

INFLUENCE OF GROUND ACCESS AND EGRESS TRIP ATTRIBUTES ON INTERCITY MODE CHOICE BEHAVIOR

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ABSTRACT

This study investigates the influence of ground access and egress on intercity mode choice for travel between Sylhet and Dhaka, focusing on bus, train, and air transport modes. A revealed preference (RP) survey was first conducted to collect actual trip information and set realistic attribute ranges, followed by a stated preference (SP) survey was conducted to collect detailed information on socioeconomic characteristics, travel behavior, and preferences under access, egress, and intercity travel scenarios. The collected data were analyzed using Multinomial Logit (MNL) model to capture both deterministic and random variations in mode choice behavior. The models incorporated key variables such as access time, egress time, access cost, egress cost, and in-vehicle travel time components, enabling a comprehensive door-to-door travel behavior analysis. Model analysis results indicate that access and egress attributes in the MNL model, such as access cost, egress cost, access time, and egress time, significantly affect mode choice behavior. Among these, egress-related attributes exhibit stronger effects, with egress cost (t-test = -7.23) and egress time (t-test = -4.07) exerting greater influence compared to access cost (t-test = -0.09) and access time (t-test = -6.22). The mode share results indicate a distinct modal shift after incorporating access, egress, and intercity travel attributes, with bus use declining by 9.08%, while train and air increased by 8.37% and 0.71% respectively, reflecting higher sensitivity towards train and air travel. Statistical analysis reveals clear sociodemographic differences, like females prefer train and air compared to bus, low-income travelers favor train, and high-income travelers lean toward air. According to the Likelihood ratio test and model fit assessment, models that include access and egress variables perform better than those without for MNL discrete modelling technique. Modal share results show that reducing access and egress costs can substantially increase the attractiveness of station-based modes, particularly rail. These findings provide valuable insights for policymakers and transport planners to design interventions aimed at improving first and last-mile connectivity, enhancing intermodal integration, and promoting sustainable and equitable transport systems.

Keywords: *Mode choice modeling, Access and egress, Multinomial Logit, First and last mile connectivity*

1. INTRODUCTION

The intercity transport between Sylhet and Dhaka is an important part of the national transport network in Bangladesh that links one of the most rapidly developing urban centers in the country to the capital. Sylhet, a city in the northeast hilly area, has undergone fast urbanization with the population growth rate standing at 4% per annum, which is twice as high as the national average of 2.01% and is mainly due to migration and economic opportunities (Rahman et al., 2018; Yadav et al., 2016; Chowdhury et al., 2018). This increased traffic demand has increased the dependency on main intercity transportation modes that include bus, train, and air transportation, which are not only varying in price and comfort but also the level of accessibility (Latif and Yeasmin, 2015; Dip et al., 2024). Nevertheless, there are various modes of transport at hand, and mode choice behavior is largely affected by ground access and egress factors, time, cost, and convenience of accessing and leaving terminals, all of which affect the choice of transport mode (Horowitz, 2003; Zhong and Chen, 2016).

The existing information on the intercity mode choice in Bangladesh also considers the key elements of the travel, i.e., the fare, comfort, and travel time evenly without taking into consideration the effects of the ground access and accessibility conditions, which may contribute greatly to the change in modal utility and overall travel experience (Tanwar and Agarwal, 2025). To address this gap, this research develops a mode choice model of Sylhet-Dhaka route by incorporating both access and egress features in Multinomial Logit (MNL) model. The study will find the impacts of the access and egress time and cost on mode choice by passengers, compare the models with and without these variables and the mode shifting behaviour. The recommendations are supposed to guide the policymakers to enhance the first and last-mile linkages and promote sustainable intercity movements in Bangladesh.

2. LITERATURE REVIEW

The behavior of choosing an intercity mode of transportation is an extremely complex decision that is dependent on both the characteristics of the key modes and the ground access–egress situations that describe the first and last miles of the journey. These are access and exit factors, which can be influential variables in the travel decision process in developing countries like Bangladesh, where the integration of multimodal transport is still deficient (Barua et al., 2013). The connection between the feeders is interrelated. Accessibility to intercity terminals by routes such as rickshaws, CNGs, and walking paths has a direct impact on the attractiveness of the major modes of transport—bus, train, and air. Research has found that terminally inadequate design and intermodal coordination hamper the efficiency of intercity transport and put off travelers using sustainable alternatives such as rail (Rahman et al., 2018; Gayashani et al., 2024).

Some authors have highlighted the importance of access and egress duration and cost on perceived utility and general mode attractiveness (Allard and Moura, 2016; Azimi et al., 2021). In most cases, users tend to feel that these constituents are heavier than in-vehicle travel time. As an illustration, access time has been estimated to be 1.5 to 2 times more valuable than in-vehicle time in developed settings (Abrantes and Wardman, 2011), and long distances to stations and weak feeder connectivity put people off using trains, even when fares are lower in Bangladesh (Barua et al., 2013). Research also suggests that mode choice may be more strongly affected by egress-related variables: the last-mile cost, the transfer time, and the proximity of terminals to each other can significantly influence access variables, especially in congested urban settings (Wu et al., 2018; Yang and Liao, 2016).

A very common method of analyzing such behaviors is modeling them using Multinomial Logit (MNL) and Mixed Multinomial Logit (MMNL). Although MNL models are theoretically based and easy to construct, they have the weakness of the Independence of Irrelevant Alternatives (IIA) (Yazdizadeh, 2016). Studies on intercity mode choice in Bangladesh have centered on major routes such as Dhaka-Chittagong, and most have centered on fare, comfort, and travel time (Rahman et al., 2018; Chowdhury, 2014). These researchers identified service quality and cost as prevailing forces, although the effect of the first- and last-mile that impact the overall travelling experience of a passenger was often overlooked. Recent studies on the paratransit and feeder services in urban Sylhet and Dhaka found that mode selection depends heavily on accessibility, convenience, and distance to terminals (Ashrafuzzaman Pramanik and Shafiq-Ur Rahman, 2021; Chowdhury et al., 2018).

Nevertheless, there is no previous study that modeled systematically the effects of access and egress on intercity mode choice to the Sylhet-Dhaka corridor. This study bridges such a gap through the separate consideration of access time, egress time, access cost, and egress cost derived in discrete choice models. Combining these variables offers a more holistic representation of the door-to-door travel experience of travelers and the creation of sustainable, multimodal transport plans of the rising cities in Bangladesh.

3. STUDY AREA

The research was conducted in Sylhet, which is a big district in the northeastern region of Bangladesh and is one of the major regional centers of intercity travel in the country. The study targeted the Sylhet-Dhaka route that links Sylhet to the capital using three major means, including bus, train, and air. The bus terminal in Sylhet is located at Kodomtoli, close to the city center, and acts as the main center of all the buses to Dhaka and other areas. The intercity travel activities are also served by several smaller pick up and drop off points such as Humayun Chottor and Dorga Gate. The Sylhet Railway Station, which is next to the bus terminal at Kodomtoli, acts as the main station of the city and plays the role of providing daily trains, including the Parabat, Upaban, and Kalni Express to Dhaka.

Moreover, Osmani International Airport offers air transport to Dhaka and other destinations in domestic and international traffic, serving as a hub for domestic and international passengers. These three transport terminals collectively constitute the intercity transport system of Sylhet. These major locations were used together with other nearby residential locations as the source of the data to be used during the study, as these locations would represent a wide range of travelers and the reason behind the trip. The sampling approach involved the transportation hubs, educational institutions, and households to attain the different socioeconomic and traveling features.

4. DESIGN AND DEVELOPMENT OF THE SP SURVEY

4.1 Preliminary Survey

An initial survey was done on about 50 respondents in order to find out the influential factors on intercity mode choice over the Sylhet-Dhaka route. The levels of travel behavior and access-egress mode, and demographics data have been collected using the survey that was conducted at major bus and train stations and in the SUST campus, which contributed to identifying important variables to be considered in the design of the stated preference.

4.2 Choosing Attributes and Their Levels

Key attributes that determined intercity mode choice were identified based on the initial survey results and other past literature. These were travel cost, travel time, frequency, access time, egress time, access cost, and egress cost. The attribute was further allocated to various levels, including reduced, same, and increased, to measure the sensitivity of travelers to time and cost change. Attributes and their corresponding levels are presented in Tables 1 and 2, respectively.

Table 1: Description of attributes in SP scenario

Attributes	Description
Travel Cost	The fare of each intercity mode (bus, train, and air) was presented in taka per single trip between Sylhet and Dhaka. Different levels of cost were provided to observe whether cost variation could influence respondents to switch their mode.
Travel Time	The total in-vehicle travel time of each mode was presented in minutes per single trip. Different time levels were assigned to reflect variations in service performance and to identify how sensitive travelers are to changes in travel duration.
Frequency	The number of trips per day for each mode was varied across scenarios. For trains, frequency was presented as trips per day, while for buses and air frequency was presented as daily flight schedules.
Access Time	Time required to reach the intercity terminal from the respondent's residence was included in minutes. Different levels of access time were presented to capture the impact of first-mile connectivity on mode choice.
Access Cost	The cost incurred to reach the intercity terminal (e.g., rickshaw fare, CNG fare, bike fare) was provided in taka per trip. Levels of reduced, same, and increased costs were tested in scenarios.
Egress Time	Time required to travel from the arrival terminal in Dhaka to the respondent's final destination was considered in minutes. Different levels were assigned to capture last-mile travel sensitivity.
Egress Cost	The cost incurred for last-mile travel in Dhaka (e.g., rickshaw, CNG, bus, or ride-sharing fare) was included in taka per trip. Variations in this cost were presented to evaluate its influence on mode choice.

Table 2: Attributes of Mode Choice Model and their different levels

Attributes	Bus	Train	Air
Travel Cost	10 % less than now	10% less than now	10% less than now
	Same as now	Same as now	Same as now
	10% more than now	10% more than now	10% more than now
Travel Time	15% less than now	15% less than now	5% less than now
	Same as now	Same as now	Same as now
	15% more than now	15% more than now	5% more than now
Frequency	Every 30 minutes	3 trains per day	Every 1.5 hours
	Every 45 minutes	4 trains per day	Every 2hours
	Every 1 hour	5 trains per day	Every 2.5 hours
Access Time	50% less than now	50% less than now	50% less than now
	Same as now	Same as now	Same as now
	50% more than now	50% more than now	50% more than now

Egress Time	30% less than now	30% less than now	30% less than now
	Same as now	Same as now	Same as now
	30% more than now	30% more than now	30% more than now
Access Cost	100% less than now	100% less than now	100% less than now
	50% less than now	50% less than now	50% less than now
	same as now	same as now	same as now
Egress Cost	50% more than now	50% more than now	50% more than now
	100% less than now	100% less than now	100% less than now
	50% less than now	50% less than now	50% less than now
	same as now	same as now	same as now
	50% more than now	50% more than now	50% more than now

4.3 Generation of Choice Sets and Scenarios

According to the outlined characteristics and their values as obtained during the initial survey and literature search, the SPSS software was used to create choice sets for the stated preference (SP) experiment using a partial factorial orthogonal design. Three intercity alternatives were generated (bus, train, and air) with different levels of travel cost, travel time, frequency, access time, egress time, access cost, and egress cost. Extreme choice scenarios were excluded to reduce respondents' burden, resulting in a total of 62 choice cards, and these cards were randomly mixed to make three scenarios for each respondent to ensure unbiased responses and balanced alternative representation. Although a D-efficient design using specialized software was not feasible due to insufficient funds and access limitations, the final design ensured logical consistency, adequate attribute quality, and reliable data quality, which produced 500 questionnaires completed as the final survey.

4.4 Main Survey

The main survey was carried out based on wide field data gathering of some Revealed Preference (RP) questions and three Stated Preference (SP) situations for each participant. The questionnaire included demographic data, commonly used modes of travel, mode choice rationales, and characteristics of the trip on the Sylhet-Dhaka route. Each SP scenario had three choices, namely bus, train, and air, which were defined by seven important variables, namely access time, access cost, egress time, egress cost, travel time, travel cost, and service frequency. Only SP choice data were used for model estimation, with demographic variables included as explanatory terms; no RP data were combined, so scale adjustment was not required. The data were taken during the period between the months of January and March 2025 in the major terminals, i.e. Kodomtoli Bus Terminal, Sylhet Railway Station, and Osmani International Airport, and in residential areas to have representative coverage.

4.5 Experimental Design and Statistical Efficiency of SP Survey

The stated preference (SP) experiment was designed following principles of efficient experimental design to minimize respondent burden and maximize parameter estimation accuracy. An initial full-factorial design was infeasible due to the large number of attributes and levels; therefore, a fractional factorial approach was adopted. Although SPSS was initially used to generate combinations, the final design was refined to ensure attribute-level balance and orthogonality. Each respondent was presented with three choice scenarios to reduce cognitive fatigue, resulting in a total of 1,416 SP observations. While a formal D-efficient design was not implemented during initial data collection, post-survey diagnostics confirmed adequate variation across attribute levels and statistically significant parameter estimates, indicating acceptable experimental efficiency for model estimation.

5. DATA ANALYSIS

To examine the influence of ground access and ground egress on mode choice behavior, a total of 1,416 responses were collected from 472 travelers along the Sylhet–Dhaka intercity route. A stratified convenience sampling strategy was applied to collect data at mode-specific places in Sylhet, such as bus terminals, railway stations, airports, as well as residential areas and educational institutions. Post-survey weighting with raking and trimming was done based on important socio-demographic variables (gender, age, marital status, and income) to match the sample distributions with census and observed population proportions to make it more representative. Socioeconomic percentages are shown in Table 3.

Table 3: Socio-demographic characteristics

Characteristics	Categories	Percentage (%)
Gender	Male	62.9
	Female	37.1
Age (Years)	<20	2.1
	21-30	37.9
	31-40	28.2
	41-50	19.3
	51-60	9.7
	>60	2.8
Marital Status	Married	66.1
	Unmarried	33.9
Occupation	Student	23.3
	Jobholder	32.0
	Businessman	16.9
	Housewife	14.2
	Retired	0.8
	Others	14.2
Transportation Inertia	Bus	46.9
	Train	39.2
	Air	12.9
	Others	1.0
Personal Income (BDT)	<30000	19.5
	30000-50000	30.5
	50000-70000	20.3
	70000-100000	16.5
	>100000	13.1
Education	Below Secondary	15.2
	Secondary	11.5
	Higher Secondary	26.5
	Graduation	27.9
	Above Graduation	19.0

Analysis of mode choice behavior revealed that before including access and egress variables, bus (47.5%) and train (39.2%) were the dominant modes, while air accounted for 12.9%, as shown in Figure 1. However, after incorporating access and egress factors, a notable shift occurred: bus decreased to 38.05%, train increased to 43.65%, and air rose to 18.29%, highlighting that first- and last-mile connectivity significantly influences travelers' final choices.

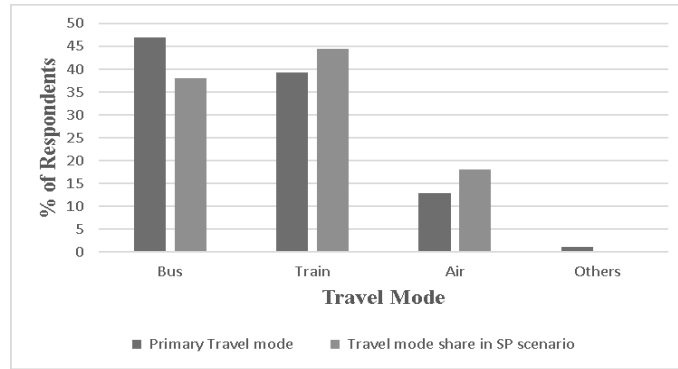


Figure 1: Respondents Primary Travel Mode and Travel mode in SP scenario

Currently, the Bus is the primary travel mode for both genders (Males: 29%, Females: 20%). In the SP scenario, preference shifts toward Trains, reaching 29% for males and 15% for females. Notably, air travel preference converges to an equal 9% for both genders in this scenario. Younger travelers mostly chose bus and train, whereas older travelers preferred air travel for comfort. Income-wise, higher earners leaned toward air, while lower-income groups favored bus and train. Distributions of respondents primary and SP scenario travel modes by gender, age and income are shown in Figures 2, 3 and 4, respectively.

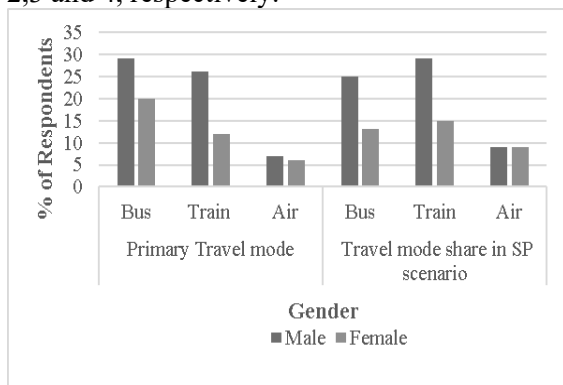


Figure 2: Gender Based Respondents Primary Travel Mode and Travel mode in SP scenario

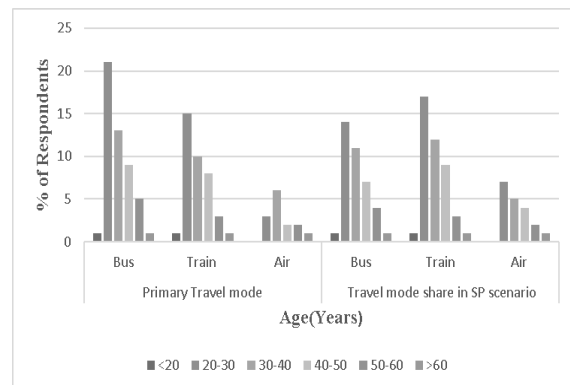


Figure 3: Age-Based Respondents Primary Travel Mode and Travel mode in SP scenario

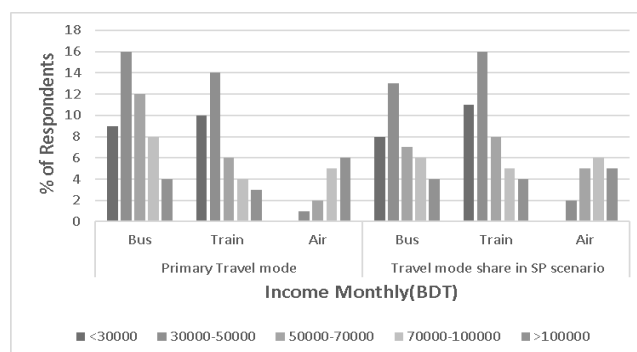


Figure 4: Income-Based Respondents Primary Travel Mode and Travel mode in SP scenario

6. MODEL DEVELOPMENT & RESULT ANALYSIS

Multinomial Logit (MNL) model was developed to understand the intercity mode choice behavior between Sylhet and Dhaka by considering the ground access and egress factors in the decision-making of the traveler. Travel time, travel cost, frequency, access time, access cost, egress time and egress cost are included in the model, which was estimated based on the stated preference data in a series of specification tests, which resulted in behavioral and theoretical consistency. Pearson

correlation analysis was employed to determine the multicollinearity of the variables in the socioeconomic and travel variables, with most variables showing negligible correlation ($r=0$ to ± 0.10). However, only the cost of bus and train travel is strongly correlated ($r = 0.79$) and, therefore, was not modeled in the same utility function. In general, multicollinearity is not raised as an important issue. This model presumes that travelers are time- and cost-sensitive, i.e., increases in travel, access, or egress time or cost will decrease the mode choice probability, whereas an increased frequency of service will increase the probability of selection. Hypothesis of these variables are shown in Table 4.

Table 4: Hypothesis of Mode Choice Variables

Variables	Hypothesis
Travel Time	Travelers are sensitive to travel time differences. An increase in total travel time reduces the attractiveness of a mode as people tend to prefer faster and more time-efficient options.
Travel Cost	The higher the travel cost, the less the chances of using that mode because most people would prefer cheaper ways of traveling through mediums with low fares or overall trip costs.
Frequency	A mode with a higher frequency is more attractive since it has a shorter waiting time, and it is more reliable, and a mode with a lower frequency can make the traveler not to use the mode.
Access Time	The longer access time makes a mode less useful to the total utility of a mode because passengers tend to use the terminal or station that can be easily and relatively fast reached at home.
Access Cost	The mode is also less desirable as the access cost increases since travelers aim to do away with the overall cost of the first-mile connection.
Egress Time	Mode choice is adversely affected by an increase in the egress time since the travelers will prefer flight modes that offer faster and more convenient last-mile access.
Egress Cost	Increased egress cost decreases the appeal of a mode, since the added costs in the last-mile portion of the trip decrease the overall cost-effectiveness of the trip.

To represent socioeconomic and categorical variations, several dummy variables were introduced in Table 5, including transportation inertia, monthly income, and categorized levels of access and egress time and cost. These variables capture differences in preferences among traveler groups.

Table 5: Dummy variables for the response model

Dummy Variable	Description
Transportation Inertia Dummy	1 = Passengers have inertia toward buses, 2 = Passengers have inertia toward train, 3 = Passengers have inertia toward air
Monthly Income Dummy	1 = Less than 30 thousand, 2 = 30–50 thousand, 3 = 50–70 thousand, 4 = 70–100 thousand, 5 = ≥ 100 thousand
Access Cost Level Dummy	1 = Free cost, 2 = Lower than present cost, 3 = Equal to present cost, 4 = Higher than present cost
Egress Cost Level Dummy	1 = Free cost, 2 = Lower than present cost, 3 = Equal to present cost, 4 = Higher than present cost
Access Time Level Dummy	1 = Shorter than present time, 2 = Equal to present time, 3 = Longer than present time
Egress Time Level Dummy	1 = Shorter than present time, 2 = Equal to present time, 3 = Longer than present time

Three alternatives (Bus, Train, and Air) were considered in their choice set as stated above. The utility functions of the mode choice alternatives for main travel trips are presented below, where ASC_i indicates the alternate specific constant of the alternative.

$$U_{Bus} = ASC_{Bus} + \beta_{ic1} * (\text{Access cost for Bus}) + \beta_{ic2} * (\text{Egress cost for Bus}) + \beta_{ic3_b} * (\text{Travel cost of Bus}) + \beta_{it1} * (\text{Access time for Bus}) + \beta_{it2} * (\text{Egress time for Bus}) + \beta_{it3_b} * (\text{travel time of Bus}) + \beta_{max_b1} * (\text{Train as a preferred mode of travel}) + \beta_{max_b2} * (\text{Air as a preferred mode of travel}) + \beta_{freq1} * (\text{Frequency of Bus}) + \beta_{inc_b_mid} * (\text{Monthly income from 50 to 70 thousand BDT}) + \beta_{inc_b_high} * (\text{Monthly income above 70 thousand BDT})$$

$$U_{Train} = ASC_{Train} + \beta_{ic1} * (\text{Access cost for Train}) + \beta_{ic2} * (\text{Egress cost for Train}) + \beta_{ic3_t} * (\text{Travel cost of Train}) + \beta_{it1} * (\text{Access time for Train}) + \beta_{it2} * (\text{Egress time for Train}) + \beta_{it3_t} * (\text{Travel time of Train}) + \beta_{max_t1} * (\text{Bus as a preferred mode of travel}) + \beta_{max_t2} * (\text{Air as a preferred mode of travel}) + \beta_{freq2} * (\text{Frequency of Train}) + \beta_{inc_t_mid} * (\text{Monthly income from 50 to 70 thousand BDT}) + \beta_{inc_t_high} * (\text{Monthly income above 70 thousand BDT})$$

$$U_{Air} = ASC_{Air} + \beta_{ic1} * (\text{Access cost for Air}) + \beta_{ic2} * (\text{Egress cost for Air}) + \beta_{ic3_a} * (\text{Travel cost of Air}) + \beta_{it1} * (\text{Access time for Air}) + \beta_{it2} * (\text{Egress time for Air}) + \beta_{it3_a} * (\text{Travel time of Air}) + \beta_{freq3} * (\text{Frequency of Air})$$

The Multinomial Logit (MNL) model was developed to analyze the effect of access and egress components on intercity mode choice by examining estimated beta coefficients, t-tests, and standard errors. In the baseline MNL model (without access and egress), estimated on 1,416 observations, air was used as the reference alternative ($ASC_{Air} = 0$) while the bus and train constants were estimated. Results show that travel cost for bus and train is negative and significant, respectively ($\beta_{ic3_b} = -0.0008$, t-stat = -6.77 ; $\beta_{ic3_t} = -0.0024$, t-stat = -9.01), indicating higher fares reduce choice probability. Travel time is negative for bus and train ($\beta_{it3_b} = -0.0024$, t-stat = -3.70 ; $\beta_{it3_t} = -0.0017$, t-stat = -2.52), so longer travel time reduces utility; air travel time is also significant. Mode-shift inertia parameters are negative and significant, implying that travelers resist switching from habitual modes. The subscripts refer to either mode of travel or the name of the variable. The betas (β) refer to the sensitivity associated with each parameter. Coefficients of the utility functions were estimated using the maximum likelihood approach. Model outputs with sign, magnitude, and t-test are presented in Table 6.

Table 6: Estimated Coefficients and Model Performance Indicators for MNL Models With and Without Access–Egress Variables

Attribute (Coefficient Code)	Estimated Coefficient (Without Access–Egress)	Std. Error	t-test	Estimated Coefficient (With Access–Egress)	Std. Error	t-test
Alternative Specific Constant(ASC_{Bus})	-0.4805	0.5015	-0.96	-0.8764	0.5477	-1.60
Alternative Specific Constant(ASC_{Train})	0.8223	0.5315	1.55	0.5262	0.5482	0.96
Alternative Specific Constant(ASC_{Air})	0	NA	NA	0	NA	NA
Access Cost (β_{ic1})	–	–	–	0.0000	0.0002	-0.09
Egress Cost (β_{ic2})	–	–	–	-0.0010	0.0001	-7.23
Travel Cost Bus (β_{ic3_b})	-0.0008	0.0001	-6.28	-0.0008	0.0001	-6.77
Travel Cost Train (β_{ic3_t})	-0.0023	0.0003	-8.66	-0.0024	0.0003	-9.01
Travel Cost Air (β_{ic3_a})	-0.0009	0.0001	-9.22	-0.0009	0.0001	-9.22
Access Time (β_{it1})	–	–	–	-0.0081	0.0013	-6.22
Egress Time (β_{it2})	–	–	–	-0.0034	0.0008	-4.07
Travel Time Bus (β_{it3_b})	-0.0024	0.0006	-3.78	-0.0024	0.0006	-3.70
Travel Time Train (β_{it3_t})	-0.0016	0.0007	-2.36	-0.0017	0.0007	-2.52
Travel Time Air (β_{it3_a})	-0.0065	0.0016	-4.16	-0.0060	0.0016	-3.75

Train-to-Bus Shift Inertia (β_{\max_b1})	-0.3970	0.1229	-3.23	-0.2800	0.1251	-2.24
Air-to-Bus Shift Inertia (β_{\max_b2})	-3.0438	0.1655	-18.39	-2.8966	0.1702	-17.02
Bus-to-Train Shift Inertia (β_{\max_t1})	-1.5832	0.1181	-13.41	-1.6249	0.1199	-13.56
Air-to-Train Shift Inertia (β_{\max_t2})	-2.9264	0.1689	-17.32	-2.8626	0.1698	-16.86
Bus Travel Frequency ($\beta_{\text{freq}1}$)	0.0076	0.0028	2.67	0.0062	0.0029	2.16
Train Travel Frequency ($\beta_{\text{freq}2}$)	0.0184	0.0421	0.44	0.0192	0.0424	0.45
Air Travel Frequency ($\beta_{\text{freq}3}$)	-0.0009	0.0018	-0.53	-0.0016	0.0018	-0.86
Bus Travelers' Middle Income ($\beta_{\text{inc_b_mid}}$)	-1.2956	0.1481	-8.75	-1.1934	0.1480	-8.06
Bus Travelers' High Income ($\beta_{\text{inc_b_high}}$)	-0.9591	0.1327	-7.23	-0.8952	0.1327	-6.75
Train Travelers' Middle Income ($\beta_{\text{inc_t_mid}}$)	-1.1817	0.1485	-7.96	-1.1141	0.1478	-7.54
Train Travelers' High Income ($\beta_{\text{inc_t_high}}$)	-1.2253	0.1357	-9.03	-1.1869	0.1362	-8.71
Model Summary	Without Access–Egress Variables		With Access–Egress Variables			
Number of Observations	1416		1416			
Initial Log-Likelihood	-4709.796		-4709.796			
Final Log-Likelihood	-3537.484		-3476.735			
McFadden's R²	0.249		0.262			
Adjusted R²	0.245		0.257			

The effect of incorporating access and egress variables on the mode choice model was evaluated using a likelihood ratio (Chi-square) test. A likelihood ratio test comparing models with and without access–egress attributes demonstrates significant behavioral improvement. An extended Mixed Multinomial Logit Model (MMNL) is being developed to explain unobserved heterogeneity, and the performance of the MNL and MMNL models will be compared in the subsequent analysis. The model without access–egress variables had a final log-likelihood of -3537.484, while the model with these variables improved to -3476.735. Using the Chi-square test, the improvement in fit can be quantified as $\chi^2 = -2 \times (\text{LL}_{\text{without}} - \text{LL}_{\text{with}}) = 121.50$ with 4 degrees of freedom, which is far greater than the critical value of 9.488 ($p < 0.05$), indicating a highly significant improvement. Moreover, the Adjusted McFadden R² rose by 0.245 to 0.257 as well which indicates that the model did show a substantial improvement in the explanatory power as well as a better-representation of observed mode choice behavior when access and egress variables were added. The income effects are strong in both specifications of the model. Income effects also play a major role, and the negative coefficients of bus and train users suggest that more income will reduce the likelihood of using these transport methods, which, in turn, will prefer air transport.

Table 7 presents the sensitivity analysis of the mode shares before and after the addition of the access and egress factors to the MNL model. Results show a steep change in modes when the factors are put into consideration, which means that the travelers are sensitive to changes in the overall trip cost. Bus usage decreased from 47.66% to 38.58%, reflecting reduced preference due to higher first- and last-mile burdens, while train usage increased from 39.36% to 47.73%, indicating improved attractiveness when access and egress conditions were favorable. Similarly, air mode share rose from 12.98% to 13.69%, mainly among higher-income travelers who value time savings despite higher fares.

Table 7: Comparison of Primary, SP Choice and Modeled Mode Share

Category	P_{bus}	P_{train}	P_{air}
Primary Mode Share	47.66%	39.36%	12.98%
SP Choice Mode Share	38.06%	43.65%	18.29%
Modeled (Predicted) Mode Share	38.58%	47.73%	13.69%

Model validation was conducted through the comparison of the mode shares that are predicted with the estimated choice model with the observed stated preference (SP) shares. Root means square error

(RMSE) was used to determine the predictive accuracy. The RMSE obtained is low (3.56), thus indicating that the error of prediction is small. These results showed that the model can reproduce known SP choices, the proper modal ranking, as well as providing decent predictive accuracy, which shows the effectiveness of the model in making predictions on mode choice patterns.

7. CONCLUSION

This paper examined the role of ground access and egress factors on intercity mode choice behavior on the Sylhet-Dhaka corridor using a Multinomial Logit (MNL) model. The results point out that access and egress conditions that determine the first and the last miles of a journey are key determinants of the choices made by the travelers that are not solely based on the in-vehicle factors like travelling time and cost. The baseline MNL model that omitted the access and egress factors gave a fair fit, though the addition of the two variables did improve model performance significantly, where the adjusted McFadden's R^2 value ranged between 0.245 and 0.257. The negative and significant coefficients of access cost, egress cost, access time, and egress time proved that travelers are very sensitive to the total trip convenience. Mode shares sensitivity analysis also found that there was a significant modal change after consideration of these elements; the bus utilization decreased, and the train and air utilization grew as a result of the increasing preference of modes with excellent first- and last-mile connectivity. The income effects also indicated that travelers who have higher incomes prefer air travel more than low-income individuals who use buses and trains. Findings also reiterate the need to enhance intermodal integration and accessibility of terminals by policymakers and planners in order to enhance sustainable and fair mobility. One of the limitations of the study is that the D-coefficient design of SP card generation was not applied with the help of specific design software, and the research in the future may utilize a Mixed Multinomial Logit (MMNL) model to represent unobserved heterogeneity and compare the performance of MNL and MMNL models. Therefore, an improved intercity transport system in Bangladesh can be made more attractive by improving the cost of travel over the last-mile distance, the connectivity of stations, and making feeder networks more appealing, which will result in more efficient and inclusive intercity transport.

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9. DECLARATION OF USE OF AI

Grammarly and Artificial intelligence-based tools were used solely for language editing purposes to improve grammar, clarity, and readability of the manuscript. The research conception, methodological design, data collection, statistical analysis, model estimation, and interpretation of results were performed entirely by the authors without the use of AI tools. An originality assessment using Turnitin indicates that the proportion of AI-assisted writing is around 15%, while the overall similarity index is around 10%, confirming the originality and human authorship of the work. The use of AI tools did not influence the scientific content, analytical procedures, or conclusions of the study.

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