Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

Development of Activity Based Trip Pattern Choice Model - A Case study of Biratnagar Metropolitan City

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Abstract
Activity Pattern Choice modeling is based on sound economic principles, where the work commuters make choices based on comparing the utility they receive from each alternative and choosing the one with the highest utility. Activity based approach determines the traveler's behavior as the derivative of activities. Activity based pattern choice models are developed by predicting the travel patterns of the activities carried out at particular destination and time. The objective of this paper is to develop activity based pattern choice model for work commuters in order to understand the activity travel pattern behavior of individuals. In this study, Home-interview Survey method has been used to collect data for the households in Biratnagar Metropolitan City (BMC). The collected data are then extracted on the excel sheet from the survey form to carry out the Multinomial Logit (MNL) Model analysis using R Programming. Activity patterns are classified into five types and selected as dependent variables while other variables like age, gender, profession, income, trip mode, travel distance, travel time, travel cost, etc., are selected as independent variables. The results of this paper shows that the variables like age, gender, income, profession and trip mode have significant effect on pattern choice of the work commuters for the Transportation Analysis Zone i.e. Biratnagar Metropolitan City. Bike users are found to follow the complex pattern of primary tour along with a secondary tour. Females are most likely to make a tour with at least one additional stop for non-work activity while returning to home form primary destination. Most of the students follow the pattern of tour with sub-tour returning to home. Public sector employee follows the pattern of tour with at least one additional stop while returning to home whereas private sector employee follows the pattern of tour with one secondary destination before primary destination.

Keywords
Trip Generation, Activity Based Approach, Choice Model, Work Commuters, Activity Travel Pattern, Multinomial Logit Model

1. Introduction

Transportation is considered as the vein and arterial of the country's economy [1]. The development of the country's transportation infrastructure is one of the most essential and important prerequisites for both its overall development and for its economic development. The goal of industrial development can be achieved with the help of transportation infrastructure of the nation. As a result, the transportation sector needs better and improved planning.

In Nepal, there are numerous cities that are still expanding. However, these developing cities lack an adequate rigid, systematic framework or model for the transportation sector in both the planning and development phases. As a result, their expansion is proceeding haphazardly, which could lead to major issues in the near future due to the need to accommodate growing traffic and infrastructure-related development. Biratnagar Metropolitan City (BMC), among other cities, is the largest city with significant economic activity as well as a city that is quickly growing in terms of the number of vehicles and the situation of traffic flow.

According to the 2011 Nepal census conducted by the Central Bureau of Statistics (CBS), there are 2,14,663 people living in Biratnagar Metropolitan City (BMC). According to this data, the population of BMC will soon outnumber its current transportation infrastructure, and the rising trend in vehicle registration data over the previous five years in Koshi Zone indicates that BMC's use of vehicles will soon exceed its capacity for transportation. Due to the population and vehicle growth that is occurring so quickly, the current transportation infrastructure will soon be unable to handle the demand for future traffic flow. Since transport sector development in BMC is still in its infancy, Biratnagar's transport sector could be developed in a more organized and efficient manner.

Four Stage Travel Modeling (FSTM) is essential for systematic development that takes into account traffic demand and requirements. Trip Generation Model (TGM) is a tool that advises planners about the existing and future traffic flow demand. It is the first stage of the traditional transport demand model, or FSTM [2]. In addition, it gives a good picture of the direction and pattern of traffic flow based on different home characteristics. TGM provides a firm understanding of the methods and approaches that are efficient and cost-effective for planning and developing the transportation sector.

Estimating the total number of trips entering or departing a specific area per time period in relation to that area's socioeconomic, geographic, and land-use factors is known as trip generation [3]. Trip generation is calculated using the zone's vehicle ownership, employment, income, and other factors [4].

There are many factors that affect trip generation. The primary determinants of personal trip production are income, vehicle ownership, household (HH) structure, and family size. At the zonal level, modeling also takes into account factors like residential density, land value, and accessibility [4].

One of the key studies for creating the present and future transportation infrastructure to meet the demands of the current and future traffic flow is the research of trip generation. Numerous studies in this topic have been conducted on a global scale. At various nations and study regions, various outcomes are attained. Therefore, due to the socioeconomic disparities, cultural differences, geographic differences, differences in human nature and habits, differences in life standards, etc., these results are not directly applicable to and acceptable for our country and cities. Biratnagar Metropolitan City (BMC), being one of the biggest cities of Nepal, is quickly growing. BMC has a lot of potential to grow into the most modern and well-equipped city in Nepal. But careful preparation and a distinct vision are needed. Both the rate of population increase and the growth in vehicle numbers are accelerating. Without careful planning, this increase could have a disastrous impact on how the city develops in the near future. Therefore, enough and necessary research is needed to establish the fundamental instrument or model that will direct the development of the transportation infrastructure both now and in the near future. To ensure the correct development of the city, it is essential to create various transportation infrastructures in a methodical and planned manner. However, this city also lacks research on trip generating models, which is the fundamental component of the Four Stage Travel Modeling process (FSTM). Due to this deficiency, there is no suitable and rigid model or tool that specifies how and in what manners the city's transportation infrastructure should be planned and developed. Understanding the travel behavior pattern of the work commuters and forecasting travel demand is the key and most important responsibility for building out the transportation infrastructure, and this is where the BMC really falls short. There is no set model for how the city should build its transportation system. This omission shows that the city's transportation planning is inadequate to meet the anticipated rise in demand. Therefore, FSTM must be carried out in BMC, which begins with trip generation modeling.

2. Literature Review

The improvement of the transportation infrastructure of the city is a key indicator of level of its development. The growth of the city's or country's transportation infrastructure must be systematic and planned if the goal of development is to be accomplished. For better citywide transportation planning, forecasting of the transportation demand is required prior to this. Hensher and Button, in their article [2], suggested a four-step travel demand modeling approach that consists of trip generation, trip distribution, mode choice, and network assignment [2]. In Nepalese context, this kind of research or modeling is not done at the appropriate scale for transportation planning.

The first stage of the classical first-generation aggregate demand models is trip generation, and it provides an estimate of the total number of trips that are produced and attracted to each zone of the study area, i.e., it provides the answer to the question of "How many trips originate at each zone" from the data on household (HH) and socio-economic attributes [4].

Khadka [5] studied about “Development of Trip Generation Model of Bharatpur Meteropolitian City”. This study aims to identify the factors that have a significant impact on the frequency of household trips for various purposes, including work, shopping, business, education, and leisure, and to develop a total trip model using a trip-based approach and multiple linear regression analysis. The study’s findings revealed that the number of trips made from a home is influenced by a variety of factors, including the number of family members living there, the number of bicycles and two-wheelers present, the proximity of the home to the central business district (CBD), the number of four-wheelers present, the number of employees living there, the number of bicycles and two-wheelers available, the distance from the home to the CBD, the number of members in the home with ages ranging from 18 to 60 years. Only the distance to the CBD, whose increase lowers total trip generation, has a negative impact on total trip generation, whereas the other limits have a favorable effect.

Wootton and Pick [6] examined the drawbacks of the trip-based approach in their work ”A model for trips generated by Households.” The findings of the study demonstrated that the methodology is empirical in nature because it is unable to establish causal links between the dependent and independent variables or give a true understanding of how trips are generated. Because it is unclear what, in terms of actual experience, is being assumed, and because the meaning of a regression coefficient is difficult to comprehend, the method’s assumptions that regression coefficient created at one time are applicable at another are unacceptable.

Using an activity-based approach, Hedau and Sanghai [7] presented their research on ”Development of Trip Generation Model.” In order to construct an activity travel pattern choice model for commuters to work in Trimurti Nagar, Nagpur, this paper focuses on identifying people’s activity travel pattern behavior. The study’s findings demonstrated that a person’s choice of activity for a particular trip depends on a number of factors, including age, mode, gender, travel distance, time, cost, and monthly income.

An integrated activity-based discrete choice model system of a person’s daily activity and travel schedule was presented in a 1995 study at Massachusetts Institute of Technology on Activity Based Travel Demand Model System with Daily Activity Schedules, which was intended for use in forecasting urban passenger travel demand. Data from the Boston metropolitan area’s transportation system’s level of service and a 1991 travel survey are used to illustrate the system. The model system is built as a collection of choice models that are combined to form a layered logit model system that is progressively estimated. The system is made up of three different models: daily activity pattern, primary tour, secondary tour, and so forth. The choice of the day’s primary activity, the level of difficulty of the primary tour, and the number and purpose of other trips are all part of the daily activity pattern decision. The options for time, location, and method of transportation are included in both the primary and secondary tour types. The choice of a daily activity pattern affects the tour models, which in turn are conditioned by the projected maximum utility derived from the various tour possibilities. For various daily activity patterns, the estimated maximum benefit received from the tour alternatives varies. It also fluctuates as a result of socioeconomic and environmental changes. Using the sample enumeration method, often known as micro-simulation, the daily activity schedule model system may be used to forecast travel demand by generating origin destination trip tables by time of day. In comparison to trip and tour-based models now in use, the daily activity schedule model system is intended to improve travel demand projections for policy choices such roadway extension, employer-provided carpooling incentives, and increasing fuel pricing. Under all possible policy scenarios, it ought to result in better emission estimates [8].

3. Methodology

The different procedures or actions that must be completed in order to complete the study’s required objectives are included in the methodology. The methodology for this study involved developing the topic, selecting the study region, calculating the sample size, preparing the household interview survey form, collecting the data, extracting the data, analyzing the data, coming to a conclusion, and making recommendations. The crucial methodology work that is carried out during the complete research study is the literature review.

3.1 Selection of Study Area

This study analyses the activity travel pattern choices of Biratnagar Metropolitan City. According to the 2011 census, it had a population of 2,14,663 and served as both the provincial capital and the administrative center for the Morang district. BMC has 19 wards. Out of these, only 14 wards (1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14) were chosen as the study area based on residential density, distance, and access time to the Central Business District because the daily travel from the wards to the CBD is significant.

3.2 Sample Size Collection

Data for this study were gathered using a Household (HH) interview survey. The main objective for the study is to choose an appropriate sample size for the household survey because it is essential for producing trustworthy models and reasonable conclusions without using excessive resources on data gathering. Using the equation 1, the sample size for the HH interview survey was determined.

$$n = \frac{CV^2 {Z_a}^2}{E^2} \quad (1)$$

Where CV is the coefficient of variation, E is the level of accuracy (expressed as a proportion) and Z_a is the standard normal value for the confidence level (a) required (Smith 1979).

For this study CV was taken as a 1.0, sample size was calculated for 95% confidence interval. So, value of Z_a was taken as 1.96 and E was taken as 0.10. Hence the minimum required sample size for the study was calculated as near about 385.

3.3 Preparation of Household Interview Survey Form

After sample size calculation, Household (HH) interview survey form was prepared to collect the required information to develop the Trip Generation Model of the selected study area. HH interview survey form consists of two sections as Household data sheet and Activity data sheet. Household data sheet collects the information about the head of household, details of respondent like age, gender, profession, education, monthly income, driving license, etc whereas Activity data sheet comprises the details of trip as trip origin, trip destination, purpose of trip, mode of trip, travel distance, travel time of trip, travel cost of trip, etc.

3.4 Data Collection and Extraction

Data were collected by visiting house to house for the selected sample house and the HH interview survey form was filled for each sample house in the presence of HH members. Data collection process for this study was lengthy for single person, so some final year engineering studying students were informed about the study field and study purpose and then trained to collect data. With the help of these students, a total of 572 data were collected from the selected study area with active involvement of those students. It took about 2 months for the collection of data.

These collected data then extracted on the excel sheet from the HH interview survey form. Extraction of data on the Excel sheet nearly took about 7 days for a person. From the collected data, 70% (about 395) data were used for calibration purpose and remaining 177 data were used for validation purpose. The calibration and validation data set were selected randomly from the whole data set.

3.5 Data Analysis

This step initiates with coding of collected data in required formats. To develop the models for travel pattern choice for work commuters, Multinomial Logit Model was used with the help of R Programming. Different categories of variables that were selected for analysis is presented in following section:

Dependent Variable: It includes Home Based (HB) Trip Production. In this research study, five dependent variables were used for developing different models based on the five different activity patterns i.e. HPH, HSPH, HPSH, HPSPH and HPHPH.

Independent Variable: It includes various variables viz. Head of Household, Gender, Student, Private Sector Employees, Public Sector Employees, Businessmen, Labour, Age, Income, Vehicle Ownership, Travel Time, Travel Cost, Travel Distance, etc.

From the collected data, all the trips were categorized in five types of activity pattern and the frequency of the trips were computed and tabulated as in Table 1.

4. Analysis and Result Discussion

Correlation matrix

After selecting the dependent and independent variables, correlation between the variables needs to

Table 1: Distribution of Activity Pattern Based on Frequency of Trip

Activity Pattern	Description	Frequency of Trips(%)
HPH	No secondary destination	49.30
HSPH	Secondary destination before primary destination	16.26
HPSH	Secondary destination after primary destination	12.59
HPSPH	Work-based tour with non-home destination	6.29
HPHPH	Work-based tour with home destination	15.56

be checked. Correlation matrix is generated from correlation between each set of variables. Chi square test was used to assess the relationship between the independent variables. For a pair of variables having correlation coefficient above 0.8, only one of the variables was taken for the analysis to avoid multi-colinearity of coefficients.

Model Calibration

Model is developed for each activity pattern using independent variable by Multinomial Logit(MNL) Model analysis with the help of R programming. Activity Patterns are dependent variables and other variables that are likely to have effect on the model are taken as independent variables. Utility of any activity pattern can be defined as:

$$U_i q = V_{iq} + {}_i q \tag{2}$$

Where V_{iq} is the systematic part and ${}_i q$ is the random part of utility function. The probability that an individual q chooses i as alternative is:

$$P_i q = Probability(V_{iq} + \varepsilon_i q > V_{jq} + \varepsilon_j q \forall j \neq i) \tag{3}$$

$$= Probability(\varepsilon_j q < \varepsilon_j q + V_{iq} - V_{jq} \forall j \neq i)$$

In case of Multinomial logit model, ε_{jq} among alternatives are Independently and Identically Distributed (IID) with Gumbel distribution, known as IID extreme. The model assumes Independence of Irrelevant Alternative (IIA). The formula for choice probability takes a closed form (Train, 2009).

The probability is given as:

$$P_i q = \frac{e^V_{iq}}{\sum_j e^V_{iq}} \tag{4}$$

Table 2: Coefficients and their properties of activity pattern

	Estimate	Std. Error	Pr(>|z|)	Signif.
(Intercept):1	-4.431823475	1.372520822	0.001242385	**
(Intercept):2	-1.854880779	1.547594089	0.230699983	
(Intercept):3	-0.638076053	1.401076936	0.648808344	
(Intercept):4	-1.931777138	0.971840578	0.046839229	*
Age:1	-0.091068851	0.018915885	1.48E-06	***
Age:2	-0.006464002	0.018065974	0.720493144	
Age:3	-0.026034384	0.019206534	0.175259519	
Age:4	-0.012612508	0.013349025	0.344747659	
Gender(Male):1	2.245490726	0.686639621	0.001074483	**
Gender(Male):2	0.254979176	0.486556058	0.600244516	
Gender(Male):3	2.376801745	0.74735466	0.001471296	**
Gender(Male):4	0.840895743	0.414900483	0.042688926	*
Income:1	8.54E-05	1.58E-05	6.81E-08	***
Income:2	-2.12E-05	2.25E-05	0.346044859	
Income:3	-1.73E-05	2.04E-05	0.398058643	
Income:4	2.03E-05	1.19E-05	0.088481193	
Trip_Mode(Bike):1	-0.560621732	0.739167645	0.448181609	
Trip_Mode(Bike):2	0.046597553	0.595829026	0.937663991	
Trip_Mode(Bike):3	-2.138777935	0.662526885	0.001245662	**
Trip_Mode(Bike):4	0.053657671	0.511356253	0.916429709	
Trip_Mode(Bus):1	1.448806208	0.841685538	0.085193622	
Trip_Mode(Bus):2	2.111571247	0.745621604	0.00462635	**
Trip_Mode(Bus):3	-0.581700038	0.844459058	0.490921829	
Trip_Mode(Bus):4	1.799123897	0.600325141	0.00272726	**
Trip_Mode(Car):1	2.880743225	1.099344589	0.008782184	**
Trip_Mode(Car):2	2.784890171	1.186853234	0.018953278	*
Trip_Mode(Car):3	1.384514865	1.037234423	0.181937282	
Trip_Mode(Car):4	0.806504436	1.113726468	0.468973974	
Trip_Mode(Non_Motorised):1	2.3990841	1.017402593	0.01837132	*
Trip_Mode(Non_Motorised):2	2.302596354	0.95802847	0.016240129	*
Trip_Mode(Non_Motorised):3	-0.4805564	1.098059724	0.661646252	
Trip_Mode(Non_Motorised):4	1.869156532	0.803886442	0.020063943	*
Profession(Labour):1	-0.088371417	1.296379407	0.945652007	
Profession(Labour):2	-1.375340007	1.365430528	0.313811094	
Profession(Labour):3	-1.287062425	1.297999921	0.321405584	
Profession(Labour):4	-0.941941688	0.919340815	0.305559621	
Profession(Public_Sector_Employee):1	-0.491742903	0.988691665	0.618930061	
Profession(Public_Sector_Employee):2	3.473501925	0.716913757	1.27E-06	***
Profession(Public_Sector_Employee):3	0.154024676	0.836212329	0.853861845	
Profession(Public_Sector_Employee):4	0.454167096	0.537909521	0.398491309	
Profession(Private_Sector_Employee):1	0.980135973	0.568278492	0.084573283	
Profession(Private_Sector_Employee):2	-1.651965063	1.019105527	0.10501869	
Profession(Private_Sector_Employee):3	-0.544022895	0.727337517	0.454481361	
Profession(Private_Sector_Employee):4	-1.140084456	0.46496774	0.014207862	*
Profession(Student):1	2.876762057	1.194774399	0.016049549	*
Profession(Student):2	-1.92230444	1.632363953	0.238948132	
Profession(Student):3	-1.803818746	1.480425406	0.223054448	
Profession(Student):4	-0.352764373	0.965076735	0.714715914	
Pseudo R^2 value	0.2983			
Log-likelihood value	-385.7			

In the Table 2, the numbers 1, 2, 3 and 4 represent the activity pattern HPHPH, HPSH, HPSPH and HSPH respectively. Psuedo R^2 value is found to be 0.2983.

Model Validation

Confusion Matrix was created for the validation of the developed model using R programming as in Table 3.

Table 3: Confusion Matrix for Activity Pattern

Confusion Matrix		**Observations**				
		HPH	**HPHPH**	**HPSH**	**HPSPH**	**HSPH**
Predictions	**HPH**	80	13	1	8	13
	HPHPH	2	13	2	2	5
	HPSH	8	3	13	0	3
	HPSPH	0	0	0	0	1
	HSPH	5	3	0	1	1
Accuracy of Model		60.45%				

5. Conclusion and Recommendation

5.1 Conclusion

From the study, it can be concluded that different variables have significant effect on the activity based pattern choice of the trip. Some of the conclusions can be drawn as:

- The variables like travel time, head of household, license, travel distance, travel cost and vehicle ownership are found to be insignificant for all types of activity pattern.
- Students are more likely to make the tour with sub-tour returning to home. Public sector employee are found to be making the pattern of tour with at least one additional stop while returning to home from the primary destination whereas private sector make the tour with one secondary destination before primary destination.
- Those using bike as the trip mode are most likely to make the complex pattern of primary tour along with a secondary tour whereas people using other mode of trip are found to be using mixed choice of mode for travelling.
- Females are most likely to make a tour with at least one additional stop for non-work activity while returning to home whereas males are found to be using the other remaining patterns of tour significantly.

5.2 Recommendation

This study creates the platform for further research studies in the field of trip generation and transportation planning related field. Some of the recommendations for further researches can be as follows:

- Some other advanced methods of analysis like nested logit model, mixed logit model, etc, can be used to compare the results of the predicted model.
- Landuse Pattern of Biratnagar Metropolitan City is not taken into account during this study. Thus it can also be considered for further research purpose.

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