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A Study on Mode Choice Behaviour of Working Population in Dhaka: A way towards Sustainable Transportation

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Abstract

Work trips constitute about 44% of the daily trips in Dhaka according to the Dhaka Structure Plan (2016-2035). The increasing trend of registered automobiles over the past decade warranted for a closer insight into the mode choice decisions made by working people. The study attempted to identify the factors influencing the modal choice for work trips using the Household Income Survey (HIS) data. Binary logit models were used to explore the impact of socio-economic and built environment factors on choosing non-motorized, private vehicle and public transport. The study revealed that vehicle ownership status, income, and driving license is likely to influence the modal choice of all three modes. Other variables like the size of the areas, fare, mode preference and availability of alternate modes also impacted the model. Income plays a major role in mode selection and vehicle ownership is connected to it. With the increase in income, people tend to own cars and change their mode choice behavior and this issue has a massive impact on the sustainability of the environment of the city. Since Dhaka is a populous city, the available public transport system can be a sustainable medium for working trips. However, for this, the public bus has to overcome the issues of safety, comfort and improper service provision which are just some of the factors deterring the majority of female passengers. According to the findings of the study, private automobiles have almost 2.5 times higher carbon emission than the public bus at per person per kilometer and thus, are likely to have a high impact on the sustainability of the transportation system of Dhaka. Since work trips constitute a noticeable share of the daily trip, these results may aid in planning upcoming strategies and management of sustainable transportation systems in the cities of developing countries like Dhaka.

Keywords: Working population, Binary model, Modal choice, Sustainable transportation.

1. BACKGROUND

Bangladesh is a developing country having a population of 16.7 million. Dhaka, the capital and the only megacity of this country has a population of about 1.04 million (Worldometers, 2018; World Population Review, 2018). Currently, Dhaka is facing the problem of rapid unplanned urbanization. The population growth with rapid unplanned urbanization trend has had a great influence on the transportation system of Dhaka (The Daily Star, 2018). Each day 34.88 million trips are made of which 44% trips are made for work purpose (RAJUK, 2016). In Dhaka, the existing transportation system consists of both motorized and non-motorized vehicles. Since almost half of the trips are work trips, it is required to have a closer insight into the factors influencing the mode choice behavior of the

working population. Moreover, the increasing traffic of Dhaka and unplanned urbanization trend has a great impact on the environment of Dhaka city.

Hence, it is essential to study the mode choice behavior and its impact on the urban environment.

Although almost half of the trips in Dhaka are generated for work purpose, still a handful of researches have been conducted to study their mode choice behavior. Anwar (2013) developed a nested logit model with a relatively small and under-representative sample, to study travel behavior without any indication of its effect on environment and sustainability. To fulfill the gap, this study was conducted and discrete mode choice models for different modes were developed considering several socio-economic and built environmental factors. The influence of these factors on mode choice and how the increase of private automobiles could impact the environment were also discussed. This study intended to draw the scenario of the existing environmental deterioration caused due to mode choice behavior.

2. METHODOLOGY

2.1. Data Sources

The study used 'Household Income Survey (HIS) of 2010' dataset under the study of 'Dhaka Urban Transport Network Development Studies in Bangladesh (DHUTS)' to develop regression models for mode choice behavior. The study was conducted from March 2009 until March 2010 and the entire Dhaka Metropolitan Area including sub-urban areas like Savar, Narayanganj, and Tongi were considered as the study area. Through the Household Income Survey (HIS), socio-economic information of households such as their residence location, age, gender, member number, working place, household income, household type, car ownership, and license ownership were collected. Apart from these data, their daily trip information including trip purpose, travel time, travel mode, and distance were also collected. While collecting their trip information, data regarding comfort, vehicle availability, reliability issue, and alternative mode availability were also collected. In order to identify the influence of the built environment on mode choice behavior for the study, the land use data was collected from the 'Detailed Area Plan 2010'. The relation of population density with mode choice was also investigated, for which the density value was collected from 'Population and Housing Census 2011: Community Series Dhaka'. To assess the relation of accessibility with mode choice, the total person employed in different employment sectors was collected from 'Economic Census 2013: Community Series Dhaka'.

2.2. The Selection of Working Population

From the database of HIS survey, the data regarding the working trips were extracted and used for this survey. Therefore, people belonging to the age group of 15 to 64 years old were considered as the working group and were addressed in the study as the target group of people (Liton and Molla, 2017).

2.3. Determination and Description of the Variables

For the concept of sustainable transportation along with mode choice behavior of people of Dhaka, an extensive literature review of both local and global context was carried out. Nasrin (2017) observed that cost, comfort, time and option of alternative modes played significant roles in modal selection for university students of Dhaka. In previous studies, it was seen that the commuters of Dhaka revealed to be significantly affected by socioeconomic conditions, land use and availability of proper facilities (*Rahman et al, 2009*; Rahman 2017). Models can be used to represent the travel behavior revealing the factors that dictate mode choice which plays a major role in the level of pollution caused by the transportation system in a city (Khattak, Miller, and Fontaine, 2017). It was learned that factors from the socio-economic, built environment and trip characteristics played important roles which dictated the mode choice behavior. According to the attainments from previous studies in this field, the

variables were considered in the first phase. Initially, 24 independent variables of different aspects were considered and based on these variables, the mode choice models were developed. In the models, only mode choice was the dependent variable.

Table 1. List of Initially Considered Independent Variables along with their Statistical Measurements

Data Aspects	Variables	Meaning	Statistical Measurements
Spatial Characteristics	Area	Area of the corresponding ward of the respondent	Maximum value= 14.6 sq. km Minimum value=0.2 sq. km
	Proportion of residential land use	The proportion of residential land use in the area of the corresponding ward of the respondent	Maximum value= 0.88 Minimum value=0
	Proportion of commercial land use	The proportion of commercial land use in the area of the corresponding ward of the respondent	Maximum value= 0.42 Minimum value=0
	Proportion of mixed land use	The proportion of mixed land use in the area of the corresponding ward of the respondent	Maximum value= 0.26 Minimum value=0
	1. Accessibility of the ward for 30 minutes travel time	A comparative value representing the ability to reach employment opportunities in other wards within 30 minutes	Maximum value= 25844.9 Minimum value=0
Trip Characteristics	Transportation cost	Monthly expenditure of respondent behind transportation	Maximum value= 25000 taka Minimum value= 0 taka
	Trip frequency	Number of trips made by the individual respondent	Maximum value= 10 Minimum value=0
	Travel fare	Typical fare to the workplace by the usual travel mode	Maximum value= 500 taka Minimum value= 0 taka
	Trip time	The average time taken to reach the workplace in minutes	Maximum value= 160 minutes Minimum value= 0 minutes
Rider preferences	Affordability	Does fare affect mode choice behaviour?	Yes=3467, No=102
	Reliability	Does reliability affect mode choice?	Yes=1102, No=207
	Time-Saving	Does time-saving affect mode choice?	Yes=924, No=207
	Comfort	Does comfort affect mode choice?	Yes=439, No=213
	Convenience	Does convenience affect mode choice?	Yes=431, No=229
	Safety	Does safety affect mode choice?	Yes=564, No=214
	Parking problem	Does parking problem affect mode choice?	Yes=260, No=249
Rider Characteristics	Gender	Gender of respondent	Male=4494, Female=521
	Age	Age of the respondent	Maximum age=78 Minimum age=16
	Education level	The education level of the respondent	Below graduation=2659 Graduate=1114 Above graduate=1239
	Employment type	Type of employment in which respondent is engaged in	Full-time=4842, Part-time=51, Casual=10, Others=112
	License ownership	Whether or not the respondent has a driving license	Yes=663 No=4352
	Occupation	Occupation of the respondent	Government service=776 Non-government service=2152 Others=2087
	Industrial sector	Sector of the industry of the member	Agriculture=2 Livestock=6 Fishing/forestry=17 Mining/quarrying=1 Manufacturing industry=259 Construction=158 Trade and commerce=346 Transportation and storage=99 Communication=114 Agricultural labour=3 RMG=217 Shops=1118 Service=2536 Others=141
	Income	Monthly personal income of the respondent	Maximum value=7,50,000 taka Minimum value=0 taka
	Car ownership	Car ownership status	Yes=1106, No= 3909

Table 1 provides the list of variables considered for developing the mode choice models. All of these variables were correlated to the dependent variable whereas, there were no internal linkages among these variables themselves.

2.4. Classification of Modes

Apart from the variables, the existing transportation modes of Dhaka were also classified to learn about the factors influencing the mode choice behavior. In this study, three categories were considered while deriving the mode choice models and factors influencing the mode choice behavior in these categories were identified and discussed. In Table 2, the classification of existing modes is provided.

Table 2. Classification of Existing Transportation Modes of Dhaka

Class	Considered Modes
Non-motorized	Walking, Rickshaw, Bicycle
Private automobile	Car, Motorcycle, Microbus
Public Transport	Public bus, Human Hauler, Leguna

Based on the classification of Table 2 the models were developed and factors influencing the mode choice behavior is discussed.

3. RESULTS AND DISCUSSION

3.1. Model Estimation and Discussion

In order to identify the factors affecting mode choice, binary logistic regression was used where mode choice was the only dependent variable for all the three models for each form of mode. Spatial characteristics, trip characteristics, rider characteristics, and rider preference variables were used for the study. These aspects would enhance the understanding of how personal user characteristics and preferences combined with spatial features and trip characteristics may dictate mode choice. The B value obtained from the regression model acts as a coefficient for the variables defining the dependent variable.

It helps to predict the dependent variable based on the independent variable through the odds ratio.

Table 3. Estimated Binomial Logit Model of Mode Choice

Variable Characteristics	Model 1: Private Automobile			Model 2: Public Transport			Model 3: Non-motorized Vehicle		
	Variables	B value	Odds ratio	Variables	B value	Odds ratio	Variables	B value	Odds ratio
8.5	-	-	-	Log Area	-0.21	0.81	Log Area	-0.68	0.51
Trip Characteristics	Log Fare	0.51	1.67	-	-	-	Log Fare	-0.62	0.54
	-	-		-	-	-	Member Trip Frequency	0.25	1.29
Rider Preferences	Affordability	-0.42	0.66	Reliability	0.22	1.25	Mode Preference	3.19	24.22
	Other Transport Option	-0.19	0.83	Mode preference	2.67	14.45	Parking problem	1.56	4.74
	Parking problem	0.43	1.54	Time-Saving	0.14	1.14	Comfort	0.71	2.03
	-	-	-	Other Transport Option	0.47	1.60	-	-	-
	-	-	-	Affordability	0.60	1.83	-	-	
Rider Characteristics	Log Income	0.45	1.56	Log Income	-0.51	0.60	Log Income	-0.69	0.50
	License	1.21	3.34	Car Ownership	-0.50	0.61	Car Ownership	-1.19	0.30
	Car Ownership	1.07	2.92	License	-0.55	0.58	License	-0.62	0.54
	Education	0.14	1.15	Gender	-0.66	0.52	-	-	-

level								
Gender	0.61	1.83	-	-	-	-	-	-

Nagelkerke R Square 0.507 (Private automobile)
Nagelkerke R Square 0.467 (Public transport)
Nagelkerke R Square 0.633 (Non-motorized modes)

Model 1 of Table 3 shows that the likelihood of using private cars decreases for people with greater importance on the affordability of transportation cost (low odds ratio); that is, users concerned about affordability are less likely to avail private automobiles. Users are more likely to use private vehicles if they are driving license holders (high odds ratio). Model 1 also shows that car owners and individuals with high income are more likely to use their private vehicles. These variables, although do not affect one another significantly, are connected as with the increase in income, the likelihood of owning private car rises as shown by PPRC (2016) and BRTA (2018) reports. The model suggests that women tend to prefer private cars over other modes which confirms the results of a study by Saha and Rahman (2015). However, individuals with multiple transportation options are less likely to use private automobiles (low odds ratio). The inclusion of spatial characteristics and trip characteristics shows that although spatial features have no effect on the choice of private vehicles, people are more likely to use private vehicles as fare rises which reduce the gap in transportation cost using the modes. Finally, model 1 shows that rider preferences and characteristics are the major influences dictating the choice of private automobiles.

Model 2 from Table 3 shows that individuals with a preference for public transport are most likely to use public transit while women were least likely to avail this mode based on odds ratio. The model shows that users having a driving license, car ownership, and high income are also less likely to use public modes. Compared with model 1, it is noticed that these factors increase the likelihood of using private modes rather than public modes. This matches with PPRC (2016) as when income rise, the tendency to use private vehicles rise and public transport falls.

However, individuals concerned about affordability and having alternate transportation options are more likely to use public transport. This may be explained by the median income value of the data used which is Tk 18,000. Although the model suggests that trip characteristics do not affect the choice of public transit, spatial characteristics are seen to affect it. People living in larger travel analysis zones are less likely to use public transport. This may be explained by the shortage of bus stops which make it difficult to avail public transportation in larger areas (Sen, 2016).

Model 3 in Table 3 shows that likelihood for using non-motorized vehicles is the most for individuals who already have a modal preference of non-motorized modes while it is least likely to be used by car owners (based on odds ratio). A reason for this may be that the majority prefer non-motorized mediums of travel for short trips (*Hoque et al, 2014*). Furthermore, the likelihood of using non-motorized modes increases with the increase of parking problem which is acting as a force for shifting usage away from private vehicles. The findings of the model match with Hoque et al (2014). Based on the responses in the database in Dhaka, the model also suggests that users who prioritize comfort are also likely to use non-motorized modes. However, individuals are less likely to use non-motorized modes with a rise in income and an increase in the area of their travel analysis zones. Increased area increases travel distance making non-motorized modes unsuitable as the average distance for non-motorized travel is only 2.34 km (*Hoque et al, 2014*). A rise in income is followed by car and license ownership which reduces the use of non-motorized modes. Trip characteristics also influence modal choice. While users who have to make frequent trips are more likely to use non-motorized modes, the likeliness for use of this mode falls with rising trip fares. This can be explained by the fact that the majority of the non-motorized mode users are from the middle-income background. Model 3 concludes that unlike the model 1 and model 2, the variables from spatial characteristics, trip characteristics, rider preferences, and rider characteristics determine the use of non-motorized modes.

3.2. Impact of Increasing Car Ownership on The Environment

The models discussed in the previous sections illustrates that the use of private automobiles is influenced by factors like income, car ownership and license ownership. An increment in income would result in an increment in car ownership and the usage of public transport will decrease. These things affect the sustainability of the urban environment.

In the case of Dhaka, mostly private automobiles use petrol and CNG as a medium of energy source and public buses mostly use diesel and CNG. These are major sources of carbon dioxide emission and affects the sustainability of the environment. In Table 4, the level of carbon dioxide emission by private automobile and public transport is discussed

Table 4. Emission Level of Carbon-dioxide by Private Automobiles and Public Transport in Dhaka

Vehicle Type	Capacity (no. of persons) *	Fuel Type**	Total Number of Vehicles***	Vehicle activity (km/day) ****	Emission (Ton/day) **	Emission (gram per km per person in one vehicle)
Private car	4	Petrol	15219	40	157.06	64.50
Private car	4	CNG	95066	40	901.22	59.25
Public transport	40	Diesel	3448	130	397.61	22.18
Public transport	40	CNG	10801	130	1359.16	24.20

Source: *Jahan et al (2013), **Labib et al (2014), ***BRTA (2018), ****Khaliquzzaman (2006)

Table 4 depicts that each day if a person travels one kilometer by private automobile, it would emit carbon-dioxide which is almost 2.5 times higher than the emission by public transport, considering both modes at maximum seating capacity. Moreover, the carrying capacity of a private automobile is quite less than public transport. But the private automobile holds almost 64% of total modal composition whereas, for public transport, the value is 2% (*Labib et al, 2013*). This high percentage of private automobiles add to the emission of carbon dioxide into the environment and makes the community more vulnerable.
So, the increasing trend of car ownership would lead to the destruction of the environment. In this case, the increment in public transport usage would make the scenario better.

4. CONCLUSION

The future of the environment depends on the greenhouse gases released into the atmosphere. Since transportation is a major source of environmental pollution (*Fuglestvedt et al, 2007*), it is imperative that an in-depth study is conducted. In this aspect, this study models the behaviors of work trip makers using three different transportation modes in order to identify the factors affecting their mode choice. It was realized that gender, car ownership, license ownership, affordability, the option of alternate modes and parking played important roles during the selection of modes in the models. The models suggested that the selection of private automobiles and public transport primarily depends on rider characteristics and preferences while for non-motorized modes, spatial and trip characteristics also determined their selection. With a rise in income, individuals are likely to use more private vehicles and less public transport. These result in more carbon emissions into the environment. For a sustainable urban transportation system, non-motorized vehicles should be the most preferred modes, followed by public transport for motorized transport while discouraging the use of private modes. However, in Dhaka, people are increasingly getting interested in using cars with the rise in their income. The Strategic Transportation Plan (Revised and Updated) 2015-2035 shows that Dhaka is moving towards an unsustainable future as car ownership and usage rate has been increasing in the last five years. The public transport system should be updated and improved in order to solve the current issues of gender equality, safety, and rider experience to attract users towards a more environmentally sustainable means of transport. Furthermore, while the study has been conducted on the work trip makers, it can be extended to non-work trips in order to confirm the variables affecting mode selection.

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