7.166543946368620e-005 -2.342668303754181e-004

#outputAxonBackpropGradient Momentum
2 -2.878279929063865e-006 7.257609104271978e-005
```

B.3 Weight result for personal vehicle and air for pleasure purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 6224.

#NSWeightFileVersion 225

#inputFile File
21
1.499999966472387e-002 -8.999999761581421e-001
1.999999880790710e-001 -1.100000023841858e+000
2.499999850988388e-002 -1.299999952316284e+000
1.680112181929871e-004 -9.084005355834961e-001
9.473683685064316e-002 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
10 1
1
10 6.669734120368958e-001 -1.394400447607040e-001 3.960679471492767e-
002 -1.194757342338562e+000 -4.130996227264404e+000
9.332600831985474e-001 -2.894592583179474e-001 4.079298973083496e-001
-3.731214404106140e-001 -3.860616683959961e-001

#outputAxon TanhAxon
2 1
```

```
1
2 -1.088435769081116e+000 4.028233587741852e-001

#criterion L2Criterion
2 1
1
0

#hidden1Synapse FullSynapse
210 -8.199660181999207e-001 -4.963268935680389e-001 -
2.111532390117645e-001 -8.058942556381226e-001 -4.293769001960754e-001
3.587281405925751e-001 -7.089135646820068e-001 -6.048831343650818e-001
-6.460372209548950e-001 3.574621677398682e-001 -4.397121667861939e-001
-2.817220687866211e-001 -6.904651522636414e-001 -5.339938998222351e-
001 -1.029674485325813e-001 -4.300059974193573e-001 -
5.883042216300964e-001 4.834198951721191e-002 -5.370840430259705e-001
-3.833122551441193e-001 3.714935183525085e-001 6.893944740295410e-001
-7.275305688381195e-004 1.618037074804306e-001 3.579360008239746e+000
-1.294189333915710e+000 -2.538050115108490e-001 -7.398124784231186e-
002 -2.267135120928288e-002 -2.268688976764679e-001
2.997237741947174e-001 -3.462239205837250e-001 -1.056848049163818e+000
3.534447550773621e-001 1.934814900159836e-001 1.734709739685059e-001
1.376735717058182e-001 -1.052839085459709e-001 -2.994197010993958e-001
2.970378100872040e-001 -1.749712675809860e-001 -2.654976248741150e-001
-6.036072373390198e-001 -1.571405827999115e-001 -9.114139676094055e-
001 -5.942688941955566e+000 1.996500611305237e+000 1.668178290128708e-
001 -3.215800821781158e-001 4.455043077468872e-001 2.505998015403748e-
001 -8.560323715209961e-001 7.008169889450073e-001 -
4.569352865219116e-001 7.278071045875549e-001 2.093197256326675e-001
6.042626127600670e-002 1.589192748069763e+000 -1.202332496643066e+000
-1.739958822727203e-001 9.544274806976318e-001 -9.703050553798676e-002
-5.624779462814331e-001 5.694675445556641e-001 -2.034181594848633e+000
1.276053309440613e+000 2.995037138462067e-001 7.831962108612061e-001 -
1.257362246513367e+000 9.540957212448120e-001 3.248121440410614e-001
1.433871150016785e+000 -3.036496043205261e-001 4.240361452102661e-001
7.813793420791626e-001 1.168824553489685e+000 1.230367720127106e-001 -
6.845229864120483e-001 -5.901911258697510e-001 1.645306587219238e+000
-2.056559920310974e-001 9.189314842224121e-001 3.872230648994446e-001
-4.294149279594421e-001 -3.213693201541901e-001 1.406622767448425e+000
2.032120376825333e-001 -1.722316932678223e+001 -1.629328727722168e-001
1.586111187934876e+000 2.040957212448120e+000 1.936076879501343e+000
1.610593438148499e+000 -6.430418789386749e-002 8.508507907390595e-002
1.748330712318420e+000 1.858442425727844e+000 1.826724410057068e+000
1.759537339210510e+000 1.001772403717041e+000 1.571438789367676e+000
1.033201932907105e+000 1.306444048881531e+000 1.189242601394653e+000
1.215916991233826e+000 -7.680208683013916e-001 1.556335687637329e+000
-1.110521912574768e+000 -3.330781161785126e-001 -4.173954427242279e-
001 8.991870880126953e-001 -8.375781178474426e-001 -
3.264492452144623e-001 -1.273783087730408e+000 2.982355654239655e-001
-3.415116965770721e-001 -6.302487254142761e-001 -9.933593869209290e-
001 -8.398656547069550e-002 4.749991893768311e-001 5.409868955612183e-
001 -1.345193028450012e+000 2.559745013713837e-001 -
6.425620913505554e-001 -2.003868073225021e-001 3.931850194931030e-001
```

```
3.092525482177734e+000 1.049630880355835e+000 7.654212117195129e-001
4.854960441589356e-001 2.192216634750366e+000 -8.199713826179504e-001
-3.629046678543091e-002 2.357385158538818e+000 -1.727504611015320e+000
2.259097397327423e-001 -5.227663740515709e-002 5.176321268081665e-001
-2.343546897172928e-001 5.800096392631531e-001 -1.047634124755859e+000
1.948352605104446e-001 -1.853259563446045e+000 1.606847047805786e+000
7.316878437995911e-001 -1.317897677421570e+000 3.386742174625397e-001
-4.563089609146118e-001 4.258102416992188e+000 -1.162547349929810e+000
-2.642973423004150e+000 -1.767422795295715e+000 4.365214407444000e-001
-2.184976339340210e-001 -1.709595620632172e-001 -2.208232432603836e-
001 1.218905672430992e-001 -1.472841501235962e-001 -
1.760494112968445e-001 -3.492401838302612e-001 -1.250669509172440e-001
2.974430024623871e-001 4.137063026428223e-001 -5.844488143920898e-001
9.097568690776825e-002 -7.912347465753555e-002 -2.820112407207489e-001
1.435803174972534e-001 -6.836590170860291e-001 -1.865338347852230e-002
-1.513006985187531e-001 -3.541391849517822e+000 1.287016987800598e+000
1.606703102588654e-001 -3.589849174022675e-002 -5.789575725793839e-002
1.280674487352371e-001 -3.664502799510956e-001 2.702634036540985e-001
8.925842642784119e-001 -4.072261154651642e-001 -2.383987158536911e-001
-2.253020256757736e-001 -1.982701569795609e-001 3.174632415175438e-002
2.401864379644394e-001 -3.582885563373566e-001 1.110579222440720e-001
1.988134682178497e-001 1.870322227478027e-001 2.902860164642334e+000
4.864198267459869e-001 1.341936349868774e+000 1.293922867625952e-002 -
8.395846486091614e-001 1.321786880493164e+000 2.158456742763519e-001 -
2.222805321216583e-001 -5.208241343498230e-001 4.879900813102722e-001
2.173171937465668e-001 1.344355106353760e+000 -1.325599312782288e+000
1.434419304132462e-001 2.920625805854797e-001 1.053952813148499e+000 -
9.665960669517517e-001 7.118092775344849e-001 -6.661645770072937e-001
1.992489099502564e-001

#hidden1SynapseBackprop BackFullSynapse
210 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
20 1.297540187835693e+000 -1.689987063407898e+000 3.179644644260407e-
001 2.899862051010132e+000 9.498031139373779e-001 5.890519618988037e-
```

001 1.542603611946106e+000 1.381823897361755e+000 -1.233464628458023e-001 -1.378937840461731e+000 -1.342771053314209e+000 -4.645520821213722e-002 -3.177541196346283e-001 -4.051520526409149e-001 -9.484285116195679e-001 2.577798128128052e+000 -1.524610757827759e+000 -1.415413498878479e+000 -1.540279507637024e+000 1.343302488327026e+000

#outputSynapseBackprop BackFullSynapse
20 0.000000000000000e+000

#outputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
2
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
210 2.621795147206285e-006 4.169626663497184e-006 2.071125209113234e-006 3.486519517537090e-006 2.422930492684827e-006 -2.559213044150965e-006 2.908498117903946e-006 3.007921577591333e-006 2.702280426092329e-006 -3.275787321399548e-006 3.275787321399548e-006 -2.661504595380393e-006 -1.984939217436477e-006 3.539214503689436e-006 7.166709110606462e-006 1.893774538075377e-006 -2.429928599667619e-006 3.565894303392270e-006 5.209640676184790e-006 8.047638402786106e-006 -1.022753804136301e-005 4.766568308696151e-004 1.119533262681216e-004 5.111076170578599e-004 3.460831358097494e-004 4.359511949587613e-004 2.656156138982624e-004 4.059763450641185e-004 4.182534758001566e-004 -2.421876852167770e-004 -3.259987861383706e-004 3.259987861383706e-004 4.281500296201557e-004 9.974044514819980e-004 4.092277958989143e-004 -9.871245129033923e-004 -6.627468974329531e-004 1.183693180792034e-003 -9.711663733469322e-005 -5.358209600672126e-004 -6.492449901998043e-004 1.608895137906075e-003 -2.459797360643279e-005 1.489800924900919e-004 2.934498661488760e-005 1.603590935701504e-004 5.603984027402476e-005 -4.693179562309524e-006 -1.300372241530567e-004

3.028619539691135e-005 1.485561951994896e-004 -2.044518914772198e-004
2.044518914772198e-004 -7.447903044521809e-005 -7.495323079638183e-004
1.176937512354925e-004 7.504298700951040e-004 2.120279168593697e-005 -
8.180203149095178e-004 8.188729989342392e-004 1.137978761107661e-004
1.176690915599465e-003 -1.268432824872434e-003 -1.145294299931265e-005
-2.802831295412034e-005 1.000677821139107e-005 -3.552759380909265e-006
-4.208854807075113e-005 -2.154350659111515e-005 -8.385702676605433e-
005 -1.215466636494966e-005 9.120293543674052e-005 7.591484609292820e-
005 -7.591484609292820e-005 -4.181455733487383e-005
3.485804700176232e-005 -9.239344763045665e-006 -1.015642828861019e-005
-6.201909127412364e-005 6.821652641519904e-005 -1.937356501002796e-005
-3.322223710711114e-005 -8.006371353985742e-005 1.001097916741855e-004
2.879933454096317e-003 3.207208355888724e-003 1.629896112717688e-003
2.801617374643683e-003 2.457383088767529e-003 -2.899361308664084e-003
2.982214558869600e-003 3.186452202498913e-003 3.091275226324797e-003 -
2.969919936731458e-003 2.969919936731458e-003 6.319364765658975e-004
7.126012351363897e-004 3.199443919584155e-003 1.816599979065359e-003
3.178009763360024e-003 -8.871149038895965e-004 8.893965859897435e-004
4.185818135738373e-003 2.287156181409955e-003 -3.292684210464358e-003
2.367063279962167e-005 3.480299346847460e-005 -1.038458140101284e-005
1.725150650599971e-005 3.515414937282912e-005 -3.770229639599165e-008
7.862369238864631e-005 2.503580435586628e-005 -5.171013617655262e-005
-2.877431325032376e-005 2.877431325032376e-005 1.424673246219754e-005
-9.049188520293683e-006 2.624265289341565e-005 2.047140515060164e-005
5.644111297442578e-005 -5.706530282623135e-005 2.658003541000653e-005
4.309615906095132e-005 4.373734554974362e-005 -6.087765359552577e-005
-2.085881278617308e-004 -4.530812657321803e-005 7.607109000673518e-005
-2.596293370515923e-006 -3.062860196223483e-005 -1.142872133641504e-
004 1.101933667086996e-004 -4.339653969509527e-005 -
3.738214581971988e-005 1.972812169697136e-004 -1.972812169697136e-004
2.903884451370686e-004 -5.955320739303716e-005 -1.061452203430235e-004
-2.095623494824395e-004 -4.385231295600534e-005 -4.888819967163727e-
005 5.030429747421295e-005 4.797892761416733e-004 -4.192760388832539e-
005 -4.802980110980570e-004 -9.959135059034452e-005
1.912794323288836e-005 5.179791478440166e-004 -2.573558413132560e-005
-1.239254488609731e-004 2.590432413853705e-004 -1.910250139189884e-004
-7.142836693674326e-005 -1.301335869356990e-004 -4.686793545261025e-
004 4.686793545261025e-004 -2.759880153462291e-004 -
4.336568817961961e-004 1.325715857092291e-004 4.435301525518298e-004 -
2.733870351221412e-004 -4.705073952209204e-004 6.771227344870567e-004
-1.881759999378119e-005 7.558132056146860e-004 -8.037674124352634e-004
-4.101712838746607e-004 -5.630871964967810e-005 -4.384425119496882e-
004 -2.821151283569634e-004 -3.648237907327712e-004 -
2.871839096769691e-004 -3.282795369159430e-004 -3.413918602745980e-004
2.651889226399362e-004 2.570452052168548e-004 -2.570452052168548e-004
-3.511871909722686e-004 -9.200067725032568e-004 -3.284537233412266e-
004 9.079806040972471e-004 6.369376205839217e-004 -1.096724998205900e-
003 1.139543528552167e-004 5.234061391092837e-004 6.233706371858716e-
004 -1.492609619162977e-003 2.866594004444778e-004 1.949772413354367e-
004 -1.860385964391753e-005 2.804335090331733e-004 2.566086768638343e-
004 -1.068611672963016e-004 1.085805051843636e-004 3.103269555140287e-
004 3.081348550040275e-004 1.273025554837659e-004 -1.273025554837659e-
004 3.140410408377647e-004 -7.213420030893758e-005 2.430812310194597e-

004 1.351930986857042e-004 3.102753835264593e-004 -2.951589412987232e-004 2.949742192868143e-004 3.104986972175539e-004 3.001958830282092e-004 -3.006039769388735e-004

#hidden1AxonBackpropGradient Momentum
10 -3.366380724401097e-006 -4.709209024440497e-004 -2.450671854603570e-005 1.464020169805735e-005 -3.533656941726804e-003 -2.883981142076664e-005 4.715140312328003e-005 7.419129542540759e-005 3.842592414002866e-004 -3.445450856816024e-004

#outputSynapseBackpropGradient Momentum
20 -2.416404749965295e-004 2.829912700690329e-004 1.411592675140128e-004 2.442328841425479e-004 -1.593829074408859e-004 -2.449881867505610e-004 2.385076804785058e-004 -2.371881855651736e-004 -2.836391213349998e-004 2.476855588611215e-004 2.467827871441841e-004 -2.851793542504311e-004 -1.393886341247708e-004 -2.496655215509236e-004 1.654929801588878e-004 2.496850793249905e-004 -2.406050625722855e-004 2.396075869910419e-004 2.858327352441847e-004 -2.427898725727573e-004

#outputAxonBackpropGradient Momentum
2 -2.416455245111138e-004 2.467879385221750e-004

B.4 Weight result for personal vehicle, air, and ground for business purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 5860.

#NSWeightFileVersion 225

#inputFile File
21
3.461538255214691e-002 -8.999999761581421e-001
3.599999845027924e-001 -1.259999990463257e+000
2.465753443539143e-002 -1.294520497322083e+000
1.814894785638899e-004 -9.090744256973267e-001
1.999999880790710e-001 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
10 1
1
10 2.519263982772827e+000 1.810568332672119e+000 -3.156745731830597e-
001 -4.688417613506317e-001 3.202158510684967e-001 5.604232549667358e-
001 8.082438111305237e-001 3.305808067321777e+000 -9.242773056030273e-
001 -1.680912852287293e+000

#outputAxon TanhAxon
```

```
3 1
1
3 1.173404306173325e-001 -3.513468503952026e-001
1.225019335746765e+000

#criterion L2Criterion
3 1
1
0

#hidden1Synapse FullSynapse
210 1.177736401557922e+000 -1.768060564994812e+000
2.335027933120728e+000 6.746177196502686e+000 -4.131740629673004e-001
-1.250183105468750e+000 -9.339540600776672e-001 -
2.217033386230469e+000 -9.039963483810425e-001 -7.450729608535767e-001
7.731559276580811e-001 -8.808238506317139e-001 -1.777148485183716e+000
-3.144450187683106e-001 -2.094748735427856e+000 -1.116136163473129e-
001 -2.064111709594727e+000 -4.214862883090973e-001 -
2.264110743999481e-001 -1.515326738357544e+000 -9.164295196533203e-001
1.240410566329956e+000 2.895084857940674e+000 -3.426791191101074e+000
-3.897763729095459e+000 -4.664317131042481e+000 1.068775177001953e+000
-6.660908460617065e-001 -3.949692249298096e-001 -
2.387410879135132e+000 -6.402885913848877e-001 7.092661857604981e-001
-1.374613791704178e-001 -9.602611660957336e-001 -2.628193199634552e-
001 -1.202992796897888e+000 -1.792138516902924e-001 -
6.227661371231079e-001 -2.656235992908478e-001 -6.469999551773071e-001
-1.681379675865173e-001 -2.580034434795380e-001 1.595868945121765e+000
-1.589698433876038e+000 2.895214319229126e+000 5.457497596740723e+000
1.883258819580078e+000 -3.044059872627258e-001 -3.056421689689159e-002
-6.877234578132629e-001 1.398686170578003e+000 1.034816861152649e+000
-9.907981157302856e-001 -1.217975854873657e+000 4.917921125888825e-001
-1.602300167083740e+000 2.637653350830078e+000 -7.884978652000427e-001
2.565505027770996e+000 -1.565431833267212e+000 1.398442029953003e+000
-1.124492168426514e+000 4.058188199996948e-002 2.957606911659241e-001
4.419969618320465e-001 3.562036037445068e+000 2.267798662185669e+000
1.116669178009033e+000 -5.359854549169540e-002 -2.641080319881439e-001
3.558122366666794e-002 1.481681227684021e+000 7.129517197608948e-001 -
5.686867833137512e-001 9.324255585670471e-001 4.593238830566406e-001
3.686563074588776e-001 -6.712723970413208e-001 4.607830643653870e-001
8.497096300125122e-001 -6.071769595146179e-001 -3.716182112693787e-001
5.583905577659607e-001 2.466855496168137e-001 -3.122743129730225e+000
1.617247983813286e-002 1.845043420791626e+000 4.703771591186523e+000
2.207725763320923e+000 1.694359183311462e+000 -2.972381114959717e+000
2.284844160079956e+000 -2.325023889541626e+000 1.933782219886780e+000
-1.892283797264099e+000 -6.240288019180298e-001 8.420145511627197e-001
5.002357065677643e-002 -1.391973614692688e+000 3.564168810844421e-001
-3.851668238639832e-001 -7.904928326606751e-001 -1.885078698396683e-
001 1.706175565719605e+000 -2.248856306076050e+000 -
3.407748699188232e+000 2.414861202239990e+000 2.178887367248535e+000
4.007432162761688e-001 4.412273406982422e+000 2.719955146312714e-001 -
6.116641163825989e-001 -6.741060875356197e-003 -4.371654391288757e-001
5.630972385406494e-001 -3.913118839263916e-001 -1.197425842285156e+000
4.828050136566162e-001 1.307035446166992e+000 -1.484494924545288e+000
```

```
-1.458459854125977e+000 9.987593442201614e-002 1.080144762992859e+000
-4.762859642505646e-002 -6.559159755706787e-001 2.514417171478272e-001
7.632796764373779e-001 -6.259553432464600e-001 -2.934458732604981e+000
6.493500232696533e+000 -2.258966565132141e-001 -9.820705652236939e-001
8.183958530426025e-001 -1.504177153110504e-001 -8.897091150283814e-001
2.811237573623657e-001 -4.060865640640259e-001 3.957510739564896e-002
-1.406552910804749e+000 -5.554118156433106e-001 9.478250145912170e-001
-8.518900871276856e-001 4.005916416645050e-001 9.423382580280304e-002
-3.823844194412231e-001 1.469989567995071e-001 -3.052239716053009e-001
8.615103363990784e-001 -2.411670923233032e+000 -1.404774665832520e+000
1.832726860046387e+001 -1.574903130531311e+000 -1.590994477272034e+000
-2.251773118972778e+000 -1.348975300788879e+000 -
1.608789682388306e+000 -4.375782236456871e-002 -1.640163734555244e-002
-1.502237796783447e+000 -1.647650241851807e+000 -
2.509766101837158e+000 -9.448342919349670e-001 -1.085118293762207e+000
-1.123922348022461e+000 -1.138361692428589e+000 -
2.125868082046509e+000 -5.636891722679138e-001 -5.899226665496826e-001
-2.035549730062485e-001 -4.346642792224884e-001 1.480768918991089e+000
1.551556110382080e+000 3.069674730300903e+000 -1.290182620286942e-001
1.668239831924439e-001 6.571224927902222e-001 1.419349908828735e+000
3.979958891868591e-001 -3.687048554420471e-001 2.475266009569168e-001
6.437589526176453e-001 2.106690704822540e-001 9.132537245750427e-001
3.223193883895874e-001 2.310063689947128e-001 5.397852659225464e-001
5.429707765579224e-001 -3.610178828239441e-001 6.179580688476563e-001
-1.961316227912903e+000 2.060395479202271e+000 1.284169435501099e+000
-3.148010730743408e+000 6.494287848472595e-001 -5.441433787345886e-001
-8.512117862701416e-001 9.355335235595703e-001 3.160910129547119e+000
-2.031950473785400e+000 1.902837157249451e+000 6.175522804260254e-001
6.064384579658508e-001 9.637565612792969e-001 1.041496917605400e-001
5.525873303413391e-001 6.204915046691895e-001 2.921120822429657e-001
1.154353171586990e-001 -6.911620497703552e-001 1.884465694427490e+000

#hidden1SynapseBackprop BackFullSynapse
210 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
```

30 -1.926229715347290e+000 2.503940343856812e+000 -
1.288761615753174e+000 1.685951948165894e+000 -1.103305459022522e+000
-5.116690993309021e-001 -1.496182203292847e+000 -
1.585194587707520e+000 1.553443431854248e+000 -1.069532990455627e+000
2.107140779495239e+000 1.190861940383911e+000 1.495177507400513e+000 -
2.296541213989258e+000 1.148176908493042e+000 6.231067776679993e-001
1.548265457153320e+000 1.706416845321655e+000 2.508922100067139e+000
1.188087582588196e+000 -5.683652311563492e-002 -1.922742724418640e+000
-2.603500485420227e-001 5.388543605804443e-001 6.317392736673355e-002
-4.750542715191841e-002 4.493260756134987e-002 8.516033738851547e-002
2.270349711179733e-001 1.809891127049923e-002

#outputSynapseBackprop BackFullSynapse
30 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
210 -2.913129515945911e-003 -3.004224039614201e-003 -
8.595971739850938e-004 -2.819292712956667e-003 -8.253722335211933e-004
2.829418051987886e-003 -2.936270786449313e-003 -3.033683169633150e-003

-2.944234060123563e-003 3.081137780100107e-003 -3.081137780100107e-003
-3.284661099314690e-003 -2.983988262712956e-003 -3.047004342079163e-003 3.230883739888668e-003 -2.745837904512882e-003 -1.852861139923334e-003 1.556314178742468e-003 -3.161037340760231e-003
-3.412739606574178e-003 3.531391499564052e-003 7.114941254258156e-004
7.150781457312405e-004 5.517968747881241e-005 6.964313797652721e-004
9.463338210480288e-005 7.137483335100114e-004 7.119703222997487e-004
7.119819056242704e-004 -7.144129485823214e-004 -7.139064255170524e-004
7.139064255170524e-004 8.849838632158935e-004 7.117196219041944e-004
7.142951944842935e-004 -8.877110667526722e-004 7.105375407263637e-004
6.991339614614844e-004 -6.980277248658240e-004 7.200079271569848e-004
9.467692580074072e-004 -9.551334078423679e-004 -7.804225606378168e-005
-6.995332660153508e-005 9.672476153355092e-005 -7.458427717210725e-005
-6.167183983052382e-006 -5.630363011732698e-004 -6.352096534101293e-005 -6.605175440199673e-005 5.605270853266120e-004 6.050961746950634e-005 -6.050961746950634e-005 -7.890861888881773e-005 -6.582282367162406e-005 -8.236968278652057e-005 9.501930617261678e-005
-1.165056710306089e-005 -6.356883386615664e-005 9.178455002256669e-006
-6.673696916550398e-004 -5.277828313410282e-005 6.541070179082453e-004
6.740429398632841e-006 3.201508661732078e-006 1.474137434342993e-006
1.079301728168502e-005 -5.665709068125580e-006 2.583481773399399e-006
4.795553195435787e-006 5.102276645629900e-006 -1.608244929229841e-006
-4.249126504873857e-006 4.249126504873857e-006 1.084075665858109e-005
4.312706550990697e-006 9.073622095456813e-006 -1.335403067059815e-005
1.238403569914226e-006 9.851589311438147e-006 -5.653462267218856e-006
7.280933914444177e-006 -7.311423814826412e-006 5.467017672344809e-006
-1.784099033102393e-003 -1.736513338983059e-003 -4.679020203184336e-004 -1.651922124437988e-003 -4.166223516222090e-004
1.731326919980347e-003 -1.745058107189834e-003 -1.748859765939415e-003
-1.729582436382771e-003 2.495547290891409e-003 -2.495547290891409e-003
-2.546287141740322e-003 -1.754714525304735e-003 -1.818849588744342e-003 2.627677982673049e-003 -1.600048621185124e-003 -7.765367627143860e-004 6.304992712102830e-004 -1.752490526996553e-003
-2.412349451333284e-003 2.418753458186984e-003 -1.119313761591911e-003
-1.139579690061510e-003 -1.857822062447667e-004 -1.112686004489660e-003 -5.506699671968818e-004 1.178226550109685e-003 -1.121856039389968e-003 -1.153078163042665e-003 -1.217313460074365e-003
-3.578201576601714e-004 3.578201576601714e-004 -1.587528269737959e-003
-1.156370271928608e-003 -1.158939441666007e-003 1.588816638104618e-003
-1.117910374887288e-003 -7.014491129666567e-004 6.623489898629487e-004
-1.420961110852659e-003 -1.252342481166124e-003 1.516293035820127e-003
-1.979160122573376e-003 -2.111359266564250e-003 -4.596457583829761e-004 -1.975998515263200e-003 -5.452891346067190e-004
2.136638155207038e-003 -1.917853835038841e-003 -2.090025926008821e-003
-2.365174004808068e-003 3.244266845285893e-003 -3.244266845285893e-003
-2.549757249653339e-003 -2.125738887116313e-003 -2.122470410540700e-003 2.561551053076983e-003 -2.066508168354631e-003 -4.180624382570386e-004 3.663626557681710e-004 -2.665719483047724e-003
-3.728783922269940e-003 4.276294726878405e-003 -4.513416904956102e-003
-4.443415906280279e-003 -9.655591566115618e-004 -4.290080629289150e-003 -4.160265671089292e-004 4.828575532883406e-003 -4.732612520456314e-003 -4.471280146390200e-003 -4.574966616928577e-003
1.267917250515893e-004 -1.267917250515893e-004 -7.118304260075092e-003

-4.540007561445236e-003 -4.663474392145872e-003 7.371502462774515e-003
-3.987594507634640e-003 -1.053581596352160e-003 5.660345777869225e-004
-5.192576441913843e-003 -5.136573221534491e-003 5.854006391018629e-003
-9.114189015235752e-005 -9.186888200929388e-005 1.770172821125016e-005
-8.297798194689676e-005 4.148278094362468e-005 -7.901460776338354e-005
-9.541637700749561e-005 -8.939632971305400e-005 8.494094799971208e-005
9.100854367716238e-005 -9.100854367716238e-005 -8.905605500331149e-005
-8.898346277419478e-005 -9.240637882612646e-005 9.155951556749642e-005
-9.120668255491182e-005 -8.786998660070822e-005 8.963345317170024e-005
-9.528749069431797e-005 -8.666060602990910e-005 9.250493894796819e-005
-1.504091196693480e-003 -1.468052272684872e-003 -3.187636320944876e-004 -1.537176081910729e-003 -4.371042014099658e-004
8.939862600527704e-004 -1.426198636181653e-003 -1.442328211851418e-003
-9.103704360313714e-004 -9.244040120393038e-004 9.244040120393038e-004
-1.418664935044944e-003 -1.439324580132961e-003 -1.456255908124149e-003 1.429334050044417e-003 -2.712380606681109e-003 -1.439307932741940e-003 2.709233202040196e-003 -1.450043171644211e-003
-1.437198254279792e-003 1.444786088541150e-003

#hidden1AxonBackpropGradient Momentum
10 3.380428766831756e-003 -7.907156832516193e-004 7.337865827139467e-005 -6.040587777533801e-006 1.940094633027911e-003 1.285567181184888e-003 2.353564137592912e-003 4.972381982952356e-003 9.938141010934487e-005 1.602730248123407e-003

#outputSynapseBackpropGradient Momentum
30 -1.986985080293380e-005 -2.628595393616706e-004 -6.637334536208073e-006 2.969782799482346e-004 3.476377460174263e-004 -3.644134558271617e-004 1.131836252170615e-004 -7.831931725377217e-006
2.802227390930057e-004 1.733158860588446e-004 2.558677442721091e-005
2.618175640236586e-004 -2.378988938289695e-005 -3.052367246709764e-004
-6.841437425464392e-005 3.260371740907431e-004 -2.688854292500764e-004
-4.079875361640006e-005 -2.792549203149974e-004 -1.781530881999061e-004 1.705426439002622e-005 -7.971642480697483e-005 7.901305798441172e-005 3.664084943011403e-005 -2.816722553689033e-004 -3.514589843689464e-005 7.541976628999692e-006 -2.254720129712950e-005
5.198920553084463e-005 1.355093554593623e-004

#outputAxonBackpropGradient Momentum
3 -2.985621104016900e-004 3.041733871214092e-004 -3.156333332299255e-005

B.5 Weight result for personal vehicle, air, and ground for personal business purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 1318.

#NSWeightFileVersion 225

#inputFile File
21
1.395348832011223e-002 -8.999999761581421e-001
1.999999880790710e-001 -1.100000023841858e+000
2.812499925494194e-002 -1.349999904632568e+000
3.342537675052881e-004 -9.167126417160034e-001
1.799999922513962e-001 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
8 1
1
8 2.993662953376770e-001 2.535320259630680e-002 -
1.046814441680908e+000 6.528498530387878e-001 4.485232830047607e-001
5.423136949539185e-001 2.159998178482056e+000 -4.779878556728363e-001

#outputAxon TanhAxon
3 1
```

```
1
3 -6.257660984992981e-001 2.544730305671692e-001 -2.612104713916779e-
001

#criterion L2Criterion
3 1
1
0

#hidden1Synapse FullSynapse
168 -2.331962585449219e-001 1.888180732727051e+000 7.305248379707336e-
001 8.402847051620483e-001 4.107785820960999e-001 -6.914792060852051e-
001 -5.248239040374756e-001 3.446457684040070e-001 1.023937240242958e-
001 1.843775212764740e-001 -2.115000784397125e-001 7.202467322349548e-
002 -8.483611345291138e-001 -2.327160984277725e-001
2.471249550580978e-001 -2.826688289642334e-001 4.827489256858826e-001
-3.875241577625275e-001 -1.541698724031448e-001 1.202271729707718e-001
-4.646586477756500e-001 1.554668903350830e+000 -1.977536678314209e+000
-1.758159399032593e+000 2.661125183105469e+000 -1.958966851234436e-001
2.908448874950409e-001 9.920394420623779e-001 -1.067393720149994e-001
-1.730853617191315e-001 1.211122795939446e-001 -6.839726120233536e-002
5.288900136947632e-001 1.449773609638214e-001 4.550598263740540e-001 -
1.317253261804581e-001 1.151757001876831e+000 -9.324265718460083e-001
7.623603940010071e-002 -2.437634170055389e-001 6.744070649147034e-001
1.822851151227951e-001 8.657057881355286e-001 9.035949409008026e-002 -
1.956683874130249e+000 -2.242692232131958e+000 -5.403127148747444e-002
1.454109400510788e-001 8.788293600082398e-001 7.595126628875732e-001
6.873020529747009e-001 4.628367722034454e-001 -5.092893242835999e-001
1.151401042938232e+000 1.379514783620834e-001 7.835249900817871e-001
3.409752547740936e-001 7.705480456352234e-001 7.542180418968201e-001 -
1.549408584833145e-001 2.294914424419403e-001 9.681957364082336e-001
2.362594902515411e-001 -2.237987041473389e+000 -9.947542548179627e-001
1.581886261701584e-001 6.678674221038818e+000 2.489035576581955e-002 -
5.708026289939880e-001 -7.848872542381287e-001 4.981848299503326e-001
-4.572458267211914e-001 1.061511263251305e-001 5.444959923624992e-002
-3.513659834861755e-001 -3.667298257350922e-001 -3.622651398181915e-
001 -3.751720488071442e-001 -8.674643635749817e-001 -
3.511552810668945e-001 3.444172739982605e-001 -7.188877463340759e-001
1.263038720935583e-002 8.902452886104584e-002 -1.607005000114441e-001
-9.430248141288757e-001 -1.930909633636475e+000 -8.752523660659790e-
001 -1.368483424186707e+000 7.639694213867188e-001 -
9.038627147674561e-001 2.912087598815560e-003 6.717801839113236e-002
6.255952119827271e-001 -7.401204109191895e-001 9.733826518058777e-001
2.742961645126343e-001 -5.443741679191589e-001 -1.086536288261414e+000
-6.049789488315582e-002 -1.048871994018555e+000 8.441191315650940e-001
-5.505419895052910e-002 -8.810479640960693e-001 6.566013693809509e-001
-2.719793319702148e-001 4.410957336425781e+000 1.129724264144898e+000
1.061912417411804e+000 2.625690221786499e+000 1.129212021827698e+000
2.948474586009979e-001 -7.415665984153748e-001 -9.461043477058411e-001
1.209976673126221e+000 -1.174358367919922e+000 3.894817531108856e-001
-6.780928969383240e-001 -6.244157552719116e-001 7.089636325836182e-001
3.368558585643768e-001 1.224850654602051e+000 -1.690416693687439e+000
3.811013698577881e-001 1.282869875431061e-001 -8.554300665855408e-001
```

-2.594564437866211e+000 1.956673860549927e+000 7.752401828765869e+000
-8.834683299064636e-001 3.617527484893799e-001 -7.567234039306641e-001
-1.077542185783386e+000 -1.280905842781067e+000 -1.214162036776543e-
001 -3.933339938521385e-002 2.240855246782303e-001 -
1.332930564880371e+000 -5.668761953711510e-002 -1.064492225646973e+000
-7.580198049545288e-001 -9.176613688468933e-001 -3.687759041786194e-
001 -2.499108612537384e-001 -7.194947600364685e-001 -
4.104784429073334e-001 -4.619331955909729e-001 1.283443421125412e-001
-1.327911019325256e+000 -2.324829995632172e-001 -9.567542672157288e-
001 1.448550224304199e-001 7.080669403076172e-001 5.551497936248779e-
001 -4.874999821186066e-001 -1.913939416408539e-001 -
2.859032452106476e-001 2.307184338569641e-001 -2.278217673301697e-001
6.478462815284729e-001 1.712437868118286e-001 -2.140792012214661e-001
1.762197166681290e-001 -5.638025999069214e-001 5.808798670768738e-001
2.040429562330246e-001 -5.063153505325317e-001 4.513326585292816e-001

#hidden1SynapseBackprop BackFullSynapse
168 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000

```
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
24 1.824752807617188e+000 -1.255750179290772e+000
2.823871374130249e+000 -2.489469051361084e+000 2.064963579177856e+000
-2.043685674667358e+000 2.247732877731323e+000 1.852438449859619e-001
1.975282728672028e-001 1.684716939926148e+000 2.907530367374420e-001
2.332423448562622e+000 -1.328847169876099e+000 1.945223331451416e+000
1.067490220069885e+000 1.523478984832764e+000 -3.201328516006470e-001
-1.933612227439880e+000 2.230144500732422e+000 4.312835037708283e-001
-1.193805575370789e+000 -1.085843682289124e+000 -
2.716712713241577e+000 1.615029811859131e+000

#outputSynapseBackprop BackFullSynapse
24 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
```

```
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
168 -3.915942506864667e-004 -3.353870415594429e-004 -
5.530783164431341e-005 -3.128107346128672e-004 -9.584818326402456e-005
1.030131898005493e-004 -3.521376056596637e-004 -4.362148756626993e-004
-2.005228743655607e-004 3.246444393880665e-004 -3.246444393880665e-004
-7.340646116062999e-004 -4.623714776244015e-004 -2.440661546643241e-
006 3.130146942567080e-004 -1.053831656463444e-003 4.626973241101950e-
004 1.482036313973367e-004 -4.650819173548371e-004 -
2.902319829445332e-004 3.123827045783401e-004 5.953104700893164e-004
3.279777884017676e-004 4.998626536689699e-004 5.973733495920897e-004 -
1.526701526017860e-004 -4.088993882760406e-004 4.229399200994521e-004
4.858963657170534e-004 4.717789997812361e-004 2.252854319522157e-004 -
2.252854319522157e-004 4.210877523291856e-004 4.557874635793269e-004 -
3.087856748607010e-004 4.036274622194469e-004 4.405025902087800e-005
5.353160086087883e-004 -9.350860636914149e-005 4.799998714588583e-004
-1.395226689055562e-003 1.401084591634572e-003 -5.355503526516259e-005
-1.073934545274824e-004 -6.913489778526127e-005 -4.203963180771098e-
005 1.681458343227860e-005 1.193259959109128e-004 -9.876499825622886e-
005 -6.340854451991618e-005 -7.589517190353945e-005
5.902516568312421e-005 -5.902516568312421e-005 1.950074329215568e-005
-7.040740456432104e-005 -2.008535520872101e-004 1.330175437033176e-004
-3.229223511880264e-005 8.572727529099211e-005 -1.128066724049859e-004
-1.156876460299827e-004 2.512517676223069e-004 -1.949355646502227e-004
-4.241249916958623e-005 -8.562216680729762e-005 -7.739649736322463e-
004 -8.374636672670022e-005 -3.715990751516074e-004
9.466761548537761e-005 2.110209024976939e-004 1.353843399556354e-004 -
2.172343520214781e-004 1.058941357769072e-003 -1.058941357769072e-003
1.672551152296364e-003 2.393278118688613e-004 -7.519836071878672e-004
-9.360574185848236e-004 1.524502062238753e-003 -3.249836387112737e-003
1.837253803387284e-003 9.281114034820348e-005 1.346883800579235e-004 -
1.155799691332504e-004 -3.252713577239774e-005 -3.637661939137615e-005
-1.232159320352366e-005 -4.065691246069036e-005 -3.290592576377094e-
005 -3.000111428264063e-005 2.555518949520774e-005 -
3.449849828029983e-005 -2.520111047488172e-005 -7.002498750807717e-005
7.002498750807717e-005 -3.923428448615596e-005 -2.848779331543483e-005
3.051057865377516e-005 -2.693412534426898e-005 -7.350706437136978e-005
-3.105112409684807e-005 7.248537440318614e-005 -4.166595681454055e-005
-1.449073897674680e-005 2.408397085673641e-005 -4.450518190424191e-006
```

2.684624632820487e-004 -2.146564220311120e-004 5.332403816282749e-005
7.397015724563971e-005 1.164030109066516e-004 -1.098038337659091e-004
6.321662112895865e-006 -8.208910912799183e-006 -1.221041748067364e-004
1.221041748067364e-004 7.436921587213874e-004 1.976452585950028e-005 -
7.056682079564780e-005 -6.881771842017770e-004 5.161523586139083e-004
-3.049872175324708e-004 -2.088096080115065e-004 2.382430648140144e-005
-4.482363001443446e-004 4.267678305041045e-004 1.035714056342840e-003
1.056743087247014e-003 1.074225176125765e-003 1.104344963096082e-003
6.980243488214910e-004 -1.071023754775524e-003 1.044043339788914e-003
1.041437964886427e-003 1.067867618985474e-003 -1.572041655890644e-003
1.572041655890644e-003 -4.261655267328024e-004 1.073242630809546e-003
4.105834814254195e-004 1.024664612486959e-003 -1.049126731231809e-003
1.312208944000304e-003 7.780806045047939e-004 1.093048835173249e-003
4.185499710729346e-005 -9.374116780236363e-005 5.230210372246802e-004
4.350816307123750e-004 -9.309940651291981e-005 3.784500295296311e-004
2.113450173055753e-004 -3.077649162150919e-004 4.171590262558311e-004
5.581410368904471e-004 4.660987469833344e-004 -5.406845011748374e-004
5.406845011748374e-004 8.136513060890138e-004 5.963605944998562e-004
2.093671791953966e-004 -4.857455496676266e-004 5.422885296866298e-004
-2.117244584951550e-004 2.362523518968374e-004 5.651798564940691e-004
-1.703263696981594e-004 1.719634747132659e-004

#hidden1AxonBackpropGradient Momentum
8 4.921456566080451e-004 -5.398417706601322e-004 6.596820458071306e-
005 -1.243549340870231e-004 3.563645805115812e-005 -
2.617601012389059e-006 -1.156847225502133e-003 -6.297967629507184e-004

#outputSynapseBackpropGradient Momentum
24 1.444645022274926e-004 -8.439724479103461e-005 2.432201108604204e-
005 1.381254987791181e-004 -7.500908395741135e-005 1.719408646749798e-
005 7.839406316634268e-005 -1.230023044627160e-004 1.072054656106047e-
004 1.847128150984645e-004 1.795585267245770e-004 -1.436719176126644e-
004 -2.340283390367404e-004 1.772171090124175e-004 -
3.180550411343575e-004 -7.113961328286678e-005 -1.577864459250122e-004
3.370979538885877e-005 -7.394913700409234e-005 -3.747292066691443e-005
1.701997389318422e-004 -9.356301598018035e-005 -2.669679361133603e-006
1.401845656801015e-004

#outputAxonBackpropGradient Momentum
3 -8.087738387985155e-005 -2.230343525297940e-004 1.640584086999297e-
004

B.6 Weight result for personal vehicle, air, and ground for pleasure purpose

```
// Weights saved from breadboard .
// Saved after epoch 5000, exemplar 6311.

#NSWeightFileVersion 225

#inputFile File
21
1.682242937386036e-002 -8.999999761581421e-001
1.999999880790710e-001 -1.100000023841858e+000
2.499999850988388e-002 -1.299999952316284e+000
1.680112181929871e-004 -9.084005355834961e-001
9.473683685064316e-002 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#desiredFile File
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
0

#inputAxon Axon
21 1
1
0

#hidden1Axon TanhAxon
10 1
1
10 -1.041026234626770e+000 -3.740228712558746e-001 -
7.440576553344727e-001 1.038953304290772e+000 -8.497160077095032e-001
1.094373345375061e+000 7.254336476325989e-001 3.480413913726807e+000 -
1.140094757080078e+000 -1.273392081260681e+000

#outputAxon TanhAxon
```

```
3 1
1
3 -3.719303905963898e-001 -9.241415262222290e-001
1.224191188812256e+000

#criterion L2Criterion
3 1
1
0

#hidden1Synapse FullSynapse
210 8.124820590019226e-001 -1.225696802139282e-001 5.993610024452210e-
001 -6.786817073822022e+000 1.107738733291626e+000 6.441199034452438e-
002 1.956118047237396e-001 1.010902285575867e+000 1.053558290004730e-
002 8.561978116631508e-003 9.029547870159149e-002 3.191010057926178e-
001 -1.243725717067719e-001 3.509713113307953e-001 5.870284438133240e-
001 2.421843111515045e-001 -6.734242439270020e-001 8.775576949119568e-
001 -5.400831103324890e-001 5.641767382621765e-001 5.964757204055786e-
001 6.585966944694519e-001 5.226982831954956e-001 2.732431590557098e-
001 7.459250688552856e-001 4.693122208118439e-001 -9.198378771543503e-
002 4.946025907993317e-001 6.709177494049072e-001 3.526243269443512e-
001 -1.517175287008286e-001 2.205820530653000e-001 3.602763116359711e-
001 4.814631044864655e-001 3.220200836658478e-001 3.767483532428742e-
001 3.216753005981445e-001 3.956354558467865e-001 1.435222923755646e-
001 7.105502486228943e-001 2.085676044225693e-001 -1.947342604398727e-
001 2.076692879199982e-001 -9.996755123138428e-001 6.018841266632080e-
002 -1.219018578529358e+000 -1.877707004547119e+000 -
5.618084073066711e-001 1.957776784896851e+000 1.055339932441711e+000 -
4.713785946369171e-001 -4.121440947055817e-001 5.125277638435364e-001
5.261288881301880e-001 5.294386744499207e-001 5.752041935920715e-001
5.253717675805092e-002 1.167111754417419e+000 2.454107552766800e-001 -
5.397129058837891e-001 6.048591136932373e-001 5.174093842506409e-001 -
4.226472079753876e-001 -2.013466358184815e+000 3.121783256530762e+000
-2.485127896070480e-001 -2.563527822494507e+000 -8.199249953031540e-
002 7.223472744226456e-002 -3.387600779533386e-001 -
1.253152370452881e+000 1.848600506782532e-001 1.536449432373047e+000 -
1.521305561065674e+000 3.440277576446533e-001 7.029392123222351e-001 -
8.227416276931763e-001 -1.087100267410278e+000 6.313037872314453e-001
-1.045663118362427e+000 -1.734702587127686e-001 -4.294234514236450e-
001 -4.157334566116333e-001 2.100767344236374e-001
1.082189559936523e+000 3.121188580989838e-001 3.288410604000092e-002 -
4.094067096710205e+000 7.698057889938355e-001 1.553447127342224e+000 -
1.927187204360962e+000 6.704311817884445e-002 1.195034861564636e+000
3.780802488327026e-001 -4.916621446609497e-001 -2.751573920249939e-001
-3.505218327045441e-001 1.173202872276306e+000 3.622327744960785e-001
-3.296230137348175e-001 -5.930534601211548e-001 1.252197504043579e+000
-4.625696539878845e-001 -3.518227338790894e-001 1.568129420280457e+000
-2.411013126373291e+000 1.790610671043396e+000 7.423282265663147e-001
-1.891401529312134e+000 4.559692859649658e+000 2.883106470108032e-001
-1.508871197700501e+000 -8.690010309219360e-001 -5.834662318229675e-
001 -2.742825075984001e-002 -7.025376707315445e-002 -
1.143668293952942e+000 -8.700382709503174e-001 -2.346634566783905e-001
-3.914788961410523e-001 -1.166913270950317e+000 -1.397089958190918e-
```

001 -1.665329039096832e-001 -8.094657063484192e-001 -
6.739940643310547e-001 2.470355927944183e-001 -9.987394809722900e-001
8.899142742156982e-001 4.630573689937592e-001 -1.060149669647217e+000
1.238671422004700e+000 -5.316268801689148e-001 -1.065655350685120e-001
2.487629055976868e-001 -1.468840003013611e+000 -9.827551990747452e-002
-3.307315334677696e-002 -6.955476999282837e-001 -
1.526296973228455e+000 -2.256784588098526e-002 2.343820482492447e-001
2.674754261970520e-001 -1.896333456039429e+000 6.139066219329834e-001
-1.476139307022095e+000 -1.643631421029568e-002 6.024848818778992e-001
-1.067105054855347e+000 -1.556963086128235e+000 2.264216244220734e-001
1.683852195739746e+001 -6.195275783538818e-001 -1.258456349372864e+000
-1.476281523704529e+000 -1.939731359481812e+000 -
1.328173160552979e+000 -6.823914498090744e-002 -5.167793855071068e-002
-1.532103538513184e+000 -1.546188712120056e+000 -
1.494932651519775e+000 -1.404155254364014e+000 -7.344824671745300e-001
-1.348729610443115e+000 -8.050808906555176e-001 -
1.090468287467957e+000 -9.413685202598572e-001 -9.939771890640259e-001
9.142906069755554e-001 1.610342860221863e+000 -4.114887714385986e-001
-9.066435694694519e-001 -8.107398152351379e-001 9.095994234085083e-001
-1.231290698051453e+000 2.858305871486664e-001 2.091075420379639e+000
9.795086085796356e-002 2.253321744501591e-002 9.042173027992249e-001
1.417766571044922e+000 5.393970012664795e-001 -7.294690012931824e-001
2.739984989166260e-001 2.118926048278809e+000 -1.244073987007141e+000
1.855380415916443e+000 -7.485172152519226e-002 -7.587506771087647e-001
6.564915180206299e-001 5.576308071613312e-002 -2.285030484199524e-001
8.032697439193726e-001 8.695856481790543e-002 -4.834882020950317e-001
1.038308262825012e+000 5.785111188888550e-001 8.948832750320435e-001 -
2.476577833294869e-002 -1.039613783359528e-001 -3.367370665073395e-001
1.707066416740418e+000 2.738054394721985e-001 -3.770098462700844e-002
1.286182165145874e+000 -8.792087435722351e-001 5.198515653610230e-001
1.408172726631165e+000 -1.354401260614395e-001 -3.579891324043274e-001

#hidden1SynapseBackprop BackFullSynapse
210 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputSynapse FullSynapse
```

```
30 1.422296047210693e+000 -2.662493288516998e-001
1.409102082252502e+000 -1.013661265373230e+000 1.119857907295227e+000
1.931012392044067e+000 -4.800041317939758e-001 -9.393638372421265e-001
1.991340517997742e+000 -1.052395820617676e+000 -1.569093704223633e+000
1.447845220565796e+000 -1.319256067276001e+000 1.014531493186951e+000
-1.150197863578796e+000 -2.197028249502182e-001 1.212566256523132e+000
9.780948758125305e-001 -1.169848442077637e+000 1.061437465250492e-002
6.976950168609619e-001 9.538593888282776e-001 1.835542358458042e-002 -
1.287945955991745e-001 1.765152513980866e-001 -1.404672980308533e+000
-9.661101102828980e-001 -8.168770074844360e-001 -5.310655832290649e-
001 1.210543870925903e+000

#outputSynapseBackprop BackFullSynapse
30 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
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0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000 0.000000000000000e+000 0.000000000000000e+000
0.000000000000000e+000

#outputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVOutputDesiredDataGraph DataGraph
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#desiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#CVDesiredViewer MatrixViewer
3
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001
1.799999952316284e+000 -8.999999761581421e-001

#hidden1SynapseBackpropGradient Momentum
210 9.663131786510348e-004 9.236734476871789e-004 -3.028428182005882e-
004 9.794444777071476e-004 7.932138396427035e-004 -1.748864538967609e-
003 1.729233423247933e-003 1.105126924812794e-003 1.085871597751975e-
```

003 -1.034794608131051e-003 1.034794608131051e-003 1.671547768637538e-003 7.927833939902484e-004 1.166154281236231e-003 -1.459119725041091e-003 7.028506952337921e-004 -3.455937549006194e-004 7.284269086085260e-004 3.726336290128529e-004 1.652681385166943e-003 -9.396313107572496e-004 -4.645447006623726e-006 -5.198168310016627e-006
5.153817994596466e-008 -4.640985935111530e-006 -4.030497620988172e-006
4.711650035460480e-006 -5.702459930034820e-006 -6.091442173783435e-006
-2.878122131733107e-006 3.386551725270692e-006 -3.386551725270692e-006
-5.369781320041511e-006 -3.129340484520071e-006 -5.235757726040902e-006 3.774504648390575e-006 -2.816664391502854e-006 -2.188833605032414e-006 2.531061937816048e-008 -3.730786602318403e-006
-3.132934580207802e-006 1.883533627733414e-006 1.037269597873092e-003
9.567446541041136e-004 5.252656410448253e-004 9.934635600075126e-004
7.949835853651166e-004 -1.361908507533371e-004 1.241611782461405e-003
1.105244504287839e-003 -2.998476884386037e-005 -8.486927836202085e-004
8.486927836202085e-004 5.369201535359025e-004 1.191783463582397e-003
9.405930759385228e-004 -4.886158858425915e-004 -1.056889770552516e-003
1.164956716820598e-003 9.822739521041513e-004 1.157292048446834e-003 -1.048814621753991e-003 9.818626567721367e-004 -1.205535008921288e-004
-1.121549867093563e-004 -3.729188392753713e-006 -1.297048147534952e-004 -3.563901191228069e-005 1.287826889893040e-004 -1.186972804134712e-004 -1.174994031316601e-004 -1.250212662853301e-004
-1.048281264957041e-004 1.048281264957041e-004 2.457877053529955e-005
-1.094325125450268e-004 -1.214461954077706e-004 -2.613536344142631e-005 -7.858585740905255e-005 2.988440428453032e-006 -4.062021980644204e-005 -1.092164966394194e-004 5.924907236476429e-005
-6.625019886996597e-005 8.050155593082309e-004 7.129482692107558e-004
2.191861276514828e-004 7.389065576717258e-004 6.518668960779905e-004
5.257694865576923e-004 8.711441769264638e-004 8.501652628183365e-004 -6.010632496327162e-004 -6.365042645484209e-004 6.365042645484209e-004
6.794962100684643e-004 6.763439741916955e-004 7.853878778405488e-004 -4.952118033543229e-004 -1.480193692259491e-003 1.491120783612132e-003
8.120818529278040e-004 7.339318399317563e-004 -7.502471562474966e-004
8.393233874812722e-004 -8.059052197495475e-005 -6.549793033627793e-005
-2.051719202427194e-004 -8.001458627404645e-005 -4.747042839881033e-005 -1.124774207710289e-004 2.905743895098567e-004 -6.086472421884537e-005 -2.622665779199451e-004 7.699656271142885e-005
-7.699656271142885e-005 3.558573080226779e-004 3.305329591967166e-004
-7.297849515452981e-005 -7.584462873637676e-004 -2.411183522781357e-004 -5.931801206315868e-005 2.279191830893979e-004 -1.089109427994117e-004 -3.170107374899089e-004 3.534044953994453e-004
2.042284759227186e-004 2.224541531177238e-004 2.251848054584116e-004
1.863718935055658e-004 2.852038305718452e-004 5.825737389386632e-005
5.885485006729141e-005 2.147124178009108e-004 9.605239029042423e-005 -4.279909771867096e-004 4.279909771867096e-004 2.458910421410110e-005 -2.235740794276353e-005 3.119136672466993e-004 1.137319413828664e-004
2.482954587321729e-004 -2.505418960936368e-004 2.161849697586149e-004
2.656263823155314e-004 1.212456991197541e-004 -1.729335635900497e-004
-3.899357747286558e-003 -3.381111891940236e-003 -1.130776596255601e-003 -3.665843512862921e-003 -3.077237401157618e-003
2.786584431305528e-003 -4.244487266987562e-003 -4.086401313543320e-003
-2.624418586492539e-003 3.716992447152734e-003 -3.716992447152734e-003
-2.848799573257566e-003 -4.105343949049711e-003 -2.619708655402064e-

003 1.405130256898701e-003 -2.190718892961741e-003 -
2.807402051985264e-003 9.137599263340235e-004 -3.357053501531482e-003
-7.355836569331586e-004 8.275580512417946e-006 4.441872806637548e-005
9.313222108175978e-005 -3.604317898862064e-004 7.426001684507355e-005
3.969746830989607e-005 -4.318805295042694e-004 5.101275382912718e-005
5.067402889835648e-005 4.289828648325056e-004 3.567898529581726e-004 -
3.567898529581726e-004 7.864923099987209e-004 -5.381318042054772e-004
-8.366182737518102e-005 -6.590918201254681e-005 6.778916576877236e-005
-5.297103416523896e-005 3.457654020166956e-005 -8.125332533381879e-005
1.008136314339936e-004 2.983469312312082e-005 1.301776956097456e-005
1.485949906054884e-005 1.380336198053556e-005 1.456972768210108e-005
1.162132048193598e-005 1.515888652647845e-005 -4.472663476917660e-006
1.283359597437084e-005 3.358090907568112e-006 -1.379746663587866e-005
1.379746663587866e-005 9.816024430620018e-006 -1.927272933244240e-005
1.449866158509394e-005 2.183594733651262e-005 2.798267087200657e-005
1.460155999666313e-005 -2.914527613029350e-005 2.911713409048389e-006
-9.707199751574080e-006 2.023443812504411e-005

#hidden1AxonBackpropGradient Momentum
10 -1.206316170282662e-003 5.533542207558639e-006 -1.211489317938685e-
003 1.291306543862447e-004 -9.144535288214684e-004 8.057482045842335e-
005 -2.377095806878060e-004 4.538180772215128e-003 -
5.488341776072048e-005 -1.493217769166222e-005

#outputSynapseBackpropGradient Momentum
30 -6.923990440554917e-004 7.038709009066224e-004 7.741154404357076e-
004 -6.977157318033278e-004 -7.738544372841716e-004 -
7.090767030604184e-004 -7.149879238568246e-004 9.032597881741822e-005
7.159915403462946e-004 7.053767330944538e-004 4.701497673522681e-004 -
5.284954095259309e-004 -5.082823336124420e-004 5.294565344229341e-004
4.476190661080182e-004 5.579913267865777e-004 5.274600698612630e-004 -
2.340080754947849e-005 -5.344109958969057e-004 -5.344775854609907e-004
-4.796778284799075e-006 -8.000324305612594e-005 -1.298300485359505e-
004 7.925878162495792e-005 1.305404439335689e-004 1.114087790483609e-
004 -7.292167993000476e-006 -1.005432386591565e-005 -
6.365845911204815e-005 -7.994952466106042e-005

#outputAxonBackpropGradient Momentum
3 -7.039006450213492e-004 5.285215447656810e-004 7.999438093975186e-
005

APPENDIX C

RESULTS FROM NEURAL NETWORKS BACKPROPAGATION

C.1 Personal vehicle and air choices

Business purpose with 1 hidden layer and tanh activation function on calibration

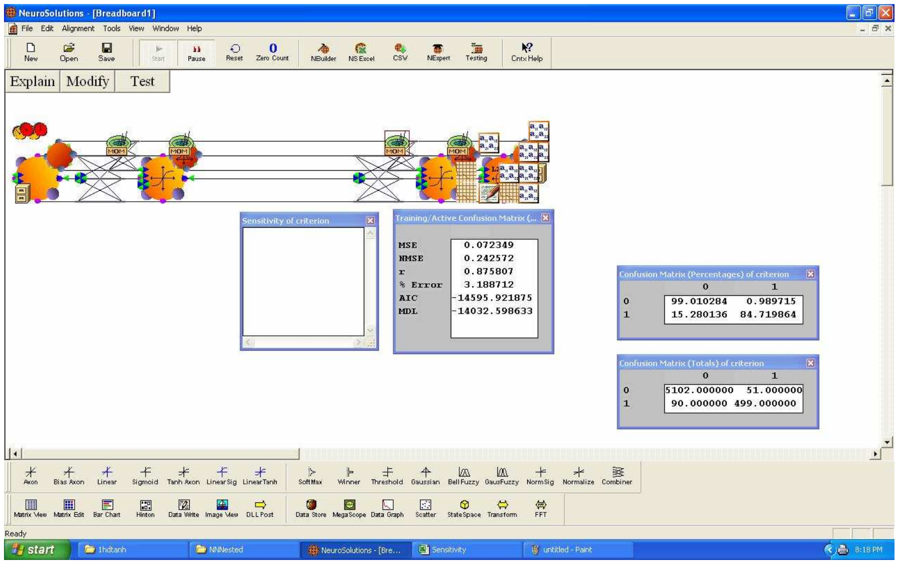

Figure C.1 Calibration with 1 layer and tanh for business purpose; 2modes

Business purpose with 1 hidden layer and tanh activation function on validation

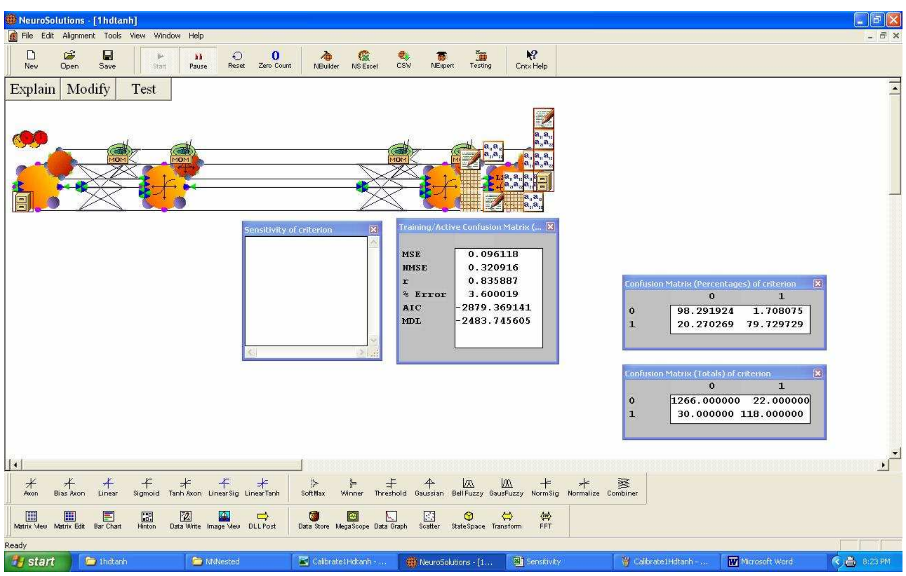

Figure C.2 Validation with 1 layer and tanh for business purpose: 2 modes

Business purpose with 1 hidden layer and tanh activation function on Texas

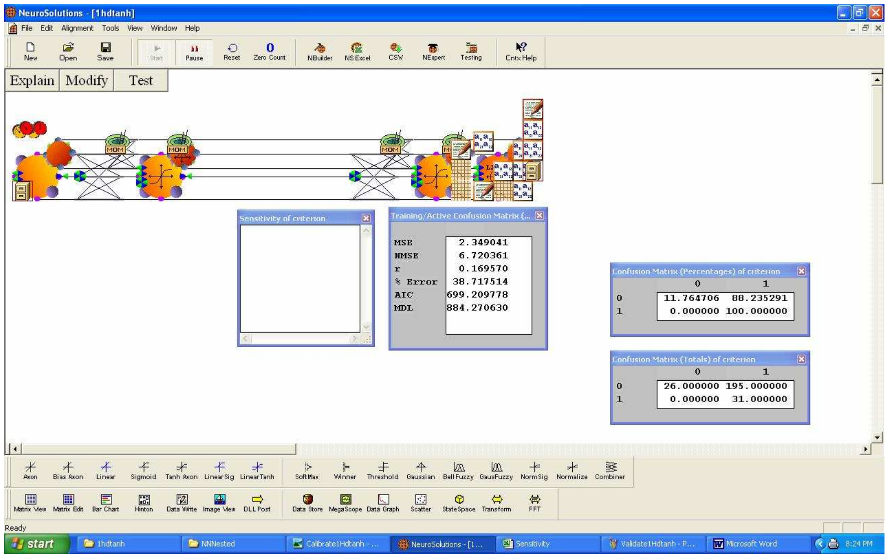

Figure C.3 Texas with 1 layer and tanh for business purpose: 2 modes

Business purpose with 1 hidden layer and tanh activation function on Wisconsin

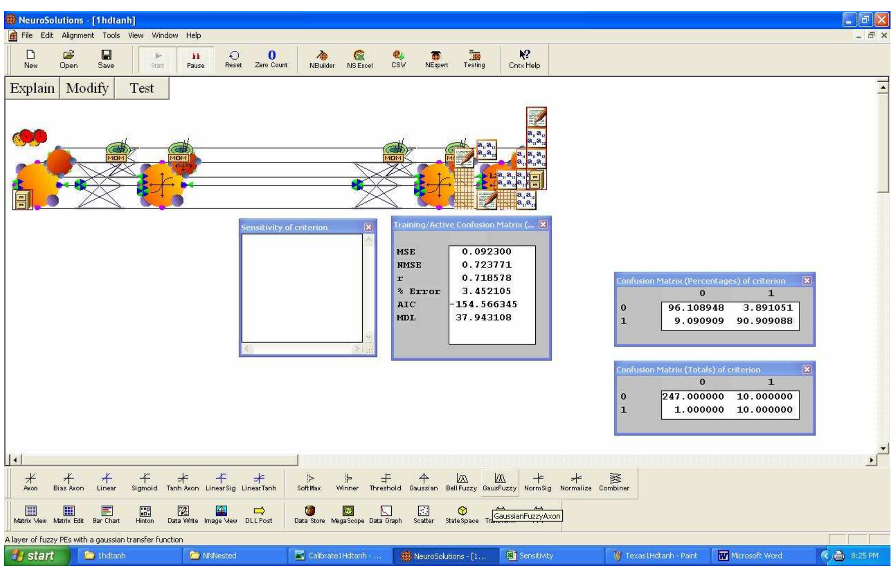

Figure C.4 Wisconsin with 1 layer and tanh for business purpose: 2 modes

Personal business purpose with 1 hidden layer and tanh activation function on calibration

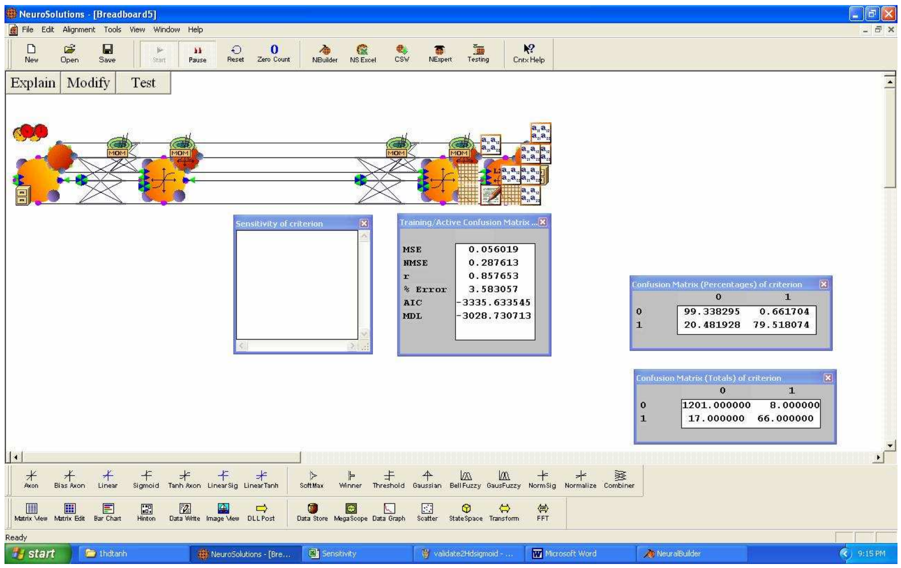

Figure C.5 Calibration with 1 layer and tanh for personal business purpose; 2modes

Personal business purpose with 1 hidden layer and tanh activation function on validation

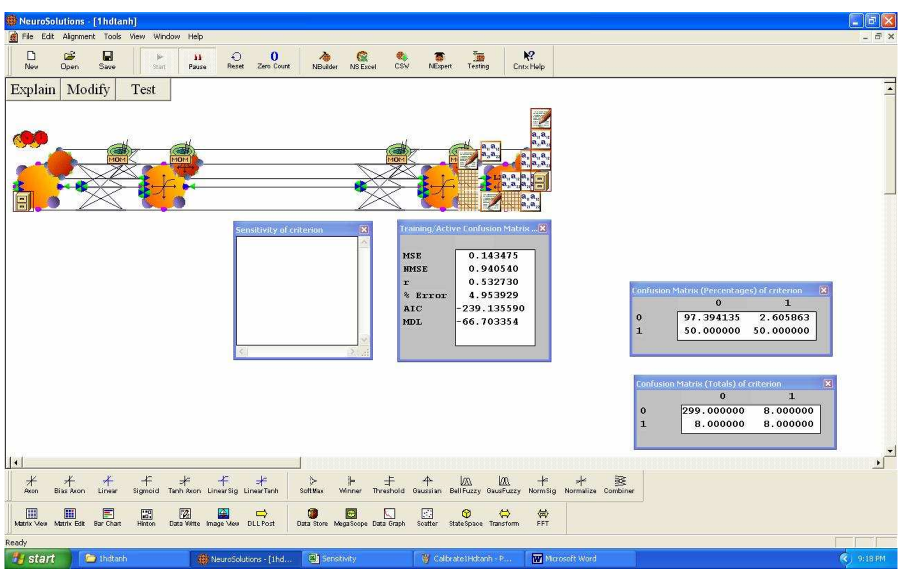

Figure C.6 Validation with 1 layer and tanh for personal business purpose: 2 modes

Personal business purpose with 1 hidden layer and tanh activation function on Texas

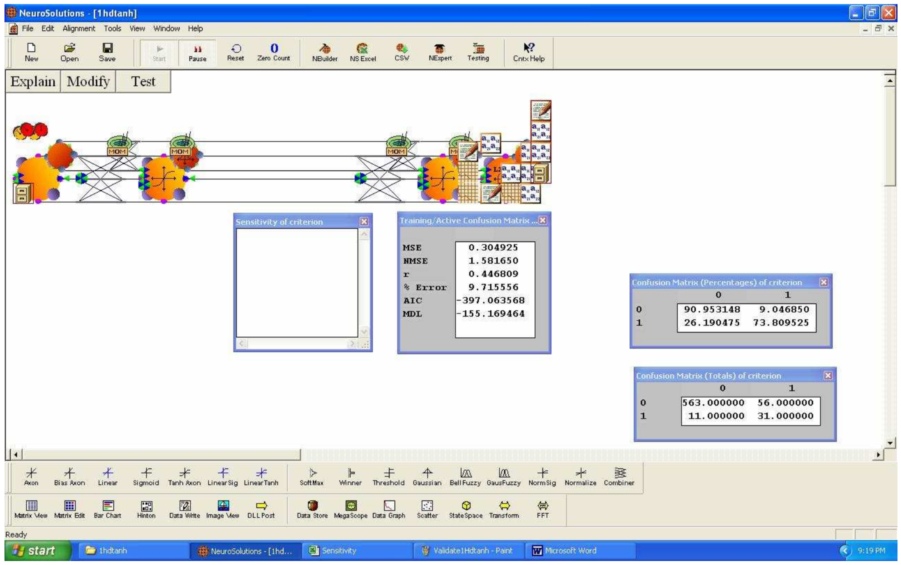

Figure C.7 Texas with 1 layer and tanh for personal business purpose: 2 modes

Personal business purpose with 1 hidden layer and tanh activation function on Wisconsin

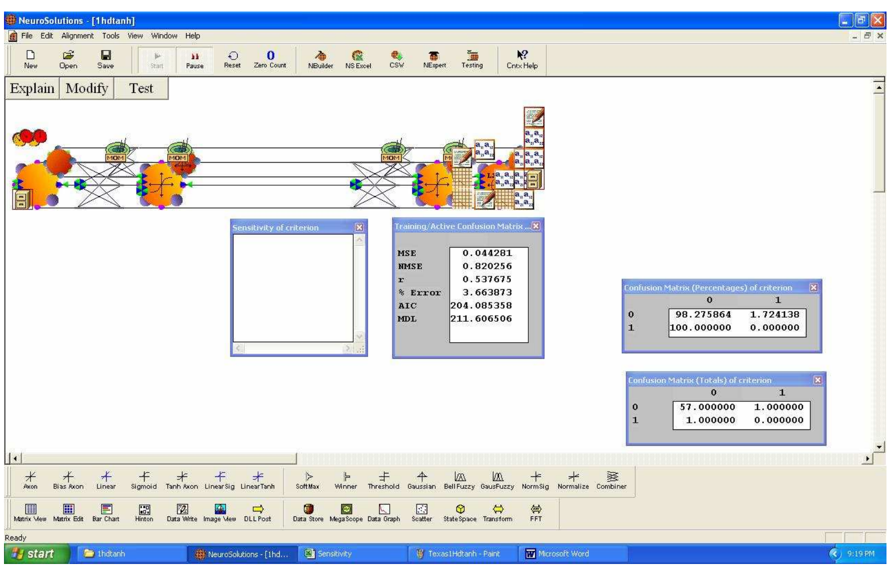

Figure C.8 Wisconsin with 1 layer and tanh for personal business purpose: 2 modes

Pleasure purpose with 1 hidden layer and tanh activation function on calibration

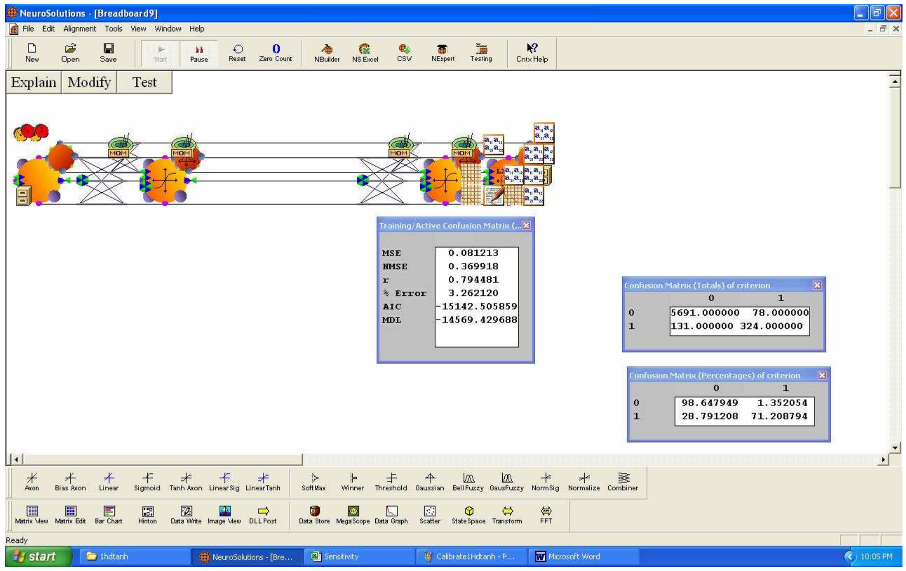

Figure C.9 Calibration with 1 layer and tanh for pleasure purpose; 2modes

Pleasure purpose with 1 hidden layer and tanh activation function on validation

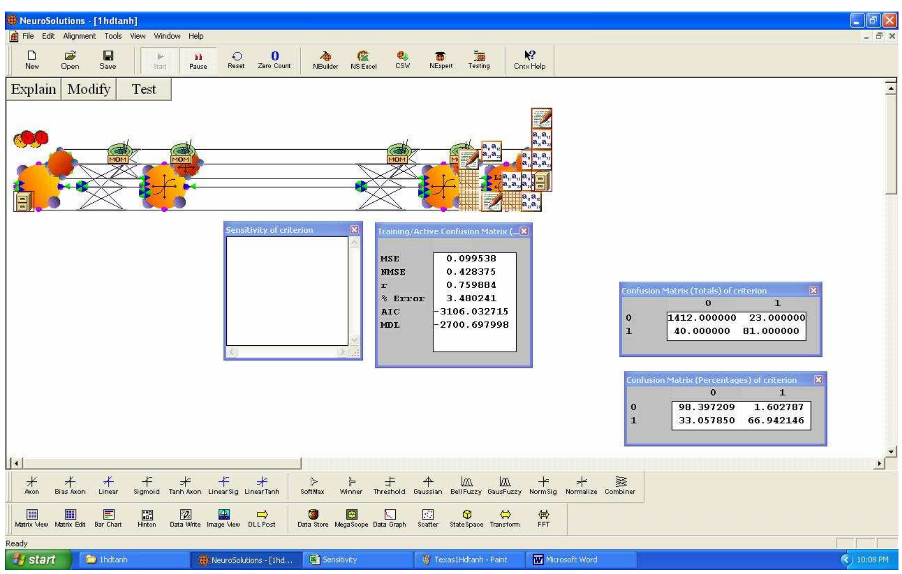

Figure C.10 Validation with 1 layer and tanh for pleasure purpose: 2 modes

Pleasure purpose with 1 hidden layer and tanh activation function on Texas

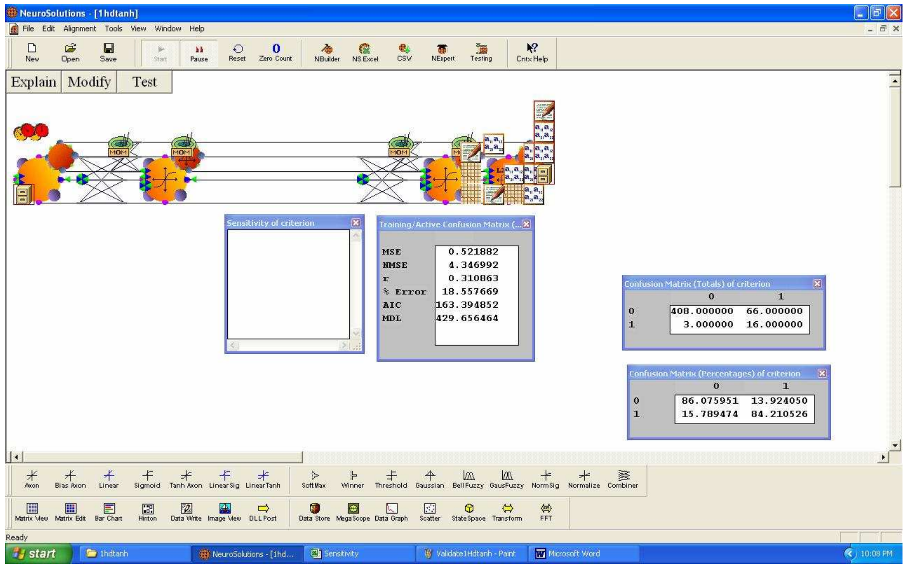

Figure C.11 Texas with 1 layer and tanh for pleasure purpose: 2 modes

Pleasure purpose with 1 hidden layer and tanh activation function on Wisconsin

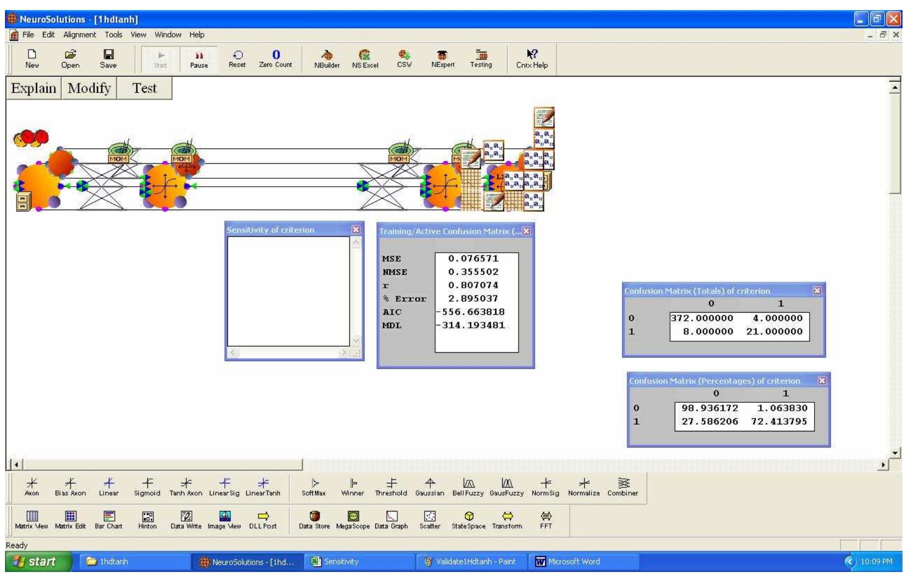

Figure C.12 Wisconsin with 1 layer and tanh for pleasure purpose: 2 modes

C.2 Personal vehicle, air, and ground choice

Business purpose with 1 hidden layer and tanh activation function on calibration

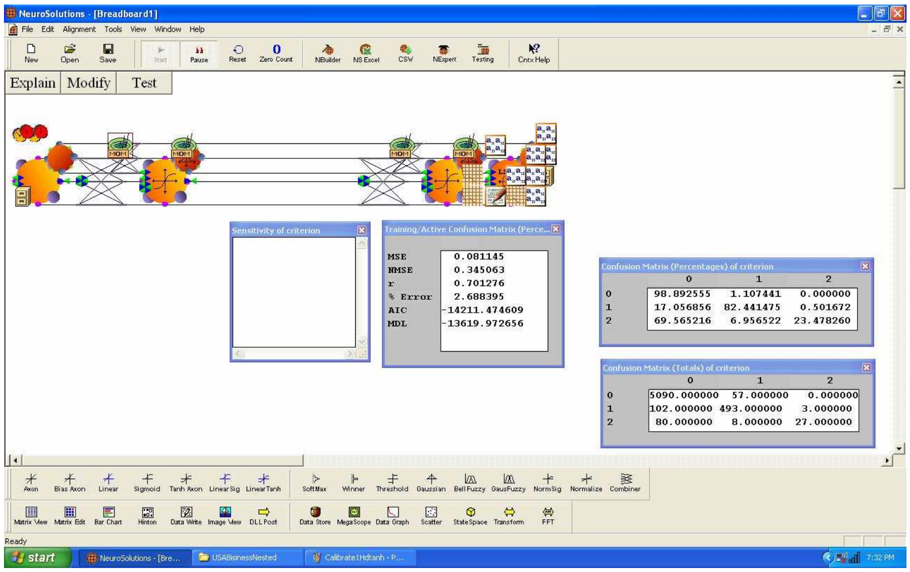

Figure C.13 Calibration with 1 layer and tanh for business purpose; 3modes

Business purpose with 1 hidden layer and tanh activation function on validation

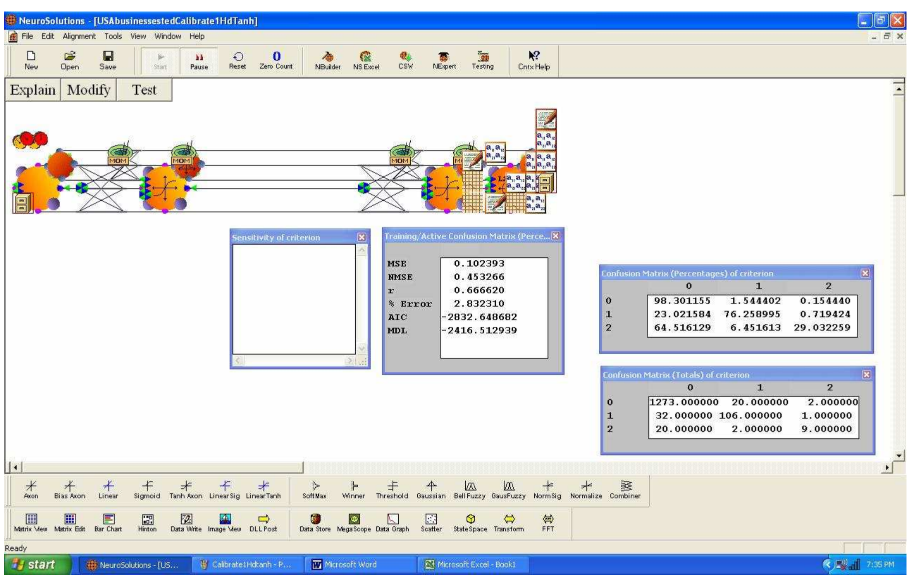

Figure C.14 Validation with 1 layer and tanh for business purpose: 3 modes

Business purpose with 1 hidden layer and tanh activation function on Texas

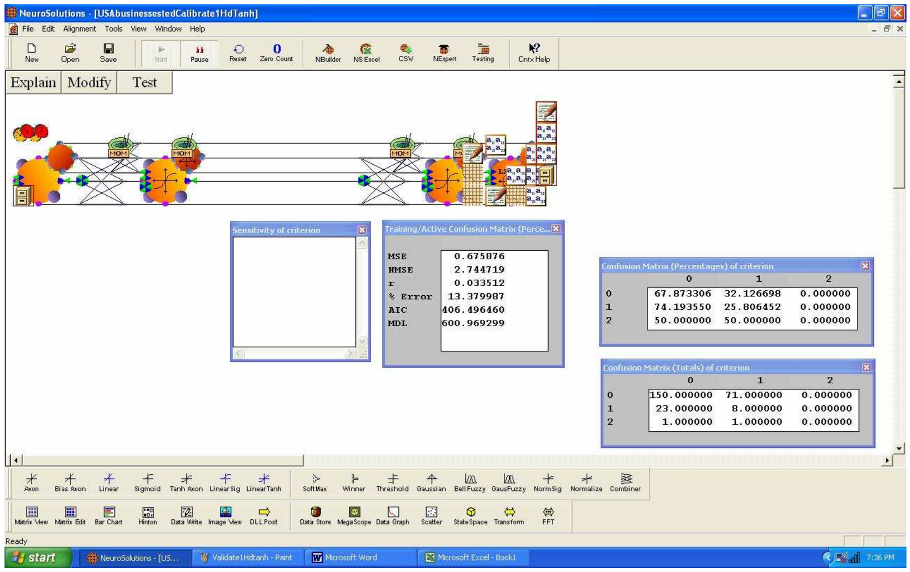

Figure C.15 Texas with 1 layer and tanh for business purpose: 3 modes

Business purpose with 1 hidden layer and tanh activation function on Wisconsin

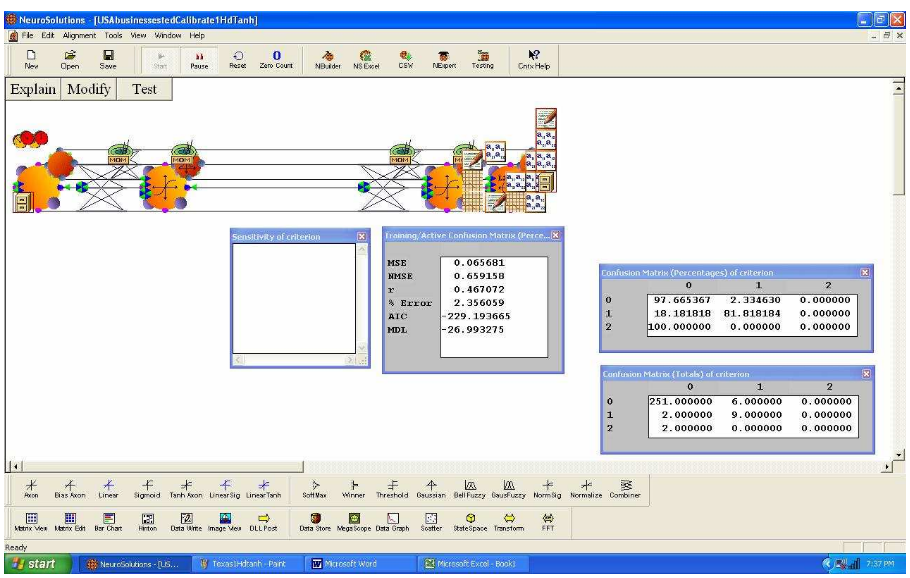

Figure C.16 Wisconsin with 1 layer and tanh for business purpose: 3 modes

Personal business purpose with 1 hidden layer and tanh activation function on calibration

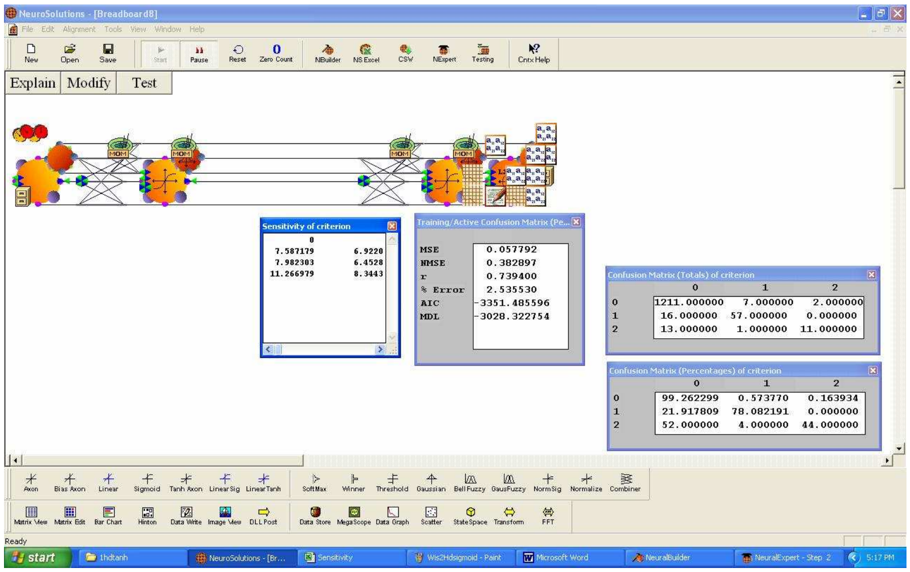

Figure C17 Calibration with 1 layer and tanh for personal business purpose; 3modes

Personal business purpose with 1 hidden layer and tanh activation function on validation

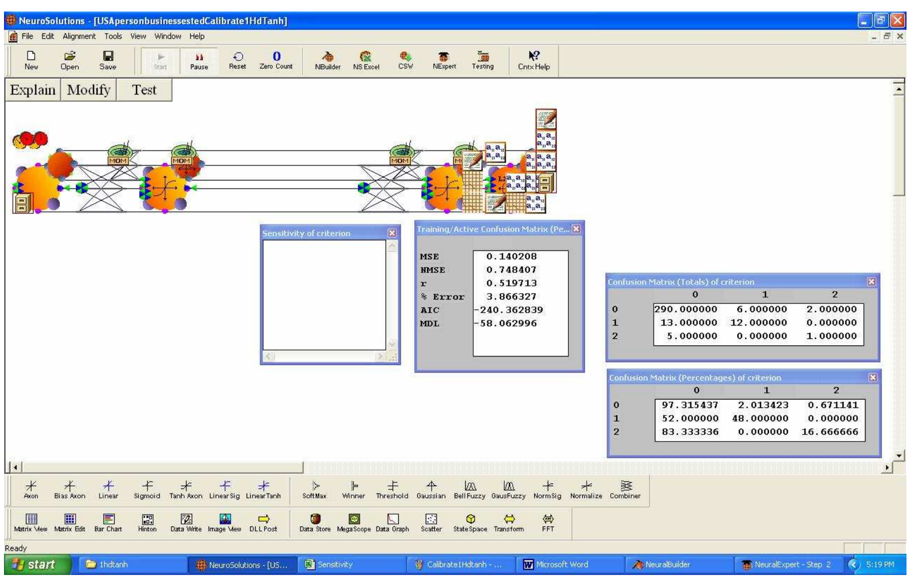

Figure C.18 Validation with 1 layer and tanh for personal business purpose: 3 modes

Personal business purpose with 1 hidden layer and tanh activation function on Texas

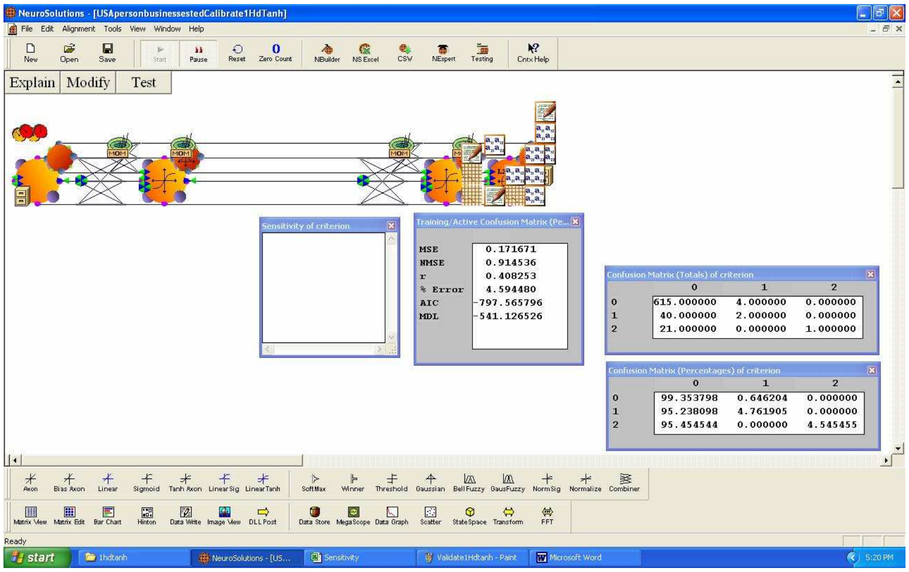

Figure C.19 Texas with 1 layer and tanh for personal business purpose: 3 modes

Personal business purpose with 1 hidden layer and tanh activation function on Wisconsin

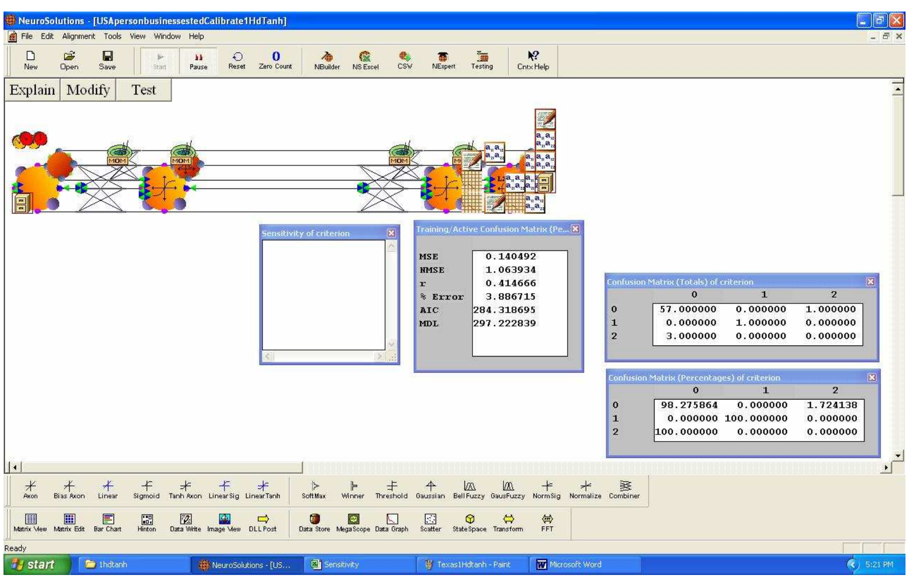

Figure C.20 Wisconsin with 1 layer and tanh for personal business purpose: 3 modes

Pleasure purpose with 1 hidden layer and tanh activation function on calibration

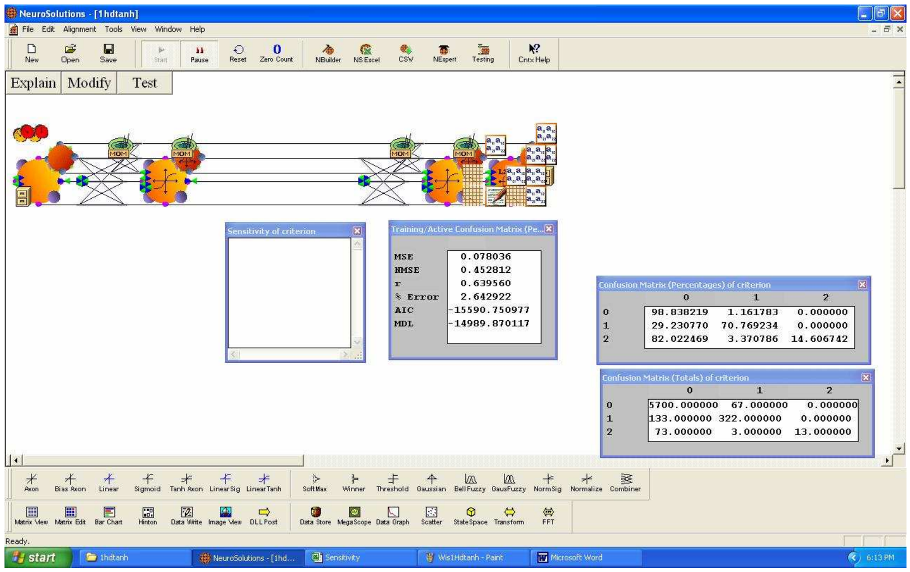

Figure C.21 Calibration with 1 layer and tanh for pleasure purpose; 3modes

Pleasure purpose with 1 hidden layer and tanh activation function on validation

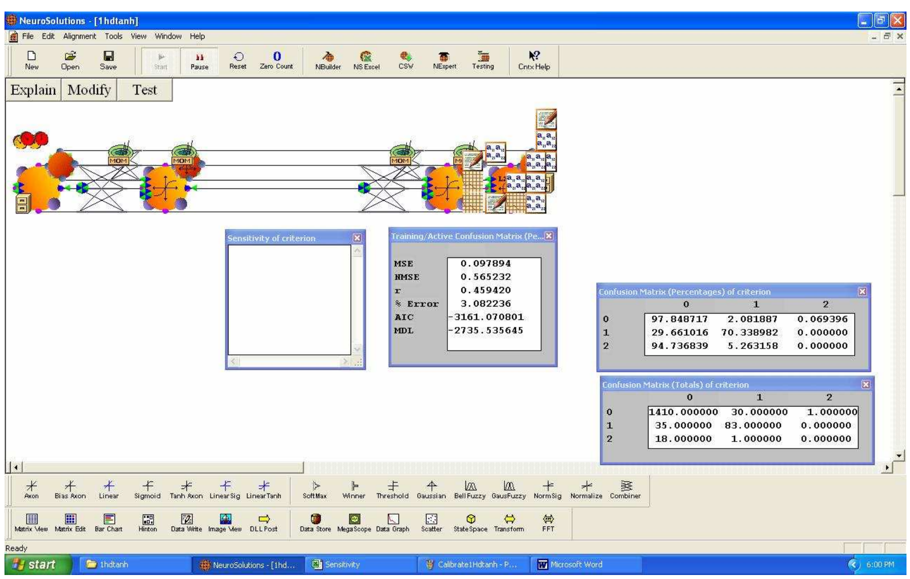

Figure C.22 Validation with 1 layer and tanh for pleasure purpose: 3 modes

Pleasure purpose with 1 hidden layer and tanh activation function on Texas

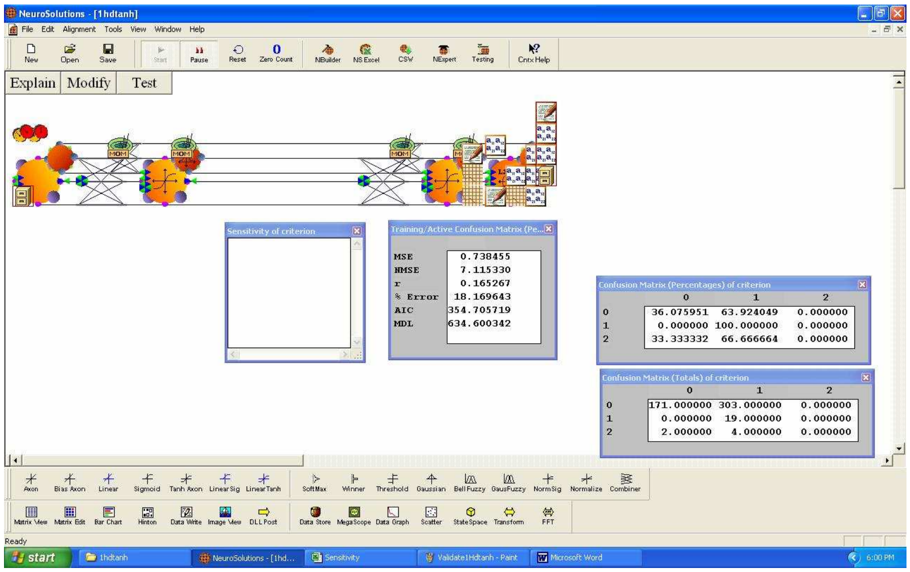

Figure C.23 Texas with 1 layer and tanh for pleasure purpose: 3 modes

Pleasure purpose with 1 hidden layer and tanh activation function on Wisconsin

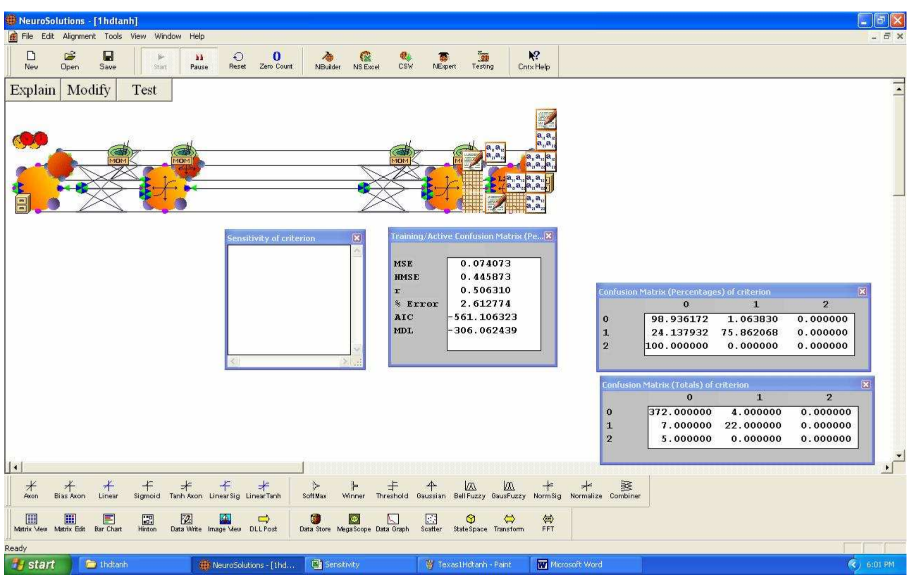

Figure C.24 Wisconsin with 1 layer and tanh for pleasure purpose: 3 modes

APPENDIX D

RESULTS FROM NEURAL NETWORKS
HIDDEN WEIGHT OPTIMIZATION

D.1 Personal vehicle and air for business purpose

D.1.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
5.66	1	{4, }
5.43	2	{4, 1, }
5.33	3	{4, 1, 15, }
5.21	4	{4, 1, 15, 2, }
5.14	5	{4, 1, 15, 2, 3, }
5.09	6	{4, 1, 15, 2, 3, 10, }
5.07	7	{4, 1, 15, 2, 3, 10, 14, }
5.10	8	{4, 1, 15, 2, 3, 10, 14, 5, }
5.02	9	{4, 1, 15, 2, 3, 10, 14, 5, 9, }
5.05	10	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, }
5.02	11	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, }
4.98	12	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, }
4.95	13	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, }
4.95	14	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, }
4.95	15	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, 18, }
4.95	16	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, 18, 16, }
4.95	17	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, 18, 16, 17, }
4.95	18	{4, 1, 15, 2, 3, 10, 14, 5, 9, 20, 13, 19, 7, 8, 18, 16, 17, 12, }

```
  4.95                 19         {4, 1, 15, 2, 3, 10, 14, 5, 9, 20,
13, 19, 7, 8, 18, 16, 17, 12, 6, }

  4.95                 20         {4, 1, 15, 2, 3, 10, 14, 5, 9, 20,
13, 19, 7, 8, 18, 16, 17, 12, 6, 11, }

  4.95                 21         {4, 1, 15, 2, 3, 10, 14, 5, 9, 20,
13, 19, 7, 8, 18, 16, 17, 12, 6, 11, 21, }
```

D.1.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USABisinessBinar
y\Calibrate.txt
      Inputs: 21
      Classes: 2
      Patterns: 5742

Network Information:

      Hidden Units: 10
      Network File: C:\Program Files\Nuclass7\Work\MLPPruneWts10.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            65
         2            110

      Total Error Patterns: 175
      Percentage Error:       3.05
```

D.1.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USABisinessBinar
y\Validation.txt
      Inputs: 21
      Classes: 2
      Patterns: 1436

Network Information:
```

```
      Hidden Units: 10
      Network File: C:\Program Files\Nuclass7\Work\MLPPruneWts10.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            19
         2            29

      Total Error Patterns: 48
      Percentage Error:       3.34
```

D.1.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNBinary\BusinessBi.txt
      Inputs: 21
      Classes: 2
      Patterns: 252
      Desired Class ID present: YES

Network Information:

      Hidden Units: 10
      Network File: C:\Program Files\Nuclass7\Work\MLPPruneWts10.wts

      Class ID    No. of Error Patterns
         1            0
         2            31

      Total Error Patterns: 31
      Percentage Error:      12.30

Select Processed Output from the drop down list.
```

D.1.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNBinary\BusinessBi.txt
      Inputs: 21
      Classes: 2
      Patterns: 268
      Desired Class ID present: YES
```

```
Network Information:

       Hidden Units: 10
       Network File: C:\Program Files\Nuclass7\Work\MLPPruneWts10.wts

       Class ID    No. of Error Patterns
          1            10
          2            1

       Total Error Patterns: 11
       Percentage Error:       4.10

Select Processed Output from the drop down list.
```

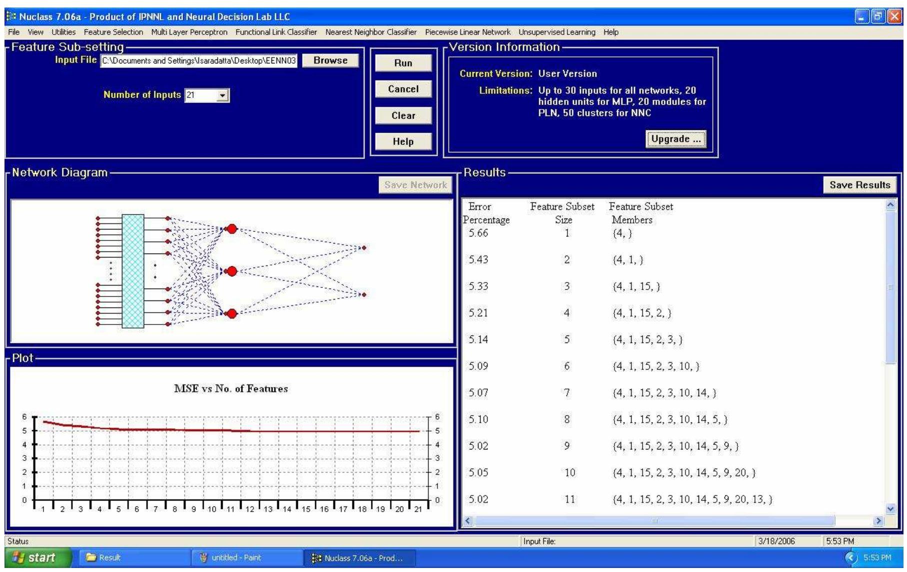

Figure D.1 Feature selection for business purpose (personal vehicle and air)

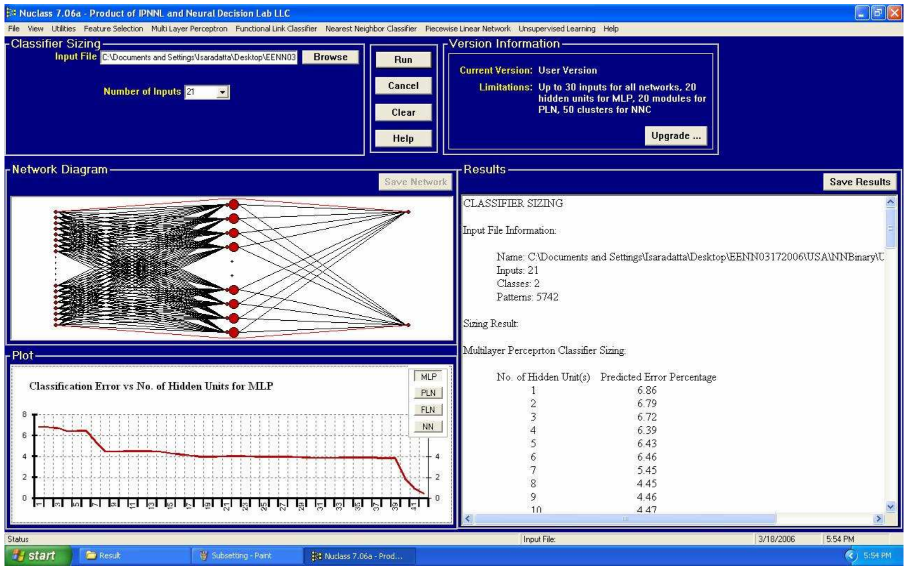

Figure D.2 Sizing for business purpose (personal vehicle and air)

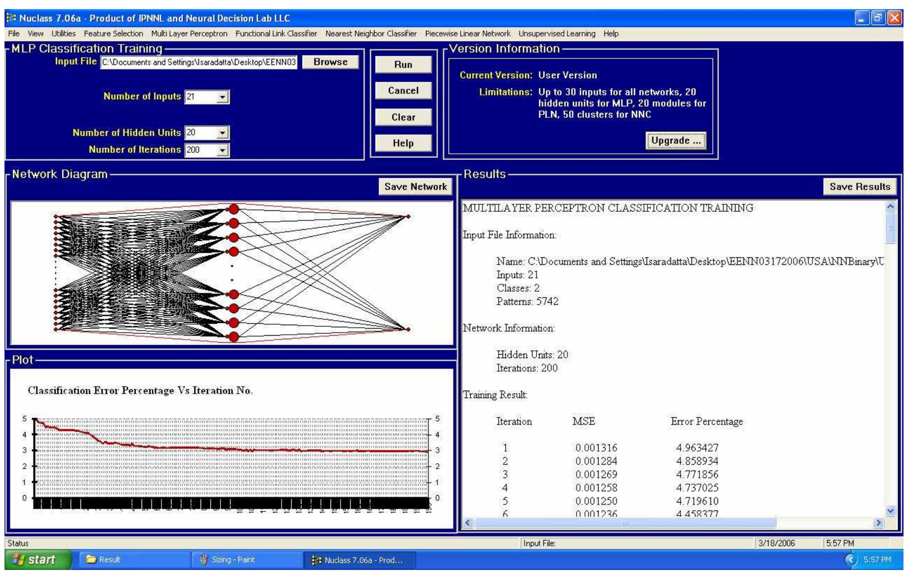

Figure D.3 Training for business purpose (personal vehicle and air)

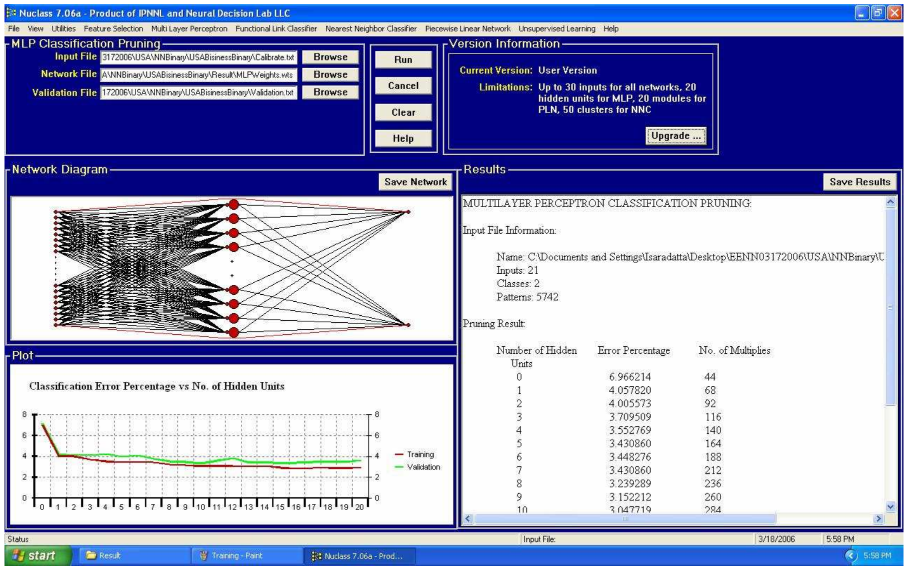

Figure D.4 Pruning for business purpose (personal vehicle and air)

Based on sizing tool result in Figure D.2, twenty neurons are first selected to train the network and, for training tool result in Figure D.3, 200 iterations are to perform primary selection. From Figure D.4, pruning tool result, ten neurons are selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for business purpose (personal vehicle and air), ten neurons with 200 iterations are selected.

D.2 Personal vehicle and air for personal business purpose

D.2.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
3.72	1	{4, }
3.48	2	{4, 18, }
3.41	3	{4, 18, 1, }
3.17	4	{4, 18, 1, 2, }
2.86	5	{4, 18, 1, 2, 13, }
2.71	6	{4, 18, 1, 2, 13, 10, }
2.55	7	{4, 18, 1, 2, 13, 10, 15, }
2.55	8	{4, 18, 1, 2, 13, 10, 3, 5, }
2.48	9	{4, 18, 1, 2, 13, 10, 3, 5, 12, }
2.48	10	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, }
2.40	11	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, }
2.32	12	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, }
2.32	13	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, }
2.32	14	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 16, }
2.32	15	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 16, 6, }
2.32	16	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 19, 6, 17, }
2.32	17	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 19, 6, 17, 16, }
2.32	18	{4, 18, 1, 2, 13, 10, 3, 5, 12, 7, 21, 14, 8, 19, 6, 17, 16, 9, }

```
  2.32                  19         {4, 18, 1, 2, 13, 10, 3, 5, 12, 7,
21, 14, 8, 19, 6, 17, 16, 9, 15, }

  2.32                  20         {4, 18, 1, 2, 13, 10, 3, 5, 12, 7,
21, 14, 8, 19, 6, 17, 16, 9, 15, 20, }

  2.32                  21         {4, 18, 1, 2, 13, 10, 3, 5, 12, 7,
21, 14, 8, 19, 6, 17, 16, 9, 15, 20, 11, }
```

D.2.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Cal.txt
      Inputs: 21
      Classes: 2
      Patterns: 1292

Network Information:

      Hidden Units: 2
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Result\MLPPruneWts2.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            16
         2            24

      Total Error Patterns: 40
      Percentage Error:       3.10
```

D.2.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Val.txt
      Inputs: 21
      Classes: 2
      Patterns: 323
```

```
Network Information:

      Hidden Units: 2
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Result\MLPPruneWts2.wts

Testing Result:

      Class ID    No. of Error Patterns
         1           5
         2           6

      Total Error Patterns: 11
      Percentage Error:       3.41
```

D.2.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNBinary\PersonBusiness
Bi.txt
      Inputs: 21
      Classes: 2
      Patterns: 661
      Desired Class ID present: YES

Network Information:

      Hidden Units: 2
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Result\MLPPruneWts2.wts

      Class ID    No. of Error Patterns
         1           14
         2           21

      Total Error Patterns: 35
      Percentage Error:       5.30

Select Processed Output from the drop down list.
```

D.2.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNBinary\PersonBusinessBi
.txt
      Inputs: 21
      Classes: 2
      Patterns: 59
      Desired Class ID present: YES

Network Information:

      Hidden Units: 2
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPersonBusines
sBinary\Result\MLPPruneWts2.wts

      Class ID    No. of Error Patterns
         1            0
         2            0

      Total Error Patterns: 0
      Percentage Error:       0.00

Select Processed Output from the drop down list.
```

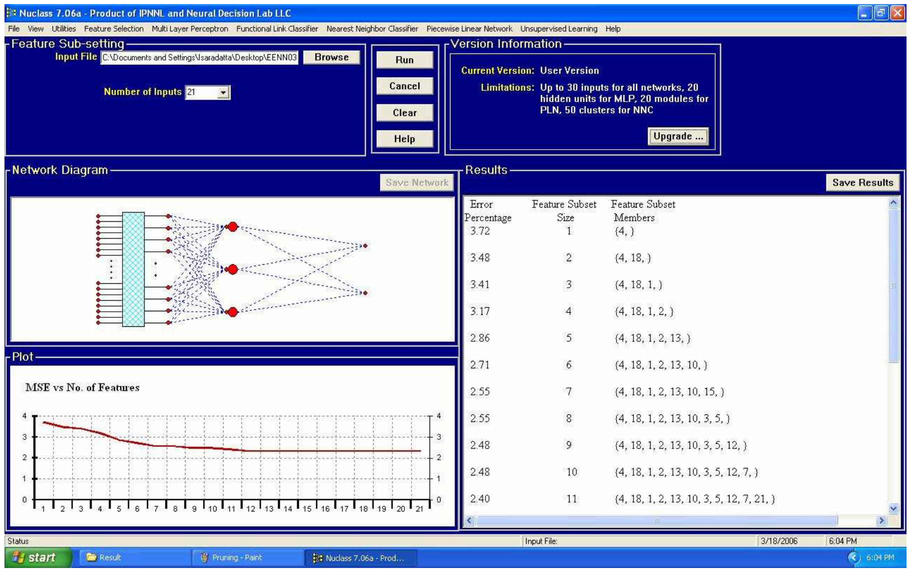

Figure D.5 Feature selection for personal business purpose (personal vehicle and air)

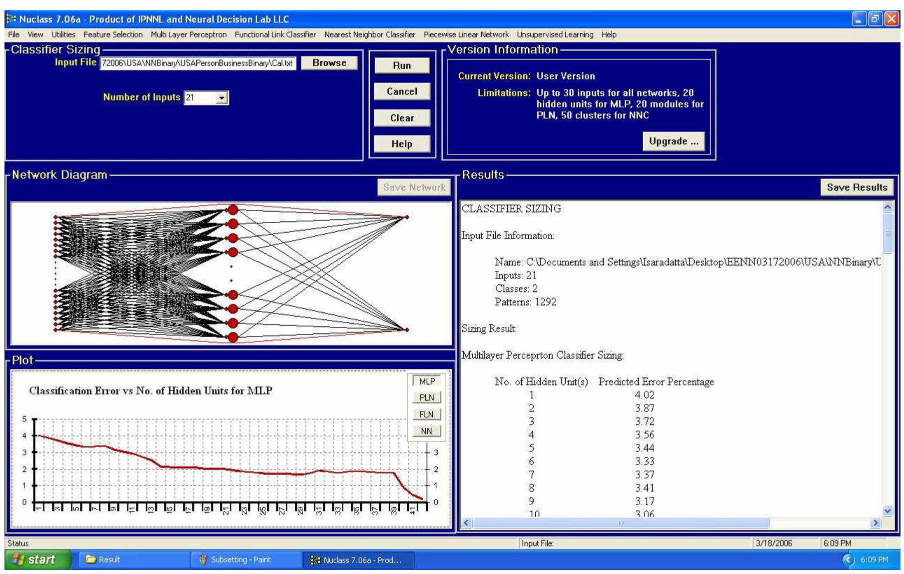

Figure D.6 Sizing for personal business purpose (personal vehicle and air)

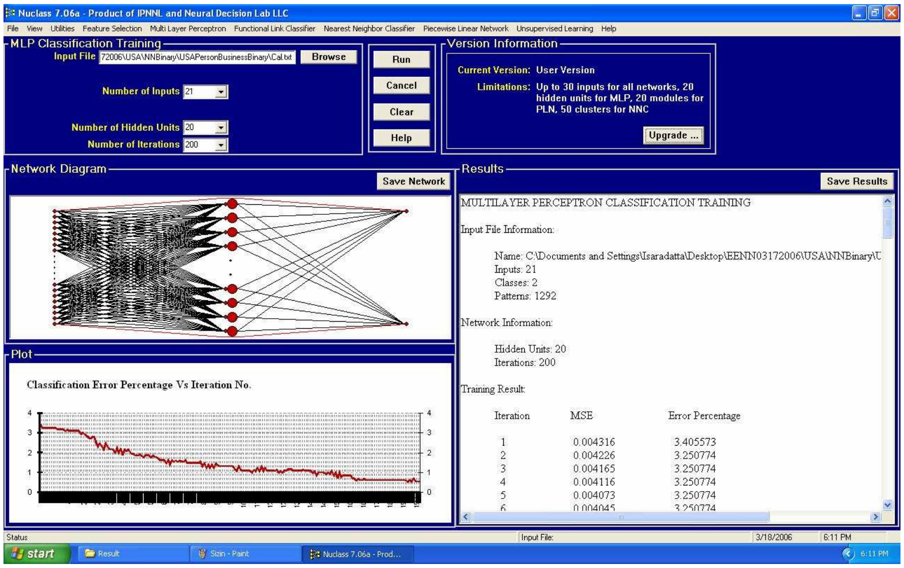

Figure D.7 Training for personal business purpose (personal vehicle and air)

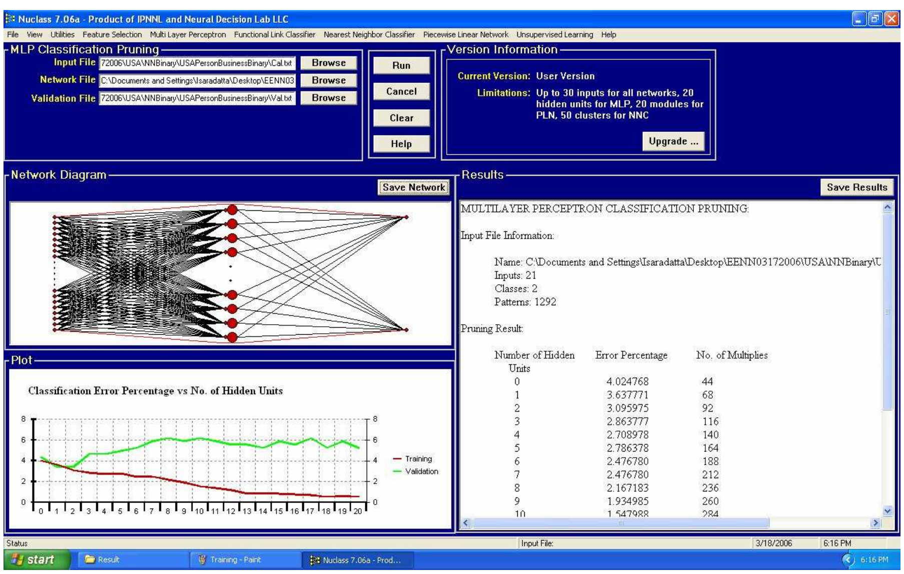

Figure D.8 Pruning for personal business purpose (personal vehicle and air)

Based on sizing tool result in Figure D.6, twenty neurons are first selected to train the network and, for training tool result in Figure D.7, 200 iterations are to perform primary selection. From Figure D.8, pruning tool result, two neurons are selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for personal business purpose (personal vehicle and air), two neurons with 200 iterations are selected.

D.3 Personal vehicle and air for pleasure purpose

D.3.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
3.95	1	{4, }
3.81	2	{4, 1, }
3.82	3	{4, 1, 2, }
3.81	4	{4, 1, 2, 5, }
3.79	5	{4, 1, 2, 5, 17, }
3.76	6	{4, 1, 2, 5, 17, 16, }
3.78	7	{4, 1, 2, 5, 17, 16, 15, }
3.71	8	{4, 1, 2, 5, 17, 16, 15, 12, }
3.71	9	{4, 1, 2, 5, 17, 16, 15, 12, 10, }
3.66	10	{4, 1, 2, 5, 17, 16, 15, 12, 10, 3, }
3.66	11	{4, 1, 2, 5, 17, 16, 15, 12, 10, 3, 20, }
3.66	12	{4, 1, 2, 5, 17, 16, 15, 12, 10, 3, 20, 6, }
3.66	13	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, }
3.65	14	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, }
3.65	15	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, 19, }
3.65	16	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, 19, 9, }
3.65	17	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, 19, 9, 8, }
3.65	18	{4, 1, 2, 5, 17, 16, 14, 12, 10, 3, 20, 6, 13, 7, 19, 9, 8, 15, }

```
  3.65                  19         {4, 1, 2, 5, 17, 16, 14, 12, 10, 3,
20, 6, 13, 7, 19, 9, 8, 15, 11, }

  3.65                  20         {4, 1, 2, 5, 17, 16, 14, 12, 10, 3,
20, 6, 13, 7, 19, 9, 8, 15, 11, 18, }

  3.65                  21         {4, 1, 2, 5, 17, 16, 14, 12, 10, 3,
20, 6, 13, 7, 19, 9, 8, 15, 11, 18, 21, }
```

D.3.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Calibrate.txt
      Inputs: 21
      Classes: 2
      Patterns: 6224

Network Information:

      Hidden Units: 3
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Result\MLPPruneWts3.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            90
         2            137

      Total Error Patterns: 227
      Percentage Error:       3.65
```

D.3.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Validation.txt
      Inputs: 21
      Classes: 2
```

```
      Patterns: 1556

Network Information:

      Hidden Units: 3
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Result\MLPPruneWts3.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            23
         2            35

      Total Error Patterns: 58
      Percentage Error:       3.73
```

D.3.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNBinary\PleasureBi.txt
      Inputs: 21
      Classes: 2
      Patterns: 493
      Desired Class ID present: YES

Network Information:

      Hidden Units: 3
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Result\MLPPruneWts3.wts

      Class ID    No. of Error Patterns
         1            3
         2            12

      Total Error Patterns: 15
      Percentage Error:       3.04

Select Processed Output from the drop down list.
```

D.3.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNBinary\PleasureBi.txt
      Inputs: 21
      Classes: 2
      Patterns: 405
      Desired Class ID present: YES

Network Information:

      Hidden Units: 3
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNBinary\USAPleasureBinar
y\Result\MLPPruneWts3.wts

      Class ID    No. of Error Patterns
         1             6
         2             7

      Total Error Patterns: 13
      Percentage Error:       3.21

Select Processed Output from the drop down list.
```

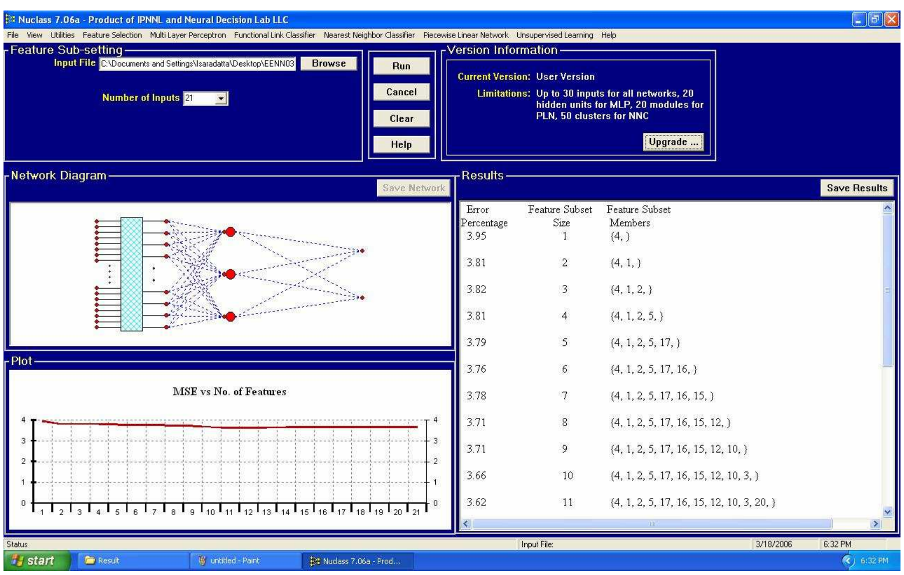

Figure D.9 Feature selection for pleasure purpose (personal vehicle and air)

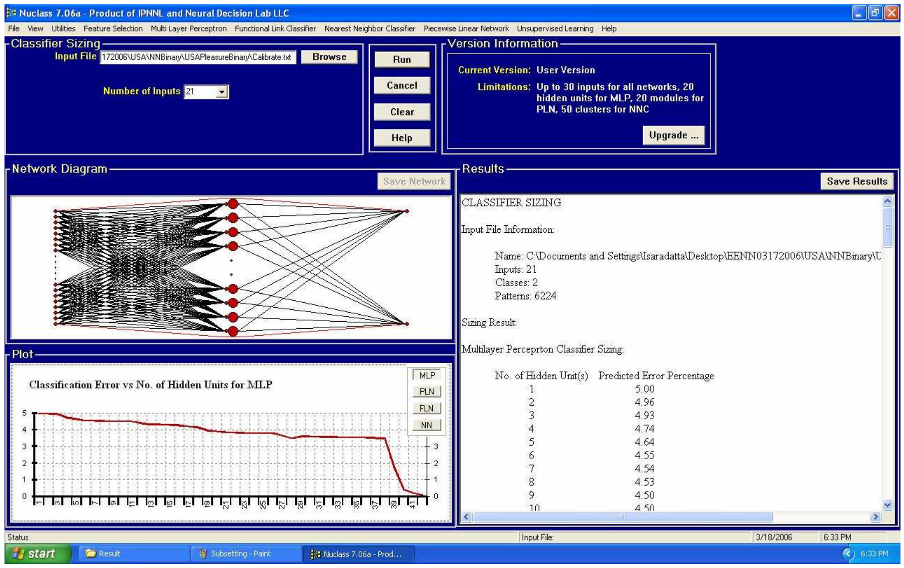

Figure D.10 Sizing for pleasure purpose (personal vehicle and air)

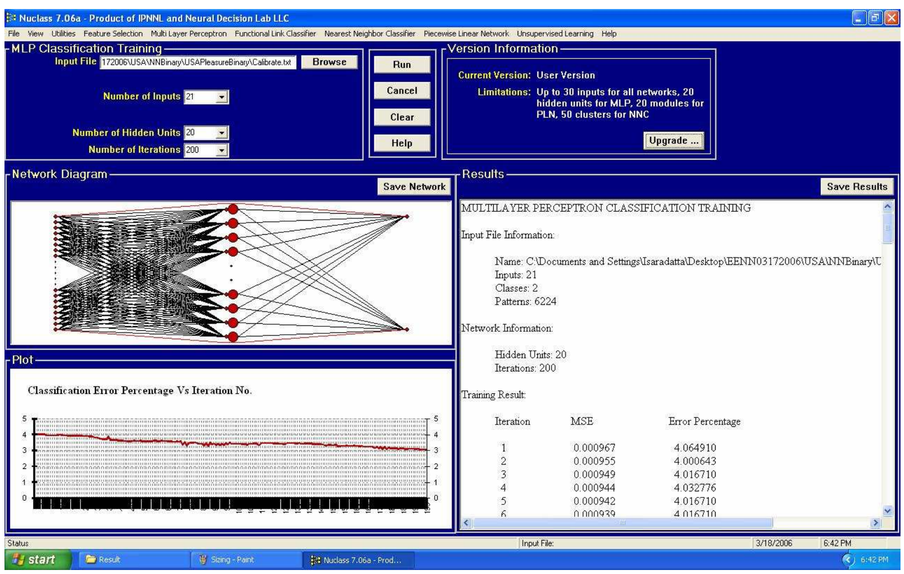

Figure D.11 Training for pleasure purpose (personal vehicle and air)

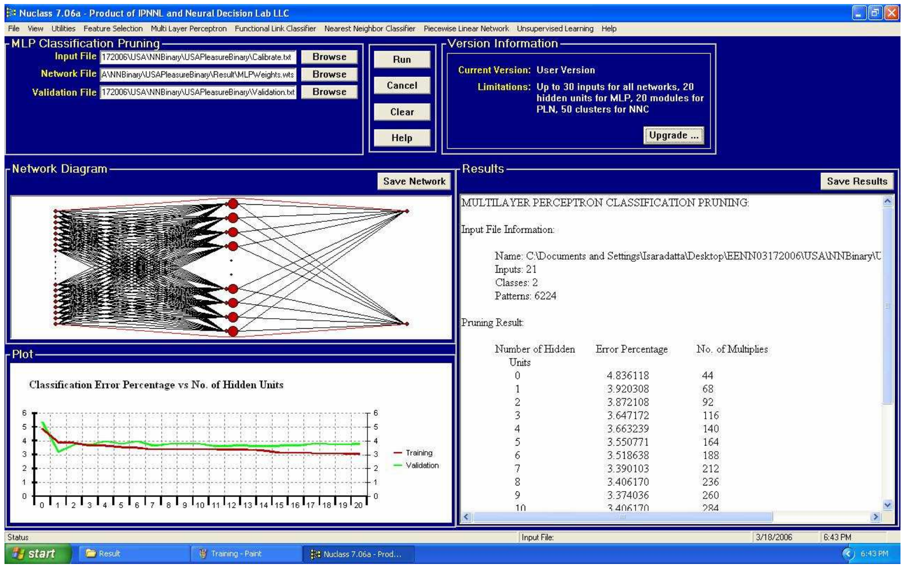

Figure D.12 Pruning for pleasure purpose (personal vehicle and air)

Based on sizing tool result in Figure D.10, twenty neurons are first selected to train the network and, for training tool result in Figure D.11, 200 iterations are to perform primary selection. From Figure D.12, pruning tool result, three neurons are selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for pleasure purpose (personal vehicle and air), three neurons with 200 iterations are selected.

D.4 Personal vehicle, air, and ground for business purpose

D.4.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
7.71	1	{4, }
7.44	2	{4, 15, }
7.27	3	{4, 15, 1, }
7.00	4	{4, 15, 1, 2, }
7.01	5	{4, 15, 1, 2, 5, }
7.01	6	{4, 15, 1, 2, 5, 3, }
6.96	7	{4, 15, 1, 2, 5, 3, 14, }
6.98	8	{4, 15, 1, 2, 5, 3, 14, 10, }
6.95	9	{4, 15, 1, 2, 5, 3, 14, 10, 6, }
6.93	10	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, }
6.89	11	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, 13, }
6.86	12	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, 13, 19, }
6.86	13	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, 13, 19, 18, }
6.86	14	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, 13, 19, 18, 7, }
6.86	15	{4, 15, 1, 2, 5, 3, 14, 10, 6, 21, 13, 19, 18, 7, 17, }
6.86	16	{4, 15, 1, 2, 5, 3, 14, 10, 9, 20, 13, 19, 18, 7, 17, 8, }
6.86	17	{4, 15, 1, 2, 5, 3, 14, 10, 9, 20, 13, 19, 18, 7, 17, 8, 16, }
6.86	18	{4, 15, 1, 2, 5, 3, 14, 10, 9, 20, 13, 19, 18, 7, 17, 8, 16, 6, }

```
  6.86                 19         {4, 15, 1, 2, 5, 3, 14, 10, 9, 20,
13, 19, 18, 7, 17, 8, 16, 6, 12, }

  6.86                 20         {4, 15, 1, 2, 5, 3, 14, 10, 9, 20,
13, 19, 18, 7, 17, 8, 16, 6, 12, 21, }

  6.86                 21         {4, 15, 1, 2, 5, 3, 14, 10, 9, 20,
13, 19, 18, 7, 17, 8, 16, 6, 12, 21, 11, }
```

D.4.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\Calibrate.txt
      Inputs: 21
      Classes: 3
      Patterns: 5860

Network Information:

      Hidden Units: 10
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\result\MLPPruneWts10.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            75
         2            118
         3            107

      Total Error Patterns: 300
      Percentage Error:       5.12
```

D.4.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:
```

```
      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\validation.txt
      Inputs: 21
      Classes: 3
      Patterns: 1465

Network Information:

      Hidden Units: 10
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\result\MLPPruneWts10.wts

Testing Result:

      Class ID    No. of Error Patterns
         1           22
         2           27
         3           28

      Total Error Patterns: 77
      Percentage Error:       5.26
```

D.4.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNNested\BusinessNested
.txt
      Inputs: 21
      Classes: 3
      Patterns: 254
      Desired Class ID present: YES

Network Information:

      Hidden Units: 10
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\result\MLPPruneWts10.wts

      Class ID    No. of Error Patterns
         1           45
         2           13
         3           2
```

```
      Total Error Patterns: 60
      Percentage Error:      23.62

Select Processed Output from the drop down list.
```

D.4.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNNested\BusinessNested.t
xt
      Inputs: 21
      Classes: 3
      Patterns: 270
      Desired Class ID present: YES

Network Information:

      Hidden Units: 10
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USABisinessNeste
d\result\MLPPruneWts10.wts

      Class ID    No. of Error Patterns
         1            4
         2            2
         3            2

      Total Error Patterns: 8
      Percentage Error:       2.96

Select Processed Output from the drop down list.
```

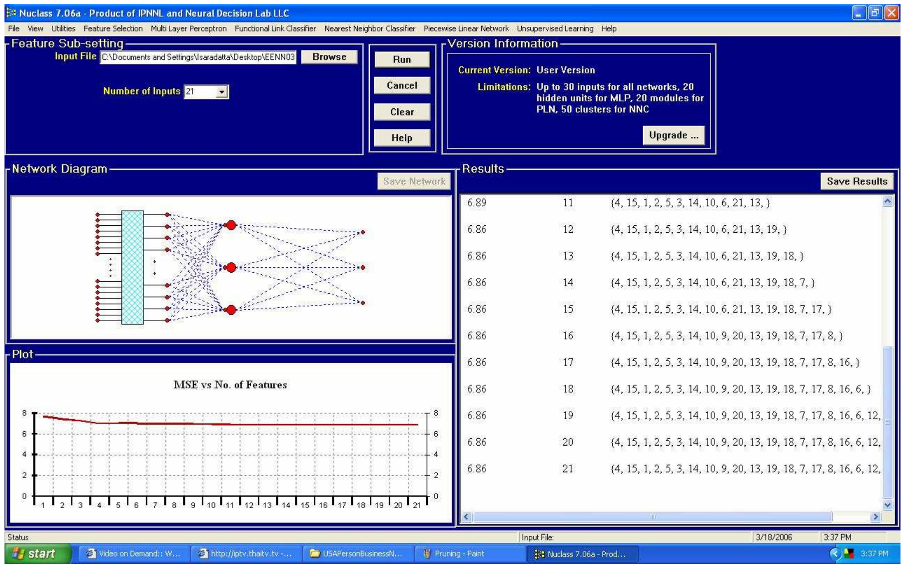

Figure D.13 Feature selection for business purpose (personal vehicle, air, and ground)

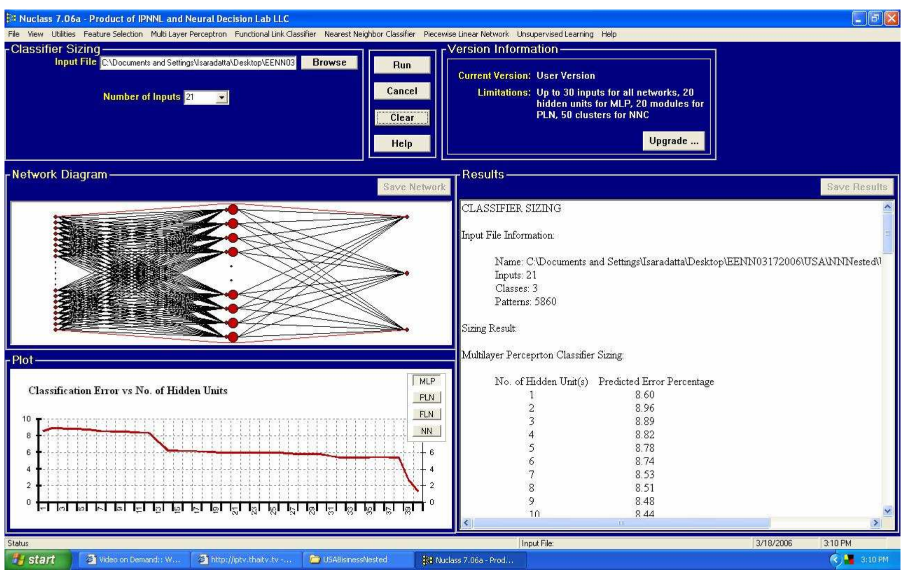

Figure D.14 Sizing for business purpose (personal vehicle, air, and ground)

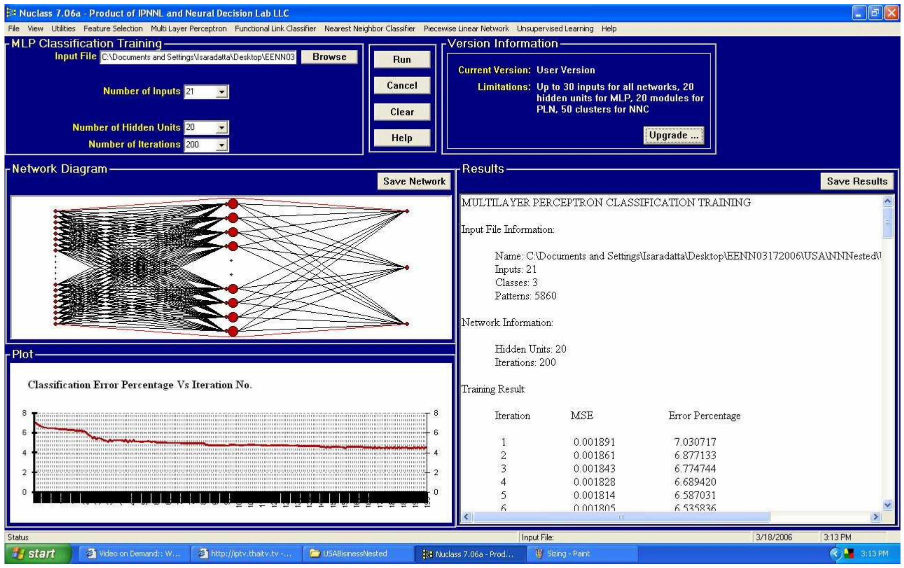

Figure D.15 Training for business purpose (personal vehicle, air, and ground)

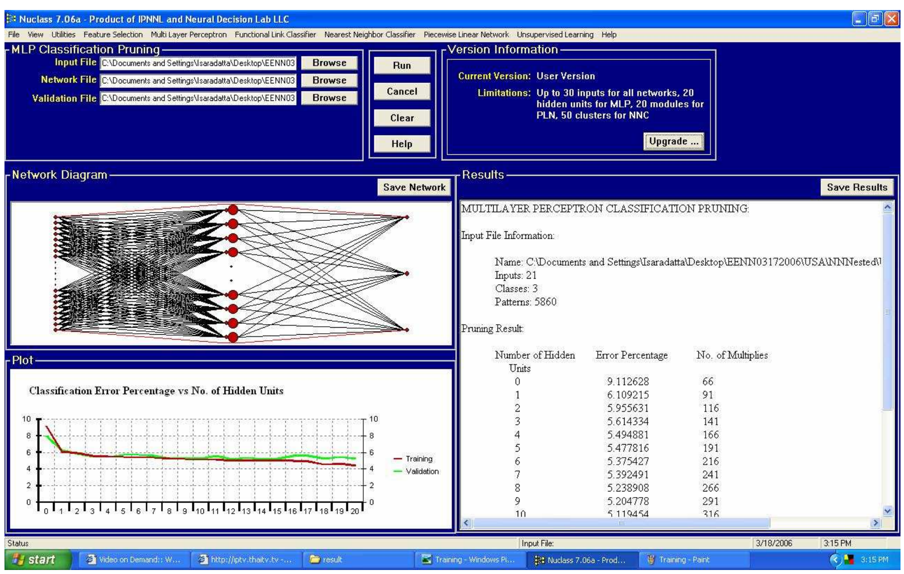

Figure D.16 Pruning for business purpose (personal vehicle, air, and ground)

Based on sizing tool result in Figure D.14, twenty neurons are first selected to train the network and, for training tool result in Figure D.15, 200 iterations are to perform primary selection. From Figure D.16, pruning tool result, ten neurons are selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for business purpose (personal vehicle, air, and ground), ten neurons with 200 iterations are selected.

D.5 Personal vehicle, air, and ground for personal business purpose

D.5.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
6.07	1	{4, }
5.31	2	{4, 18, }
5.01	3	{4, 18, 15, }
5.31	4	{4, 18, 10, 3, }
4.93	5	{4, 18, 10, 3, 1, }
5.08	6	{4, 18, 10, 3, 1, 12, }
4.93	7	{4, 18, 10, 3, 1, 12, 5, }
4.70	8	{4, 18, 10, 3, 1, 12, 5, 15, }
4.78	9	{4, 18, 10, 3, 1, 12, 5, 15, 2, }
4.78	10	{4, 18, 10, 3, 1, 12, 5, 15, 2, 7, }
4.55	11	{4, 18, 10, 3, 1, 12, 5, 15, 2, 7, 13, }
4.55	12	{4, 18, 10, 3, 1, 12, 5, 15, 2, 7, 13, 9, }
4.55	13	{4, 18, 10, 3, 1, 12, 5, 15, 2, 7, 13, 9, 20, }
4.55	14	{4, 18, 10, 3, 1, 12, 5, 15, 2, 7, 13, 9, 20, 16, }
4.55	15	{4, 18, 10, 3, 1, 12, 5, 14, 2, 7, 13, 9, 20, 17, 8, }
4.55	16	{4, 18, 10, 3, 1, 12, 5, 14, 2, 7, 13, 9, 20, 17, 8, 19, }
4.55	17	{4, 18, 10, 3, 1, 12, 5, 14, 2, 7, 13, 9, 20, 17, 8, 19, 16, }
4.55	18	{4, 18, 10, 3, 1, 12, 5, 14, 2, 7, 13, 9, 20, 17, 8, 19, 16, 21, }

```
  4.55                  19          {4, 18, 10, 3, 1, 12, 5, 14, 2, 7,
13, 9, 20, 17, 8, 19, 16, 21, 6, }

  4.55                  20          {4, 18, 10, 3, 1, 12, 5, 14, 2, 7,
13, 9, 20, 17, 8, 19, 16, 21, 6, 15, }

  4.55                  21          {4, 18, 10, 3, 1, 12, 5, 14, 2, 7,
13, 9, 20, 17, 8, 19, 16, 21, 6, 15, 11, }
```

D.5.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\Cal.txt
      Inputs: 21
      Classes: 3
      Patterns: 1318

Network Information:

      Hidden Units: 1
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\Result\MLPWeights.wts

Testing Result:

      Class ID    No. of Error Patterns
         1           14
         2           24
         3           26

      Total Error Patterns: 64
      Percentage Error:       4.86
```

D.5.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:
```

```
      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\val.txt
      Inputs: 21
      Classes: 3
      Patterns: 329

Network Information:

      Hidden Units: 1
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\Result\MLPWeights.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            6
         2            8
         3            6

      Total Error Patterns: 20
      Percentage Error:       6.08
```

D.5.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNNested\PersonBusiness
Nested.txt
      Inputs: 21
      Classes: 3
      Patterns: 683
      Desired Class ID present: YES

Network Information:

      Hidden Units: 1
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\Result\MLPWeights.wts

      Class ID    No. of Error Patterns
         1            17
         2            19
         3            22
```

```
      Total Error Patterns: 58
      Percentage Error:       8.49

Select Processed Output from the drop down list.
```

D.5.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNNested\PersonBusinessNe
sted.txt
      Inputs: 21
      Classes: 3
      Patterns: 62
      Desired Class ID present: YES

Network Information:

      Hidden Units: 1
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPersonBusines
sNested\Result\MLPWeights.wts

      Class ID    No. of Error Patterns
         1           0
         2           0
         3           3

      Total Error Patterns: 3
      Percentage Error:       4.84

Select Processed Output from the drop down list.
```

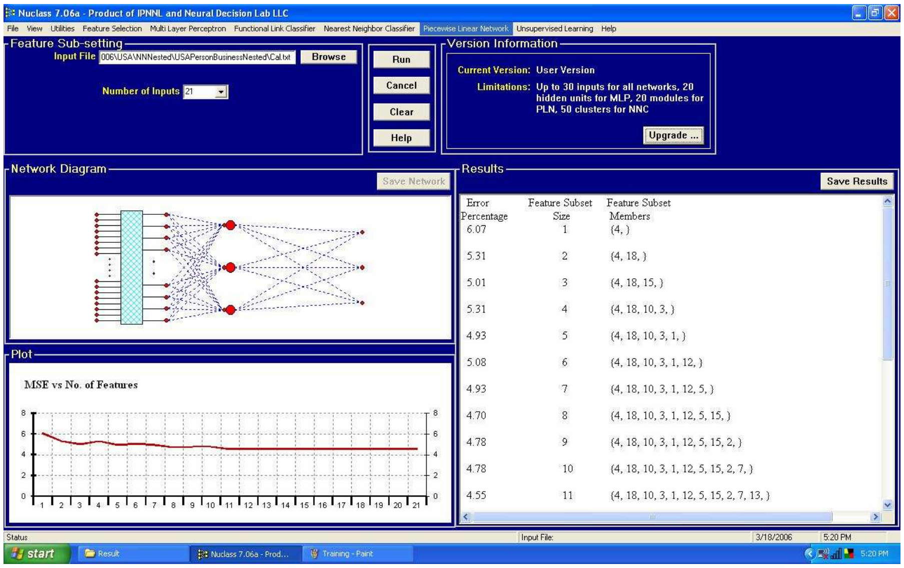

Figure D.17 Feature selection for personal business purpose (personal vehicle, air, and ground)

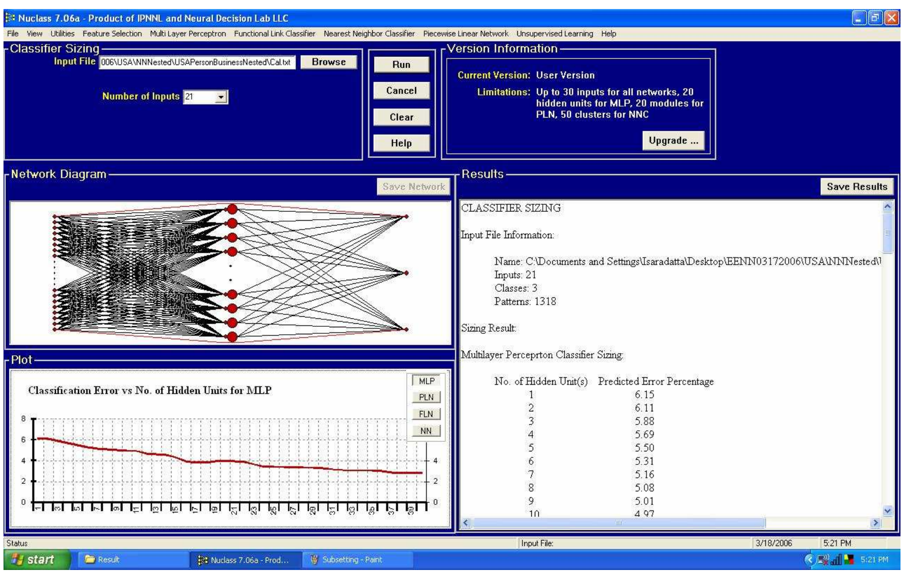

Figure D.18 Sizing for personal business purpose (personal vehicle, air, and ground)

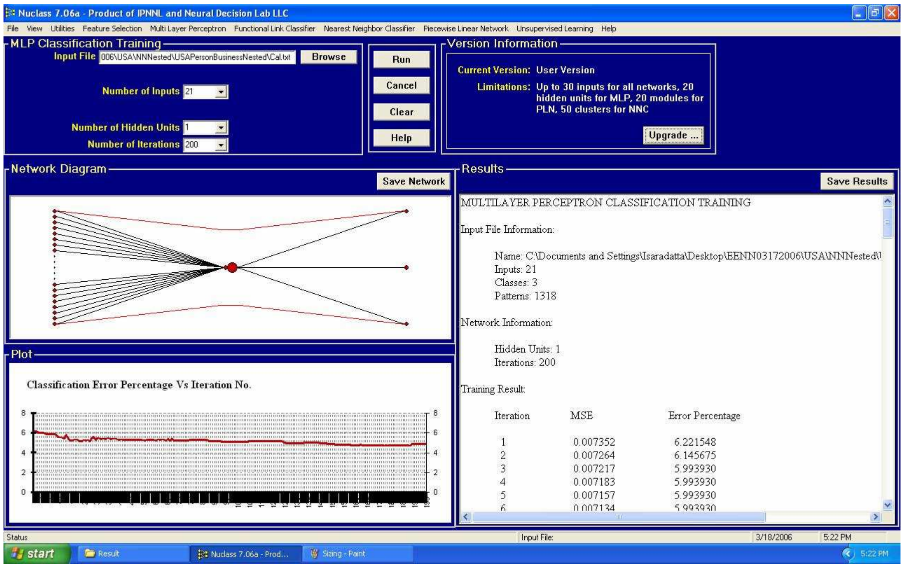

Figure D.19 Training for personal business purpose (personal vehicle, air, and ground)

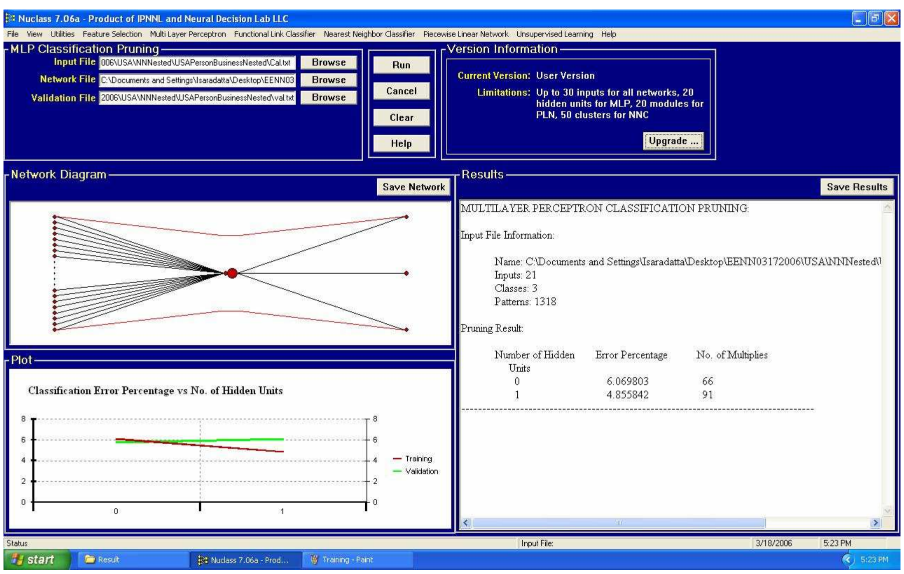

Figure D.20 Pruning for personal business purpose (personal vehicle, air, and ground)

Based on sizing tool result in Figure D.18, twenty neurons are first selected to train the network and, for training tool result in Figure D.19, 200 iterations are to perform primary selection. From Figure D.20, pruning tool result, one neuron is selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for personal business purpose (personal vehicle, air, and ground), one neuron with 200 iterations is selected.

D.6 Personal vehicle, air, and ground for pleasure purpose

D.6.1 Feature result

Error Percentage	Feature Subset Size	Feature Subset Members
5.31	1	{4, }
5.34	2	{4, 2, }
5.37	3	{4, 2, 10, }
5.18	4	{4, 2, 10, 1, }
5.20	5	{4, 2, 10, 1, 5, }
5.17	6	{4, 2, 10, 1, 5, 12, }
5.13	7	{4, 2, 10, 1, 5, 12, 3, }
5.09	8	{4, 2, 10, 1, 5, 12, 3, 20, }
5.09	9	{4, 2, 10, 1, 5, 12, 3, 20, 7, }
5.09	10	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, }
5.07	11	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, 17, }
5.10	12	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, 17, 13, }
5.09	13	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, 17, 13, 16, }
5.05	14	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, 17, 13, 16, 9, }
5.02	15	{4, 2, 10, 1, 5, 12, 3, 20, 7, 14, 17, 13, 16, 9, 19, }
5.02	16	{4, 2, 10, 1, 5, 12, 3, 21, 6, 14, 17, 13, 16, 9, 19, 8, }
5.02	17	{4, 2, 10, 1, 5, 12, 3, 21, 6, 14, 17, 13, 16, 9, 19, 8, 7, }
5.02	18	{4, 2, 10, 1, 5, 12, 3, 21, 6, 14, 17, 13, 16, 9, 19, 8, 7, 20, }

```
  5.02                  19         {4, 2, 10, 1, 5, 12, 3, 21, 6, 14,
17, 13, 16, 9, 19, 8, 7, 20, 11, }

  5.02                  20         {4, 2, 10, 1, 5, 12, 3, 21, 6, 14,
17, 13, 16, 9, 19, 8, 7, 20, 11, 18, }

  5.02                  21         {4, 2, 10, 1, 5, 12, 3, 21, 6, 14,
17, 13, 16, 9, 19, 8, 7, 20, 11, 18, 15, }
```

D.6.2 Calibration result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\Calibrate.txt
      Inputs: 21
      Classes: 3
      Patterns: 6311

Network Information:

      Hidden Units: 8
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\Result\MLPPruneWts8.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            79
         2            144
         3            90

      Total Error Patterns: 313
      Percentage Error:       4.96
```

D.6.3 Validation result

```
MULTILAYER PERCEPTRON CLASSIFICATION TESTING:

Input File Information:
```

```
      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\validation.txt
      Inputs: 21
      Classes: 3
      Patterns: 1578

Network Information:

      Hidden Units: 8
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\Result\MLPPruneWts8.wts

Testing Result:

      Class ID    No. of Error Patterns
         1            21
         2            39
         3            19

      Total Error Patterns: 79
      Percentage Error:       5.01
```

D.6.4 Texas result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Texas\NNNested\PleasureNested
.txt
      Inputs: 21
      Classes: 3
      Patterns: 499
      Desired Class ID present: YES

Network Information:

      Hidden Units: 8
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\Result\MLPPruneWts8.wts

      Class ID    No. of Error Patterns
         1            5
         2            11
         3            6
```

```
      Total Error Patterns: 22
      Percentage Error:       4.41
```

Select Processed Output from the drop down list.

D.6.5 Wisconsin result

```
MULTILAYER PERCEPTRON CLASSIFICATION PROCESSING:

Input File Information:

      Name: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\Wis\NNNested\PleasureNested.t
xt
      Inputs: 21
      Classes: 3
      Patterns: 410
      Desired Class ID present: YES

Network Information:

      Hidden Units: 8
      Network File: C:\Documents and
Settings\Isaradatta\Desktop\EENN03172006\USA\NNNested\USAPleasureNeste
d\Result\MLPPruneWts8.wts

      Class ID    No. of Error Patterns
         1            3
         2            7
         3            5

      Total Error Patterns: 15
      Percentage Error:       3.66

Select Processed Output from the drop down list.
```

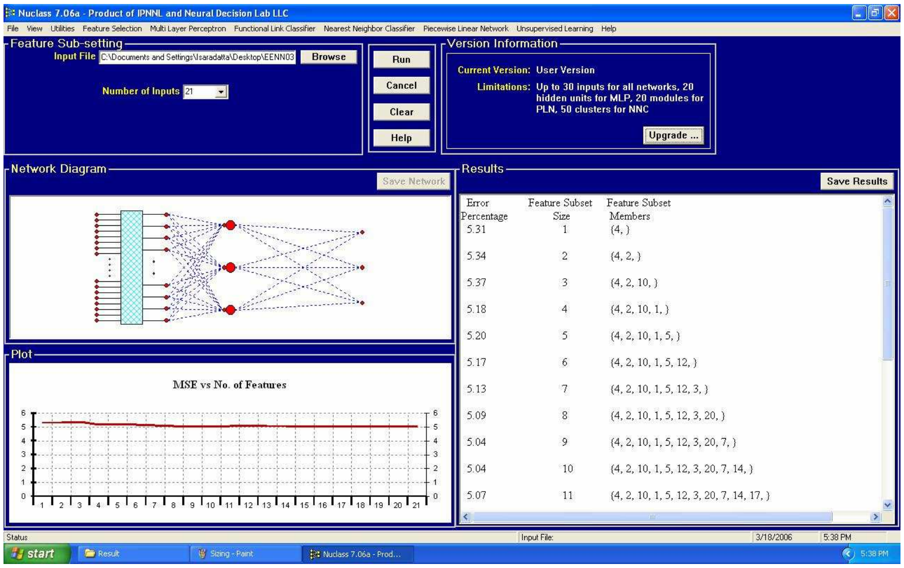

Figure D.21 Feature selection for pleasure purpose (personal vehicle, air, and ground)

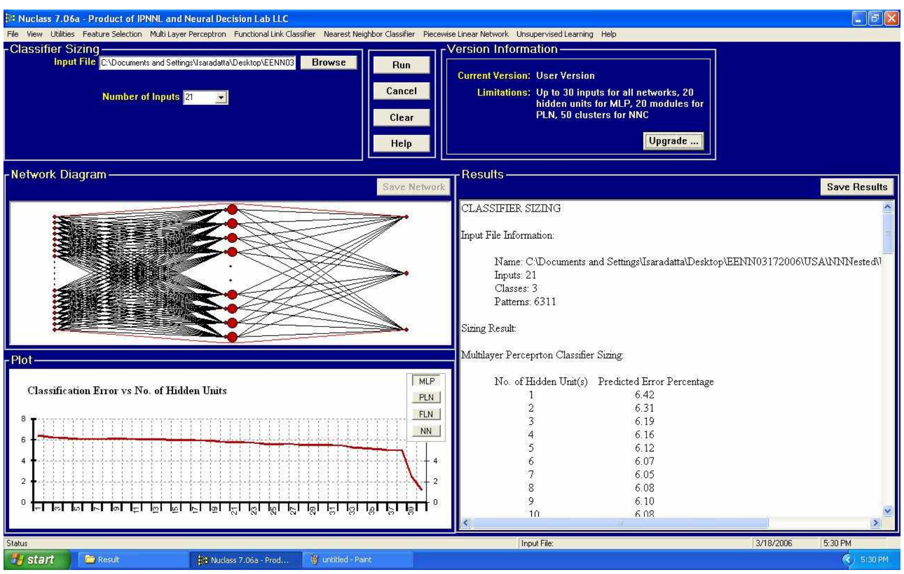

Figure D.22 Sizing for pleasure purpose (personal vehicle, air, and ground)

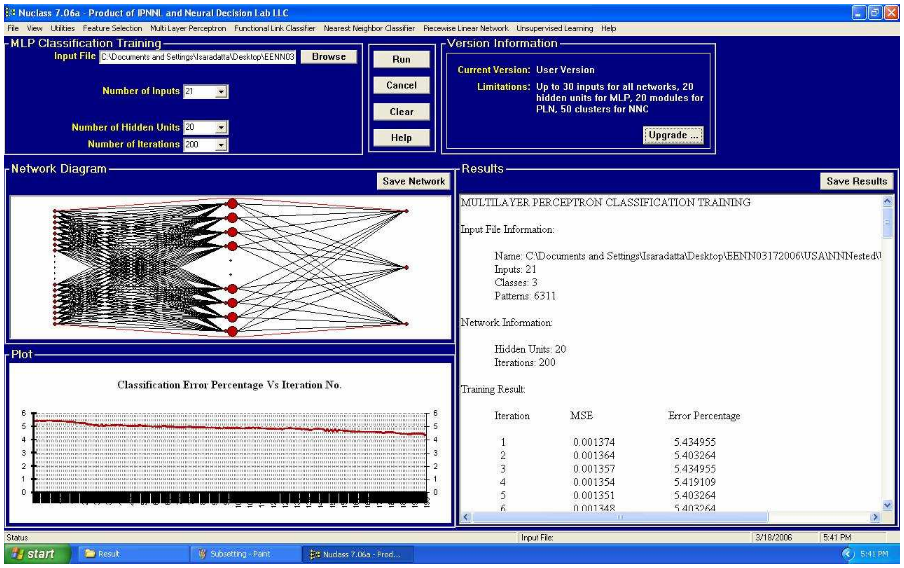

Figure D.23 Training for pleasure purpose (personal vehicle, air, and ground)

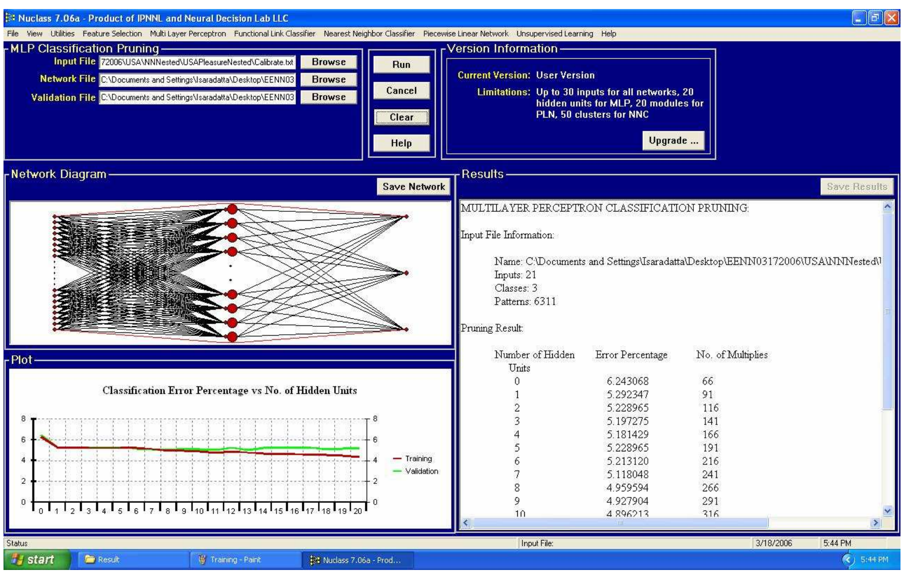

Figure D.24 Pruning for pleasure purpose (personal vehicle, air, and ground)

Based on sizing tool result in Figure D.22, twenty neurons are first selected to train the network and, for training tool result in Figure D.23, 200 iterations are to perform primary selection. From Figure D.24, pruning tool result, eight neurons are selected because the difference between training and validation is lowest different with regard to error percentage. Therefore, for pleasure purpose (personal vehicle, air, and ground), eight neurons with 200 iterations are selected.

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