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Capturing Behavioral Nonlinearity in BRT Uptake at Sylhet City of Bangladesh

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Abstract Sylhet is one of the rapidly growing cities of Bangladesh with a population density of more than 20,000 people per square kilometer. However, no sustainable public transport is available in the city resulting in the worsening of traffic conditions day by day. In this situation, the implementation of a suitable public transport system like BRT (Bus Rapid Transit) can improve the situation. Before implementing a new transport mode in the city, a proper understanding of the people's preferences and perceptions is needed. Therefore, this study aimed to estimate the mode choice model based on Stated Preference (SP) data to understand the driving factors of BRT uptake in Sylhet city. In addition, the driving factors of choice may have nonlinear relation with the change in preferences. Therefore, this study is focused to capture the behavioral nonlinearity (changes in the BRT preferences due to changes in the attributes level) in the mode choice preferences of Sylhet city dwellers. From the model, it is observed that people's preference is not shifting linearly in response to the changes in the attributes level (travel time, travel cost, frequency, stoppage distance, and stoppage facilities) of the new travel mode. This study's findings can be useful in policy formulating for implementing BRT in Sylhet or any other similar cities.

Keywords: *BRT uptake, multinomial logit model, stated preference survey, Sylhet city, traffic congestion*

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1. Introduction

Sylhet city corporation is the fourth largest city corporation in Bangladesh in respect of population [1]. Rapid urbanization and a high migration rate resulted in a higher population growth rate in the city with a consequence of a sharp increase in the number of vehicles on the city roads. Among all the vehicles operating in the Sylhet city area, the CNG (Compressed Natural Gas) auto-rickshaw, rickshaw, and motorcycle constitute the major share [2]. These modes are very popular due to accessibility, flexibility of movement, easy and unimpeded lane movement, low operating and maintenance cost, and the feeling of using a personal vehicle [3,4]. However, the growth of these vehicles in urban areas where the population density is high can be a big barrier to the development of a sustainable transport system. Due to low occupancy and a higher level of speed variations, these vehicles reduce the roadway capacity significantly increasing the traffic congestion level. The existing city roads have been underutilized due to the presence of floating shops, mobile hawkers, artisans, and temporary traders [5]. Besides, the unplanned development of the city reduced the scope of the further widening of the road networks or creating alternate routes. Therefore, in the next 10 to 20 years, the city's traffic condition is anticipated to deteriorate dramatically due to the large volume of uncontrolled and mixed traffic unless a sustainable transport policy is adopted soon.

A mass transit system (Bus Rapid Transit, Metro Rail) or transit-oriented development has successfully been adopted in many cities in developed and developing countries to minimize the urban transport problem. Mass transit can facilitate many people at a time to travel from one place to another place, therefore, it increases the capacity of the existing road network. For instance, the capacity of a single-lane road occupied by cars only is 2000 passengers per hour per direction which is 9000 for regular buses, and 22000 for rail [6]. Although mass transit in the urban cities in Bangladesh is not an attractive option due to poor service quality, low to middle-income people are considering it as an affordable option. More improved mass transit service (BRT, Metro Rail) is being implemented in Dhaka to minimize the traffic congestion in the city [7]. However, the narrow road link and less flexibility of further widening of the road due to roadside development are not allowing to connect a larger portion of the city to the improved mass transit system offsetting the full benefit to achieve [8]. Although a few small buses are running on a few selected roads in Sylhet city, mass people are not considering them as a suitable option to choose from. A few studies have investigated travel demand and mode choice preferences in Sylhet city [9,10,11]. There are few studies that investigated BRT feasibility and developed a mode choice model for BRT preference in Dhaka city [12,13,14]. However, none of these studies have exclusively captured the behavioral nonlinearity in the mode choice preference in the case of Dhaka or Sylhet.

2. Materials and Methods

2.1. Preliminary Survey

A preliminary survey was carried out to investigate major attributes of different transportation mode uptake and to get an understanding of the upper and lower limits of attribute levels for SP survey design. A preliminary survey was conducted on 40 people (online survey). Based on the findings from the preliminary survey, eight attributes such as travel time, travel cost, frequency, stoppage, deck, comfort, stoppage facilities, and security were found most influential.

2.2. Stated Preference Survey Design

Design of SP survey is required to capture the future choice preference for BRT. A choice experiment was used for the SP survey design. For the final survey, the level of each variable was determined based on the findings of the preliminary survey.

In the choice experiment, respondents select an ideal mode from hypothetical choice scenarios based on their socio-demographic condition. The partial factorial method was used to develop the choice set of these attributes in statistical software "SPSS". The choice scenarios presented to the respondents comprised of BRT, CNG auto-rickshaw, and other modes. The stated preference survey was conducted on 348 respondents and each respondent was asked for three different scenarios. Therefore, the total number of observations was 1044. Details are presented in Table 1.

2.3. Hypothesis of Attributes

Hypotheses regarding different attributes from the preliminary survey that may have a substantial impact on city transportation mode choice are described in Table 2.

Table 1. BRT Attributes and their Levels

Attributes	Level of attributes of alternate travel modes		
	In BRT	In CNG auto-rickshaw	In Others
Travel cost	30% less price than the current CNG auto-rickshaw	40% more than now	Same as now
	15% less price than the current CNG auto-rickshaw	30% more than now	
	Same price as current CNG auto-rickshaw	20% more than now	
	15% more price than the current CNG auto-rickshaw	Same as now	
	30% more price than the current CNG auto-rickshaw		
Travel time	Same as now	20% more than now	Same as now
	10% less time than the current CNG auto-rickshaw	10% more than now	
	20% less time than the current CNG auto-rickshaw	Same as now	
	30% less time than the current CNG auto-rickshaw		
Frequency	Every 5 minutes	20% less than now	Same as now
	Every 10 minutes	30% less than now	
	Every 15 minutes	40% less than now	
	Every 20 minutes	Same as now	
Stoppage	Every 0.5 km	Same as now	Same as now
	Every 1 km		
	Every 1.5 km		
Deck of BRT	Single-decker	Same as now	Same as now
	Double-decker		
A.C facility	Yes	Same as now	Same as now
	No		
Stoppage facility	Shed facility with timetable display	Same as now	Same as now
	Shed facility without timetable display		
	No shed & no timetable display		
Security camera	No security cameras in BRT	Same as now	Same as now
	Security cameras in BRT		

Table 2. Hypothesis of mode choice attributes

Attributes	Hypothesis
Travel cost	Depending on the mode characteristics, travel cost sensitivity may vary. An increase in travel cost for a particular type of vehicle may reduce the mode's utility.
Travel time	Travel time can be different for different modes of transport. An increase in the travel time is likely to decrease the utility of that specific mode.
Frequency	The frequency of the vehicles also affects mode choice behavior. The utility of any vehicle should decrease as the frequency of that vehicle decreases.
Stoppage	Passengers may have a strong desire to ride a vehicle if it stops frequently, but too many stops increase the travel time, which is undesirable.
Deck type	A double-decker bus can accommodate more people than a single-decker bus. Young people may be more interested in the double-decker. However, elderly people may not be interested in riding the bus on the upper floor.
Air conditioning facility	People prefer to travel in air-conditioned vehicles. However, comfort may not be a major consideration for a short trip.
Stoppage facility	People may choose a shed with a timetable display facility over a shed without a timetable display. Because a timetable display will show BRT's waiting period in real-time. But the preference of shed (with or without timetable) might be more than of not having shed.
Security camera facility	People might have an interest in a CCTV surveillance system.
Vehicle ownership	Passengers who drive their own car or ride motorcycles may not be interested in taking public transportation such as the BRT or CNG auto-rickshaw.

2.4. Model Estimation Technique

In the beginning, a preliminary survey is conducted on the city dwellers to know their perception and desire for mass transit along with their sociodemographic characteristics. Based on the findings from the preliminary survey, a detailed questionnaire survey is conducted where respondents have been presented with new public transport facilities with a better level of services along with the existing travel options. People express whether they will accept the new service, or they will stay with their current preferences even though better public transport is available.

The collected data from the final survey is analyzed using standard statistical tools (e.g. descriptive analysis). The preferences of the respondents regarding their daily travel mode are investigated using the Discrete Choice Modelling technique (DCM). DCM is a widely used tool to analyze consumer choices in which the available options are discrete in nature and mutually exclusive. Multinomial logit (MNL) model from the family of DCM is estimated to estimate the parameters that influence the choice of travel mode including BRT. The basic mathematical formulation of discrete choice analysis is presented below

The utility of an individual n $(n=1\ldots N)$ for mode i $(i=1\ldots I)$ can be expressed as (1)

$$U_{ni} = V_{ni} + \varepsilon_{ni} = \alpha_{ni} + \beta_{ni} x_{ni} + \varepsilon_{ni} \quad (1)$$

Where α is the constant, β is the estimated parameters, x_{ni} are observed variables and ε_{ni} is the error term. If the error term is considered independently and identically distributed extreme value, the probability of individual n choosing alternative i can be presented as follows:

$$P_{ni}(\beta) = \frac{\exp(V_{ni})}{\sum_{i=1}^{j} \exp(V_{nj})} \quad (2)$$

The corresponding log-likelihood function of the model for all the observations is as follows:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i=1}^{I} y_{ni} \ln(P_{ni}(\beta)) \quad (3)$$

Where, $y_{ni} = 1$ if individual n chose zone i and $y_{ni} = 0$ for all other unchosen alternatives. The maximization of this *LL* function yields the maximum likelihood estimates for model parameters.

3. Results

3.1. Descriptive Statistics

The descriptive analysis of the respondents from the final survey is presented in Table 3. The majority of respondents in the survey were male and most of the respondent's ages lie between 20 to 49 years. Low-income and middle-income respondents were found significant compared to high-income respondents. In the case of travel mode choice, CNG auto-rickshaws were the most popular mode of transportation in Sylhet, but motorcycles and private cars were also popular among those who own a vehicle. A significant number of users were found dissatisfied with the current system of transportation.

Table 4 depicts that private car users prefer comfortable rides with less travel time and better security. Motorcycle users are inclined to have less travel time, comfortable rides, and less cost. The users of CNG auto-rickshaw prefer shared mode because of low travel cost, less travel time, and higher availability. Rickshaw users are concerned about comfort facilities, security, and higher availability. Individuals interested in walking are concerned about not paying any cost as well as other reasons (e.g. less travel distance, physical exercise).

In Table 5 respondent's current mode is provided based on socio-demographic characteristics. As CNG auto-rickshaw is the primary public transport system in Sylhet city, most female respondents use CNG auto-rickshaw as their primary mode. Males, on the other hand, prefer to travel in CNG auto-rickshaws, cars, and motorcycles. Females are not interested in driving motorcycle because of the social aspects. CNG auto-rickshaw is the main public transport system in Sylhet city with high frequency and ease of accessibility. Therefore, low-income people are more attracted by CNG auto-rickshaws than other modes. High-income people are attracted by private cars and they are not attracted by CNG auto-rickshaw due to being less comfortable and for security purposes. Middle-income male people have a higher tendency to use motorcycle than public transport. Rickshaws are pretty widely used by individuals of all social strata. Most unmarried respondents have been using CNG auto-rickshaw as their primary mode, while married people mostly use Private Cars, Motorcycle, and CNG auto-rickshaw equally. Since unmarried respondents are younger and have low incomes, they don’t use private cars.

Table 3. Sociodemographic Characteristics of the Respondents in the Final Survey

Characteristics	Distribution (%)
Gender	
Male	71
Female	29
Age (years)	
<19	4
20-29	29
30-39	30
40-49	23
50-59	12
>60	2
Education	
Primary	4
Secondary	16
Higher Secondary	20
Graduate	29
Post Graduate	31
Income	
<20000 BDT	37
20000-40000 BDT	27
40000-60000 BDT	14
60000-80000 BDT	7
80000-100000 BDT	9
>100000 BDT	6
Current travel mode	
Rickshaw	13
CNG auto-rickshaw	33
Private Car	19
Motorcycle	22
Walking	10
Others	3

Table 4. Respondent’s Reasons for Choosing Different Modes

Mode	Reasons
Private Car	Comfort (43%), Less time (26%), Availability (5%), No alternate mode (3%), Security (20%), Others (3%)
Motorcycle	Less time (26%), Comfort (21%), Less cost (17%), Availability (11%), Frequent (6%), No alternate mode (2%), Security (9%), Others (8%)
CNG auto-rickshaw	Less time (27%), Less cost (25%), Availability (19%), Frequent (11%), Comfort (7%), No alternate mode (8%), Security (2%), Others (1%)
Rickshaw	Comfort (24%), Security (21%), Availability (18%), Less time (5%), Less cost (14%), Frequent (8%), No alternate mode (5%), Others (5%)
Walking	No cost (27%), Less time (8%), Comfort (3%), Security (3%), Others (59%)

Table 5. Connection of Current Mode of Transport with Socio-demographic Characteristics

Sociodemographic characteristics	Levels	Choice of different modes (%)					
		CNG auto-rickshaw	Motorcycle	Private car	Rickshaw	Bus	Walking
Gender	Male	25.5	29.5	22.3	7.3	2.4	13
	Female	51.4	2	12.9	27.7	3	3
Income (BDT)	<20000	52.4	14.3	1.6	17.5	2.4	11.9
	20000-40000	34	24.5	5.3	16	2.1	18.1
	40000-60000	30.6	44.9	8.2	10.2	-	6.1
	60000-80000	-	20	72	8	-	-
	80000-100000	6.3	12.5	71.9	6.2	3.1	-
	100000<	-	13.7	72.7	-	13.6	-
Marital status	Married	25.6	24.4	26.8	12.4	2	8.8
	Unmarried	52	14.3	1	15.3	4.1	13.3

3.2. Model Outputs

Discrete choice analysis has been used to develop the mode choice model. Three alternative modes (BRT, CNG auto-rickshaw, and others) have been considered. In the model, mode-specific attributes (travel cost, travel time, frequency, stoppage, deck type, air conditioning facility, stoppage facility, and security camera facility) are used as the independent variable. The socio-economic characteristics of the respondents are used as an interaction with the explanatory variables. Alternate specific constant (ASC) of the BRT, and others have been measured assuming CNG auto-rickshaw as the base. "RStudio" was used for estimation of the model

3.2.1. Testing Linear Relationship of the Explanatory Variables with the Choices

In this model, it is assumed that the change in people's sensitivity to the change in the attributes (travel time, travel cost, frequency, and stoppage distance) of the alternatives is linear. Therefore, these attributes are tested as linear continuous variables. The followings are the utility functions of the alternatives:

$$U_{BRT} = ASC_{brt} + \beta_{tt\_b} * (BRT\ travel\ time)$$
$$+ \beta_{tc\_b} * (BRT\ travel\ cost) + \beta_{fr\_b} * (BRT\ frequency)$$
$$+ \beta_{stp\_b} * (BRT\ stoppage) + \beta_{dk\_b} * (Single\ decker\ BRT)$$
$$+ \beta_{ac\_b} * (BRT\ with\ Air\ conditioning\ facility)$$
$$+ \beta_{stn1\_b} * (Shed\ facility\ with\ timetable\ display)$$
$$+ \beta_{stn2\_b} * (Shed\ facility\ without\ timetable\ display)$$
$$+ \beta_{scrt\_b} * (BRT\ with\ Security\ camera)$$
$$+ \beta_{v\_b} * (vehicle\ owner)$$

$$U_{CNG\ auto-rickshaw}$$
$$= \beta_{tt\_c} * (CNG\ auto-rickshaw\ travel\ time)$$
$$+ \beta tc\_c * (CNG\ auto-rickshaw\ travel\ cost)$$
$$+ \beta\ fr\_c * (CNG\ auto-rickshaw\ frequency)$$
$$+ \beta v\_c * (vehicle\ owner)$$
$$+ \beta_{inc} * (income\ less\ than\ 20\ thousand\ BDT)$$

$$U_{OTHERS} = ASC_{OTHERS}$$

In Table 6 the estimated model parameters are presented. The estimated coefficients indicate that BRT is the most preferred mode if all else is equal. Coefficients of travel cost and travel time for BRT have given negative signs as expected. BRT travel cost, BRT frequency, BRT stoppage can be considered significant as its *t*-statistic is greater than 1.96 at 95% confidence level and travel time is greater than 1.65 at 90% confidence level. Increased travel costs, travel time, frequency, stoppage would decrease the utility of each mode individually.

Although the CNG auto-rickshaw travel time coefficient is negative, it is insignificant. This is because the CNG auto-rickshaw is the cheapest and most widely used mode of transportation in Sylhet city. Due to the lack of public transportation in Sylhet city, people do not have any other cheap mode available. Passengers who use CNG auto-rickshaw belong to the low-income category and most likely do not possess a car or motorcycle. Also, the travel time of the rickshaw is much higher than the CNG auto-rickshaw. As a result, increased travel time will not encourage them to switch from CNG auto-rickshaw to another mode. The model also revealed that the deck type isn't a huge factor for BRT uptake. Because the bottom floor of BRT can be used by any group of people if it is not entirely occupied.

Table 6. Model Results with Linear Estimates of the Explanatory Variables

Type of variables	Parameters	Estimated Values	t-statistics
Constants	ASC_{BRT}	3.5193	7.69
	ASC_{OTHERS}	-1.5641	-5.28
	$ASC_{CNG\ auto-rickshaw}$	Base	N/A
BRT	Travel time (β_{tt_b})	-0.0124	-1.83
	Travel cost (β_{tc_b})	-0.022	-6.17
	Frequency (β_{fr_b})	-0.1348	-9.3
	Stoppage (β_{stp_b})	-2.0182	-10.54
	Single decker (β_{dk_b})	-0.0065	-0.04
	Air conditioning facility (β_{ac_b})	-0.1192	-0.75
	Shed facility with timetable display (β_{stn1_b})	0.4994	2.79
	Shed facility without timetable display (β_{stn2_b})	0.2609	1.46
	Security camera (β_{scrt_b})	0.0727	0.46
	Vehicle owner (β_{v_b})	-2.1705	-11.85
CNG auto-rickshaw	Travel time (β_{tt_c})	-0.0045	-0.39
	Travel cost (β_{tc_c})	-0.0335	-5.08
	Frequency (β_{fr_c})	0.0115	1.72
	Vehicle owner (β_{v_c})	-3.5904	-11.75
	Income less than 20 thousand BDT (β_{inc})	0.4517	2.29
Goodness of fit parameters			
No. of estimated parameters		17	
No. of observation		1044	
Initial log-likelihood		- 1146.95	
Final log-likelihood		- 746.08	
Adjusted Rho-Square		0.349	

The majority of the respondents were unlikely to be interested in an air conditioning system. This could be because of the shorter travel distance as the city is small and has relatively less congestion in the road network. The shed facility with the timetable display had caught people's interest. This is because passengers will know when the next BRT will arrive and how much time they will have to wait. People who own a car or a motorcycle were less likely interested in BRT or CNG auto-rickshaw. This is due to people's preference for private transportation over public transportation. However, Compared to CNG auto-rickshaws, vehicle owners would be 140 percent more favorably sensitive to BRT.

3.2.2. Testing Nonlinear Relationship of the Explanatory Variables with the Choices

In this model, it is assumed that the change in people's sensitivity to the change in the attributes (travel time, travel cost, frequency, and stoppage distance) of the alternatives is nonlinear. Therefore, these attributes are used as categorical variables to estimate people's sensitivity to different levels of attributes.

After developing both models, the Likelihood Ratio test was performed to examine the goodness of fit of the second model, and the Chi-square value for the 99.99 percent confidence interval rejects the null hypothesis of the linear sensitivity MNL model. As a result, it can be stated that the model developed utilizing categorical variables is the best-fitted model. Table 7 indicates that a 30% increase in travel costs is found to decrease the utility of BRT, and a 30% decrease in travel costs is found to increase the utility. However, the sensitivity of a 30% increase in travel cost is twice as negative as the sensitivity of a 30% decrease in travel cost. This indicates that people are more sensitive to increasing travel costs than decreasing.

It is also seen that passenger's sensitivity towards BRT declines linearly for 10 and 15-minute frequency, but it declines exponentially for 20-minute frequency. When the frequency period is doubled, the sensitivity is reduced by four times. The 20-minute interval BRT frequency is the least appealing to passengers, whereas the 5-minute interval is the most acceptable. Passengers are least interested in the 1.5-kilometer interval stoppage. 0.5-kilometer interval stoppage is found most attractive. The drop of utility for increasing the stoppage distance from 1 km to 1.5km is twice the drop of utility due to an increase in the stoppage distance from 0.5 km to 1 km. Therefore, the change in the utility with the change in the stoppage distance is nonlinear.

Table 7. Model Results with Nonlinear Estimates of the Explanatory Variables

Type of variables	Parameter's coefficient	Estimated Values	t-statistics
Constants	ASC_{BRT}	1.5784	3.02
	ASC_{OTHERS}	-1.4914	-3.3
	$ASC_{CNG\ auto\text{-}rickshaw}$	Base	N/A
BRT	Travel time decreased 20% & more($\beta_{tt\text{-}20\_b}$) (Base: 0)	0.5408	2.84
	Travel time 10% decrease ($\beta_{tt\text{-}10\_b}$) (Base: 0)	0.2774	1.27
	Travel cost 30% increase (β_{tc30_b}) (Base: 0)	-1.2252	-4.9
	Travel cost 15% increase (β_{tc15_b}) (Base: 0)	-0.0846	-0.35
	Travel cost 15% decrease (β_{tc15_b}) (Base: 0)	0.2844	1.22
	Travel cost 30% decrease ($\beta_{tc\text{-}30\_b}$) (Base: 0)	0.5538	2.48
	Frequency 10 minutes (β_{fr10_b}) (Base: 5 minutes)	-0.5894	-2.6
	Frequency 15 minutes (β_{fr15_b}) (Base: 5 minutes)	-1.0328	-4.62
	Frequency 20 minutes (β_{fr20_b}) (Base: 5 minutes)	-2.1495	-8.78
	Stoppage 1 km (β_{stp1_b}) (Base: 0.5km)	-0.5472	-3.05
	Stoppage 1.5 km ($\beta_{stp1.5\_b}$) (Base: 0.5km)	-2.0401	-10.44
	Single decker (β_{dk_b}) (Base: double decker)	0.0982	0.61
	Air conditioning facility (β_{ac_b}) (Base: No A.C facility)	-0.1282	-0.80
	Shed facility with timetable display (β_{stn1_b}) (Base: no shed & no timetable display)	0.4272	2.37
	Shed facility without timetable display (β_{stn2_b}) (Base: no shed & no timetable display)	0.2295	1.22
	Security camera ($\beta_{scrt\_b)}$ (Base: No security camera)	0.0814	0.51
	Vehicle owner (β_{v_b}) (Base: No vehicle owner)	-2.2148	-11.62
CNG auto-rickshaw	Travel time increased 10% & more (β_{tt10_c}) (Base: 0)	-0.0725	-0.33
	Travel cost 20% increase (β_{tc20_c}) (Base: 0)	-0.3472	-1.18
	Travel cost 30% increase (β_{tc30_c}) (Base: 0)	-1.0322	-3.16
	Travel cost 40% increase (β_{tc40_c}) (Base: 0)	-1.3693	-4.10
	Frequency 20% decrease ($\beta_{fr\text{-}20\_c}$) (Base: 0)	-0.4288	-1.40
	Frequency decreased 30% & more ($\beta_{fr\text{-}30\_c}$) (Base: 0)	-0.4428	-1.73
	Vehicle owner (β_{v_c}) (Base: No vehicle owner)	-3.6285	-10.70
	Income less than 20 thousand BDT (β_{inc}) (Base: More than 20 thousand BDT income)	0.4022	1.88
Goodness of fit parameters			
No. of estimated parameters		27	
No. of observation		1044	
Initial log-likelihood		-1146.95	
Final log-likelihood		-730.09	
Adjusted Rho-Square		0.363	
Likelihood ratio test		32	
Chi-square stat (10, 0.001)		29.58	

3.2.3. Testing Sensitivity Differences of Different Demographic Groups to the Choice Attributes

This model has been estimated to investigate the sensitivity differences of different demographic groups to different levels of attributes. Therefore, the explanatory variables are interacted with the socioeconomic dummy. Estimated model outputs are presented in Table 8.

According to the model results (Table 8), Passengers without a personal vehicle are strongly opposed to a 30% increase in price over the existing CNG auto-rickshaw fare. Passengers who own a personal vehicle, on the other hand, have half the negative sensitivity to a 30% increase in price than individuals who don't own a personal vehicle. This could be because people having personal vehicles have a decent source of income that allows them to afford a 30% price increase. A statistically significant difference was not found in this comparison.

Both male and female genders are pretty much equally sensitive to BRT frequency. The difference in sensitivity towards stoppage for both male and female is also negligible. Hence, it can be stated that male and female attitudes toward stoppage and frequency are nearly the same.

It has also been explored that after the deployment of BRT if the fare for CNG auto-rickshaws increases from 30% to 40%, high-income individuals (income more than 20,000BDT) are more likely to switch from CNG auto-rickshaws to other modes than low-income people.

Table 8. Model Results that Captured Sensitivities of Different Demographic Groups

Type of variables	Parameter's coefficient	Estimated Values	t-statistics
Constants	ASC_{BRT}	1.9194	3.09
	ASC_{OTHERS}	-1.4293	-1.68
	$ASC_{CNG\ auto\text{-}rickshaw}$	Base	N/A
BRT	Travel time decreased 20% & more($\beta_{tt\text{-}20\_b}$)	0.5712	2.81
	Travel time 10% decrease ($\beta_{tt\text{-}10\_b}$)	0.2743	1.23
	Travel cost 30% increase, personal vehicle (β_{tc30_b})	-0.7247	-1.67
	Travel cost 30% increase, No personal vehicle (β_{tc30_b})	-1.6174	-4.11
	Travel cost 15% increase, personal vehicle (β_{tc15_b})	-0.4259	-1.05
	Travel cost 15% increase, No personal vehicle (β_{tc15_b})	-0.2609	-0.54
	Travel cost 15% decrease, personal vehicle ($\beta_{tc\text{-}15\_b}$)	0.4863	1.22
	Travel cost 15% decrease, No personal vehicle ($\beta_{tc\text{-}15\_b}$)	0.1029	0.28
	Travel cost 30% decrease, personal vehicle ($\beta_{tc\text{-}30\_b}$)	0.8265	2.12
	Travel cost 30% decrease, No personal vehicle ($\beta_{tc\text{-}30\_b}$)	0.319	0.79
	Frequency 10 minutes, male (β_{fr10m_b})	-0.345	-1.11
	Frequency 10 minutes, female (β_{fr10f_b})	-1.1017	-2.3
	Frequency 15 minutes, male (β_{fr15m_b})	-1.0204	-3.24
	Frequency 15 minutes, female (β_{fr15f_b})	-0.9843	-1.78
	Frequency 20 minutes, male (β_{fr20m_b})	-2.186	-5.97
	Frequency 20 minutes, female (β_{fr20f_b})	-2.2108	-3.98
	Stoppage 1 km, male (β_{stp1m_b})	-0.6044	-2.49
	Stoppage 1 km, female (β_{stp1f_b})	-0.4997	-1.51
	Stoppage 1.5 km, male ($\beta_{stp1.5m\_b}$)	-2.0669	-7.67
	Stoppage 1.5 km, female ($\beta_{stp1.5f\_b}$)	-2.1222	-5.96
	Single decker (β_{dk_b})	0.0789	0.49
	Air conditioning facility (β_{ac_b})	-0.1398	-0.85
	Shed facility with timetable display (β_{stn1_b})	0.4634	2.44
	Shed facility without timetable display (β_{stn2_b})	0.2826	1.42
	Security camera (β_{scrt_b})	0.0832	0.51
	Vehicle owner (β_{v_b})	-2.7864	-7.01
CNG auto-rickshaw	Travel time increased 10% & more (β_{tt10_c})	-0.0717	-0.3
	Travel cost 20% increase, income less than 20thousand BDT (β_{tc20_c})	-0.6835	-1.36
	Travel cost 30% increase, income less than 20thousand BDT (β_{tc30_c})	-1.1385	-1.95
	Travel cost 40% increase, income less than 20thousand BDT (β_{tc40_c})	-1.3802	-2.34
	Travel cost 20% increase, income more than 20thousand BDT (β_{tc20_c})	-0.0739	-0.12
	Travel cost 30% increase, income more than 20thousand BDT (β_{tc30_c})	-1.0144	-1.69
	Travel cost 40% increase, income more than 20thousand BDT (β_{tc40_c})	-1.5221	-1.9
	Frequency 20% decrease ($\beta_{fr\text{-}20\_c}$)	-0.4391	-1.09
	Frequency decreased 30% & more ($\beta_{fr\text{-}30\_c}$)	-0.4333	-1.36
	Vehicle owner (β_{v_c})	-3.6485	-8.2
	Income less than 20 thousand BDT (β_{inc})	0.5873	1.35
Goodness of fit parameters			
No. of estimated parameters		39	
No. of observation		1044	
Initial loglikelihood		-1146.95	
Final log-likelihood		-724.35	
Adjusted Rho-Square		0.368	

4. Discussion

Using discrete choice modeling approaches, a mode choice model based on SP data has been built in this research. This research revealed that BRT uptake depends on BRT travel time, travel cost, frequency, stoppage distance, and stoppage facilities (e.g. timetable display). As in existing literature, Travel time and travel cost are found negatively associated with travel mode choice [13,14,15]. This implies that a rise in the value decreases the mode's utility. Less frequency and an increase in stoppage distance are also found to decrease the choice utility. These findings are also aligned with the literature finding where waiting time and walk time to stoppage or accessibility have been found to have a negative impact on the choice [16]. However, the changes in the preferences do not follow a linear pattern due to changes in the level of attributes of the travel mode. As in previous studies, interacting the explanatory variables with the socio-demographic dummy resulted in a significant improvement in the model fit over the model without interaction [13].

5. Conclusion

The study revealed that travel time, travel cost, frequency, stoppage, and shed facility with timetable display are the most influential parameters for the uptake of BRT. It is observed that over 52% of citizens will switch to BRT after it is implemented, 16% will stick with CNG auto-rickshaw, and the remaining 32% will choose other modes. The MNL model developed in this study did not allow to capture the random taste heterogeneity that could be a direction for future study. Autonomous vehicles, am immerging technology in the transport sector, is expected to be safer and attractive than vehicle driven by human drivers [17]. Therefore, presence of Autonomous vehicle may change the people preference of human driven vehicle like BRT and other mode of transport. The future study can focus on investigating mode choice behavior considering both human driven and driver less vehicle. However, the findings of the current study could provide beneficial insight to the authorities to develop a sustainable mass transportation policy.

Statement of Competing Interests

The authors have no conflict of interest.

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