GENDER DIFFERENCE IN ACTIVE TRANSPORT UPTAKE IN CONTEXT OF A DEVELOPING MEGACITY

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of
BACHELOR OF SCIENCE IN CIVIL ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINNERING
ISLAMIC UNIVERSITY OF TECHNOLOGY

JUNE 2024

APPROVAL

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DECLARATION

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

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DEDICATION

We thank our family and teachers for their support and belief in us.

ACKNOWLEDGEMENT

All glory to Almighty Allah, by his graciousness we were able to finish our research objectiv
e. We are grateful to Allah, who is most merciful and compassionate.

We are grateful to Dr. Moinul Hossain, Professor, Department of Civil and Environmental Engineering, IUT, for his expert guidance in completing our dissertation. We are forever thankful for your incredible insights, continual mentoring, and never-ending inspiration.

We appreciate Md. Asif Raihan, Assistant Professor, Accident Research Institute (ARI), Bangladesh University of Engineering and Technology (BUET), for his unwavering dedicatio
n
and responsibility. Without his continual supervision, the study would be hard to rationalize.

Finally, we want to thank our family members and others who supported us do our research.

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LIST OF ABBREVIATIONS

AUC	Area Under the Curve
BBN	Bayesian Belief Network
DAG	Directed Acyclic Graph
EM	Expectation Maximization
GeNIe	Graphical Network Interface
PC	Peter and Clark
LOO	Leave One Out
NMV	Non-Motorized Vehicle
ROC	Receiver Operating Characteristic
SEM	Structural Equation Modelling
WHO	World Health Organization

ABSTRACT

Active transport is a significant component of sustainable urban transportation, but its uptake in developing megacities is hindered by gender disparities. Previous research has shown that females are more likely to walk and use public transport in comparison to males. However, as Bangladesh is on its way to transition into a developing country, a literature gap exists to address the issues and challenges faced by women in terms of commuting actively.

This study will contribute to the existing literature on active travel and gender by providing insights into the specific needs and challenges of female active travelers in different suburbs of Dhaka. The possible study areas of Dhaka can be Uttara, Gulshan, Banani, Mirpur DOHS, Dhanmondi, Bashundhara and Mohammadpur because these are the suburbs in Dhaka with diverse socio-economic backgrounds and transportation infrastructure.

A multi-faceted approach is employed, involving quantitative methods (SEM and BBN) and qualitative techniques (online and in-person surveys) to produce solid outcomes which aligns with the research objectives.

The principal findings of the study will include the causal relationship of factors such as demographic characteristics, socio-economic status, land use, infrastructure and accessibility, culture and societal norms, network characteristics, attitude towards active travel and trip purpose. The findings will inform targeted interventions to promote AT uptake among women in Dhaka, contributing to efforts to reduce the prevalence of car usage and its negative impact on environmental and public health.

Keywords: Active transport; Sustainable Transport; SEM; Bayesian Belief Network; Land Use; Infrastructure; Accessibility; Network Characteristics.

CHAPTER ONE INTRODUCTION

1.1. Background

At the present time, the number of megacities, defined as cities with a population of ten million or more, is 33. By 2050, this number is expected to increase significantly, with estimations indicating at least 50 megacities all over the world (Ecological Threat Report 2023: Analysing Ecological Threats, Resilience & Peace, 2023). According to a study conducted by World Population Review, Dhaka, one of the fastest growing megacities in the world is now home to an approximate 23.2 million people on a land of 306.4 square kilometers only (Dhaka Population 2023, 2023). With a growth rate of 3.26% and rising, The Ecological Threat Report (ETR 2023) projects a significant increase in the city's population, with an anticipated rise to 34.6 million by 2050, representing a 53% growth from the current population (Ecological Threat Report 2023: Analysing Ecological Threats, Resilience & Peace, 2023). The fast-growing population has already put enormous stress on the city, as evidenced by its high rates of poverty, and future concerns include increasing congestion, a higher percentage of unemployment and inadequate infrastructure. In addition to that, a global climate report ranked Dhaka fourth amongst the 20 most unsustainable megacities in the world, while the capital reels from rapid depletion of greenery, water scarcity and exploding population (Yousuf, 2022). Women are increasingly participating in all aspects of society, including education, the workforce, and public affairs, on an equal footing with men. However, despite women's growing awareness of their educational, professional, and social aspirations, gender inequality persists due to a lack of equal opportunities and treatment. Policy initiatives have been introduced to address disparities in women's access to formal employment and to acknowledge their multifaceted roles as economic contributors, caregivers, and community leaders (Wong, 2012). To this day, women cannot access all the facilities when they set out to travel outside of their homes. Women's travel patterns differ from those of men, yet their recognition remains underrepresented by transportation planners and stakeholders, leading to negative travel experiences and attitudes among women. As a result, women often have concerns about the safety and reliability of public transportation (Quinones, 2020).

In Dhaka, women constitute 34% of the labor force, reflecting their increasing contribution (Bangladesh Bureau of Statistics, 2020). Yet, the transportation services to accommodate women-folk is staggeringly low. The findings from an investigation report illustrates that the number of women-only buses operating is not sufficient with 71% users expressing their unfortunate experiences of encountering problems with the existing on-route services (Rahman M. S.-U., 2010). To combat several challenges caused due to rapid-urbanization and increasing population, popularizing active transportation modes like walking and bicycling have become inevitable.

Both male and female perspectives are indispensable to develop and adopt the sustainable transportation system in a developing megacity like Dhaka. This study will assess the most influential factors in active mode choice selection from both genders' vantage points. This research will also focus on actions that can strengthen the use of active transportation across the sprawling suburbs of Dhaka city.

1.2. Problem Statement

As a megacity, Dhaka faces a huge problem in the transportation field struggling to facilitate proper transportation facilities to the growing population. As a result, roads are clogged during peak hours and it becomes troublesome to reach one's destination in time. A huge portion of one's daily life is expended in the severe traffic congestion. On average the commuters of Dhaka city lose about one working hour per day due to the jam-packed condition of Dhaka city's roads (Haider & Papri, 2021). One way to relieve this problem is the execution of the idea of active transport, where commuters will either walk or cycle to their destination given that the destination is considerably close. Particularly in Dhaka, the scope of active transport is very narrow as the roads are not pedestrian or cyclist friendly. As the footpaths are encroached by the street hawkers and tea stalls, pedestrians face difficulty using footpaths which affect their mindset of walking negatively. Active transport may be somewhat effective in saving time when travelling short distances on a busy road instead of using cars. It also proves beneficial to the health and as it leaves zero carbon footprint, it is very important for the environment. Regrettably there is a difference in the active transport uptake based on gender in Dhaka, which is the main focus of this thesis. The differences may arise due to the factors such as- socio-cultural norms, safety concerns and access to transportation resources. Delhi, being similar to Dhaka in terms of culture, overpopulation and high traffic congestion, females there are found to have nearly 0% of active travel time from cycling, whereas men have 20% for the same (Goel, et al., 2023). Due to the reluctance of women to engage in active transport due to various factors affecting their choice; urban mobility, public health and gender equity are being impacted. Moreover, the majority have the mindset of cycling to be a male activity. Females having the role of handling the family and the children have unequal distribution of roles compared to males leading towards limiting their participation in active transport (Prati, Marín Puchades, & Pietrantoni, 2017). Safety, social and environmental factors are very much impactful towards the behavior of women towards cycling (Emond, Tang, & Handy). This thesis summarizes important findings about gender and transportation by drawing on previous research, with a particular emphasis on studies carried out in Dhaka or similar settings. The objective of the study is to enhance and augment the current corpus of knowledge by pinpointing gaps and constraints in existing research.

1.3. Purpose and Objectives

This study aims to contribute to the existing literature on gender disparities in active travel backdrop through the perspective of Dhaka, a developing megacity by addressing the following specific research objectives:

1. To identify gender-specific determinants influencing active transport uptake in Dhaka, a developing megacity.
2. To investigate potential gender differences in these factors and their impact on diverse active transport mode choices.
3. To assess variations within female road users based on demographic characteristics, socio-economic status, land use, network characteristics, and trip purpose.
4. To derive policy implications aimed at promoting sustainable and gender-inclusive active transport options as alternatives to car usage in developing megacities.

1.4. Scope of the Study

The study focuses on multiple suburbs within Dhaka, a developing megacity, and aims to examine gender-specific determinants influencing active transport choices across various

socioeconomic boundaries. It will include a representative sample of non-captive riders, stratified by gender and socioeconomic status. The study will investigate determinants such as demographic characteristics, socio-economic status, land use, infrastructure and accessibility, culture and societal norms, network characteristics, attitude towards active travel and trip purpose. The motivation behind this study is to identify key relationships and relevance among the factors and how gender biasness affects the outcome of mode choice. The findings gathered from the study will provide valuable insights which will assist policymakers and related stakeholders to promote active travel uptake in Dhaka contributing to efforts to reduce car usage prevalence and its environmental and public health impacts.

1.5. Chapter Breakdown of the Thesis

This study has been categorically organized into six chapters. All the chapters have titles along with subtitles that provide sufficient explanations to justify the entire framework. The following breakdown offers a coherent outline of the entire thesis in a chronological order.

Chapter 1: Introduction

The first chapter sets out with an extensive introduction that will act as the groundwork for the entire thesis. This chapter introduces the study by providing background and motivation, highlighting problem statement, relevance of the study against timeframe and geographic backdrop and finally outlining its goals, objectives and scope it wishes to address essentially laying the roadmap for the rest of the study.

Chapter 2: Literature Review

The second chapter includes a detailed literature analysis to elucidate the research issue at hand and how it correlates in the given sector, consequently leading to the identification of research gaps. This chapter provides insights of what already has been researched about the study so far and how other authors have approached the issue in their study.

Chapter 3: Study Area and Data Collection

The third chapter discusses the possible study areas to ensure best representative response. A number of areas are selected based on diverse socio-economic backgrounds and transportation infrastructure. A succinct brief of different methods of data collection, how the data was processed and filtered to highlight the data relevant to the study has been included in this section.

Chapter 4: Methodology

The third chapter briefs about the methodologies used in this study to evaluate reliability and validity of the study. An overview of each of the methods as well as why the selected method was chosen to represent the best-case scenario outcomes has been included in this chapter.

Chapter 5: Analysis and Results

The fourth chapter assists to report the findings concisely and objectively in a logical order. Furthermore, visuals (in the form of graphs, charts and tables) have been added to provide an in-depth understanding from the brief observations.

Chapter 6: Conclusion and Recommendations

The final chapter presents an overview of the research's principal findings and recommends plausible policy implications. In addition, this chapter reflects on the study's limitations and suggests directions for future research that can build upon the findings of the current study.

CHAPTER TWO LITERATURE REVIEW

2.1. Role of Transportation in Urban Development

The nature of urban transit and the urban structure are inextricably linked (Pacione, 2009) (Ogunsanya, 2002) (Muller, 1986). Accessibility is enabled by efficient transportation networks, which connect residents to jobs, education, and important services. The amount of accessibility determines the characteristics of the transport system, which in turn influences the location of activities (Land use). The spatial location of activities influences the pattern of daily activity, which influences the necessity to travel (Huang, 2003) . The importance of transport in the spatial and economic development of cities and regions cannot be overstated. Cities grow around their transport networks, and as the city grows, so do its transit needs. Because different sites of activity within the urban area are geographically separated, mobility is essential to overcome spatial barriers and for cities to function efficiently. (Hanson, 1986)emphasizes the importance of mobility and accessibility by emphasizing the fact that the location of goods and services, employment locations, and public facilities are frequently (though inappropriately) geographically dispersed and thus require an efficient transportation system to connect these places. As a result, cities are made up of many land uses that are linked together via transportation. (Kehinde, 2019)

2.2. Sustainable Urban Transport

Sustainable urban transportation prioritizes low-emission modes such as public transportation, cycling, and walking to reduce environmental effect. The goal is to build efficient, accessible, and environmentally friendly transport systems that reduce congestion and pollution while supporting greener energy sources and innovative technologies. Adopting sustainable urban transport improves not only the quality of life for city dwellers, but also contributes to a more resilient and ecologically conscious urban future. Options for promoting sustainable urban transport in developing cities can be- rail based public transport, road based public transport, control of land use, non-motorized modes e.g. cycling, walking. (Dorina Pojani, 2015)

Changes in the transport system inevitably cause changes in human behavior, which analysts who fail to recognize these wider systems will ignore in their policy judgements. There are numerous examples of how behavioral change defies precisely defined policies:

Induced travel is any increase in travel caused by an improvement in transportation circumstances, and it is a normal market response to a reduction in journey time. Congestion that recurs sooner than expected on a highway that has been extended as a congestion reduction strategy is an example of this phenomena. While the mechanics underlying induced travel can be difficult to decipher, simple microeconomics can account for it. (Pickrell, 2001) (Todd Goldman, 2006)

2.3. Factors Influencing Mode Choice

A variety of factors influence mode selection in sustainable transportation. Several transport-related factors have been investigated, including the significant influences of transit systems' ability to attract passengers and service quality, travel characteristics, travel time, combination of in-vehicle time and cost, value of travel time, tour complexity, availability of car parking at work, traffic safety, and the number of non-motorized trips by other family members.

Residential site decisions and urban form have also been mentioned as key spatial causes. Furthermore, people's attitudes, perceptions, behavioral norms, beliefs, and habits have been identified as decisive factors in mode selection. (Fang Zhao, 2002) (David p. Racca) (Bhat, 2006) (Masoumi, 2019)

2.4. Active Modes for a Sustainable Transportation System

In increasing cities and regions, extended suburbanization is a common planning challenge. Before the region expands on the urban outskirts, evaluating possible regions for intensive use informs sustainability-driven planning actions. Land use/land cover (LULC) models can help planners choose areas with high growth potential. Current models that have not adequately included non-auto transportation modes, on the other hand, may exaggerate the effects of automobile travel while underestimating the value of walking or bike accessibility. As a result, it is more likely that suburban development along highways will be prioritized. (Cong Cong, 2022) Active transportation includes all travel that involves walking, cycling, or using public transportation (PT) systems, because getting to a transit station usually entails walking or cycling. Active forms of transport perform best when they have strong synergy and adequate support. (Abolfazl Dehghanmongabadi P. S., 2018) (Abolfazl Dehghanmongabadi S. H., 2020) Creating safe and linked infrastructure for active transportation, such as well-kept sidewalks and bike lanes, can assist to address safety issues while also encouraging more people to walk and cycle. (Patil, 2018)

2.5. Gender Disparities in Transportation Behavior

The disparities in men's and women's travel and activity patterns have become a central and recurrent feature in transportation systems worldwide, as acknowledged by transportation planners, geographers, economists, and policy makers over the last ten years for both developed and developing countries (Peters, 2001). No matter how developed the economy is in their nation or area, women are more likely than comparable men to have unique and complicated travel habits, have less access to quicker or better transportation options, and feel more anxious about being attacked or harassed (Rosenbloom & Plessis-Fraissard, 2009).

To understand gender difference in active mode of transport it’s essential to understand gender disparities in transportation behavior in both developed and developing countries. Compared to males, women now use modes of transportation that are better suited to a sustainable transportation system in terms of the environment in European countries (Polk, 2003; Laker, 2021; Carboni, Pirra, Costa, & Kalakou, 2021). Men are four times more likely than women to drive passenger cars and travel for work in Novi Sad, Serbia (Basarić, Vujičić, Simić, Bogdanović, & Saulić, 2016). (Tran & Schlyter, 2010) analyzed that in Xian, China, and Hanoi, Vietnam, women walk more while males are more motorized. In Hanoi, women also ride their bicycles longer. Compared to men, women from Thailand, Malaysia and India are more likely to favor public transit (Satiennam, Jaensirisak, Natevongin, & Kowtanapanich, 2011; Nurdden, Rahmat, & Ismail, 2007; Arasan & Vedagiri). For the mobility of women commuters in Dhaka, neither independence nor equity have been attained (Nasrin & Bunker, 2021).

2.6. Gender Considerations in Sustainable Transport Choice with Emphasis on Active Modes

Promoting environmentally friendly transportation options over private vehicles, such as walking, cycling, and public transportation, can have a significant impact on the development of sustainable transportation systems (Ko, b, & Byun, 2019; Cools, Moons, Janssens, & Wets, 2009; Marshall & Banister, 2000). In order to do this, we must investigate factors related to commuter mode selection. (Quinn, John M Jakicic, & Gibbs, 2016) has demonstrated how sociodemographic characteristics such as family income, age, gender, race, and education affect the use of active transportation in the USA and finds that males, younger people, urban dwellers, and those with lesser incomes were found to walk more frequently on their way to work.

Several active travel behavior theories have postulated that safety and security might influence the decisions made about walking and bicycling (Schneider, 2013; Alfonzo, 2005). In places with fewer secure transit options, people were less inclined to choose active travel mode (Singleton & Wang, 2014). On the other hand, infrastructure is another major factor in here because walking and riding pathways that are away from moving vehicles are preferred. Air pollution and traffic noise levels are two main obstacles to riding and walking in general (Winters, Davidson, Kao, & Teschke, 2011). There is a favorable correlation between the quantity of bike lanes and the number of Americans who commute by bicycle every day (Buehler & Pucher, 2012). There is a dearth of research on these variables influencing the choice of sustainable transportation in developing nations compared to wealthy nations. Research utilizing device-measured active transportation (e.g., GPS technology) on a large scale is still scarce in low- and middle-income nations (Ferrari, et al., 2021).

2.7. Mode Choice Dynamics for Women in Developing Countries

Researchers studying transportation are particularly interested in the analysis of women's travel habits. Numerous studies have examined the factors that influence women's expectations for everyday activities and travel preferences. In general, women commute shorter distances and travel less than men do, particularly when it comes to business and work-related travel and compared to males, they make more grocery trips (Crane & Takahashi, 2009; Prashker, Shiftan, & Hershkovitch-Sarusi, 2008; Axisa, Scott, & Newbold, 2012; Taylor & Mauch, 1996). In addition, women seem to be less sensitive to travel time than males and make fewer pauses than men do when commuting (Hainan, Guensler, & Ogle, 2004; Patterson, Ewing, & Haider, 2005).

Nevertheless, these studies were conducted for developed country lifestyles. (Arman, Khademi, & Lapparent, 2018) has conducted research on Iranian women and found that, in addition to the problem being worse in developing nations, studies on women's behavior and travel habits have not matured to the same degree as other areas of transportation demand analysis. (Mejia-Dorantes, 2018) agrees to this point where research on Mexican women has been conducted. In Pakistan, women are less mobile than males in practically every way and for almost every reason (Adeel, Yeh, & Zhang, 2017). As per Dhaka, Bangladesh, there are very limited studies but according to (Rahman, Bari, Islam, & Joyonto, 2020), bus service plays an essential role.

2.8. Gender Influence on Active Mode over Public Mode

It is well recognized that travel behavior is linked to attitudes that suggest mode choice may be altered when traveler attitudes shift about driving, using public transportation, bicycling, carpooling, and walking (Gilbert & Foerster, 1977; Johansson, Heldt, & Johansson, 2006; Kuppam, Pendyala, & Rahman, 1999). Research conducted in a variety of geographical contexts has repeatedly demonstrated that satisfaction with active travel modes is better than that of cars and public transportation trips, and that happiness with travel is lowest for various public transportation options (Ettema, Friman, Gärling, & Olsson, 2015).

Whereas women are more prone to worry about assured trips and safety on buses and at bus stops, males had generally more positive opinions regarding public transit (Beirão & Cabral, 2008; Rosenvloom & Burns, 1993). However, many studies proved that women are more likely to cut back on driving because they care more about the environment (Matthies, Kuhn, & Klöckner, 2002). Since there aren't many research on underdeveloped countries, we can only hypothesize that men and women would choose active mode more frequently if infrastructure and safety could be guaranteed.

CHAPTER THREE DATA COLLECTION AND METHODOLOGY

3.1. Introduction

This chapter describes the subject area, data gathering methods, data formulation, and methodology that were used throughout the thesis. Much of the work started with a contemporaneous literature review. After conducting a thorough assessment of the literature and seeking expert guidance, the issue statement and research objective were defined. Following that, a questionnaire was created in compliance with the objectives. A model was built with appropriate variables, and an analysis was conducted. The figure displays the general course of the research. (Miti, 2022)

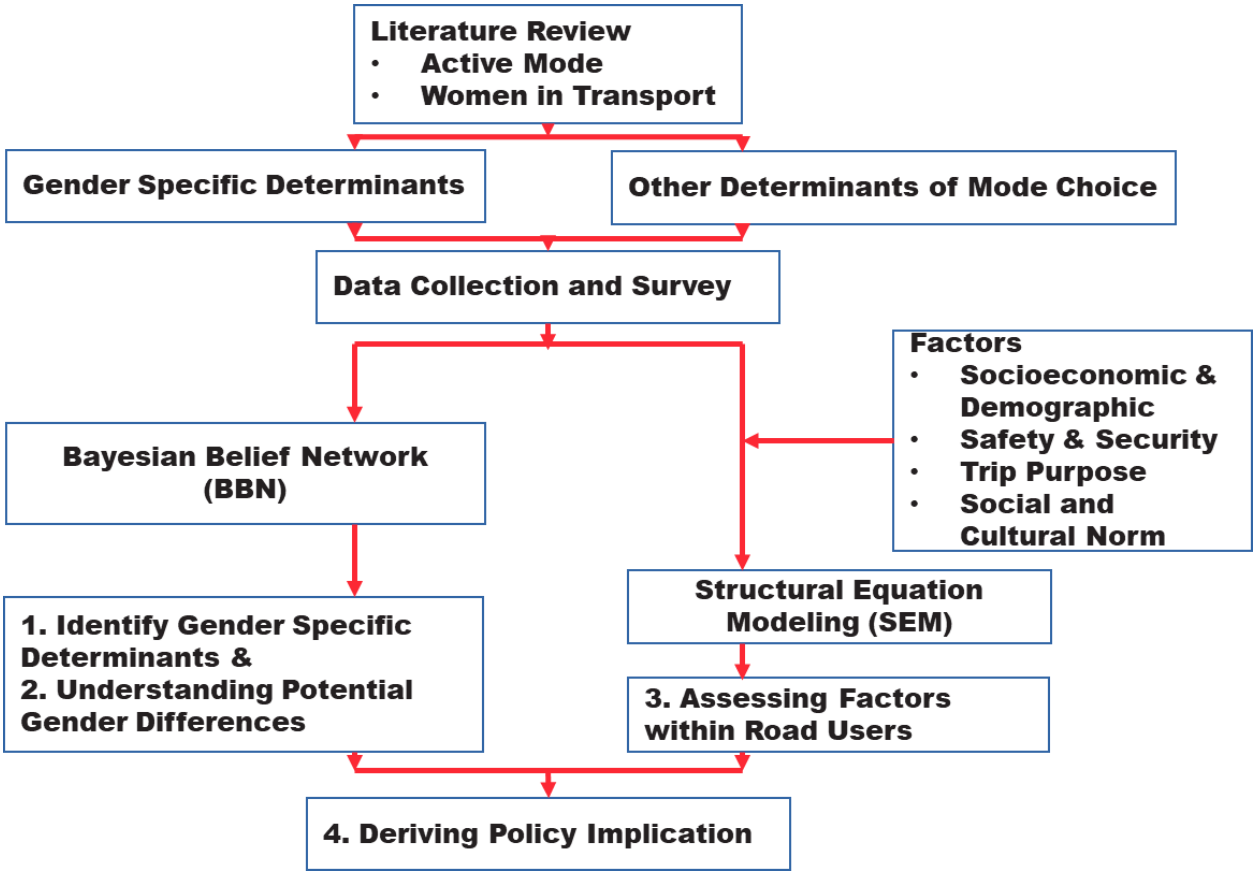

Figure 1: Overall Workflow

3.2. Study Area and Data

3.2.1. Study Area

The study was primarily based on a questionnaire survey (in-person and online). The questionnaire was used to generate two models, which were later analyzed. The questionnaire survey was conducted in several cities within Dhaka. The cities were chosen to ensure that

survey data accurately reflect the demographic and socioeconomic features of the general population. The cities were classed according to their land use: residential, industrial, commercial, and mixed. The figure 2 illustrates all the selected cities. (Choudhury)

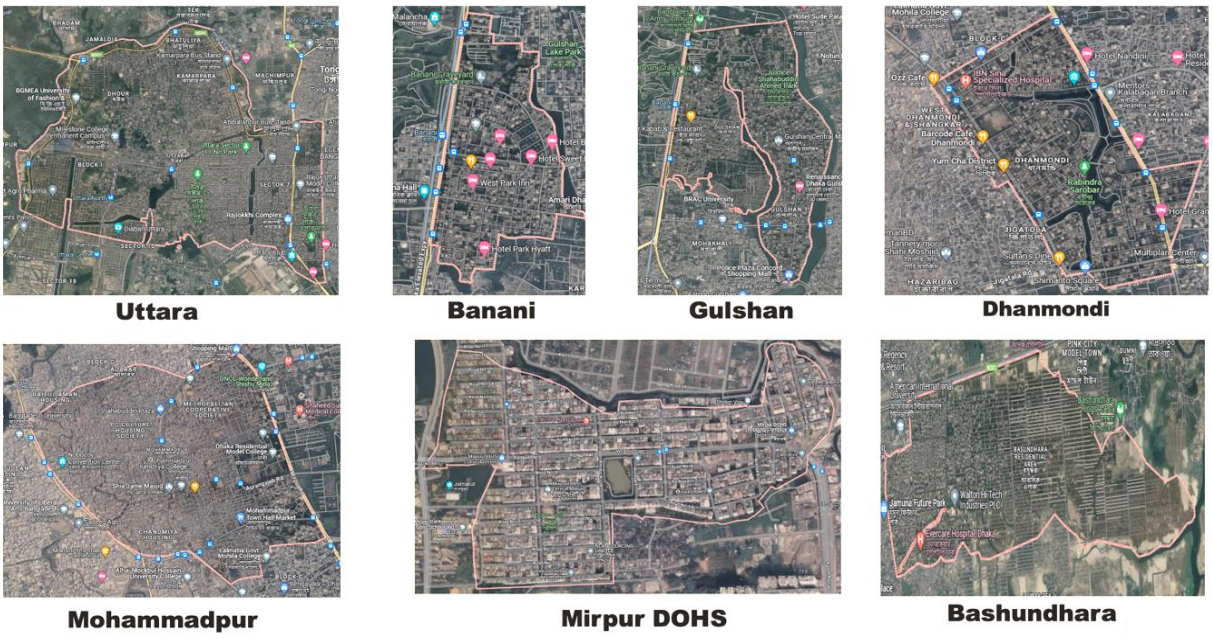

Figure 2: Data Collection Locations

3.2.2. Data

A questionnaire for user-mode choice patterns was developed using a review of the literature and the comments of transportation professionals. The questionnaire includes questions regarding gender, age group, education level, occupation, marital status, car ownership, views of safety and security, perceptions of mode choice trends, and other variables that may impact active mode choice. There were around 46 questions in the questionnaire. For the thesis, several factors from the entire questionnaire were chosen. After careful deliberation, the study regions were chosen to guarantee that the data collected from them accurately represented the bulk of the population in the country. Prior to analysis, the data was processed, and the final data set included 510 responses from both rural and urban locations.

3.3. Methods

To analyses our collected data, we have incorporated Bayesian Belief Network (BBN) as well as Structural Equation Modelling (SEM). Our reasoning to use BBN is that it mathematically proves the relationships among variables and the level of impact of the variables on expected results. Again, in from our data we have few latent variables (variables which cannot be quantified directly), these latent variables are best expressed using SEM. So, we have separately used both these modelling approaches.

From the following figure 3 and figure 4 we will have a brief over-view of our model developments for BBN (Richard Torkar) and SEM (Moody, 2019):

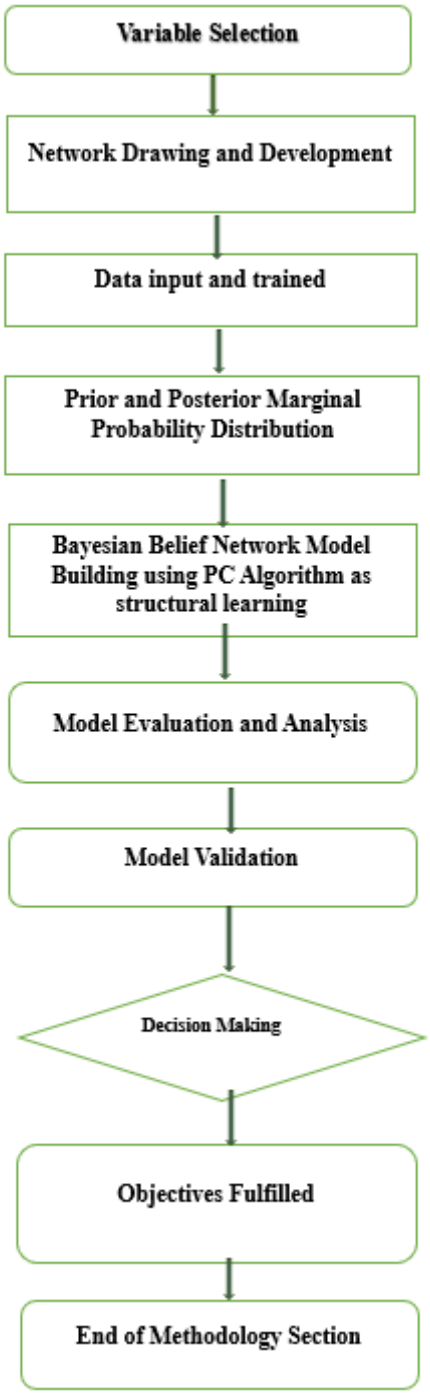

Figure 3: BBN Model Development

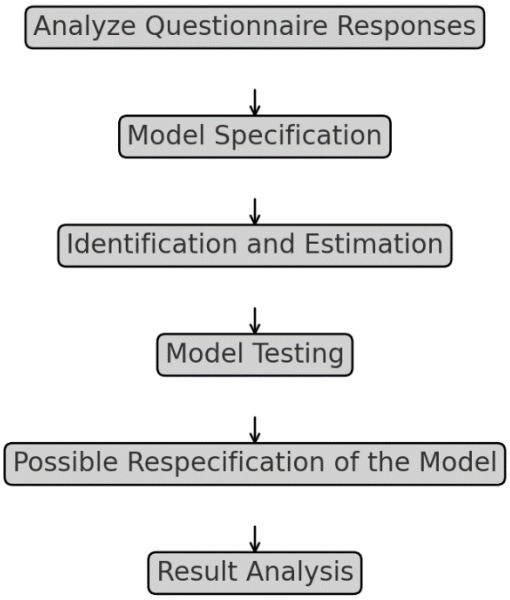

Figure 4: SEM Model Development

3.3.1. Bayesian Belief Network (BBN)

A modern probabilistic graphical model is called a Bayesian belief network. A Bayesian Belief Network is a straightforward method for using the Bayes Theorem to solve complicated issues. It is also referred to as a belief network, causal network, or Bayesian network. The Bayesian framework is based on the Bayes hypothesis, sometimes known as the Bayes rule [71]. The Bayes rule goes as follows:

$P(M|N) = P(N|M) \times P(M)/P(N)$ …… (1)

In the following equation, P(M) represents the likelihood of M occurring, whereas P(N) represents the probability of N occurring. Furthermore, P(N │ M) shows the chance of occurrence of N given that M has already occurred, while P(M │ N) is the likelihood of M given that N has already occurred.

A Bayesian network is a sort of predictive model in which a directed acyclic graph is used to describe a set of variables and their conditional relationships. Bayesian networks, which are acyclic directed graphs, reflect the factorizations of joint probability distributions. Every joint probability distribution over x random variables can be factored x! times and expressed as a product of probability distributions for each variable, depending on the other variables. The BBN's graphical component is made up of two sorts of elements: nodes and directed edges (also called as arcs). The arcs depict the interactions between the nodes, which are variables with a finite number of mutually incompatible values.

$P_r (A, B, C, D) = P (A \mid B, C, D) \times P (B \mid C, D) \times P (C \mid D) \times P (D)$ …… (2)

$P_r (A, B, C, D) = P (A \mid B, C, D) \times P (B \mid C, D) \times P (D \mid C) \times P (C)$ …… (3)

P_r (A, B, C, D) = P (A | B, C, D) x P (B | C, D) x P (C | D) x P (C) ……..……... (4)

P_r (A, B, C, D) = P (D | A, B, C) x P (B | A, C) x P (B | A) x P (A) …… (5)

The following figure shows a sample of Bayesian Network for the first factorization (Ramon Sangüesa, 1997):

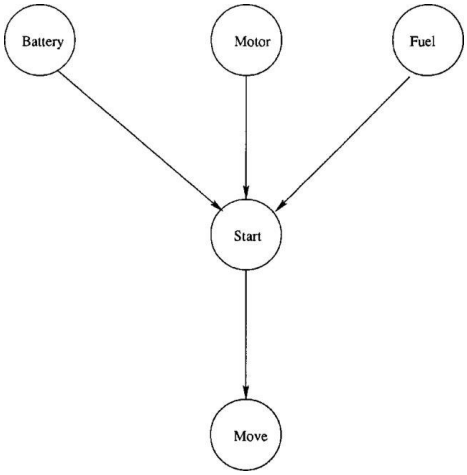

Figure 5: Bayesian Network for First Factorization

To further grasp the numerical component, let us consider a BBN with infinite variables U = X_1, X_2,..... X_n. The joint probability distribution P(U), which is produced by multiplying each conditional probability table inside the BBN, may then be used to characterize the Bayesian Belief Network. The joint probability distribution is visually represented by the Bayesian network, whose function is as follows.:

$P(U) = P(X_1, X_2, ..., Xn) = \prod^{n}_{i=1} P(X_i \mid pa(X_i))$ ……. (6)

The structure of a Bayesian network can be determined using data or a combination of expert knowledge and structural learning techniques. This study's network was constructed using a hybrid technique. The structural learning was completed when the questionnaire data was entered into software. There are various software solutions for working with Bayesian network models. The most popular programs include GeNIe (Graphical Network Interface), Hugin, BUGS, and R. GeNIe, Hugin, BUGS, and R. GeNIe Academic Version 3 was employed in our analysis (Genie, 2016)

A PC technique was used to do structural learning after data import. PC algorithm is a prominent constraint-based approach for causal discovery. Using parameter learning and the Expectation Maximization (EM) technique, GeNIe generates the joint probability distribution. A technique for estimating maximum likelihood is the EM algorithm. EM first guesses the values of latent variables and then iteratively refines them to increase estimation accuracy. The two phases in the iteration process are the M-Step (maximization step) and the E-Step (expectation step). Until the two phases are consistent, the procedure is repeated. The graphic that follows displays the data we utilized for BBN:

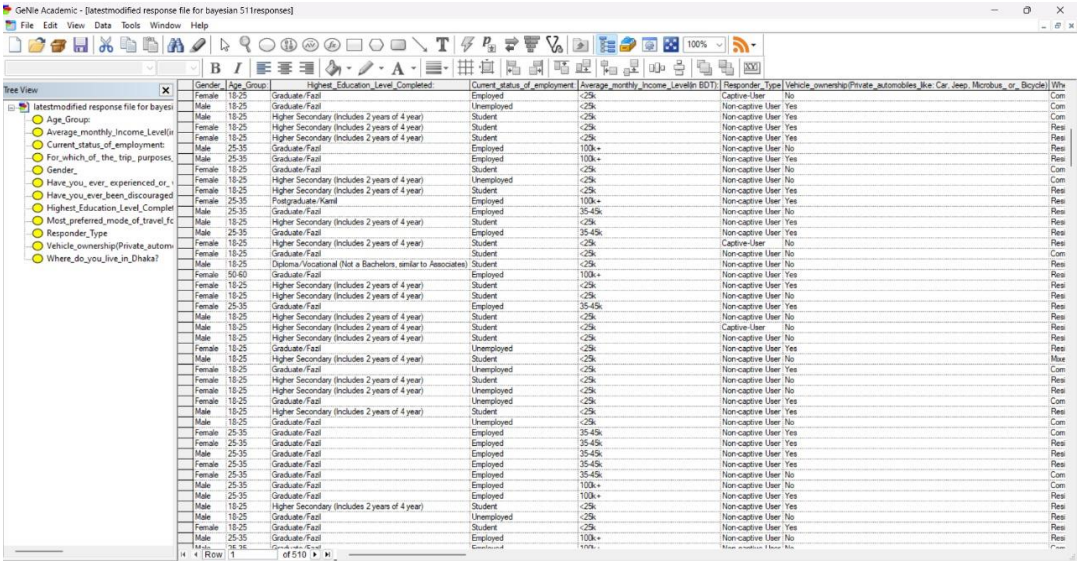

Figure 6: Sampled Data for BBN

3.3.2. Structural Equation Modelling (SEM)

SEM is a powerful technique that combines factor analysis and multiple regression to examine complex relationships between observed and unobserved variables (Kline, 2015). We used Structural Equation Modeling (SEM) to analyze how latent variables (Socio-economic and Demographic Characteristics, Safety and Security, Trip Purpose, Social and Cultural Norms) impact Mode Choice. We used STATA for SEM due to its fully integrated module that supports a wide range of models, advanced estimation methods, robust standard errors, and extensive model fit evaluation tools, making it ideal for rigorous structural equation modeling (Acock, 2013)

Structural equation modeling was chosen for this study because it allows for the examination of both direct and indirect effects between variables. This is particularly useful in understanding the complex relationships between the variables that influence women's active transport uptake in the context of a developing megacity. SEM also enables the analysis of latent variables, which are not directly observable but can be inferred from the observed variables. For this study, STATA was used for structural equation modeling. STATA is a statistical software package that provides a comprehensive set of tools for data analysis and visualization. It is widely used in various fields for data analysis and modeling, including structural equation modeling. (Bag, 2015) (Tarka, 2017)

The study employed a mixed-methods approach, combining both qualitative and quantitative data collection and analysis methods. The data was collected through surveys administered to a representative sample of women commuters, ensuring a nuanced understanding of their commuting behaviors and preferences. The data was then analyzed using structural equation modeling techniques in STATA to examine the relationships between the variables that influence women's active transport uptake in the study area.

The following figure will help us understand the SEM structure-

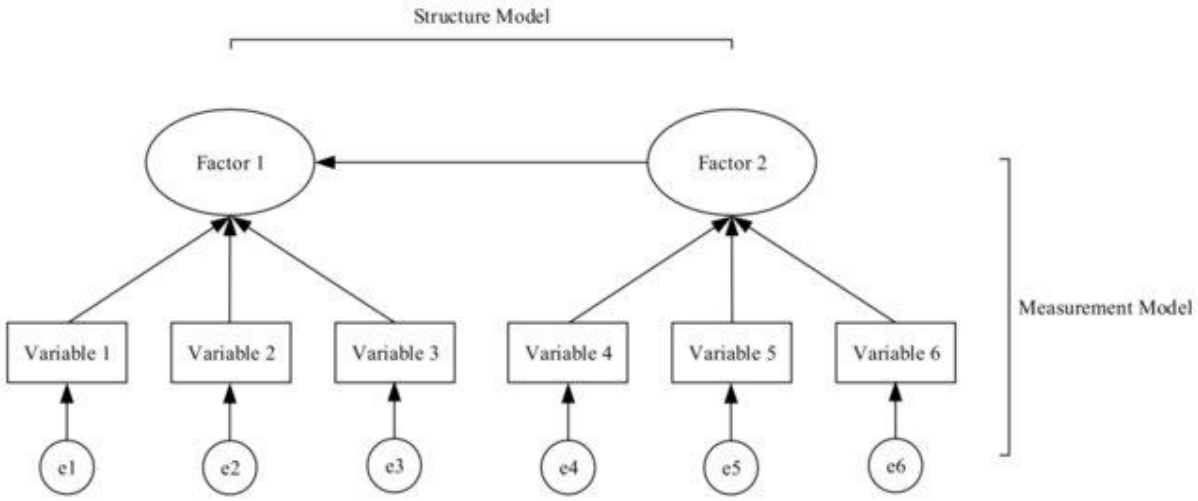

Figure 7: SEM Structure

Figure3.6: SEM Structure

Here firstly we created the measurement model- $y=\lambda y+\epsilon$

Where y is the latent variable

λ is the factor loading

ϵ is the measurement error.

Then we created the structural model $y=\Gamma x+\zeta y$

Where y is the latent variable

x is the exogenous variable

Γ is the structural coefficient

ζ is the structural error.

Finally, we get our overall model $y=\lambda y+\Gamma x+\epsilon+\zeta$

Where y is the latent variable

x is the exogenous variable

λ is the factor loading

Γ is the structural coefficient

ϵ is the measurement error

ζ is the structural error.

The following figure shows our data which we have used for SEM:

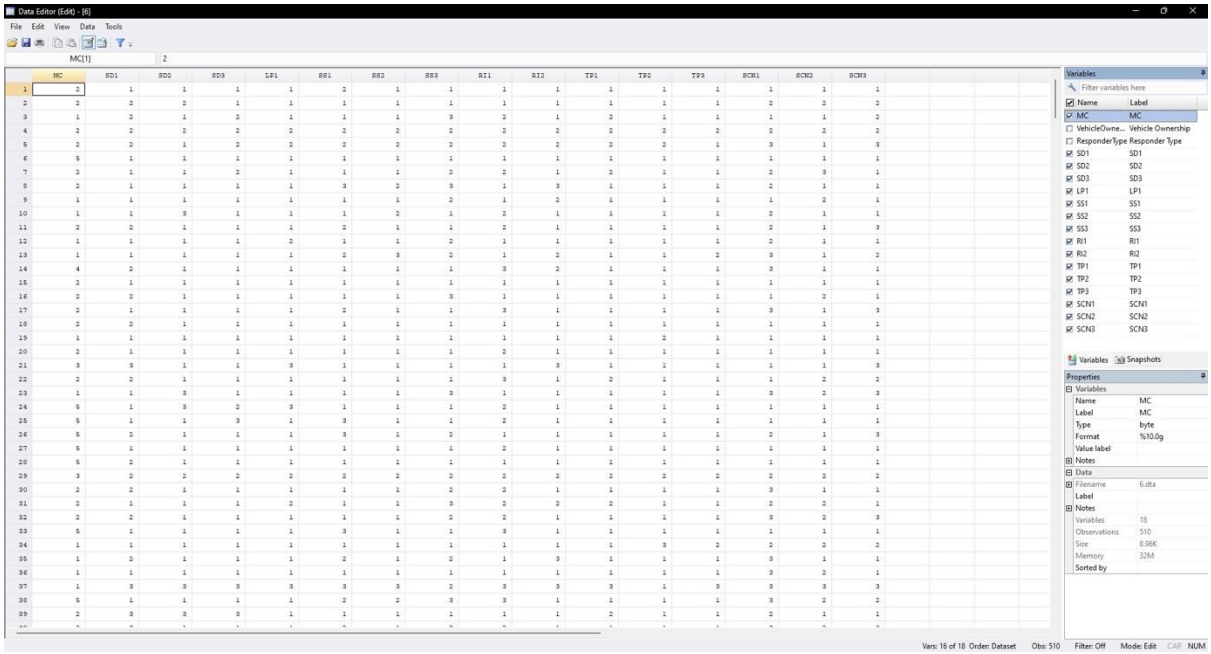

Figure 8: Sampled Data for SEM

3.3.3. 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). 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. The figure shows the workspace of the GeNIe software that was used for our research work:

Figure 9: GeNIe Workspace

3.3.4. STATA Workspace

Stata is a comprehensive statistical software that provides a broad range of tools for data analysis, visualization, and modeling. It is particularly useful for structural equation modeling (SEM) and has a dedicated package for item response theory (IRT). The software offers both command-line and graphical user interfaces, making it accessible to users with varying levels of programming expertise. Stata provides advanced data management capabilities, including data visualization and automated reporting, as well as a wide range of statistical methods. It also offers advanced graphical visualization tools and can automate many tasks, allowing users to focus on higher-level tasks. Additionally, Stata is cross-platform compatible and can run on cloud virtual machines, making it a versatile tool for various research fields. The STATA workspace upon opening it are in the following figure:

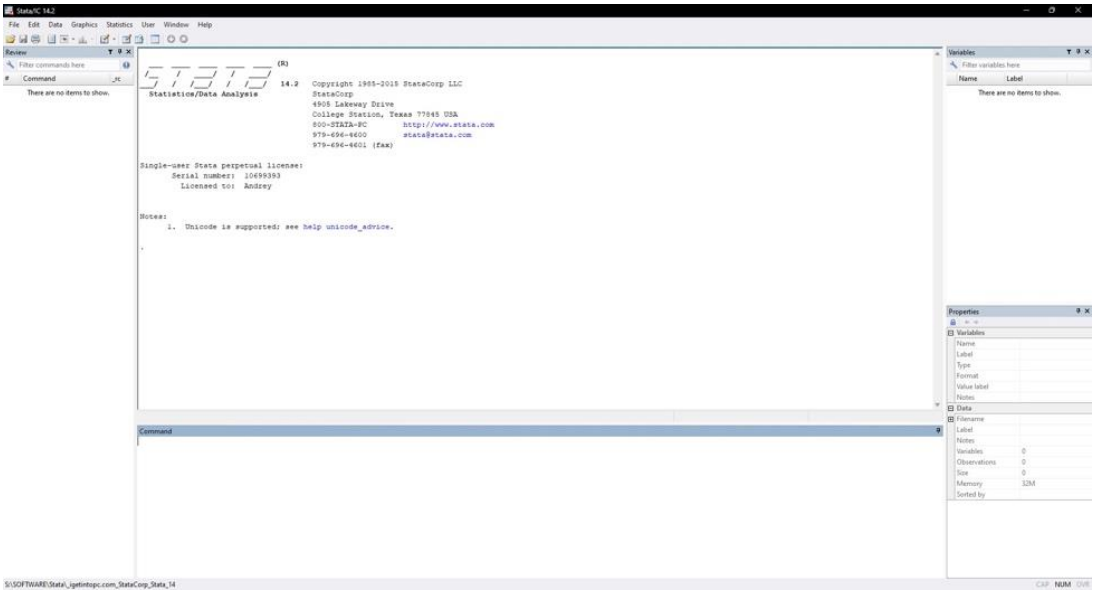

Figure 10: STATA Workspace

CHAPTER FOUR ANALYSIS, MODEL DEVELOPMENT AND RESULTS

4.1. Introduction

The main conclusions of the study, as well as the sections on model building and data analysis, are compiled in this chapter. Initially, the survey data was reviewed, categorized, and structured. Subsequently, the data was cleaned up and incorporated into a Bayesian Belief Network and Structural Equation Modelling. For BBN, to ascertain the impact of each variable on the target variable, the network's nodes underwent testing and modification. The model was subjected to a number of analyses, including tornado diagrams and sensitivity analysis. Using the GeNIe program's built-in model validation tool, the accuracy of the model was further examined. Following the completion of the analytical process, all research findings were compiled and made available in this chapter. Similarly, STATA has been used for SEM. A path diagram has been drawn and the impact of latent variables on user's mode choice has been identified.

4.2. Descriptive Statistics of the Survey

In the chosen cities, data were collected at random from the designed questionnaire. The purpose of the questionnaire was to gather data on user mode preferences in active transport and how these choices vary from different perspectives. Data processing was done before it was entered into the model. Selected variables were taken from the whole questionnaire and grouped. In all, 510 data points were gathered from areas that would be representative of Dhaka City. The survey's respondents were nearly 45% female and about 55% male.

Table 1: Descriptive Statistics of the Survey

SL	Variables	Item	Frequency	Percentage (%)
1	Gender	Male	282	55
		Female	228	45
2	Age Group	<18	6	1.2
		18-25	259	51
		25-35	127	25
		35-50	28	6
		>50	90	16.8
3	Highest Education Level Completed	Primary/Ibtedayi	31	6.5
		Higher Secondary (Includes 2 years of 4 year)	151	30
		Diploma in Engineering & Nursing, HSC Vocational)/ Alim	3	0.6
		Diploma/Vocational (Not a Bachelors, similar to Associates)	31	6

		Graduate/Fazil	220	43
		Postgraduate/Kamil	72	14
4	Marital Status	Unmarried	279	55
		Married	153	30
		Single	68	13
		Divorce	10	2
5	Average Monthly Income Level (in BDT)	<25k	276	54
		25-35k	61	12
		35-45k	32	6.4
		45-55k	31	6
		55-65k	51	10
		65-100k	8	1.6
		100k+	51	10
6	Responder Type	Captive	104	20
		Non-captive	406	80
7	Vehicle Ownership	No	178	35
		Family automobile ownership	226	45
		Personal automobile ownership	91	18
		Personal bicycle ownership	8	1.6
		Office automobile ownership	4	0.8
8	Most Preferred Mode of Travel for Short Trips	Active Transport	235	46
		Non-motorized Vehicle	157	31
		Private Automobile	83	16
		Public Transport	20	4
		Ride Sharing & Sourcing	15	3
9	Location	Gazipur	71	14
		Uttara	54	11
		Mirpur	43	8.4
		Bashundhara	41	8
		Moghbazar	26	5
		Banani	23	4.5
		Mohammadpur	21	4.1
		Agargaon	21	4.1
		Dhanmondi	17	3.3
		Monipuripara	17	3.3
		Banasree	15	3
		Azimpur	14	2.75
		Khilkhet	13	2.7
		Kuril	13	2.7
		Tikatuli	13	2.7
		Gulshan	12	2.4
		Mohakhali DOHS	10	2

		Others	78	16

4.3. Bayesian Belief Network

4.3.1. Bayesian Network Preparation

GeNIe provided the original Bayesian network, which was produced by structural learning using the PC algorithm. Literature review, and expert knowledge were used to modify the network to fit the purpose. After the data filtering procedure, the data was inputted into GeNIe. The portion of the dataset that was imported in order to form the network is depicted in Figure 10.

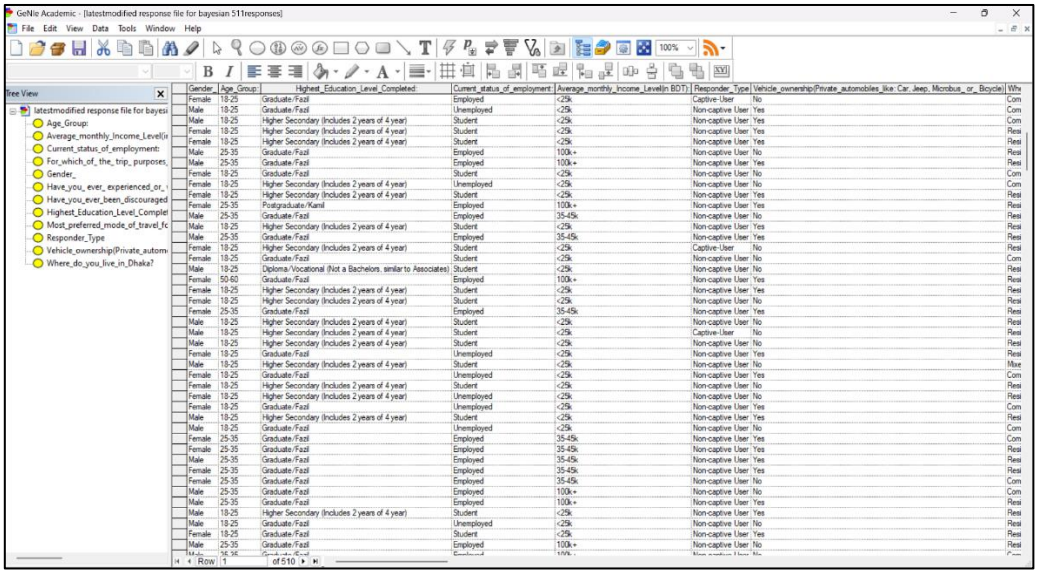

Figure 11:: Parts of Dataset Imported for Building the Network

In this study, automatic learning is used to educate the network. At a significance level of 0.05, structural learning from an entire data set is accomplished using the PC algorithm. The learning method's screen is depicted in Figure 11, while Figure 12 illustrates how the network was modified in light of the literature review, engineering judgment, and how the relationship exists among the variables.

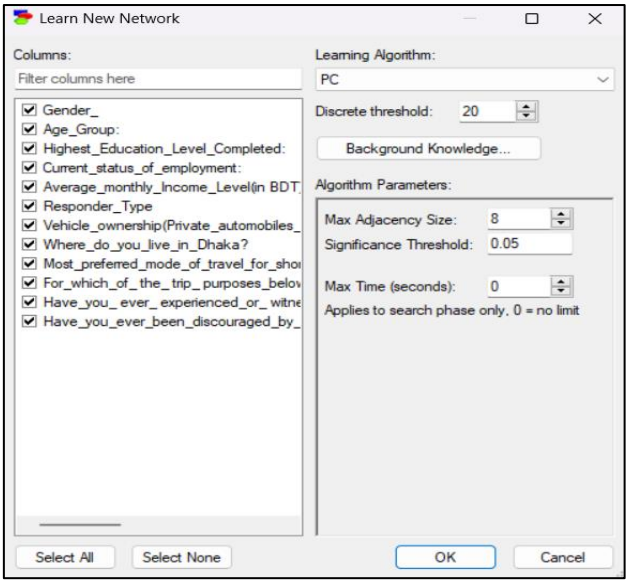

Figure 12: Screen of the Parameter Notebook

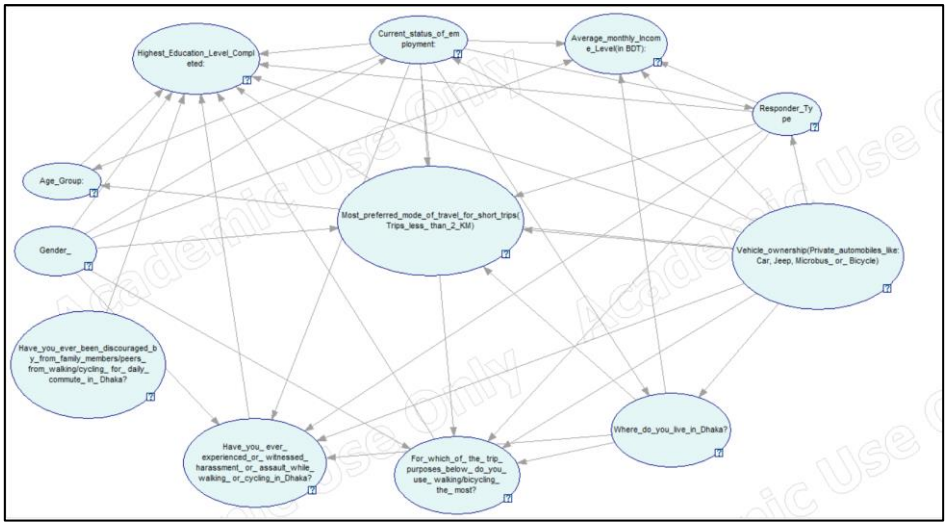

Figure 13: Bayesian Network Depiction

Parameter learning is the first step in the GeNIe software analysis process. The Expectation-Maximization (EM) parameter learning strategy is the default one in GeNIe. Therefore, to obtain marginal probabilities for each node, the integrated EM approach is utilized. The marginal probability of the network structure is shown in Figure 13.

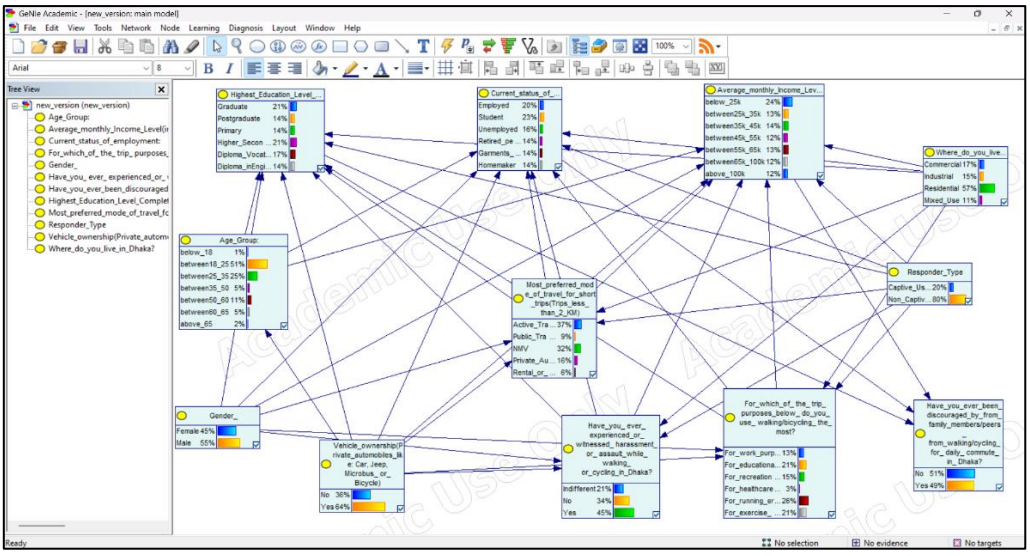

Figure 14: Prior Marginal Probability Distribution Diagram

The model was developed with the intent of identifying the factors that influence active mode choosing patterns. In the model, the preferred mode for short trips was divided into six groups. The several categories are covered in the paragraphs that follow.

Active Transport: This refers to using one's own body power to get around, making everyday trips by walking, and cycling. This decision is mostly based on short travel purpose.

Public Transport: Public transportation includes services like buses and trains. Most vehicles in this category are those that carry a large number of people. In a different way it can be stated that, mass transit was included in the category of public transportation.

NMV: There were numerous Non-Motorized Vehicle modes included in this category. This group included vans, rickshaws, and bicycles. The majority of the vehicles in this category can be operated without the aid of a machine.

Private Automobile: Private transportation, such as cars and motorcycles were included in the private automobile's sections.

Rental and Ride-sharing Transport: This category included rented and ride-sharing vehicles. This category included, in particular, non-personal vehicle services e.g.: Uber, Pathao, Obhai etc.

4.3.2. Model Validation

Every model must have model validation, often known as validation of the results. GeNIe's default validation tool was used in this work to assess the models' validity. In the study, two validation methods were applied. Initially, a standard validation procedure was employed, in which no data were chosen for training and all data were regarded as test data. The term "Test Only Validation" refers to this evaluation, meaning that the model is only tested using the data file. When the model was trained using a different data set or constructed using expert knowledge, this is helpful. The screen with validation tabs is shown in Figure 14.

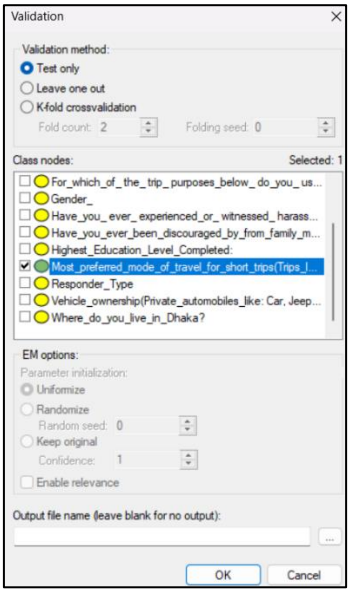

Figure 15: Validation Tab's Screen

An illustration of the evaluation's findings is a Receiver Operating Characteristic (ROC) curve. The diagonal line indicates a perfect 50% likelihood of correct model prediction, while the area indicates a 50% chance of accurate model prediction. The ROC curve is a plot of sensitivity vs. false positive rate. According to (Hoo, Candlish, & Teare, 2017), the Area Under the ROC Curve (AUC) is a numerical value that ranges from 0 to 1, where a value nearer 1 denotes superior model performance. The basic rule listed in table 2 is taken into consideration for the ROC curve value, as per the book Applied Logistic Regression (Scott, 1991).

Table 2: 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 behavior prediction, including all the elements that can influence (Rice & Harris, 2005). Using the test method, all the AUC value is found greater than 0.9 which represents Outstanding Impact. The ROC curve for preferred mode of active transport is attached in figure 15.

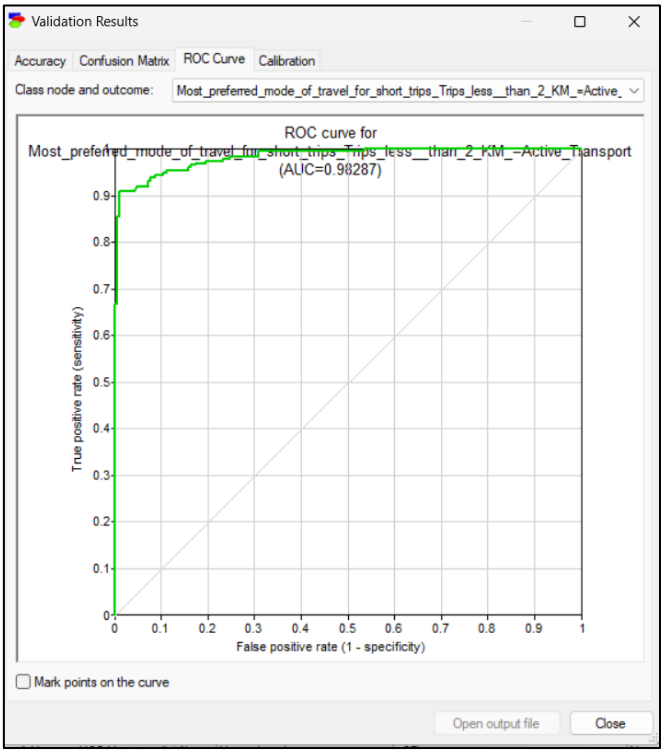

Figure 16: ROC Curve for the Model (Preferred Mode= Active Transport, Validation Method=Test)

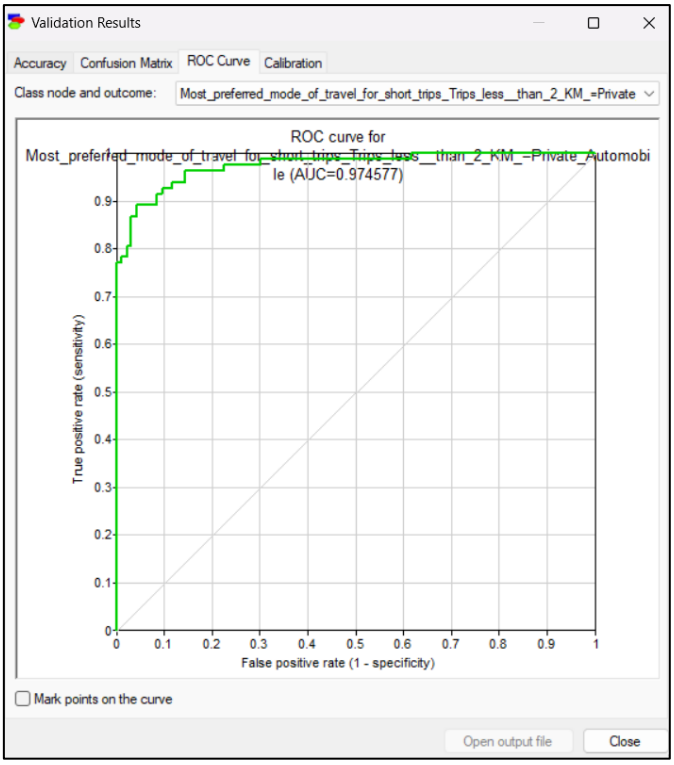

Figure 17: ROC curve for the model (preferred mode= private automobile, method=LOO)

At second, the Leave One Out (LOO) method—which is thought to be the most effective method—was used to carry out the validation operation. This approach is favored since the analysis's model is trained and evaluated using the same set of data. K fold cross-validation, in where K is equal to the number of records (n) in the data set, as exemplified by the LOO approach. Prior to testing on the final record, the network in LOO is trained on n-1 records. The process is repeated n times. The primary drawback is that if the data set is vast, it may take longer even if it is the most advised way. All other values are within acceptable bounds. Figure 17 depicts the ROC curve for Private Automobiles.

4.3.3. Model Output and Explanation

Outcomes for the preferred mode of travel (short trip):

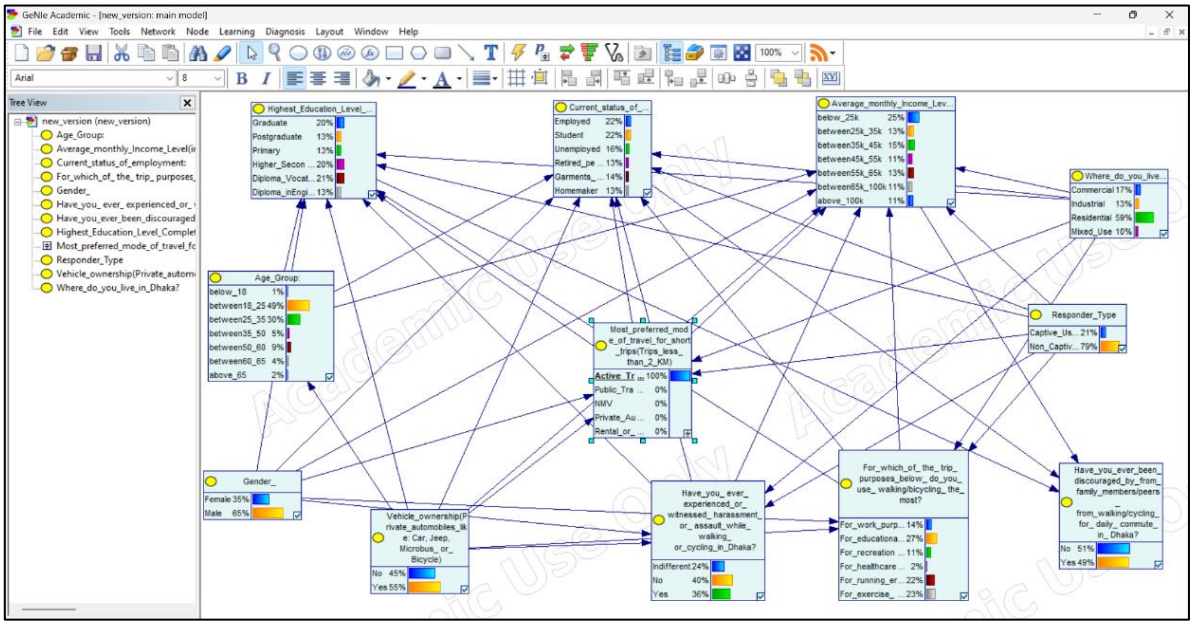

Figure 18: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is Active Transport.

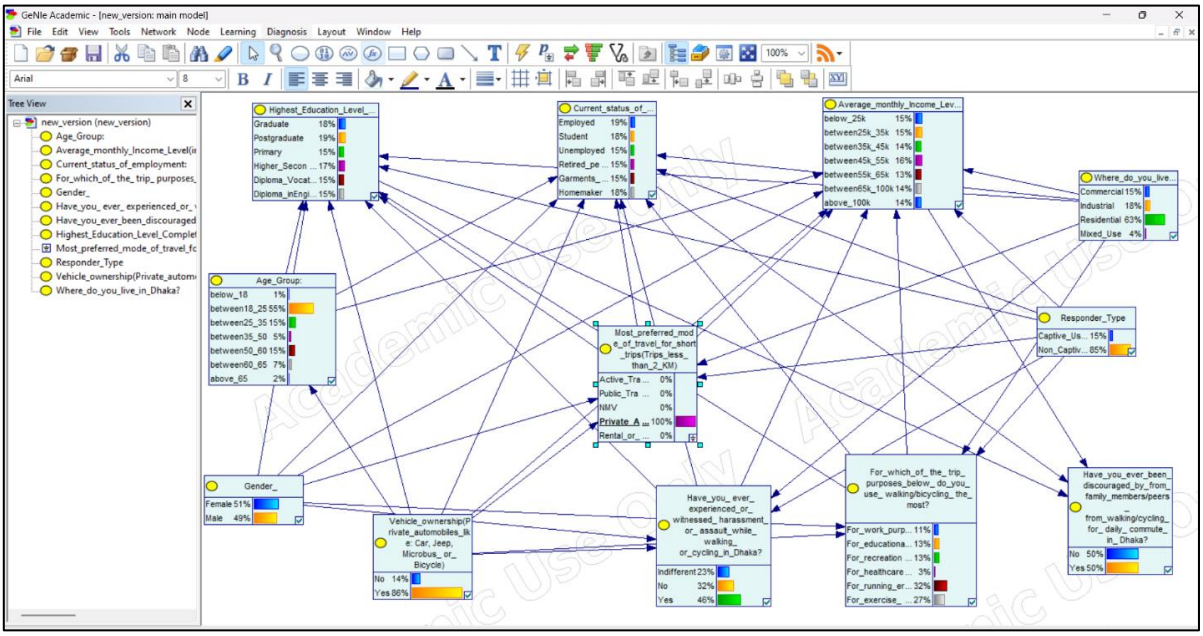

Figure 19: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is Private Automobile.

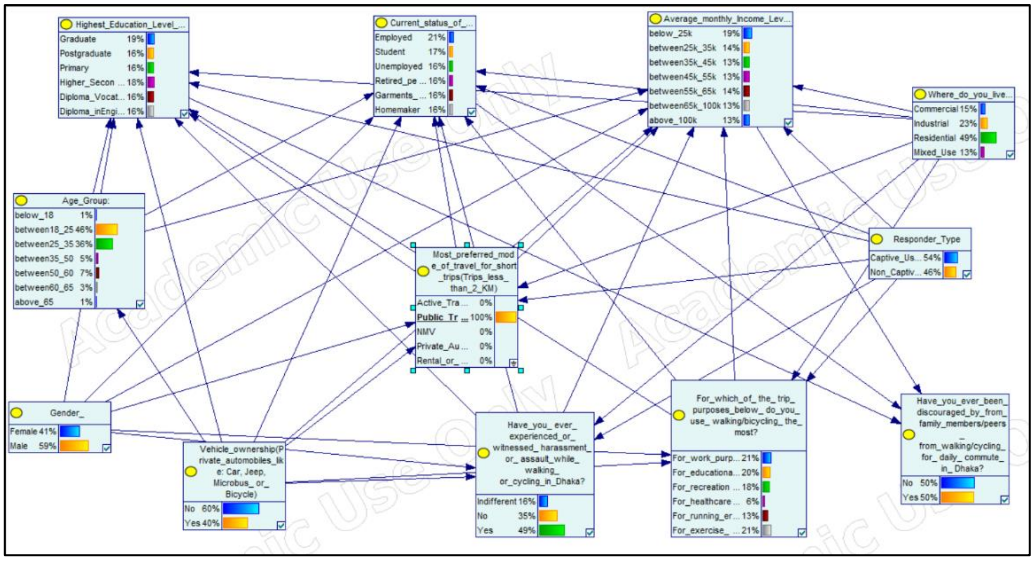

Figure 20: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is Public Transport.

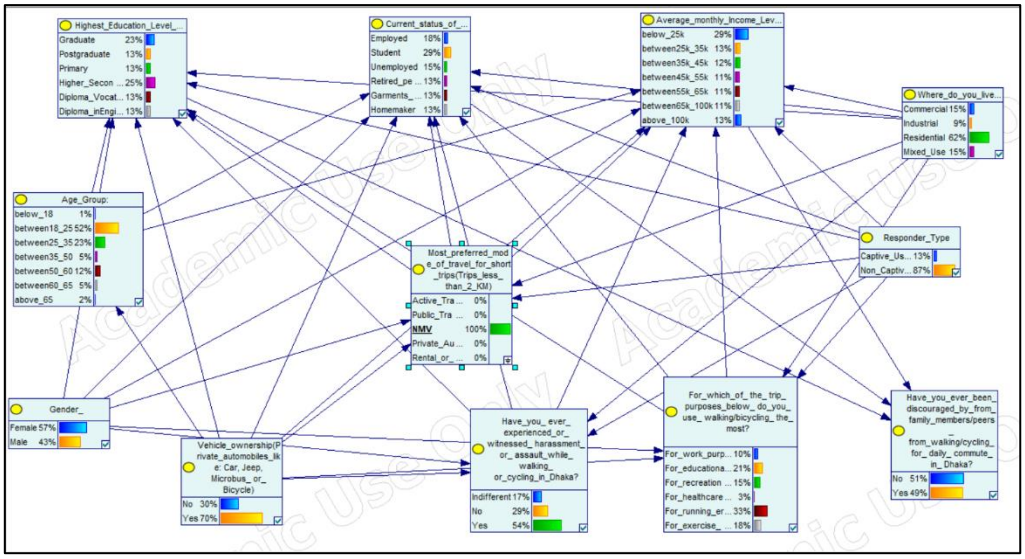

Figure 21: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is NMV.

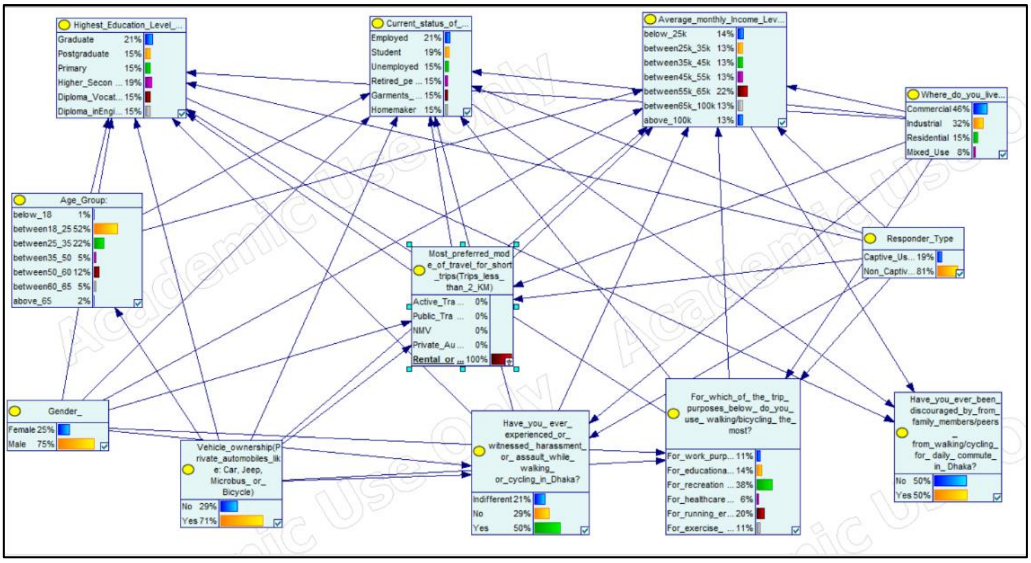

Figure 22: Posterior marginal probability distribution diagram when the preferred mode of travel in short trip is Rental or Ride-sharing.

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 3.

Table 3: All Nodes Marginal Probabilities for all the States of Target Variable 'Preferred mode of transport in short trip'

SL NO	Variables	Item	Evidence (%)				
			Active Transport	Public Transport	Private Automobile	NMV	Rental or Ride-Sharing Transport
1.	Gender	Male	65	59	49	43	75
		Female	35	41	51	57	25
2.	Age Group	<18	12	3	7	3	2
		18-25	49	46	55	52	52
		25-35	22	35	15	25	24
		35-50	5	5	5	5	5
		50-60	9	7	10	13	12
		60-65	4	3	7	5	6
		>65	2	1	2	3	2
3.	Highest Education Level	Graduate	20	19	18	23	21
		Postgraduate	13	16	19	13	15
		Primary	13	16	15	13	15
		Higher Secondary	20	18	17	25	19
		Diploma in Vocational	21	16	15	13	15
		Diploma in Engineering	13	16	15	13	15

4.	Current Status of Employment	Employed	22	21	19	18	21
		Student	22	17	18	29	19
		Unemployed	16	16	15	15	15
		Retired personnel	13	16	15	13	14
		Garments Worker	14	16	15	13	15
		Homemaker	13	16	18	13	13
5.	Average Monthly Income (BDT)	<25k	25	19	15	29	14
		25k-35k	13	14	15	13	13
		35k-45k	15	13	14	12	12
		45k-55k	11	13	16	11	13
		55k-65k	13	14	13	11	22
		65k-100k	11	13	14	11	11
		>100k	11	13	14	13	16
6.	Landuse Pattern	Commercial	17	15	15	15	46
		Industrial	13	23	18	9	32
		Residential	59	49	63	62	15
		Mixed-Use	10	13	4	15	8
7.	Responder Type	Captive User	21	54	15	13	19
		Non-Captive User	79	46	85	87	81
8.	Have you ever been discouraged from walking/cycling for daily commute in Dhaka?	Yes	51	50	50	49	50
		No	49	50	50	51	50
9	Have you ever experienced/witnessed harassment or assault while walking/cycling in Dhaka?	Indifferent	24	16	23	17	21
		No	40	35	32	29	29
		Yes	36	49	46	54	50
10	For which of the trip purposes below do you use	Work-related	14	21	11	10	11
		Educational related	27	20	13	21	14

	walking/cycling the most?	Recreational	11	18	13	15	38
		Healthcare related	2	6	3	3	6
		Running Errands	22	13	32	33	20
		Exercise or fitness related	23	21	27	18	11
11	Vehicle Ownership (car,jeep, microbus or bicycle)	No	45	60	14	30	29
		Yes	55	40	86	70	71

Sensitivity Analysis for Preferred Mode for Short Trips:

A sensitivity analysis was conducted to better understand crucial factors in the existing network. GeNIe depicts the implications of tweaking the target variable in a sensitivity analysis. The variables in dark red exhibit the most influence on the target variable. The impact steadily declines as the red color intensity decreases. White variables have a minor impact on the target variable, while grey variables have no effect. Figure 22 shows the sensitivity analysis results.

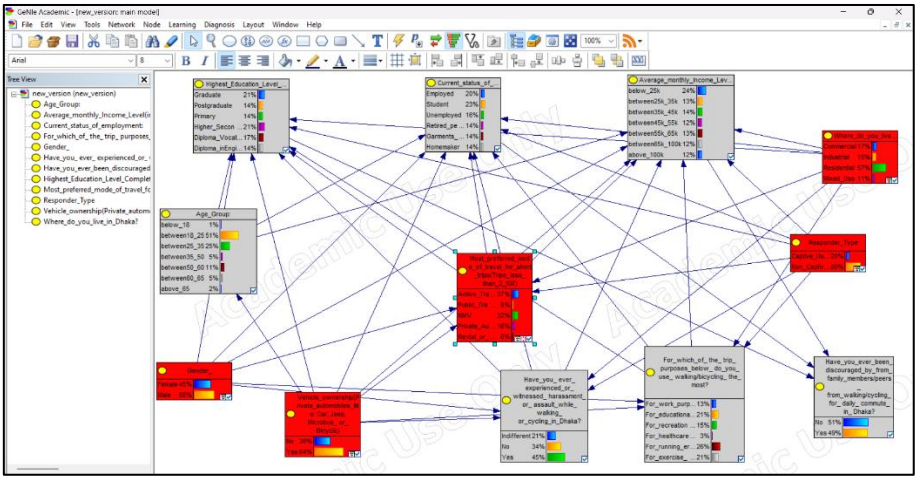

Figure 23: Significant variables after sensitivity analysis for preferred mode (short trips)

Sensitivity analysis was used to determine the most crucial factors that affect the target variable "Preferred Mode Choice for short trips". The variables found in the sensitivity analysis are 'location', 'gender', 'responder type' and 'vehicle ownership'. Active transportation uptake might vary considerably between places depending on the land use pattern. Residential regions may have better walking and cycling infrastructure, such as sidewalks, bike lanes, and shorter distances between destinations, which can encourage these forms of transportation. In contrast, suburban or rural locations may lack such facilities, making active transportation less viable. People's travel decisions are frequently impacted by their daily activities. Students, for example, may be more inclined to walk or cycle to and from school than workers traveling from a distant section of the city. Individuals who own vehicles may be less likely to use active transport modes due to the convenience and status associated with vehicle ownership. Lack of automobile ownership is frequently associated with lower income levels; therefore, many residents rely on active transportation as their major way of mobility. Women may have different safety concerns than men, which influences their chances of participating in active

transportation. Women are particularly affected by issues like street harassment and a lack of safe infrastructure.

Following the sensitivity analysis, a tornado diagram was constructed. It shows the most sensitive features for a given target node state, listed from most to least sensitive. The graphic illustrates the exact placement of each parameter in the model. The bar displays the desired state range as the parameter changes. The bar color reflects the direction of change in the target state, with red indicating negative change and green indicating positive change. In sensitivity analysis, a tornado diagram displays the most significant state of a variable for a specific target variable. Figures 23–27 show the tornado diagram for the model.

Figure 24: Tornado diagram in sensitivity analysis when the preferred mode is Active Transport for short trip

Figure 25: Tornado diagram in sensitivity analysis when the preferred mode is Public Transport for short trip

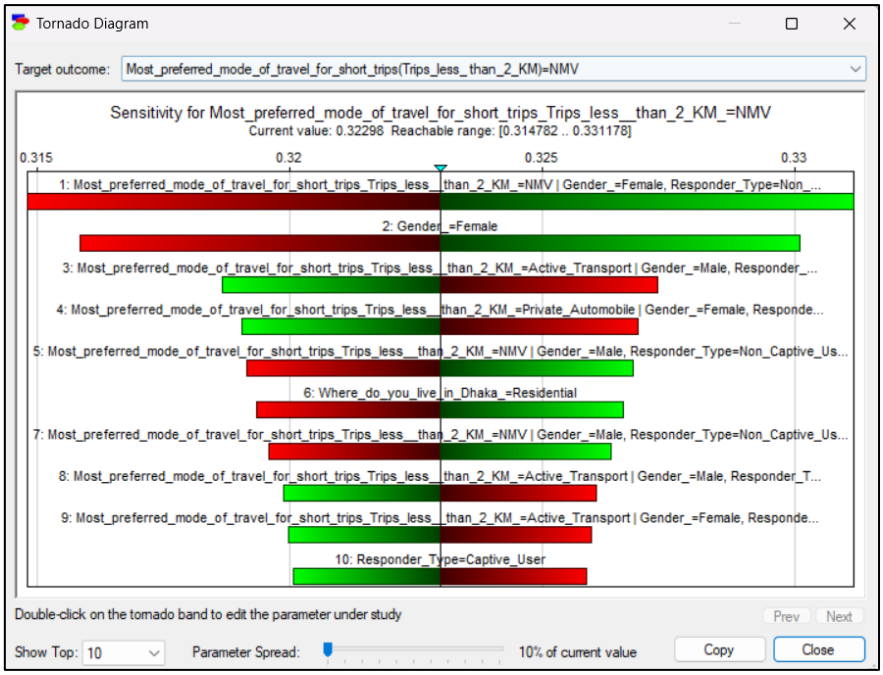

Figure 26: Tornado diagram in sensitivity analysis when the preferred mode is NMVs for short trip

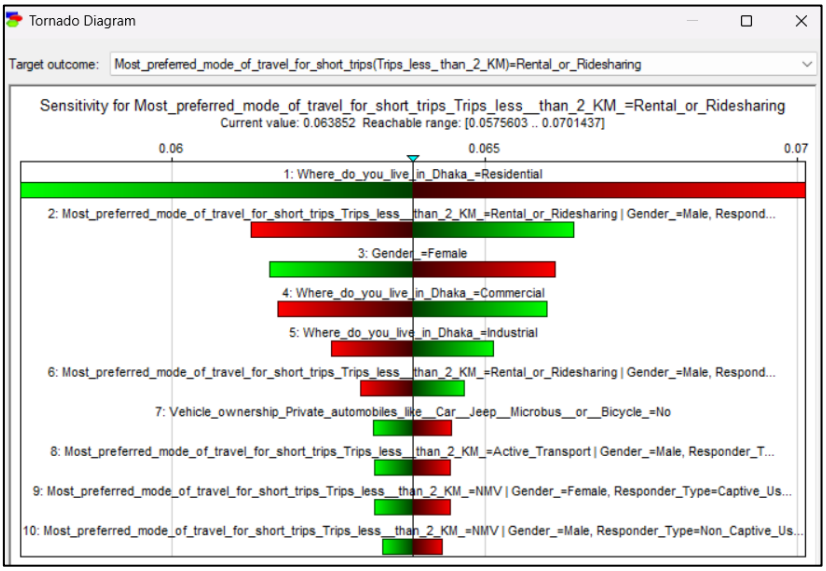

Figure 27: Tornado diagram in sensitivity analysis when the preferred mode is Rental or Ridesharing for short trip

The tornado diagram indicates gender is the most affected characteristics in case of active transport while vehicle ownership affects choice of public transportation. Location plays a crucial role in determining the mode choice for a responder.

Figure 28: Tornado diagram in sensitivity analysis when the preferred mode is Private Automobile for short trip

Outcomes for the Models:

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

As previously said, multiple questions were tackled one by one. The chance of various modes was computed based on gender, location, and vehicle ownership. Attached are the figures from the analysis, numbered 28-33.

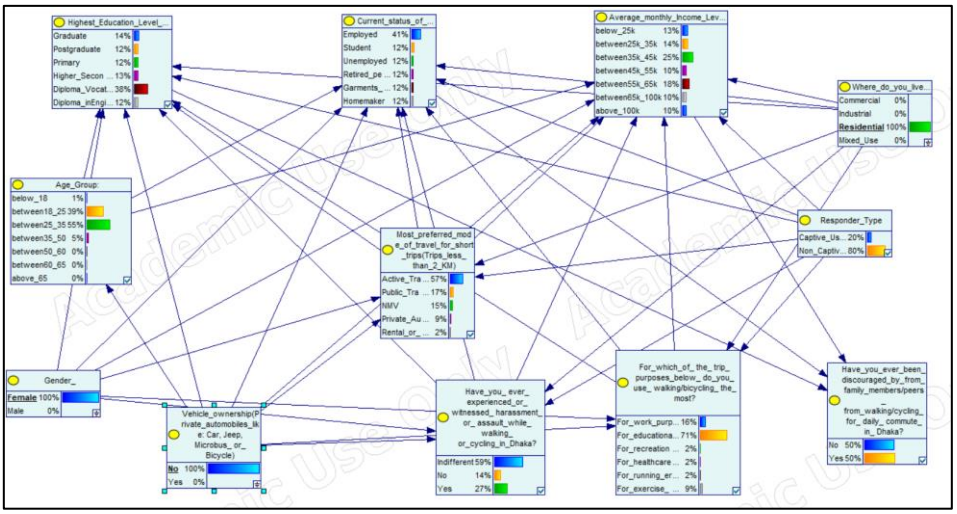

Figure 29: Posterior marginal probability distribution diagram when the female in residential location has no personal vehicle accessibility.

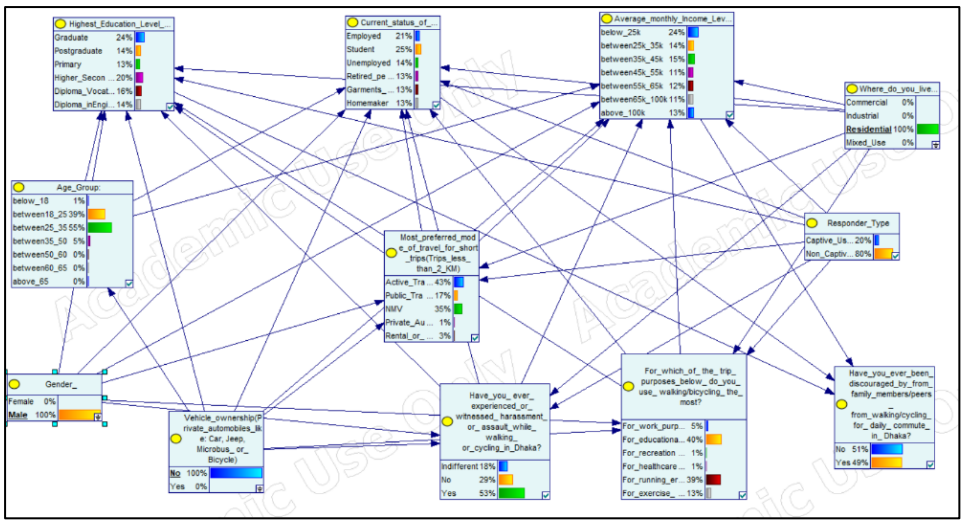

Figure 30: Posterior marginal probability distribution diagram when the male in residential location has no personal vehicle accessibility.

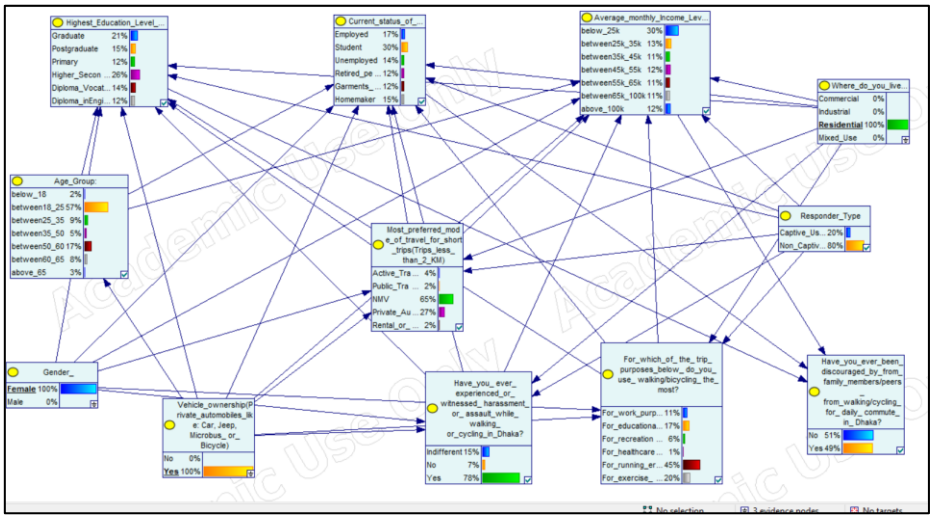

Figure 31: Posterior marginal probability distribution diagram when the female in residential location has personal vehicle accessibility.

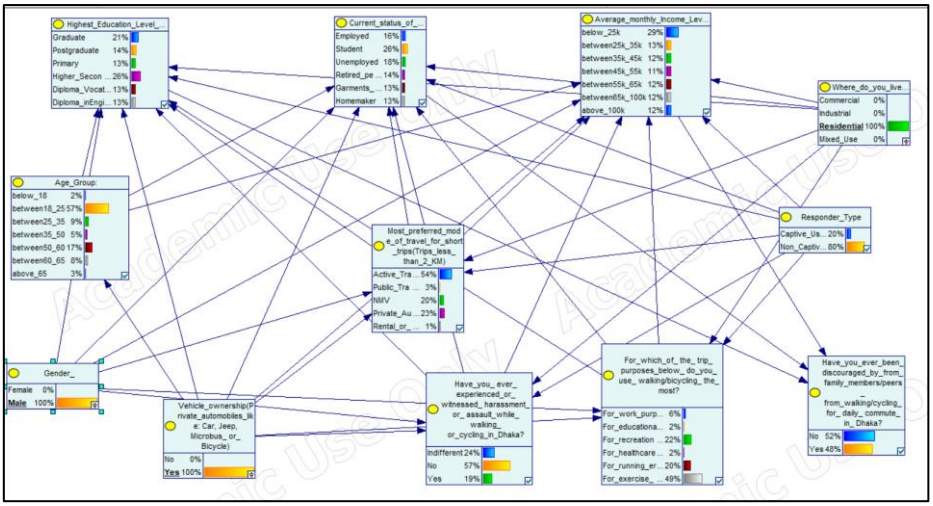

Figure 32: Posterior marginal probability distribution diagram when the male in residential location has personal vehicle accessibility.

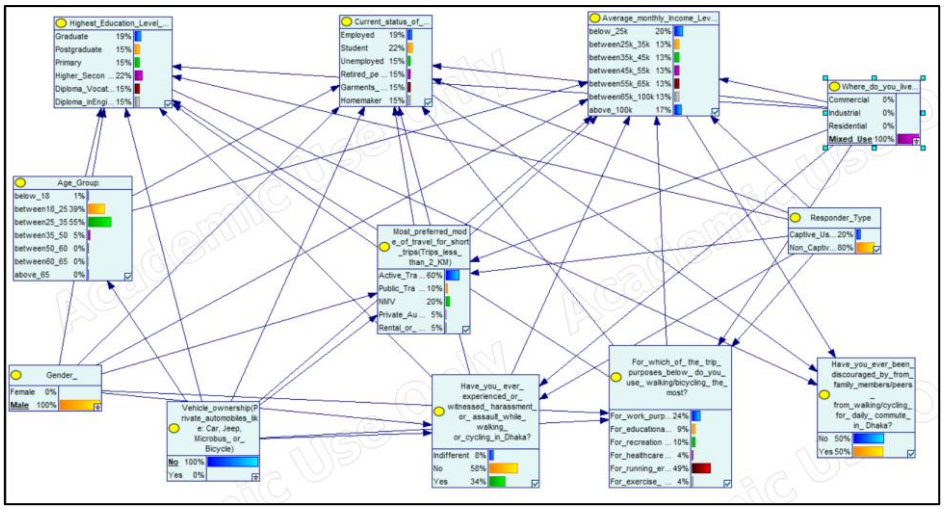

Figure 33: Posterior marginal probability distribution diagram when the male in mixed-use location has personal no vehicle accessibility.

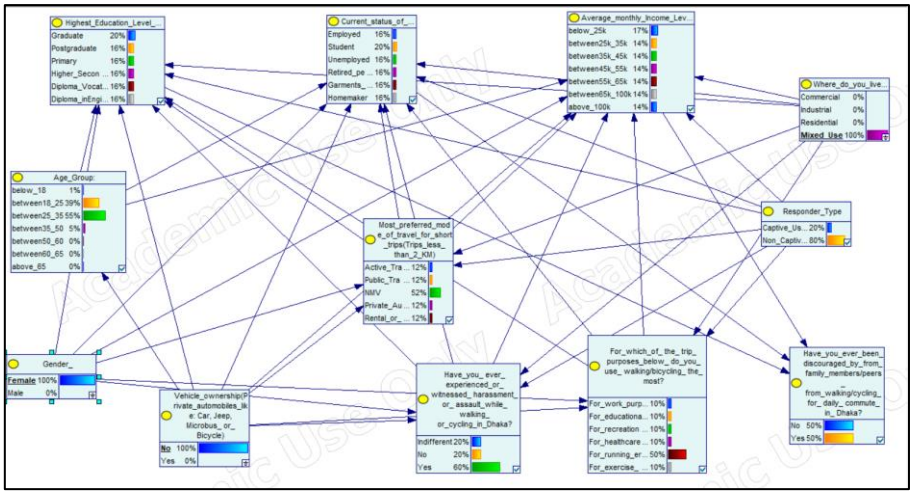

Figure 34: Posterior marginal probability distribution diagram when the female in mixed-use location has personal no vehicle accessibility.

According to findings, women in residential areas with no personal automobile ownership are likely to take active transport (either walking or cycling) as their preferred mode for short trips

mostly for work or educational purposes. Such scenario represents that they are less likely to experience or witness harassment. On the contrary, males in same scenario are likely to active transport as well as NMVs for their trip purposes. The decision to not own a personal automobile varies by gender and location. Another significant finding is that, most women are likely to use their personal vehicles for running errands in case of short trips. This rather indicates gender norms and cultural expectations may limit women's mobility and transportation options even if their key destinations are within close proximity. Even after owning personal vehicles, women have experienced or witnessed staggeringly high number of harassments compared to males in residential areas which further necessitates the lack of safe infrastructure. In other scenario, mixed-use land patterns show a higher number of dependencies on active transport mode choice for males without personal vehicle ownership. Mixed-use land pattern incorporates residential, commercial and recreational spaces keeping them in close proximity thus making active transport more likely to be feasible and increase the likelihood of one-stop destinations. Bayesian analysis is a dynamic strategy that can address several problems with a single model. However, the prepared model may be useful for further exploration.

4.4. Structural Equation Modelling

4.4.1. Variable Definition

We used Structural Equation Modeling (SEM) to analyze how latent variables (Socio-economic and Demographic Characteristics, Safety and Security, Trip Purpose, Social and Cultural Norms) impact Mode Choice.

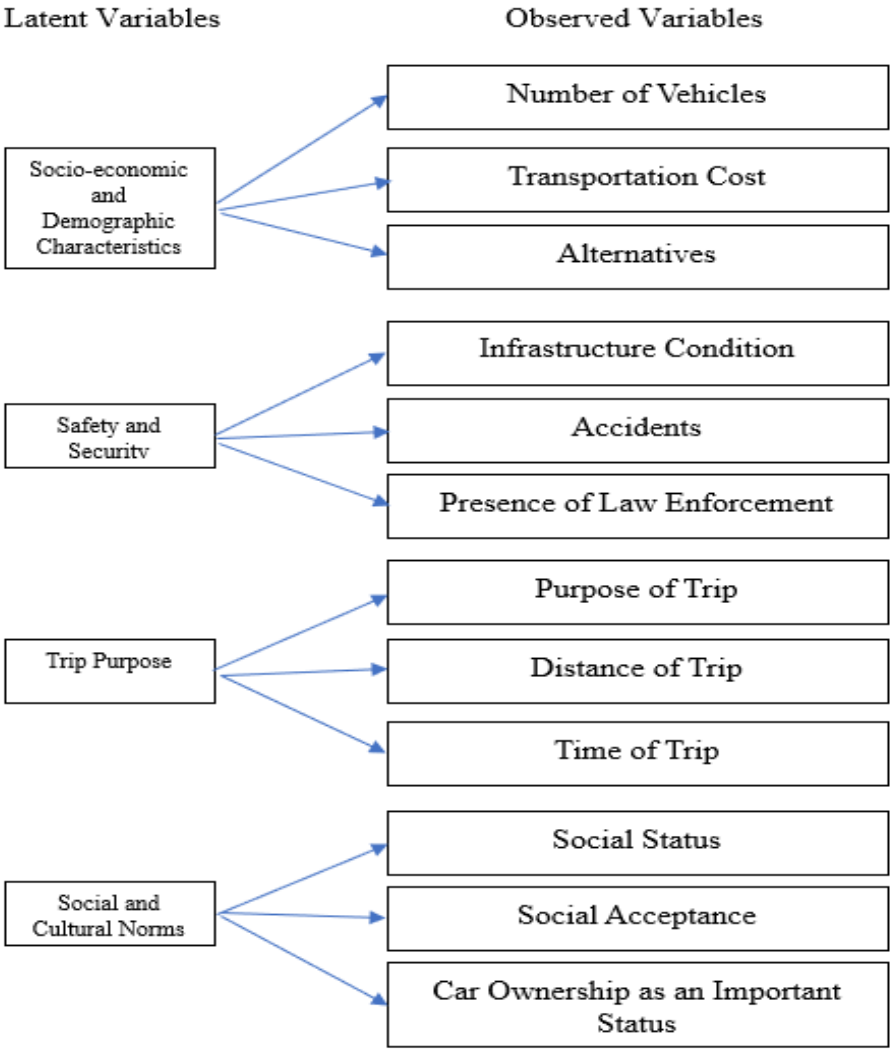

Figure 35: Variables in Model

Table 4: Variable Definition in Model

Variables	Definition	Variables	Definition
MC	Mode Choice	TP	Trip Purpose
SD	Socio-economic and Demographic	TP1	Purpose of Trip
SD1	Number of Vehicles	TP2	Distance of Trip
SD2	Transportation Cost	TP3	Time of Trip
SD3	Alternatives	SCN	Social and Cultural Norm

SS	Safety and Security	SCN1	Social Status
SS1	Infrastructure Condition	SCN2	Social Acceptance
SS2	Accidents	SCN3	Car Ownership as an Important Status
SS3	Presence of Law Enforcement		

4.4.2. Path Diagram

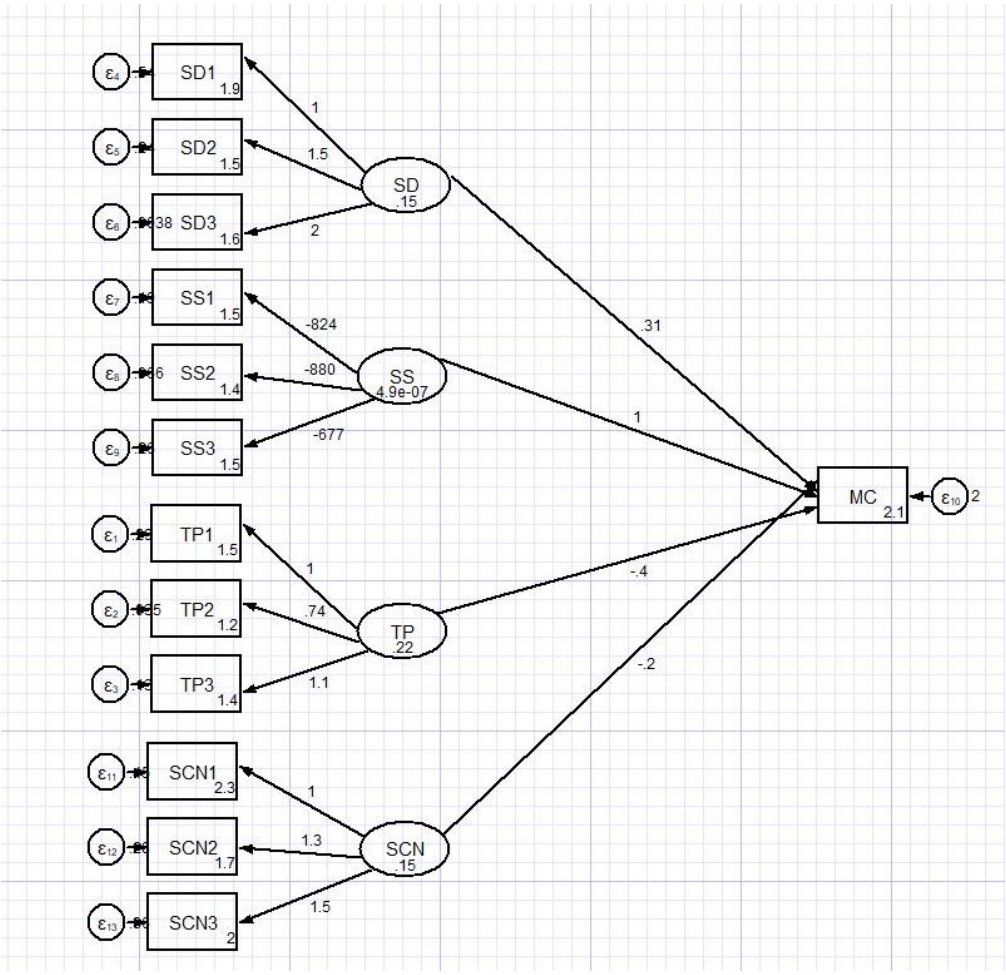

Figure 36: Path Diagram in Stata

The path diagram demonstrates how different socio-economic and demographic characteristics, safety and security factors, trip purposes, and social and cultural norms influence the mode of transportation choice. Each latent variable is measured by specific indicators, and the relationships among these variables and the outcome variable (Mode Choice) are analyzed using SEM.

4.4.3. Model Output and Result Analysis

Table 5: Model Output

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
SD	.3052057	.2239766	1.36	0.173	-.1337805	.7441918
SS	1 (constrained)					

TP	-.3956159	.1853623	-2.13	0.033	-.7589193	-.0323125
SCN	-.1951903	.2333542	-0.84	0.403	-.6525562	.2621756

Result Analysis:

1. Socio-economic and Demographic Characteristics: Coefficient is 0.3052057, but it's not statistically significant since the p-value is 0.173 (greater than 0.05).

2. Safety and Security: Coefficient is set to 1 (constrained for identification purposes). This is a model constraint and doesn't directly tell you the statistical impact.

3. Trip Purpose: Coefficient is -0.3956159 and it's statistically significant with a p-value of 0.033 (less than 0.05). This suggests that as the importance of Trip Purpose increases, the preference for a specific Mode Choice decrease.

4. Social and Cultural Norms: Coefficient is -0.1951903, but it is not statistically significant as the p-value is 0.403 (greater than 0.05).

Conclusion:

Significant Impact: Only Trip Purpose (TP) has a statistically significant impact on Mode Choice (MC), with a negative relationship. This means as the relevance or importance of trip purpose increases, the likelihood of choosing a particular mode decrease.

Non – Significant Impact: Socio-Demographic (SD) and Social Norm (SCN) do not have a statistically significant impact on Mode Choice in this model.

Constrained: Coefficient from Safety & Security to Mode Choice is set to 1 by the model, meaning it does not reflect the actual impact of SS on MC in the same way other coefficients do. Instead, it serves as a reference point to help estimate other relationships in the model.

CHAPTER FIVE CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter covers the study's main findings, its various limitations, its potential future scope, and how policymakers, transportation planners, and other stakeholders can consider the study's various outputs when developing and implementing policies that will improve the transportation system and lessen gender-based disparities especially when it comes to active transportation.

5.2 Major Findings

The important goal of this research was to see how different factors influence men's and women's mode choosing tendencies for short trips. To ascertain the conclusion of this objective, the model was given a series of questions. Variables including gender, location, demographic and socio-economic characteristics, vehicle ownership, trip purpose, safety and security, infrastructure accessibility and socio-cultural norms were assigned questions that would best represent preferred mode choice which were then thoroughly examined.

Based on the model (BBN) developed, the key variables include: location, gender, responder type, car ownership that affect the choice of preferred mode selection in case of short trips. The mode selection process is also impacted by harassment faced on daily commute and gender disparity. The most significant consideration to take into account while selecting a mode is security and safety. Active transport was selected as the preferred mode where males had outnumbered females. Younger people are more likely to walk or cycle compared to older people. The study also supported that people having no access to personal vehicles depended on active transport and NMVs for their short trips. The thorough investigation pointed out that majority of responders expressed lack of adequate safe infrastructure built around their areas. The findings showed substantial disparity in case of harassment faced by women as compared to men. Mixed-use land pattern has been proven to be highly effective in increasing active transport mode choices as supported by our findings. A slightly different take on socio-cultural related variables indicated that gender roles and cultural expectations might limit women’s mobility and their choice of transport modes. The study further revealed a nearly fifty-fifty situation between both genders being discouraged from family and peers to take up active transport as a means of daily commute. One of the main reasons included vehicle ownership being markers of high social status. Not stated explicitly in the study but it can be inferred from the responses based on model that the people of Dhaka City are yet to realize the full impact of active transport in environmental benefits (lower emissions being one of many).

Again, in case of the Structural Equation Modelling, we had our questionnaires arranged in a Likert scale which would cover the variables- Socio-economic and Demographic Characteristics, Land-use Pattern and Network Characteristics, Safety and Security, Road Infrastructure and Accessibility, Trip Purpose and Social and Cultural Norms. Through the model, it was found out that although Socio-economic and Demographic Characteristics along with Social and Cultural Norms may have impact on choices of Mode, they are not statistically significant. On the other hand, in case of Trip Purpose, it was found to be statistically significant and the model suggests that as the importance of Trip Purpose increases, the preference for a specific choice of Mode increases or decreases.

5.3 Policy Implications

The study focuses on Active Travel in Dhaka, a developing megacity. The primary focus of the study is to identify the causes that prevent people from considering Active Travel as an option from their choices of modes for travelling, mitigate the causes and the differences based on gender that impact the uptake of Active Travel.

From a previously done study, it can be seen that when the neighborhoods are designed with higher mixed land usage rather than complete residential land or other usage, an increase in the uptake of Active Transport is seen (Cervero & Kockelman, 1997).

Another study has shown that addressing the gender-based violence and harassment in policy implication along with promoting the benefits of Active Transport such as- improved health and environmental outcomes may lead to higher uptake of Active Transport (Pucher, Dill, & Handy, 2010).

According to a different study, the best way to maximize mode choice and encourage more su stainable and active transportation options is to build transportation systems that can accomm odate various trip reasons, such as work-related, fitness, or educational travels (Handy, Weston, & Mokhtarian, 2005).

Another study claims that in order to create a safer and more inclusive environment for all users, it is essential to invest in pedestrian friendly and cyclist friendly infrastructure such as- sidewalks, bike lanes and traffic calming measures (Jacobsen, 2003).

5.4 Limitations and Future Scope

The study has been done to identify the gender differences in the uptake of Active Travel and to identify the different reasons which are preventing people from considering Active Travel to be an option for travelling despite its benefits of health and sustainability. The study is unique in its nature since the study regarding gender differences in the uptake of Active Travel has not been done in developing megacities and there is a gap in research. The study might be regarded as significant from many angles. Nonetheless, there are a few issues with the study that need to be addressed.

Although the study was conducted in different parts of Dhaka city- Uttara, Banani, Gulshan, Dhanmondi, Mohammadpur, Mirpur DOHS and Bashundhara, the study was unable to capture the whole picture of Dhaka city and the outputs of the study might not align with some parts of Dhaka city due to this gap.

The outputs of the study would've been more significant given that the number of data collected had been more. The collected data upon analysis has been found to be skewed since most of the data collected came from students.

The bulk of the data that was gathered showed that most people were walking, with very few people riding bicycles.

As a result, the study produced no meaningful conclusions about riding.

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APPENDIX

Questionnaire Survey for Thesis

1. Gender:
   - ☐ Male
   - ☐ Female
   - ☐ Transgender
   - ☐ Prefer not to say
2. Age Group:
   - ☐ <18
   - ☐ 18-25
   - ☐ 25-35
   - ☐ 35-50
   - ☐ 50-60
   - ☐ 60-65
   - ☐ >65
3. Highest Education Level Completed:
   - ☐ Illiterate
   - ☐ No formal education
   - ☐ Drop-out from primary level education
   - ☐ Primary/Ibtedayi
   - ☐ Drop-out from secondary level education
   - ☐ Secondary (Includes Trace Certificate/SSC Vocational)/ Dakhil
   - ☐ Higher Secondary (Includes 2 years of 4 year)
   - ☐ Diploma in Engineering & Nursing, HSC Vocational)/ Alim
   - ☐ Diploma/Vocational (Not a Bachelors, similar to Associates)
   - ☐ Graduate/Fazil
   - ☐ Postgraduate/Kamil
4. Marital Status:
   - ☐ Unmarried
   - ☐ Married
   - ☐ Single
   - ☐ Divorce
   - ☐ Widow
   - ☐ Others _____
5. Current status of employment:
   - ☐ Govt. employee
   - ☐ Self-employed
   - ☐ Teacher
   - ☐ Private employee
   - ☐ Garments worker
   - ☐ Home maker
   - ☐ Student
   - ☐ Doctor
   - ☐ Engineer
   - ☐ Unemployed
   - ☐ Others _____

6. Average monthly Income Level (in BDT):
   - ☐ <25k
   - ☐ 25-35k
   - ☐ 35-45k
   - ☐ 45-55k
   - ☐ 55-65k
   - ☐ 65-100k
   - ☐ 100k+

7. Captive vs. Non-Captive User:
   - ☐ I rely on walking/cycling for most daily trips
   - ☐ I choose to walk/cycle for some trips but have other options

8. Vehicle ownership (Private automobiles like: Car, Jeep, Microbus or Bicycle)
   - ☐ Yes, personal automobile ownership
   - ☐ Yes, family automobile ownership
   - ☐ Yes, office automobile ownership
   - ☐ Yes, personal bicycle ownership
   - ☐ Yes, on-rental bicycle ownership
   - ☐ No

9. If yes in case of automobile ownership, how many vehicles do you own?
   - ☐ 1
   - ☐ 2
   - ☐ 3+

10. Where do you live? _____

11. Most preferred mode of travel for short trips (Trips less than 2 KM)
   - ☐ Walking
   - ☐ Bicycle
   - ☐ Non-motorized vehicle (NMV) (Rickshaw, Van)
   - ☐ Public Transport (Bus, Rail)
   - ☐ Rent-a-car, Ride Sharing (Uber, Pathao)
   - ☐ Private Automobile (Car, Microbus, Jeep, Motorbike)
   - ☐ Others (CNG, Leguna)

12. Rank the below factors (from 1 to 5) in terms of importance when choosing any mode of travel?

Safety and Security _____
Distance _____
Fare _____
Availability _____
Hassle _____

13. For which of the trip purposes below do you use (walking/bicycling) the most?
   - ☐ For work or work-related trips
   - ☐ For educational purposes (e.g.: tuition, dropping children off to school)
   - ☐ Running Errands (e.g.: shopping, grocery shopping, banking)
   - ☐ Recreation (park visits)
   - ☐ Healthcare related visits
   - ☐ Exercise or physical activity

14. Which factors do you consider the most during walking/cycling?

- ☐ Cost savings
- ☐ Safety and Security of the location
- ☐ Distance
- ☐ Travel Time
- ☐ Environmental Reasons (e.g.: to reduce pollution)
- ☐ Weather
- ☐ Traffic-related Reasons
- ☐ Availability of pedestrian paths/ bicycle lanes
- ☐ Others _____

15. How far do you reside from your regular destination (workplace/educational institutions)?
    - ☐ Less than 1 kilometer
    - ☐ 1-2 kilometers
    - ☐ 3-6 kilometers
    - ☐ More than 6 kilometers
16. Do you walk/cycle for the following destinations?

Workplace	☐ Yes (for the whole trip)	☐ Yes, (some part of the trip)	☐ No
Educational Institutions	☐ Yes (for the whole trip)	☐ Yes, (some part of the trip)	☐ No
Shopping	☐ Yes (for the whole trip)	☐ Yes, (some part of the trip)	☐ No

17. Are there any security measures in place along pedestrian/bicycle paths in your area, such as CCTV cameras or police patrols?
    - ☐ Yes
    - ☐ No
18. Have you ever encountered crime-related(theft/vandalism) while walking/cycling?
    - ☐ Yes
    - ☐ No
19. Have you ever experienced or witnessed harassment or assault while walking or cycling in Dhaka?
    - ☐ Yes
    - ☐ No
20. If yes, what were the probable causes for harassment?
    - ☐ Eve-teasing
    - ☐ Sexual harassment
    - ☐ Being followed or stalked
    - ☐ Harassment by law enforcement authority
    - ☐ Others _____
21. Have you ever changed your route/transport mode you felt unsafe while walking/cycling?
    - ☐ Yes
    - ☐ No
22. What time of the day do you feel safer and more comfortable using active transport? (Multiple answers applicable)
    - ☐ At morning
    - ☐ At noon

- ☐ At evening
- ☐ At night

23. Rank the following physical barriers (from 1-4) that affects your decision to not pursue walking in sidewalks?

Infrastructure Maintenance Issues _____ • Poor road surface construction • Uneven surfaces, cracks, and potholes • Lack of signage/markings for users • Narrow/Obstructed/Unfinished sidewalks	Encroachment _____ • Illegally parked vehicles on sidewalks • Illegal shops and vendors on footpaths • Street beggars occupying sidewalks • Construction materials laid on sidewalks
Safety Issues _____ • Unsorted trash dumps/untidy footpaths • Manholes • Absence of street lighting at night • Movement of motorbikes on footpaths	Accessibility _____ • Lack of ramp and railing • Lack of foot-over bridge • Lack of shade and crosswalks • Lack of tactile pavement (for disabled persons)

24. Have you ever faced challenges or criticism from family members or peers for choosing to walk/cycle for daily commute in Dhaka?

- ☐ Yes
- ☐ No

25. If yes, what were the likely cultural/social motivated concerns discouraging walking/cycling? (Multiple answer applicable)

- ☐ To use private vehicles as they are more "respectable"/ "appropriate" mode
- ☐ Women should always have a male guardian accompanying her when walking/cycling
- ☐ Traditional patriarchal mentality where women are discouraged to travel at nighttime
- ☐ Cycling alone in public is considered "unconventional" and "inconvenient" for women
- ☐ Others _____

26. Have you ever faced criticism/judgment from others for choosing to walk/cycle over car ownership, especially considering your socio-economic status or lifestyle?

- ☐ Yes
- ☐ No

27. Have you ever felt pushed to buy a car because it's becoming more common, even though you might prefer other ways of commuting?

- ☐ Yes
- ☐ No

28. Tick the kind of campaigns/interventions that can be implemented by the policy makers to promote active travel in your neighborhood. (Multiple answers applicable)

- ☐ Creation of dedicated bicycle lanes and pedestrian paths
- ☐ Install and repair adequate street lightings
- ☐ Companies offering their employees free bicycle parking/ bicycle commuting incentives
- ☐ Introduce parking fees to discourage car usage
- ☐ Community wise bicycle rental programs
- ☐ Secured bicycle parking facilities

☐ Others: _____

What is your perception regarding the following statements?

Variables	Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Socio-economic and Demographic Characteristics	1. The number of vehicles owned by my household influences my choice of transportation mode.	☐	☐	☐	☐	☐
	2. I believe the cost of transportation affects my mode choice.	☐	☐	☐	☐	☐
	3. Having access to alternative transportation options (public transportation, ridesharing) affects my mode choice.	☐	☐	☐	☐	☐
Land-use Pattern and Network Characteristics	4. The availability of amenities (e.g., shops, schools) within walking/cycling distance influences my mode choice.	☐	☐	☐	☐	☐
Safety and Security	5. Condition of pedestrian/bicycle infrastructure influences my mode choice.	☐	☐	☐	☐	☐
	6. Concerns about safety (e.g., traffic accidents, crime) significantly influence my mode choice.	☐	☐	☐	☐	☐
	7. The presence of visible law enforcement (e.g., police patrols) influences my mode choice.	☐	☐	☐	☐	☐
Road Infrastructure and Accessibility	8. The presence of dedicated bike lanes influences my choice of cycling as a mode of transportation.	☐	☐	☐	☐	☐
	9. The condition of pedestrian sidewalks influences my choice of walking as a mode of transportation.	☐	☐	☐	☐	☐
Trip Purpose	10. The purpose of my trip (e.g., work, leisure,	☐	☐	☐	☐	☐

	shopping) affects my choice of transportation mode.					
	11. Distance of trip affects my mode choice.	☐	☐	☐	☐	☐
	12. I consider the time it takes to reach my destination when choosing a transportation mode.	☐	☐	☐	☐	☐
Social and Cultural Norms	13. The selection of my transportation mode is influenced by societal perceptions of status.	☐	☐	☐	☐	☐
	14. In my household, it is socially acceptable for women to use active transport modes such as walking or cycling regardless of daytime or nighttime.	☐	☐	☐	☐	☐
	15. In my community, car ownership is seen as an important status symbol and its affect my mode choice.	☐	☐	☐	☐	☐