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ESTIMATING THE ENVIRONMENTAL EFFECTS OF THE CAR SHIFTING BEHAVIOR ALONG EDSA

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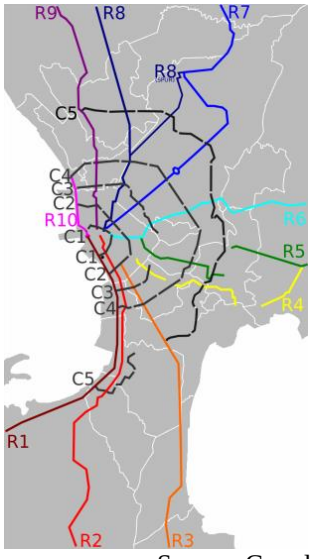
ABSTRACT: Metro Manila is the most populated region in the country. It is the largest contributor to the economy of the country at around 40 percent. Situated in this metropolis is the Epifanio Delos Santos Avenue (EDSA), which currently serves an estimated average of 330,000 vehicles daily. This number has greatly increased since the early 2000s. Because of EDSA's significance, many transportation-related studies had focused on it. Among the largest studies is the Metro Manila Urban Transportation Integration Study (MMUTIS) that was completed in 1999 and has recently been updated through the MMUTIS Update and Capacity Enhancement Project (MUCEP). There is also another ongoing project entitled Integrated and Optimal Scheduling of a Public Transport System in Metro Manila (PUBFix), which is funded by the government (DOST-PCIEERD). The project intends to improve the public transportation system in the metropolis, specifically bus operation along EDSA. In this research, the aim is to formulate stated preference (SP) logit choice models in order to predict the mode choices of commuters along EDSA. Such results are important in order to determine the changes in travel behavior of commuters when certain policies and measures are introduced. An EMME model is also prepared for this study in order to quantify the differences between baseline and hypothetical scenarios. Aside from quantifying the difference of these scenarios in terms of environmental effects, other traffic parameters were also calculated in order for transport policymakers to be guided in considering more appropriate measures.

Keywords: Logit Choice Models, Urban Public Transport, Stated Preference, Environmental Effects

1. INTRODUCTION

The road network of Metro Manila is defined by ten radial and six circumferential roads which links the different areas in the metropolis, as seen in Fig.1.



Source: Google Images
Fig.1 Circumferential and Radials Roads in Metro Manila

Among the region's major thoroughfares, Epifanio Delos Santos Avenue (EDSA), located at the heart of Metro Manila, is one of the busiest roads in the Philippines. It is 24 kilometers long and passes through six (6) of the 17 cities comprising the metropolis. It caters to both private and public transportation linking the North Luzon Expressway at Balintawak in the north and the South Luzon Expressway at the Magallanes Interchange in the south. EDSA serves an average daily traffic of an estimated 330,000 vehicles, growing from approximately 195,000 in 2007 [1], [2]. In addition, the MRT3 line runs along its entire stretch. Currently, over 3,700 public utility bus units run along EDSA, while over 60,000 jeepneys and 3,184 AUVs are currently in operation all over the metropolis, as seen in Fig.2 [3]. Note that all public vehicles are operated by private entities.

Most of the public transportation routes in Metro Manila are concentrated along EDSA because a greater proportion of land uses along the highway are economic in nature. Despite the number of buses and other travel alternatives traversing EDSA, many commuters are inclined to use their own private vehicles that add more volume to the already congested roads of the metropolis brought about by various reasons.

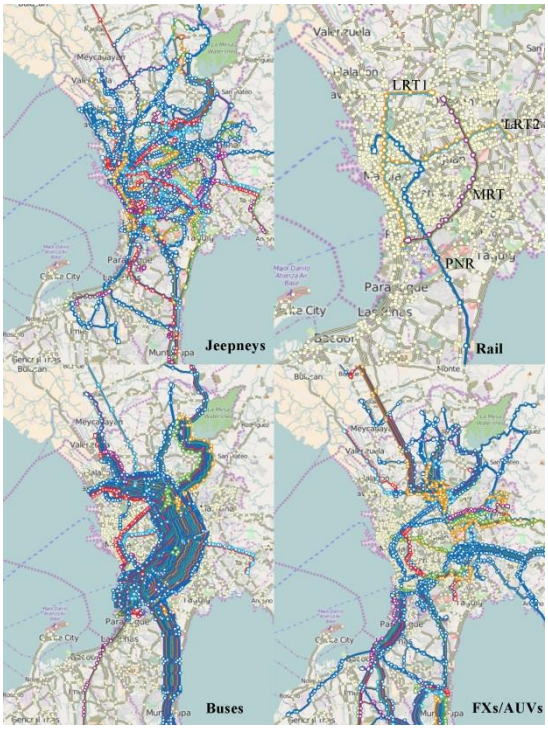
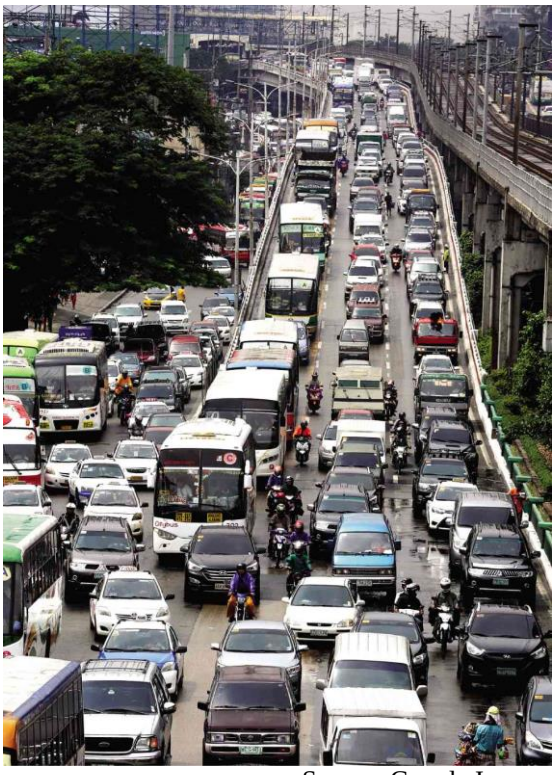


Fig.2 Public transportation routes in Metro Manila

Because of the importance of EDSA to the commuters of Metro Manila and the complexity of the problems related to each of the transport alternatives serving the corridor, EDSA demands much more attention to improve its current state. The unorganized public transport system in Metro Manila is one of the reasons that cause commuters to be more inclined to use their own private modes of transportation. The inefficiencies caused by the disorderly system are enormous that costs the Filipino people and the economy a huge amount in monetary terms. Added to this is the stress and anxiety it brings the commuters on a daily basis, just like the very long MRT queue shown in Fig.3 and road congestion shown in Fig.4.


Source: Google Images
Fig.3 Long queue in one of the MRT stations

The Department of Transportation (DOTr) and the Metro Manila Development Authority (MMDA) have tried improving the current situation through various means by introducing a number of policies such as (a) number coding scheme, (b) removal of the window time for number coding, and (c) designated bus stops. However, the effects of these measures are largely insufficient to provide a better level of mass transport service.


Source: Google Images
Fig.4 Traffic condition of a stretch along EDSA

This research is part of the project entitled An Integrated and Optimal Scheduling of Public Transport Operations in Metro Manila (PUBFix) that is funded by the Department of Science and Technology, Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD). PUBFix is undertaken in order to assess the actual and potential demand for public transport service along EDSA. It also aims to provide a more integrated transportation plan by considering both existing and forecasted supply. To achieve these project objectives, logit choice models are developed in order to aid in planning for the improvement of the urban transportation network. In the process, shifts in the travel behavior of commuters may be estimated whenever changes in the transportation system are introduced in the transportation network models. Therefore, the effects of certain

policies, infrastructure improvements in the network, addition of new transport alternatives, may be reasonably estimated and quantified. The findings are expected to support one of the main objectives of PUBFix, which is to propose, test, evaluate, and recommend, using scenario modeling, possible new high-capacity public transport systems (i.e. Light Rail Transit, Metro Rail Transit, Bus Rapid Transit or BRT, and/or city buses) in Metro Manila under 10-year and 20-year planning horizons.

There is an increasing level of concern for the alarming traffic condition in Metro Manila [4], [5]. It is imperative that measures are immediately devised in order to alleviate the worsening situation. Several strategies may be implemented in order to achieve the desired result and one of these measures may include reducing the number of private cars on the roads. When introducing transport planning strategies and options, decision makers are best guided on the basis of empirical evidences so that viable options are operationalized in the interest of optimizing resources and results.

This paper focuses on estimating stated preference (SP) logit choice models of private car users. Various choice situations were presented to them as respondents, and they were made to choose between their currently used mode and shifting to a hypothetical public transportation mode where improvements in the transportation system are introduced. The various significant factors affecting their choice were determined using logit choice models. The models enable transport planners to estimate the sensitivity of private mode users in shifting to public transport modes. The estimated SP logit choice models will then be used to assess the effects of the introduction of hypothetical transport modes in the urban transportation network of Metro Manila. Results from such analyses may aid in devising plans on how to induce the private car users to shift to public transport modes.

In this study, only private vehicle users are included in the database that will serve as basis for logit choice modeling. The origin-destination matrix used for the transportation network is taken from the Metro Manila Urban Transportation Integration Study Update and Capacity Enhancement Project (MUCEP) that is funded by JICA.

2. REVIEW OF RELATED LITERATURE

The transportation sector, specifically road transport, has consistently been cited as one of the leading causes of air pollution [6]–[10]. In India, a developing country like the Philippines, mobility is correlated with income as well as population growth, resulting in higher demand for passenger transport [11]. The personal mobility offered by a private car makes it more appealing than other alternatives, thus, increasing and unmitigated auto use aggravates traffic congestion. This causes the deterioration of air quality in urban and suburban areas where road traffic congestion is severe [12]–[14].

Several schemes may be introduced in order to reduce emissions. Drastic behavioral and technological changes are needed in order to attain targets. Among those widely suggested are to (a) encourage active transport, (b) increase car occupancy rates, (c) reduce total urban car kilometers traveled, (d) improve vehicle efficiency, and (e) increase public transport's mode share of urban travel [7]. Reference [15] mentioned that the implementation of a BRT is considered by many developing countries because of its lower investment cost and flexible implementation than rail systems. Providing better alternatives to cars make the transport system sustainable [16]. Aside from pollution emissions, public transit also reduces traffic congestion, accidents, parking congestion, excessive energy consumption, road and parking infrastructure costs, among others [17]. From the experience of the British Government in providing a competitive alternative to private cars, several conditions should be implemented in order to increase modal shift to public transportation such as effective marketing and strict implementation of traffic laws. Reference [18] stated that public transit has significant benefits, especially when relieving congestion in urban areas like Metro Manila.

3. THEORETICAL BACKGROUND

The multinomial logit model is the simplest, most practical, and most popular discrete choice model available [19]. It adheres to the utility maximization theory, which assumes that when respondents are faced with a choice situation they will choose the alternative that maximizes their utility [20].

Utilities can be divided into two parts, the systematic or observable component (V) and the disturbance or random component [19], [21], [22]. In specifying the systematic part, the linear combination of the estimated parameters and the attributes of the alternatives are taken. The error terms are assumed to be independent and identically Gumbel distributed where the choice probability is specified as

$$\boldsymbol{P_n(i)} = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \quad (1)$$

where,
C_n – choice set of respondent, *n*,
V_{in} – systematic component of utility of the chosen alternative, *i*, and
V_{jn} – systematic component of utility of the feasible choices, *j*.

4. URBAN TRANSPORT AND SOCIO-ECONOMIC STATISTICS

Survey questionnaires were administered to private car users traversing EDSA, where a total of 592 observations were compiled and included for analysis. Table 1 shows the descriptive statistics for the data collected. The usual departure time of the respondents was between 0800 and 0900 in the morning, where the average length of travel is approximately 48 minutes and costs 84PHP (≈1.75USD) on the average. The average parking cost for the travelers was 25.20PHP (≈0.52USD). The average age of the respondents was 35 years old. As for the civil status, 32 percent were married, separated, or widowed, while 68 percent were single. Seventy-three percent of the respondents were male and 27 percent were female. Lastly, the average size of the traveling group of the respondents is about two (2) persons.

Table 1 Descriptive statistics of the sample

Usual departure time	0800–0900
Usual length of travel	47.43min
Usual sum of costs	84.02PHP
Average parking cost	25.20PHP
Average age (all) Male Female	35.01 35.19 34.55
Civil Status	Single: 68% Married: 32%
Gender	Male: 72.97% Female: 27.03%
Average number of people in the group	1.85
Number of observations	592

The majority of respondents (61%) included in the sample were college graduates. Next is the group of high school graduates with 27 percent. Respondents with master's degrees comprised 11 percent of the dataset, while the remaining 1 percent were vocational training graduates. Almost half of the total trips were work-bound. This is understandable because commuters using EDSA are mostly going to their offices especially during the morning rush hours. This is followed by the shop/personal/others trip purpose (19%), and then school trips (18%), and finally. business trips (12%).

Majority of the individual incomes of the respondents was close to 100,000PHP/month (≈2060USD/month), with an average value of approximately 1100USD/month. This shows that majority of the respondents belonged to the high-income group according to the income categories of the National Statistics Office.

5. LOGIT CHOICE MODELING RESULTS

From the 592 observations, SP logit choice models were estimated. The final model is formulated as seen in the following utility equations. Respondents shifting to public transportation are assigned to choice A, whereas those who chose to remain using one's private vehicle is assigned to choice B.

$$\boldsymbol{U(SHIFT) = ASCA + TOTTIME * (Total\ travel\ time) + AGE * (Age\ of\ respondent) + ACC3 * (Access\ and\ egress\ type\ 3) + COMF * (Level\ of\ comfort\ of\ proposed\ mode) + COLL * (College\ degree\ holder) + POST * (MS\ degree\ or\ higher)} \quad (2)$$

$$\boldsymbol{U(STAY) = TOTTIME * (Total\ travel\ time)} \quad (3)$$

Table 2 shows the final model estimated through the use of NLOGIT software. It can be seen that the model is significant with a corresponding high Chi-squared value. The model performance is acceptable with an *R-squared* value of 0.30651. Looking at the final model, the various factors significantly affecting the choices made by the respondents are identified. It can be verified that total travel time, age, access and egress type 3, level of comfort of the new mode, and educational attainment affect mode choice. This is indicated by the individual significance values in which all had less than the 0.05 level of significance.

Looking at the TOTTIME parameter which is specified generic for both choices, it can be stated that it negatively affects choice and serves as a disutility to the commuters. As for the age which is specific to choice A, it can be said that older people will be less likely to shift from their private vehicles to a public transport. However, when one looks at the educational attainment variable assigned to choice A, the opposite is true. As the level of educational attainment increases, the more they are likely to shift to public transport modes. This could probably be explained by the fact that when the questionnaires were administered, the current traffic situation is explained to everyone. Most likely, those people with higher levels of educational attainment understand how to

contribute to solving the problem of traffic congestion.

Access type 3 is a dummy variable assigned to choice A. It takes a value of 1 when the access and egress modes are similar to high-occupancy on-call shared taxis. By inspecting the parameter, it can be noted that when the access and egress modes are upgraded, then the respondents will tend to shift modes. Only this type of improvement in the access and egress modes to and from EDSA was found to be significant among the other three options. It just shows that private car users, indeed, value the comfort and convenience of door-to-door transport and avoid the inconvenience of transfers. Lastly, the comfort and convenience variable has three levels and is orthogonally coded and assigned to choice A; high level of comfort is designated a value of +1. For the purpose of this study, comfort was represented by the load factor of the mode. Inspection of the COMF coefficient shows that it is positive, which only demonstrates that improving the level of comfort of public transportation along EDSA attracts private car users to shift.

Note that when the SP part of the questionnaire was designed, it was assumed that all the improvements in the access, egress, and main modes would not translate to any change in the costs already incurred by the respondents. This is somewhat a limitation of this study. The total cost incurred is the same for the current private mode of travel and shifting to public transportation combined with all the improvements specified in the questionnaire.

Table 2 SP Logit Choice Model

No. of observations		592
R-squared		0.30651
Chi-squared		105.30987
Prob [chi squared > value]		0.00000
Variable	Coefficient	P [|Z|>z]
ASCA	-1.09028140	0.0007
TOTTIME	-0.02546769	0.0001
AGE	-0.03568077	0.0003
ACCESS3	0.81024906	0.0013
COMF	0.76930538	0.0000
COLL	0.96494867	0.0009
POST	1.09526421	0.0189

The model performance was checked by looking into the accuracy of estimating the choices made by the respondents. The following table is a cross-tabulation matrix that shows the distribution of model predictions. It can be verified that 406 or (59+347) out of the 592 choice situations have been correctly predicted by the model. This represents a 68.58 percent accuracy which is acceptable.

Table 3 SP Logit Choice Model

Category	A	B	Total
A (Shift)	59	93	152
B (Stay)	93	347	440
Total	152	440	592

6. EMME MODELING RESULTS

The EMME4 transportation planning software was used in order to incorporate the SP model results in measuring the economic and environmental effects of the mode-shifting behavior of travelers in Metro Manila. First, the baseline transportation network of the whole Metro Manila was modeled using the MUCEP data for peak-hour traffic. All the necessary data were encoded, the model calibrated and important travel-related statistics obtained. After this, a second scenario was developed that incorporated the SP logit choice model. Finally, the model was rerun. The differences in travel-related statistics between the results of the two models were then recorded. The following figure shows the EMME baseline model for Metro Manila.

Fig.5 Metro Manila EMME Model

Table 4 shows the values of the different parameters measurable in the EMME model when the baseline and with transfer scenarios were run. An increase of 3kph in speed along EDSA, on the average, has been registered. This outcome is a result of the 12% private car users shifting to the new hypothetical transport mode. Along with the increase in average speed are the reductions in vehicle operating costs and value of travel time which are quite significant.

Also, quite noticeable are the reduction in environmental pollutants. The differences in the CO2, NOx, and SPM values translate to a total of 36% reduction in environmental cost when they are converted to monetary units. This suggests that when a competitive public transport alternative such as a BRT is introduced along EDSA, the current traffic situation will be

addressed, as well as reducing the harmful environmental impacts of congestion. The effects are quite significant and should be given ample consideration by the government.

Table 4 Differences between the baseline and with transfer scenarios during the peak hour

	BASELINE	WITH TRANSFER
Average speed (kph)	18.39	21.32
Vehicle operating cost (PHP)	386,382.7	329,641.2
Value of time (PHP)	28,151,511	15,846,214
CO2 (g)	2,765,655.92	1,885,906
NOx (g)	599,308.71	518,045.6
SPM (g)	47,666.68	27,579.6
Environmental Cost (PHP)	198,483.07	126,430.72

7. CONCLUSION

The PUBFiX project is looking into the current traffic condition in Metro Manila and is formulating strategies in order to improve the public transportation system along EDSA, as well as lessening the harmful environmental effects of traffic congestion. In order to achieve this, choice modeling is necessary in order to estimate the effects of certain policies on the choices made by the commuters. For this study, SP logit choice models were estimated in order to aid in the planning of the transportation system in the metropolis. The behavior of private car users was investigated and assessed when they were given several hypothetical scenarios that involve several improvements in the public transportation system traversing EDSA. This was done in order to investigate the environmental effects of mode shifting in the metropolis.

Based on the results of the SP logit choice model formulated, it was determined that travel time, age, educational attainment, the existence of access type 3, and comfort and convenience significantly affect the mode shifting behavior of private car users in Metro Manila. It is interesting to note that the numerical coefficients of travel time, access type 3, and comfort and convenience suggest that the provision of high-occupancy on-call shared taxis to private car users has a similar effect of reducing the disutility of travel time by approximately 32 minutes. This suggests that the convenience of a somewhat door-to-door travel is particularly desired by private car users. Also, the provision of a high level of comfort for the hypothetical BRT mode along EDSA is equivalent to a significant amount of reduction in travel time, approximately 31 minutes. The high level of comfort is characterized by load factor of less than 1.0, more organized stops, and roomier cabins for passengers. Again, this reinforces the notion that private car users are sensitive to the level of comfort of their mode of travel.

As seen from the EMME modeling results, the shifting of private car users to the hypothetical public transport mode greatly affects the transportation system of the metropolis. The number of vehicles on the road decreases while the average travel speed increases. This not only translates to savings in terms of travel time and vehicle operating costs, but savings on environmental pollution as well. This analysis proves that when level of comfort, reliability, and speed of public transport modes are upgraded, it can be reasonably expected that a significant amount of private transport users would be willing to shift to alternative public transport modes. This is what the future of Metro Manila should be. In order to have a sustainable transportation system, various schemes should be employed in order to attract private car users to shift to the more efficient public transport modes. Strict implementation of laws, major behavioral changes, and technological improvements should be among the government's priorities to improve the current transportation sector, with emphasis on curbing the worsening environmental pollution. Enormous investments in public transportation are imperative in order to achieve this vision. Current policies such as modifying the number coding scheme are momentary solutions to the serious transportation problem of the metro. What this country needs are long-term solutions if the government truly intends to address the problem. Transportation studies such as PUBFix should not just be encouraged by the government. Their results and recommendations should warrant the consideration of the government, as well.

8. ACKNOWLEDGEMENTS

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