# Analysis of Travel Behavior in Khulna Metropolitan City, Bangladesh

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**Abstract**

In modeling travel demand and analyzing travel behavior, it is important to know the behavior of a large number of individuals. How the individuals choose an alternative among others given in the choice set, and how they assess and consider the different alternatives, must be a function of several factors including their need, task, socio-economic, environmental and the level of service offered by the various alternatives. A qualitative analysis of travel behavior was done with a number of individuals as the samples. To provide the required data, a field survey as direct home interview survey and travel time survey were conducted and given a number of 233 households and 871 respondents obtained as the samples. Meanwhile, the socio-economic data were obtained directly from the institution concerned. . The collected data were analyzed by using the Statistical Package for Social Science (SPSS) Software.The results of the analysis show that people with higher income and more automobile availability make more travel than people with low income and less automobile availability. The home-based trips take the largest percentage (50%) of people in the study area. The result also indicates that the shopping trips (15%) contribute higher among different trip purpose. The results also show that about 57% of individuals are between 20-50 years. The number of trips generated from each zone is strongly related to the amount of households, population, active workers and students of that zone. By considering a significant level of 5% four trip generation models have been developed. By using these models future trip generation from each zone can be determined. By applying the Gravity Model and the Fratar Method, the trip distribution models have been developed. Three basic models have been introduced by using travel time, road distance and straight distance as the resistance index. From these models the future travel pattern of Khulna Metropolitan city, Bangladesh can be predicted.

**Keywords:** Khulna Metropolitan City, Household survey, Travel behavior, Trip Distribution Models, Trip Generation Models.

## 1. Introduction

The environment in which transport analysis and infrastructure planning is taking place has changed radically during the last few decades. The urbanization in developing countries is dynamic; the big cities in these countries are reporting sustained pressure due to heavy migration from rural areas and high growth of private mode of transportation along with public transportation services (Domencish and McFadden, 1975). The urban transportation problem has become one of the main problems faced by cities in developing countries. The rapid growth of motorization and city structure, such as mixed land- use and the increasing rate of urbanization are some causes of this phenomenon (Black, 1991). Another reason is lack of planning in the past.

Travel behaviour is an essential element for the modern transportation system. Travel behaviour is complex, not only in terms of its motivations, but also in terms of how it manifests itself (Parsons *et al.*, 2002). People travel because they get benefits from it, or more precisely, they get benefits from the things they do or buy at the end of the trip (Puget Sound Regional Council, 2001). One of the key issues of travel behavior is travel mode choice decision. More choice plays a vital role in transportation planning and policy making in any city. Past research has clearly shown that individual and household socio-economic characteristics have strong influence on mode choice decision. They identified that income, gender, vehicle ownership, employment status are the most influencing variables in mode choice decision (Miller *et al.*, 2005; Bhat and Sardesai, 2006). Residential location and built environment attributes also play an important role in travel mode choice decisions (Pinjari *et al.*, 2007; Frank *et al.*, 2000).

Many urban transportation studies have been done in several metropolitan areas such as in Bangkok, Thailand, Manila, Philippine, Kuala Lumpur, Malaysia and Jakarta, Indonesia. Among these studies various concepts of modeling have been developed as well. These models are mostly applicable for metropolitan area, i.e. cities with two million people or over (Itorralba, 1988). Meanwhile, it is realized that the number of metropolitan areas is much smaller than that of cities in other categories.

In order to develop economic condition in nationwide, some middle sized cities must be built up as regional centers. However, only a few of these cities, especially in developing countries, can be identified as the regional centers. Since the planning concepts for metropolitan area might not be justified when applied to middle sized cities, major target of studies has moved to middle cities, i.e. population between 0.3 - 1 million. Planner, therefore, is required to provide the data as well as a better concept of planning for middle cities. In order to provide better concepts of transportation planning in middle sized cities, the particular problem that occur or might be faced in future need to identify and the guidelines for collecting the travel data need to provide (Pederson, 1980).

Bangladesh, which is one of the developing countries in the world, is situated at the southern part of the Asia. Although Bangladesh has seven metropolitan cities, very few transportation studies have been conducted to these cities. In fact in Bangladesh the middle sized cities are the majority but, as yet, a few studies have been conducted, the availability of data is also very low. The study area, Khulna Metropolitan City (KMC) is one of the most important middle sized cities and urbanizing area in south-west of Bangladesh. The traffic load is rapidly increasing day by day due to the urbanization trend and changes in socio-economic level of the people. An efficient transportation system is essential to cater the travel need of the city commuters. As such, the travel behavior in KMC is carried out. This study approaches to analyze the travel behavior in KMC.

## 2. Methodology

This study was carried out by dividing the city into three divisions, namely Division I (Zone 4 and Zone 5), Division II (Zone 18 and Zone 21) and Division III (Zone 26 and Zone 28) according to the land use pattern. The zones were selected randomly for field survey. Preliminary data were collected from Bangladesh Bureau of Statistics (2001) on the history and demography of the city. It was also necessary to study the behavior of the dwellers. The size of dwellers to be interviewed depends upon the total population, household number, city size, and sometimes the density of population. Although the recommended sample size is 1.5% of total household (Rumayar, 1992), in this study a sample size of 1.0 % is used due to inconvenient time, money and man power. Questionnaires were handed out to a random sample of the dwellers. As the postage for the return of questionnaires were not prepared for the financial reasons, the questionnaires were collected from the dwellers. The questionnaire was designed to collect data on the number of persons residing the household, personal of household (age, gender, and place of work, occupation, and income) and cars per household. The questionnaire also requested information on origin and destination of trips, number of total daily trips, purpose of trips, as well as mode of transport used.

The trip generation model was developed by using the regression analysis. To estimate the future trip generation, a basic model of the regression analysis was applied in this study. Equation (1) shows a typical basic model for trip generation.

$$T_i = k + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n \quad (1)$$

Where, $T_i$ = the dependent variable of trip generation or attraction (i.e. the zonal measure of traffic in terms of person movements, or movements by mode and purpose in zone i); $X_1$ **to** $X_n$ = the related independent variables; for example, zonal land-use or socio-economic characteristics; $b_1$ **to** $b_n$ = the coefficients of the respective independent variable; and $k$ = a constant included to represent that portion of the value of $T_i$ not explained by the independent variables.

Trip generation model was developed by several categories of trip purposes namely, home to work, home to school, home to business, and home to shopping. It was considered that these categories cover the majority of trips. The standard statistical test was used to assess the validity of each model. In this analysis the t-test was used to determine whether an estimated regression coefficient is statistically significant (5% significance level).

The Gravity Model was developed as the trip distribution model. The formula of Gravity model is expressed as in equation (2).

$$T_{ij} = k \frac{O_i^{\alpha} D_j^{\beta}}{d_{ij}^{\gamma}} \quad (2)$$

Where; $T_{ij}$ = Number of trip distribution from zone i to zone j; $O_i$ = Number of trip generated from zone i; $D_j$ = Number of trip attracted to zone j; $d_{ij}$ = resistance index between zone i and zone j; $\alpha, \beta, \gamma, \kappa$ = constant parameter

By using Gravity model, the result does not guarantee that the number of total trip generation and attraction in each zone equal to the future value. Therefore, iteration procedures need to be used. For iteration process, Fratar method was used to converge to the value. In applying the Gravity model, the resistance index of the model was selected as the value of travel time, distance between the zones at present condition and straight distance. While the trip generation and attractions were used as the attractive force index of origin and destination zones.

## 3. Results and Discussions

A total of 233 households were interviewed, and the questionnaires were distributed among 765 individuals over 7 years old. The respondents consist of 395 (49.7%) male and 390 (50.3%) female. Reported 1556 trips were used in the analysis. Lot of trips were generated and attracted within a zone. The reason to this might be the relative size of the zones .That is because the study area was a medium city, where the distance between different land use facilities were not so far.

In this study, the age structure was grouped into 4 age divisions as less than 7 years old, 7-20 years old, 20-50 years old and greater than 50 years of age. It was assumed that the people between 20-50 years old are active and independent travelers. Meanwhile, people between 7-20 years can be active but have some limitations as they have no fixed income yet. For people less than 7 years or more than 50 years old are considered groups who could not travel independently. This group also may travel less or differently than the working age groups. Figure 1 shows the age structure of the household members obtained from the survey. It is seen that the age between 7-20 years and 20-50 years are 19.3% and 56.9% respectively. It is also seen that the percent of young children and elderly are 12.2% and 11.6% respectively.

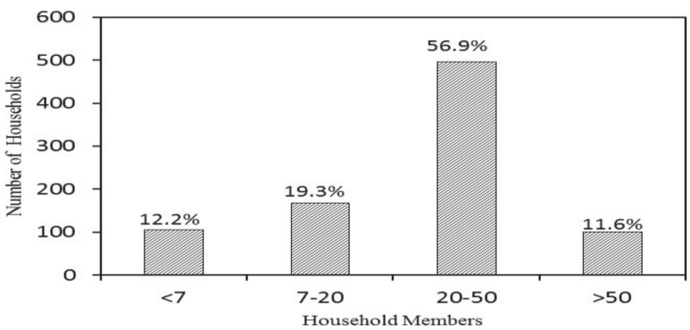


Figure 1. Age Structure of Household Members

The income is one of the most important factors shaping the travel patterns. In this study, the household income was calculated including whole monthly income of the members and head of household. Figure 2 shows the household income structure. It is seen that 89 (38.2%) households have monthly income ranging from BDT10001 to BDT20000. It is also seen that the monthly income ranging from BDT5001 to BDT10000 followed with 80 (34.3%) households and BDT20001 to BDT50000 followed with 38 (16.3%) households.

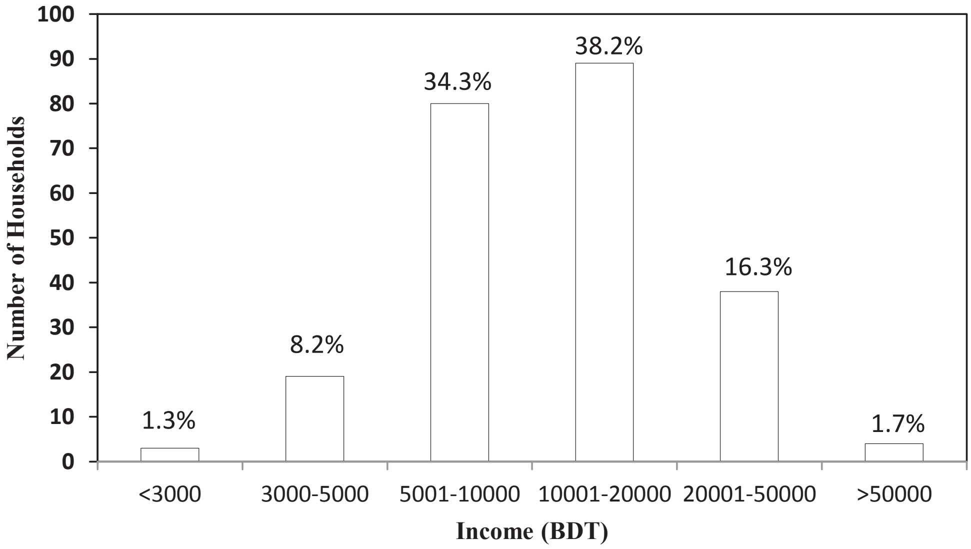


Figure 2. Household Income Structure

Figure 3 shows percentage occupation of respondents. Most of the individuals interviewed came from housewives 242 (31.6%), student 196 (25.4%), businessmen 99 (12.9%), and private service 110 (14.4%). It also shows that the Government employee followed with 44 individuals (5.8%). Meanwhile, retired and others have proportion of 18(2.4%) and 56 (7.3%), respectively.

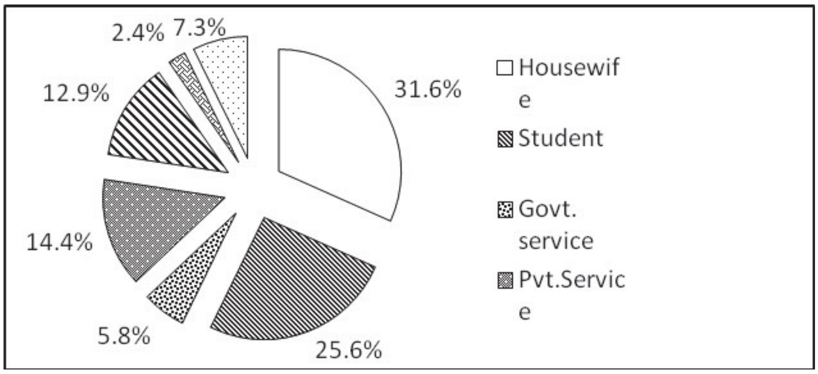


Figure 3. Totals and Percentage Occupation of Respondent

Car occupancy is associated with the access to private vehicles. Table 1 shows the distribution of households belonging to vehicles ownership and vehicle rate per households. It is seen that the car ownership is very low (3.9% share) compare with motorcycle (8.6%). Car ownership includes private and official cars; it is categorized that the role of an official car is similar to private car. More than 65% have no access to private vehicles and about 22% have access to bicycle only.

Table 1. Distribution of Vehicle Ownership

| Vehicle ownership | Numbers | % of Households | Vehicle Rate Per Household |
|---|---|---|---|
| No Vehicle | 153 | 65.7 | - |
| Bicycle | 51 | 21.9 | 0.22 |
| Motorcycle | 20 | 8.6 | 0.09 |
| Car | 9 | 3.9 | 0.04 |
| Total | 233 | 100.0 | |

The distribution of types and numbers of the vehicles are concentrated with the income of the household especially with the upper income group and these groups are much more mobile than lower income groups. Figure 4 shows the relationship between car ownership level and household monthly income. It is seen that the level of car ownership increased rapidly with their income. Higher income group has more luxurious vehicle than the lower income groups.

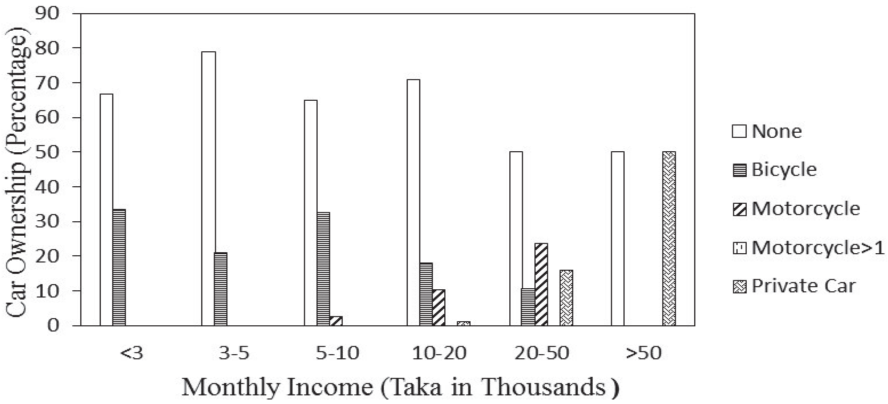


Figure 4. Relationships between Vehicle Ownership and Monthly income

In Khulna, the office hour is different for government and private sector. Government office hour usually finish at 17:00, and different private sectors have different time limit. Figure 5 shows the distribution of trips by time of trip start. It is seen that at 8:00 am to 10:00 am there is peak in the trip distribution.

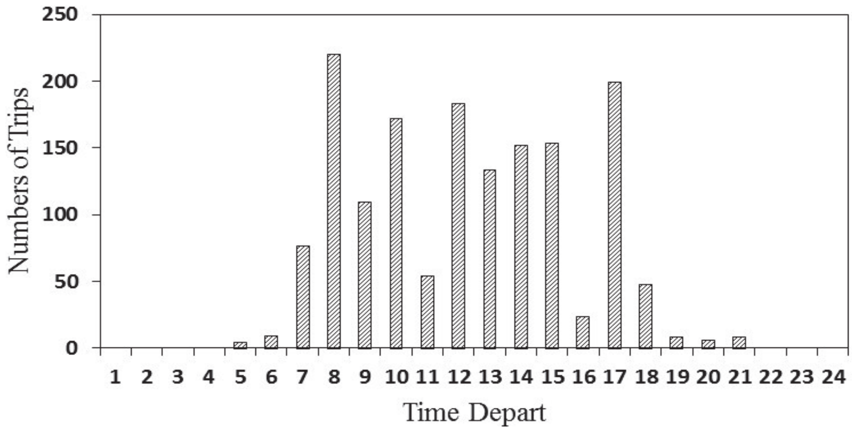


Figure 5. Distribution of Trip by Time of Trip Start

Figure 6 shows that most of the trips are generated from home (50% of the total trips) followed with trips from office (16.6%). Trips generated from education facilities, shopping, recreational and others are 12.5%, 16.2%, 2.4% and 2.3%, respectively.

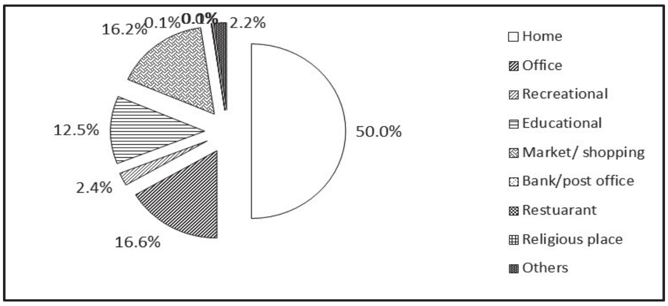


Figure 6. Total trip Based on Facility of Origin

Table 2 shows the daily trips per household for various purposes. It is seen that most of the trip makers are distributed among four purposes; home (50%), work (15%), school (13%) and shopping (12%). Business trip has shared of 8%, recreation 2% and others 1%.

 

Table 2. Daily Trips per Household for Various Purposes

| Trip purpose | Trips | Trips per household per day | Percentage of trips |
|---|---|---|---|
| Home | 780 | 3.3 | 50 |
| Work | 232 | 1.0 | 15 |
| School | 195 | 0.8 | 13 |
| Shopping | 185 | 0.8 | 12 |
| Business | 119 | 0.5 | 8 |
| Recreation | 33 | 0.1 | 2 |
| Others | 12 | 0.1 | 1 |
| Total | 1556 | 6.7 | 100.0 |

In Khulna, public transport is provided for fixed route which is mainly on the major streets. Many households, especially those who have income at the average level or live away from the major streets, walk trips are the first mode to access the public mode on the major streets. The number of trips for each mode is presented in Table 3. It is seen that the dominant mode in Khulna is walking with 46.6%. Travel within shorter distance in choice of public modes, favorable mode is rickshaw and auto rickshaw. People choose city bus mainly for long distance trips, also the access to bus is slightly limited as all buses have operated with fixed route as well as fixed stop. There is no doubt that walking is the dominant mode of travel in Khulna. Now a day's auto rickshaw has become more popular than rickshaw. For the relatively longer trips for work and business purpose auto rickshaw, bus and motorcycle are frequently used.

Table 3. Numbers of Trips by Mode

| Mode | Numbers | Trips per Household | % of Trips |
|---|---|---|---|
| Walking | 725 | 3.11 | 46.6 |
| Bicycle | 92 | 0.39 | 5.9 |
| Rickshaw | 351 | 1.51 | 22.6 |
| Motorcycle | 48 | 0.21 | 3.1 |
| Auto rickshaw | 218 | 0.94 | 14.0 |
| Bus | 107 | 0.46 | 6.9 |
| Microbus | 0 | 0.00 | 0 |
| Private car | 10 | 0.04 | 0.6 |
| Others | 5 | 0.02 | 0.3 |
| Total | 1556 | 6.7 | 100.0 |

As transportation studies of cities in Bangladesh are very limited, a study of Manado, Indonesia was selected to compare with Khulna Metropolitan City (KMC). Manado is the Capital city of North Sulawesi province in Indonesia. It has played an important role in the entire North Sulawesi as centre of administration, education, trade, business, culture, and tourism. Table 4 shows the comparison of daily trips household for various purposes between KMC and Manado. The result of Manado is based on the result of Rumayar (1992) and the rate of trip generation in Manado was 8.3 trips per household per day; whereas the value for Khulna is 6.7 trips per household per day. Although, the trip per person per day is 1.5 trips compare with 1.8 trips/person/day of Manado. The rate of trip per person per day can be reflected from several factors such as number active worker, size, and income of a household. It is seen that home-based trip in Khulna and Manado is 50% and 43% respectively. Whereas, the work trips in KMC and Manado are shared about 15% and 17%, respectively. Educational trip in Khulna (13%) is also lower than Manado (14%). Trips related to shopping in Khulna (about 12%) are found higher than Manado (about 7%).

Table 4. Daily Trips per Household comparison

| Trip Purpose | Trips Per Household Per Day | | Percentage of Trips | |
|---|---|---|---|---|
| | Khulna | Manado | Khulna | Manado |
| Home | 3.3 | 3.6 | 50 | 43 |
| Work | 1.0 | 1.4 | 15 | 17 |
| School | 0.8 | 1.1 | 13 | 14 |
| Shopping | 0.8 | 0.6 | 12 | 7 |
| Business | 0.5 | 1.1 | 8 | 13 |
| Recreation | 0.1 | 0.2 | 2 | 2 |
| Others | 0.1 | 0.3 | 1 | 4 |
| Total | 6.7 | 8.3 | 100.0 | 100 |

Table 5 shows the comparison of modal split by trip purpose of the study area, KMC and Manado. The access to the private vehicle in KMC is still low with respect to Manado. The average rate is about 4%. Household income is the main factor reflected to this pattern.

Table 5. Mode by Trip Purpose Comparison

| City | Mode | Trip purpose (%) | | | | |
|---|---|---|---|---|---|---|
| | | Home | Work | School | Shopping | Others |
| Khulna | Walking | 52.80 | 43.50 | 50.30 | 45.90 | 41.70 |
| | Bicycle | 5.90 | 7.30 | 7.70 | 0.50 | 0.00 |
| | Rickshaw | 17.90 | 34.90 | 23.10 | 30.30 | 25.00 |
| | Motorcycle | 3.20 | 0.40 | 4.60 | 0.00 | 16.70 |
| | Auto Rickshaw | 14.00 | 10.30 | 7.20 | 15.70 | 0.00 |
| | Bus | 5.30 | 2.20 | 5.60 | 7.60 | 16.70 |
| | Microbus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Private Car | 0.60 | 0.40 | 1.00 | 0.00 | 0.00 |
| | Others | 0.30 | 0.90 | 0.50 | 0.00 | 0.00 |
| Manado | Walking | 25.08 | 12.90 | 25.07 | 28.0 | 46.20 |
| | Bicycle | 1.20 | 1.80 | .60 | 1.40 | .90 |
| | Motorcycle | 15.60 | 16.30 | 9.30 | 10.80 | 12.30 |
| | Bus | 41.10 | 44.00 | 57.60 | 46.30 | 17.30 |
| | Car | 11.40 | 18.60 | 5.10 | 10.80 | 17.00 |

In order to develop trip generation model, the data set were categorized into two parts; dependent variables (present number of trips), and independent variables (zonal population, households, active workers, students, car per household, and car per population). The trip generation and socio-economic data are given in Table 6 and Table 7

Table 6. Data Set for Trip Generation

| Zone | Trip Generation from Home to | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Work | | | School | | | Business | | | Shop | | |
| | Tot trip (smp) | Tot trip (pop.) | Tot trip (HH) | Tot trip (smp) | Tot trip (pop.) | Tot trip (HH) | Tot trip (smp) | Tot trip (pop.) | Tot trip (HH) | Tot trip (smp) | Tot trip (pop.) | Tot trip (HH) |
| 4 | 20 | 2444 | 2021 | 29 | 3544 | 2930 | 16 | 1955 | 1617 | 23 | 2811 | 2324 |
| 5 | 21 | 2702 | 2079 | 19 | 2445 | 1881 | 23 | 2960 | 2277 | 24 | 3089 | 2376 |
| 18 | 25 | 2931 | 2500 | 33 | 3869 | 3300 | 44 | 5158 | 4400 | 36 | 4221 | 3600 |
| 21 | 29 | 4472 | 2916 | 40 | 6169 | 4023 | 40 | 6169 | 4023 | 56 | 8636 | 5632 |
| 26 | 26 | 3114 | 2602 | 30 | 3593 | 3002 | 45 | 5390 | 4503 | 39 | 4671 | 3903 |
| 28 | 27 | 3134 | 2717 | 44 | 5108 | 4428 | 51 | 5920 | 5132 | 54 | 6268 | 5434 |

Tot=Total, Pop=Population, Smp=Sample, HH= Household

Table 7. Socio-economic Data for Trip generation

| Zone | Zonal total population (2001) | Zonal total HH (2001) | Active worker by place of residence | Student by place of residence | No. of car per population | No. of car per HH |
|---|---|---|---|---|---|---|
| 4 | 14299 | 2930 | 4522 | 3544 | 0 | 0 |
| 5 | 15314 | 3267 | 4890 | 2445 | 129 | 0.03 |
| 18 | 16765 | 3400 | 6800 | 3869 | 234 | 0.06 |
| 21 | 24984 | 4425 | 8328 | 6169 | 308 | 0.05 |
| 26 | 18087 | 3903 | 6947 | 3718 | 120 | 0.03 |
| 28 | 22404 | 5434 | 7197 | 5224 | 348 | 0.06 |

In order to realize the statistical correlation between the independent variables and dependent variable and check the multicollinearity, a simple correlation matrix was developed. Table 8 shows the correlation matrix of the variables of trip generation. It is seen that most of the possible pairs of the independent variables i.e. population, household, active workers and students have a strong correlation with each other. Consequently, a simple regression equation was developed rather than a multiple regression.

Table 8. Correlation Matrix of Trip Generation Variables

<table>
<tr><td colspan="3" rowspan="2"></td><td colspan="6">Independent variables</td></tr>
<tr><td>P</td><td>HH</td><td>AW</td><td>S</td><td>COH</td><td>COP</td></tr>
<tr><td colspan="2" rowspan="6">Independent variable</td><td>P</td><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>HH</td><td>0.848</td><td>1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>AW</td><td>0.895</td><td>0.72</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>S</td><td>0.932</td><td>0.742</td><td>0.841</td><td>1</td><td></td><td></td></tr>
<tr><td>COH</td><td>0.645</td><td>0.667</td><td>0.761</td><td>0.533</td><td>1</td><td></td></tr>
<tr><td>COP</td><td>0.848</td><td>0.841</td><td>0.821</td><td>0.745</td><td>0.933</td><td>1</td></tr>
<tr><td rowspan="12">Dependent variable</td><td rowspan="3">Work trip</td><td>SPL</td><td>0.916</td><td>0.779</td><td>0.995</td><td>-</td><td>0.756</td><td>0.835</td></tr>
<tr><td>POP</td><td>0.898</td><td>0.538</td><td>0.862</td><td>-</td><td>0.506</td><td>0.666</td></tr>
<tr><td>HHT</td><td>0.921</td><td>0.784</td><td>0.994</td><td>-</td><td>0.742</td><td>0.829</td></tr>
<tr><td rowspan="3">School trip</td><td>SPL</td><td>0.817</td><td>0.82</td><td>-</td><td>0.917</td><td>0.602</td><td>0.76</td></tr>
<tr><td>POP</td><td>0.925</td><td>0.717</td><td>-</td><td>0.999</td><td>0.527</td><td>0.738</td></tr>
<tr><td>HHT</td><td>0.814</td><td>0.816</td><td>-</td><td>0.917</td><td>0.59</td><td>0.752</td></tr>
<tr><td rowspan="3">Business trip</td><td>SPL</td><td>0.662</td><td>0.769</td><td>0.844</td><td>-</td><td>0.841</td><td>0.793</td></tr>
<tr><td>POP</td><td>0.84</td><td>0.781</td><td>0.971</td><td>-</td><td>0.84</td><td>0.857</td></tr>
<tr><td>HHT</td><td>0.667</td><td>0.774</td><td>0.846</td><td>-</td><td>0.839</td><td>0.794</td></tr>
<tr><td rowspan="3">Shopping trip</td><td>SPL</td><td>0.973</td><td>0.898</td><td>0.943</td><td>0.923</td><td>0.729</td><td>0.885</td></tr>
<tr><td>POP</td><td>0.986</td><td>0.553</td><td>0.912</td><td>0.942</td><td>0.613</td><td>0.803</td></tr>
<tr><td>HHT</td><td>0.973</td><td>0.898</td><td>0.932</td><td>0.927</td><td>0.724</td><td>0.822</td></tr>
</table>

Where, T= Number of trip generation, P= Number of population, HH= Number of household, AW= Number of active workers, S= Number of students, COH= Number of car per household, COP= Number of car per population, SPL= Number of sample trip, POP= Number of population trip, HHT= Number of household trip.

Several combinations and transformations of both the dependent and independent variables were tried to develop the potential regression equations by using the SPSS Software. The trip generation models are shown in Table 9. It is seen that there are strong correlation between dependent and independent variables in most of the models. By using the highest coefficient of determination ($R^2$) and critical value of t-test, the regression equation was selected. It is also seen that the independent variable of car ownership did not contribute any relation to trip generation. It may be due to a not as much of car ownership of city dwellers.

Table 9. Trip Generation Model

| Trip Purpose | Model No. | Regression Equation | $R^2$ | DOF | t-value | | Result | | Comment |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | X1 | X2 | X1 | X2 | |
| Home to work | 1 | T=317.305+0.151P | 0.706 | 5 | 3.076 | 0 | 0.045 | 0 | * |
| | 2 | T=1290.205+0.305HH | 0.615 | 5 | 2.529 | 0 | 0.065 | 0 | # |
| | 3 | T=435.997+0.418AW | 0.744 | 5 | 3.408 | 0 | 0.027 | 0 | * |
| | 4 | T=2035.714+11394.41COH | 0.551 | 5 | 2.214 | 0 | 0.091 | 0 | # |
| | 5 | T=2449.79+3.598COP | 0.444 | 5 | 1.787 | 0 | 0.148 | 0 | # |
| | 6 | T=-230.63-1.812 COP + 0.0199P | 0.723 | 5 | -0.766 | 2.698 | 0.5 | 0.074 | # |
| Home to school | 1 | T=-1282.783+0.29P | 0.856 | 5 | 4.877 | 0 | 0.008 | 0 | * |
| | 2 | T=156.772+0.797HH | 0.666 | 5 | 2.827 | 0 | 0.047 | 0 | * |
| | 3 | T=-7.985+0.992S | 0.998 | 5 | 42.77 | 0 | 0.001 | 0 | * |
| | 4 | T=2711.426+7.427COP | 0.545 | 5 | 2.19 | 0 | 0.094 | 0 | # |
| Home to Business | 1 | T=-1832.525+0.345P | 0.706 | 5 | 3.1 | 0 | 0.036 | 0 | * |
| | 2 | T=-897.012+1.17HH | 0.599 | 5 | 2.446 | 0 | 0.071 | 0 | # |
| | 3 | T=-2811.776+1.148AW | 0.943 | 5 | 8.161 | 0 | 0.001 | 0 | * |
| | 4 | T=2449.37+11.287COP | 0.735 | 5 | 3.332 | 0 | 0.029 | 0 | * |
| | 5 | T=1730.429+50301.863COH | 0.704 | 5 | 3.085 | 0 | 0.037 | 0 | * |
| Home to Shopping | 1 | T=-4640.398+0.514P | 0.973 | 5 | 12.002 | 0 | 0.001 | 0 | * |
| | 2 | T=-1569.355+1.399HH | 0.806 | 5 | 4.082 | 0 | 0.015 | 0 | * |
| | 3 | T=-3890.283+1.371AW | 0.832 | 5 | 4.445 | 0 | 0.011 | 0 | * |
| | 4 | T=-1529.679+1.557S | 0.887 | 5 | 5.594 | 0 | 0.005 | 0 | * |

Where, T= Number of trip generation, P = Number of Population, HH= Number of household, AW= Number of active workers, S= Number of students, COH= Number of car per household, COP= Number of car per population, *= Accepted at 5% level of significance # = Rejected at 5% level of significance.

Based on the criteria of coefficient of determination and t-statistic, the following equations are recommended for future demand forecasting.

Home to work : $T=435.997+0.418AW$
Home to school : $T = -7.985 + 0.992\ S$
Home to business : $T = -2811.776 + 1.148\ AW$
Home to shopping : $T = -4640.398 + 0.514\ P$

For forecasting future value of trip distribution, three models have been obtained by using Gravity model as presented in Table 10. The models shown that some of the power of the resistance index $d_{ij}$, have a value greater than one. This can be interpreted that the long distance trip is included for this index. The power also indicated that when the duration increases the number of trips rapidly decreases. Power of $O_i$ and $D_j$ were obtained almost same in each model. The reason to this can be drawn as the activity of the origin and destination influence the trip with almost same manner.

Table 10. Trip Distribution model

| O-D matrix | Resistance index | Model Number | Model Equation | $R^2$ | Standard error of gravity model | Error after Fratar model |
|---|---|---|---|---|---|---|
| Original 6*6 matrix | Travel time | 1 | $T_{ij}=4.76 * 10^{-7} O_i^{2.133} D_j^{2.133} / d_{ij}^{2.136}$ | 0.673 | 8.52352 | 8.499 |
| | Road distance | 2 | $T_{ij}=0.04689 * O_i^{1.139} D_j^{1.1339} / d_{ij}^{0.816}$ | 0.360 | 8.67581 | 8.656 |
| | Straight distance | 3 | $T_{ij}=.025655 * O_i^{1.239} D_j^{1.232} / d_{ij}^{0.877}$ | 0.361 | 8.67566 | 8.658 |

Finally, all the models were tested at 95% confidence interval. All the partial regression coefficients or the power of the regression explained by the model are significant. The value of t-test, p-value and standard error are enlisted in Table 11. For forecasting future demand it is recommended to use model number 1 to its small value of standard error and greater $R^2$ value.

Table 11. t-test and standard error of trip distribution

| Model Number | | Model Name | Mean | t-value | p-value | Standard Error |
|---|---|---|---|---|---|---|
| 1 | Observed | Gravity model | 25.03 | 2.397 | 0.019 | |
| | Predicted | | 5.59 | 2.397 | 0.022 | 8.524 |
| | Observed | Fratar model | 25.03 | 1.627 | 0.108 | |
| | Predicted | | 11.17 | 1.627 | 0.111 | 8.499 |
| 2 | Observed | Gravity model | 25.03 | 2.478 | 0.016 | |
| | Predicted | | 5.12 | 2.478 | 0.018 | 8.676 |
| | Observed | Fratar model | 25.03 | 1.794 | 0.077 | |
| | Predicted | | 10.24 | 1.794 | 0.080 | 8.656 |
| 3 | Observed | Gravity model | 25.03 | 2.481 | 0.016 | |
| | Predicted | | 5.09 | 2.481 | 0.018 | 8.676 |
| | Observed | Fratar model | 25.03 | 1.800 | 0.076 | |
| | Predicted | | 10.18 | 1.800 | 0.079 | 8.658 |

Table 11 advocated that, standard error for Fratar model (8.499) is less than Gravity model (8.523). So, Fratar model will be preferred for future trip estimation. The Gravity model and Fratar model for each resistance index are given below:

Table 12. Model Number 1(With respect to travel time)

Gravity Model

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | $O_i$ |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 27.5 | 0.1 | 2.0 | 0.2 | 0.2 | 29.9 |
| 5 | 27.5 | 0.0 | 0.3 | 6.5 | 0.5 | 0.5 | 35.2 |
| 18 | 0.1 | 0.3 | 0.0 | 16.0 | 1.3 | 0.4 | 18.1 |
| 21 | 2.0 | 6.5 | 16.0 | 0.0 | 25.5 | 16.7 | 66.7 |
| 26 | 0.2 | 0.5 | 1.3 | 25.5 | 0.0 | 2.9 | 30.4 |
| 28 | 0.2 | 0.5 | 0.4 | 16.7 | 2.9 | 0.0 | 20.8 |
| $D_j$ | 29.9 | 35.2 | 18.1 | 66.7 | 30.4 | 20.8 | 201.1 |

After Fratar Iteration

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | Oi |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 54.9 | 0.2 | 4.1 | 0.3 | 0.4 | 59.8 |
| 5 | 54.9 | 0 | 0.5 | 12.9 | 1.0 | 1.0 | 70.4 |
| 18 | 0.2 | 0.5 | 0 | 31.9 | 2.6 | 0.9 | 36.1 |
| 21 | 4.1 | 12.9 | 31.9 | 0 | 51.1 | 33.4 | 133.4 |
| 26 | 0.3 | 1 | 2.6 | 51.1 | 0 | 5.8 | 60.8 |
| 28 | 0.4 | 1 | 0.9 | 33.4 | 5.8 | 0 | 41.5 |
| $D_j$ | 59.9 | 70.3 | 36.1 | 133.4 | 60.8 | 41.5 | 402.1 |

Table 13. Model Number 2 (With respect to Road distance)

Gravity Results

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | $O_i$ |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 12.5 | 0.6 | 4.4 | 1.1 | 1.3 | 20.0 |
| 5 | 12.5 | 0.0 | 1.0 | 7.5 | 1.9 | 2.2 | 25.1 |
| 18 | 0.6 | 1.0 | 0.0 | 21.0 | 1.6 | 1.8 | 25.9 |
| 21 | 4.4 | 7.5 | 21.0 | 0.0 | 14.7 | 15.5 | 63.2 |
| 26 | 1.1 | 1.9 | 1.6 | 14.7 | 0.0 | 5.0 | 24.3 |
| 28 | 1.3 | 2.2 | 1.8 | 15.5 | 5.0 | 0.0 | 25.8 |
| $D_j$ | 20.0 | 25.1 | 25.9 | 63.2 | 24.3 | 25.8 | 184.2 |

After Fratar Iteration

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | $O_i$ |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 24.9 | 1.2 | 8.9 | 2.3 | 2.7 | 39.9 |
| 5 | 24.9 | 0 | 2.0 | 15.1 | 3.8 | 4.4 | 50.1 |
| 18 | 1.2 | 2 | 0 | 42.0 | 3.2 | 3.5 | 51.9 |
| 21 | 8.9 | 15.1 | 42 | 0 | 29.4 | 31.0 | 126.4 |
| 26 | 2.3 | 3.8 | 3.2 | 29.4 | 0 | 9.9 | 48.6 |
| 28 | 2.7 | 4.4 | 3.5 | 31.0 | 9.9 | 0 | 51.5 |
| $D_j$ | 40 | 50.2 | 51.8 | 126.3 | 48.6 | 51.5 | 368.5 |

 

Table 14. Model Number 3 (With respect to straight distance)

Gravity Results

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | $O_i$ |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 12.3 | 0.5 | 4.2 | 1.2 | 1.2 | 19.4 |
| 5 | 12.3 | 0.0 | 0.8 | 7.6 | 1.9 | 2.0 | 24.7 |
| 18 | 0.5 | 0.8 | 0.0 | 20.9 | 1.6 | 1.5 | 25.2 |
| 21 | 4.5 | 7.6 | 21.2 | 0.0 | 15.3 | 15.5 | 64.1 |
| 26 | 1.2 | 1.9 | 1.6 | 15.2 | 0.0 | 4.9 | 24.9 |
| 28 | 1.2 | 2.0 | 1.5 | 15.4 | 4.9 | 0.0 | 25.0 |
| $D_j$ | 19.7 | 24.7 | 25.5 | 63.4 | 25.0 | 25.0 | 183.4 |

After Fratar model

| O-D | 4 | 5 | 18 | 21 | 26 | 28 | $O_i$ |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 24.6 | 0.9 | 8.7 | 2.5 | 2.4 | 39.1 |
| 5 | 24.5 | 0 | 1.5 | 15.2 | 3.9 | 4.1 | 49.3 |
| 18 | 0.9 | 1.5 | 0 | 42.1 | 3.3 | 2.9 | 50.7 |
| 21 | 8.7 | 15.2 | 42.1 | 0 | 30.6 | 30.8 | 127.4 |
| 26 | 2.5 | 3.9 | 3.3 | 30.6 | 0 | 9.8 | 50.1 |
| 28 | 2.4 | 4.1 | 2.9 | 30.8 | 9.8 | 0 | 50 |
| $D_j$ | 39 | 49.3 | 50.8 | 127.5 | 50.0 | 50.0 | 366.5 |

From these models it is found that in each model trip distribution within the zone is considered as no trip. These models also advocated that the maximum numbers of trips were distributed toward the zone 21. Because, zone 21 has all facilities including market, railway station, hospital, police station and city corporation office.

## 4. Conclusions

Consideration of users' socio-economic conditions and travel behavior are vital for planning an effective and sustainable transportation system. This study gives an idea about the travel pattern of the people living in Khulna. The travel pattern generally depends on the age of the traveler, socio-economic conditions, vehicle ownership etc. This study found that people with higher income generally travels more than people with lower income. Vehicle ownership is directly related to the income of the households. It is obtained that car ownership in Khulna is still low about 3.9% share compare with motorcycle 8.6%. A large proportion of home-based trips imply that most of the trips are limited and have a single purpose. The percentage of home-based trips is 50% of the total. The dominant mode in Khulna is walking with 46.6%. Rickshaw is the second highest mode with 22.6%. Now a days auto rickshaw has become more popular which is about 14% of the total trip's mode. People generally choose walking, rickshaw and auto rickshaw for travelling shorter distances. Whereas, people choose city bus mainly for travelling longer distances. The analysis of this study reveals that the travel behavior in the study area is quite similar to the middle sized city in Asian countries.

The developed trip generation models describe effectively the relationship between the daily trips and the selected independent variables. In these study the independent variables, i.e. zonal population; household, active worker and student have a strong correlation with each other. So, to avoid the multicollinearity, a set of simple regression equations were developed. It is found that the home to work and the home to business trips are strongly correlated to the number of active workers at that zone. Moreover, the number of school trips is strongly related to the number of students of that zone. By using these equations the future number of trips that generated from each zone can be estimated. Consequently, it can be provided sufficient information to the planners for the future development of road network system.

The trip distribution model with respect to travel time is more reliable than the others to its small value of standard error and greater value of coefficient of determination ($R^2$). The trip distribution model indicates that most of the trips are distributed toward zone 21 for its socio-economic facilities. The standard error for Fratar model (8.499) is less than Gravity model (8.523). Because of this Fratar model will be preferred for estimation of future trip distribution.

**References**

Bangladesh Bureau of Statistics(BBS), (2001), Planning Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka, Bangladesh.

Bhat, C.R. and Sardesai, R. (2006), "The Impact of Stop-Making and Travel Time Reliability on Commute Mode Choice." Transportation Research Part B, Vol. 40, No. 9, pp. 709-730.

Black, J. (1981), Urban Transport Planning. Croom Helm Ltd., London.

Domencish, T.A. and McFadden, D. (1975), "Urban Travel Demand: A Behavioral Analysis." North Holland Publishing Company, Amsterdam, The Netherland.

Frank, L., Bradley, M., Kavage, S., Chapman, J., and Lawton, K. (2008), "Urban form, Travel Time, and Cost Relationships with Tour Complexity and Mode Choice." Transportation, Vol. 35, No. 1, pp. 37-54.

Itorralba, E.C. (1988), "Analysis of Individual Travel Behavior in Bangkok." Master's Thesis, Asian Institute of Technology, Bangkok, Thailand.

Miller, E.J., Roorda. M.J., and Carrasco, J.A. (2005), "A Tour based Model of Travel Mode Choice." Transportation, Vol. 32, pp. 399-422.

Parsons, Brinkerhoff, Quade and Douglas (2002), "Travel Demand model development and application guidelines." State of Oregon: Department of Transportation, USA.

Pederson, E.O. (1980), Transportation in Cities. Peramon Press Inc., London.

Pinjari, A.R., Pendyala, R.M., Bhat, C.R., and Waddell, P.A. (2007), "Modeling Residential Sorting Effects to Understand the Impact of the Built Environment on Commute Mode Choice." Transportation, Vol. 34, No.5, pp. 557-583.

Puget Sound Regional Council (2001), "Land use and travel demand forecasting models." Review of the literature and operational models, Washington, University of Washington, USA.

Rumayar, A.L.E. (1992), "Analysis of Travel Behavior in Manado, Indonesia". Master's Thesis, Asian Institute of Technology, Bangkok, Thailand.