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Determination of Parameters for Assessing Bus Transit and Service Area Relationships along EDSA

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ABSTRACT

Through the use of boarding and alighting data from a thoroughfare spanning across a metropolis, it can be possible to derive associations between transit activity and area characteristics. This study aims to determine statistical relationships between bus transit use and service area characteristics along the main artery of Metropolitan Manila. GIS and multi-linear regression analysis are used to establish the relationships. Evaluation and validations of the runs were executed in order to select the parameters. Numerical descriptions of the influences are developed. These establish certain land parameters to be useful for an effective modeling of the transit activity along the thoroughfare.
Key Words: bus transit, parameters, land use, population, service area

1. INTRODUCTION

1.1. Background of the Study

Epifanio Delos Santos Avenue (EDSA) is one of the major thoroughfares in Metro Manila, traversing five cities of the metropolis. It is the widest of five concentric circumferential roads linked to several key destinations in the region including the major business districts of the national capital serving the bulk of the working class during peak hours.

During November of the previous year, the Japan International Cooperation Agency (JICA) undertook the EDSA Bus Route Revalidation Survey in line with the Bus Rationalization Project the Department of Transportation and Communication (DOTC) has initiated. This

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study makes use of the data from this project. From the said survey, the count of buses plying EDSA during weekdays and weekends, boarding and alighting activity per segment of the artery, load profile of buses, specific routes and their entry and exit points were identified.

1.2. Statement of the Problem

An establishment of the influences of land characteristics in travel behavior has not been accomplished in the region thus far. Even though these practical relationships can be directly observed, a statistical and quantifiable relationship than can shed light on future modeling, urban policies and planning is non-existent. By providing a practical analysis of these travel patterns, a more precise understanding of the factors that contribute to the distribution and generation of peak hour trips can be developed.

1.3. Objectives

- Identify parameters for assessing relationships between bus transit and service area characteristics along EDSA
- Determine travel patterns along EDSA during peak hours of travel
- Quantify land use and other service area characteristics of the study area

1.4. Significance of the Study

The need for this study revolves around the issue of addressing the worsening traffic situation in EDSA. The importance of EDSA's role on the country involves influences on the economy and environment just from the sheer volume of vehicles that ply it everyday. There is also a political dimension to its prominence as it was the site of the world-renowned bloodless EDSA revolution in 1986. A more precise understanding of the travel behavior in this main artery will pave the way for the development of an accurate model that will bring effective policies to benefit the general commuting public.

1.5. Scope and Limitations

The study is confined to the whole length of Epifanio Delos Santos Avenue. All bus routes that traverse along EDSA are of primary concern. Analysis of other modes of transport such as jeepney and MRT is limited to identifying and counting transfer points that are located along EDSA. Transfer points from buses whose routes only terminate at or directly cross EDSA are likewise identified and counted. The modes of transfer along EDSA can be seen in Figure 1.

The boarding and alighting data is restricted to peak hour data of the routes surveyed in the EDSA Bus Route Revalidation Survey conducted for JICA in November 2005[1].

When it comes to the service areas accounted for within the corridor, overlapping is not considered due to the complexity of incorporating it into the GIS and other calculations.

2. METHODOLOGY

The methodology starts with the collection of data on bus transit use and land use, as shown in Figure 1. Land use data and data on other service area characteristics are encrypted in a Geographic Information System (GIS). Bus transit data and GIS data are processed

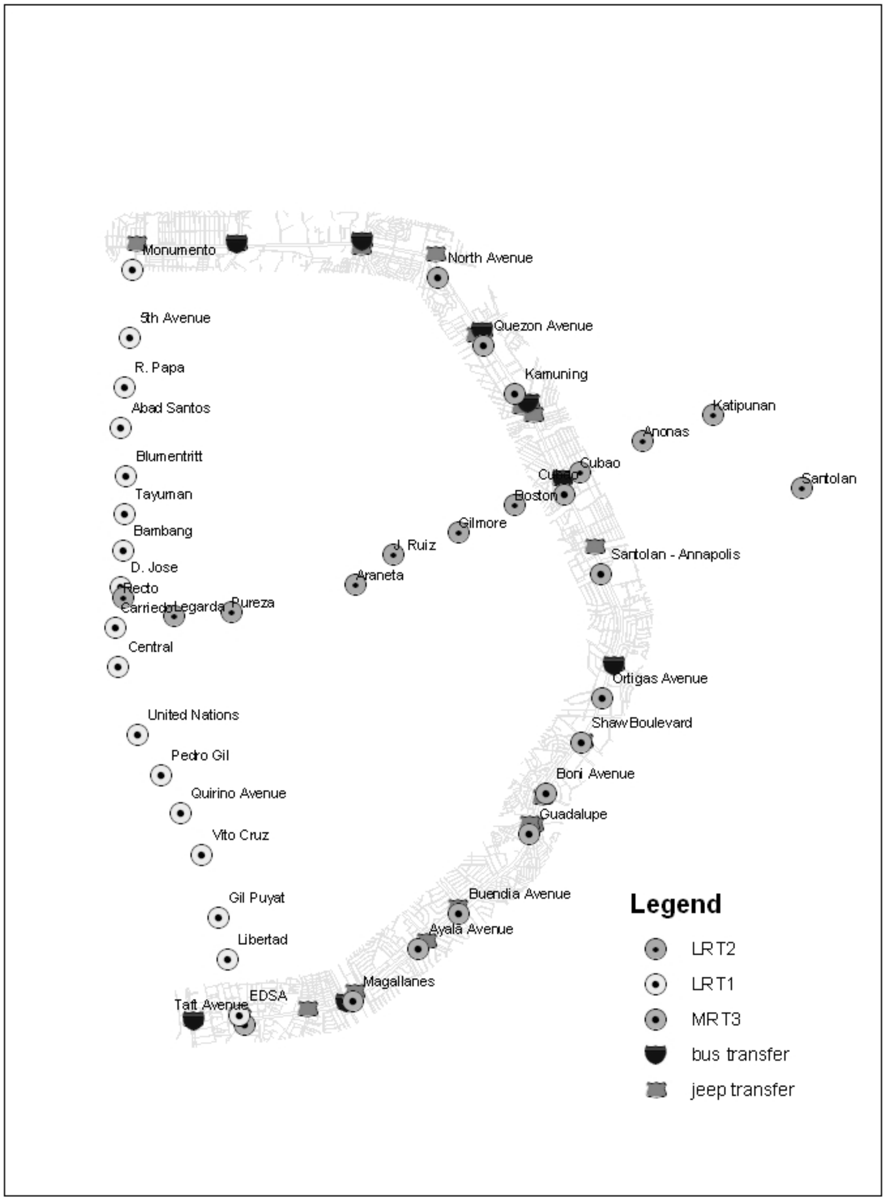

Figure 1. Mode Transfers Along EDSA Corridor and Rail Transfers in Metro Manila

using spreadsheets. Data encryption in software for statistical analysis is then performed. A correlation analysis of the bus transit data and the land use data is executed and multi-linear regression analysis follows. The runs carried out are analyzed and validated to come up with the parameters.

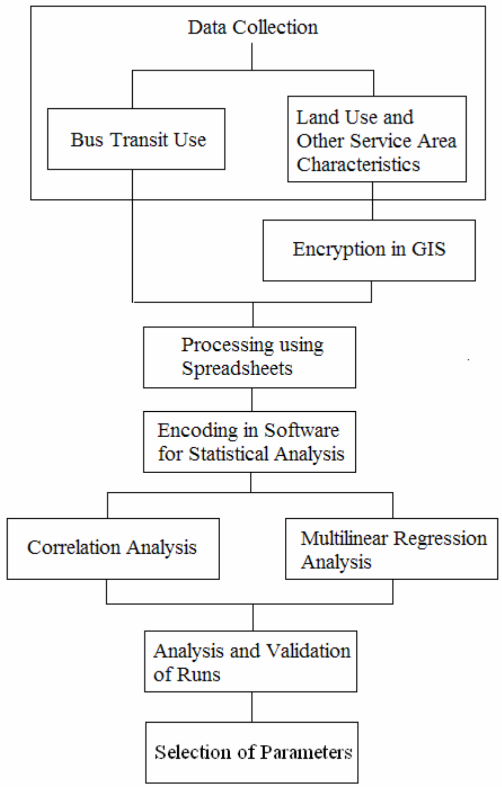

Figure 2. Methodological Framework

2.1. Data Collection

Since no actual records of current modal transfer locations exist, MMDA personnel who were familiar with the artery were interviewed. Two types of transfer points were identified namely that for jeepneys and buses. The secondary data collected was obtained from various sources, both governmental and non-governmental.

Land Use. The land use map (GIS) the study made use of was acquired from the Philippine Institute for Volcanology and Seismology (PHIVOLCS) through one of their studies called the Metro Manila Earthquake Impact Reduction Study (MMEIRS) in 2004[2]. Land use class is the type of usage an area may be allotted or is being utilized for. The land use types the study considers are described in this section.

<u>Residential</u> - These include all densities and multi-story dwelling places. In considering travel patterns during peak hours, residential land use areas are expected to be one of the main contributors to trip generation.
<u>Commercial and Business</u> - Commercial land use classes are those for office buildings, malls and other business establishments. Commercial land use classes are at the receiving end of

work trips in the morning and at the generating end of trips in the late afternoon.
Educational and Cultural - These are areas allotted for schools and cultural centers like museums and theaters.
Industrial - These are areas given for industrial plants and factories. Military-These are used for military purposes. In the case of this study, the areas classified under military land use class are the vicinities of Camp Aguinaldo and Camp Crame.
Government - These are government owned lands or those used by government offices.
Transport and Service Facility - The transportation land use class involves transportation facilities such as train depots, ports and airports.
Health and Welfare - These areas are those used by hospitals and health centers.
Religious and Cemetery - This land use class is for centers of worship and burial places.
Park and Recreational - These include places for leisure such as parks, zoos and golf.
Open Spaces - These are places that are still not being developed for any particular purpose.

Population Density. The population density map (GIS) was obtained from PHIVOLCS as part of MMEIRS as well. It is from a survey conducted by the National Statistics Office in 2000. It is divided into the densities per barangay. The population density is the number of people in a specific unit of area. In this case, it is persons/m^2.

Significant Facilities. Significant facilities include schools and malls. The schools data (GIS) were also taken from MMEIRS, similar to land use and population density while the malls (GIS) were secured from the National Center for Transportation Studies. EDSA Bus Route Revalidation Survey Data. As mentioned earlier, this study was done in conjunction with the EDSA Bus Route Revalidation Survey of JICA[1]. From that particular study, the data this research incorporated are as follows:

Boarding and Alighting - These are boarding and alighting values of the sampling of buses by the EDSA Bus Route Revalidation Survey. This is comprised of the number of passengers boarding and alighting in certain links within EDSA and the peak hours and/or places of boarding and alighting.
Bus Routes and Fleets - Bus routes are the roads certain types of buses traverse. These are important in determining the routes that converge in specific links of EDSA. Bus fleets, on the other hand, are the count of units of buses plying a certain route. This is the actual count of buses that travel at selected links along EDSA.

Rail. Rail represents the transfer points to the rail system along EDSA. The GIS data was obtained from the National Center for Transportation Studies.

Road Network. This is comprised of GIS data of the road network of Metro Manila. This is useful in identifying links of EDSA. The road network information (GIS) was obtained from the National Center for Transportation Studies.

2.2. Application of Methods of Analysis

GIS

GIS was used to create buffers for the links designated by the EDSA Bus Route Revalidation Survey. Cut areas were calculated using GIS and these were displayed in the attribute tables, among other characteristics of the buffers. This enabled the use of querying and drawing charts to graphically show the locations given specific parameter values.

Integration and Processing of Survey Data

Data from the survey was processed using Microsoft Excel. Boarding and alighting values from peak hours of weekdays from all routes converging in EDSA were used. These peak hours were chosen to be 6:00-10:00 in the morning and 4:00-8:00 in the afternoon and evening. In the EDSA Bus Route Revalidation Survey, the locations of boarding and alighting along EDSA are divided into 17 specific links in 18 designated major intersections. The mean of the boarding and alighting values in each of those links for the categories of direction (Northbound or Southbound) and time of day (PM peak or AM peak) were computed. It is important to note that in coming up with the mean boarding and alighting, one has to establish the weight each bus with a specific route contributes to that overall mean. There are route fleets with greater numbers passing a station than others. This means a bus with route X passing station A will have a different contribution to the overall mean boarding and alighting for station A compared to a bus with route Y passing the same station A. In getting the weight of each route fleet, the study assumes that this is approximately equivalent to the number of buses in a route fleet over the total number of buses in all fleets. After obtaining the mean boarding and alighting for all links, the values are then multiplied to the number of buses passing through those links. Data of number of buses in four points along EDSA are collected in the survey. By deduction and knowing the points where bus routes entered EDSA, one could determine the number of buses traversing each link. This provides a good approximation of boarding and alighting activity in the thoroughfare.

Correlation Analysis

A correlation analysis (Icasiano and Antonio, [3]) between all the variables was performed using Statistica. These variables are the AM, PM, Northbound and Southbound boarding and alighting values, influence area parameters which include land class area, total population, number of jeep, bus and rail transfer points and number of malls and schools. Areas of influence or service areas are those within 500 meters of the links defined by the EDSA Bus Route Revalidation Survey.

Multiple Regression Analysis

The process of multi-linear regression (Icasiano and Antonio, [3]) is done with the program Statistica. The boarding and alighting values are considered as the dependent variables while the independent variables are the influence area parameters. In order to refine and come-up with the best runs, a forward-stepwise ridge regression method is used.

3. RESULTS

3.1. Characterization of the Study Area

The count of buses plying EDSA during a weekday amounts to 6,367 and on a weekend, up to 5,134 units all in all with 170 operators. A total of 35 routes converge in EDSA with entry and exit points at Roxas Boulevard, Tramo, South Luzon Expressway, Ayala Avenue, Monumento, Balintawak, Congressional Road, East Avenue and Kamias.

Buffer zones were assigned to represent EDSA'a service area. For every link, the percent area of each land use class, the average population density, and the number of schools, malls and mode transfers are determined. The designated study area, 500 meters from the centerline has a total of 74 schools that contribute to increased travel activities during morning peak hours. In addition, the area is served by rail, another important mode of transport. It has a total of 13 MRT Stations and 1 LRT1 station and 1 LRT2 station. Major commercial establishments, such as malls and public markets, which are contributory to morning and afternoon peak hour trips, amount to 30 (excluding Monumento and Roxas Boulevard). Several malls, such as in Cubao, Ayala and Shaw, are adjacent to MRT stations. There are three CBD's in EDSA and these are Ortigas Center, Ayala Center in Makati, and Cubao.

Table I describes the land used assignments in the influence area. As can be seen, the residential land area is largest with 11 million m^2. Following it is commercial use, then industrial zones and government lands.

Land Use Type	Area (m^2)
Residential	11,032,765.16
Commercial and Business	5,037,650.44
Industrial	2,604,180.27
Government and Quasi-Public	941,207.51
Educational and Cultural	797,556.08
Health and Welfare	80,389.99
Park and Recreational	309,314.51
Religious and Cemetery	228,726.36
Transport and Service Facility	459,941.36
Military	900,026.52
Water Related	34,196.60701
Open Spaces	665,306.4947
Informal Settlers	283,815.6926

Table I. Land Use in the Study Area

The service area of EDSA that the study isolated includes 168 barangays of the Metropolis. In these barangays, the densest region is barangay 143 located between Taft Avenue and Roxas Boulevard with a population density of around 1.5 persons every 10 square meters (0.15216 persons/m^2) while the least dense areas are composed of high income populations such as Wack-wack Greenhills (0.00117 persons/m^2), Forbes Park, Dasmariñas, San Lorenzo and West Triangle. This is expected since high-income families have spacious lots for dwelling places. Based on population density and the areas cut by the buffer zone made in ArcMap, the service area (500 m distance from the centerline) of EDSA reaches a population of 468,189.

3.2. Boarding and Alighting Activity

	Northbound AM (6:00-10:00)		Northbound PM (16:00-20:00)		Southbound AM (6:00-10:00)		Southbound PM (16:00-20:00)	
Link	BDG	ALG	BDG	ALG	BDG	ALG	BDG	ALG
Magallanes - Pasay Rd.	197	1276	314	839	588	383	1638	403
Pasay Rd. - Ayala Ave.	176	1587	637	607	825	218	1042	95
Ayala Ave. - Buendia	130	481	319	193	861	612	1115	156
Buendia - Kalayaan	192	248	240	432	243	448	177	277
Kalayaan - Guadalupe	1416	563	860	997	728	1057	637	1037
Guadalupe - Boni	455	1038	597	563	1090	631	621	523
Boni - Shaw Blvd.	1215	1570	1310	1369	1563	751	1603	856
Shaw Blvd. - Ortigas Ave.	1320	1428	2650	1317	1425	1617	2010	1395
Ortigas Ave. - Santolan	329	354	1054	629	952	2525	842	639
Santolan - P. Tuazon	550	380	942	635	1267	1104	532	226
P. Tuazon - Aurora Blvd.	1100	732	1940	832	1222	1080	735	861
Aurora Blvd. - Kamias	1516	734	1526	1019	1111	2213	681	1611
Kamias - East Ave.	331	310	982	423	428	780	543	392
East Ave. - Quezon Ave.	490	301	1793	506	265	1260	265	278
Quezon Ave. - North Ave.	1648	480	1660	670	536	3256	441	1813
North Ave. - Congressional	1504	821	2124	1842	920	2712	1080	1196
Congressional - Balintawak	697	775	323	438	977	1013	927	578

Table II. Statistical results of survey for peak hour daily boarding (BDG) and alighting (ALG) activity (no. of persons)

3.3. Statistical Analysis

The dependent variables in the regression analysis (Icasiano, Antonio 2006) are as follows: morning boarding Northbound, morning alighting Northbound, afternoon boarding Northbound, afternoon alighting Northbound, morning boarding Southbound, morning alighting Southbound, afternoon boarding Southbound, and afternoon alighting Southbound. The independent variables are listed in Table III.

3.3.1. Correlation Analysis The following independent variables shown in Table IV were found to be highly correlated, thus they are not used simultaneously in the validated regression results.

Bus and jeep modal transfer points are identified to be highly correlated pointing to the fact that most prominent intersections in EDSA contain both types of transfer points. The relationship between jeepney stops and government land is probably representative of the accessibility jeepneys are providing to government institutions that are frequented by the public. These include the National Statistics Office, the Land Transportation Office and Land

Independent Variable	Description
BUS	No. of transfer points to buses w/ routes not traversing EDSA
JEEP	No. of jeepney transfer points
MRT	No. of MRT stations (plus LRT stations in Cubao and Tramo)
SCH	No. of schools
MALL	No. of malls and public markets
POP	Population
RES	Area for residential land use class
COMM	Area for commercial and business land use class
IND	Area for industrial land use class
GOV	Area for government and quasi public land use class
EDUC	Area for educational and cultural land use class
HEAL	Area for health and welfare land use class
REC	Area for parks and recreational land use class
REL	Area for religious and cemetery land use class
TRAN	Area for transportation facilities land use class
MIL	Area for military land use class
OPEN	Area for open spaces land use class

Table III. Independent Variables

Independent Variables	Correlation Coefficient
BUS - JEEP	0.656051
BUS - OPEN	0.614275
JEEP - GOV	0.670183
JEEP - OPEN	0.611203
SCH - POP	0.866707
GOV - OPEN	0.841207
HEAL - EDUC	0.647971

Table IV. Highly Correlated Independent Variables and their corresponding Correlation Coefficients

Transportation Franchising and Regulatory Board in the East Avenue service area. It's also not surprising to see the correlation between highly populated areas and schools. Schools can be seen to flourish in highly populated regions of the city.

3.3.2. Multi-linear Regression Analysis Tables V to VIII summarize the regression analysis done in EDSA's service area of parameters and the boarding and alighting activity in the artery. For all regressions, a total of seventeen cases, each for the links designated by the EDSA Bus Route Revalidation Survey, were evaluated. It can be said from these summaries that the assumptions of commercial and residential areas, malls and schools as significant contributors to travel patterns during peak hours are fairly accurate.

From Table V, population contributes greatest in coming up with boarding values in the Northbound morning peak hour. This shows the origin of work trips to be areas that are

Northbound (Adjusted R^2= .81801834)			Southbound (Adjusted R^2= .70892965)		
	t	β adjusted		t	β adjusted
Intercept	-1.775	-346.147	Intercept	1.953	300.166
*POP	4.314	**0.015**	*MALL	4.762	**110.015**
*MALL	3.349	**93.245**	*POP	2.596	**0.007**
*TRAN	3.621	**0.004**	MIL	2.123	0.001
REC	2.034	0.004	GOV	-1.426	-0.001
JEEP	1.023	60.429			

*statistically significant (α=5%)

Table V. Regression Summaries for AM Peak Hour Boarding (17 samples)

significantly populated. The next contributor to boarding values in the Northbound morning peak is malls. This is a characteristic unique to the Philippines where commuters use malls as intermediaries between the transportation system and places of origin or mode transfers. The same can be said for the southbound morning peak where malls contribute greatest to boarding values followed by the population factor. Note the negative sign in government land use. This reflects the tendency of government offices to be places that do not generate trips in the morning peak hours as they are expected to attract trips during this time. Note that the regression model for morning northbound boarding has a negative intercept. In practical terms, this is a limiting factor for the validity of the said model and translates to it being acceptable only for positive predicted boarding activity. Given that model for morning boarding, holding that there are no malls and jeepney stops in an area and no land use classes allotted for transport and recreational facilities, the minimum number of population residing in the vicinity of the stop will have to reach at least 23,077 persons for it to be valid.

Above is a residual plot of the population parameter for morning northbound boarding activity. Of the 17 samples, only 6 points are not within the 95% confidence interval.

In the morning peak alighting values, populated areas can be seen to be inversely proportional to places of destination. This is consistent with results in Table V where populated areas represent origins in the morning. Malls are again significant in the northbound direction, supporting the observation of these places being intermediaries. From these values, places of destination in the morning peak hours point to commercial and business, schools and industrial zones. This reflects the trips made by students to schools and those by workers to offices and factories. Note, once more, that the model for morning southbound alighting may only be valid for positive predicted activity due to the presence of a negative intercept.

The residual plot above provides an insight on the statistical significance of land use areas allotted for educational facilities and institutions on morning northbound alighting activity. As can be seen from the graph, 8 of 17 points fall outside the 95% confidence level region.

Table VII displays afternoon peak boarding values for northbound and southbound trips. As can be expected, trips originate from places of work and school. The northbound values also show significant contributions from government offices as well. In Table VII, the inverse relationship with highly populated areas and places of destination are highlighted once more

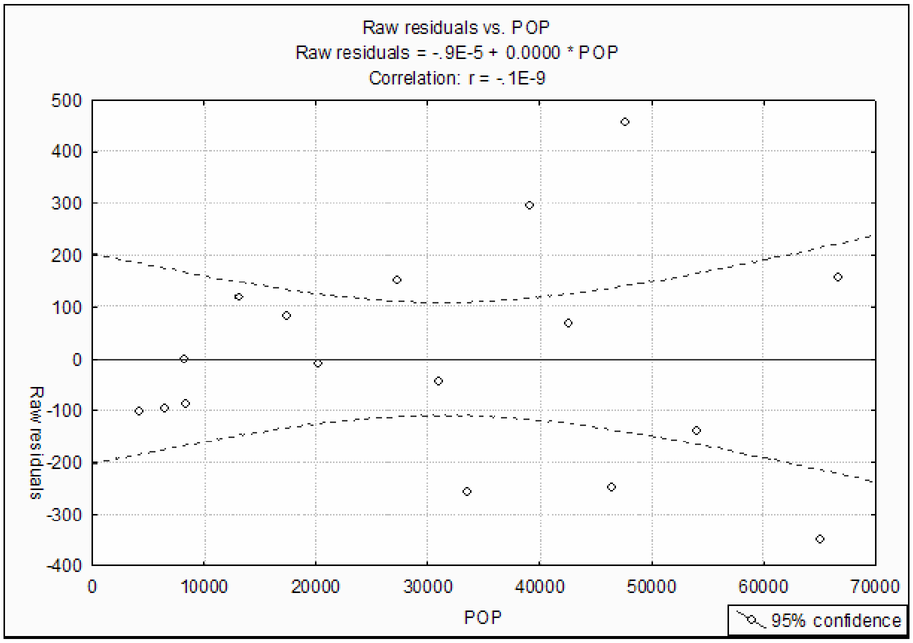

Figure 3. Residual Plot of POP for AM Northbound Boarding Activity

Northbound (Adjusted R^2= .73991863)			Southbound (Adjusted R^2= .81430180)		
	t	β adjusted		t	β adjusted
*Intercept	3.141	**785.84**	Intercept	-1.041	-479.332
*MALL	4.899	**133.146**	*TRAN	5.772	**0.01**
*IND	3.307	**0.001**	*MIL	3.853	**0.002**
*POP	-3.817	**-0.018**	*SCH	2.226	**62.708**
*REL	3.382	**0.009**	*COMM	2.583	**0.001**
*REC	-3.222	**-0.007**	RES	1.437	0
*EDUC	3.065	**0.006**			
RES	-1.804	-0.0004			

*statistically significant (α=5%)

Table VI. Regression Summaries for AM Peak Hour Alighting (17 samples)

as populated areas show a negative effect on afternoon trip generation since the commuting working class is likely to be coming from offices. The role of malls as transportation hubs is similarly evident as it is seen to contribute to trip generation in the northbound direction.

To further illustrate the statistical significance of commercial land use areas to afternoon southbound boarding activity, its residual plot is shown above. 11 of the seventeen points fall within 95% confidence level with 3 points close to the border of the confidence interval set.

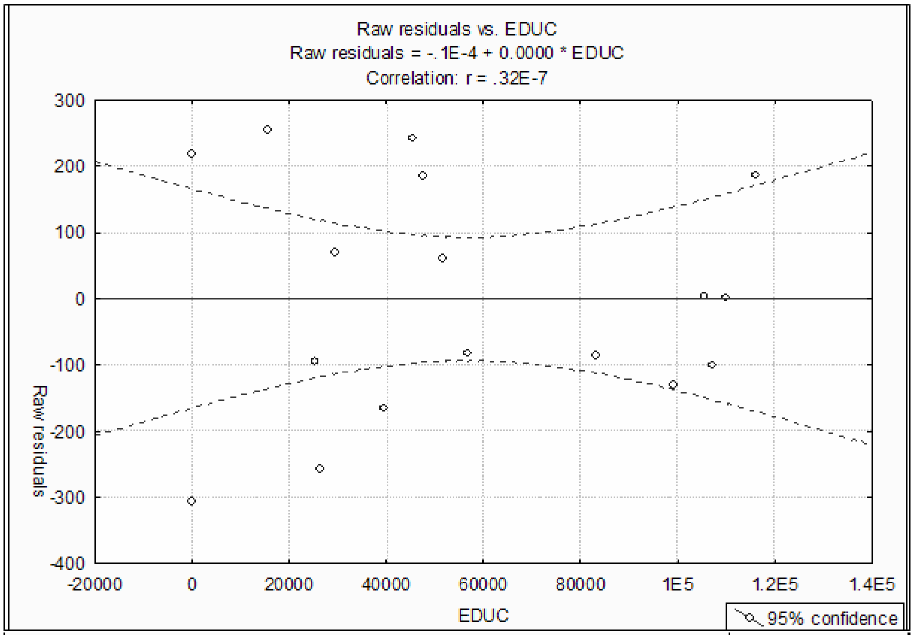

Figure 4. Residual Plot of EDUC for AM Northbound Alighting Activity

Northbound (Adjusted R^2= .75685886)			Southbound (Adjusted R^2= .72661276)		
	t	β adjusted		t	β adjusted
Intercept	1.201	487.9	*Intercept	2.524	**510.154**
REC	0.79	0.003	*COMM	4.472	**0.002**
*GOV	3.167	**0.002**	*OPEN	-3.169	**-0.005**
*MALL	2.435	**111.763**	TRAN	-0.027	0
*SCH	2.898	**191.561**	*IND	3.503	**0.001**
*POP	-2.34	**-0.028**	*POP	-3.301	**-0.02**
TRAN	1.586	0.003	*REL	2.61	**0.008**
RES	-1.268	0	REC	-1.922	-0.005

*statistically significant (α=5%)

Table VII. Regression Summaries for PM Peak Hour Boarding (17 samples)

Finally, Table VIII lists the alighting values in the afternoon peak. Here, malls and population are significant contributors once again. In addition, we again see an imperfect model for the afternoon southbound alighting activity. Similar to the first two models with negative intercepts, this model is practical only for positive alighting activity predictions.

The significance of malls in transit use is very striking. This relationship might be stemming from the profitability of locations where commuters converge. The summaries were also

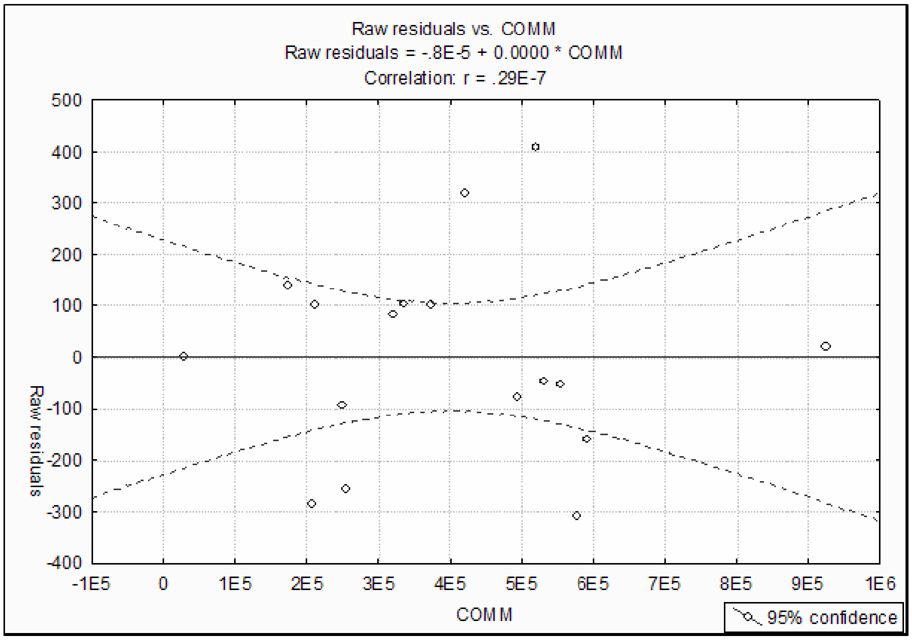

Figure 5. Residual Plot of COMM for PM Southbound Boarding Activity

Northbound (Adjusted R^2= .38897671)			Southbound (Adjusted R^2= .82449498)		
	t	β adjusted		t	β adjusted
Intercept	0.622	130.499	Intercept	-1.431	-259.504
*EDUC	2.199	**0.005**	*TRAN	5.21	**0.006**
*MALL	2.165	**68.625**	*REC	3.128	**0.005**
POP	1.149	0.005	*POP	2.357	**0.007**
			*MALL	2.613	**67.681**
			JEEP	1.767	97.071

*statistically significant (α=5%)

Table VIII. Regression Summaries for PM Peak Hour Alighting (17 samples)

successful in assigning quantitative descriptions of the relationships of populated areas as trip generating locations while commercial and industrial areas and schools as trip attracting in the morning. The opposite is true in the afternoon peak hours. The significance of the contribution of population as a factor to transit use is also remarkable in the appearance of inverse relationships.

A residual plot of Malls on afternoon southbound alighting activity is shown above. Note that unlike parameters of land use and population, MALL is a discontinuous variable. Its statistical significance as shown in the figure can be interpreted to represent concentration

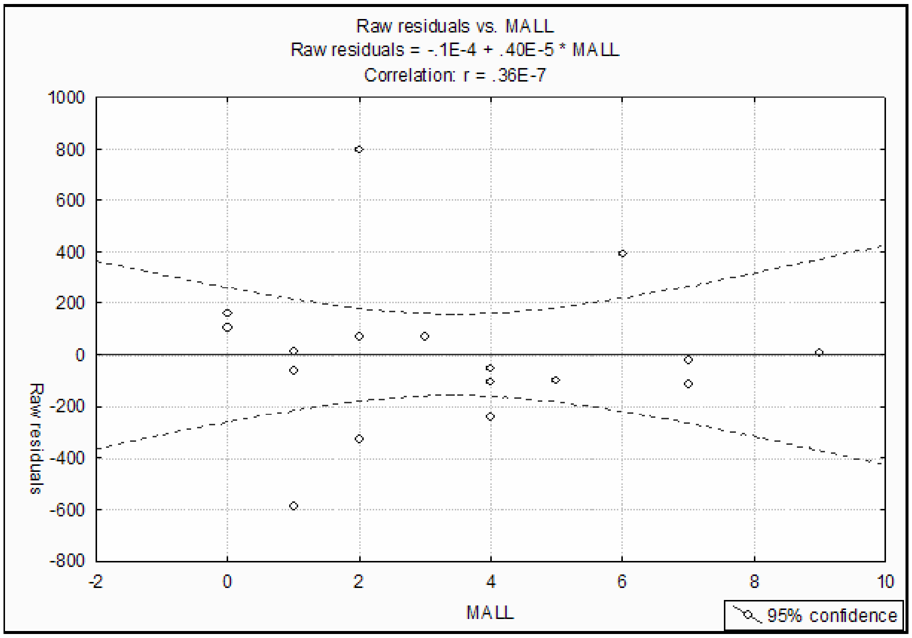

Figure 6. Residual Plot of MALL for PM Southbound Alighting Activity

points of commercial areas with its collection of retail establishments, food places and other entertainment services situated in a small geographical area. In Figure 6, only 5 of the 17 samples fall outside a 95% confidence interval.

It is interesting to note the practicality of these results. These are encouraging proofs that the observable trends have statistical foundations and that modeling can provide an acceptable amount of precision. They provide good characterizations of the trends of commuters in the morning and afternoon peak hours with respect to aspects of land use, population and presence of significant facilities. These results support the notion that land use is directly related to trip generation. Studies by Kockelman [4] and Frank and Pivo [5] support an existing relationship between land use mix and travel patterns. With regards to a direct relationship between areas of land use classes and trip generation and attraction however, no literature was found. These results show that such a relationship exists. Moreover, the volume of trips possibly relies on the level of development a particular land class exhibits. Densely occupied land use classes with their respective utilizations should be able to exhibit a more pronounced relationship with trip generation and attraction.

4. CONCLUSION

Statistical relationships between land use, population and bus transit have been successfully established. The role of commercial facilities (i.e. malls) as intermediaries of transportation has also been revealed. These facilities have the greatest influence with regards to bus transit use in EDSA. Population also exhibits a remarkable amount of relationship with boarding and alighting activity and had corresponding direct and inverse relations. For destinations in the morning and origins in the afternoon, the identifiable service characteristics with significant contributions to boarding and alighting volumes are areas for commercial, educational, industrial and government use.

The study was able to verify that a practical and accurate modeling of EDSA's bus transit can be produced with the use of service area characteristics that were revealed to have statistically significant influences. However, it is important to recognize that three of the eight models developed here have a tendency to produce negative boarding and alighting output predictions due to the fact that they have negative intercepts. On the same light, all models should be taken to be valid only as long as their outputs result in positive boarding or alighting activity.

5. RECOMMENDATIONS

It is suggested that a more thorough regression analysis involving not just a radius-defined service area but one that takes into account passenger volumes from modal transfer points be made. If the volume generated by the modal transfer points can be more accurately segregated, a more precise evaluation that involves a greater area of the metropolis can be drawn. In addition, a regression analysis that involves a check of the validity of the assumptions made in the study and the consideration of other scenarios of boarding and alighting distributions will be useful. New models that do not result in negative boarding and alighting activity predictions should be further developed to better represent EDSA's bus commuter behavior. Finally, to develop precision, it is necessary to introduce adjustments that take into consideration the overlapping of the service areas.

Prediction equations from these relationships can be generated in order to model boarding and alighting activity in EDSA. This is useful in evaluating the usefulness and necessity of present and future bus stops in an area. Furthermore, their validation may pave the way for similar studies on other modes of travel (i.e. jeepneys, FX taxi's, rail).

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