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Mode Choice Modeling of University Students in Dhaka: A Case Study on BUET

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Abstract

Planning a city's transportation infrastructure and necessary facilities, especially for the capital city of a developing country like Bangladesh, should incorporate the needs of different stakeholder groups with proper attention to the country's future leaders- the university students. Unlike regular commuters i.e. office goers, students have the flexibility to some extent in their choice of travel time and mode based on their schedules and preferences. In addition, several factors such as age, gender, income, travel time, distance, and the cost of travel of their chosen modes of transportation influence their choice. This research uses a discrete choice modeling approach to determine the mode choice behavior of undergraduate students and identify the significant factors affecting their preferences. Travel information of students was collected from Bangladesh University of Engineering and Technology (BUET) through a revealed preference (RP) survey. In this study, particular emphasis was put on the mode preferences of university people who are non-residents. An open-source statistical software program, BIOGEME, was used for analysis. Unsurprisingly, their preferred mode of transportation was the institutional bus service, given the state of the public transport system in Dhaka. The findings of this study will identify the key factors influencing the mode preferences of university students and assist in planning for the city's overall transportation infrastructure and facility development, fostering a just and sustainable society. They will also serve as precedence for other metropolitan areas of comparable settings.

Keywords: *Transport mode; discrete choice models; stated preference survey; multinomial-logit models.*

1 Introduction

Dhaka, the capital of Bangladesh, still lacks to provide modern and efficient transport to its residents. The government of Bangladesh is heavily investing in public transport infrastructure development projects such as mass rapid transit (MRT) and bus rapid transit (BRT) to meet the basic mobility demands of people from all walks of life. Universities are at the forefront of training future leadership toward innovation and sustainable development. The Dhaka metropolitan area has nine public and a substantial number of private universities. Students of these educational institutions use available modes to reach their destinations every day. Some of these institutions offer bus services for their students during work days. University students form an important group of stakeholders who, like others, are impacted by the inefficiency of Dhaka's transport system as well as any improvement initiative undertaken for its improvement. Using discrete choice models and a revealed preference (RP) survey, this study examines the mode choice behavior of the non-resident students of Bangladesh University of Engineering and Technology (BUET) for home-to-university and vice-versa trips. This study aims to identify the key factors influencing the mode preferences of university students and assist in planning for the city's overall transportation infrastructure and facility development, fostering a just and sustainable society.

Various researchers have examined mode choice behavior and relevant factors influencing mode choice decisions among university students. (Lodhi and Rana, 2021) found that family cars were the least preferred mode of transportation for educational trips in Abbottabad, Pakistan, due to distance and cost factors. Instead, students favored school buses, indicating a need for better quality bus services to meet their demands. The study by (Mandhani, et al., 2021) on female student travel behavior in Dehradun, India, found that household income, age, location, and attitude toward public transport significantly influence travel mode choices. (Mohammadzadeh, 2020) found that cost, limited car accessibility, and other factors influence students' mode choices in Auckland, New Zealand, suggesting the need for collaborative travel management policies between Auckland Transport and the University of Auckland. (Sarangi and Manoj, 2020) studied mode choice behavior in a university in New Delhi,

India, revealing that on-campus residents prefer personal cars and motorcycles, while off-campus residents own more motorcycles. (Cattaneo et al., 2018) conducted an online survey on University of Bergamo students in Italy, finding that students prioritize safety and ecology when choosing sustainable transportation modes to contribute to a sustainable and safe environment. (Nguyen-Phuoc et al., 2018) found that in Danang, Vietnam, students' age, gender, and income level significantly influence their mode choice decisions, indicating that those who currently use motorcycles would switch to public transport if there is an efficient and reliable system in place. (Moniruzzaman and Farber, 2018) studied mode choice behavior of university students in the Greater Toronto Area, finding that transit pass and bike ownership are key factors influencing sustainable mode choice. (Whalen et al., 2013) studied university students at McMaster University, finding that mode choice was influenced by cost, attitudes, and environmental factors, with travel time impacting car and bicycle choices. (Pourhashem et al., 2019) showed how analyzing mobility behavior data in the Žilina region can inform gender-sensitive mobility planning and help create sustainable policies for improved community mobility, accessibility, and gender equality. (Thynell, 2016) emphasized the importance of understanding women's needs and challenges in rapidly growing Asian cities to design comprehensive transport policies that go beyond addressing harassment, utilizing development research and gender studies for critical reflection. (Levin and Faith-Ell, 2014) proposed a strategy for integrating gender equality into transportation planning in Sweden, emphasizing the need for systematic gender impact analyses to avoid generalizations and promote tailored approaches.

2 Data Collection

This section focuses on the data collection methods and sources employed to develop the model. To gather information from non-resident students at Bangladesh University of Engineering and Technology (BUET) regarding their trips, a Revealed Preference (RP) survey was conducted. The survey included questions about participants' travel diaries, documenting factors such as distance traveled to and from BUET, commute duration, expenses incurred, and preferred modes of transportation. Hypothetical scenarios and Stated Preference (SP) surveys were not utilized. The survey received 160 responses, and participants were presented with various transportation options commonly found in the urban area of Dhaka Metropolitan area. As of the year 2023, the number of non-resident students enrolled in undergraduate studies at the university amounts to 1872. The study utilized Slovin's formula to determine the appropriate sample size for the population of this size. The necessary sample size for a 7.5% margin of error is 157 for a population size of 1872. This study satisfies this requirement, as the total number of observations is 160. The following questions were included in the survey:

- Gender of the respondents
- Age of the respondents
- Location of their household in Dhaka
- Income level
- Mode of transportation used to travel from home to BUET
- Time required to travel from home to BUET
- Incurred cost due to traveling from home to BUET
- Mode of transport used to travel from BUET to home
- Time required to travel from BUET to home
- Incurred cost due to traveling from BUET to home

The research investigated a range of transportation modes, such as BUET bus service, public bus service, rickshaw, private automobile, ride-sharing services (UBER, PATHAO, etc.), CNG, bicycle, motorbike, and walking. The data collected provides the basis for statistical analysis of students' travel behavior, including their preferred mode of transportation and the key factors influencing their mode choice.

3 Methodology

Data was collected and statistically analyzed to identify the primary mode of transportation among students and understand influencing factors. BIOGEME, an open-source Python package was used to develop a total of 12 models representing non-resident students' mode choice behavior. The study includes various parametric tests:

1. Regression Tests: These tests examine the impact of one or more continuous variables on another variable. They involve different types of regression analysis, such as logistic regression, multiple linear regression, and simple linear regression.
2. Correlation Tests: These tests assess the relationship between two variables without assuming a cause-and-effect connection.
3. Comparison Tests: These tests help researchers understand how a categorical variable influences the average value of another feature. T-tests are commonly used among different types of comparison tests.

R-squared (ρ^2) is a statistical measure indicating the extent to which the variability in the dependent variable can be explained by the independent variables in a multiple regression analysis. It ranges from 0 to 1, with 0 meaning the predictors explain none of the variability and 1 meaning they explain all of it. However, when the number of predictors increases, or the number of cases decreases, R-squared tends to overestimate the squared population correlation coefficient (pz). To address this issue, the adjusted R-squared (adjusted ρ^2) is employed. The adjusted R-squared accounts for the number of predictors and the sample size. It penalizes the inclusion of unnecessary predictors that contribute minimally to the explanatory power of the model. When multiple predictor variables are present, the adjusted R-squared is always lower than the R-squared, and it increases only if the additional variables significantly improve the model's performance. The formula for calculating the adjusted R-squared is as follows:

Adjusted $\rho^2 = 1 - [(1 - \rho^2) * (n - 1) / (n - k - 1)]$
Where:

- ρ^2 represents the ordinary R-squared.
- n is the sample size.
- k is the number of predictor variables.

If the adjusted R-squared decreases when adding a variable, it suggests that it may not be a strong predictor or duplicates information from other variables. However, other factors such as theoretical relevance, statistical significance, potential confounding, model fit, and the principle of parsimony should also be considered when deciding whether to exclude a variable from the model.

4 Results and Discussion

The following sections present the model outputs obtained from BIOGEME and their explanations.

4.1 Dummy Variables of the Model

The dummy Variables that were used for the models are mentioned below-

- Private_Car_AV = dummy variable for the availability of private cars (0 if not available, 1 if available)
- Bicycle_AV = dummy variable for the availability of bicycles (0 if not available, 1 if available)
- Motorbike_AV = dummy variable for the availability of motorbikes (0 if not available, 1 if available)
- FMSEX = Gender of the respondent (if female FMSEX = 1, and for male, FMSEX =0)

4.2 Mode Choice Model Including Mode and User Attributes: Travel Cost, Travel Time, Gender, and Distance- Home to BUET Trip

BUET bus service is considered as the base mode of the model. The analysis indicates that private modes of transportation, such as cars and motorcycles, are preferred due to their convenience and availability. It's not surprising that these modes are favored by individuals. On the other hand, modes like rickshaws and CNG have lower or insignificant values because they may not always be readily available, particularly in unfavorable weather conditions. The negative sign of the travel cost parameter indicates that as the travel cost increases, the utility of a mode and the probability that it will be chosen diminishes. Significant gender-related factors include the preference for private cars and walking. Women tend to prefer private vehicles due to the higher comfort and safety they provide. Walking alone in the streets is perceived as unsafe, particularly in the context of Dhaka city. It is to be mentioned that constants that have magnitudes of t-statistic greater than 1.96 at a 95% confidence level are considered to be significant. The adjusted rho-squared value of this model is 0.659. As the value is greater than 0.35, the model can be regarded as a meaningful one. The value of the log-likelihood ratio test is 444.3493, which is a substantial value, and it rejects the null hypothesis.

Table 1. Model output for home to BUET trips with mode-related variables.

Parameter	Estimated Value	t-statistics
Constants		
BUET Bus, ASC_BUETBus	0.00	Base Mode
Private Car, ASC_PrivateCar	26.8	7.33
Public Bus, ASC_PublicBus	0.547	0.87
Rickshaw, ASC_Rickshaw	0.781	1.02
Ride Sharing, ASC_RideSharing	-3.85	-3.4
Walking, ASC_Walking	1.94	2.22
Motorbike, ASC_Motorbike	4.91	6.75
CNG, ASC_CNG	-3.72	-1.67
Bicycle, ASC_Bicycle	0.398	0.147

Bicycle Availability, ASC_BICYCLE_AVAIL	0.398	0.147
Motorbike Availability, ASC_MOTORBIKE_AVAIL	4.91	6.5
Car Availability, CAR_AVAIL	26.8	7.33
Coefficients		
Coefficient of Cost, BETA_Cost	-0.0364	-6.15
Coefficient of Time, BETA_Time	0.00861	0.7
Gender parameter for BUET bus service, B_FMSEX_BUETBus	0.43	0.577
Gender parameter for Private Car, B_FMSEX_PrivateCar	15.6	9.35
Gender parameter for Rickshaw, B_FMSEX_Rickshaw	-0.147	-0.958
Gender parameter for Ride Sharing Services, B_FMSEX_RSS	-1.59	0.328
Gender parameter for Walking, B_FMSEX_Walking	-1.7	-6.22
Gender parameter for Public Bus, B_FMSEX_BUETBus	-0.616	-0.912
Gender parameter for Bicycle, B_FMSEX_Bicycle	0	0
Gender parameter for CNG, B_FMSEX_CNG	1.04	0.978
Gender parameter for Motorbike, B_FMSEX_Motorbike	0	0
Distance parameter for BUET Bus, B_DIST_BUETBus	-0.268	-2.13
Distance parameter for Private Car, B_DIST_PrivateCar	-4.86	-8.81
Distance parameter for Public Bus, B_DIST_PublicBus	-0.327	-6.37
Distance parameter for Rickshaw, B_DIST_Rickshaw	-0.147	-0.958
Distance parameter for Ride Sharing Services, B_DIST_RSS	1.59	4.86
Distance parameter for CNG, B_DIST_CNG	1.04	0.978
Distance parameter for Bicycle, B_DIST_Bicycle	1.91	1.96
Distance parameter for Motorbike, B_DIST_Motorbike	2.96	5.06
Distance parameter for Walking, B_DIST_Walking	-1.7	-6.22
No of Observations	160	-
No of Parameters	31	-
Initial Log Likelihood	-290.0728	-
Final Log Likelihood	-67.8982	-
Adjusted Rho Square	0.659	-
Likelihood Ratio Test	444.3493	-

4.3 Models Including Decision Maker Biases (Income) –Home to BUET Trip

Upon including the income parameter, it becomes evident that the majority of correlation coefficients in the correlation table are not statistically significant. This implies that the values fall below 1.96, which is the critical value at a 95% confidence level. Considering the principle of parsimony, which favors simpler models over complex ones when everything else is equal, it can be concluded that the current model should be disregarded. The inclusion of multiple variables has led to excessive complexity, hindering effective interpretation of the results.

4.4 Mode Choice Model Including Mode and User Attributes: Travel Cost, Travel Time, Gender, and Distance- BUET to Home Trip

In this choice model, the reference alternative is the BUET bus service. When considering all alternatives equally, except for rickshaws, bicycles, and motorbikes, all modes of transportation demonstrate significant effects based on distance parameters, indicating a preference for these modes during trips from BUET to Home. However, the only significant parameter concerning gender is the private car mode, suggesting that female students are more likely to choose modes that prioritize their safety, such as private cars. Additionally, the cost parameter has a significant negative impact, indicating a preference for more affordable transportation options, while the time parameter is not statistically significant. The model exhibits a good fit with an adjusted rho-squared value of 0.699. The likelihood value of 467.2664 leads to the rejection of the null hypothesis. Table 2 below shows the model outputs.

Table 2. Model output for BUET to home trips with mode-related variables.

Parameter	Estimated Value	t-statistics
Constants		
BUET bus service, ASC_BUETBUS	0.0 (base mode)	-
Public bus service, ASC_PublicBus	-0.625	-0.915
Private car, ASC_PrivateCar	-1.08	-1.52
Private car, ASC_CAR_AVAIL	-1.08	-1.52
Rickshaw, ASC_Rickshaw	-2.7	-1.2

CNG, ASC_CNG	-13.2	-6.59
Walking, ASC_Walking	-0.121	-0.0421
Ride-sharing services, ASC_RideSharing	-7.79	-3.27
Bicycle, ASC_Bicycle	0.173	0.0633
Bicycle, ASC_BICYCLE_AVAIL01	0.173	0.0633
Motorbike, ASC_Motorbike	4	5.47
Motorbike, ASC_MOTORBIKE_AVAIL01	4	5.47
Cost, B_Cost	-0.0456	-4.49
Time, B_Time	0.00659	0.226
Gender parameter for BUET bus service, B_FMSEX_BUETBus	0.364	0.358
Gender parameter for public bus service, B_FMSEX_PublicBus	-0.829	-0.84
Gender parameter for private car, B_FMSEX_PrivateCar	2.19	1.97
Gender parameter for rickshaw, B_FMSEX_Rickshaw	1.08	1.36
Gender parameter for ride-sharing services, B_FMSEX_RSS	-3.26	-3.23
Gender parameter for walking, B_FMSEX_Walking	1.41	1.38
Gender parameter for motorbike, B_FMSEX_Motorbike	0	0
Gender parameter for bicycle, B_FMSEX_Bicycle	0	0
Gender parameter for CNG, B_FMSEX_CNG	-0.96	-0.748
Parameter of distance for BUET bus service, B_DIST_BUETBus	-0.929	-2.58
Parameter of distance for public bus service, B_DIST_PublicBus	-0.836	-2.36
Parameter of distance for private car, B_DIST_PrivateCar	-0.968	-1.94
Parameter of distance for rickshaw, B_DIST_Rickshaw	0.623	1.12
Parameter of distance for ride-sharing services, B_DIST_RSS	2.3	4.14
Parameter of distance for walking, B_DIST_Walking	-2.1	-2.91
Parameter of distance for CNG, B_DIST_CNG	1.78	6.38
Parameter of distance for Bicycle, B_DIST_Bicycle	0.908	0.986
Parameter of distance for Motorbike, B_DIST_Motorbike	-0.774	-1.75
Coefficients		
No. of observations	160	-
No. of parameters	31	-
Initial Log likelihood	-289.7645	-
Final Log likelihood	-56.13131	-
Adjusted rho-square	0.699	-
Likelihood ratio test	467.2664	-

4.5 Models Including Decision Maker Biases (Income) – BUET to Home Trip

In a manner akin to the model of trips from home to BUET, the incorporation of the income parameter in the model resulted in a notable reduction in the adjusted R-squared value, implying that the variable may not serve as a dependable predictor or might duplicate existing variables. An analysis of correlation indicated that numerous coefficients lacked statistical significance, thereby suggesting that the observed values did not reach significance at a 95% confidence level. Following the principle of parsimony, it is recommended to dismiss the model due to its excessive complexity and limited interpretability.

5 Conclusion

The primary focus of this research consisted of university students who serve as future leaders of society. Unsurprisingly, their preferred mode of transportation is the BUET bus service, given the state of the public transport system in Dhaka. However, it is essential to investigate their travel patterns when they have access to private transportation options like cars, motorbikes, or bicycles. The observations indicated that the cost of travel influences their choice of transportation, impacting non-resident university students. Also, female students are more likely to choose modes that prioritize their safety, such as private cars. The strengths and weaknesses of this study are highlighted in the following paragraphs.

5.1 Strengths

The findings of this paper can be valuable for policymakers and transportation officials aiming to develop an inclusive and sustainable transport network in Dhaka that caters to the needs of people from all backgrounds. In addition, this study is one of its kind in BUET or any other university in Dhaka. Hence, this paper can provide a framework for investigating the travel patterns of university personnel for future research purposes.

5.2 Weaknesses

It is essential to acknowledge that one limitation of this study is the small size of the sample. Nonetheless, this smaller sample size enables the examination of various factors, although the precision in measuring their effects may be somewhat limited.

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