Impact of A Bus Rapid Transit System Along Expressways in Metro Manila

Alexis M. FILLONE
Associate Professor
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: alexis.fillone@dlsu.edu.ph

Chino Antonio Q. QUE
Undergraduate Student
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: chinoque4@yahoo.com.ph

Lorenzo Leon G. RABAT
Undergraduate Student
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: chinoque4@yahoo.com.ph

Caila Jean C. MARCIAL
Undergraduate Student
Civil Engineering Department
De La Salle University
2401 Taft Avenue, Manila
E-mail: cailamarcial@yahoo.com

Abstract: This study aims to analyze the impact of introducing a bus rapid transit along expressways linking Metro Manila to the different provinces along the North and South Luzon Expressways. Currently, provincial buses are the only mode of public transport on the expressways. These buses have terminals located within Metro Manila and are one of the factors contributing to congestion. Introducing other modes of transport such as high capacity vehicles which follow specific routes, with designated stop points and make use of a prioritized lane will help improve the current situation. The primary objective of this study was to assess the impact that the proposed BRT had in terms of traffic congestion, passenger travel time, mobility, ridership potential and pollution. The study made use of volume count and on board surveys to obtain data that were used as primary input in the transit modeling process to analyze the impact of the BRT system in the whole Metro Manila road network. The proposed design of the BRT system was then presented and was proven to have a positive impact in terms of traffic congestion, passenger travel time, mobility, ridership potential and pollution in Metro Manila.

Key Words: Bus Rapid Transit, Co-benefit analysis, Transport emissions

1. INTRODUCTION

1.1 Present Network of Metro Manila

Epefanio delos Santos Avenue, or EDSA, is one of Metro Manila's main roads prone to traffic congestion. This is due to high traffic demand in Metro Manila. Due to the fact that EDSA is prone to traffic congestions, other motorists tend to go in a different route resulting to congestion in other streets in Metro Manila leading to lower mobility of the entire metropolitan area. Buses along EDSA are prone to stopping due to boarding and alighting of passengers. Because of this, the speed of EDSA is interrupted. According to MMDA, provincial bus count is higher than city bus count plying along EDSA. Provincial buses ply along EDSA because this highway connects the two expressways to most provinces of Luzon namely North and South Luzon Expressways (NLEX and SLEX). The

NLEX extends from the Balintawak Toll Plaza to Dau Interchange which is about 84 kilometers in total due north from the north boundary of Metro Manila. It is managed by the Manila North Tollways Corporation (MNTC) via toll gates. It is classified as a primary road and it is exclusively for private vehicles, jeeps, vans, trucks, buses, and motorcycles with at least 400cc motors. The same applies with the SLEX, which stretches from the Buendia Flyover to Batangas Exit and is about 60 kilometers in length due south at the south boundary of Metro Manila. These are shown in Figure 1. Provincial buses are transit lines that travel from the city terminals to their designated provinces by means of buses having a capacity of 45-49 passengers following specific routes depending on their destinations and are mixed with traffic. Usually they do not let passengers in when the bus is already at full capacity. This occurs on routes before travelling the expressway. They usually follow a schedule in their terminals which usually determine their headway but when the bus is at full capacity before their scheduled departure, the bus departs the terminal and the next available bus is set to board the next passengers. These instances usually occur during the peak hour. Some terminals are managed by a specific bus company but there are certain terminals that are used generally by different bus companies such as the bus terminal in Angeles City. These companies control the terminals' fares, headways or schedules, and bus counts. Some terminals have 24-hr services but a number of them do not travel before dawn. A number of them use the North and South Luzon Expressway to reduce travel time from one terminal to another in northern and southern provinces.

Figure 1. Maps Of The BRT System
(From Left To Right: NLEX, Metro Manila, SLEX-Star Tollway)

Table 1. BRT Stations from Mabalacat to Batangas City

Station Number	Station Name	Station Number	Station Name
1	Mabalacat	8	Tabang Exit
2	Dau Exit	9	Bocaue Exit
3	Angeles City Exit	10	Marilao Exit
4	Mexico City Exit	11	Meycauyan Exit
5	San Fernando Exit	12	Mindanao Ave
6	San Simon Exit	13	Balintawak
7	Sta. Rita Exit	14	Quezon Avenue
8	Tabang Exit	15	E. Rodriguez Sr. Avenue
Station Number	**Station Name**	**Station Number**	**Station Name**
16	Quirino	26	Carmona
17	Buendia	27	Greenfield City
18	Epefanio Delos Santos Avenue	28	Santa Rosa
19	Nichols Bridge	29	Malitlit
20	Bicutan	30	Canlubang
21	Sucat	31	Calamba
22	Alabang	32	Tanauan
23	Susanna Heights	33	Malvar
24	San Pedro	34	Lipa City
25	Southwoods	35	Batangas City

This study analyzed the impact on urban mobility of Metro Manila by proposing a Bus Rapid Transit (BRT) along the route of the NLEX, SLEX, and above the PNR route. The proposed BRT system is a series of buses that observe an optimized headway, stop at designated stations, follow a well-planned route and make use of a prioritized lane. The BRT system is mixed with traffic and stops are determined according to ridership potential of the locations.

1.2 Objective of the Study

The primary goal of the study is to assess the impact and effectiveness of a proposed BRT system along the expressways in Metro Manila, namely the North Luzon Expressway and South Luzon Expressway. The specific objectives of the study are as follows:

- Determine the impact of the proposed BRT system along the expressways on traffic congestion in Metro Manila.
- Assess the improvement the proposed BRT system has on passenger travel time, mobility, ridership potential, and effect in the environment in Metro Manila.

2. FRAMEWORKS

2.1 Theoretical Framework

- Trip Generation – It is the initial step which determines the amount of travel activity that the socio-economic data would generate. It is a model of the number of trips that originate and end in each zone for a given jurisdiction.
- Trip Distribution – It is the second step of the modelling process which links and disperses the generated travel by identifying the origin and destination pairs. It is a model of the number of trips that occur between each origin zone and each destination zone.
- Traffic Assignment – It involves conveying traffic to a transportation network such as roads and streets or a transit network. Traffic is assigned to available transit or roadways routes using a mathematical algorithm that determines the amount of traffic as a function of time, volume, capacity, or impedance factor.
- Estimation of Transport Co-Benefits

Under Estimation of Transport Co-Benefits, time savings is the relationship between the travel time and the value of time.

$$BT = BT_O - BT_w \quad (1)$$

$$BT_i = \sum_j \sum_l \left(Q_{ijl} \; x \; T_{ijl} \; x \; \propto_j\right) x \; 365 \quad (2)$$

where :BT :benefit of travel time saving
BTi :total travel time cost with/without project,
Qijl :the traffic volume for j vehicle type on link l, with/without project
Tijl :the average travel time for j vehicle type on link l, with/without project,
αj :value of time for j vehicle type measured as monetary unit/minute*vehicle,
j :the vehicle type,
l :the link,
i : i = w with project, i = O without project.

Also included in the Estimaton of Transport Co-benefits, Vehicle Operating Costs Savings is the measure of how much a person can save depending on the use of the vehicle.

$$BR = BR_O - BR_w \quad (3)$$

$$BR_i = \sum_j \sum_l \left(Q_{ijl} \; x \; L_l \; x \; \beta_j\right) x \; 365 \quad (4)$$

where BR :benefit of vehicle operating cost reduction,
BRi :total vehicle operating cost with/without project,
Ll :link length of link,
βj :value of vehicle operating cost for j vehicle type measured as monetary unit/minute*vehicle.

The last part of the Estimation of Transport Co-benefit is the Environmental Benefits. This study considers that the emission of carbon dioxide will be lessened. According to the

Computer Program to Calculate Emissions from Road Transport or COPERT II, the emission factors were considered.

$$E = k + aV + bV^2 + cV^3 \quad (5)$$

where: E :emission rate per vehicle (g/km)
V :vehicle speed (km/hr)
a, b, c and k :the coefficients.

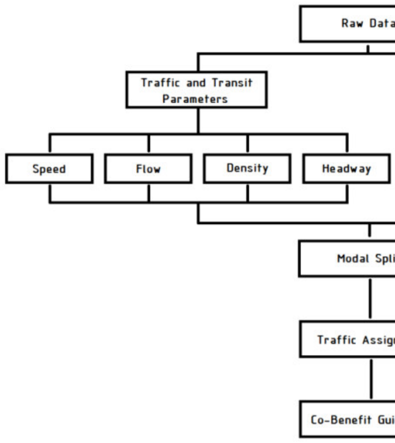


Figure 2. Theoretical Framework Of The Study

2.2 Conceptual Framework

Trip generation is a very essential concept in our study since trip generation increases passenger trip demand in an area. These sets of trips on a microscopic level have different data when it comes to origin, destination, route, and modes of transportation. The analysis then involves the two design years. For each design year, it is viewed in the three conditions under 'Mode of Transport' seen in Figure 2. The routes set by these different conditions from the origins to the respective destinations are then analyzed in terms of travel time and travel distance.

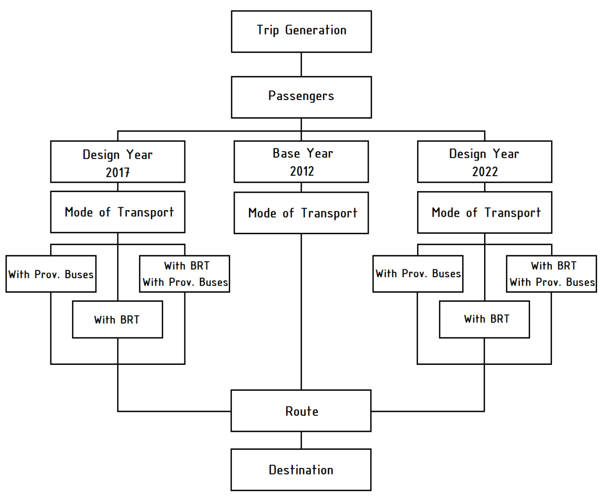


Figure 3. The Conceptual Framework of the Study

3. METHODOLOGY

3.1 Design Parameters

The volume of buses, private vehicles, and trucks were obtained by doing a volume count survey. The volume of passengers that embark and disembark at the given stop points from aircon public buses were also obtained by performing a passenger count survey.

The capacity of the buses will also be determined. The travel time per segment for southbound and northbound buses along the whole stretch of NLEX and SLEX will be obtained by doing an on-board travel time survey.

The travel time for private vehicles and trucks were obtained by measuring the speed through the use of CCTV cameras along the NLEX and SLEX. The estimated travel time of the proposed BRT system along the expressways will be obtained using the EMME4 software for the design years 2017 and 2022.
The estimated volume of passengers that use public buses along the NLEX and SLEX were obtained using the growth factor analysis of the recent HSH (2009) study data for the design years 2017 and 2022.

3.2 Methods Used

- Volume Count Survey – The manual method in traffic volume was utilized by means of CCTV cameras. Vehicles are counted using a video taken from peak hours to represent the data needed. The counting procedure includes classification of vehicles according to their type which are private vehicles (cars), jeeps, buses, taxi, and container vans. Volume Delay functions were utilized by analyzing volume data and traffic flow in the video.
- On Board Survey – An onboard survey of aircon public buses traversing along the NLEX and SLEX were performed. The purpose of the survey is to obtain the volume of passengers that embark and disembark at given exits or segments along the expressways. The travel time per segment was also obtained. The onboard survey along the NLEX were conducted from the Balintawak Toll Plaza to Dau Interchange as well as from Alabang to Santo Tomas Exit.
- EMME4 – The EMME4 software was used to analyze the impact of the proposed BRT system with the whole Metro Manila traffic network. The software gives an idea of the future scenario of the NLEX and SLEX in terms of the volume of vehicles, the volume of passengers and the travel times per segment. The summary of procedures is shown in Figure 3.

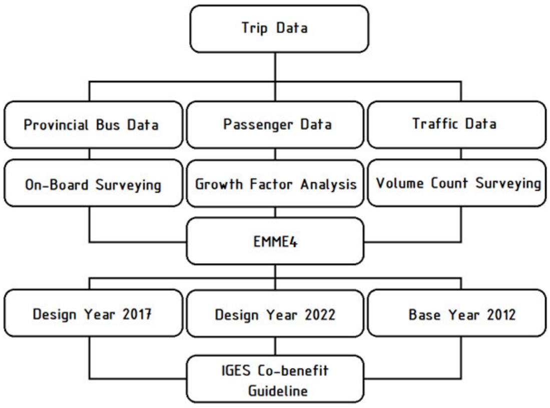


Figure 4. Summary of the study's procedures

4. DATA ANALYSIS

Data from the present conditions were collected from various methods included in the study. These data represented the base year of this study. With this base year, the researchers were able to assess the impact of BRT system for the design years. The conditions of the design years were calculated from the base year by means of the EMME4 software.

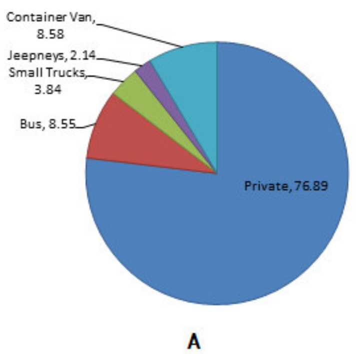
For the base year, the network of Metro Manila and the provinces adjacent to both SLEX and NLEX were plotted using the EMME4 software. The provinces were not fully plotted but its main roads are plotted and are linked to the provinces' respective zones.

Modes of transportation in Metro Manila include jeeps, ordinary and air-conditioned buses, taxi, FX taxi, LRT, LRT2, MRT3, PNR, and water ferry. These vehicles created activity on the nodes in Metro Manila. The activity is represented by the radius of the circles in Figure 5 below. The orange part of the circle represents the alighting passengers and the blue part of the circle represents the boarding passengers.

Figure 5. Node Activities in Metro Manila

A volume count survey was conducted on both expressways via video stream which was provided to the researchers by Manila North Tollways Corporation (MNTC) along the busiest segment of NLEX which was along the Bocaue Segment. The video recording of SLEX was conducted along Malitlit Exit. All videos were at normal weather conditions.

In this study, the time interval for North Luzon Expressway is from 8 am to 10 am which is considered as peak hours of travel. There are two paths considered. These are the northbound and the southbound. Figures 6 and 7 below show the actual percentage of the peak hour vehicle volume in NLEX. During the peak hours, majority of the vehicles that passes thru are private vehicles which are 76.89% of the study and minority are the jeepneys. Buses are at 8.54% of the study. At Bocaue Interchange southbound, 72.09% of the study are private vehicles while the buses are at 10.36%. Between the time boundaries given, different volumes of cars pass thru. In the study of the southbound and northbound of NLEX, the data showed that there are gradual rise and fall of total vehicles per specific time frame. The data showed that the peak total volume of vehicles rose at 9:45 am and 9:15 am for northbound and southbound respectively.



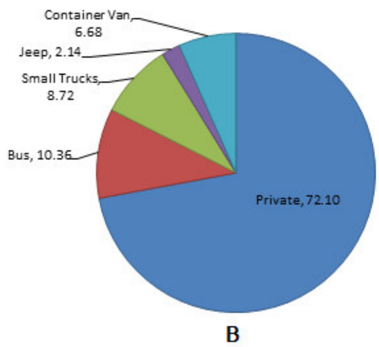


Figure 5 and 6. Percentage of the Peak Hour Volume
(A for NLEX Northbound, B for NLEX Southbound)

For the case of South Luzon Expressway, the time interval used is from 3 pm to 4 pm as it is the peak hour of travel. Northbound and southbound paths are also considered. Similarly to the results of the study in North Luzon Expressway, the majority of vehicles passing thru are the private cars as can be seen in Figures 7 and 8. On one hand, the northbound gave a result of 76.92% private vehicles and 7.74% of buses. On the other hand, the SLEX southbound gave a result of 72.81% for the private vehicles and 7.29% of the study are the buses. The peak total vehicle volumes for northbound and southbound rose at 3:30 pm and 3:15pm respectively.

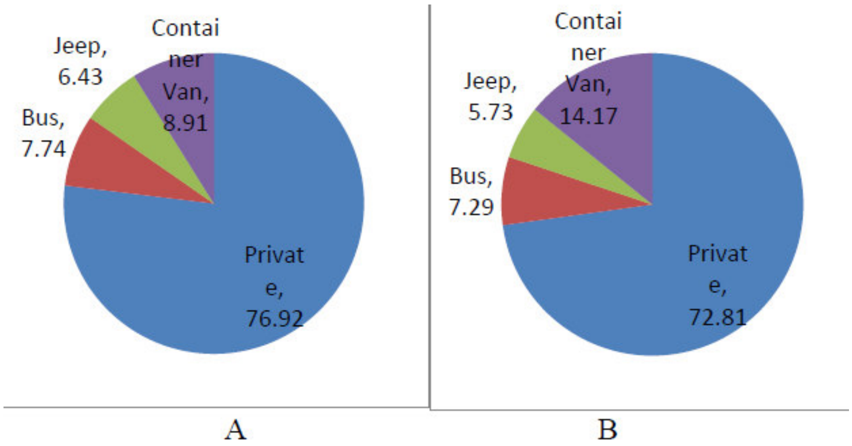


Figure 7 and 8. Percentage of the Peak Hour Volume for SLEX
(A for Northbound, B for Southbound)

4.1.2 On-Board Analysis

The researchers obtained on-board samples from air conditioned provincial buses that followed designated routes traversing along the North and South Luzon Expressways to and from Metro Manila. This was done in order to identify each provincial bus routes characteristics such as travel time, travel speed, bus capacity and the embarking or disembarking of passengers at specific landmarks. The on-board samples were conducted from terminal to terminal depending on the bus routes and the provinces they were going to or coming from. The researchers obtained 12 on-board samples from provincial buses passing through the NLEX and 20 on-board samples from provincial buses passing through SLEX.

It was observed that most passenger activity occurs at the end terminals and the vicinity around it. The inactivity of middle segments is due to the expressway route since buses are not allowed to board or alight along the expressway. Similar behavior is seen from the other routes of the other samples of on-board data the researchers obtained.

4.1.3 Growth Factor Analysis

The growth factor used in the projection of future OD person trips were from the MMUTIS (1996) and HSH (2009)

Table 2. Growth Factor (MMUTIS, 1996, HSH, 2009)

Year	1996	2010	2015
MMUTIS	1	1.62	1.84
Year	2009-2020	2021-2030	
HSH	2.5	1.5	

4.2 Design Years

4.2.1 EMME4 Networking Process

The proposed BRT system will be along the NLEX, SLEX and the proposed NLEX-SLEX expressway connection along the PNR line. The BRT system was laid on the assumed route of the connecting bridge which was along the PNR line. The stops of the BRT only include all exits of NLEX and SLEX. There are seven stops within Metro Manila in between Balintawak and Alabang namely Quezon Avenue, E. Rodriguez Sr. Avenue, Quirino Avenue, Buendia Avenue, EDSA, Nichols Bridge and Sucat. With this route, the BRT system has an approximate total trip length of 185 km. The capacity of one bus is 100 passengers (200 passengers including standing) and has an average speed of 25 km/hr. Headways between each bus is 5 minutes. The outer lanes are prioritized to the BRT system and for each stop, there will be an exclusive road for the BRT system going to safer vicinity to unload and load passengers from the BRT wherein the stations are also located.

Provincial bus routes originating in Metro Manila were excluded in the network and the provincial bus routes originating in their respective provinces will still exist but the route along the NLEX or SLEX part onwards will be terminated. With this future network, the provincial buses will serve as feeders to the BRT system. With other modes of transportation in Metro Manila still untouched, these will also serve as feeders to the BRT system especially the LRT, MRT, and city buses. The LRT system will feed the northern areas and the MRT system will feed both the northern and southern areas with reference to Metro Manila. This way, the only difference of the design year network from the actual network is that the provincial buses that use the NLEX and SLEX route that have the destinations within our study area do not exist in Metro Manila.

4.2.2 EMME4 Calibration Process

Using the videos acquired from our data gathering, we have calculated the parameters for the volume delay function (VDF) of a segment in NLEX and SLEX. Due to time onstraint and lack of resources, these videos have represented the entire stretches of both expressways.

Table 3. VDF Equations

fd1	(length/(40/60))*(1+22.2*(((volau+volad)/lanes)/1600)^1.886)
fd6	(length/(80/60))*(1+22.2 * (((volau + volad) / lanes) /1800) ^2.804)
fd8	(0.5 / 4.5) * 60
fd9	(1 / 4.5) * 60
fd10	(length/(80/60))*(1+22.2*(((volau+volad)/lanes)/1950)^1.886)

Table 4 shows the complete VDF equations using the BPR model, which were used in the EMME4 software. FD1 was used on streets and highways. FD6 was used on the two expressways, the NLEX and SLEX. FD8 was used for the passenger links for BRT while FD9 was used for passenger links on zone centroids. FD10 was used on the proposed highway connecting SLEX and NLEX. The graph of volume delay functions is shown below.

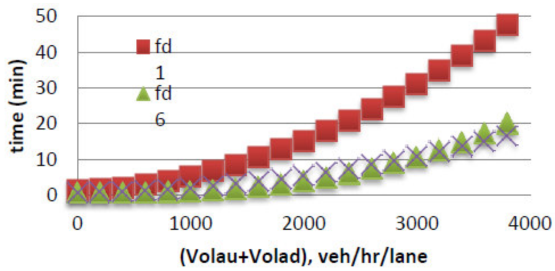


Figure 9. Volume delay functions used in the study

The network was calibrated using some of the on-board data obtained from the provincial buses within the study area. The objective of the calibration process was to obtain the same maximum volume in each route in the EMME4. So far, this was the best calibration of all the routes included in the process. With this calibration, we have set the network of South Luzon to its present state of transportation demand in the transit area of the study.

Table 4. EMME4 Data Calibration using Provincial Bus On-Board Data

Route	Max On Board	Bus Count	Max On-board/Day	EMME Volume/Day	Percent Difference
Buendia - Batangas	28	48	1344	1018	27.60%
Batangas - Buendia	39	49	1911	1826	4.55%
Buendia - Sta Cruz	40	70	2800	2242	22.13%
Sta Cruz - Buendia	24	67	160	1793	10.88%
Buendia - Binan	47	85	3995	3651	9.00%
Buendia - Sta Rosa	44	85	3740	3380	10.11%

Another transit was used in the calibration process. The transit was MRT3. Recent data of the MRT3 was obtained and was used to calibrate the transit demand in Metro Manila to its present state.

Table 5. EMME4 Data Calibration using MRT3 On-Board Data

Transit	Segment	Actual Volume	EMME4 Calibrated Volume	Percent Difference
MRT3	Taft Avenue	28653	24191	16.89%

The OD Matrix was obtained from other similar (Baron et.al., 2011, Fillone et. al., 2005) studies and was used in the EMME4 network.

Table 6 displays the characteristics of the entire network of Metro Manila. In assessing the mobility of Metro Manila, the average speeds, VDT's, average times, and VHT's of all scenarios in the design year were compared to the scenario of the design year without the BRT system. According to the EMME4 results, the BRT system had a positive impact on the network of Metro Manila in terms of mobility since there were reductions in the overall vehicle-distance traveled (VDT) and vehicle-hours traveled (VHT) and an increase in average speed of Metro Manila.

Table 6. Metro Manila Traffic Characteristics Results and Analysis from EMME4

Year	Scenario	Average Speed	Veh-km (VDT)	Veh-hr (VHT)	% Diff (speed)	% Diff (VDT)	% Diff (VHT)
2012	Without BRT with Provincial Buses	23.62	4192195	379169	-	-	-
2017	Without BRT with Provincial Buses	21.64	4695863	584933	-	-	-
	With BRT with Provincial Buses	22.43	4444791	513060	3.59	5.49	13.09
	With BRT without Provincial Buses	22.48	4442221	510643	3.81	5.55	13.56
2022	Without BRT with Provincial Buses	20.20	5245275	765251	-	-	-
	With BRT with Provincial Buses	20.98	4965487	669190	3.79	5.48	13.39
	With BRT without Provincial Buses	21.03	4961225	666185	4.03	5.57	13.84

To calculate the time cost per year, value of time from MMUEN data was used. Assuming a linear trend in growth rate, the value of time for year 2012, 2017 and 2022 for both private and public modes were obtained. The values are displayed in Philippine Peso per minute.

Table 7. Value of Time (MMUEN)

	Year					
	2009	2012	2017	2020	2022	2030
Private Mode (Php/min)	5.52	6.59	8.38	9.45	10.64	15.39
Public Mode (Php/min)	7.77	9.27	11.78	13.28	14.95	21.64

To calculate the operating cost per year, the unit cost from the MMUTIS (1996) data of public and private transports was used.

Table 8. Operating Cost (MMUTIS 1996)

Speed (km/hr)	Public			Private		
	Php/km	Php/hr	Php/min	Php/km	Php/hr	Php/min
0	4.76	25.35	0.42	3.27	16.98	0.28
10	4.20	40.25	0.67	2.85	23.68	0.39
Speed (km/hr)	Public	Private	0.80	2.64	27.08	0.45
	Php/km	Php/hr	Php/min	Php/km	Php/hr	Php/min
40	3.63	52.13	0.87	2.38	25.93	0.43
50	3.67	52.78	0.88	2.34	24.70	0.41
60	3.84	53.16	0.89	2.35	23.90	0.40
70	4.10	53.61	0.89	2.42	22.39	0.37
80	4.56	54.50	0.91	2.56	21.43	0.36
90	5.34	56.33	0.94	2.81	21.66	0.36

To calculate CO, NOx and SPM emissions, the following constants obtained from the MMUTIS (1998) data were used. For private vehicles, the gasoline emission constant was used while for public vehicles, the diesel emission constant was used.

Table 9. CO2 Constants (MMUTIS 1996)

		<10 kph	10kph-20kph	>20 kph
Gasoline	Private	27.57	23.5	18.7
Diesel	Public	8.02	6.8	6.2
Unit	g/km	g/km	g/km	

Table 10.NOx Constants (MMUTIS 1996)

		<10 kph	10kph- 20kph	>20 kph
Gasoline	Private	2.75	2.76	2.78
Diesel	Public	8.95	7.66	7.01
Unit	g/km	g/km	g/km	

Table 11. SPM Constants (MMUTIS 1996)

		<10 kph	10kph- 20kph	>20 kph
Gasoline	Private	0.07	0.05	0.05
Diesel	Public	1.8	0.9	0.81
Unit	g/km	g/km	g/km	

The summary of time and operating costs for the different design years are shown in Table 11-13 below.
*WBRT NPB – With BRT and no provincial buses
*WBRT WPB – With BRT and with provincial buses
*NBRT WPB – No BRT and with provincial buses

Table 11. Time and Operating Costs for Base Year (2012)

	Base Year 2012
Time Cost (Php/year)	65,593,334,383
Operating Cost (Php/year)	660,803,868

Table 12. Time and Operating Costs for Design Year (2017)

	WBRT NPB 2017	WBRT WPB 2017	NBRT WPB 2017
Time Cost (Php/year)	82,143,191,739	82,913,026,085	82,981,551,511
Operating Cost (Php/year)	666,941,358	685,129,286	667,177,782

Table 13. Time and Operating Costs for Design Year (2022)

	WBRT NPB 2022	WBRT WPB 2022	NBRT WPB 2022
Time Cost (Php/year)	4,436,136,058,864	4,450,144,909,168	4,453,591,766,085
Operating Cost (Php/year)	1,914,043,302	1,919,567,241	1,919,285,808

The summary of CO, NOx and SPM emissions for the different design years are shown in Tables 14-20 below. Depending on vehicle speed, the emission constants were multiplied by the number of vehicles per day and their corresponding trip length.

Table 14. Emissions for Base Year

Base Year (2012)			
	CO2	NOx	SPM
Private (g/day)	98,009,671	11,324,830	235,616
Public (g/day)	1,505,426	1,691,020	254,381
Total	99,515,097	13,015,850	489,997

Table 15. Emissions for Design Year 2017 (WBRT NPB)

WBRT NPB (2017)			
	CO2	NOx	SPM
Private (g/day)	97,878,082	11,318,452	235,209
Public (g/day)	1,356,532	1,523,425	230,768
Total	99,234,614	12,841,878	465,977

Table 16. Emissions for Design Year 2017 (WBRT WPB)

WBRT WPB (2017)			
	CO2	NOx	SPM
Private (g/day)	100,060,642	11,575,376	240,246
Public (g/day)	1,510,734	1,696,689	257,017
Total	101,571,376	13,272,065	497,263

Table 17. Emissions for Design Year 2017 (NBRT WPB)

NBRT WPB (2017)			
	CO2	NOx	SPM
Private (g/day)	98,041,127	11,327,931	235,678
Public (g/day)	1,506,110	1,691,751	254,715
Total	99,547,237	13,019,682	490,393

Table 18. Emissions for Design Year 2022 (WBRT NPB)

WBRT NPB (2022)			
	CO2	NOx	SPM
Private (g/day)	471,764,739	47,618,296	1,194,452
Public (g/day)	1,500,622	1,676,280	325,803
Total	473,265,361	49,294,576	1,520,255

Table 19. Emissions for Design Year 2022 (WBRT WPB)

WBRT WPB (2022)			
	CO2	NOx	SPM
Private (g/day)	472,212,933	47,639,040	1,196,412
Public (g/day)	1,668,192	1,863,752	360,231
Total	473,881,125	49,502,792	1,556,643

Table 20. Emissions for Design Year 2017 (NBRT WPB)

NBRT WPB (2022)			
	CO2	NOx	SPM
Private (g/day)	472,166,336	47,630,609	1,196,425
Public (g/day)	1,668,319	1,863,888	360,293
Total	473,834,655	49,494,497	1,556,719

The summary of savings from time and operating cost for the different design years with and without project are shown in Table 21 below.

Table 21. Savings from Time and Operating Costs

	WBRT WPB (2017)	WBRT NPB (2017)	WBRT WPB (2022)	WBRT NPB (2022)
Time Cost (Php/year)	68,525,426	838,359,772	3,446,856,917	17,455,707,221
Operating cost (Php/year)	-17,951,504	236,424	-281,433	5,242,506

The percent differences in terms of emission savings for the different design years with and without project are shown below.

5. CONCLUSION

With the use of the whole network of Metro Manila, North Luzon Expressway and South Luzon Expressway in the EMME4 software, the researchers were able to generate the demand of Metro Manila and the said expressways. The researchers assessed the impact of the BRT system for the base year (2012) and two design years (2017 and 2022) by simulating using EMME4. Three scenarios were taken into account for the design years. We have gathered enough data to conclude that the BRT system has improved Metro Manila in terms of Vehicle-Hours Traveled (VHT) and Vehicle-Distance Traveled (VDT) for each scenario as shown in Table 6. For the impact using the transport co-benefit analysis, there is a significant difference in terms of time cost, operation cost and emission savings if the proposed BRT is present on the expressways for the years 2017 and 2022. From the results, it can be concluded that time and operation savings increase each year. They have a directly proportional relationship. It can also be concluded that in terms of operation and time savings, the BRT is more efficient when there are no provincial buses traversing along Metro Manila and the expressways. Overall, the most productive design in terms of total savings is when the BRT is present on the expressways without provincial buses.

6. RECOMMENDATIONS

For the BRT system to become more effective and efficient, provincial buses should be restricted and should only exist along the city limits. The BRT system will serve as feeders along the expressways once the provincial buses were restricted to travel along the expressway and the central areas of Metro Manila. In the metropolitan area, the BRT will be the trunk and the other forms of transportation (such as MRT, LRT, and city buses) will serve as feeders to the BRT system. With these recommendations, there will be a higher improvement on the network of Metro Manila in terms of mobility and environmental impact.

There should also be an extensive research in inter-city travel in Luzon to have a more accurate simulation in the EMME4 and our analysis. Zonings from different provinces may also yield to accurate results in expressway flows and passenger volume in the simulated BRT system.

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