GENDER-BASED HETEROGENEOUS CHOICE BEHAVIOR TOWARDS SUSTAINABLE MODES IN THE URBAN AND RURAL AREAS OF A DEVELOPING SOCIETY

A THESIS SUBMITTED BY

MASUMA MOLLIKA MITI

(Student ID: 170051079)

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

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APPROVAL

The dissertation entitled "GENDER-BASED HETEROGENEOUS CHOICE BEHAVIOR TOWARDS SUSTAINABLE MODES IN THE URBAN AND RURAL AREAS OF A DEVELOPING SOCIETY", submitted by Masuma Mollika Miti, Student ID- 170051079, has been found as satisfactory and accepted as partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering.

Supervisor

Dr. Moinul Hossain
Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT),
Board Bazar, Gazipur, Bangladesh.

DECLARATION

It is hereby declared that this thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma.

Name of Supervisor

Dr. Moinul Hossain
Professor
Department of Civil and Environmental Engineering (CEE)
Islamic University of Technology (IUT),
Board Bazar, Gazipur, Bangladesh.

Name of Candidate

Masuma Mollika Miti
Student No: 170051079

DEDICATION

This thesis is dedicated to my family and all of my teachers who have helped me get to this point. I respect their guidance, patience, and, most importantly, their faith in me.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AUC	Area Under the Curve
BBN	Bayesian Belief Network
CPT	Conditional Probability Table
DAG	Directed Acyclic Graph
EM	Expectation Maximization
GeNIe	Graphical Network Interface
LOO	Leave One Out
ROC	Receiver Operating Characteristic
SDG	Sustainable Development Goals
TRB	Transportation Research Board
WIiT	Women's Issues in Transportation

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First and foremost, I am grateful to Almighty Allah for conferring upon me the ability to complete my thesis work successfully. Allah, the kindest and merciful, will always have my profound appreciation.

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ABSTRACT

Gender equity and the development of sustainable cities and communities are two critical aspects of the sustainable development goals (SDG). In this expanding globe, women make up half of the world population. Women explore every element of modern life, including education, economics, and public welfare, on an equal basis with males. Even though women are more aware of their education, profession, and societal norms, gender gaps persist due to a lack of equality and opportunities. A long-term, equitable plan is essential to meet traffic demand effectively and efficiently in today's environment. However, academics and planners have paid less attention to women's concerns in most cases. Furthermore, better-informed transportation policy and planning with appropriate (sustainable) modes of transport are undoubtedly required for the sustainable growth of cities. Sustainable transportation should be designed in such a way that it benefits both men and women equally.

This study intends to explain how to boost the use of sustainable transportation in developing countries, regardless of gender or demographic changes, in order to accomplish the SDGs. To attain the goals, the research identified several objectives. One of the primary purposes of this study is to look into the challenges that women and men experience when choosing sustainable transportation options. Additional research objectives include determining the relationship between various factors impacting mode choice patterns and making additional recommendations to transportation authorities and planners for future planning.

A significant correlation was formed among variables that describe the relationship between the factors that influenced mode choice behavior, particularly in the field of sustainable transportation, for achieving the study's goals. This study was carried out using the Bayesian Belief Network (BBN) approach. The network was built on the foundation of previous research findings and expert knowledge. The data for this study came from four different Bangladeshi cities. The researchers did not collect the data directly; instead, a secondary source was operated to acquire data. The data was processed before being imported into the software. The analysis was done with GeNIe software. The PC algorithm, which is based on conditional independence, was used to create the Bayesian network. The expectation-maximization approach and sensitivity analysis were used to obtain the posterior probability

for all variables using the Bayesian network. Finally, multiple results were obtained from the network.

Location, marital status, vehicle ownership, age, and the state of the pickup location, according to the model, are the most important characteristics that determine sustainable mode choice. In addition, the mode selection process is influenced by gender and harassment on public transit. The most crucial factor to consider when choosing a mode is safety and security. In other cases, however, the cost of travel is considered while selecting a means of transportation. Apart from that, persons with personal automobiles always prefer personal vehicles in urban settings; nevertheless, in rural locations, this preference shifts. NMV has a considerable effect on mode selection patterns. People who do not have access to a personal vehicle prefer NMVs in both rural and urban areas. In this case, however, females in metropolitan areas favor public transportation.

To sum up, adequate NMV lanes should be designed so that people can move around smoothly and sustainable development goals of using sustainable transport are met. The public transportation system can be improved in order to increase the number of people who use it. "Gender-balanced budget," which can lessen or eliminate gender bias, should be supplied for the gender-based perspective. Furthermore, programs such as "Safe Route to School" can be established to assist women in walking more readily and accessing educational, career, and other possibilities.

Keywords: Sustainable Transport, Bayesian Network, Developing Country, Gender Equity.

CHAPTER ONE
INTRODUCTION

1.1 Background

Men and women have diverse travel needs worldwide for two key reasons. Firstly, the varying gender roles that women and men play have a significant impact on mobility. Secondly, harmful situations and personal safety concerns are more likely to hinder women's mobility (ITF, 2021). Women's engagement in the transportation sector has received little attention throughout history. The first conference on Women's Issues in Transportation (WIiT) by one of the recognized organizations Transportation Research Board (TRB), was conducted in 1978, despite substantial opposition to researching women's travel habits, which was not considered a legitimate research topic at the time. The meeting, however, created some awareness about the importance of studying women's travel patterns and behaviour. It was surprising that the second conference took 17 years to happen (Rosenbloom, 2019). A sustainable, equitable plan is required to fulfil traffic demand effectively and efficiently in today's world. However, researchers and planners have paid less attention to the concerns of women in most strategies.

Half of the population in this growing world are women. In today's society, women are exploring every aspect, including education, economics, and public welfare, equal footing with men. Despite women being more aware of their education, career, and societal ideals, disparities between men and women continue due to a lack of equality and opportunities. Policies have been implemented to remove inequalities in women's access to formal jobs and recognize their triple roles as productive, reproductive, and community-managing activities (Wong, 2016).

However, women do not have access to all of the amenities, particularly while traveling outside the home. They are constantly concerned about whether everything will go smoothly if they use public transit. Different travel patterns are observed among women than that of men, but planners and stakeholders in transportation planning have yet to fully realize this, resulting in their unfavorable travel experiences and attitudes (Quinones, 2020). Women and men have different viewpoints on several issues such as personal safety, risk, and travel costs, and time whenever it comes to mode choice (Lecompte & Juan Pablo, 2017).

Gender equality and a sustainable developed city are two significant parts of the sustainable development goals. Figure 1.1 (ONU, 2020) depicts all the SDGs for a country –

Figure 1.1: SDGs for a country

Any country must include sustainable transportation modes in order to meet the demand for sustainable development. There are several approaches to describe sustainable transportation. In this research sustainable transportation is defined as any mode of transportation that is "green," has a minimal environmental impact, and satisfies existing and future demands. Figure 2.1 shows the modes of sustainable transportation in order of priority (Milner, 2019). According to the priority list, sustainable transports includes walking, cycling, utility bicycles/NMVs, public transportation, carpooling, car sharing, private transport and others.

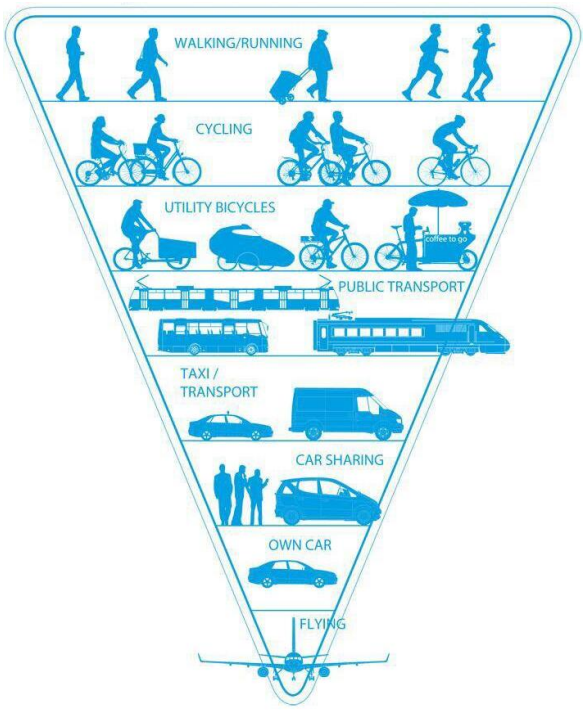

Figure 1.2: Sustainable transport modes in priority order

However, understanding the perspectives of both men and women on sustainable transportation is critical. Factors that influence sustainable mode selection are also a source of concern. This study will examine which factors have the most significant influence on women's mode selections. In terms of mode selection, men and women will be compared. This research will also look into measures to increase the use of sustainable transportation in both rural and urban areas of a developing society.

1.2 Problem Statement

Gender differences, socio-demographic issues, regional differences, and other factors should be taken into consideration when designing an effective, sustainable transportation system (Khoo & Ong, 2014; Ramezani et al., 2018). Gender equality is a prerequisite for society's progress, innovation, and sustainability (Stanković et al., 2021). For the advancement of sustainable transportation solutions, there is a clear need for better-informed transportation policy and planning to guarantee that services and innovation serve men and women equally (ITF, 2021). However, several studies showed that males make the majority of planning and development decisions in developing countries, with few consideration for the needs of women

(Rivera, 2007; Turner & Fouracre, 1995). Transportation planning should consider regional disparities since a generalization of mobility trends may hide regional travel demands (Xu, 2020). Furthermore, relatively few studies have taken into account spatial issues, gender inequities, and other factors when evaluating sustainable transportation in developing nations.

1.3 Purpose and Objectives

This study aims to show how to increase the usage of sustainable transportation in developing nations, regardless of gender or demographic changes. The study has established the following particular objectives to achieve this:

- To explore the factors women and men face while using sustainable transportation (walking, cycling, NMVs, public transports, paratransit) options.
- To determine the relationship among various factors that affects the mode choice patterns between men and women.
- To provide recommendations to transportation authorities and planners for future planning that takes gender into account in order to resolve mode choice characteristics.

1.4 Scope of the study

The study's purpose is to identify key characteristics that influence the utilization of sustainable transportation alternatives. The study will also reveal whether the relevant determinants are consistent across male and female users and urban and rural settings. Besides, the investigation will also reveal the relationship among the factors affecting mode choice. The people who took part in this study came from different rural and urban places in the country. The survey participants' variety ensured the most representative response.

1.5 Organization of the thesis

This research is primarily organized into five chapters. All the chapters have titles along with subtitles that provide adequate explanations and justify the entire work. The following is a concise summary of the entire thesis in chronological order.

Chapter 1: Introduction

The first chapter begins with a comprehensive introduction that will act as the foundation for the entire thesis. This chapter sets the objectives of the problem statements, the research goal, and the specific milestones the study aims to attain. This chapter also introduces the research topic, outlines its scope, and identifies the thesis structure.

Chapter 2: Literature Review

The second chapter includes a detailed literature analysis to explain the current research issue in the given sector, consequently leading to the identification of research gaps.

Chapter 3: Data Collection and Methodology

The third chapter goes through the methodology used in this study in detail. This chapter also covers the study area, data collection methods, a brief description of each model, and why the method was chosen for this study.

Chapter 4: Analysis and Result

The fourth chapter goes into the entire analysis procedure as well as the outcomes. This chapter guided readers through each phase of the analysis, along with the final results.

Chapter 5: Conclusion and Recommendations

The final chapter summarizes the research's principal findings and recommends policy implications. Furthermore, this chapter also attempts to summarize the study's shortcomings and potential opportunities.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Several considerations were considered when organizing the thesis's literature review chapter. At first, studies related to transport and gender were discussed. After that, the factors that influence the utilization of sustainable modes of transportation were discussed. Besides, the significant findings of several published papers on transportation modes will be described to enable readers to understand the variables and contributing elements used. Finally, relevant research in emerging countries and policies and recommendations that can be implemented based on the results are discussed.

The research began with a search of scholarly publications and other relevant information. A comprehensive search for relevant publications, journals, research papers, books, and research articles was carried out earlier. The investigation was conducted by searching articles for key terms like factors affecting sustainable transport choice, mode choice patterns among male and female, factors affecting mode choice, mode choice patterns in developing countries, and so on.

Table 2.1 shows the number of articles found by a simple online search.

Table 2.1: Number of articles found in online search

Databases	Search Terms/ Keywords	Results
Science Direct	Factors affecting sustainable transport choice	43,305
Science Direct	Mode choice pattern among male and female	45,137
Science Direct	Women mode choice behaviour	43,195
Science Direct	Factors affecting mode choice	113,573
Google Scholar	Mode choice patterns in developing countries	73,840
Google Scholar	Factors affecting mode choice	About 1,610,000
Google Scholar	Mode choice pattern among male and female	About 1,570,000
Google Scholar	Women mode choice behaviour	About 736,000
Google Scholar	Factors affecting sustainable transport choice	About 805,000
Google Scholar	Mode choice patterns in developing countries	About 2,280,000
TRID	Factors affecting mode choice	351

TRID	Mode choice pattern among gender	28
TRID	Women mode choice behaviour	64
TRID	Factors affecting sustainable transport choice	45
TRID	Mode choice patterns in developing countries	56
ProQuest	Factors affecting mode choice	685,354
ProQuest	Mode choice pattern among gender	556,934
ProQuest	Women mode choice behaviour	421,561
ProQuest	Factors affecting sustainable transport choice	267,778
ProQuest	Mode choice patterns in developing countries	788,571

In addition to keyword searching, a bibliographic map was constructed with the intention of bibliometric analysis. More than 1,500 data sets were obtained over the web and processed into the VOSviewer (version 1.6.16) software, which is a useful tool for a more in-depth analysis of bibliometric map graphical representations. The map was generated by utilizing co-occurrence data to analyze the keywords (van Eck & Waltman, 2010, 2020). The network that was produced is a visualization of the authors' keywords that covered a threshold of 14 occurrences, resulting in 173 (out of 9,935) keywords. However, in Figure 2.1, all the terms with the highest overall link strength are chosen.

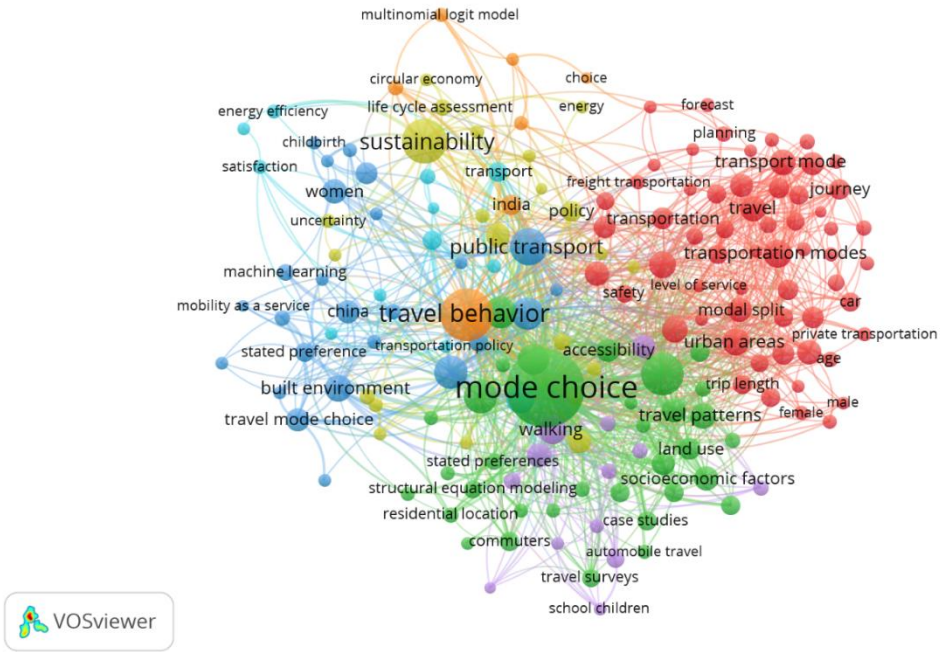

Figure 2.1: Bibliometric map of the keywords co-occurrences

The figure illustrates the co-occurrences of keywords in similar papers. It was evident from the image that mode choice patterns are linked to commuter travel behaviour. Furthermore, public transportation, walking and bicycling significantly impact mode choice patterns. Furthermore, other vital terms to investigate for further research are safety, security, and socioeconomic aspects. Residential location can also influence mode selection. The mode's sustainability depends on public transportation, policy, and an accurate assessment of choice patterns. Furthermore, changes in demographics, car ownership, and gender have impact on transportation mode choice. So, based on the keywords and expert opinions, more research was done and a literature review was completed in order to generate a background research.

2.2 Transport and gender

Men and women have varied travel patterns due to various economic and societal roles, responsibilities, and activities in terms of gender inequality (McGuckin & Nakamoto, 2004; Peters, 1999; Rosenbloom, 2004). Since the 1990s, it has been widely acknowledged that women and men have significantly different patterns of demand for transportation services, and that interventions in the transportation sector have typically failed to meet the requirements of women (Riverson et al., 2006a). The problem with transportation is still prevalent. In recent decades, a study undertaken by the United Nations Commission on the Status of Women discovered a male bias in the planning, provision, and design of transportation networks (Economic and Social Council, 2013).

In developing countries, males make the majority of planning and development choices, with little or no consideration for women's interests (Turner & Fouracre, 1995). As a result, gender inequities persists till this day. There is inequity in access to private motorized cars in developing countries, with women having less access than men due to societal standards about women's appropriate travel behavior (Peters, 1999; Rosenbloom & Plessis-Fraissard, 2009). According to the Women's Budget Group (WBG) report, women are more dominating than males in active transportation and public buses in England, and vice versa on trains. Same study also disclosed that, in Sweden women outnumber males when it comes to walking, cycling, and taking public transportation (Laker, 2021). Women's travel patterns are more intricate than men's, and they undertake more household and family support trips, but their mode choice is

less flexible, and they use public transportation to a greater extent, making them captive riders (Nobis & Lenz, 2005; Rosenbloom, 1987).

2.3 Mode choice patterns in developing countries

Men and women's travel patterns in developing nations differ significantly due to socioeconomic, cultural, traditions, and knowledge inequalities (Riverson et al., 2006b). The study by Hamilton et al. (2005) demonstrated a non-homogeneous character due to differences in individual travel patterns, which are influenced by their ages, terrestrial location, socioeconomic class and ethnicity, occupation, and parenting status (Hamilton et al., 2005).

By researching women's travel habits in both developed and developing countries around the world, Rosenbloom and Plessis-Fraissard (2009) identified two versions of the same story about their mobility (Rosenbloom & Plessis-Fraissard, 2009). The study found that women, regardless of their socioeconomic status, have less access to better or faster transit options and have more diversified and complex travel patterns than men. According to a study by Rahman et al (2017), bus service plays an essential role in the movement of a large number of people in developing cities, where mobility demands are increasing due to rapid urbanization (F. Rahman et al., 2017) . According to a survey carried out in Mexico City, gender mobility issues are not receiving enough attention in developing countries (Mejia-Dorantes, 2018). As per a study in Dhaka, the private car is a more popular mode of transportation for individuals with higher income levels (F. I. Rahman et al., 2020).

2.4 Factors influencing mode choice

A study was undertaken in Pakistan to address the problem of a lack of mobility patterns across cultures and contexts. The goal of the study was to look into gender disparities in daily trip rates, mode of transportation, travel duration, and purpose of travel, as well as the effects of key demographic factors (Adeel et al., 2017). According to another Pakistani research, family honors, cultural standards, gender-based socio-cultural atmosphere, and geographic effect are significant factors that affect women's mobility (Adeel & Yeh, 2018). Although public transit is supposed to be the safest mode of transport, it has recently become one of the

vulnerable zones due to lack of safety and security (Joevono & Kubota, 2006). This phenomenon has progressed to the point where women are reluctant to use public transportation. They frequently prefer private transportation as their best means of transportation, even though it is more expensive.

2.5 Factors affecting sustainable transport choice

Females are less interested in utilizing non-motorized vehicles than men, as per a study conducted by Adeel et al. in Pakistan (Adeel et al., 2017). Most female commuters at Samarra University are embarrassed to walk or cycle because of cultural norms and customs (Hasan et al., 2019). Even though public transportation is meant to be the safest means of transportation, it has recently become one of the most vulnerable zones due to a lack of safety and security (Joevono & Kubota, 2006). In Oman, women find public transportation inconvenient and dislike sharing cabs with males; instead, they prefer to drive their cars for convenience, flexibility, maneuverability, privacy, safety, and the lack of public transportation (Belwal & Belwal, 2010). According to a study performed in Dhaka, 57% of female respondents are concerned about harassment and misbehaviour when riding public transport (Guliani et al., 2020).

CHAPTER THREE
DATA COLLECTION AND METHODOLOGY

3.1 Introduction

The study area, data collection methods, data formulation, and methodology employed throughout the thesis are all described in this chapter. The majority of the effort began with a concurrent literature review. The problem statement and objective for the research study were determined after a thorough review of the literature and expert advice. Following that, a questionnaire was developed in accordance with the objectives. A model was constructed with appropriate variables, and an analysis was performed. Figure 3.1 depicts the overall process flow of the research.

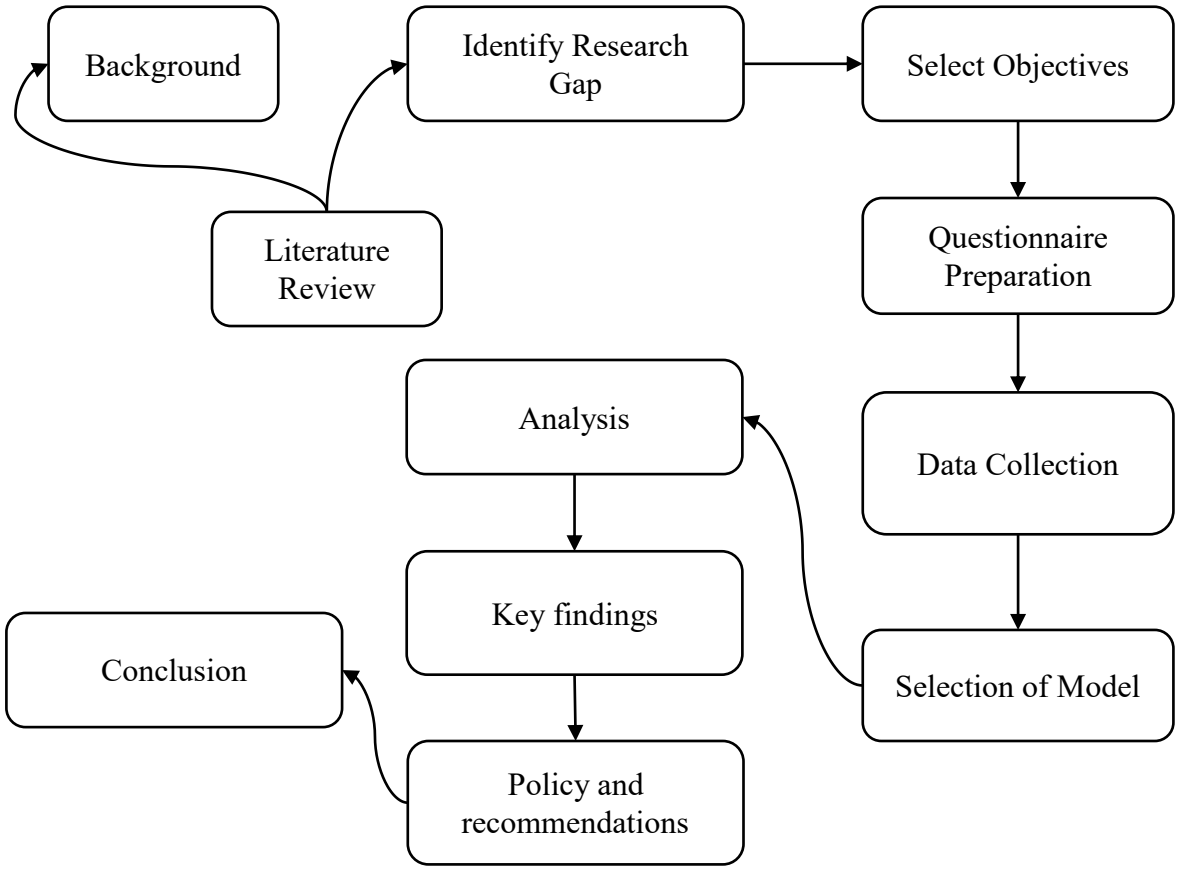

Figure 3.1: Overall workflow

3.2 Study area and data

3.2.1 Study area

The study was mainly concentrated on a questionnaire survey. The questionnaire was used to create a model, which was then analyzed. The questionnaire survey was carried out in several Bangladeshi cities. The cities were chosen so that survey data might reflect the demographic and psychographic characteristics of the majority of Bangladesh's population. Dhaka city was chosen as an urban area, whereas Narayangang, Gazipur, and Tangail were chosen as examples of rural areas. The following map figure 3.2 depicts all of the selected areas.

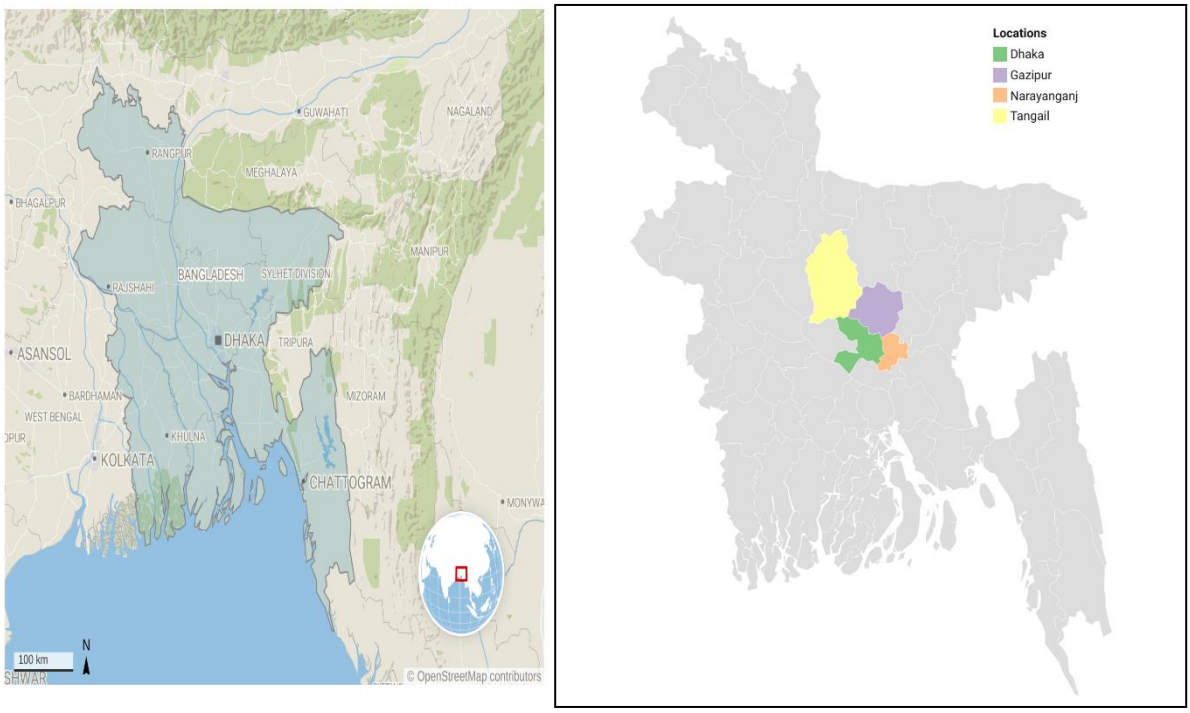

Figure 3.2: Data collection locations on the map

3.2.2 Data

Based on a literature review and the opinions of transportation experts, a questionnaire for user-mode choice patterns was designed. The survey contains questions about age, gender, education level, occupation, perceptions of mode choice patterns and factors that influence mode choice. There were around 40 questions in the questionnaire. For the purpose of the thesis, some variables from the whole questionnaire were chosen. After many considerations,

the study regions were chosen to ensure that the data obtained from them represent the majority of the people across the country. Before any analysis, the data was processed, and the final data included 1602 responses from both rural and urban areas. The data was obtained through a secondary source rather than directly by the researchers.

3.3 Methods

The Bayesian Belief Network (BBN) was primarily used in the study to achieve the goal of identifying characteristics that influence the utilization of sustainable transportation alternatives. BBN establishes a link between various variables and calculates their probabilities. The BBN is a dynamic process that can represent a variety of events. The entire procedure is broken down into numerous steps. Figure 3.3 depicts the development of the proposed model step-by-step:

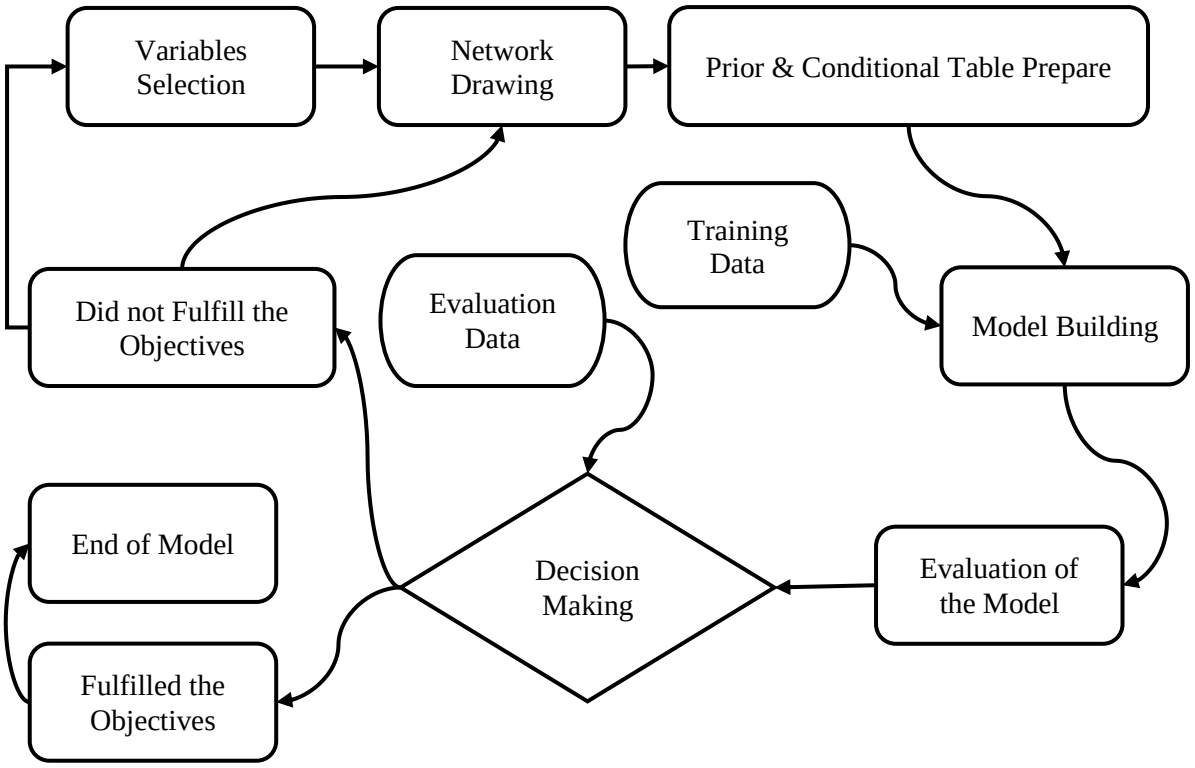

Figure 3.3: Flow chart of the model development

The next portions go over each stage one by one.

3.3.1 Bayesian Belief Network (BBN)

A Bayesian belief network is a modern probabilistic graphical model. A Bayesian Belief Network, often called belief networks, causal networks, or Bayesian network is a straightforward technique to apply Bayes Theorem to complex issues. The Bayesian framework is developed on the Bayes hypothesis, sometimes referred to as the Bayes rule (Stone, 2013; Wang & Vassileva, 2003). The Bayes rule is as follows:

$$P(M|N)=\frac{P(N|M)\times P(M)}{P(N)} \quad (1)$$

In the above equation (1), **P(M)** indicates the probability of occurrence of M and **P(N)** indicates the probability of occurrence of N. Besides, **P(N | M)** indicates the probability of occurrence of N given that M has already occurred and **P(M | N)** is the probability of M given that N has already occurred.

A Bayesian network is a predictive model that depicts a set of variables and their conditional interactions using a directed acyclic graph (DAG). The factorizations of joint probability distributions are represented by Bayesian networks, which are acyclic directed graphs. Every joint probability distribution over x random variables can be factored x! times and written as a product of probability distributions of each variable conditional on the other variables (Genie, 2016). The BBN's graphical component comprises two sorts of elements: a set of nodes and a set of directed edges, commonly called arcs. The arcs show the inter-relationship between the nodes, variables with a finite set of mutually incompatible states. Though this inter-relationship generally pertains to causal effect, it is not a strict condition for constructing a BBN (Jensen, 2001). Consider a model with four variables: A, B, C & D. There are 4! = 24 ways to factorize the combined probability distribution of these four variables. The probability can be written as-

$$Pr(A, B, C, D) = P(A | B, C, D) \times P(B | C, D) \times P(C | D) \times P(D) \quad (2)$$

$$Pr(A, B, C, D) = P(A | B, C, D) \times P(B | C, D) \times P(D | C) \times P(C) \quad (3)$$

$$Pr(A, B, C, D) = P(A | B, C, D) \times P(B | C, D) \times P(C | D) \times P(C) \quad (4)$$

$$\Pr(A, B, C, D) = P(D \mid A, B, C) \times P(B \mid A, C) \times P(B \mid A) \times P(A) \quad (5)$$

A Bayesian network can represent each of these factorizations. A Bayesian network is developed below in figure 3.4 for the first factorization (2) mentioned above.

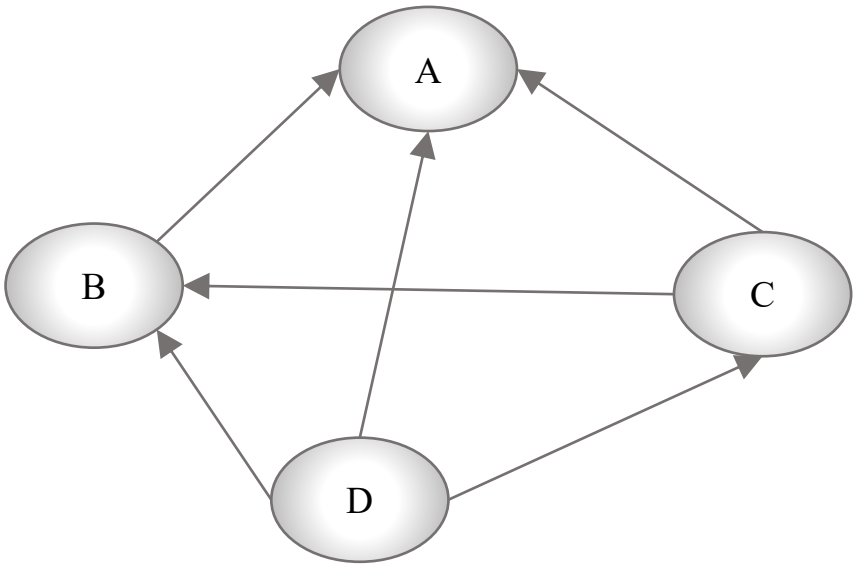

Figure 3.4: Bayesian network for the first factorization

Assume a BBN over a universe of variables U = X_1, X_2, … … …., Xn to understand the numerical component. The BBN can then be characterized using a joint probability distribution P(U) produced by multiplying all conditional probability tables within the BBN. The Bayesian network graphically shows the joint probability distribution, and its function can be expressed as follows-

$$P(U) = P(X_1, X_2, \ldots\ldots\ldots, X_n) = \prod_{i=1}^{n} P(X_i \mid pa(X_i)) \quad (6)$$

The structure of a Bayesian network can be acquired from data or a combination of expert knowledge and structural learning techniques. The mixed approach was used to construct the network in this study. The structural learning was finished when the data from the questionnaire was put into software. There are several software options for dealing with Bayesian network models. The most popular packages are GeNIe (Graphical Network Interface), Hugin, BUGS, and R. GeNIe Academic Version 3 was used for our analysis.

Following the data import, the structural learning was performed using a PC algorithm. For causal discovery, the PC algorithm is a prominent constraint-based method. GeNIe uses the Expectation Maximization (EM) algorithm to produce the joint probability distribution through parameter learning. The EM algorithm is a method for performing maximum likelihood estimation. To increase the accuracy of the estimation, EM estimates the values of latent variables first and then improves them iteratively. There are two steps in the iteration process: E-Step (Expectation Step) and M-Step (Maximization Step). The procedure is continued until the two phases are in consistent.

3.3.2 GeNIe Workspace

GeNIe Modeler is a graphical decision theoretic modeling development environment. It was designed and developed at the University of Pittsburgh's Decision Systems Laboratory between 1995 and 2015 (Genie, 2016). In our study, GeNIe 3.0 Academic Version was employed for structure learning (network formation) and parameter learning (CPT preparation). Figure 3.5 shows the version and other information of the GeNIe software that was used for our research work.

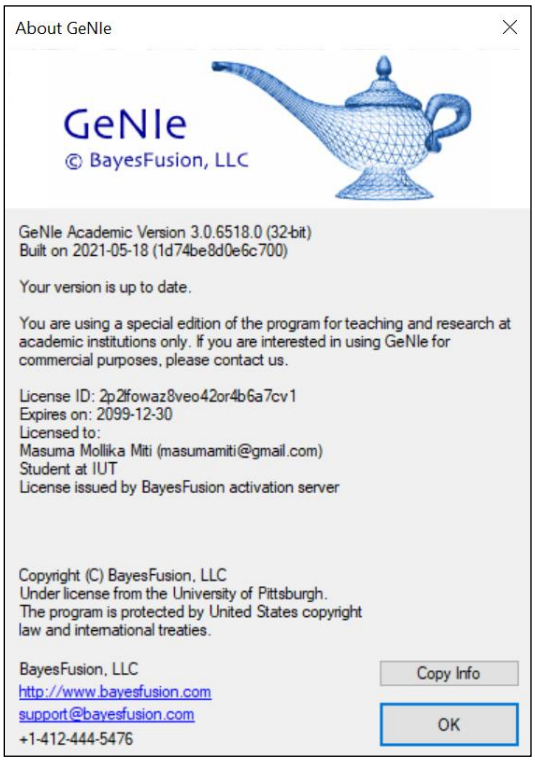

Figure 3.5: Version and other information of GeNIe software

The workspace will appear when the GeNIe software is run, as shown in Figure 3.6.

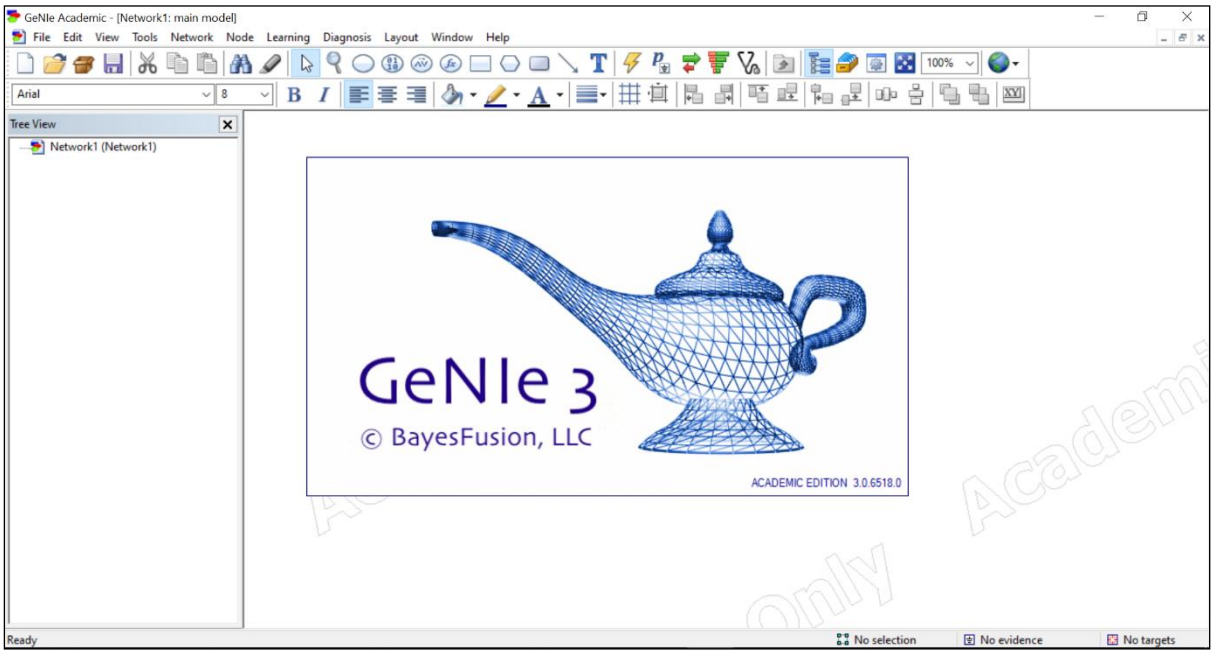

Figure 3.6: GeNIe workspace

GeNIe offers various analysis choices after parameter learning is complete, such as observing prior and posterior marginal probability, sensitivity analysis, tornado diagram, degree of influence, and so on. In the result and analysis section, all of the terms will be discussed.

CHAPTER FOUR
ANALYSIS, MODEL DEVELOPMENT AND RESULTS

4.1 Introduction

This chapter summarizes the study's primary findings and the model construction and data analysis sections. The survey data was initially review and organized along with categorization. After then, the data was fine-tuned before being put into a Bayesian network structure. The nodes of the network were modified and tested to determine how each variable influenced the target variable. Several analyses were performed on the model, including sensitivity analysis and tornado diagrams. The model's accuracy was further tested using the built-in model validation tool in the GeNIe program. All of the research findings were collated and presented in this chapter after the analytical procedure was done.

4.2 Descriptive statistics of the survey

Data were collected at random from the prepared questionnaire in the selected cities. The questionnaire was designed to collect information regarding sustainable transportation and user mode choices. Before entering the data into the model, it was processed. From the entire questionnaire, specific variables were selected and categorized. A total of 1602 data points were collected from Bangladesh's rural and urban areas. While conducting the survey, the gender distribution of consumers was always kept in mind. The survey's respondents were nearly 50% female and about 50% male.

The descriptive statistics of the survey responses are shown in Table 4.1 below.

Table 4.1: Descriptive statistics of the questionnaire survey

SL	Variables	Item	Frequency	Percentage (%)
1	Location	Urban	801	50
		Rural	801	50
2	Gender	Female	794	49.5
		Male	808	50.5
3		Unmarried	472	29.5

	Marital Status	Married	1069	66.7
		Others	61	3.8
4	Age	<25	411	25.7
		25-35	573	35.8
		35-50	471	29.3
		>50	147	9.2
5	Vehicle ownership	Yes	192	12
		No	1410	88
6	Condition of pickup location	Crowded	1159	72.3
		Not crowded	419	26.2
		Others	24	1.5
7	Preferred mode for short trip	Walking	48	3.00
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	820	51.20
		Rent a Car, Ride sharing (Uber, Pathao)	10	0.60
		Private automobile (Car, Microbus, Jeep, Motorbike)	166	10.40
		Public transport (Bus + Rail)	337	21.00
		Others(CNG, Leguna)	221	13.80
8	Safe mode of travel	Walking	6	0.40
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	97	6.10
		Rent a Car, Ride sharing (Uber, Pathao)	264	16.50
		Private automobile (Car, Microbus, Jeep, Motorbike)	427	26.70
		Public transport (Bus + Rail)	521	32.50
		Others(CNG, Leguna)	287	17.90
9	Comfortable mode of travel	Walking	6	0.40
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	91	5.70
		Rent a Car, Ride sharing (Uber, Pathao)	383	23.90
		Private automobile (Car, Microbus, Jeep, Motorbike)	510	31.80
		Public transport (Bus + Rail)	304	19.00
		Others(CNG, Leguna)	308	19.20

10	Factors considered most for choosing any mode	Safety and security	1017	63.50
		Harassment	7	0.50
		Availability	199	12.40
		Fare	367	22.90
		Others	12	0.70
11	Harassed in Public Transport	Yes	488	30.50
		No	1103	68.80
		Indifferent	11	0.70

4.3 Model development

4.3.1 Correlation analysis

GeNIe provided the original Bayesian network, which was produced by structural learning using the PC algorithm. Correlation analysis, literature review, and expert knowledge were used to modify the network. The significance of the link between two variables was investigated using correlation analysis with Microsoft excel. The correlation analysis results are attached here in table 4.2 and the definition of each variable is listed in table 4.3.

Table 4.2: Result of correlation analysis

	A1	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***A8***	***A9***	***A10***	***A11***
A1	1.00										
A2	0.00	1.00									
A3	0.20	-0.08	1.00								
A4	-0.02	0.11	0.65	1.00							
A5	0.14	-0.02	-0.10	-0.20	1.00						
A6	0.49	0.04	0.15	0.09	-0.16	1.00					
A7	-0.11	-0.12	0.03	0.02	-0.07	-0.03	1.00				
A8	0.20	0.01	0.10	0.01	0.09	0.10	0.00	1.00			
A9	0.32	-0.02	0.16	0.06	0.05	0.16	0.07	0.68	1.00		
A10	0.28	0.17	0.00	-0.06	0.11	0.23	-0.11	0.27	0.23	1.00	
A11	0.14	0.19	0.05	0.08	-0.12	0.16	-0.37	0.14	0.06	0.24	1.00

Table 4.3: Variable Definition

Variables	***Definition***	***Variables***	***Definition***
A1	Location	A7	Preferred mode of travel, Short trip (Trips within 5 km)
A2	Gender	A8	Which mode do you consider as safe mode of travel?
A3	Marital_status	A9	Which mode do you consider as comfortable mode of travel?
A4	Age	A10	Which factor do you consider most when choosing any mode?
A5	Vehicle_ownership	A11	Have you ever been harassed in Public Transport?
A6	Condition of the pick-up location		

4.3.2 Bayesian network preparation

The data was imported into GeNIe following the data screening process. Figure 4.1 shows the part of dataset that was imported for building the network.

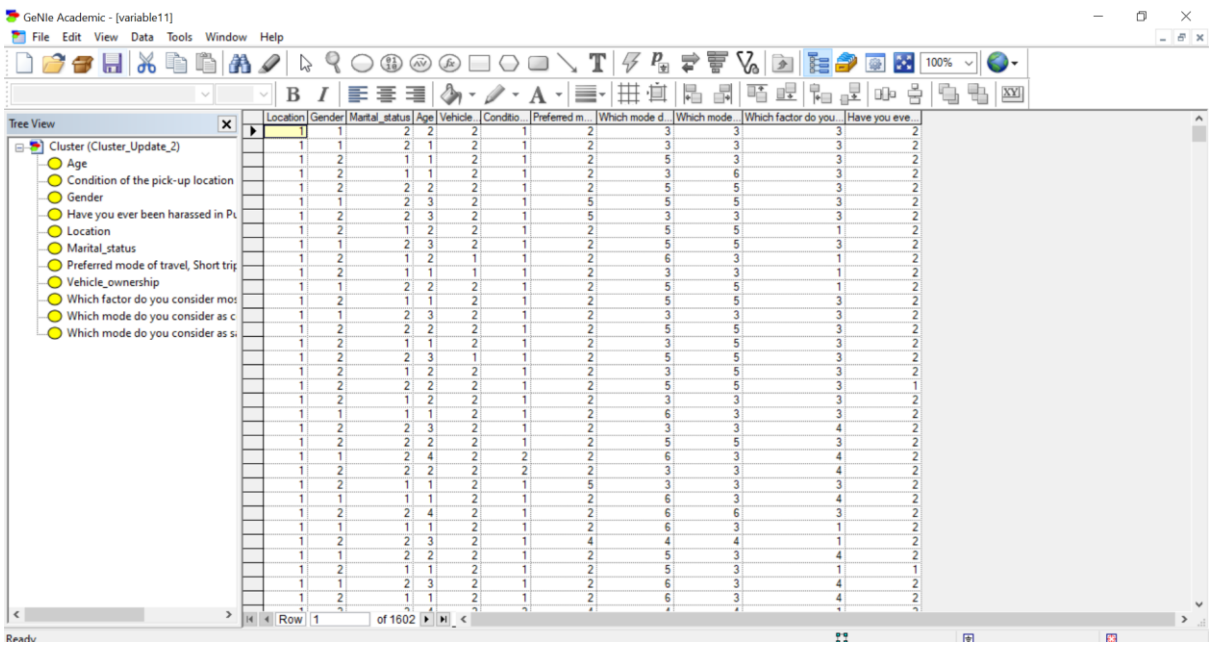

Figure 4.1: Parts of dataset imported for building the network

The network is then learned using automated learning in this study. The PC algorithm is used to do structural learning from a complete data set, with a significance level of 0.05. Figure 4.2 shows the screen of learning method and Figure 4.3 shows how the network was changed based on the connection between variables, literature review, and engineering judgment.

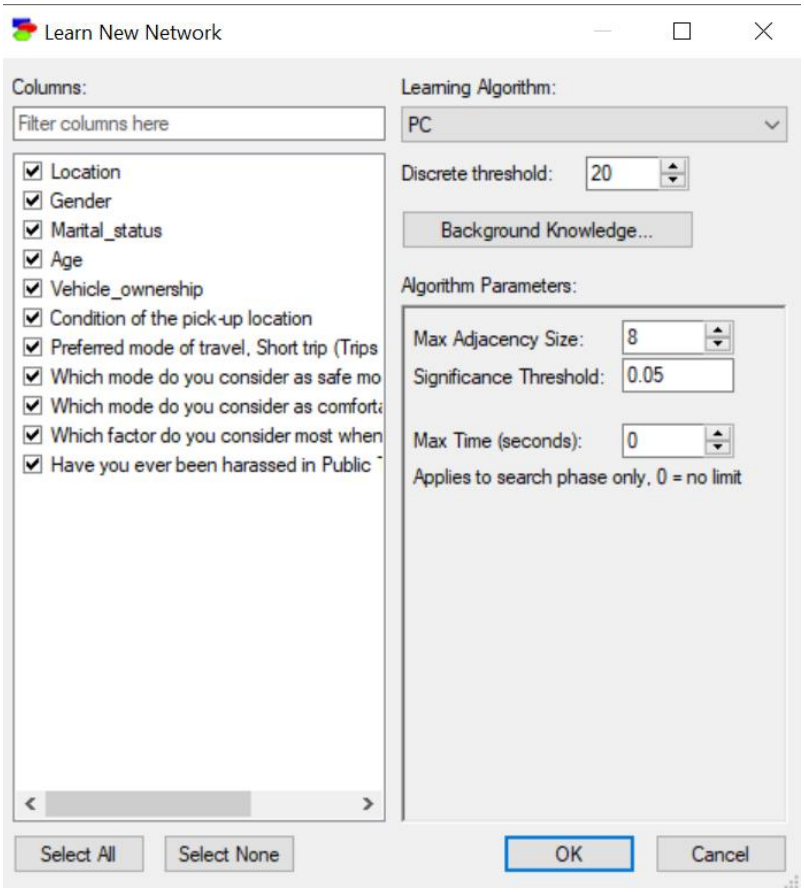

Figure 4.2: Screen of the parameter notebook

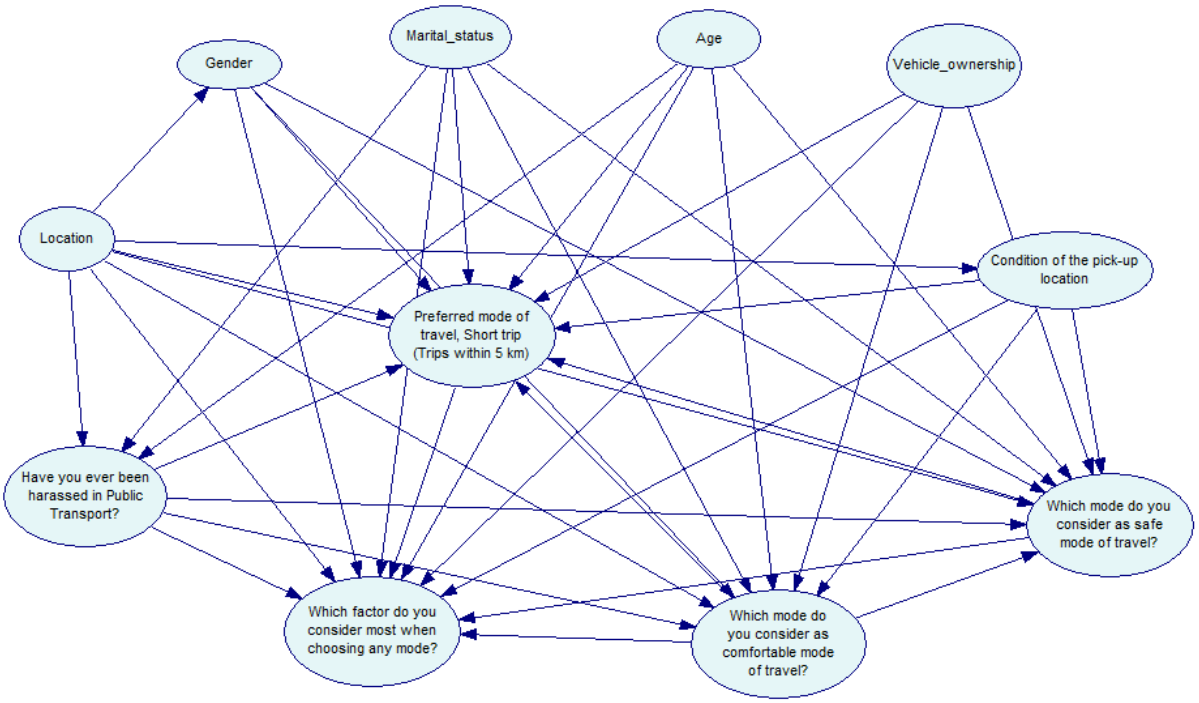

Figure 4.3: Bayesian network

The initial phase in the GeNIe software analysis process is parameter learning. GeNIe's default parameter learning approach is EM (Expectation-Maximization). So, the built-in EM method is employed to generate marginal probabilities for all nodes. Figure 4.4 depicts the network structure's marginal probability.

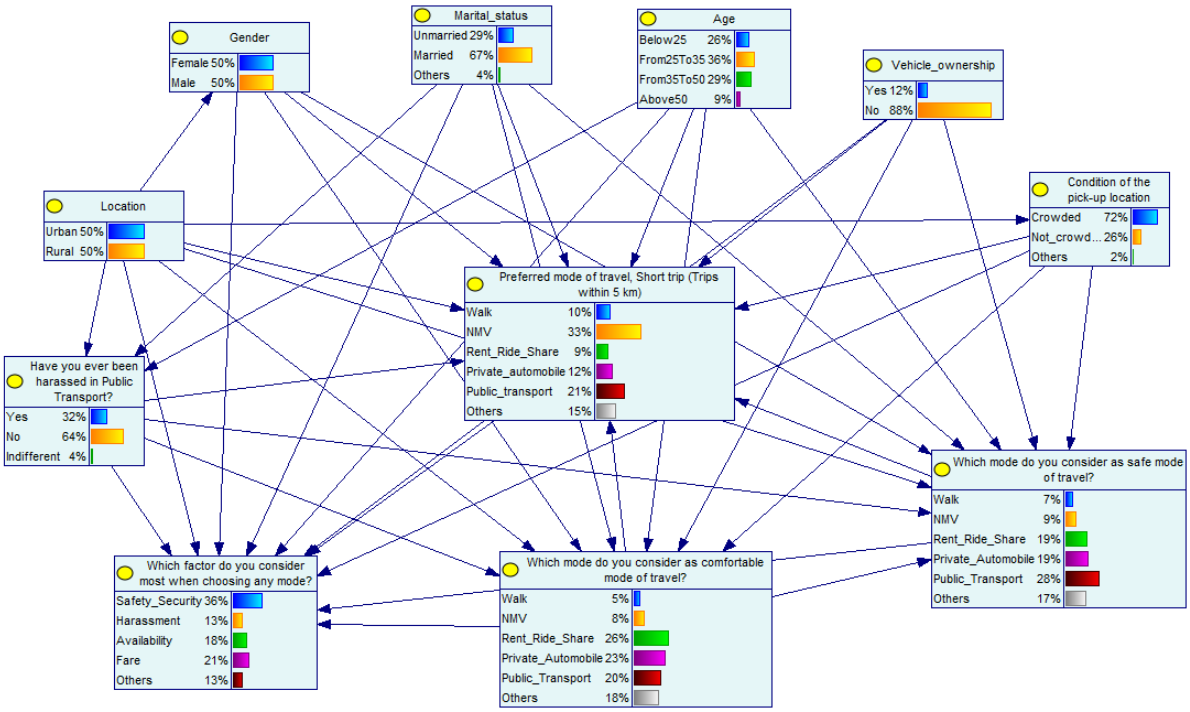

Figure 4.4: Prior marginal probability distribution diagram

The model was developed with the intent of identifying the factors that influence mode choosing patterns. The mode was separated into six groups in the model. The following paragraphs go over the various categories.

Walking: The decision was made mostly for short travels. As a result, walking was selected as a mode.

NMVs: Several types of modes were listed in this category. This group featured bicycles, rickshaws, and vans. This category mostly included vehicles that do not require the use of a machine to operate.

Rented transports: This category included rented and ride-sharing vehicles. This category included, in particular, non-personal car services.

Private automobiles: Private transportation, such as cars and motorcycles were included in the private automobiles sections.

Public transport: Bus and train services are examples of public transportation. Vehicles that convey a big number of passengers are mostly seen in this category. In other words, public transportation category included mass transit.

Others: The paratransit modes were primarily covered in this section. This category included CNGs, legunas, and any other type of vehicle.

4.4 Model Validation

Model validation or validation of results is an essential aspect of every model. The validity of the models was determined in this study by utilizing GeNIe's default validation tool. Two validation were used in the research. Firstly, a normal validation method was used where all the data were considered as test data and no data were selected as training data. This assessment is known as Test only validation, which implies the model is just tested on the data file. This is useful when the model was developed with expert knowledge or trained with a separate data set. Figure 4.5 illustrates the validation tabs screen.

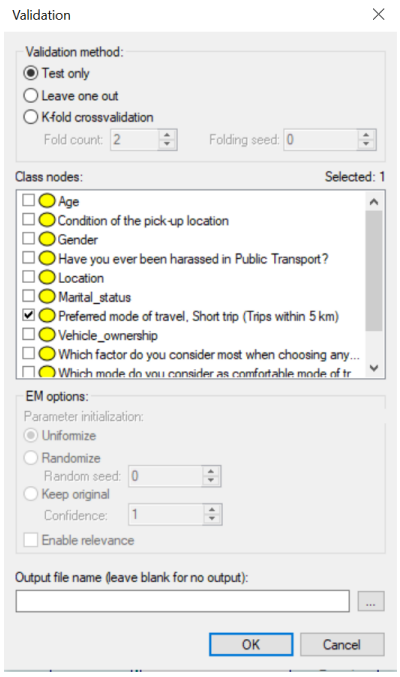

Figure 4.5: Validation tab's screen

The evaluation's results are represented as a Receiver Operating Characteristic (ROC) curve. The ROC curve is a plot of sensitivity vs. false positive rate, with the diagonal line representing a perfect 50% chance of correct model prediction, and Area representing a 50% chance of accurate model prediction. The Area Under the ROC Curve (AUC) represents a value between 0 and 1, with a value closer to 1 indicating higher model performance (Hoo et al., 2017). According to the book Applied Logistic Regression, the following basic rule mentioned in table 4.4 is considered for the value of the ROC curve (Scott et al., 1991).

Table 4.4: The general value of ROC curve and their meaning

Value	**Description**
0.5	No impact
0.5-0.7	Poor impact
0.7-0.8	Acceptable impact
0.8-0.9	Excellent impact
>0.9	Outstanding impact

However, AUC values of 0.70 and higher would be regarded as powerful impacts in applied psychology and future behaviour prediction, including all the elements that can influence (Rice et al., 2005). Using the test method, all the AUC value is found greater than 0.9. The ROC curve for preferred mode of public transport is attached in figure 4.6 and rest of the ROC curve is attached in Appendix-B.

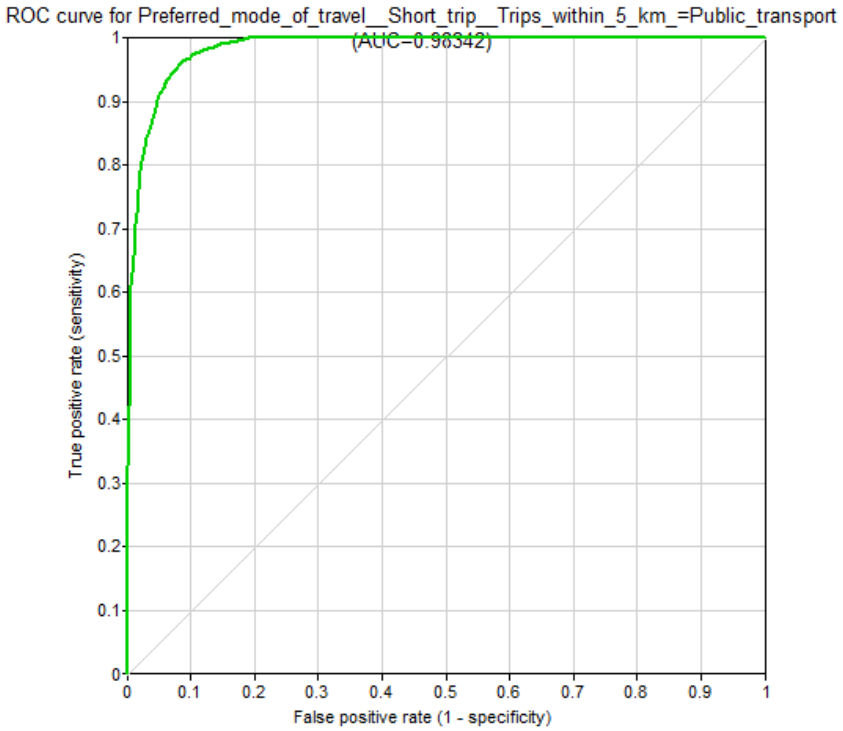

Figure 4.6: ROC curve for the model (preferred mode= public transport, validation method=test)

Secondly, the validation procedure was carried out using the Leave One Out (LOO) method, which is considered the most effective method. This strategy is preferred since the model for the analysis is learned and assessed on the same data set. The LOO technique is a special example of K fold cross-validation, in which K equals the number of records (n) in the data set. In LOO, the network is trained on n-1 records before being tested on the last one. The procedure is carried out n times. Though it is the most recommended method, the main disadvantage is that it may take longer if the data set is large. In this analysis, the preferred mode of NMV has an AUC of 0.75, 0.87 for the preferred mode of private vehicles, 0.88 for the preferred mode of public transit, 0.69 for the preferred mode of walking, 0.76 for the preferred mode of others, and 0.50 for preferred mode hire vehicles. The model's value of renting a car and ridesharing is not up to standard. All other values are within acceptable bounds. Figure 4.7 depicts the ROC curve for public transportation. Other ROC curves are attached in Appendix-B.

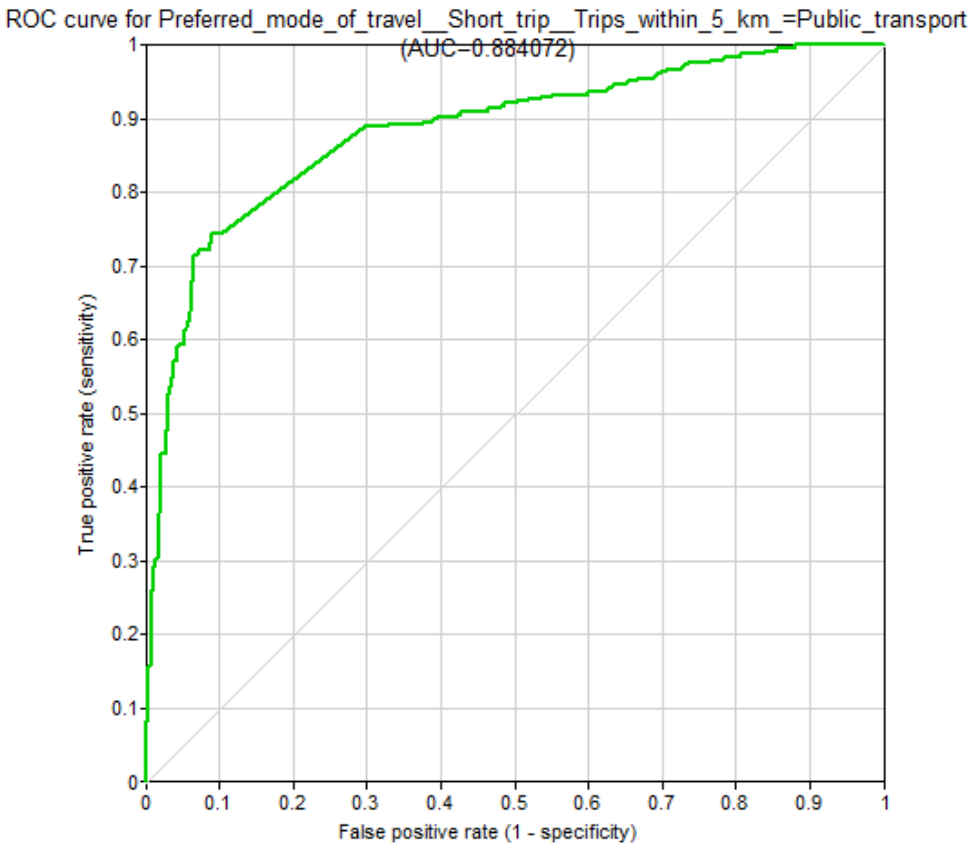

Figure 4.7: ROC curve for the model (preferred mode= public transport, method=LOO)

4.5 Model output and explanation

4.5.1 Outcomes for preferred mode of travel (short trip)

As long as the dependent variable is unchanged, the prior marginal probabilities of variables in a Bayesian network structure are identical to the observed data. However, utilizing GeNIe, the posterior marginal probability for any change in the dependent variable's events may be observed. The model was constructed with several questions to determine the probabilities of various travel patterns. Initially, the preferred mode for a short journey was chosen as the target variable, and the types of modes were modified to determine the value of the other parameters. The posterior probability of the model was calculated by selecting each of the six types of mode one by one. The posterior probability for the preferred mode for short distances is illustrated in figures 4.8 to 4.13.

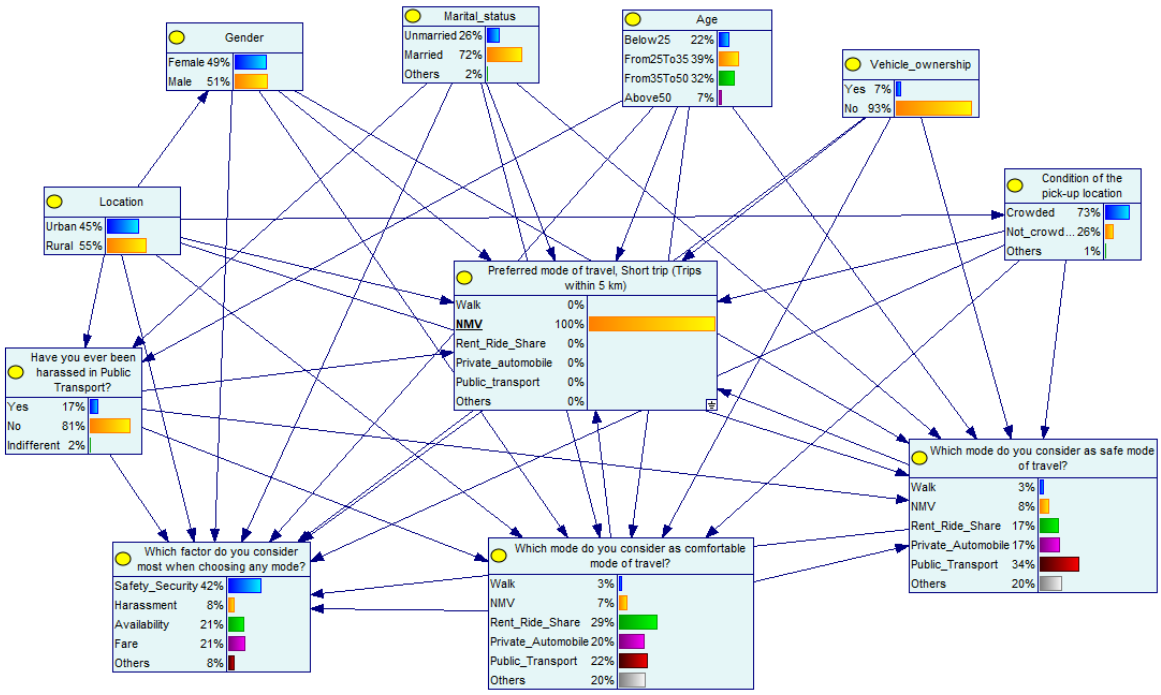

Figure 4.8: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is NMVs

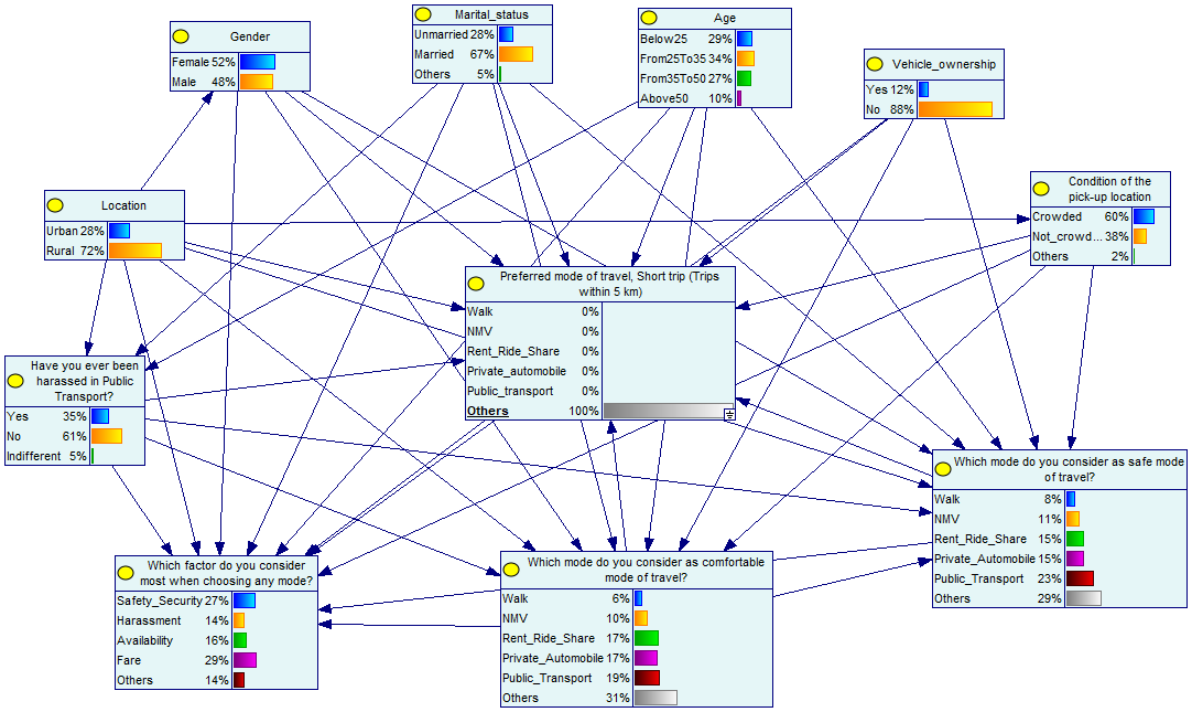

Figure 4.9: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is others

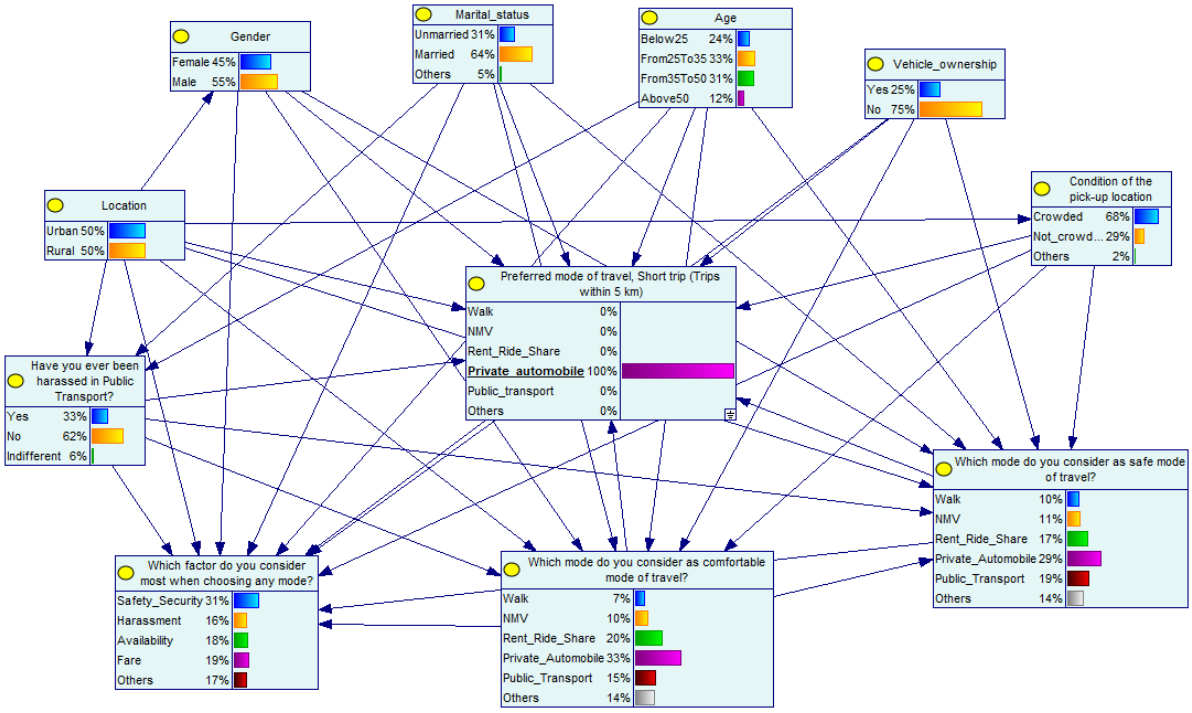

Figure 4.10: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is private transport

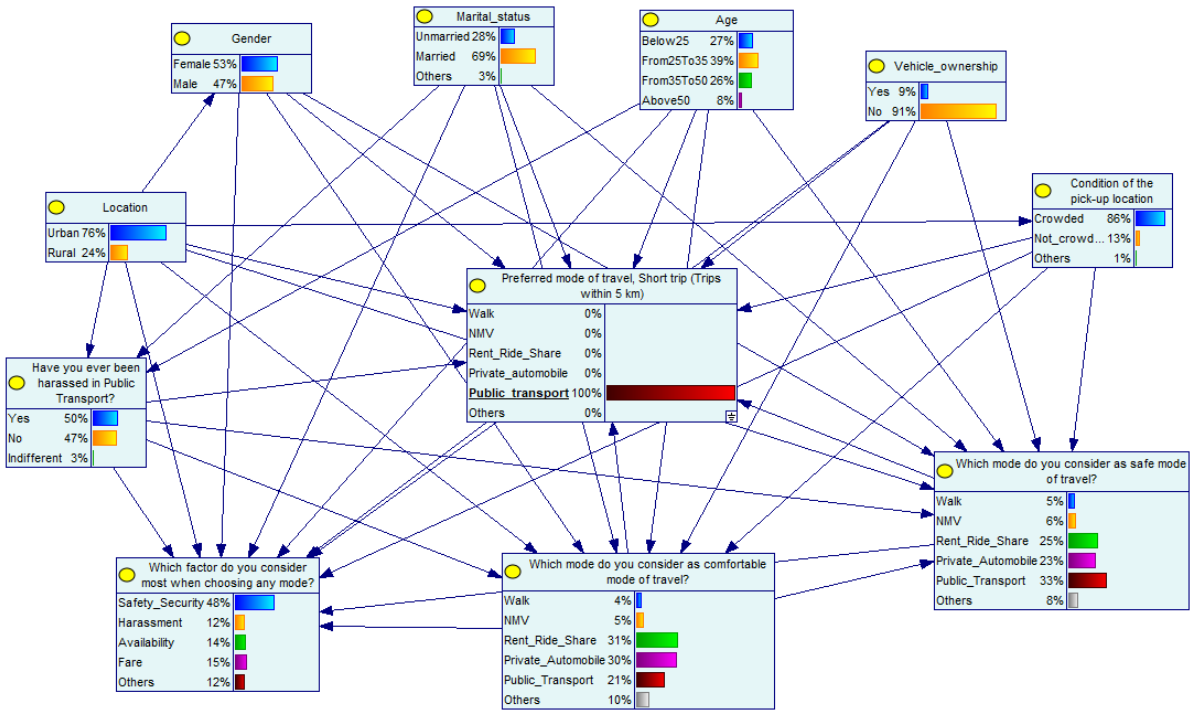

Figure 4.11: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is public transit

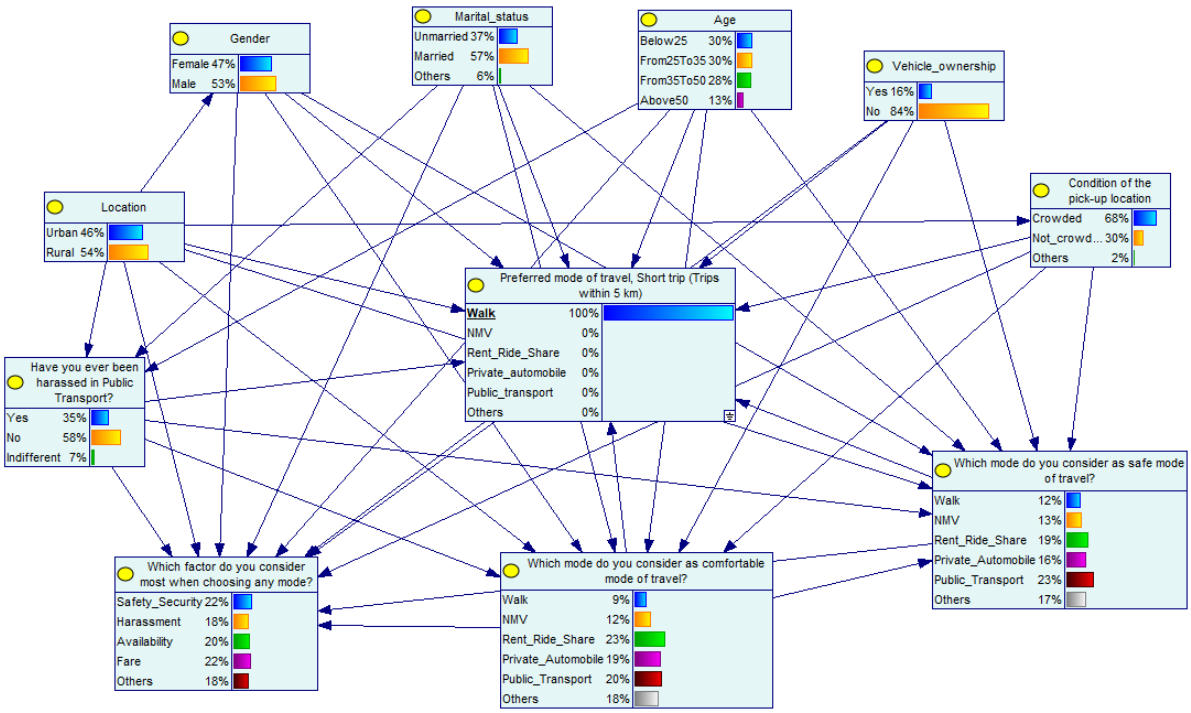

Figure 4.12: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is walking

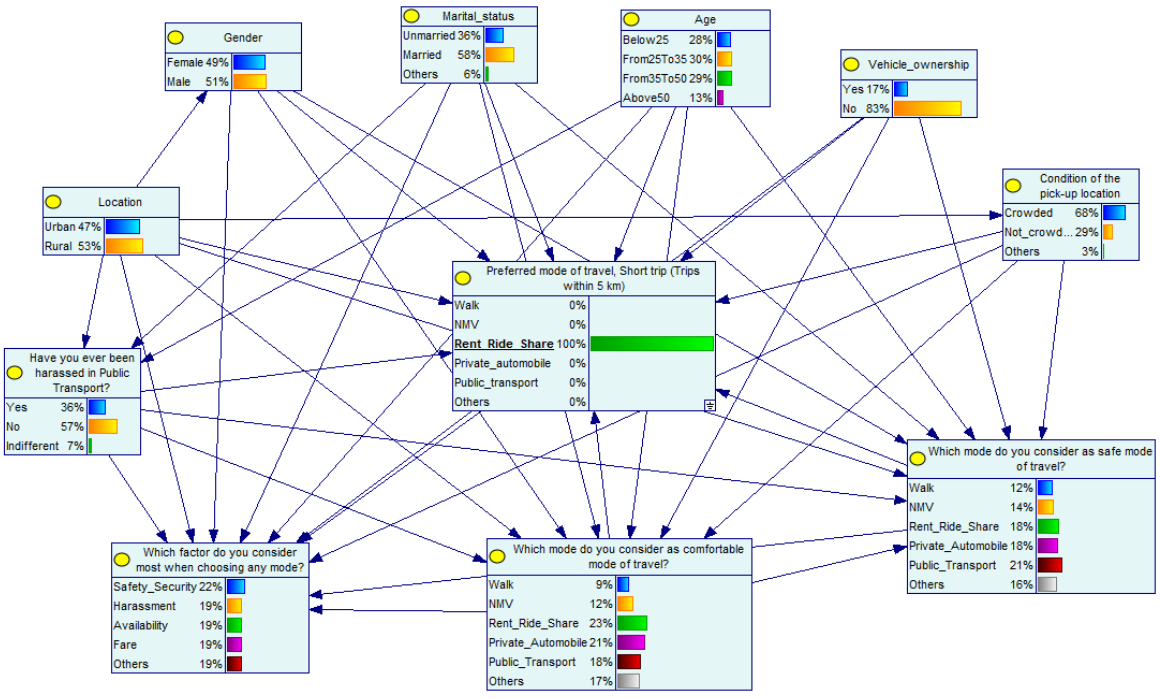

Figure 4.13: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is rented vehicles

For the evidence of the target variable 'Preferred mode of transport, short trip', the posterior marginal probabilities of each node were observed. The results of the observation are shown in table 4.5.

Table 4.5: All nodes marginal probabilities for all the states of target variable 'Preferred mode of transport, short trip'

SL	Variables	Item	Evidence (%)					
			Walk	NMV	Rented	Private	Public	Others
1	Location	Urban	46	45	47	50	76	28
		Rural	54	55	53	50	24	72
2	Gender	Female	47	49	49	45	53	52
		Male	53	51	51	55	47	48
3	Marital Status	Unmarried	37	26	36	31	28	28
		Married	57	72	58	64	69	67
		Others	6	2	6	5	3	5
4	Age	<25	30	22	28	24	27	29
		25-35	30	39	30	33	39	34
		35-50	28	32	29	31	26	27
		>50	13	7	13	12	8	10
5	Vehicle ownership	Yes	16	7	17	25	12	12
		No	84	93	83	75	88	88
6	Condition of pickup location	Crowded	68	73	68	68	60	60
		Not crowded	30	26	29	29	38	38
		Others	2	1	3	2	2	2
7	Safe mode of travel	Walking	12	3	12	10	5	8
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	13	8	14	11	6	11
		Rent a Car, Ride sharing (Uber, Pathao)	19	17	18	17	25	15
		Private automobile (Car, Microbus, Jeep, Motorbike)	16	17	18	29	23	15
		Public transport (Bus + Rail)	23	34	21	19	33	23
		Others(CNG, Leguna)	17	20	16	14	8	29
8		Walking	9	3	9	7	4	6

	Comfortable mode of travel	Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	12	7	12	10	5	10
		Rent a Car, Ride sharing (Uber, Pathao)	23	29	23	20	31	17
		Private automobile (Car, Microbus, Jeep, Motorbike)	19	20	21	33	30	17
		Public transport (Bus + Rail)	20	22	18	15	21	19
		Others(CNG, Leguna)	18	20	17	14	10	31
9	Factors considered most for choosing any mode	Safety and security	22	42	22	31	48	27
		Harassment	18	8	19	16	12	14
		Availability	20	21	19	18	14	16
		Fare	22	21	19	19	15	29
		Others	18	8	19	17	12	14
10	Harassed in Public Transport	Yes	35	17	36	33	50	35
		No	58	81	57	62	47	61
		Indifferent	7	2	7	6	3	5

This investigation revealed the likelihood of several factors when the preferred mode is chosen early on. The preferred mode is categorized such that sustainable transportation can be easily distinguished. Walking was picked as the preferred means of transportation at first, with males (53%) outnumbering females (47%). Furthermore, people in rural areas prefer to walk in more significant numbers than those in metropolitan ones. Younger people should be more likely to walk than elderly persons. People without a personal automobile prefer to walk more. Despite the fact that walking is preferred for the actual journey, most believe that renting a vehicle is the most comfortable option (23%) and that public transportation is the safest option (23%). Secondly, NMVs were chosen as evidence. This mode produced results that were similar to those of walking. The considered elements impacting mode choice are the one that differs significantly. The most significant elements determining mode choice patterns in this scenario were safety and security (42 %).

When using public transit as evidence, city dwellers outnumbered rural dwellers. It suggests that more people use public transportation in urban areas (76%). Women (53%) take public transportation at a higher rate than men (47%). The majority of those who use public

transportation are of working age (39%). People who do not have a personal vehicle (91%) use public transportation in this instance. Surprisingly, the preferred option and the safe mode are both public transportation, but the comfortable mode is rental vehicles (31%).

4.5.2 Sensitivity analysis for preferred mode of travel (short trip)

A sensitivity analysis was performed on the existing network to understand the most critical variables in a better way. GeNIe illustrates the results of variation in the target variable in a sensitivity study. The dark red variables have the most influence on the target variable. The impact gradually reduces as the red color intensity lowers. White variables have a very minimal impact on the target variable, whereas the grey variables have no impact. The sensitivity analysis results is shown in figure 4.14.

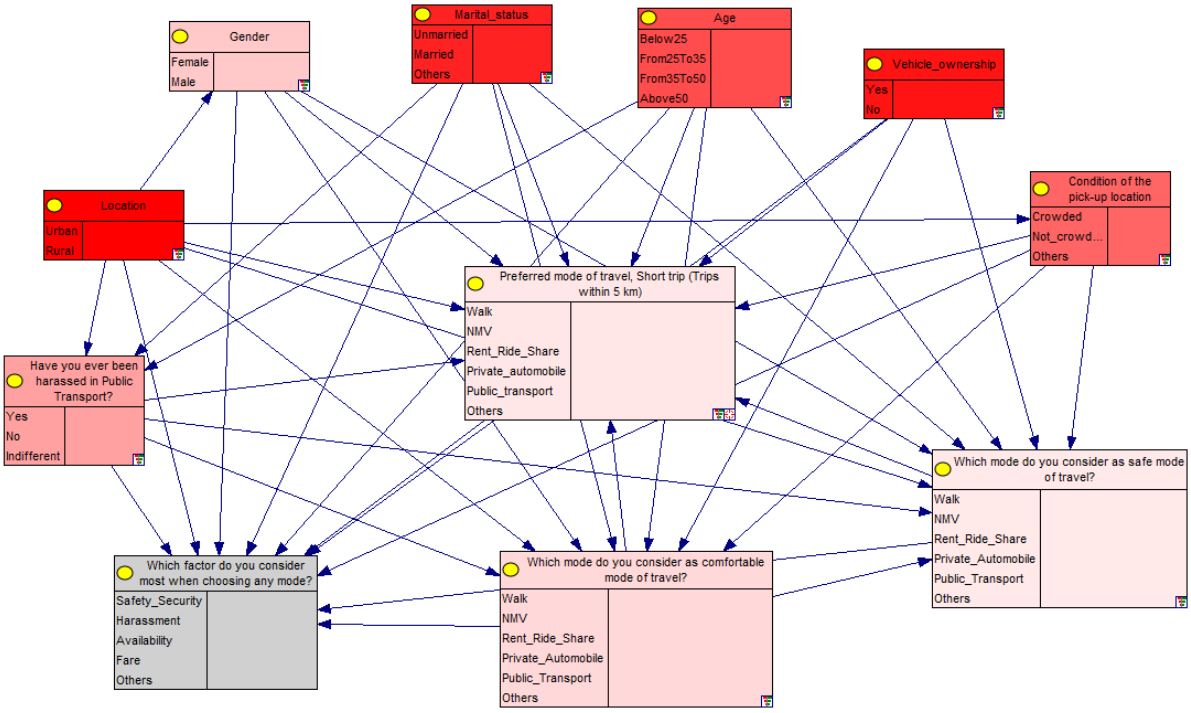

Figure 4.14: Significant variables after sensitivity analysis for preferred mode (short trips)

Sensitivity analysis was used to determine the most important factors. The essential variables in the sensitivity analysis are ‘location’, ‘marital status’, and ‘vehicle ownership’. The second most relevant factors were 'Age' and 'Condition of the pickup location.' Gender, harassment frequency, comfortable mode, and safe mode all impact the target variable.

A tornado diagram was created after the senility analysis. It displays the most sensitive characteristics for a specified target node state, ranked from most to least sensitive. The exact placement of each parameter in the model is seen in the diagram. As the parameter's range changes, the bar shows the range of changes in the desired state. The bar color indicates the direction of change in the target state; red indicates a negative change, while green indicates a positive change. In short, in sensitivity analysis, a tornado diagram shows the most significant state of a variable for a given state of the target variable. The tornado diagram for the model is depicted in Figure 4.15 to 4.20.

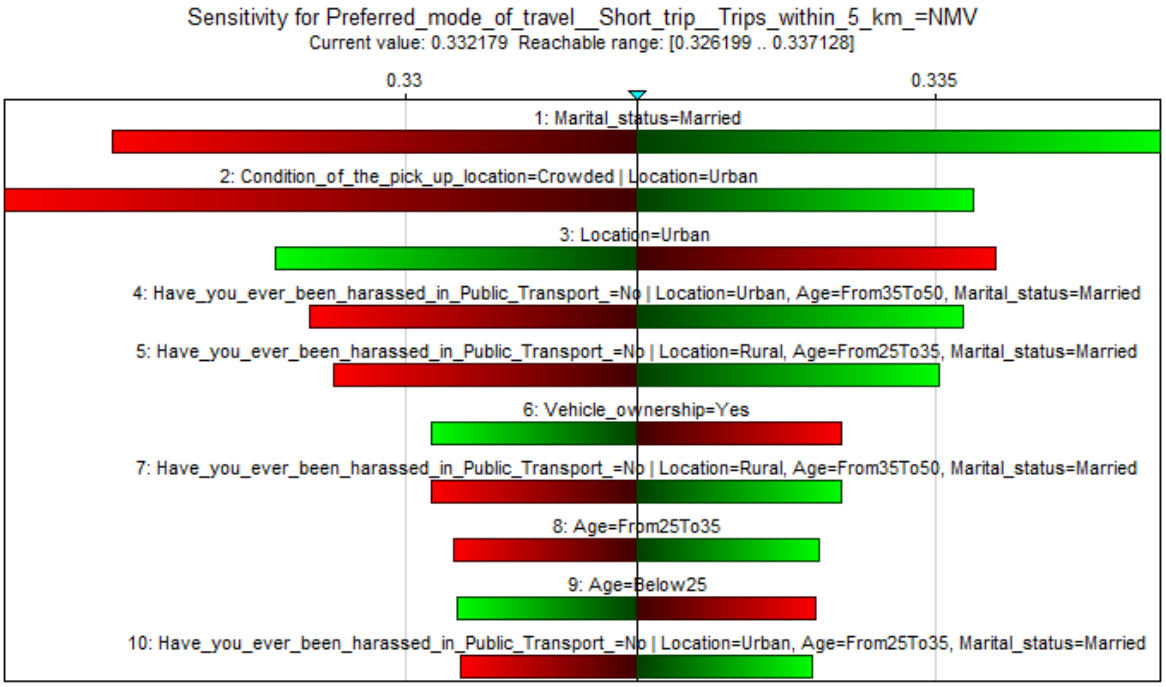

Figure 4.15: Tornado diagram in sensitivity analysis when the preferred mode is NMVs for short trip

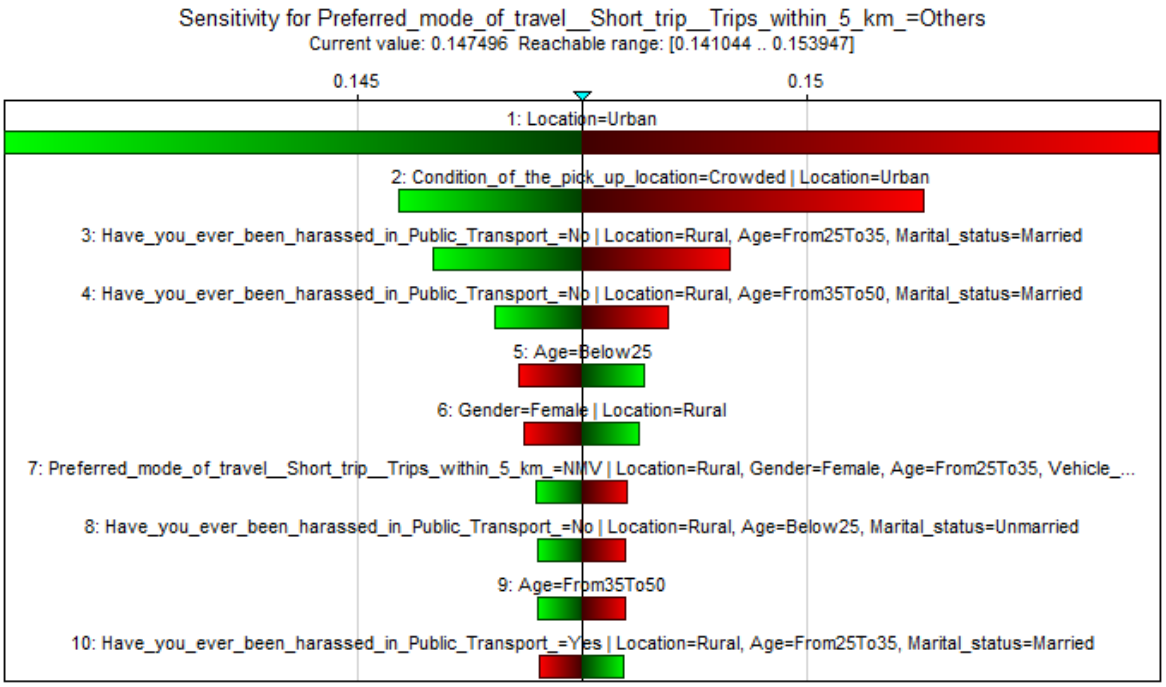

Figure 4.16: Tornado diagram in sensitivity analysis when the preferred mode is others for short trip

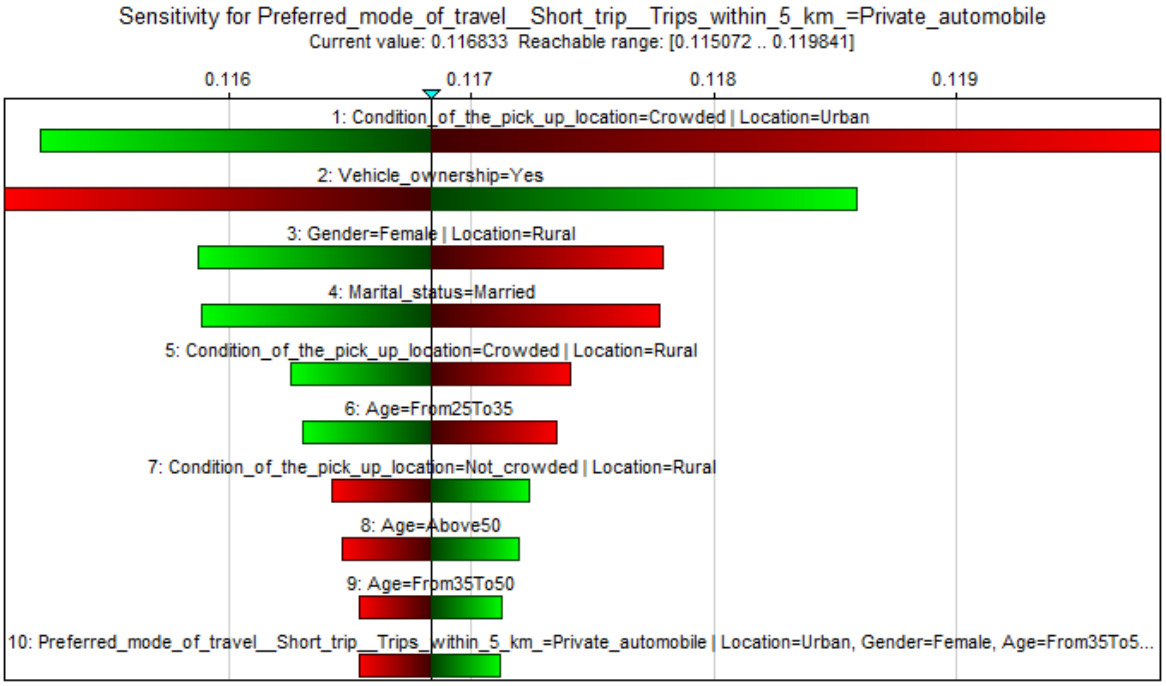

Figure 4.17: Tornado diagram in sensitivity analysis when the preferred mode is private vehicles for short trip

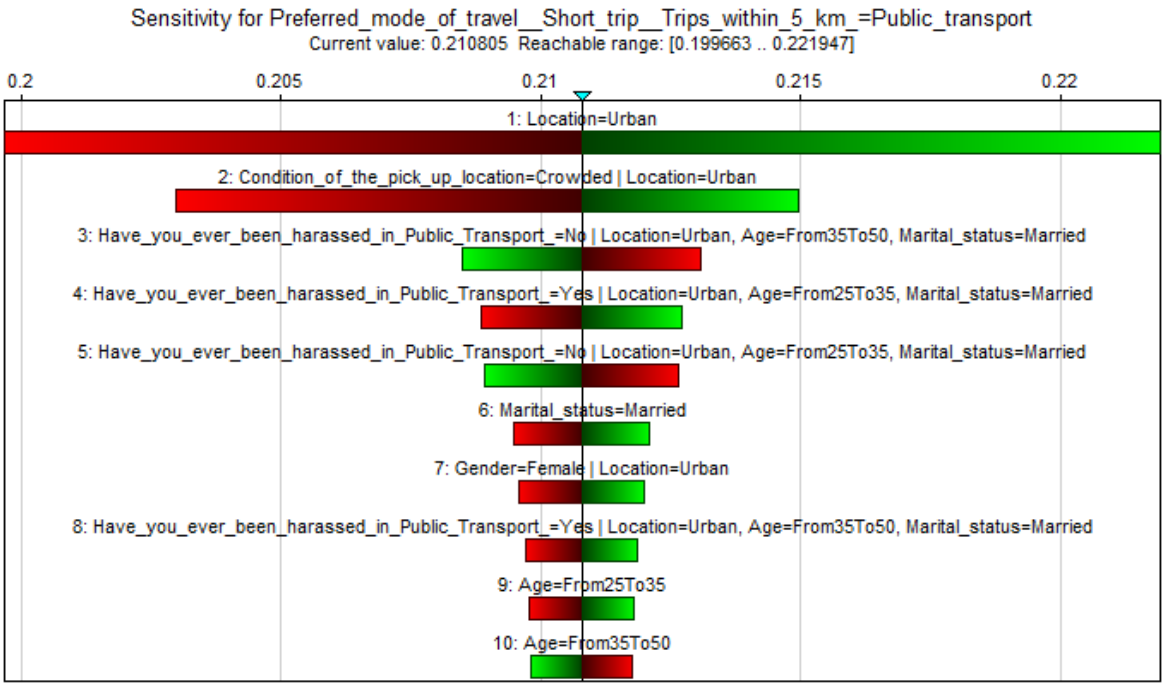

Figure 4.18: Tornado diagram in sensitivity analysis when the preferred mode is public transit for short trip

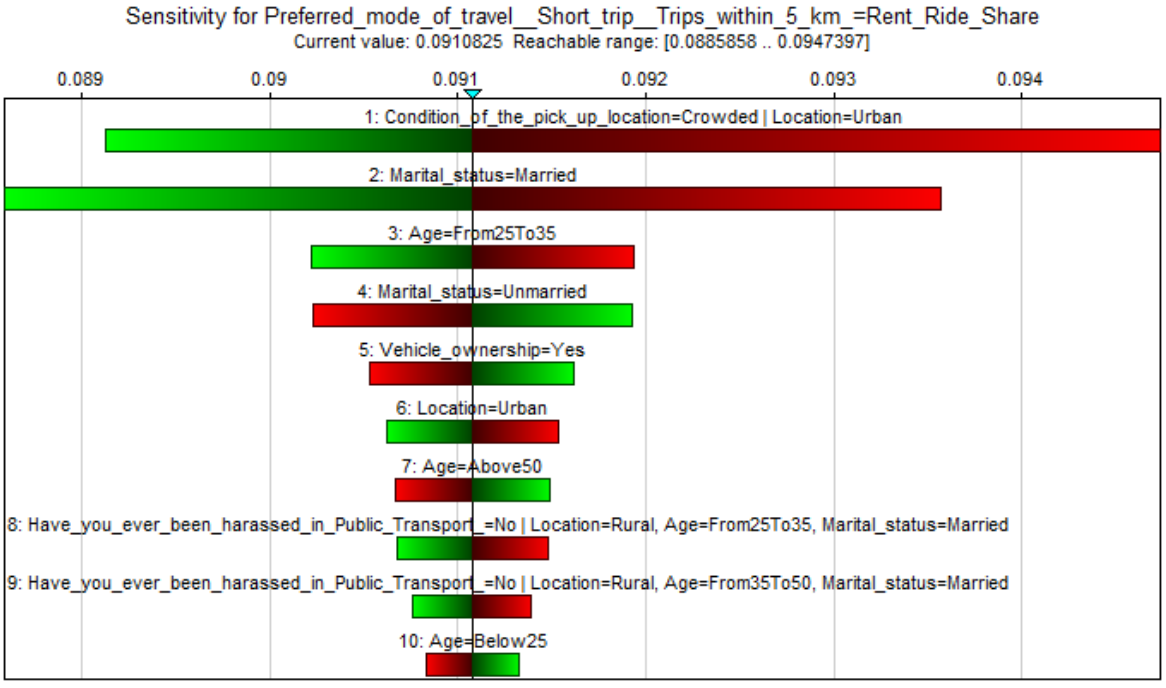

Figure 4.19: Tornado diagram in sensitivity analysis when the preferred mode is rented vehicle for short trip

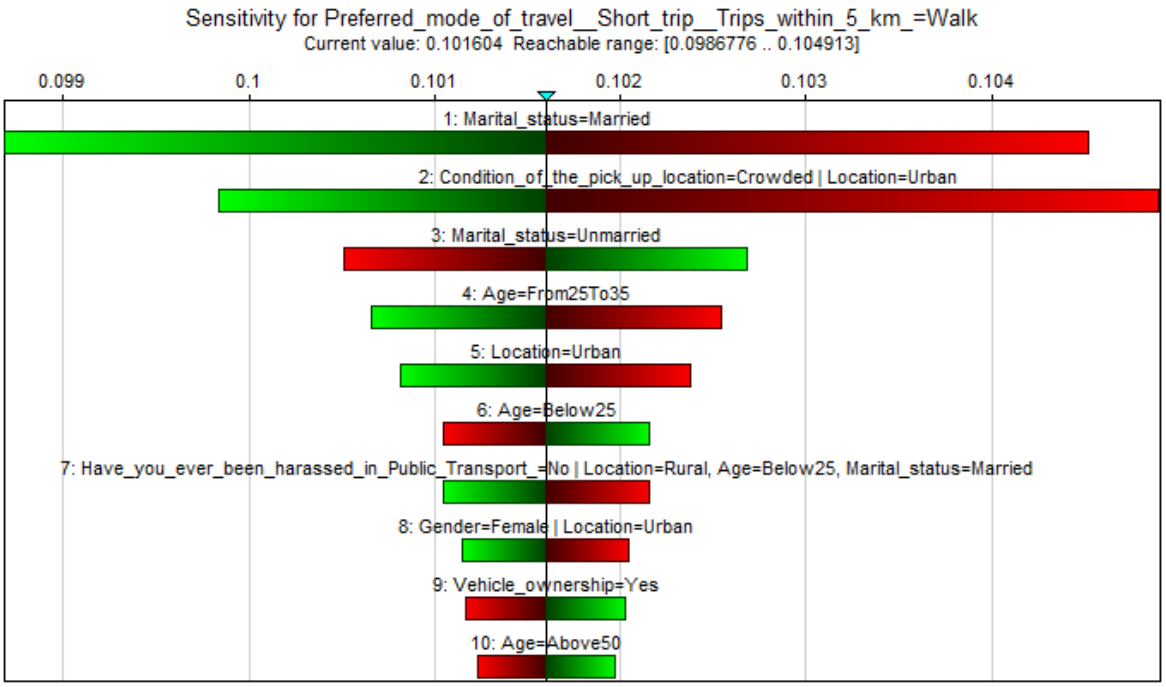

Figure 4.20: Tornado diagram in sensitivity analysis when the preferred mode is walking for short trip

The tornado diagram shows that marital status (married) is the most affected attribute during walking and NMVs. Moreover, for rental vehicles and private automobiles, the situation of crowded pickup locations and urban regions are crucial characteristics. Additionally, metropolitan location influences public transit and other modes more than other factors.

4.5.3 Outcomes for other models

4.5.3.1 Mode choice patterns when the locations, gender and vehicle ownership is variable

As previously said, several questions were addressed one by one. In this scenario, the probability for various modes was calculated using the variables of gender, location, and vehicle ownership. The figures from the analysis are attached following from figure 4.21 to 4.26.

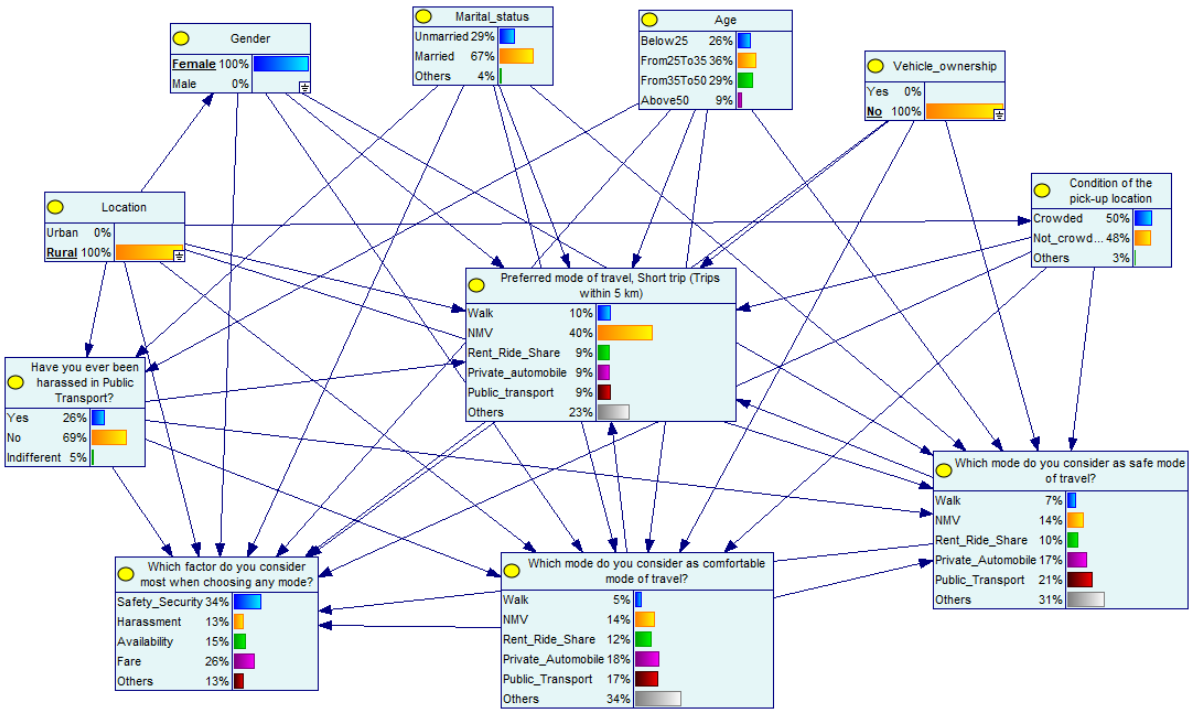

Figure 4.21: Posterior marginal probability distribution diagram when the female in rural location has not any personal vehicle access

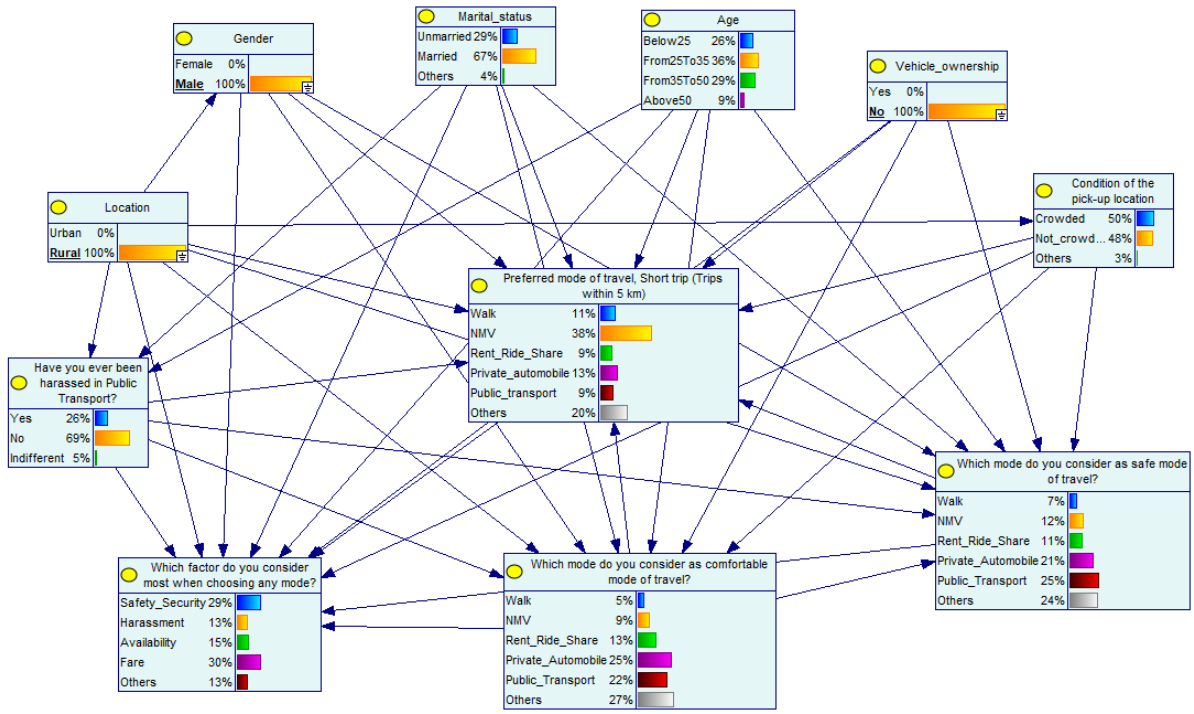

Figure 4.22: Posterior marginal probability distribution diagram when the male in rural location has not any personal vehicle access

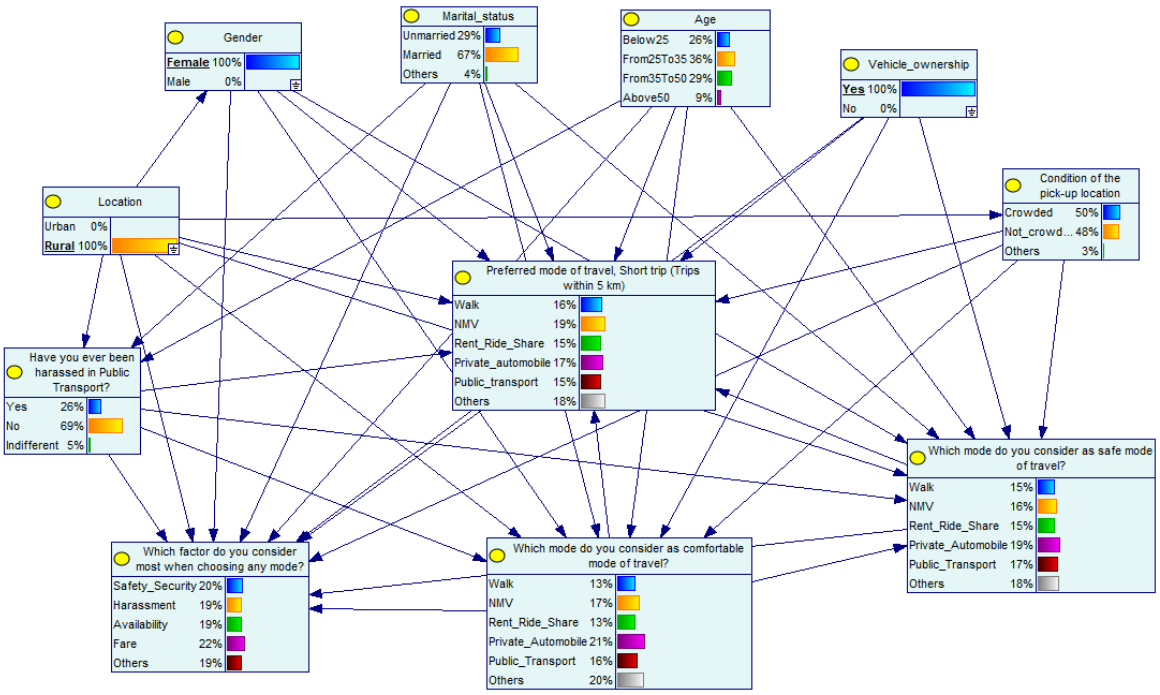

Figure 4.23: Posterior marginal probability distribution diagram when the female in rural location has the access of personal vehicle

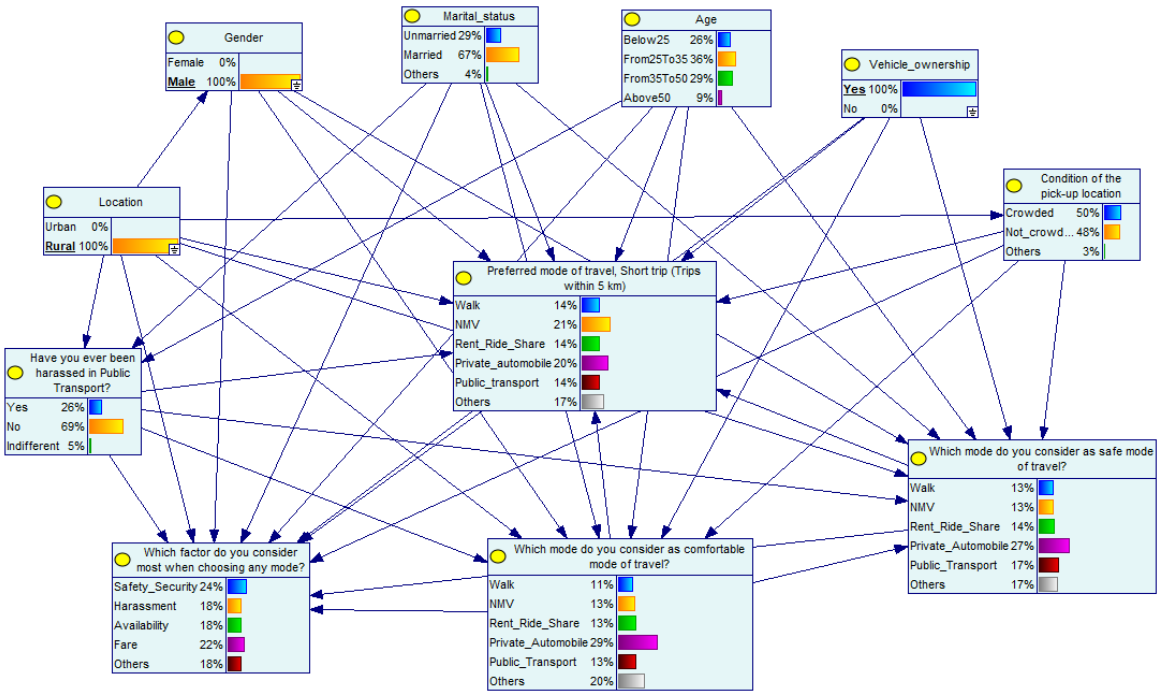

Figure 4.24: Posterior marginal probability distribution diagram when the male in rural location has the access of personal vehicle

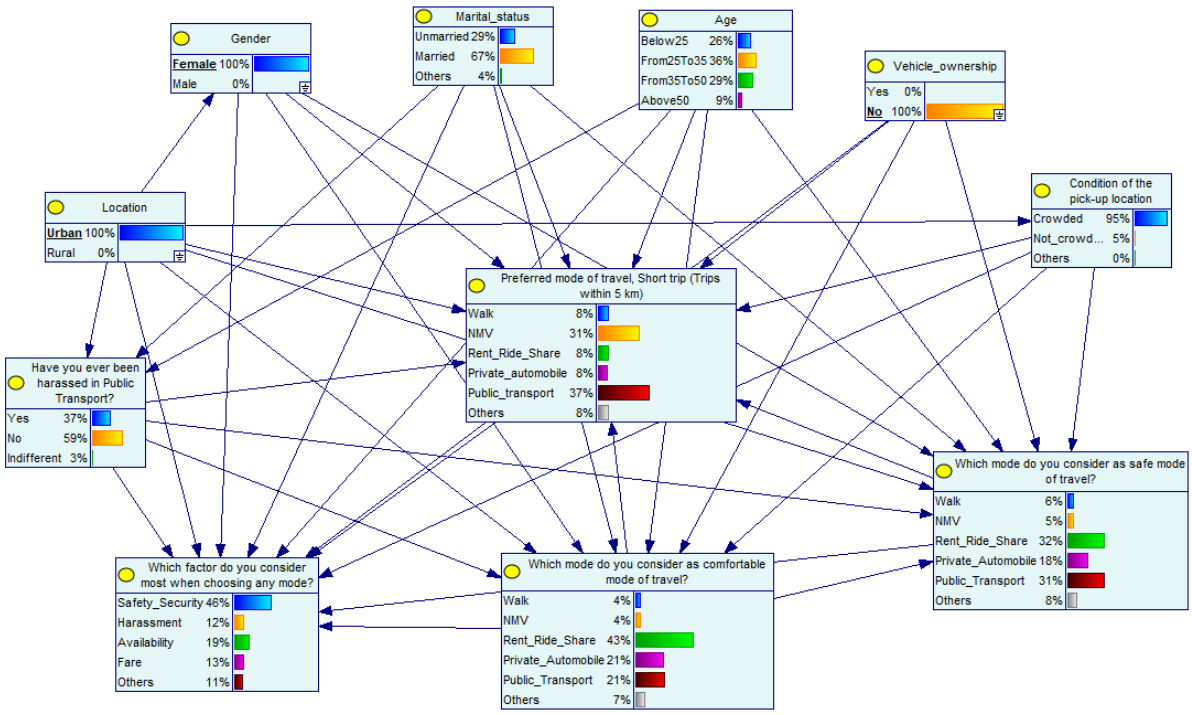

Figure 4.25: Posterior marginal probability distribution diagram when the female in urban location has not any personal vehicle access

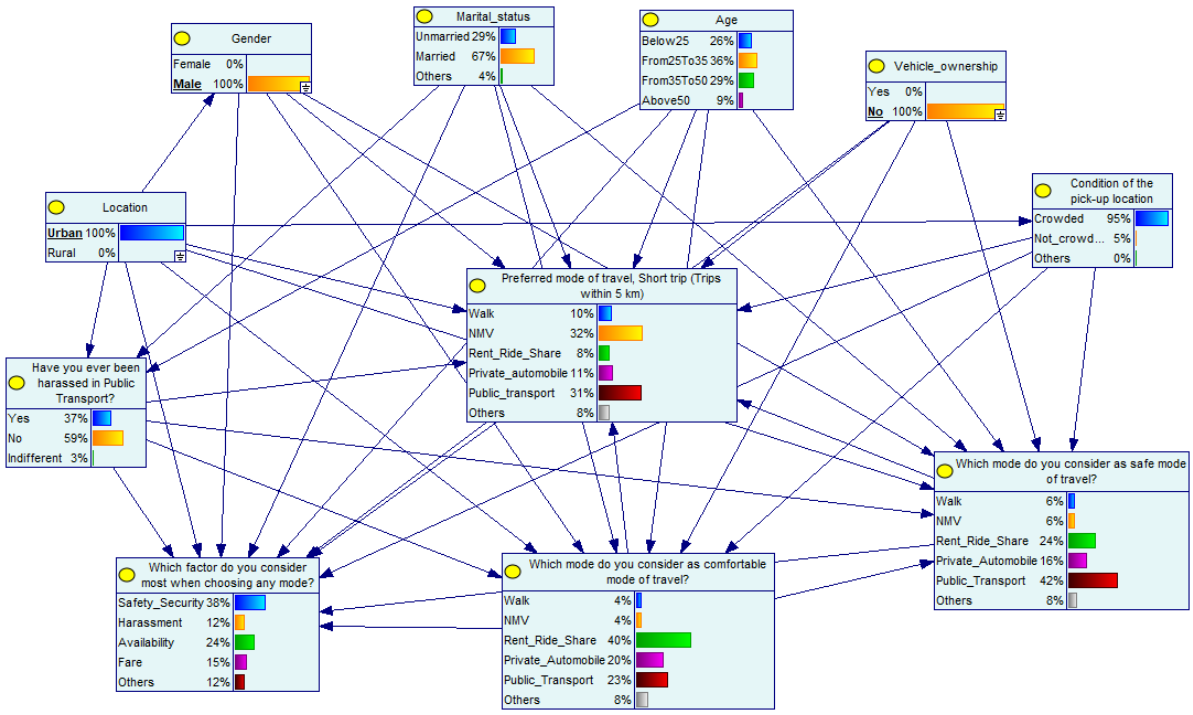

Figure 4.26: Posterior marginal probability distribution diagram when the male in urban location has not any personal vehicle access

The result from the analysis are tabulated in the table 4.6 below-

Table 4.6: Marginal probabilities for all the states of target variable for 'mode choice patterns when the locations, gender and vehicle ownership is variable'

SL	Variables	Item	Evidence (%)							
			FUY	MUY	FUN	MUN	FRY	MRY	FRN	MRN
1	Safe mode of travel	Walking	9	11	6	6	15	13	7	7
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	9	11	5	6	16	13	14	12
		Rent a Car, Ride sharing (Uber, Pathao)	10	22	32	24	15	14	10	11
		Private automobile (Car, Microbus, Jeep, Motorbike)	53	27	18	16	19	27	17	21
		Public transport (Bus + Rail)	10	17	31	42	17	17	21	25
		Others(CNG, Leguna)	9	12	8	8	18	17	31	24
2	Comfortable mode of travel	Walking	7	9	4	4	13	11	5	5
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	7	9	4	4	17	13	14	9
		Rent a Car, Ride sharing (Uber, Pathao)	9	18	43	40	13	13	12	13
		Private automobile (Car, Microbus, Jeep, Motorbike)	61	42	21	20	21	29	18	25
		Public transport (Bus + Rail)	7	12	21	23	16	13	17	22
		Others(CNG, Leguna)	7	10	7	8	20	20	34	27
3	Factors considered most for choosing any mode	Safety and security	44	31	46	38	20	24	34	29
		Harassment	14	17	12	12	19	18	13	13
		Availability	15	18	19	24	19	18	15	15
		Fare	14	17	13	15	22	22	26	30
		Others	14	17	11	12	19	18	13	13
4	Preferred mode of travel for short trips	Walking	11	13	8	10	16	14	10	11
		Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)	14	22	31	32	19	21	40	38
		Rent a Car, Ride sharing (Uber, Pathao)	10	13	8	8	15	14	9	9

		Private automobile (Car, Microbus, Jeep, Motorbike)	40	22	8	11	17	20	9	13
		Public transport (Bus + Rail)	15	18	37	31	15	14	9	9
		Others(CNG, Leguna)	10	13	8	8	18	17	23	20

**F= Female; M= Male; U= Urban; R= Rural; Y= has vehicle ownership; N= hasn't vehicle ownership

** Highlighted value shows the maximum value in the choice list

According to the findings, people who own vehicles in rural and urban areas consider private vehicles to be a safe and comfortable method of transportation. Surprisingly, private vehicles are preferred in metropolitan areas, while NMVs are preferred in rural areas. When it comes to not having a personal automobile, the decision varies by gender and place. In this scenario, the urban female believes that NMVs are safer, whereas the man believes public transportation is superior. Women prefer CNG and Leguna in rural areas, whereas males have similar opinions as urban men. In terms of comfort, urban residents prefer a rented vehicle, whereas rural residents prefer a private vehicle. With the exception of one scenario, NMVs are the preferred mode in this case. Women in urban areas who do not have access to a personal vehicle prefer to take public transportation.

Except in two categories, safety and security are always the most influencing elements in mode selection. Rural women with personal vehicles and rural males without personal vehicles believe fare to be the paramount consideration in mode selection. However, only two analyses from the created model are given in the analysis section. Bayesian analysis is a dynamic method that may answer a variety of problems with a single model. Nonetheless, the prepared model might be used for further investigation.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the research's primary findings as well as plausible recommendations derived by various researchers in their literature. Policymakers, city planners, public transportation operators, and other stakeholders may find the proposals useful in improving the transportation sector, particularly public transportation. Finally, the chapter summarizes the limitations as well as future research directions.

5.2 Major findings

The study's main goal was to look into women's and men's challenges when using sustainable transportation (walking, cycling, NMVs, public transportation, and paratransit) in rural and urban areas. According to the model, the primary factors that influence sustainable mode choice are location, marital status, vehicle ownership, age, and the state of the pickup location. In addition, gender and harassment on public transportation have an impact on the mode selection process. The most significant consideration when choosing a mode is safety and security. However, in some situations, the cost of travel is taken into account while choosing a mode of transportation.

Another important goal of this research was to see how different factors influence men's and women's mode choosing tendencies. The model was assigned various questions in order to determine the outcome of this objective. Questions about mode choice are investigated thoroughly, while gender, car ownership, and geographical location are all variables. According to the model, people with personal vehicles always prefer personal vehicles in urban settings; however, this preference shifts in rural areas. NMV has a significant impact on mode selection patterns.

Another goal was to make recommendations to transportation authorities and planners for future planning that took gender into account to resolve mode choice characteristics. The policy and recommendations are presented in the next section in accordance with previous work references.

5.3 Policy implications

The study concentrated on two sustainable development goals (SDG). Gender equity is addressed in goal 5, whereas sustainable cities and communities are addressed in target 11 (ONU, 2020). Sustainable development and gender equity should be prioritized as a prerequisite for achieving the SDGs. Policies and recommendations should be presented that are specific to the issues.

Previous surveys have consistently shown that Sweden is the country with the most stories about gender equality in transportation. Karlskoga and other Swedish towns implemented a "gender-balanced budget," which benefited both men and women equally (Laker, 2021). This kind of gender-balanced budget can assist in achieving gender equity goals. Besides, programs like "Safe Route to School" can help women walk more easily and gain access to educational, employment, and other opportunities (Adeel et al., 2016).

Location, both rural and urban, was discovered to impact mode selection significantly. The investigation also revealed that mode choice tendencies vary depending on the demography. This is supported by research (Adeel et al., 2017). More transports and stops can be provided to disperse the crowd at the pick-up location. People may use public transportation more if bus services are improved. Bus service quality and design can be enhanced to encourage those who now use private transportation (Belwal & Belwal, 2010; Rouf et al., 2019).

Many restrictions have been put in place to limit harassment on public transit, and women, in particular, have employed certain strategies to avoid such unpleasant circumstances. Some of the solutions described in research include a zero-tolerance policy, a shift away from the public transportation, and the adoption of active modes of transportation (Arabikhan et al., 2016; Capasso da Silva & Rodrigues da Silva, 2020; Redman et al., 2013; Schulz et al., 1996; Verma et al., 2017).

NMVs are preferable options, according to the study's findings; however, there are no NMV lanes. NMV lanes can be constructed to encourage people to utilize NMVs, particularly bicycles. According to The Indian Express, these types of lanes have already been built in India (Mathur, 2015). Aside from putting the lanes in place, adequate maintenance and rules should be followed, as the Delhi government has done (TNN, 2016). The Asian Development Bank

(ADB) has a good guideline for building NMV lanes on their website. Figure 5.1 depicts the methods outlined on the ADB website (ADB, 2008)-

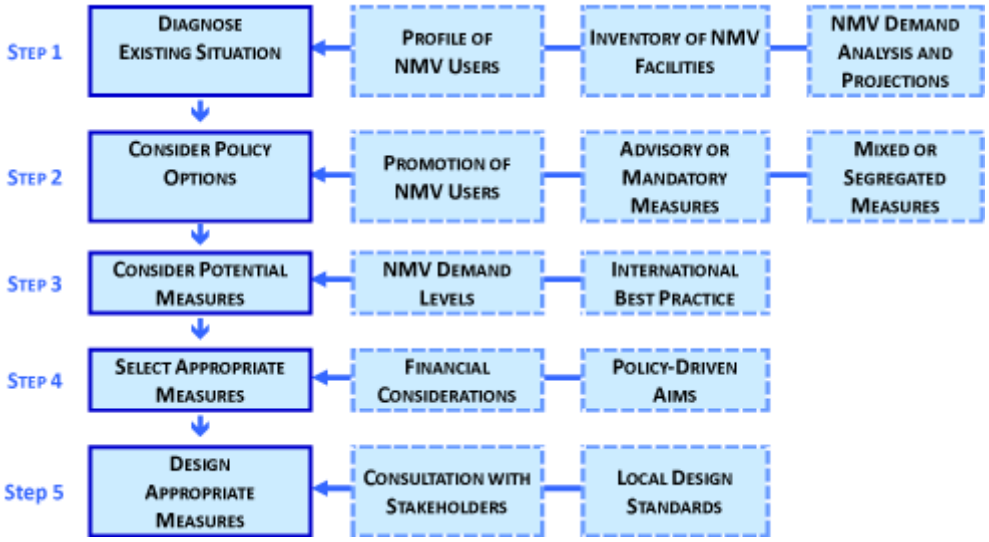

Figure 5.1: Stages in Designing an NMV Scheme

5.4 Limitations and future scope

From a variety of perspectives, this study is significant. This research revealed characteristics that influence gender mode choosing in various locations and a relationship between the aspects that aid in determining a person's method of choice. The mode choice of sustainable transportation was not undertaken significantly, taking into account gender and location characteristics. In this regard, this study is unique. This study does, however, have certain flaws that must be addressed.

One of the fundamental limitations of the study was the survey's location. For the study, only four locations were considered. In the future, the study area should be broadened to include more urban and rural areas in order to obtain more representative data. Furthermore, the data acquired, particularly for bicycling and walking, was insufficient. These aspects should be considered in future investigations. Another crucial component was the data entry procedure. The data for mode selection cannot be prioritized throughout the data input procedure. Data should be collected in the future in such a way that the preferred mode or mode choice can be prioritized for better analysis. Moreover, stakeholders, policymakers, and

relevant authorities must actively participate in the policy implications and recommendations presented in this study, which can be a difficult task.

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APPENDIX-A

Sample of the questionnaire survey form

Questionnaire on Mode Choice

1. Gender

- □ Male
- □ Female
- □ Others

2. Age

- □ Below 25
- □ 25 - 35
- □ 35 - 50
- □ Above 50

6. Marital status

- □Unmarried
- □Married
- □Others

7. Vehicle ownership (Private automobile like car, microbus)

- □ Yes
- □ No

18. Condition of the pick-up location

- □Crowded
- □ Not crowded
- □Others

19. Preferred mode of travel for short trip (Trips within 5 km)

□Walking

□Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)

□ Rent a Car & Ride sharing (Uber, Pathao)

□Private automobile (Car, Microbus, Jeep, Motorbike)

□ Public transport (Bus, Rail)

□ Others (CNG, Leguna)

30. Which mode do you consider as safe mode of travel?

□Walking

□Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)

□ Rent a Car & Ride sharing (Uber, Pathao)

□Private automobile (Car, Microbus, Jeep, Motorbike)

□ Public transport (Bus, Rail)

□ Others (CNG, Leguna)

31. Which mode do you consider as comfortable mode of travel?

□Walking

□Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)

□ Rent a Car & Ride sharing (Uber, Pathao)

□Private automobile (Car, Microbus, Jeep, Motorbike)

□ Public transport (Bus, Rail)

□ Others (CNG, Leguna)

32. Which factor do you consider most when choosing any mode?

□Walking

□Non-motorized vehicle (NMV) (Rickshaw, Van, Bicycle)

□ Rent a Car & Ride sharing (Uber, Pathao)

□Private automobile (Car, Microbus, Jeep, Motorbike)

□ Public transport (Bus, Rail)

□ Others (CNG, Leguna)

33. Have you ever been harassed in Public Transport?

□ Yes

□ No

□ Indifferent

APPENDIX-B

ROC curves generated by the test method

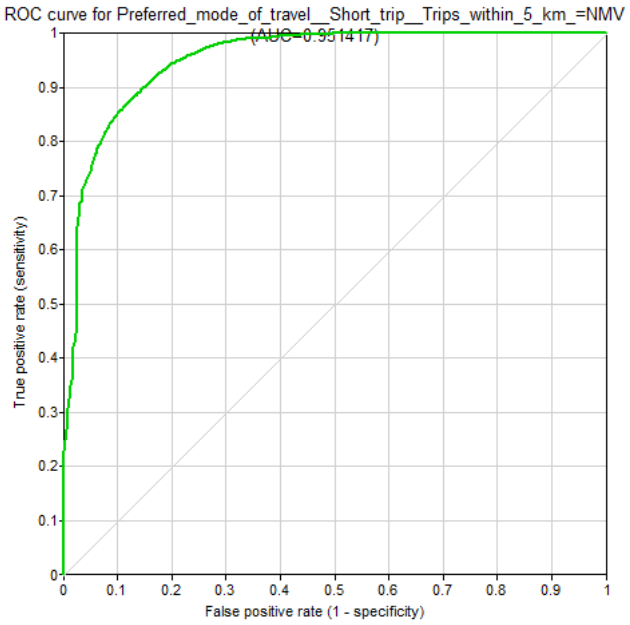

Figure B. 1: ROC curve for the model (preferred mode=NMV, validation method=test)

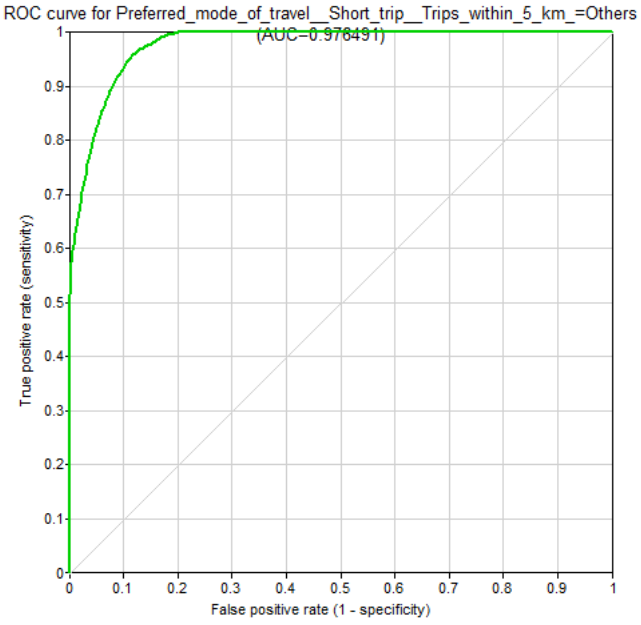

Figure B. 2: ROC curve for the model (preferred mode=others, validation method=test)

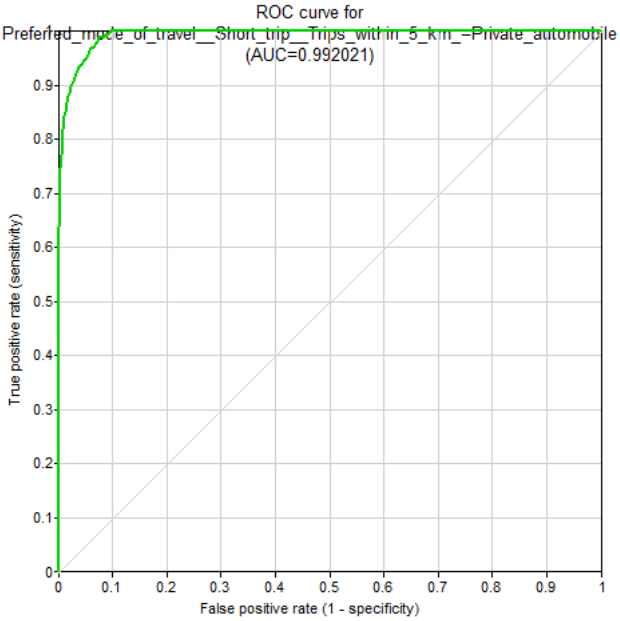

Figure B. 3: ROC curve for the model (preferred mode=private vehicles, validation method=test)

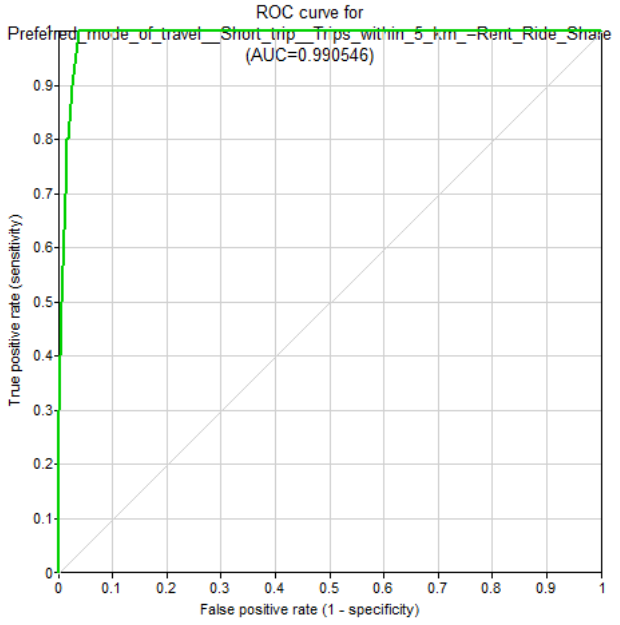

Figure B. 4: ROC curve for the model (preferred mode= rented vehicles, validation method=test)

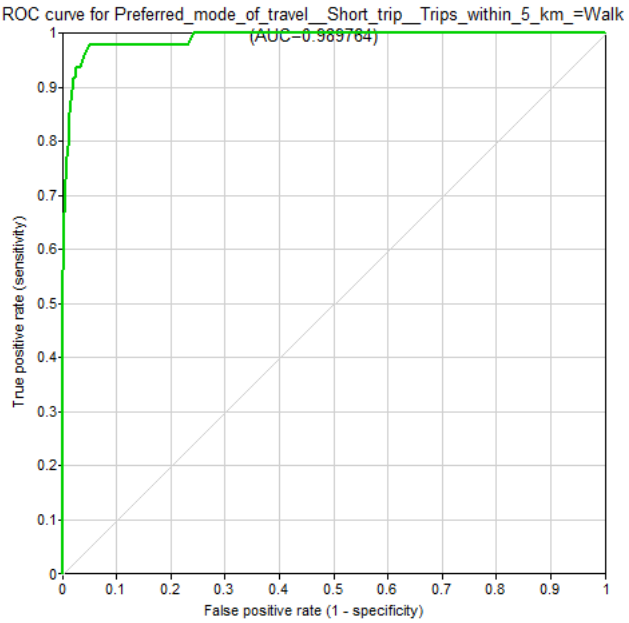

Figure B. 5: ROC curve for the model (preferred mode=walking, validation method=test)

ROC curves generated by the LOO method

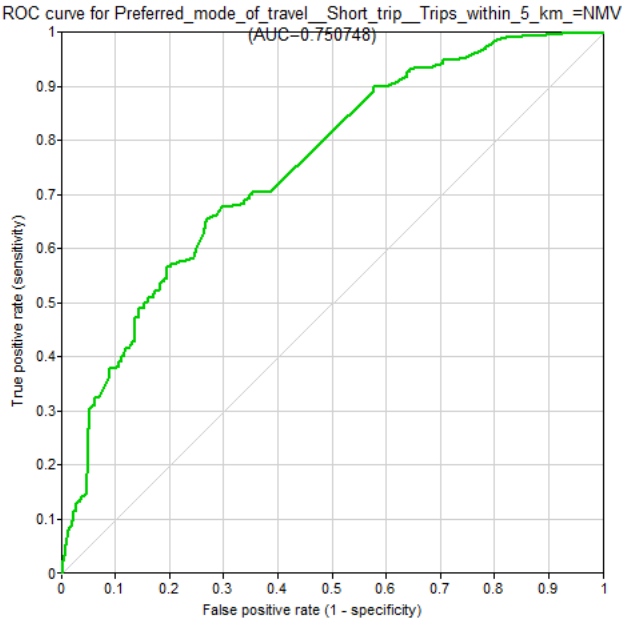

Figure B. 6: ROC curve for the model (preferred mode=NMV, validation method=LOO)

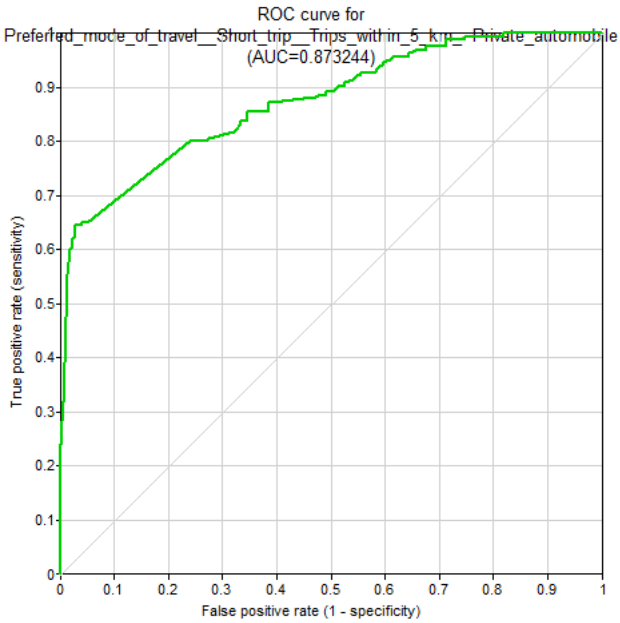

Figure B. 7: ROC curve for the model (preferred mode= private transport, validation method=LOO)

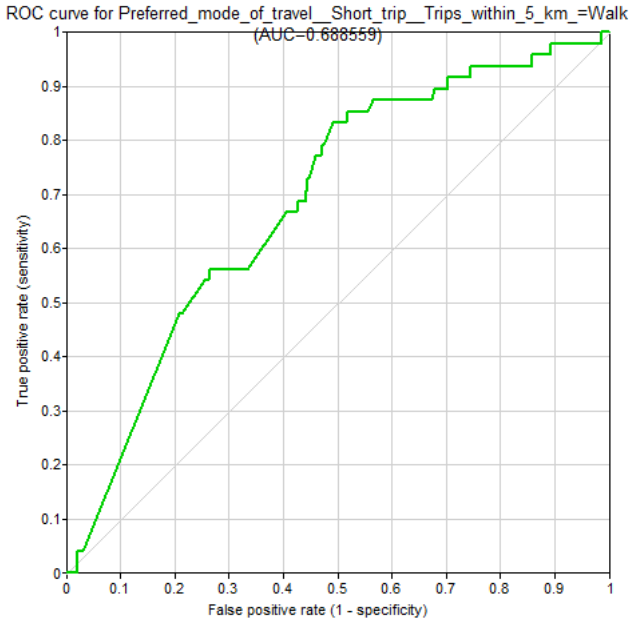

Figure B. 8: ROC curve for the model (preferred mode= walk, validation method=LOO)

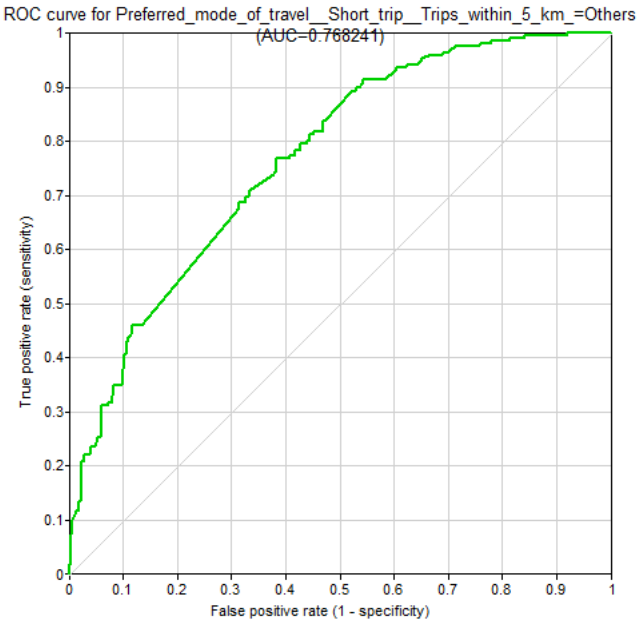

Figure B. 9: ROC curve for the model (preferred mode= others, validation method=LOO)

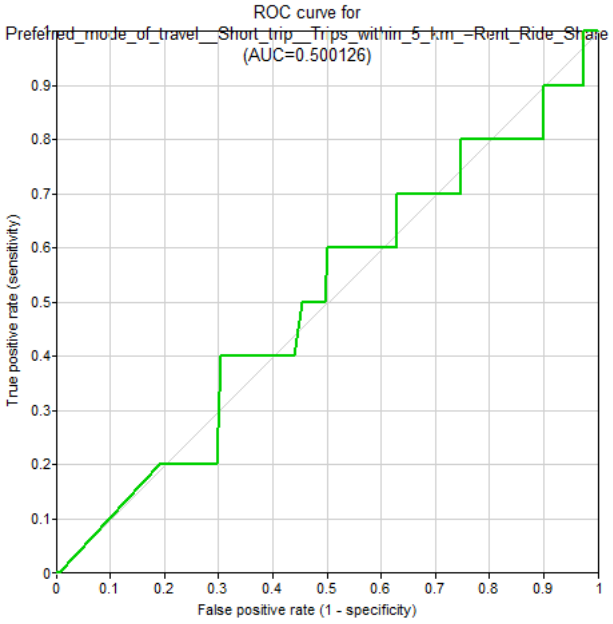

Figure B. 10: ROC curve for the model (preferred mode= rented vehicle, validation method=LOO)