Current Bus Service Operating Characteristics Along EDSA, Metro Manila

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Abstract: The Epifanio Delos Santos Avenue (EDSA) has been the focal point of many transportation studies over the past decade, aiming towards the improvement of traffic conditions across Metro Manila. Countless researches have tested, suggested and reviewed proposed improvements on the traffic condition. This paper focuses on investigating the overall effects of the operational and administrative changes in the study area over the past couple of years, from the full system operation of the Mass Rail Transit (MRT) in the year 2000 to the present (2014), to the service operating characteristics of buses plying the EDSA route. It was found that there are no significant changes in the average travel and running speeds for buses running Southbound, while there is a noticeable improvement for those going Northbound. As for passenger-kilometers carried, only minor changes were found. The journey time composition percentages did not show significant changes over the two time frames as well. For the factors contributing to passenger-related time, the presence of air-conditioning and the direction of travel were found to contribute as well, aside from the number of embarking and/or disembarking passengers and number of standing passengers. For the location of stop times and delays, most have shifted to the portions further along each direction along EDSA. It was also found that the biggest delay was incurred in the Ortigas-Shaw segment, in both directions, for both the morning and afternoon peak periods.

***Key words*:** Bus transit; Mass rail transit; Public transport system

1. INTRODUCTION

One of the busiest road corridors in the Philippines is the 24 km stretch of the Epifanio Delos Santos Avenue (EDSA), located at the heart of Metro Manila. It is the main thoroughfare in the region, passing through six (6) of the seventeen (17) cities comprising the National Capital Region, namely from Caloocan, Quezon City, San Juan, Mandaluyong, Makati and Pasay. It has been catering to both private and public transport across the region, linking the North Luzon Expressway in Balintawak in the north to the South Luzon Expressway at the Magallanes Interchange in the south.

Understandably, the EDSA has been the focal point of many transportation studies over the past decade, aiming towards the improvement of traffic conditions across Metro Manila. Efforts from both the public and private entities have been endless, all exhausting their capacities trying to find the best solution to the worsening traffic situation along the avenue. Countless research projects have been undertaken, all aimed to decongest EDSA, and ultimately improve transport mobility and accessibility in the region.

EDSA is easily one of the longest and busiest highways in the metropolis, serving an average daily traffic of approximately 330000 vehicles (Vallarta, 2011), growing from an approximate number of 195000 in 2007 (Kawabata and Sakairi, 2008). Currently, over 3700 public utility bus units run along EDSA (LTFRB). This paper focuses on the bus operating characteristics plying the avenue. Analysis involves average travel and running speed, passenger-kilometer performances and journey time composition of buses. These are compared to the corresponding values computed from data gathered from early 2001, around six (6) months after the opening of the

Metro Rail Transit on July 2000. This paper focuses on the overall effects of numerous traffic system and policy changes over the past decade to the bus operating conditions.

2. LITERATURE REVIEW

Numerous research projects focused on bus transport operations over the past decade. Along with these, a lot of changes have been proposed and implemented aiming to improve the traffic congestion. Finn and Mulley (2011) presented a framework to understand regulatory and institutional changes in urban bus services. The framework identifies three types of changes 1) changes in the role of the regulator and market structure, 2) changes in the structure of the operator and of private sector participation, and 3) changes in the transport supply.

2.1 Bus Operation Regulation

In a study by Chen, X. (2003), the merits and demerits of three alternatives of subregional governance of bus services, namely 1) transferring bus services to local municipal operators, 2) transferring bus services to local transportation zones, and 3) reorganizing transit operations into bus service sectors, were compared and found that no model is applicable for every circumstance, but a mixed alternative balancing both regional and local interests and reconciling the conflicts among different governance models is feasible.

In the study of Md. Nor, N., et.al. (2006) on the relationship of service quality and ridership, it was found that although it has a positive effect, modal split is generally not very sensitive to the quality of the public transport service, thus requiring demand management measures implemented as policy. Morris, M. (2005) discussed the role of local authorities in the use of city bus services as part of an integrated solution to reducing traffic-related congestion in urban areas.

Starting December 2012, the Metro Manila Development Authority (MMDA) implemented a bus segregation scheme aimed to decongest traffic along EDSA, classifying buses into groups A, B, and C, where A buses stop at A bus stops, B buses stop at B bus stops, and C buses at all stops, with 40%, 40%, and 20% unit shares, respectively (GMA News, 2012).

Last August 2013, the MMDA implemented the Bus Management Dispatch System (BMDS) in the south-west integrated bus terminal, which is expected to decongest EDSA, as well as address the problem of “colorum” or “out-of-line” vehicles (Liza, 2013). The Integrated Transport Terminal project is a centralized, intermodal and integrated bus terminal system which aims to improve the mobility of people and the traffic situation inside Metro Manila road network by consolidating all existing 85 terminals scattered all over the inner core of Metro Manila to three central terminals located at the fringes of Metro Manila (DOTC).

2.2 Bus Operation Structure

McLeod and Hounsell (2003) evaluated different strategy options in providing bus priority at traffic signals, varying the strength of priority awarded and selection of the buses that are to receive it. Agrval, et.al. (2013) estimated the impact of bus priority lanes on bus speeds while addressing the access and mobility needs of other transportation system users. Tu, et.al. (2013) analyzed three popular types of bus lane operation including 1) roadside exclusive bus lane, 2) bus priority lane, and 3) ordinary lane, and figured out suitable areas for bus lane type applications under various conditions of the main road traffic volume and the number of passengers on the bus.

Hillsman, et.al. (2012) investigated the design and operation of shared bicycle/bus lanes, designated for use by public transit buses, bicycles, and also for right-turning vehicles. The purpose of such lanes is to provide a time advantage to public transit service by taking the buses out of the general traffic flow and into a designated lane, as well as provide a more direct route for bicyclists, provide greater level of service to bicyclists and some degree of separation between general traffic and bicyclists for their greater safety and comfort.

2.3 Bus Transport Supply

Research focusing on controlling transport supply to improve efficiency can be classified into two categories: 1) control of the number of operating vehicles, and 2) control of the operation along the route. Guariño, et.al. (2001) examined the viability of consolidating bus companies operating in Metro Manila into an optimum that would promote public interest, as too many operators with few units result to stiff competition between operators for more profit, resulting to inefficiency of bus services.

Antonio and Icasiano (2006) formulated rational criteria on designating bus stop locations in order to aid in the development of a sustainable stop policy, using GIS and statistical analysis to examine service area parameters and relate them to bus transit use. Shrestha and Zolnik (2013) estimated the impact on bus demand, operating costs, and service improvement of eliminating some bus stops.

3. METHODOLOGY

Bus services operations were surveyed using onboard bus passenger survey from the origin of the bus service line to its end point. Relevant data gathered include the number of alighting and boarding passengers, moving and stop times and causes of delays. Times of arrival on predetermined points were also noted for traffic segment analysis. The data were then processed to obtain bus service operational characteristics such as average travel and running speeds, dwell time at stops and intersections, passenger-kilometer performance and journey time composition.

These variables were compared between two time frames: 1) after MRT 3 became operational; and 2) the current conditions. The comparison focused on the critical directions along EDSA. Critical numbers of commuters travelling Southbound occur in the morning, while for those travelling Northbound, the critical numbers are reached in the afternoon. Analysis also focused on the significant segment of EDSA from Gil Puyat (Buendia) Avenue to Aurora Boulevard, illustrated as points A and B, respectively, in Figure 1. This segment is where all buses converge as they travel along EDSA.

Assumptions for hypothesis testing were first verified. The test procedures for comparing population means are as follows: 1) the two samples should be drawn from different populations, hence, independent of each other; 2) the two samples should be drawn from normal populations; and 3) the two population variances should be equal. The two sets of data are then compared to show changes in bus operating characteristics.

4. PUBLIC TRANSPORT ALONG EDSA

EDSA is the main thoroughfare traversing Metro Manila. It has 5-lane roads in both directions and caters to both public and private travel. MRT, buses, jeepneys and megataxis have provided public transport service across EDSA since the mid-1990s. Now, majority of the transport demand fall onto the MRT and bus transit, especially for trips traversing long distances along EDSA. Figure 1 shows the several bus service lines operating in Metro Manila, as well as the MRT line, with its 13 stations encircled red. Table 1 gives the list of bus routes and the portion of their route lengths plying the EDSA. Coded links of the bus routes are also provided.

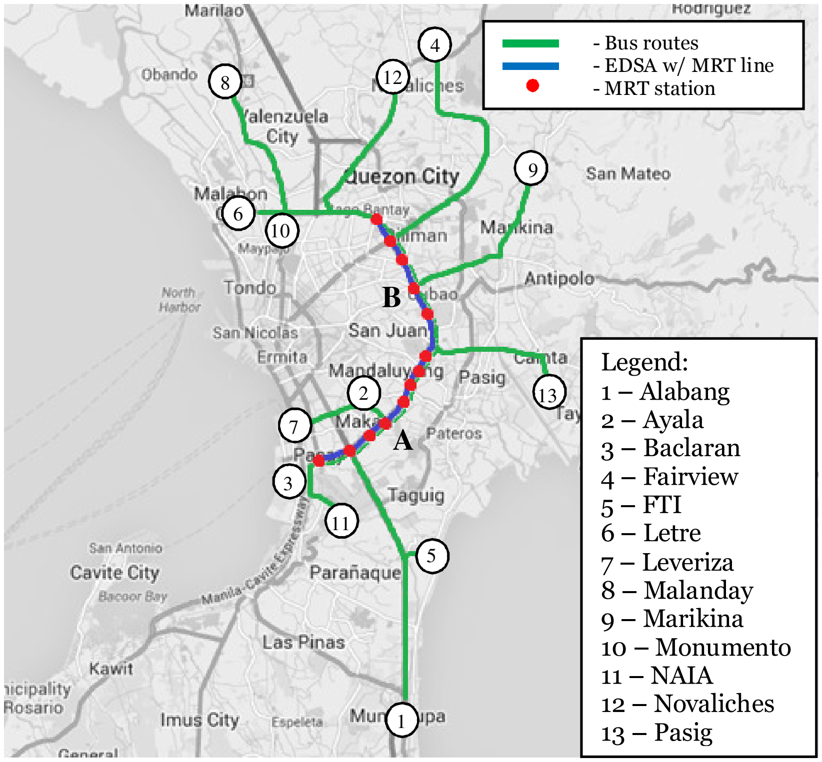


Figure 1. MRT and Bus Service Routes Passing EDSA

Currently, a great majority of the travel demand falls onto the MRT 3, given its reduced fares and shorter travel time. The MRT 3 fare starts at Php 12.00 for the shortest journey, to Php 16.00 for the longest. For the airconditioned buses, the current fare is Php 12.00 for the first five (5) kilometers, and increases by Php 2.50 for every kilometer thereafter. For non-airconditioned buses,the current fare starts at Php 10.00 for the first five kilometers, and increases by Php 2.00 for every kilometer thereafter.

Table 1. Bus Route Service Traversing EDSA with MRT 3 Operation

Bus routes	Coded Links	Estimated Length of Bus Routes with MRT Service [km]	Estimated Total Length of Bus Route [km]
Leveriza – Fairview	7-4	9.915	28.90
Leveriza – Letre	7-6	12.590	24.61
Leveriza – Malanday	7-8	12.590	29.29
Leveriza - Monumento	7-10	12.590	21.62
Leveriza – Marikina	7-9	8.560	26.91
Leveriza – Pasig	7-13	4.065	13.92
NAIA – Letre	11-6	15.825	29.50
NAIA – Malanday	11-8	15.825	33.01
NAIA – Fairview	11-4	13.140	32.67
Alabang - Monumento	1-10	14.310	31.94
Alabang - Novaliches	1-12	14.310	37.15
Alabang - Letre	1-6	14.310	34.78
Alabang - Malanday	1-8	14.310	39.44
Alabang - Fairview	1-4	11.625	38.81
Baclaran - Monumento	3-10	15.825	23.35
Baclaran - Novaliches	3-12	15.825	31.23
Baclaran - Letre	3-6	15.825	26.60
Baclaran - Fairview	3-4	13.140	27.17
Ayala - Novaliches	2-12	12.590	22.90
FTI - Monumento	5-10	14.310	26.44

5. BUS SERVICE OPERATING CHARACTERISTICS

This section discusses changes in bus operation characteristics from the time of opening of MRT3 to the present. The values tested for changes using hypothesis testing includes 1) the mean of the average travel speed, 2) the mean of the average running speed and 3) the mean of the average passenger-kilometer carried. Journey time composition from both time frames were also compared, as well as the average delay incurred at selected segments along EDSA.

5.1 Bus Volume Study

Table 2 shows the bus volumes passing through EDSA using the post-MRT3 and current data. As shown in the data, the average volume of public utility buses decreased for both directions of travel. It can also be seen that the peak hour shifted to a later time in the morning, and to an earlier time in the afternoon. For the percentages of airconditioned buses to non-airconconditioned, negligible difference can be seen for the morning peak period data. As for the afternoon peak period, an increase in the percentage of airconditioned buses is notable. However, in comparison with the percentages of the morning peak data, the values are relatively similar. This shows that the percentage of airconditioned to non-airconditioned only stabilized to normal levels, coming from the time when non-airconditioned bus numbers greatly increased resulting from the opening of the MRT 3, to compete with the lower fares of the MRT 3.

Table 2. Comparison of Post MRT 3 and Current Bus Volume

Direction of Travel	Period	Peak Hour Period	**Post MRT 3 (2001)**		
			Aircon No. (%)	Non-Aircon No. (%)	Total No. (%)
Southbound	AM	6:45-7:45	187 (52.82)	167 (47.18)	354 (100.00)
Northbound	PM	17:00-18:00	88 (36.07)	156 (63.93)	244 (100.00)
			Current (2014)		
Southbound	AM	9:00-10:00	142 (53.18)	125 (46.82)	267 (100.00)
Northbound	PM	16:00-17:00	88 (56.05)	69 (43.94)	157 (100.00)

5.2 Bus Service Performance

Several requirements were first tested before the data were subjected to hypothesis testing. First, both samples should be independent of each other. This was fully satisfied considering data samples being compared are gathered from two different time frames. Second, both samples were tested for normality of data. The method introduced by Looney and Gulledge (1985) was used in determining normality of data using the results of R^2 of the data and the critical R^2. Figure 2 shows the normal probability plot of the average travel speed of buses in the morning peak period going South-bound. As the R^2 would show, little deviation from normality is observed as the plot follows the diagonal line. Table 3 shows the corresponding R^2 values of for average running speed and passenger kilometers, for both time frames. As the data suggests, there are no significant deviations observed, hence, normality assumption is upheld.

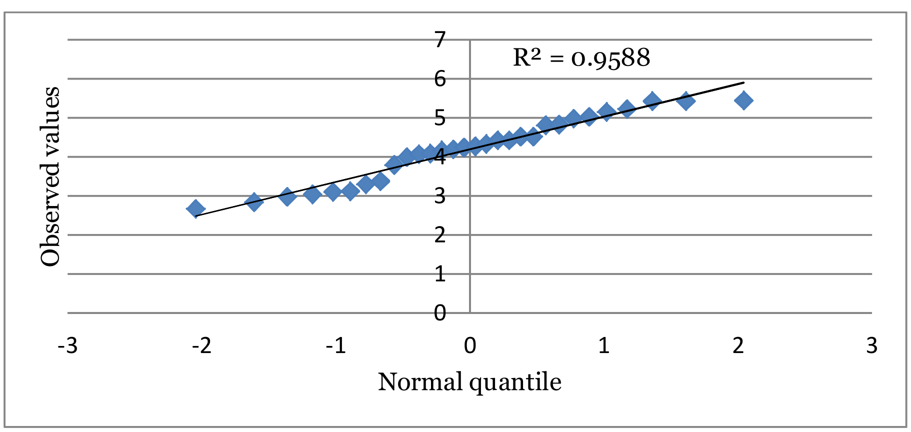


Figure 2. Normal probability plot of average travel speed

Table 3. R^2 test for normality of data using the normal probability plots (α=0.05)

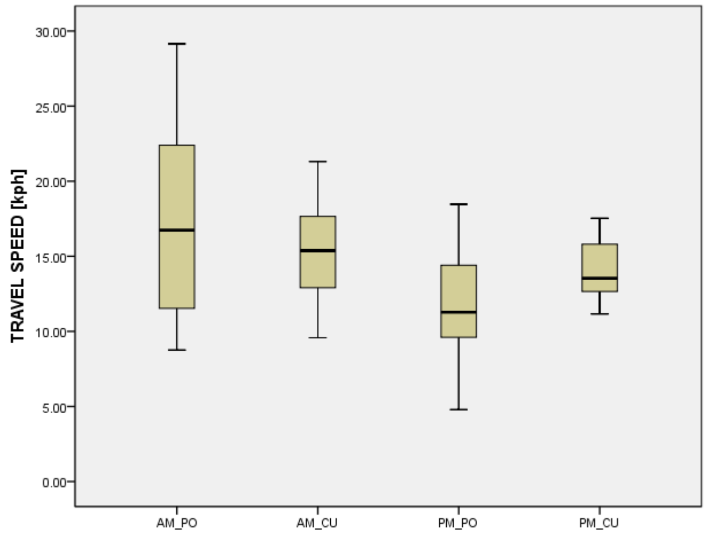
Variable	Southbound, AM Peak			Northbound, PM Peak		
	N	R^2	$R^2_{critical}$	N	R^2	$R^2_{critical}$
Post-MRT 3						
1. Average travel speed	38	0.9443	0.972	44	0.9795	0.972
2. Average running speed	38	0.9439	0.972	44	0.9660	0.972
3. Average passenger-km carried	38	0.9282	0.972	44	0.9106	0.972
Current						
1. Average travel speed	31	0.9588	0.964	12	0.9423	0.918
2. Average running speed	31	0.9327	0.964	12	0.9065	0.918
3. Average passenger-km carried	31	0.9757	0.964	12	0.9571	0.918

The third requirement considers equality of variance. Table 4 shows the test statistic F with (N_1-1) and (N_2-1) degrees of freedom where N_1 and N_2 are the sample sizes for data gathered after the opening of the MRT3 and those gathered in the current year, respectively. As shown in the data, only the data for average travel and running speed for the afternoon peak period passed the test. The rest of the values for average travel speed, running speed, and passenger-km carried failed to satisfy the equal variance assumption. As a result, t-test for means of independent samples, an alternative for data variances not assumed as equal, was used to compare the sample data.

Table 4. Test for Equality of Variance

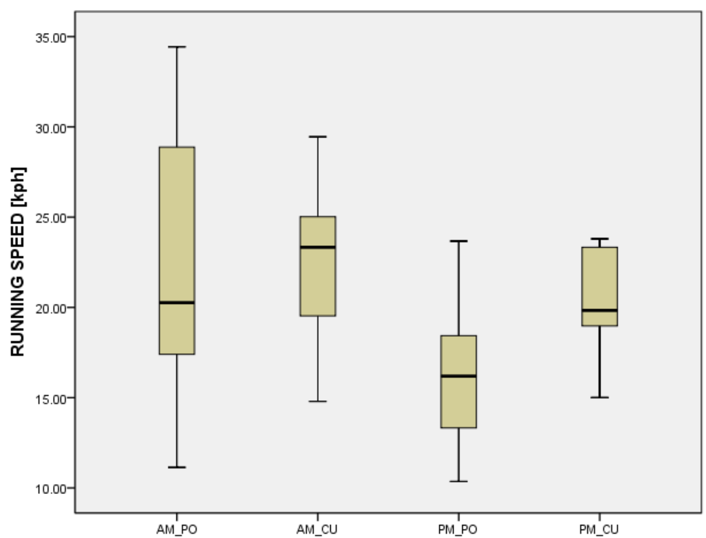
Variable	Southbound, AM Peak (N_1=38,N_2=31)		
	Levene's Test for Equality of Variance F	P-Value	Remarks
1. Average travel speed	21.169	0.000	Fail
2. Average running speed	14.492	0.000	Fail
3. Average passenger-km carried	4.834	0.031	Fail
	Northbound, PM Peak (N_1=44,N_2=12)		
1. Average travel speed	2.836	0.098	Pass
2. Average running speed	0.365	0.548	Pass
3. Average passenger-km carried	4.975	0.030	Fail

Figures 3 to 5 show the box plots of the average travel speed, average running speeds, and the average passenger- kilometer performance of buses, respectively. As the box plots reveal, there is a small reduction in the average travel speed for the morning peak period. For the afternoon peak period data, there is a noticeable improvement. For the average running speed, there is a significant increase for both the morning and afternoon peak periods. As for the passenger-kilometer performance of buses, small changes were observed for the respective sets of data.



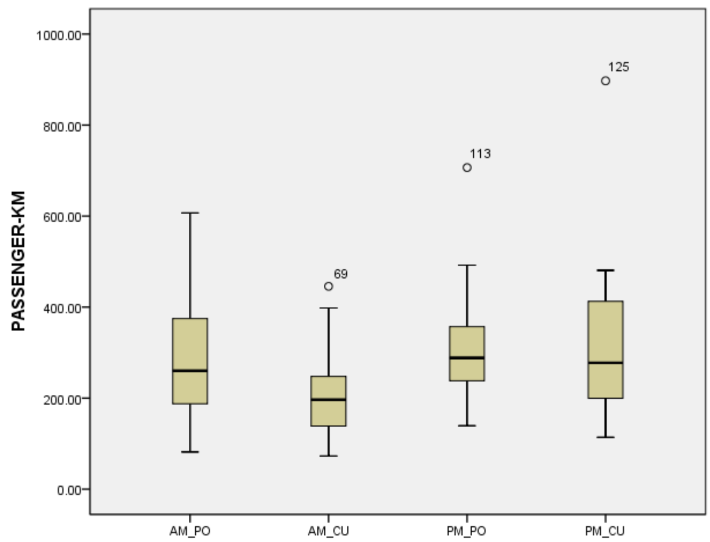
Legend:
AM_PO = morning peak post MRT 3
AM_CU = morning peak current
PM_PO = afternoon peak post MRT 3
PM_CU = afternoon peak current

Figure 3. Box Plots of Average Travel Speeds of Buses



Legend:
AM_PO = morning peak post MRT 3
AM_CU = morning peak current
PM_PO = afternoon peak post MRT 3
PM_CU = afternoon peak current

Figure 4. Box Plots of Average Running Speeds of Buses



Legend:
AM_PO = morning peak post MRT 3
AM_CU = morning peak current
PM_PO = afternoon peak post MRT 3
PM_CU = afternoon peak current

Figure 5. Box Plots of Passenger-Km Performance of Buses

Using hypothesis testing at 95% level of confidence, changes in the mean of the average travel speed, running speed, and passenger-kilometer performance of buses for both data sets were determined. The following are the null and alternative hypotheses used in the test.

$$H_0 : \mu_1 = \mu_2 \qquad (1)$$
$$H_1 : \mu_1 \neq \mu_2 \qquad (2)$$

Where $\mu1$ = the sample used to represent interchangeably the mean of the average travel speed, average running speed, and passenger-kilometer performance of buses after the opening of the MRT3, and

$\mu2$ = the sample used to represent interchangeably the mean of the average travel speed, average running speed, and passenger-kilometer performance of buses operating currently

Table 5 shows the result of the hypothesis test (α=0.05). As shown, there is enough evidence to reject Eq. 1 for the average passenger-kilometer carried by buses in the morning peak period, as well as for the average travel and running speeds data in the afternoon peak period. The results confirmed the changes exhibited in the box plots regarding the bus data considered. There is a small reduction, although tested to be negligible, in the average travel speed, while a slight increase in the average running speed can be seen for buses in the morning peak period. The increase in values for the average travel and running speed for buses in the afternoon peak period reflects the behavior shown in the box plots as well. For the the passenger-kilometer performance of the buses, the values agree with behavior seen in Figure 5 as well.

Table 5. Test for Means of Bus Variables

Variable	Period	Mean	No. of Samples	(t-test, P-value)	Remarks
	Southbound, AM Peak				
1. Average travel speed [m/s]	Post-MRT	17.57	38	1.949, 0.056	Do not reject H_o
	Current	15.29	31		
2. Average running speed [m/s]	Post-MRT	22.19	38	-0.168, 0.867	Do not reject H_o
	Current	22.40	31		
3. Average passenger-km performance	Post-MRT	282.91	38	2.851, 0.006	Reject H_o
	Current	206.88	31		
	Northbound, PM Peak				
1. Average travel speed [m/s]	Post-MRT	11.79	44	-2.336, 0.005	Reject H_o
	Current	14.12	12		
2. Average running speed [m/s]	Post-MRT	16.04	44	-4.579, 0.000	Reject H_o
	Current	20.40	12		
3. Average passenger-km performance	Post-MRT	311.09	44	-0.320, 0.754	Do not reject H_o
	Current	331.67	12		

5.3 Journey Time Composition

The travel time of public utility vehicles is divided into three parts: running time, passenger-related time, and traffic-related consumed time. Running time is the time consumed by the vehicle for travelling the stretch of segment being served. Passenger-related times are specifically those consumed by embarking and disembarking passengers. Traffic-related consumed time includes those consumed due to traffic lights, obstruction of other vehicles, and the like.

For situations where it is difficult to discern whether the time under consideration is passenger-related or traffic-related (e.g. at intersections where buses are waiting for the traffic light to turn green, passengers can also use this time to embark or disembark), time consumed by passengers was extracted using a polynomial linear regression equation developed to estimate the time commuters embark or disembark from the public utility vehicle. This is to separate the actual passenger-related time from the traffic-related time.

From samples of embarking and disembarking passengers, the passenger-related time was obtained. An equation was developed to estimate the time consumed by boarding and alighting passengers. The equation in a previous study (Fillone, 2001) was used as the basis for the equation developed. The updated equation is given as

$$y = 3.329+1.299*x_1+0.030*x_1*x_2+0.677*x_1*x_3+0.115*x_1*x_4 \quad (3)$$

Where y = the time consumed in embarking and/or disembarking passengers,
x_1 = the number of embarking and/or disembarking passenger,
x_2 = the number of standing passengers,
x_3 = the presence of air-conditioning [1-air-conditioned; 0-non-air-conditioned], and
x_4 = the direction of travel [1-Northbound; 0-Southbound]

As shown in the equation, the passenger-related time relies on the number of embarking and/or disembarking passengers. The presence of standing passengers also contributes as movement inside the vehicle is hindered. The presence of air-conditioning also contributes positively to the passenger-related time. This can be attributed to the number of doors the buses have. Air-conditioned buses have single doors in the front while non-air-conditioned buses have two, one in the front and another at the middle. The direction of travel was also found to affect the passenger-related time, such that those travelling Northbound take more time to embark and/or disembark. A possible explanation could be that critical periods going Northbound occur in the afternoon, when majority is comprised of home trips, meaning the passengers are probably in less of a hurry.

Figure 6 shows the percentages of journey time composition. As shown, the highest percentages of time were spent on movement for all sets of observations. Comparing percentages between the post-MRT3 and current data, during the morning peak period, very negligible differences can be discerned. However, for the afternoon peak period, it can be noticed that the stop time or delay significantly decreased. This agrees with the earlier findings where travel and running speeds are found to have improved, which consequently means a decrease in delays.

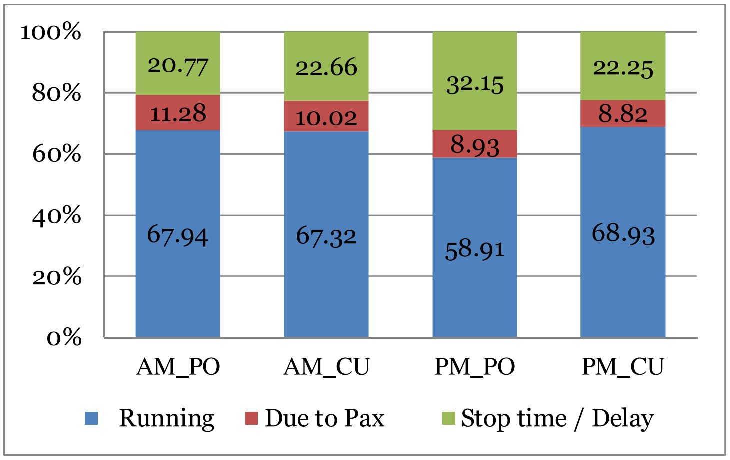


Figure 6. Bus Journey Time Composition During Morning and Afternoon Peak Periods

5.4 Delay Breakdown Along EDSA

Figures 7 and 8 show the delays for the selected segments along EDSA for buses travelling Southbound and Northbound, respectively. Table 6 shows the cumulative delays for both data sets. As shown in the first figure, for the morning peak period, there are noticeable changes in the location of delays and dwell times. Generally, the delays shifted towards the latter part of the route, from Ortigas to Buendia, with the largest delay incurred in the Ortigas-Shaw segment. As for the afternoon peak period, the delays were incurred in the latter part as well, from Shaw to Aurora, with the largest delay occurring in the Shaw-Ortigas segment. It can be seen that the largest delay shifted from the Aurora-Tuazon segment to the Ortigas-Shaw segment, for both sets of data.

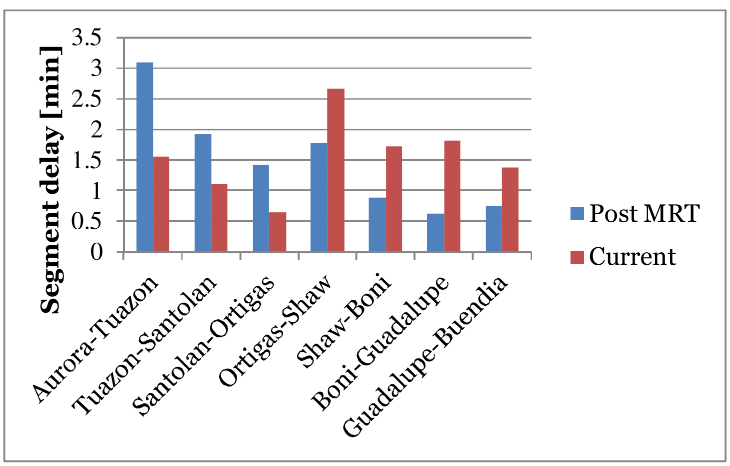


Figure 7. Segment Delays Along EDSA during the Southbound Morning Peak Period

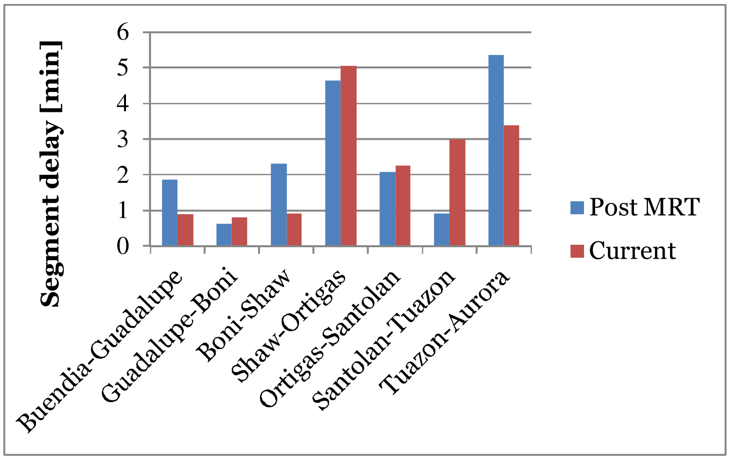


Figure 8. Segment Delays Along EDSA during the Northbound Afternoon Peak Period

Table 6. Total Delay Along EDSA

		Total Delay [min]	
Direction	Period	Post MRT3	Current
Southbound	AM Peak	10.46	10.88
Northbound	PM Peak	17.77	16.30

For both data sets, it can be seen that delays build up towards the farther stretches of EDSA, for both directions of travel. Considering the end points of the segment being studied are the points of convergence and divergence for both directions, it is understandable that there is no significant exit of vehicles along the segment. As for the total delays shown in Table 6, it can be seen that there is no significant difference when comparing the morning peak data. As for the afternoon peak data, a reduction in total delay can be seen. Like that of the previous sub-chapter, this agrees with the earlier findings stating significant improvement in travel and running speeds.

6. CONCLUSIONS AND RECOMMENDATIONS

Over the years, EDSA has been the main thoroughfare across Metro Manila for both public and private vehicles. Countless research studies have analyzed EDSA and all the public transport modes plying it, and proposed solutions to alleviate the traffic congestion. However, as shown in the current operating conditions along EDSA in this paper, it can be seen that there is still room for traffic condition improvement.

Travel and running speeds were found to have changed minimally in the Southbound direction. In the Northbound direction, improvement in both travel and running speeds was observed. The average passenger-kilometers carried by buses were found to experience minor changes as well.

As for the journey time composition, no significant changes in percentages were noted. For the equation used in estimating passenger-related time, the presence of airconditioning and the direction of travel were found to contribute as well.

It was also found that the biggest delay was incurred in the Ortigas-Shaw segment, for both directions of travel. This can be attributed to the traffic congestion caused by vehicles massing near the malls located along this segment.

Although the data shows a general improvement in the bus operation conditions over the years, this does not necessarily show in the actual situation. It has been a general notion that the traffic condition along EDSA has never been worse. Two possible explanations can be that 1) people's perception of the traffic situation is skewed negatively, or 2) there are quantities not considered in this analysis. Considering the first option is questionable, the latter shall be reconsidered.

A possibility could be that some delays incurred are unaccounted for by the terms of analysis used in this paper. A possible factor can be found in the requirements for classification as traffic-related time. This quantity only considers time consumed while the vehicle is not moving, for reasons other than passenger embarking or disembarking.

In reality, delays occur while the vehicle is moving as well. However, other sources of delays like those resulting from traffic congestion (e.g. traffic congestion results to lower speeds but does not necessarily add to delay time as the vehicle is still mobile) are harder to extract. It is, therefore, recommended to conduct studies on developing methods to account for delays aside from dwell times.

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