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Analysis of Mode Reliability Factors among Off-campus Students using Structural Equation Modelling in Dhaka City †.

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Abstract: Determining the mode choice for movement in developing cities like Dhaka is beset with multifaceted challenges and intricacies, rendering it an arduous undertaking. Numerous factors contribute to the complexity, thereby impeding the selection of an optimal transportation mode. Bangladesh University of Engineering & Technology (BUET) attracts students from various regions and cultures in Dhaka city. Examining users' perceptions of preferred mode choice is the primary objective of this study. Transportation performance of buses and institutional buses were considered as most of the off-campus students are highly dependent on these two modes. Structural equation modeling (SEM) was implemented to create two distinct empirical models to investigate the correlations between key factors that impact public transportation mode choice. Models were calibrated using data of 1664 respondents who were formally surveyed about their expectations, experiences, and opinions regarding their usual means of transportation. There were 20 attributes of travel experience like safety, comfort, cost, travel time, waiting time, convenience, reliability, availability, environment- friendliness, driver behavior, overtaking tendency, vehicle speed, obeying law, accident probability, weather, punctuality of arrival and departure etc. Policy implications have been analyzed in the context of a developing country as Bangladesh from the perceived ratings on mode choice so that by providing reliable, efficient, and student-friendly transportation options; educational institutions, planners, and transportation authorities can support the success and overall well-being of off-campus students.

Keywords: modal analysis; structural equation modeling; mode choice

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1. Introduction

A relatively specialized area of transportation study, analysis of student travel behavior examines how students commute to and from institutions as well as for other objectives such as extracurricular activities, employment, and social engagements. Educational Institutions are in a prime position to lead in the sustainable transportation sector [1]. Off-campus students are highly dependent on either public buses or institutional buses for their day-to-day commute. The STP (2005) stated that the modal share of trips on public transport in capital of Bangladesh, Dhaka is about 44%. Dhaka has announced its intentions to introduce route clusters to enhance the reliability of its bus services. Despite numerous plans and initiatives, the city continues to grapple with the challenge of achieving a dependable bus service [2]. Hence assessing reliability and mode preferences is vital at this stage. To design policies and infrastructure that can assist to lessen

congestion and shorten travel time, transportation planners can get insight into the special mobility needs of this demographic by examining the mode preferences of students.

Individual mode preferences vary according to numerous reasons. Students, especially university students, are more versatile than others in mode choice. Since they are independent on campus and make their own daily decisions, they have complicated and diverse travel behavior. They live, study, and socialize with different types of students and so their preferences of mode frequently are influenced by others [3]. At McMaster University, Canada, students' mode choice depends on factors like cost, environment, and attitude; longer travel times reduce car and bicycle preference [4]. In Sylhet, Bangladesh, 43% of university students choose walking/cycling (Active mode), while 57% opt for motorized/non-motorized vehicles (Passive mode) for travel [5]. Another study examines mode choices for school travel among university members in New Delhi, revealing differences in vehicle ownership based on residence; parents' higher education discourages walking/bicycling; and regardless of safety perception, private vehicles are preferred, particularly by mothers [6]. In another study of Abbottabad, Pakistan, gender based mode choice preferences are analyzed. [7]. One study in Los Angeles shows university students' multimodal behavior; discounted transit passes decrease car use, while factors like commute distance, gender, and social proximity influence commuting choices [8]. Key findings from a study of six universities in Vietnam show that characteristic of students such as age, gender and income have a significant impact on their mode choice decision [9].

A mode choice behavior study of students in University of Asia Pacific, Dhaka found that for education purpose, a significant percentage of students uses public bus [10]. In a study of University of Central Florida, USA, conducted by DeFrancisco et al. employed structural equation models (SEM) to identify the primary factors impacting the choice to carpool when commuting to a university campus [11].

Therefore, insufficient research on barriers and preferences except socio-demographic factors of students in choosing sustainable transportation modes (public and institutional buses simultaneously), in congested and polluted cities like Dhaka can be acknowledged. This SEM study compares public and institutional bus transportation services for off-campus students to identify reliability variables and barriers, with policy implications for promoting sustainable modal shift, reducing carbon emissions and congestion, and improving quality of student life.

2. Methodology

2.1. Data Collection and Demographic of Respondents'

The data collection method was mainly an offline questionnaire survey. It was tried to sort out constraints by giving brief descriptions to the respondents and incorporating translations to Bangla (native language) for better interpretation. After filtering and eliminating anomalies, 1664 sets of data were selected for analysis. The rating of each observed variable was arranged according to Table 1. Moreover, socio-demographic data on age, gender, payment method, and arrival time were also amalgamated.

Table 1. Variable Considered for Survey with Qualitative Scale for Parameters.

Variable Name [1]	Qualitative Scale	Variable Name [1]	Qualitative Scale
Vehicle Quality	Very bad quality to very good quality	Vehicle Speed	Lowest speed to highest speed
Arrival Punctuality	Very low to very high punctuality	Availability	Never to very frequently available
Driver Behavior	Very bad to very good behavior	Travel Cost	Highest cost to lowest cost
Departure Punctuality	Very low to very high punctuality	Waiting Time	Highest time to lowest time
Safety	Least safe to highly safe	Travel Time	Highest time to lowest time
Driving Skill	Very poor skill to very good skill	Overtaking	High tendency to Low tendency
Obeying Law	Never obeying to always obeying law	Travel Distance	Shortest to largest Distance
Comfort	Least to highly comfortable	Accident Proneness	Highest accident to least accident
Convenience	Least to highly Convenient	Weather	High effect of weather to no effect
Env. Friendliness	Least to highest friendliness		of weather

[1] Numerical Scale for All Variables are 1 to 5.

The percentage of male participants is 68.4% and the percentage of female participants is 31.6%. This disparity is attributed to higher participation and representation of male students at engineering universities in the context of developing country like Bangladesh.

2.2. SEM Model

SEM (Structural Equation Modeling) was implemented to develop structural relationship between observed and latent variables. This method combines confirmatory factor analysis and path analysis with appropriateness for determining latent constructs from observed questionnaire variables and assessment of the association between unobserved and target variable. SEM, however, performs well when the sample size exceeds 200 [12]. A general rule of thumb is that the simple size to the number of observed parameters might range from 5 to 1 [13] to 20 to 1 [14]. Considered sample sizes for each model satisfied all the above requirements. The model consists of 20 observed variables and two latent variables and among the 20 observed variables, Reliability is considered as target variable. The observed variables are vehicle quality, arrival punctuality, driving behavior, departure punctuality, safety, driving skill, obeying of law, comfort, convenience, environment friendliness, vehicle speed, availability, travel cost, waiting time, travel time, overtaking, travel distance, accident proneness, weather. The two latent variables are overall transportation experience and travel hassle. Principal Component Analysis was carried out with VARIMAX rotation using SPSS 16.0 package. After the factor analysis, insignificant precursor for determining reliability of bus modes "Travel Cost "was eliminated. It may be because of the very lower rate of cost for students in both institutional and public bus services. Additionally, institutional buses receive subsidies from either educational institutions or the government. Therefore, it was proved as an insignificant precursor for determining reliability of bus modes.

However, the factor analysis can be considered acceptable according to the Kaiser-Meyer-Olkin (KMO) measure and the Barlett's Sphericity Test. This factor analysis can be considered appropriate according to the KMO value (Table 2) and the Bartlett's Sphericity test was also found significant (Table 2). KMO values are classified as "Great" between 0.8 to 0.9 and factor analysis is significant when $p<0.05$ [15]. Later structuring SEM models with target variable "Reliability" along with other observed variables, were completed on STATA13 and models were run for the results. Results for both models are illustrated in Figure 1, Figure 2, Table 3 and Table 4. Models were used to determine the associations between the target variable and other latent and observable variables. The two-tailed t-test with a 95% confidence interval was employed to verify the significance of a parameter. The models underwent a goodness of fit test as well; the results are displayed in Table 5. The values were in line with the accepted values.

3. Results and Discussion

3.1. Factor Analysis

Confirmatory Factor analysis (CFA) was used to reduce the twenty observed variables into smaller sets of factors. Two factors were extracted from the factor analysis. The findings showed that 45.983% of the variation could be explained. After factor analysis, observed variables were clustered into two latent attributes: "Overall Transportation Experience" and "Travel Hassle".

Table 2. KMO and Bartlett's Test.

Measures	**Analysis Values**	[15] **Standard**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.826	0.8-0.9
Bartlett's Test of Sphericity Approx. Chi-Square	0.0002	<0.05

3.2. SEM Model: Reliability of Public Bus

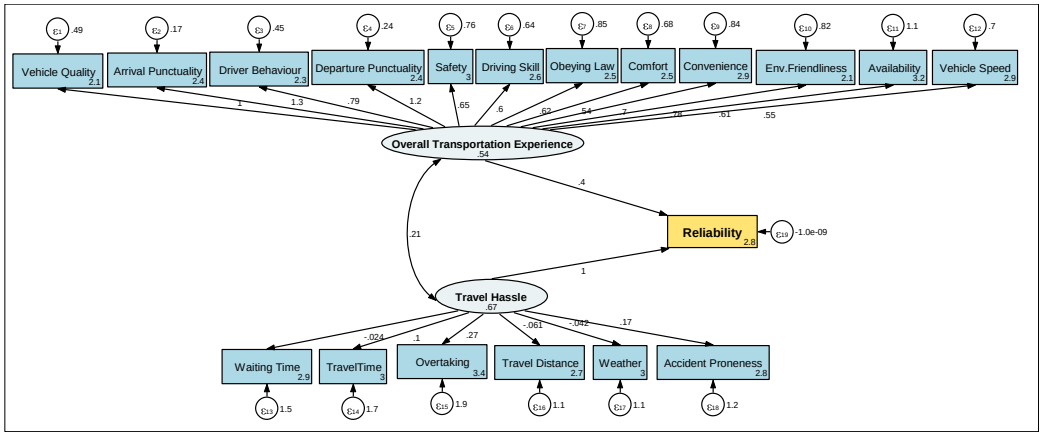

Figure 1. Reliability Model for Public Bus.

Table 3. Model Outputs (Public Bus).

Latent Variables	Observed Variables	Parameters Estimated from Model			Rank
		Coefficient	z-value	p-value	
Overall Transportation Experience	Vehicle Quality	1.000	-	-	3
	Arrival Punctuality	1.304	26.85	0.000	1
	Driver Behavior	0.791	19.54	0.000	4
	Departure Punctuality	1.214	25.44	0.000	2
	Safety	0.652	13.29	0.000	7
	Driving Skill	0.600	13.82	0.000	10
	Obeying Law	0.619	12.71	0.000	8
	Comfort	0.544	12.45	0.000	12
	Convenience	0.699	13.83	0.000	6
	Env. Friendliness	0.777	15.56	0.000	5
	Vehicle Speed	0.554	12.56	0.000	11
	Availability	0.605	10.76	0.000	9
Travel Hassle	Waiting Time	-0.024	-0.44	0.662	6
	Travel Time	0.105	1.49	0.135	4
	Overtaking	0.272	3.25	0.001	2
	Travel Distance	-0.614	-1.33	0.183	1
	Accident Proneness	0.167	3.27	0.001	3
	Weather	-0.042	-0.88	0.381	5
Observed Variables	**Latent Variables**	**Coefficient**	**z-value**	**p-value**	**Rank**
Reliability	Overall Transportation Experience	0.401	2.51	0.012	2
	Travel Hassle	1.000	-	-	1

3.3. SEM Model: Reliability of Institutional Bus

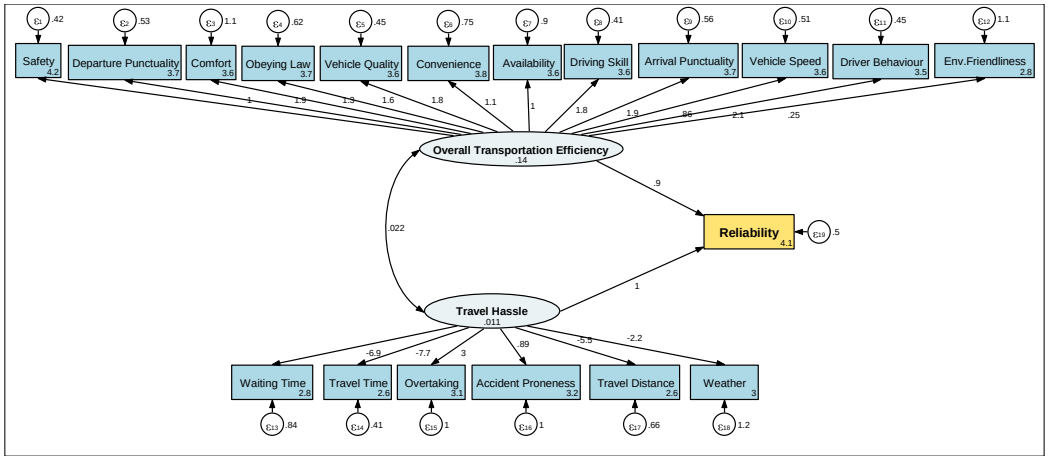

Figure 2. Reliability Model for Institutional Bus.

Table 4. Model Outputs (Institutional Bus).

Latent Variables	Observed Variables	Parameters Estimated from Model			Rank
		Coefficient	z-value	p-value	
Overall Transportation Experience	Safety	1.000	-	-	11
	Departure Punctuality	1.850	12.97	0.000	2
	Comfort	1.331	10.23	0.000	8
	Obeying Law	1.600	12.40	0.000	7
	Vehicle Quality	1.795	13.47	0.000	6
	Convenience	1.111	10.14	0.000	9
	Availability	1.033	9.11	0.000	10
	Driving Skill	1.843	13.75	0.000	5
	Arrival Punctuality	1.883	13.02	0.000	3
	Vehicle Speed	0.865	9.56	0.000	4
	Driver Behavior	2.053	13.80	0.000	1
	Env. Friendliness	0.254	2.46	0.014	12
Travel Hassle	Waiting Time	-6.858	-2.66	0.008	2
	Travel Time	-7.686	-2.64	0.008	1
	Overtaking	3.019	2.54	0.011	4
	Accident Proneness	0.890	1.73	0.084	6
	Travel Distance	-5.483	-2.59	0.010	3
	Weather	-2.225	-2.31	0.021	5
Observed Variables	**Latent Variables**	**Coefficient**	**z-value**	**p-value**	**Rank**
Reliability	Overall Transportation Experience	0.903	8.24	0.000	2
	Travel Hassle	1	-	-	1

3.4. Model Interpretation

In the SEM model of public bus (Figure 1, Table 3) waiting time (p=0.662), travel time (p=0.135), travel distance (p=0.183), weather (p=0.381) were emerged as insignificant precursors for predicting reliability. However, in the SEM model of Institutional bus (Figure 2, Table 4), only accident proneness (p=0.084) was found to be insignificant precursor. Waiting times and travel times have little bearing on public bus network reliability because, as a developing nation, Bangladesh struggles to maintain an effective transportation infrastructure. In addition, bus schedules are impacted by poor road conditions, high urban densities, mechanical issues, rising population densities, traffic congestion, and so, a general perception among students has been formed that these issues are common and far beyond the control of administration. Therefore, due to tolerance, lower expectations than developed countries and limited affordability to use other modes, waiting and travel time is not a striking indicator for predicting reliability of public buses. Moreover, travel distance is also insignificant precursor for reliability of public buses because in developing countries like Bangladesh, bus routes are relatively shorter having less variability in travel distance. Besides, bus systems operate in fixed routes and between frequent predetermined stops. As in Bangladesh, weather condition is not extreme and there are better adaptive systems of buses, weather is perceived as an insignificant indicator of reliability. However, waiting time, travel time, travel distance, weather are significant indicators for the model of institutional bus (Figure 2) because there are more expectations of students from institutional bus services regarding these issues. Accident proneness was proved to be insignificant for the model of institutional bus services because there is ingrained reliability among students from the institutional bus services to be accident free.

In the models of public bus (Figure 1, Table 3) and institutional bus (Figure 2, Table 4), latent variable travel hassle impacts reliability more than transportation experience. Overtaking (Coeff. 0.272, Table 3), accident proneness (Coeff. 0.167, Table 3), were the influencing precursors of travel hassle impacting reliability in model for public buses. Less accident proneness and overtaking tendency enhance the reliability of using bus services. In Bangladesh, bus accident is severe where there are lack of police control and median [16]. For the lack of law enforcement, accident probability increases and overtaking, over speeding also appear in road network resulting in losing of reliability. Arrival punctuality

(Coeff. 1.304), Departure punctuality (Coeff. 1.214), vehicle quality (Coeff. 1.000) were the top three (Table 3) striking factors of reliability under the latent variable "Overall transportation experience". Punctuality is seen as an important factor in student life and reliability perception is increased among them if the transportation service is punctual. Students are also more concerned about the vehicle quality of public buses for better perception and consciousness.

In the institutional bus model (Figure 2), waiting time, travel time, and travel distance negatively affect reliability because students can access institutional bus services from different remote routes and reach their remote destination from university. Under the latent variable of overall transportation experience driver behavior, departure punctuality, arrival punctuality were influencing reliability more than other observed variables. Vehicle quality was perceived as a mid-ranked influencing factor of reliability. As safety, availability can be ensured properly from university, the influence was lesser from those factors. It was also noticeable that there was proclivity of lesser environmental concern from administration in public bus services than institutional bus services. There was more expectation of vehicle speed, driving skill, comfort in institutional bus services than public bus services according to the models.

3.5. Model Fit

The models have undergone a goodness-of-fit test, and the obtained value indices are presented in Table 5. These values confirm that the model exhibits reasonably favorable fit indices [17].

Table 5. Goodness of Fit.

Fit Indices	Public Bus	Inst. Bus	Standard
Absolute Fit Index			
Root Mean Squared Error of Approximation (RMSEA)	0.065	0.070	0.05- 0.08
Standardized Root Mean Square Residual (SRMR)	0.101	0.050	< 0.1
Incremental Fit Index			
Comparative Fit Index (CFI)	0.825	0.833	0.95
Tucker-Lewis Fit index (TLI)	0.784	0.810	0.95

4. Conclusions

Based on the findings of this research, it is evident that users of both public buses and institutional buses are primarily concerned with issues related to travel inconvenience. To enhance the reliability of these modes of transportation, it is imperative to prioritize factors such as optimizing routes, improving the efficiency of boarding and alighting, minimizing travel time and distance in public services, and effectively managing driver behavior and attitude. Developing efficient and well-planned routes, implementing measures to streamline boarding and disembarking, introducing dedicated lanes for public transportation, minimizing unnecessary detours and distances for users, enforcing strict training, monitoring protocols for drivers to ensure safe and customer-oriented behavior, and prioritizing facilities according to the convenience of the students from survey can be accomplished by policy makers and urban planners to introduce a reliable and sustainable transportation mode for students in a developing country like Bangladesh.

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