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Travel behavior of workers in a developing city: analysis in the context of Dhaka

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Abstract

his paper presents a revealed preference survey conducted to understand workers' travel behavior in Dhaka. The survey data are analysed using a multinomial logit (MNL) model to scrutinize social and economic factors' impact on participant's mode choices. Analysis MNL model results reveal that travel behaviour of commuters for work trip varies among different social economic groups. Elasticity analysis of different attributes showed that travel difference significantly varies between developed and developing cities. Presence of effective, efficient transport system and higher affordability make commuters in developed cities relatively more elastic with travel attributes, such as travel cost and travel time. In Dhaka opposite scenario is predominating. However, commuters in Dhaka relatively elastic with car travel cost because of its excessive high cost.

Keywords: Dhaka, Multinomial Logit Model, Travel Behaviour

1. Introduction

Dhaka is the capital city of Bangladesh. Like other megacities Dhaka is experiencing serious traffic congestion (Alam and Habib, 2003). To improve traffic situation it is necessary to understand travel behaviour of commuters.

Research questions addressed in this paper are: 1) what is the travel behaviour of commuters for the work trip in a developing country's mega city considering Dhaka as a case study, and 2) how do travel attributes, and socio-demographics act differently on workers' mode choice decisions in the context of Dhaka compared with developed cities?

As very limited research exist for understanding commuter travel behaviour and ultimately factors influencing mode choice decision in the context of a megacity in a developing country, this paper will have significant importance to practitioner and researcher.

This study uses a discrete choice modelling approach. A revealed preference survey (RP) (i.e. actual choice survey) was conducted in Dhaka from September 2011 to December 2012. This survey data is used for calibrating model. A mode choice model was developed using the RP data and “LIMDEP” software (Greene 1998). Remaining of this paper starts with literature review, followed by modelling analysis and conclusion.

2. Literature Review

2.1 Travel Behaviour Elasticity

Elasticity is defined as the measure of a change in response to a change in attribute. Many published and unpublished elasticity values of travel time and travel cost of different modes are available from research on other cities (BITRE 2014). Elasticity values obtained from this research will be compared with elasticity value from European, US and Australian cities to understand the uniqueness of travel behaviour of a developing city like Dhaka. However, elasticity values for personalized public transport (PPT) (i.e., rickshaw and auto-rickshaw, which is named as CNG in Dhaka) are not available for developed cities, because such mobility options are unique features of a developing city like Dhaka. BITRE (2014) provides a comprehensive dataset on transport elasticity. Elasticities obtained by other researchers are usually provided in three ways; short run (less than two years), medium run (within five years), and long run (more than five years). Analyses based on short and medium run elasticity tend to understate the result. According to Goodwin (Goodwin 1992) and Litman (Litman 2014) the long term impact would be twice the short term impact. Therefore, comparative analysis between very short run elasticity from this research and other cities will still provide indication uniqueness of travel behaviour in a developing city. Balcombe, Mackett et al. (2004) reported the impact of different factors on public transport in context of UK. More specifically, elasticity of in-vehicle time for bus ranges from -0.4 to -0.6.

Dargay, Hanly *et al.* (2002)_ENREF_52 compared transit elasticity between England and France from 1975 to 1990, and found that income rise did not negatively impact French people’s decision to use public transport, whereas it did impact English people’s. Dargay and Hanly (2002) analysed demand for local bus service in England. They used a dynamic econometric model (separate short- and long-run effects) of per capita bus patronage, per capita income, bus fares and service levels. Their research found that commuters are relatively fare sensitive with wide variation of elasticity. Deb and Filippini (2013) determined elasticity values for twenty-two Indian states over the period from 1990 to 2001. Their research found that for all states public transport demand is inelastic with respect to fare.

Goodwin (1992) produced average elasticities based on studies on UK and Europe. His research found that price impact will increase over time. Therefore, short run impact will be always less than long run. Hague Consulting Group (1999) discussed impact of car travel cost and car travel time mainly for European cities in the report conducted for the Trace project. Their research found that 10% change in car time has a bigger impact on trips and kilometres than a 10% change in car cost. Research finding also suggest that the short term elasticities of car km are more or less 50% of the long run counterparts.

Hensher and Louviere (1998) drew on a 1994 data set collected in 6 Australian capital cities to estimate a series of commuter mode choice models in the presence and absence of two

Table 1
Direct and Cross elasticity of travel time and in vehicle travel time of various modes from other studies

City relevant to study or project	Attribute	Direct Elasticity value	Cross Elasticity
Chicago[1]	Rapid Transit Travel Time	Direct elasticity of rapid transit –1.51	
Montreal[1]	Bus and rapid rail in vehicle travel time	Direct elasticity of Bus and rapid rail in vehicle travel time -0.27	
Australia[2]	BRT travel time	Direct elasticity of BRT travel time –0.857	
Australia and New Zealand[3]	Bus in-vehicle travel time	Direct elasticity of bus -0.50	
Karachi city in Pakistan Based on study of Thorbani (1984)[4]	Bus in-vehicle time	Direct elasticity of bus -0.77	Cross elasticity of car 0.03 Cross elasticity of PPT 0.17 Cross elasticity of walk 0.06
Chicago city[5]	Bus in-vehicle time	Direct elasticity for bus -1.10	
San Francisco[5]	Bus in-vehicle time	Direct elasticity for bus ranges from -0.46 to -0.60	
Minnepolis[5]	Bus in-vehicle time	Direct elasticity for bus -0.52	
Chicago[1]	Bus travel time	Direct elasticity of bus travel time –3.03	
East Bay San Francisco[1]	Bus in vehicle travel time	Direct elasticity of bus in vehicle travel time –0.46	Cross elasticity of car in vehicle travel time 0.15
Australia and New Zealand[3]	Car in-vehicle travel Time	Direct elasticity of car in short run -0.3 and in long run -0.6	
Karachi city in Pakistan Based on study of Thorbani (1984)[4]	Car in-vehicle time	Direct elasticity of car –0.04	Cross elasticity of bus from 0.01 to 0.02
Great Britain[4]	Car in-vehicle time	Direct elasticity of car -0.44	
Europe[3]	Car in-vehicle time	Direct elasticity of car -0.62 for short run and -0.41 for long run	
Dutch National Model[1]	Car in-vehicle time	Direct elasticity of car -0.39 for short run and -0.58 for long run	Cross elasticity of bus 0.18 for short run and 0.16 for long run
Italian national model[1]	Car in-vehicle time	Direct elasticity of car -0.54 for short run and -0.56 for long run	Cross elasticity of bus 0.22
Model for Brussels[1]	Car in-vehicle time	Direct elasticity of car -0.23 for short run and -0.26 for long run	Cross elasticity of bus 0.38 for short run and 0.37 for long run
Chicago[1]	Car Travel Time	Direct elasticity of car travel time -0.64	
Minneapolis[5]	Walk travel time	-0.26 for work trip -0.14 for non-work trip	

**Source: [1]Hague Consulting Group (1999); [2]Hensher and Louviere (Hensher and Louviere 1998); [3]Wallis and Schmidt (2003); [4]BITRE (2014); [5]Lago, Mayworm et al. (1981)*

Table 2
Direct and Cross Elasticity of Travel Cost of Different Modes from Other Studies

City	Attribute	Direct Elasticity	Cross Elasticity
Chicago[1]	Rapid transit travel cost	Direct elasticity of rapid transit –0.17	
Australia[2]	BRT fare	Direct elasticity of BRT –0.573	
Study on Leeds City[3]	Public Transport travel cost	Direct elasticity of public transport is -0.65	Cross elasticity of car 0.14 Cross elasticity of walk is 0.56
Study on Dortmund City[3]	Public Transport travel cost	Direct elasticity of public transport -0.58	Cross elasticity of car 0.12 Cross elasticity of walk is 0.23
Study on Tokyo City[3]	Public Transport travel cost	Direct elasticity of public transport -0.03	Cross elasticity of car 0.09 Cross elasticity of walk 0.09
Study on UK and Europe[4]	Bus fare cost	Direct elasticity of bus for short run -0.28 and for long run -0.55	
Study on Australia[1]	Bus fare cost	Direct elasticity of bus fare is -0.29	
Chicago[1]	Bus travel cost	Direct elasticity of bus -0.16	
Study on Australia[5]	Bus fare cost	Direct elasticity of bus from -0.18 to -0.22	Cross elasticity of car is 0.1
UK City[6]	Bus Cost	Direct elasticity of bus in the short run from -0.2 to -0.3 Direct elasticity of bus in the long run from -0.4 to -0.6	
UK City[7]	Bus Cost	Direct elasticity of bus in the short run -0.4 Direct elasticity of bus in the long run -1.0	
Sydney[8]	Public Transport Fare	Direct elasticity of public transport –0.15	Cross elasticity of car 0.173
Sydney[9]	Public Transport cost	Direct elasticity of public transport in the short run -0.22 long run -0.29	
Study on Leeds City[3]	car travel cost	Direct elasticity of car -0.29	Cross elasticity of walk 0.06 Cross elasticity of Public transport 0.31
Study on Dortmund City[3]	car travel cost	Direct elasticity of car for its travel cost -0.23	Cross elasticity of walk 0.41 Cross elasticity of Public transport 0.4
Study on Tokyo City[3]	car travel cost	Direct elasticity of car -0.06	Cross elasticity of Public transport 0.03 Cross elasticity of walk 0.03
Chicago[1]	Car travel cost	Direct elasticity of car –0.28	
Sydney[8]	Car cost	Direct elasticity of car –0.094	Cross elasticity of bus 0.08

**Source:* [3]*Luk and Hepburn (1993);* [5]*Hague Consulting Group (Hensher and Louviere 1998);* [1]*Banister, Cullen et al. (1991);* [2]*Goodwin (1992);* [4]*Booz Allen & Hamilton (2003);* [6]*Dargay and Hanly (1999);* [7]*Balcombe, Mackett et al. (2004));* [8]*Taplin, Hensher et al. (1999);* [9]*Tsai, Mulley et al. (2014)*

'new' alternatives (light rail and busway systems), to derive matrices of direct and cross point elasticities for travel cost and travel time. Their research found that constraining the variance of the unobserved effects to varying degrees tends to over-estimate the elasticities sufficiently to distort the real behavioural sensitivity of specific attributes influencing choice. Tsai, Mulley et al. (2014) identified public transport demand elasticity for Sydney, Australia. The research findings suggest that the public transport demand elasticity of price in Sydney is

−0.22 in the short run and −0.29 in the long run. Wallis and Schmidt (2003) updated and re-examined transport demand elasticity from Australia and New Zealand.
The literature review suggest that there are many sources that produce original elasticity for different modes and many sources that compile elasticity from other's research. Table 1 lists the elasticity of travel time and in-vehicle travel time; Table 2 lists the elasticity of travel cost and Table 3 lists the elasticity of waiting time for different cities. However, no study was found which provides comparison of impact of travel factors between developed and developing cities. This research will provide a significant contribution to knowledge by providing a comparison between developed cities and developing cities travel difference in context of Dhaka city.

Table 3
Direct and Cross Elasticity of Wait Time of Public Transport

City	Attribute	Direct Elasticity
Montreal[1]	Wait time	Direct elasticity of bus and rapid rail -0.54
San Francisco[1]	Wait time	Ranges from -0.17 to -0.19 for bus
Minneapolis[1]	Wait time	Direct elasticity of bus for work trip - 0.32 Direct elasticity of bus for non-work trip is -0.21

**Source: [1]Lago, Mayworm et al. (1981)*

2.2 Model Choice Modelling for Dhaka and Other Developing Cities

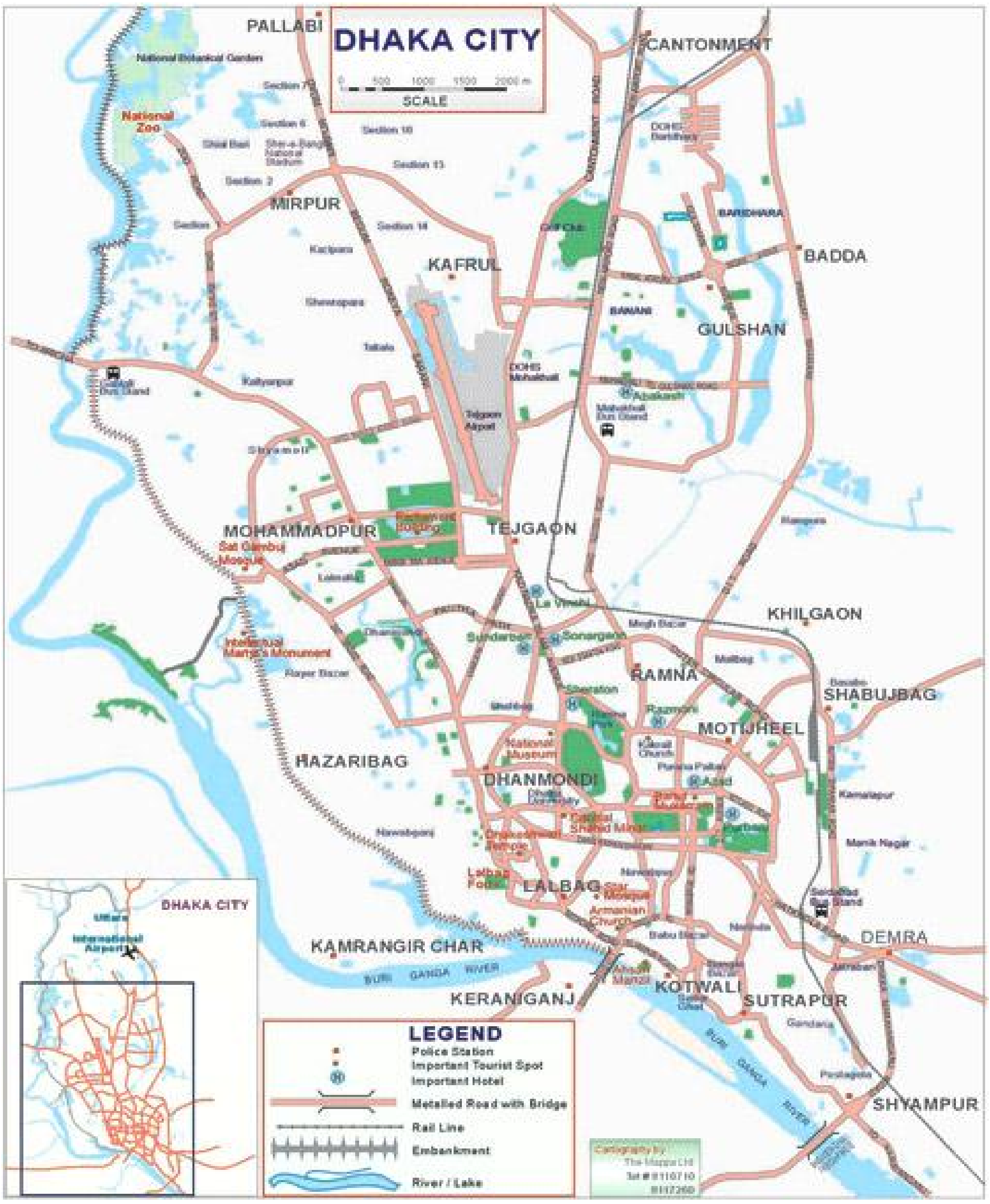
Some studies have developed mode choice models in the context of Dhaka city (Government of Bangladesh, 1994; ;The Louis Berger Group and Bangladesh Consultants Ltd, 2004; Katahira & Engineers International Oriental Consultants Co. Ltd. and Mitsubishi Research Institute Inc., 2010; Habib, 2002; Aftabuzzaman, Murumachi et al., 2010; Enam, 2010; Rahman, 2008; Alam, Jaigirdar et al., 1999). However, only Enam (2010) developed a mode choice model to perceive the preferences for mass rapid transit. Anam and Hoque (2011) analysed current performance of existing bus services and justified and proposed bus rapid transit (BRT) road cross-section in an existing right of way (ROW). They compared the minimum requirement of BRT with corridor characteristics, existing roadway widths, condition, vehicular composition, land use pattern and obstacles along the corridor.

Nkurunziza, Zuidgeest *et al.* (2012) developed a binary choice model to understand commuters' preference for the proposed BRT in Dar-es-salam, Tanzania. Palma and Rochat (2000) developed a NL model for the work trip of Geneva. They focused on the joint nature of the decision of number of cars to own in the household and the decision to use the car for the trip to work. Tushara, Rajalaksmi et al. (2013) developed a mode choice model for Cailcut, India by MNL model application. Very limited research is available in the context of developing cities provided travel behaviour of different social group commuters. This research will bridge the gap by providing travel behaviour of different social group commuter for work trip through mode choice model.

3. Survey Design and Implementation Strategy

Survey design involved two main steps; sampling plan and establishing the procedure for obtaining sample data (Glasow, 2005). Survey design for this study is divided into five steps: determine aim of survey, select sample, determine sample size, select survey medium, prepare questionnaire, and develop strategy for non-response bias.

Aims of the survey were: 1) to determine the modes commuters in Dhaka use for their home based work journeys; and 2) to determine the time, cost and distance by these modes. Two approaches were taken to recruit participants: 1) respondents approached through their employers; and 2) respondents contacted directly. Respondents, who were engaged in their usual service jobs, were contacted through their respective employer with that employer's approval. The organizations were selected randomly from Bangladesh Business Directory (T-Series Solutions, 2010). However, for covering wide range of workers Dhaka was divided into 4 zones and from each zone organizations and participants was selected randomly. Figure 1 illustrates Dhaka city map and 4 zones for survey. A list of randomly selected organization was generated and organizations less than or equal to 2 employees were excluded from the list. The responsible authority at the organization was contacted through email, phone or from personal visit and with their consent respondent was given questionnaires.



Zone 1: Mirpur, Zone 2: Uttora, Banani, Gulshan. Zone 3: Dhanmondi,
Zone 4: Motizheel and Old Town

Fig. 1. Survey Area Coverage

In Dhaka a wide range of people are engaged in domestic assistant and chauffer employment. Domestic assistants are predominantly female. They were contacted personally. These employees mainly have low income and very limited education, some being illiterate.

A large sample size was obtained by this study to ensure non-biased representation of the population. A paper based survey was chosen for its simplicity and convenience for face to face interaction. With internet usage still infrequent in Dhaka, web based surveying was not a feasible option. Survey by telephone was also not considered feasible due to high cost.

Glasow (2005) stated that survey questions should be consistent with the education level of the respondent. In this vein the survey was prepared bilingually in simple Bangla, which is easy to understand for most respondents, as well as English. The required completion time for the survey was 10 minutes or less.

Israel (1992) stated that no matter how well the sampling design is planned a poor response rate can make a study virtually useless. The response rate of this survey was about 90%. High response rate was ensured by conducting the survey at the presence of the surveyor. Some of the respondents agreed to participate at their most convenient time. Among those some of the respondents did not answer the whole questionnaire. To address non-response respondents were asked why they were not willing to respond. Questions were explained verbally to those who stated that the questions were difficult to understand. The only risk associated with this survey was time loss of workers. To reduce work hour loss they were proposed to be contacted during their most convenient time or during the hours when they had less work than normal hours.

4. Overview of Survey

The survey was conducted in two phases; between October 2011 and December 2011, and between September 2012 and December 2012. Samples differed entirely between these two phases.

The first survey was conducted to understand whether questions were understandable to the various categories of workers. This survey was divided into a revealed preference (RP) survey and demographic questions. In the RP survey, respondents were asked how they usually travelled to work, travel time, travel cost, and any problems they faced while on work trip. Accordingly second survey was also divided in the same manner.

A large sample size was obtained for this study to ensure good representation of the total population. The first and second surveys included 426 subjects and 462 subjects respectively. In both surveys respondents were asked limited demographic questions: age, income, and education. Table 4 lists the demographic characteristics of the survey data. To check the representativeness of the survey data some of the variables were compared with other sources. The ratio of male to female workers of the survey data is almost the same as the World Bank data (The World Bank, 2007).

According to STP data most people (96%) in Dhaka fall into the low and medium income groups (The Louis Berger Group and Bangladesh Consultant Ltd, 2004). Survey data also closely reflects this, although the higher income proportion is slightly higher, which is at least partially attributable to inflation. However, comparison of modal share with STP data shows that except car mode, percentages of modal share of other modes are similar.

Table 4
Percentage of Survey Data across Demographic Characteristics

Demographic Characteristics		First Phase Survey	Second Phase Survey	Comparison of Survey data with Other Sources
Gender	Male	62%	65%	67%[1]
	Female	38%	35%	33%[1]
Age	Age 0-18	3.0%	5.0%	
	Age 19-25	14.0%	18.0%	
	Age 26-35	38.1%	46.0%	
	Age 36-45	28.5%	23.0%	
	Age 46-55	12.7%	4.0%	
	Age 56-65	3.4%	3.0%	
	Age 65 above	0.3%	1.0%	
Income	Income Low(<12,500 BDT or approximately A$<180)	43.0%	40.0%	45%[2]
	Income Middle (12,500 BDT-55,000 BDT or approximately A$180-A$785)	47.0%	43.0%	51%[2]
	Income High (>55,000 BDT or >A$785)	10.0%	17.0%	4%[2]
Education	No certificate	22.0%	21.0%	
	Primary	14.0%	8.2%	
	Secondary	5.0%	4.8%	
	Higher Secondary	7.0%	3.3%	
	Graduate	23.0%	21.4%	
	Post Graduate	28.0%	41.1%	
	No answer	1.0%	0.2%	
Modal Share	Bus	45%	47%	Transit 37% [2]
	Car	9%	7%	Motorized non transit 25% [2]
	Rickshaw	17%	14%	Rickshaw 25% [2]
	CNG	5%	0.22%	
	Walk	23%	24%	Walk 37% [2]
	Other (Laguna, battery operated CNG, Tempo, motorcycles, bicycles, taxi etc.)	2%	7%	

**Source: The World Bank (2007); [2]The Louis Berger Group and Bangladesh Consultant Ltd (2004)*

5. Description of Model with RP Data

Multinomial logit choice model is based on maximum utility maximization theory (Ben-Akiva and Lerman, 1985, Hensher, Rose et al., 2005). By MNL model the probability of choosing an alternative i from a set of j alternatives is expressed by Equation 1.

$$\Pr(i) = \frac{\exp(v_i)}{\sum_{j=1}^{J} \exp(v_j)} \qquad ...(1)$$

where,

$P_r(i)$ = probability of choosing alternative i

υ_i = utility function of any mode

j = total number of alternatives

Table 5
Choices for model with RP data

Choices	Definition
bus	bus mode users' main mode for work trip is bus, which includes access to bus stand by walk and ppt
walk	walk mode users mainly walk to their work place
car	car users use cars for their work trip
personalized public transport (ppt)	ppt includes rickshaw, cng, taxi, laguna and shared cng

Table 6
Attributes Used In the Model Calibrated with RP Data

Type of Attributes	Attributes	Description	Variable State	Coded Value	Notation of Attributes
Mode Specific Attributes	Total Cost	Total money (in BDT) workers spent for work trip			TOTCOS
	Time in motion by any vehicle or by walk	Total time (in minute) workers are actually moving by any modes includes access time for reaching public transport. For those who are walking this means the total time they are actually walking.			INV
	Waiting time for Public Transport	Total time workers are waiting for either bus or PPT			OTV
Social Demographic Attributes	Income	The minimum wage rate of Bangladesh is about 5000 BDT. Therefore assumption taken that those who have income more than 5000 BDT are considered as not poor in the model.	<=5000 BDT >5000 BDT	1 0	0_5000
	Gender	Gender is a dummy Variable. Male is coded as 1 and Female 0.	Male Female	1 0	GENDER
	Education	The sample is divided into those who have a postgraduate degree and those who do not have a postgraduate degree. Postgraduate degree means 1 or 2 year Masters degree. It has been found from the survey and the author's observation that a postgraduate degree is mandatory for getting a high paid job. Those who have postgraduate degree is coded as 1.	With Post Graduate Education Without Postgraduate Education	1 0	POSTGRAD
	Age	The sample is divided into age less than 35 years and age above 35 years. Those who aged above 35 years are coded as 1	<=35 YEAR >35 YEAR	0 1	AB35
Constant		Walk, bus, car and PPT specific Constant			

The choice of model depends on the characteristics of the data. With the exception of MNL model none of the modelling methodology found appropriate. The NL model is more appropriate when the choices are interdependent and somewhat correlated (Hensher, Rose et al.,2005). For RP Model the choices are walk, bus, car, and PPT, which are not interdependent to each other. Therefore, choice of nested logit (NL) model would not be appropriate. Again mixed logit (ML) model is not suitable for the model as it is more appropriate with panel data. Table 5 lists choices for model calibrated with RP data and their definition.Table 6 lists attributes lists in the model calibrated with RP data.

Table 7 lists the model results. Generic coefficients of travel time and travel cost were used for model development. Mode specific travel cost and travel time attributes did not work as these coefficients turned out to be fixed parameter. This may be because for some modes, such as car and PPT the sample size is not very high.

The coefficients of travel cost, travel time in motion and waiting time turned as significant as t-ratio for these coefficients are greater than 2. The strongest prior knowledge a transport modeller has of the estimated coefficients is with regard to their sign. Result shows total cost, time in motion and waiting time for public transport has an expected negative sign. Therefore, increased value of these attributes will reduce the utility of the respective mode.

Table 7
Model Estimation Result for Model Calibrated with RP Data

Mode	Attribute	Coefficient	Std. Err.	t-ratio	P-value
For all Modes	Total Cost	-0.0056	0.0010	-5.8036	<0.01
	Travel Time in Motion	-0.0063	0.0023	-2.7032	<0.01
	Waiting Time	-0.0672	0.0091	-7.3747	<0.01
Bus	Gender	-0.4109	0.2103	-1.9534	<0.01
	Income	0.8634	0.3905	2.2112	<0.01
Walk	Constant	-3.1847	0.3512	-9.0678	2.89E-15
	Gender	-1.4025	0.2839	-4.9403	<0.01
	Income	3.9135	0.3936	9.9417	<0.01
Car	Constant	-4.5683	0.5658	-8.0737	2.89E-15
	Education	2.5595	0.3781	6.7692	<0.01
	Age	1.3974	0.2973	4.6999	<0.01
PPT	Constant	-1.7792	0.2923	-6.0873	<<0.01
	Education	0.3935	0.1892	2.0798	<0.01
	Age	0.4562	0.1855	2.4594	<0.01
Overall Goodness of Fit of Model Log Likelihood Function = -746.69 Pseudo R^2=0.31					

The coefficient of gender for Bus mode is negative, which means women have greater tendency to choose bus. Income coefficient for bus mode is positive which means that those who are poor are more likely to choose bus for their work trip.

For walk mode coefficient of gender is negative and coefficient of income is positive. This means women and those who are poor are more likely to walk. However the magnitude of the value gender and income are more for walk mode compared to bus mode. Therefore, more poor women workers tend to choose walking as their preferred mode of transport compared to bus.

For car and PPT modes education and age are positive. Workers with postgraduate degrees and above 35 years are more likely to choose car. Those who have higher education levels earn more money and have increased affordability to own cars or choose PPT. Those who are above 35 years have more financial security. Financial security and age increase workers' tendency to buy car.

6. Elasticity Analysis for Dhaka

Table 8 lists elasticity of travel time in motion for all modes. Elasticity values of travel time in motion for all modes less than 1 reflects that all modes are relatively inelastic for the travel time in motion attribute. This is justifiable as this represent only work trip. Work trip is less elastic than other trip purposes (Litman, 2013).

Table 8
Elasticity of Travel Time in Motion

Mode	Bus	Walk	Car	PPT
Bus	*-0.23*	0.06	0.02	0.07
Walk	0.10	*-0.15*	0.01	0.02
Car	0.20	0.03	*-0.16*	0.10
PPT	0.21	0.04	0.02	*-0.17*

**Italic Values are represented as direct point elasticity of the respective modes*

Table 9
Elasticity of Total Cost

Mode	Bus	Car	PPT
Bus	*-0.03*	0.13	0.16
Walk	0.01	0.03	0.05
Car	0.03	*-1.32*	0.22
PPT	0.03	0.19	*-0.37*

**Iitalic values represent direct point elasticity*

Table 1 lists elasticity values for in-vehicle travel time for other cities for comparison. None of the published elasticity value has been found for travel time in motion defined as this research for public transport. However, elasticity of in-vehicle time from other studies will give indicative comparison with the elasticity value of travel time in motion for this research.

Travel time in motion in this research is defined as actual time commuters are moving and time to/from bus station. Literature review of in-vehicle time defined as time commuter actually moving for their trip. Direct and cross elasticity values for bus travel time in motion in the model calibrated with RP data are closely similar to elasticity value for bus in-vehicle travel time for developed cities.

Among the listed elasticity values in the Table 1, Europe, Dutch, Italian and Brussels' elasticity value is specifically for the work trip and other elasticity values are generic applicable for any trip for the relative mode. Comparison of elasticity of travel time in motion of bus for Dhaka and elasticity of in-vehicle time for developed cities showed that for most of the developed city elasticity value of in-vehicle travel time is high compared to Dhaka. This can be explained as because all the developed cities have very good transport system. As a consequence increase of in-vehicle time would lead them to choose other modes that take less in-vehicle time. For Karachi city elasticity for in-vehicle travel time is much higher than

Dhaka city. Karachi city has variety of transport modes that made it prominent. As a consequence, increasing in-vehicle travel time would cause significant modal shift to other modes as the elasticity value is high. Another explanation is less affordability to other available modes and excessive traffic congestion on roads for Dhaka. In Dhaka bus is the cheapest option that most of the commuters use for their work trip. Using car and PPT is costlier than using bus for everyday work trip. Again during peak time most of the roads in Dhaka are in saturation level that made workers forced to less sensitive to travel time in motion.

Like bus travel time in motion workers in Dhaka are less sensitive to car travel time in motion. The absolute values of elasticity of car travel time in motion for developed countries ranges from 0.26 to 0.62, whereas for Dhaka this value is only 0.15. In Australia, Britain, Europe, cities have very efficient public transport system and road network. Also in the developed cities travelling by car is not symbol of status like Dhaka. Commuters in developed cities will be very sensitive to the increasing travel time in motion and they will shift to other modes that have less travel time than car. Commuters in Dhaka those who use car perceive the car as sense of security, status and comfort. Image of public transport in Dhaka does not provide the same sense of security, status and comfort. As a result car users are less sensitive even though travel time for car increases.

Similar to car and bus in Dhaka workers are less sensitive to travel time of walk. Again it can be explained that because of efficient transport system people in developed cities are more sensitive to travel time. However, in developed cities magnitude of absolute value of elasticity of travel time of walk is much lower than elasticity of bus in vehicle travel time and car in-vehicle travel time. However, in Dhaka magnitude of elasticity value of bus, walk, car and PPT travel time in motion are very similar. Therefore, commuters are almost similarly sensitive to travel time in motion for different modes.

Table 9 lists results for elasticity of total cost of bus, walk, car and PPT. The results show that for 1% change of total cost of bus the probability to choose bus will decrease 0.02%. Cross elasticity of walk, car and PPT will be 0.01%, 0.03% and 0.02%. Bus, walk, car and PPT are relatively inelastic with bus total cost.

The result shows that direct elasticity for total cost of car is more than 1. Car is relatively highly elastic with total cost. Increasing total cost of car would increase relative utility of PPT more than other modes as the elasticity value is the maximum. Litman (2014) stated that commuting trips are less price sensitive. Elasticity values of bus and PPT are less price sensitive. However car is relatively elastic with total cost.

Table 2 lists the direct and cross elasticity of travel cost of different modes for other cities. Compared to developed cities absolute value of elasticity for travel cost of bus for work trip in Dhaka is less. In developed countries commuters have other options that they can afford to choose for their work trip, therefore they are more price sensitive than commuters in Dhaka. However, elasticity of travel cost of public transport for Tokyo is almost similar to Dhaka. Bus is the one of the cheapest option in Dhaka compared to car and PPT. Majority of workers use bus for their work trip. There is huge gap between cost of bus and cost of other modes. As a result those commuters are less sensitive to bus travel cost compared to other cities. Comparison of direct elasticity of car cost with that of Dhaka shows that in Dhaka car is highly elastic with its total cost compared to developed cities. Car is the most expensive mode in Dhaka. Therefore, commuters would react negatively if car cost increases more.

Table 10 lists elasticity of waiting time. For 1% change of bus waiting time, probability to choose bus will decrease by 0.83%. On the other hand this will increase the probability to choose walk, car and PPT by 0.38%, 0.65% and 0.75% respectively. As the direct and cross elasticity of bus waiting time for all modes are less than one, they are relatively inelastic with waiting time. However the value of direct elasticity of bus waiting time is more than direct elasticity of bus travel time in motion. So waiting time of bus will impact more negatively on bus ridership than bus travel time in motion.

Table 10
Elasticity of Waiting Time

Mode	Bus	PPT
Bus	*-0.83*	0.17
Walk	0.38	0.06
Car	0.65	0.22
PPT	0.75	*-0.42*

**Italic values represent direct point elasticity of bus*

For 1% change of waiting time of PPT the probability to choose PPT will decrease 0.42%. Cross elasticity of waiting time of PPT for Bus, walk and car will be 0.17%, 0.06% and 0.22% respectively. Table 3 lists direct and cross elasticity of wait time for public transport for different cities. Comparing elasticity of wait time of bus with developed cities elasticity of wait time shows that commuters in Dhaka are very sensitive to waiting time for public transport. When commutes are inside vehicles on over saturated congested road they feel the sense of helplessness and know that on such a congested road they cannot shift to other vehicles. Excessive waiting for buses make commuters to choose different modes more easily. As a result commuters are more sensitive to waiting time.

7. Analysis Travel Behavior for Different Homogeneous Group of Workers from the Model Result

To understand the travel behavior of different homogeneous groups of workers the utility functions have been applied to these homogenous groups of workers.

Table 11
Groups of Men and Women Workers

Gender	Age	Education	Income Status
Female	Less than or equal to age 35	Without Postgraduate Education	Poor
Female	Above age 35	Without Postgraduate Education	Poor
Male	Above or equal to age 35	Without Postgraduate Education	Poor
Male	Above age 35	Without Postgraduate Education	Poor
Female	Less than or equal to age 35	Without Postgraduate Education	Not Poor
Female	Above age 35	Without Postgraduate Education	Not Poor
Male	Less than or equal to age 35	Without Postgraduate Education	Not Poor
Male	Above age 35	Without Postgraduate Education	Not Poor
Female	Less than or equal to age 35	With Postgraduate Education	Not Poor
Female	Above age 35	With postgraduate Education	Not Poor
Male	Less than or equal to age 35	With Postgraduate Education	Not Poor
Male	Above age 35	With Postgraduate Education	Not Poor

For analysis, average values of different travel attributes were used. The sample data is divided into the groups mentioned in the Table 11 for understanding how their travel pattern differs. Among the groups "poor" represents those who have an income 0 to 5000 BDT and "not poor" represent those who have an income of more than 5000 BDT. Figure 2 illustrates the comparison of predicted mode share among different groups of workers.

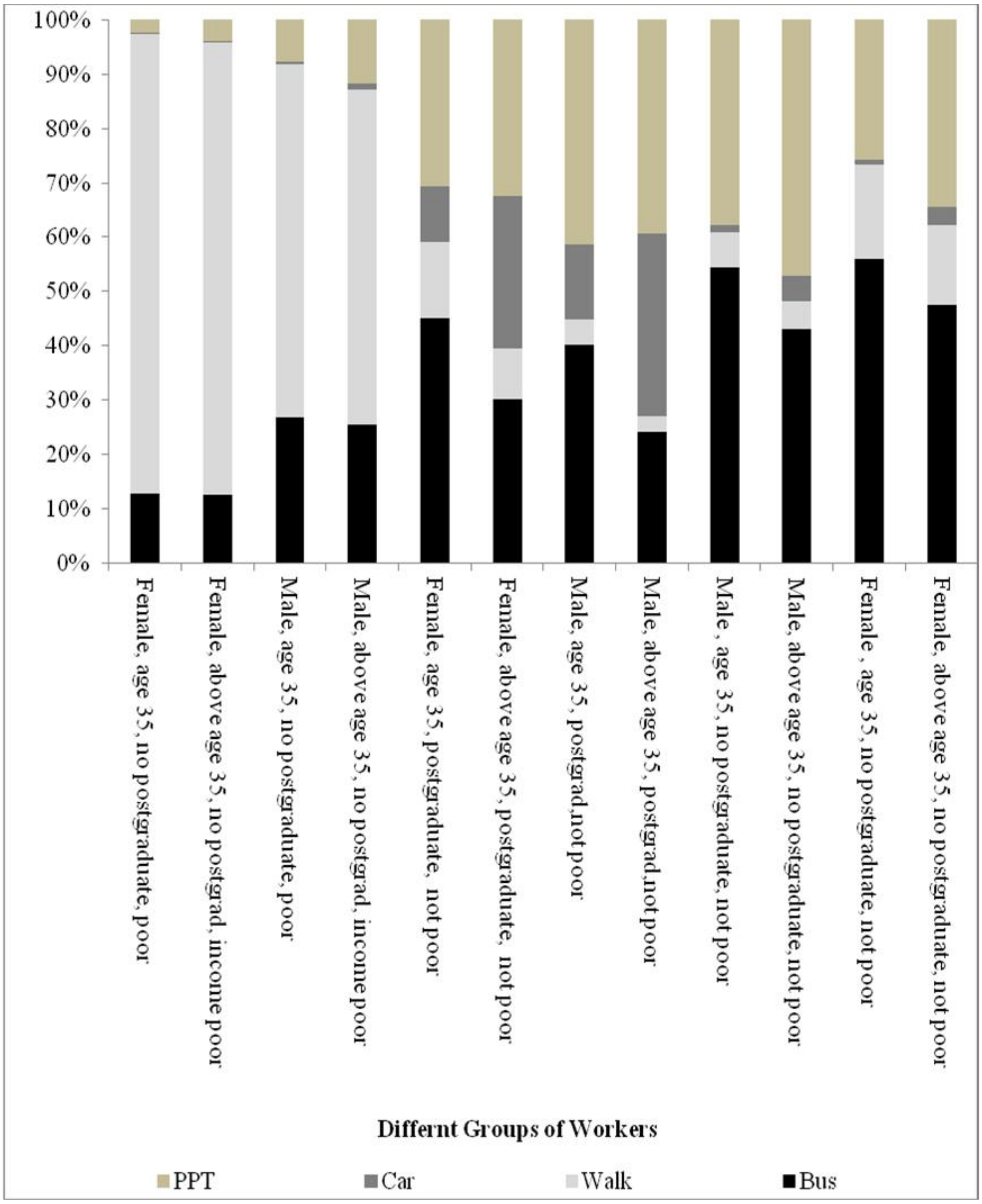


Fig. 2. Travel Pattern of Different Homogenous Groups of Workers from Model Prediction

Discussions, on travel behavior of different homogeneous groups of workers, are given bellow:

- Mode share of walk is the maximum for those who are poor and among the poor workers female workers has more probability to choose walk. Very few poor workers would choose bus for their work trip. PPT and car mode share are almost negligible for poor workers. A worker's age does not have any influence on poor workers' travel pattern. However, more male poor workers use bus for work trip compared to poor female workers.
- Workers probability to choose walk decreases with the increased income. Travel pattern of workers varies with gender, age and educational qualification for workers who are not poor.
- Female workers who are not poor aged less than or equal to 35 with or without postgraduate education, have maximum mode share of bus, then PPT, then walk, and least mode share of car. The difference between female workers aged less than or equal to 35 year, with postgraduate education and without postgraduate education, is the percentage of mode share. Mode share of car and PPT are more compared to those who do not have postgraduate education. More percentage of workers who do not have postgraduate education use bus and walk compared to those who have postgraduate education.
- For female workers who are not poor and aged above 35 with postgraduate qualification, the mode share of PPT is the maximum. On contrary female workers aged above 35 without postgraduate education bus mode share is the maximum. Car mode share is almost 9 times higher compared to those who do not have postgraduate education.
- For male workers who are not poor aged less than or equal to 35 with postgraduate education, the probability to choose PPT is the maximum for work trip. In contrast without postgraduate education the probability to choose bus is the maximum. Bus mode share is about twice as high for those who do not have postgraduate education. Car mode share is about 15 times higher for those who have postgraduate education.
- There is significant difference in car use among the male workers who are not poor aged above 35 with postgraduate education and the male workers aged above 35 without postgraduate education. Car use is about 8 times higher for those who have postgraduate education compared to those who do not have postgraduate education. For this group probability to choose PPT is the maximum for both who have postgraduate education and who do not have postgraduate education. However the percentage of mode share of PPT will be more for those who have postgraduate education.
- There is significant difference of travel behavior between poor and not poor workers. Poor workers mostly walk to their work place and use other modes less compared to the workers those who have more income. Probability to walk to the work place decreases with the increase of income.
- Male and female workers' mode choice decision varies mainly when female workers have less income. However, female workers probability to walk is more compared to male worker disregarding their income. Female workers who are not poor use less car compared to their male counterparts. For workers who are not poor probability to choose bus is less for male workers compared to female workers disregarding their education level. On the other hand male workers probability to choose PPT is more compared to female workers disregarding their income. Therefore, male workers have more affordability to spend for their work trip mode. However probability to choose car is about the same for male and female workers who are not poor disregarding their age.
- Workers aged less or equal to 35 years use less expensive and less comfortable mode compared to those workers aged above 35 years.

8. Conclusion

The model with RP data reflects the current scenario of travel pattern for workers in Dhaka. Workers mode choice decision varies with their gender, age, education and income. Poor female workers are the most vulnerable on the road. They have less affordability to choose different modes for their work trips and also they are the victim of discrimination mostly while travelling on roads. They receive aggravation not only from the bus drivers and helpers but also from other co-passengers on buses. The model result showed that poor female workers mostly walked to their work place. There are significant differences of mode choice behavior between poor female workers and female workers who are not poor. Female workers who are not poor have more affordability to choose any modes compared to the female workers who are poor. However, there are differences between female and male workers who are not poor. Female workers use less expensive modes compared to their male counterparts.

Age has an influence on workers mode choice decision. Young workers (age 35 or less) tend to choose less expensive and less comfortable mode for their work trip disregarding their gender and education qualifications. Young workers have less financial stability and they have more physical strength to walk or to travel on crowded buses. However, for poor workers age does not have any influence on their mode choice decision.

Workers with more educational qualifications have greater tendencies to choose more comfortable and expensive modes compared to workers with fewer educational qualifications. This is mainly because workers educational qualification and income is related. Those who have more education usually earn more money in Dhaka. Workers with higher educational qualification have more affordability to choose different modes.

Comparison of elasticity value between Dhaka and developed cities showed similarities and differences of impact of change of attributes for the mode choice decision. The absence of good transport system in the current transport scenario makes Dhaka workers relatively inelastic with respect to travel time in motion for all modes. Conversely generally in developed cities commuters are relatively more elastic with in vehicle time for bus, car and walk compared to Dhaka. This reveals the presence of good transportation system, and higher affordability to choose from different mode in the developed cities.

Except car commuters are relatively inelastic with travel cost of other modes. In Developed cities commuters are highly elastic in respect to travel cost. This is because good transport system and not extensive cost and level of service differences among different modes. Bus travel cost is comparatively low than car and PPT. Therefore, those who can afford bus would not react negatively with increase of bus travel cost until the cost is within their affordable limit. PPT travel cost and level of service are comparatively higher than bus but lower than car. Therefore until PPT travel cost is within affordable limit commuters would not change to other modes.

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References

Aftabuzzaman, M., Y. Murumachi, N. Harata and K. Ohta (2010). "Modeling Mode Choice Behavior for Work-Trip of a Developing City."

Alam, D. J. B., M. A. Jaigirdar and M. H. Rahman (1999). "Analysis of Behavioural Value of Travel Attributes and Their Implication On Urban Transport Policies." Journal of Civil Engineering (IEB) CE 27(1).

Alam, D. M. J. B. and K. M. N. Habib (2003). "Effects of Alternative Transportation Options On Congestion and Air Pollution in Dhaka City." Journal of Civil Engineering, The Institute of Engineers, Bangladesh CE 31(2): 165-175.

Anam, S. and A. M. Hoque (2011). Evaluation of bus rapid transit (BRT) in context of Bangladesh. 4th Annual Paper Meet and 1st Civil Engineering Congress,. Dhaka, Bangladesh.

Balcombe, R., R. Mackett, N. Paulley, J. Preston, J. Shires, H. Titheridge, M. Wardman and P. White (2004). The Demand for Public Transportation, A PracticalGuide. Report 593. London, Transportation Research Laboratory.

Ben-Akiva, M. E. and S. R. Lerman (1985). Discrete Choice Analysis: Theory and Application to Travel demand The MIT Press, Massachusets USA.

BITRE (2014). Elasticities Database Online, Australian Government, Department of Infrastructure and Regional Department.

Dargay, J., M. Hanly, G. Bresson, M. Boulahbal, J. L. Madre and A. Pirotte (2002). The Main Determinants of the Demand for Public Transit: A Comparative Analysis of Great Britain and France, ESRC Transport Studies Unit, University College London.

Dargay, J. M. and M. Hanly (2002). "The Demand for Local Bus Services in England." Journal of Transport Economics and Policy 36(1): 73-91.

Deb, K. and M. Filippini (2013). "Public Bus Transport Demand Elasticities in India." Journal of Transport Economics and Policy 47(3): 419–436.

Enam, A. (2010). Developing A Comprehensive Mode Choice Model to Capture the Preferences for Mass Rapid Transit in Dhaka. Master of Science in Civil Engineering (Transportation), Bangladesh University of Engineering and Technology.

Glasow, P. A. (2005). Fundamentals of Survey Research Methodology.

Goodwin, P. B. (1992). "A review of new demand elasticities with special reference to short and long run effects of price changes." Journal of Transport Engineering & Policy 26(2): 155-171.

Government of Bangladesh (1994). Dhaka Integrated Transport System (DITS), Dhaka Transport Coordination Board (DTCB), Dhaka-1000.

Greene, W. H. (1998). LIMDEP

Habib, K. M. N. (2002). Evaluation of Planning Options to Alleviate Traffic Congestion and Resulting Air Pollution in Dhaka City. MASTER OF SCIENCE IN CIVIL ENGINEERING (TRANSPORTATION) Traditional Bangladesh University of Engineering and Technology.

Hague Consulting Group (1999). TRACE.

Hensher, D., J. M. Rose and W. H. Greene (2005). Applied choice analysis: a primer

Hensher, D. A. and J. J. Louviere (1998). A comparison of elasticities derived from multinomial logit, nested logit and heteroscedastic extreme value SP-RP discrete choice models, Institute of Transport Studies Working Paper.

Israel, G. D. (1992). Determining Sample Size. Program Evaluation and Organizational Development, IFAS, University of Florida. PEOD-6.

Katahira & Engineers International Oriental Consultants Co. Ltd. and Mitsubishi Research Institute Inc. (2010). Dhaka Urban Transport Network Development Study (DHUTS). Draft Final Report.

Litman, T. (2013). Understanding Transport Demands and Elasticities - How Prices and Other Factors Affect Travel Behavior, Victoria Transport Policy Institute.

Litman, T. (2014). Transit Price Elasticities and Cross-Elasticities, Victoria Transport Policy Institute.

Litman, T. (2014). Transport Elasticities Impact on Travel behaviour. Sustainable Urban Transport technical Document GIZ.

Nkurunziza, A., M. Zuidgeest, M. Brussel and M. V. Maarseveen (2012). "Modeling Commuter Preferences for the Proposed Bus Rapid Transit in Dar-es-Salaam." Journal of Public Transportation 15(2).

Palma, A. d. and D. Rochat (2000). "Mode choices for trips to work in Geneva: an empirical analysis." Journal of Transport Geography 8: 43-51.

Rahman, M. S. (2008). Understanding the Linkages of Travel Behavior with Socioeconomic Characteristics and Spatial Environments in Dhaka City and Urban Transport Policy Applications. Masters Traditional, Hiroshima University, Japan.

T-Series Solutions. (2010). "Bangladesh Business Directory." Retrieved 14th July, 2011, from http://www.businessdirectorybangladesh.com/index.asp.

The Louis Berger Group and Bangladesh Consultants Ltd (2004). Strategic Transport Plan for Dhaka Final Report. Dhaka, Government of The People's Republic of Bangladesh, Ministry of Communications, Dhaka Transport Co-Ordination Board.

Tsai, C., C. Mulley and G. Clifton (2014). "A Review of Pseudo Panel Data Approach in Estimating Short-run and Long-run Public Transport Demand Elasticities." Transport Reviews 34(1): 102-121.

Tushara, T., P. Rajalaksmi and I. K. Bino (2013). "Mode Choice Modelling for Work Trips in Calicut City." International Journal of Innovative Technology and Exploring Engineering (IJITEE) 3(3): 2278-3075.

Wallis, I. and N. Schmidt (2003). Auatralian Travel Demand Elasticities- An Update of The Evidence. 26th Australasian Transport Research Forum. Wellington, New Zealand.