Proceedings of the Eastern Asia Society for Transportation Studies, Vol.11,2017

Logit Model Estimation of Public Transportation Mode Choice in Metro Manila

Nelson DOROY [a], Hussein LIDSASAN [b], Mark Richmund DE LEON [c], German AVENGOZA [d]

[a,b,c,d] *School of Urban and Regional Planning, University of the Philippines, Diliman, Quezon City, Philippines*
[a] *E-mail: nbdoroy@up.edu.ph*
[b] *E-mail: thosl76@gmail.com*
[c] *E-mail: markrichmund@yahoo.com*
[d] *E-mail: germave2001@gmail.com*

Abstract: Metro Manila is the main metropolis of the Philippines - the center of its society, government and the private sector. A significant number of trips is thus generated within Metro Manila, and between its surrounding provinces. Without alternatives, these trips are dominated by public transportation, yet private cars occupy more spaces in road infrastructure. This study aims to develop a general model to define public transport choice in Metro Manila through Logistic (LOGIT) Regression. The study results show that Household Income is a good predictor of the trip makers' mode choice between Public Transportation and Private Transportation in Metro Manila. As the total income of the household increases, there is a tendency to choose private transportation as the trip mode. The study findings will help inform decision makers in their policy directions to improve the public transportation system in Metro Manila as a sustainable mode choice.

Keywords: Public Transportation, Mode Choice, Logit Model

1. INTRODUCTION

1.1. Objectives

Manila is a typical metropolis that serve as the primate city of a developing country. It is the center of the Philippines in all aspects of its society, government, private sector and the nation-state as a whole. It is therefore a natural tendency that all roads lead to Metro Manila, so to speak. In this manner, a significant number of trips is generated within Metro Manila, and between the metropolis and its surrounding provinces that has since become the extension of sub-urbanization. Lacking in alternatives, these trips have come to be dominated by public transportation, yet private cars in general occupy more spaces in road infrastructure.

It is thus incumbent to adequately define what are the general trip patterns in Metro Manila and its environs. The main objective of the paper is to estimate the mode choice pattern of Metro Manila residents in a dichotomy of public transportation vs private transportation (i.e. private cars). More specifically, the paper seeks to use logit model as an estimation of the mode choice between public and private transportation in Metro Manila. It will do a standard statistical analysis of the trips by public and private transport modal spilt.

1.2. Related Literature

Person trips in Metro Manila can be estimated as a discrete choice model, which will analyze and predict a trip maker's choice of one alternative from a finite set of mutually exclusive and collectively exhaustive alternatives. This, of course, assumes that a typical Four Step Urban Transportation Model has been generated for a study area, in this case, Metro Manila.

There are a number of comprehensive transportation studies on Metro Manila, which has become the bases for numerous policy decisions, project appraisals, and project configurations. The Metro Manila Urban Transportation Integration Study (MMUTIS) is one such study, which is a technical assistance of the Japan International Cooperation Agency (JICA) for then Department of Transportation and Communication (DOTC) during the 1990s. The MMUTIS comprehensively estimated the trip patterns of Metro Manila and its neighboring provinces – Rizal, Cavite, Laguna, Bulacan. In 2015, JICA and DOTC (now Department of Transportation, DOTr) undertook an update of MMUTIS, which was called as the MMUTIS Update and Capacity Enhancement Program (MUCEP). The trip generation, trip distribution, modal split and route assignment rates and percentages were updated under the MUCEP, which also provided a training program for DOTr in terms of transportation science. This paper mostly utilizes data from the MUCEP and supplemented by additional information available in the public domain.

In terms of research studies, there are only a number of papers that used discrete choice models, particularly Logit Models for urban transportation in Metro Manila. Fillone and Montalbo (2007) developed a set of Multinomial and Nested Logit Model for urban transport mode choice of urban travelers during the morning home-to-work trips in Metro Manila. In the multinomial logit model, seven mode choices were available including the private car, regular taxi, Light Rail Transit, air-conditioned Bus, non-air-conditioned Bus, Jeepney, and FX Megataxi. Two-level nested logit models were further developed which divided the available modes into private and public, and the public modes were further divided into air-conditioned and non-air-conditioned modes in the three-level nested logit models. Important deterministic variables included in the utility equations include in-vehicle time, out-of-vehicle time, individual monthly income divided by out-of-pocket cost, among others. The developed models were then used to determine the utility ranking of transport modes in Metro Manila and to test the effect of proposed urban transport-related developments in Metro Manila on mode choice probabilities of urban travelers.

Similarly, Rubite and Tiglao (2004) developed a car ownership model using Logit modelling for Metro Manila as the base framework. The Metro Manila region has been continuously growing swiftly over the past years. This rapid urbanization in the city center has spilled over its periphery, the adjoining municipalities. Accessibility between the outer periphery and the city center becomes very critical especially when people seek employment within the city center. With the lack of efficient transit system on one hand, and improved socioeconomic characteristics of the household on the other, the demand for private cars is expected to increase also. However, the limited supply of road space cannot keep pace with increasing demand. Therefore, it is necessary to manage the growth of car ownership in metropolitan areas. A basic understanding of individual and household attitudes towards car ownership would enable the formulation of effective policies and plans for managing car ownership. Knowledge of car ownership paves the way for a better understanding of the people's behavior which will greatly affect policy formulation and analysis in the future. The research is concerned with determining the various household characteristics which influence the household's decision to own a car. This

decision is modeled as a binary choice incorporating the different household and individual characteristics as explanatory variables. The study used data taken from the Metro Manila Urban Transportation Integration Study Home-Interview Survey (HIS) database. The research revealed that the major factors affecting household decision to own a car are household income and number of working adults

With a very limited number of researches on Logit Model Estimation for transportation in the Philippines, it is therefore rational to say that this study will definitely contribute to the literature of logit urban transport modelling in the country. The study will also look at the dichotomy of public versus private transportation in Metro Manila as an information tool for policy directions towards urban transportation in the country.

2. STUDY AREA

2.1. Metro Manila

Metro Manila is officially called Metropolitan Manila and is considered as the National Capital Region (NCR) of the Philippines. Outside the country, it is simply referred to as Manila. It is the seat of government, the second most populous region of the country, and is the most densely populated region of the country. The National Capital Region is composed of Manila, the capital city of the country, Quezon City, the country's most populous city, the Municipality of Pateros, and the cities of Caloocan, Las Piñas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasay, Pasig, San Juan, Taguig, and Valenzuela.

The National Capital Region, with an area of 619.5 km^2, has a population of 12,877,253. This makes NCR the most populous region in the Philippines, as well as the ninth most populous metropolitan area in Asia. The total urbanized area, referring to its continuous urban expansion into the provinces of Bulacan, Cavite, Laguna, Rizal and Batangas, was listed as having a population of 24,123,000 making it the fourth most populous urban area in the world. These five provinces, plus Metro Manila and Pampanga, will have an aggregate population of 30.7 million residents as of the most recent census of 2015.

The region is the center of culture, economy, education, and government of the Philippines. The NCR is one of the 12 defined metropolitan areas in the Philippines according to the National Economic and Development Authority. Designated as a global power city, the NCR exerts a significant impact on commerce, finance, media, art, fashion, research, technology, education, and entertainment, both locally and internationally. It is the home to all the consulates and embassies in the Philippines, thereby making it an important center for international diplomacy in the country. Its economic power makes the region the country's premier center for finance and commerce. The NCR accounts for 37.2% of the gross domestic product of the Philippines.

The region was established in 1975 through Presidential Decree No. 824 in response to the needs to sustain the growing population and for the creation for the center of political power and the seat of the Government of the Philippines. The Province of Manila, the progenitor to the present-day Metro Manila, is one of the eight original provinces that revolted against the Spanish colonial rule in the Philippines. The province was honored as one of the sun rays in the Flag of the Philippines, with each of the eight sun rays symbolizing one of the eight revolutionary provinces. Figure 1 shows the map of Metro Manila.

2.2. Metropolitan Urbanization

As with any other metropolitan area, the Metro Manila (Figure 1) has expanded from its urban core of City of Manila into a circular pattern outward to Quezon City and Bulacan in the north; Marikina and Rizal eastward; and Paranaque, Las Pinas, Cavite and Laguna southward.

Figure 1. Map of Metro Manila (Source: Study Team, 2016)

The Manila Bay serves as the boundary that limits westward expansion, with the exception of a few hundred hectares of reclamation along the said foreshore areas. Figure 2 shows the urban expansion of Metro Manila towards its neighboring provinces in Region III (Central Luzon) and Region IVA (Southern Luzon).

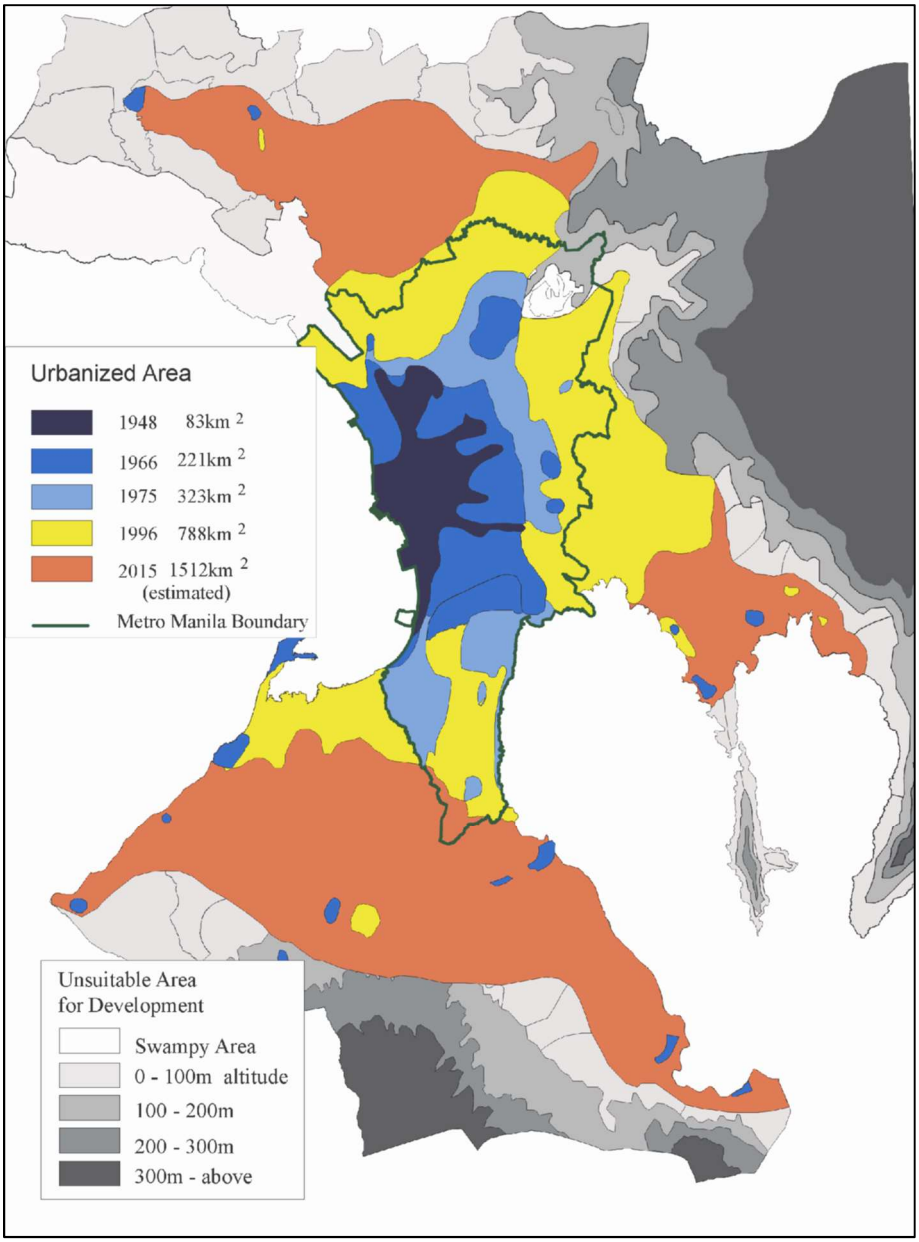

Figure 2. Urbanization Trend of Metro Manila (Source: MMUTIS, 1998)

Metro Manila and its nearby environs generates and attracts a vast number of trips (travels). The JICA and the DOTr has recently conducted a study on Metro Manila transportation called MMUTIS Update and Capacity Enhancement Project (MUCEP). The MMUTIS is the comprehensive Metro Manila Urban Transportation Integration Study undertaken in 1998, which detailed the urban transportation condition of Metro Manila and the nearby provinces of Bulacan, Rizal, Cavite and Laguna.

Car ownership in this Greater Manila Area (including Bulacan, Rizal, Cavite and Laguna) is estimated to be 2,887,992 from the MUCEP Study. The MUCEP Report also estimates that there are around 46,818,000 trips in a day within Metro Manila, including trips coming from Bulacan, Rizal, Cavite and Laguna. Majority of these trips are to-home and to-work purpose (see Figure 3).

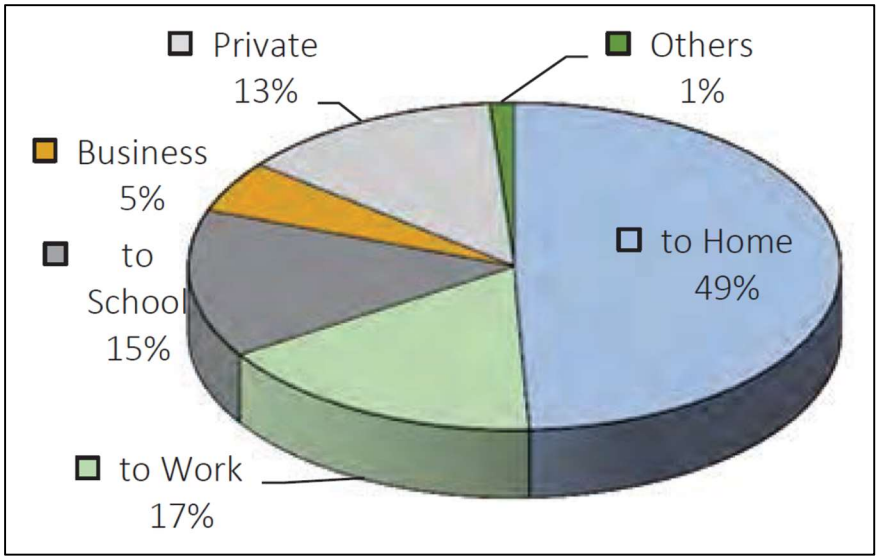

Figure 3. Trips by Purpose in Greater Manila Area (Source: MUCEP, 2015)

Most of these trips are undertaken through public transportation, for which the majority are using Jeepneys (refer to Figure 4). Makati, Pasig, and Quezon Cities have large agglomerations of business centers and attract a huge number of "to work" and "business" trips. Manila and Quezon Cities attract "to school" trips. The concentration, however, is only a small scale because the majority of students move within the same zone as generated.

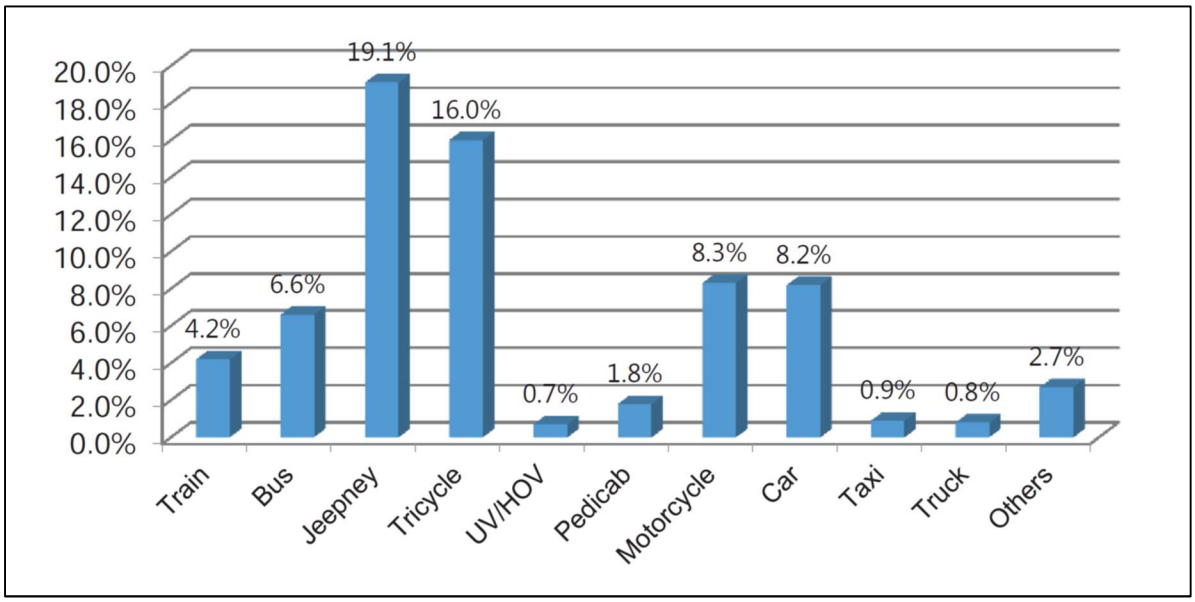

Figure 4. Trips by Transport Modes in Greater Manila Area (Source: MUCEP, 2015)

The trip desire lines are shown in Figure 5, which illustrates where the trips in the Greater Manila Area are going to and from. Majority of the trips, as can be seen in the said Trip Desire Line Map, are clustered in Makati, Ortigas, Manila and Central Quezon City. On the average, 60% of the trips occur within Metro Manila, while 30% of the trips are made to and from the nearby provinces comprising the Greater Manila Area.

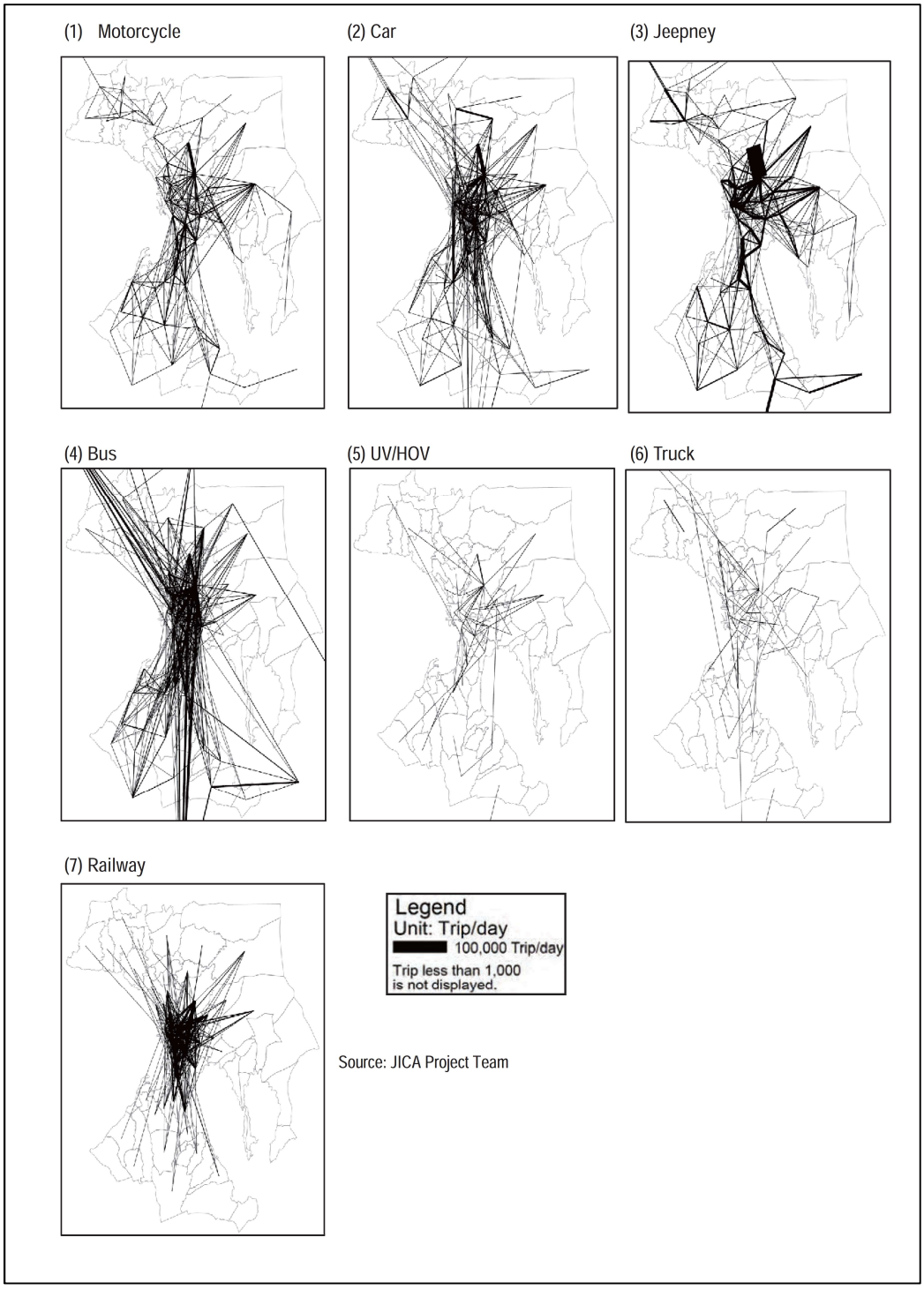

Figure 5. Trip Desire Lines in Greater Manila Area (Source: MUCEP, 2015)

The actual potential ridership of a public transport system can be derived from the Origin-Destination Matrix that was developed by the Metro Manila Urban Transportation Integration Study (MMUTIS). This Origin-Destination Matrix is shown in Table 1, and shows the daily internal and external person trips within Metro Manila in 2015.

Table 1. Origin-Destination Matrix for Metro Manila (in thousand-person trips)
[Source: MMUTIS, 1998]

Zones	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	1,418	152	141	86	202	82	148	275	101	68	98	80	**2,851**
2	137	714	136	35	48	36	47	61	62	96	82	129	**1,583**
3	150	133	544	73	79	67	85	97	107	124	126	88	**1,673**
4	88	38	72	296	81	45	45	57	102	41	35	25	**925**
5	204	74	80	76	948	181	202	215	172	35	41	28	**2,256**
6	79	35	61	49	194	1,050	134	50	66	8	21	7	**1,754**
7	150	100	92	51	231	185	1,427	115	45	11	17	6	**2,430**
8	321	59	96	62	247	69	123	1,751	45	14	20	9	**2,816**
9	105	78	119	113	197	81	47	44	1,088	45	26	10	**1,953**
10	84	115	149	48	41	10	12	15	51	568	77	33	**1,203**
11	113	85	157	41	48	19	18	23	33	70	1,231	177	**2,015**
12	89	139	106	28	28	12	8	12	10	30	169	672	**1,303**
Total	**2,938**	**1,722**	**1,753**	**958**	**2,344**	**1,837**	**2,296**	**2,715**	**1,882**	**1,110**	**1,943**	**1,264**	**22,762**

Code Notes: 1 – Manila; 2 – Pasay/Paranque; 3 – Makati/Pateros; 4 – Mandaluyong/Pasig; 5 – Quezon (EDSA); 6 – Quezon (Northeast); 7 – Quezon (North); 8 – Caloocan/Malabon; 9 – Marikina/Pasig; 10 – Taguig; 11 – Muntinlupa/LasPinas; 12 – LasPinas/Paranaque

3. METHODOLOGY

3.1. Logit Model

In statistics, logistic regression, or logit regression, or logit model is a regression model where the dependent variable (DV) is categorical. This article covers the case of binary dependent variables—that is, where it can take only two values, such as pass/fail, win/lose, alive/dead or healthy/sick. Cases with more than two categories are referred to as multinomial logistic regression, or, if the multiple categories are ordered, as ordinal logistic regression.

The binary logistic model is used to estimate the probability of a binary response based on one or more predictor (or independent) variables (features). It is also called a qualitative response/discrete choice model in the terminology of economics.

Logistic regression measures the relationship between the categorical dependent variable and one or more independent variables by estimating probabilities using a logistic function, which is the cumulative logistic distribution. Equivalently, in the latent variable interpretations of these two methods, the first assumes a standard logistic distribution of errors and the second a standard normal distribution of errors.

Logistic regression can be seen as a special case of the generalized linear model and thus analogous to linear regression. The model of logistic regression, however, is based on quite different assumptions (about the relationship between dependent and independent variables) from those of linear regression. In particular the key differences of these two models can be seen in the following two features of logistic regression. First, the conditional distribution is a Bernoulli distribution rather than a Gaussian distribution, because the dependent variable is binary. Second, the predicted values are probabilities and are therefore restricted to (0, 1) through the logistic distribution function because logistic regression predicts the probability of particular outcomes. The typical logit model is governed by the following equation:

$$\text{logit}(p) = \log\left(\frac{p}{1-p}\right) = \log(p) - \log(1-p) = -\log\left(\frac{1}{p} - 1\right) \quad (1)$$

3.2. Data Utility Approach

The actual data that is collected, utilized and analyzed by this paper are the HIS data of the MUCEP Study derived from household interviews of major locations in Metro Manila and its nearby provinces. The Household Interview Survey (HIS) data provides a 1% sample of the 2012 total households in the study area. The data covers 29,549 households and 98,255 members. This translates into an overall average of around 3.3 members per household.

The data is further cleansed by using selected attributes that have utilities related to the objective of the paper. These attributes range from household socioeconomic information to trip chain information, as well as a perception survey of the transportation issues in Metro Manila. To further ensure that the database is responsive, all data that pertain to zero and "others" as answers to survey questions are also disregarded. For information that contain continuous variables, the data are transformed into categorical values that enable the processing of information into a logit model.

More importantly, the mode choice answers of the HIS respondents have a range of 27 transport modes. However, this is translated into two (2) categorical parameters – private transportation (coded as 0); and public transportation (coded as 1). The total usable data for modelling arising from all of these data sanitization will amount to 50,554 observations from an initial population of 200,665 samples. However, in terms of data utility for descriptive statistics, the samples amount to 100,432 respondents out of the total universe of 200,665 respondents.

4. MAJOR FINDINGS

4.1. Descriptive Statistics

In the MUCEP HIS data, the most common variables that have the best utility to define the mode choice between public transportation and private transportation are the following:

a. Mode Choice;
b. Trip Purpose;
c. Trip Cost;
d. Reason for Mode Choice; and
e. Household Income.

The variables above are coded as 1 to 5, respectively for the purpose of encoding these variables in the Logit Model, which will be discussed in the next sections.

Table 2 shows the Mode Choice of respondents depending on their trip purpose. Majority of the trip purpose are To-Home trips using private transportation (Table 3). In contrast, most of the respondents have a trip cost of between Php 1 to Php 10 using public transportation (Table 4). Majority of the respondents chose their mode of transport equally due to travel time and convenience (Table 5). Lastly, majority of the trip makers have a total household monthly income of Php 5,000 to Php 20,000 – for which they can be categorized as low income to low-middle income households (Table 6).

Table 2. Cross Tabulation – Mode Choice & Trip Purpose (Source: Study Team, 2016)

Trip Purpose	Private Transport	Public Transport	Grand Total
To Home	36,064	12,998	49,062
To Work	15,376	1,941	17,317
To School	8,685	7,515	16,200
Private Business	1,207	249	1,456
Employer's Business	106	16	122
Private - Medical	477	114	591
Private - Social	694	147	841
Private - Eating	143	63	206
Private - Shopping	8,445	3,442	11,887
Private - Worship	640	222	862
Private - Recreation	359	73	432
To Send/Pickup Family	1,099	357	1,456
Grand Total	**73,295**	**27,137**	**100,432**

Table 3. Cross Tabulation of Mode Choice & Trip Cost (Source: Study Team, 2016)

Trip Cost (Php)	Private Transport	Public Transport	Grand Total
1-10	23,417	27,137	50,554
11-20	24,302	-	24,302
21-30	10,894	-	10,894
31-40	4,778	-	4,778
41-50	3,203	-	3,203
51-60	1,287	-	1,287
61-70	761	-	761
71-80	586	-	586
81-90	232	-	232
91-100	1,303	-	1,303
101-110	97	-	97
111-120	205	-	205
121-130	88	-	88
131-140	42	-	42
141-150	583	-	583
151-160	52	-	52
161-170	45	-	45
171-180	77	-	77
181-190	18	-	18
191-200	1,325	-	1,325
Grand Total	**73,295**	**27,137**	**100,432**

Table 4. Cross Tabulation – Mode Choice & Reason for Mode Choice
(Source: Study Team, 2016)

Reason for Mode Choice	Private Transport	Public Transport	Grand Total
Travel Time	23,837	8,512	32,349
Comfort	9,046	3,172	12,218
Convenience	23,795	8,259	32,054
Cost	9,809	4,271	14,080
Safety	6,808	2,923	9,731
Grand Total	**73,295**	**27,137**	**100,432**

Table 5. Cross Tabulation - Mode Choice & Household Income (Source: Study Team, 2016)

Household Monthly Income (PhP)	Private Transport	Public Transport	Grand Total
Zero Income	50	38	88
No Income	838	596	1,434
Below 2,500	4,374	3,181	7,555
2,501-5,000	12,282	8,731	21,013
5,001-10,000	13,540	8,960	22,500
10,001-15,000	13,013	2,743	15,756
15,001-20,000	9,199	1,145	10,344
20,001-25,000	6,726	715	7,441
25,001-30,000	4,205	367	4,572
30,001-35,000	2,981	198	3,179
35,001-40,000	3,026	227	3,253
40,001-50,000	1,340	107	1,447
50,001-60,000	1,057	72	1,129
60,001-80,000	305	36	341
80,001-100,000	245	8	253
100,001-150,000	58	10	68
150,001-200,000	14	2	16
200,001-300,000	24	1	25
300,001 and above	18		18
Grand Total	**73,295**	**27,137**	**100,432**

4.2. Logit Modelling

The abovementioned variables are modeled using binomial logistic regression through the Stata™ software. The Mode Choice (public transportation vs private transportation) is the dependent variable, whereas Trip Purpose, Trip Cost, Reason for Mode Choice, and Household Income are the independent variables, respectively. The results of this modelling exercise are shown in Table 5. All of the independent variables logistically modelled against Mode Choice (one is to one approach) result to less than desired fit to the Logit Model curve, except the variable Household Income. This would mean that using the Logit Model, the Household Income

is a good predictor of mode choice between public transportation (as Variable 1) and private transportation (as Variable 0).

Table 6. Logit Modelling Results (Dependent Variable = Mode Choice)
[Source: Study Team, 2016]

Independent Variable	Coefficient	Constant	Standard Error	Z	Pseudo R^2
Trip Purpose	0.0038181	1.558549	0.0028844	1.32	0.0000
Trip Cost	0.0035075	-1.412556	0.0001356	25.87	0.0062
Reason for Mode Choice	-0.0488252	1.696202	0.0062883	-7.86	0.0007
Household Income	-0.4609261	2.335962	0.0057436	-80.25	0.1273

Because only the Mode Choice vs Household Income is responsive to the Logit Model, the probability curve is developed using these two variables unto the Logit function equation. Figure 6 shows this probability curve, which illustrates that the mode choice for public transportation are highest in the lower income bracket than in the middle to high income bracket.

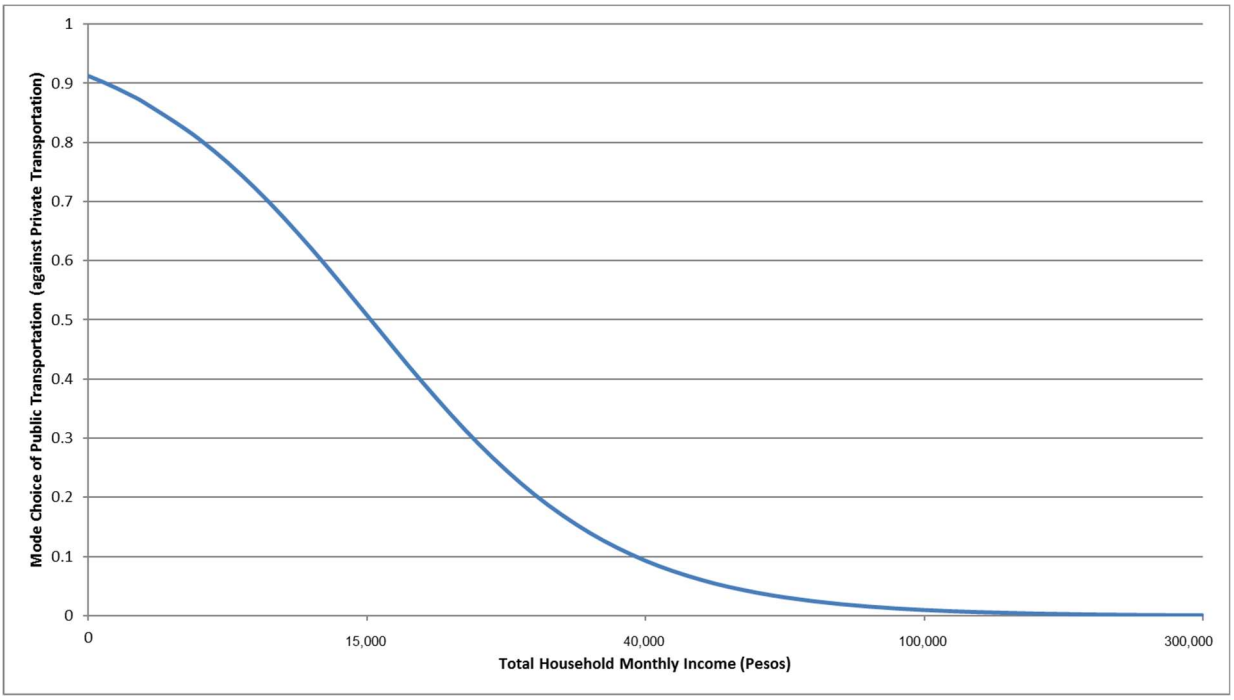

Figure 6. Logit Function Probability Curve (Mode Choice vs Household Income)
[Source: Study Team, 2016]

5. CONCLUSION AND RECOMMENDATIONS

The results of the study show that Household Income is a good predictor of the trip makers' mode choice between Public Transportation and Private Transportation in Metro Manila. As the total income of the household (or family) increases, there is a tendency to choose private transportation as the trip mode. However, the current socioeconomic profile of Metro Manila is dominated by low to middle income class trip makers. And thus, the current trip pattern is biased

or skewed towards public transportation but only for the simple reason that the household income of most trip makers is in the low to low-middle threshold.

This is certainly rationale as people have surplus income, they will have the capacity to pay for more expensive transportation mode such as the case for private transportation. The modelling endeavor also illustrate that trip purpose, trip cost and reasons for mode choice are not accurate comparator for mode choice.

And even in the reasons for mode choice, majority of the respondents did not state cost as the most important factor in the choice of their transportation modes. But rather, the respondents choose transportation mode mostly due to travel time and trip convenience. This is also partly due to the fact that public transportation is highly subsidized and does not fully capture the market price in terms of operations and maintenance costs particularly for mass transit systems.

The MUCEP data is a wealth of information that can be utilized to inform future policy directions and even policy decisions that require an objective basis rather than a political one. It is therefore suggested that the results of the data are made available to the public consistent with the Open Data objectives of the National Government, as well as an act of compliance to the Freedom of Information statute of the country.

Collaborations between universities, across academe and the public sector, as well as the academe and the private sector can be made to truly analyze the MUCEP data and make it an information tool for decision makers, local and national government officials, and development partners.

6. AREAS FOR FURTHER RESEARCH

A robust set of information on the condition and pattern of urban transportation of a metropolis can be derived from the MUCEP Data. This spectrum of information can be used by government agencies and even the private sector for policy directions on transportation, and even investment decision. This is one of the main avenues upon which further research can be made to improve the literature of transportation system in the Philippines.

More importantly, the Study Team had constraints in time and resources, in developing alternative discrete choice models on the same existing database. The Probit Model has not been extensively explored in the context of transportation systems in the Philippines. It is in this context that the Study strongly recommends that further research can be undertaken in developing a Probit Model for the same database.

REFERENCES

Department of Transportation (2015) Metro manila urban transportation integration study update and capacity enhancement program. Government of the Philippines, Manila.

Fillone, A., Montalbo, C., and Tiglao, N. (2007) Transport mode choice models for metro manila and urban transport policy applications. *Journal of the Eastern Asia Society for Transportation Studies, Volume 7.*

Koppelman, F.S. and Bhat, C. (2006) A self-instructing course in mode choice modeling: multinomial and nested logit models. U.S. Department of Transportation, Washington, D.C.

Manresa, A., Vergel, K., and Regidor, J. (2015) An assessment of the public necessity concept for estimating requirements for public transport vehicles. *Proceedings of the Eastern Asia Society for Transportation Studies.*

Rubite, C. and Tiglao, N. (2004) Development of a car ownership model in metro manila. *Philippine Engineering Journal.*