Road Capacity Imbalance at Exit Points of the Metro Manila Skyway and Adjoining Roads

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Abstract: Local roads have gradually been subjected to a great demand in vehicular transport in the past years as demand continues to increase while the road capacities stay the same. Some expressways contribute to the congestion in the local roads that are connected to its exit ramps. Local roads are unable to carry the high vehicular volume coming from the expressways. Because of this, some exit points of the expressways experience bottlenecks due to a high demand of vehicles exiting the expressway. Analysis of the exit points in the Metro Manila Skyway is needed to assess their current condition and to provide possible solutions to improve its worsening congestions. This study models the road traffic network to simulate the actual condition happening in the skyway. Mesoscopic modeling is used in analyzing the traffic flow and is used in formulating solutions to the congestion in the egress points of the skyway.

Keywords: Transportation, Expressway, Mesoscopic Modeling, Dynamic Traffic Assignment, Exit Ramps, Local Roads

1. INTRODUCTION

The traffic congestion in the Metro Manila has been getting worse in the past few years. According to Numbeo (2018), a database of variables that display the world living conditions around the world, a traffic index is a composite index of the time consumed in traffic due to inefficiencies in a traffic system. In Table 1.1, it is displayed that Manila has been given a traffic index of 268.49; placing the city at the fifth spot in the world traffic index list.

Table 1.1 Numbeo World Traffic Index Ranking

Rank	City	Traffic Index
1	Kolkata, India	320.16
2	Delhi, India	277.29
3	Mumbai, India	276.07
4	Pretoria, South Africa	268.92
5	Manila, Philippines	268.49
6	Jakarta, Indonesia	260.88
7	Tehran, Iran	258.6
8	Istanbul, Turkey	258.41
9	Colombo, Sri Lanka	257.93
10	Mexico City, Mexico	256.54

The fast-paced growth of the vehicular demand in the Philippines is one of the contributors to this phenomenon. Mercurio (2015) stated that based from the reports of the Chamber of Automotive Manufacturers of the Philippines Inc. (CAMPI) and the Truck Manufacturers Association, vehicle sales increased by 23% with 234 747 units sold. With this amount of increase in vehicle sales occurring annually, the traffic congestion in the Philippines will more likely continue to grow as time progresses. In Figure 1.1, the traffic indices of the countries worldwide are depicted through a color-coding scheme created by Numbeo, marking the countries with a high traffic index as red. Compared to the other cities in the Philippines, the congestion in Manila is significantly higher than the rest.

Figure 1.1 Numbeo World Traffic Index (Numbeo, 2018)

Expressways have been constructed to promote fast transportation among the vehicles. According to Ray (2008), an expressway allows vehicles to traverse in greater speed, greater safety, and provide convenience to the vehicle drivers while incurring lower vehicle operating costs. Although these characteristics were in the minds of the proponents of the expressways, the current circumstance defeats this idea. Studies have shown that congestions in expressways and in their off ramps have already been occurring. According to Peng, Wang & Liu's research work in 2012, Chengdu Expressway was evaluated with respect to its level of congestion and was found to have moderate congestion. The Department of Transportation in Arizona (2018) has created some criteria in evaluating the level of service of road networks. They define level of service as a qualitative measurement that characterizes road networks in terms of travel time, speed, delay, and other important factors. They have created a level of service criteria that can be used to evaluate the level of congestion in road networks. They have attributed the letters A through F for six different classifications of delay in seconds. A is for 0-10, B is for 10-20, C is for 20-35, D is for 35-55, E is for 55-80, F is for 80 or greater.

The Metro Manila Skyway is one of the longest expressways in the National Capital Region. It caters to a large volume of vehicles as it currently has two accomplished stages. Stage one connects Buendia to Bicutan while stage two connects Bicutan to Alabang South Station. Currently, the Skyway stage 3 is under construction and will connect the North and the South Luzon Expressway. The Metro Manila Skyway presently spans a length of 31.2 kilometers.

Figure 1.2 Metro Manila Skyway Road Map (Skyway O&M Corporation, 2018)

One of the busiest parts of the Metro Manila Skyway is the Makati Skyway. Makati is well known for being a host to numerous industries, such as 80 hotels, 40 shopping centers, and 4000 bars and restaurants (Why Invest in Makati, 2013). In addition to this, 46 embassies and 40 consulates also flock the city of Makati. Given the number of establishments within the city, it is inevitable for numerous vehicles to fill the streets within the city and roads entering the district such as the Metro Manila Skyway.

Since the local roads within and nearby the city of Makati are mostly the first ones subjected to congestions by vehicles located near the city, most vehicles from farther cities utilize the Makati Skyway to get into the city. With the Makati Skyway having several exit points connected to several parts in the city, people utilize this expressway to get to their destination by driving through the said exits to avoid the traffic congestion in the local roads. By accommodating a large amount of vehicular demand coming from different cities, the Makati Skyway exit points leading to the local roads tend to get congested. This is due to the fact that the capacities of the local roads are unable to absorb the demand from the said expressway. In addition to this, the Makati Skyway also experiences the congestions on its off ramps as the queuing of the bottlenecks has already reached the skyway.

Figure 1.3 Congestion in Makati Skyway Buendia Exit

Figure 1.4 Congestion in Makati Skyway

1.1 Objectives of the Study

This study intended to investigate the condition and the causes of the congestion between exit ramps of the Metro Manila Skyway and the local roads receiving the exiting vehicles from the skyway.

The following were the specific objectives:

I. To characterize the traffic conditions at the exit ramps and the local roads in the study area.

II. To identify and quantify the causes of congestion along the exit ramps of the Metro Manila Skyway

III. To recommend alternative solutions to remedy these congestion problems through mesoscopic simulation modeling of the study area and its vicinity

1.2 Scope, Limitations, and Delimitations

The study focused on the congestion occurring on the Makati exit ramps of the Metro Manila Skyway brought by an imbalance in road capacities. Through the utilization of the Dynameq software as a tool in determining the actual conditions on the Makati Skyway and in simulating the traffic assignments with respect to the available exit points, different causes of congestions along the exit ramps were identified. The traffic simulation produced by the said software were analyzed and were evaluated to use the findings in alleviating the congestion problems of exit points with high demand. The study only dealt with the vehicle volumes exiting from the skyway to the adjacent local roads.

The Makati exit ramps of the Metro Manila Skyway served as the investigatory zone of the study. It covers the congested exit ramps from Buendia to Magallanes. The entry points of the Makati Skyway were included in the model for additional analysis but the study remained focused on the egress points as the exit points of the skyway tend to be more congested. The initial adjacent adjoining roads after the exit points were also considered in the analysis.

The study did not include the analysis of any possible congestion happening along the whole stretch of the Metro Manila Skyway. It did not discuss uncontrollable variables such as drivers' driving psychology. The study did not use other dynamic traffic assignment tools such as DYNASMART-P, DynusT, Saturn, and the like.

1.3 Significance of the Study

Traffic congestion is already rampant in several cities of Metro Manila. With the fast and continuous growth of vehicular demand in the country, the current circumstances in transportation infrastructures will only worsen as time passes by if left unattended. Established road capacities will continue being unable to accommodate the rising vehicular volume utilizing the existing roads.

The typical solution to solve the problem of having low-capacity roads is to construct new roads to increase the capacities in the area. However, given the setting in Metro Manila, infrastructures have already occupied most of its land. Unnecessary construction of new roads and infrastructures in areas with crowded spaces are not only financially wasteful but also time consuming. Planning is key in determining whether there are other ways in remedying the congestion that is happening in the area.

As stated before, Makati is already filled with numerous establishments and infrastructures. Subjecting the city to new infrastructure constructions without first simulating scenarios to analyze its existing conditions may aggravate the serious congestion that it is currently facing. By using a mesoscopic modeling software to simulate a dynamic traffic assignment model reflecting the actual conditions of the Makati skyway and the local roads in its vicinity, alternative and feasible solutions can be implemented to eradicate the growing problem in the transportation sector in the city. It can simulate several scenarios to find the optimum solutions to the problems in the individual exits points of the skyway. With this, minimal cost solutions can be utilized to gradually solve the congestion in the City of Makati and in the future, may also include the country as a whole.

2. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1 Conceptual Framework

The study focused on addressing the demand-supply imbalance of the exit ramps in the Makati Skyway. With the presence of high vehicular demand and low road capacities, congestion takes place in the exit ramps of the Makati Skyway. Through mesoscopic simulation modeling by DYNAMEQ, congested exit ramps were determined. Optimum traffic control plans were identified for low capacity roads to accommodate the large demand coming from the skyway. Longer green time for road capacities accommodating greater demand led to more vehicles being able to pass through road segments which balanced out the traffic flow in the corresponding areas.

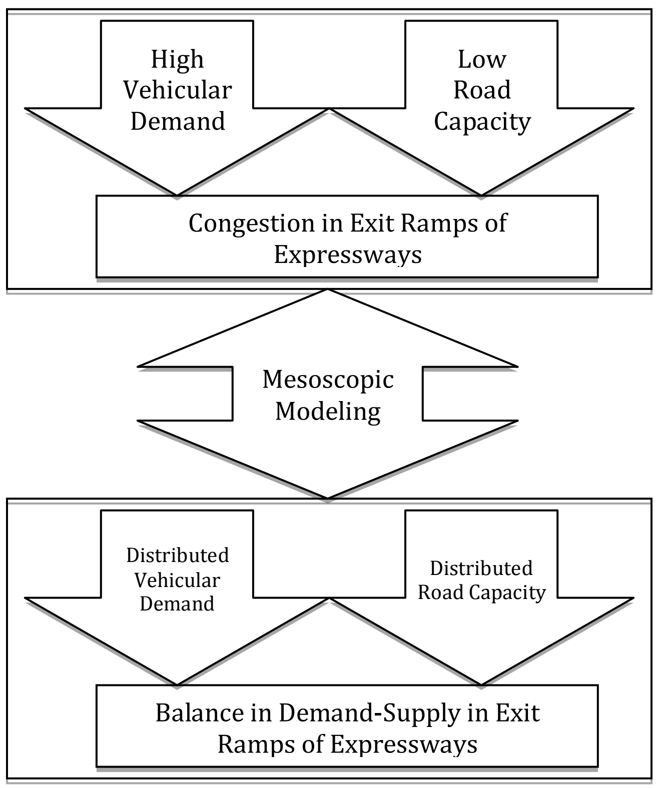


Figure 2.1 Conceptual Framework Chart

2.2 Theoretical Framework

2.2.1 DYNAMEQ

DYNAMEQ is a dynamic traffic assignment software that models the traffic network based on the principle of dynamic user equilibrium (Snelder, 2009). The objective of the program is to shorten the travel time so that vehicles leaving the same origin can arrive roughly at the same time to their destinations. DYNAMEQ incorporates the different factors affecting congestions, namely, traffic signals, conflicting intersection movements, flow capacity, lane changing, and heavy vehicles and incorporates how these congestions are manifested across the lanes of the roads being modeled. It has several applications such as modeling lane management strategies when there are vehicle specific lanes for buses, taxis, and motorcycles. It can also consider prohibited vehicles such as large trucks. It can also determine how a vehicle can be rerouted in case of incidents happening on critical locations.

DYNAMEQ incorporates an iteration method to determine the shortest travel time from the origin to the destination. Each iteration consists of the execution of a path-choice model and the execution of a traffic simulation. The traffic simulation received the path flow rates from the choice model and simulates the traffic patterns on the network. The path-choice model receives the travel time information from the traffic simulation and modifies the path choices for the next iteration. The iteration continues until dynamic user equilibrium is achieved.

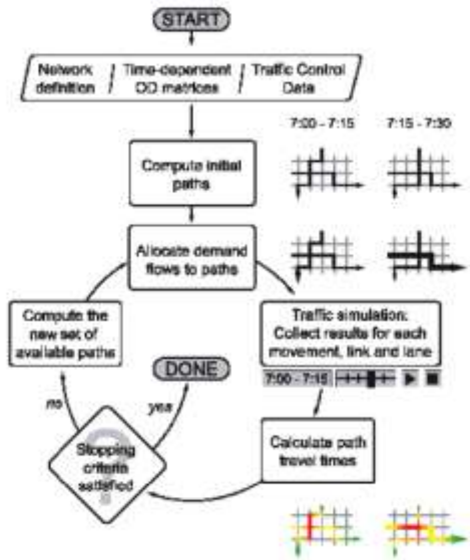


Figure 2.2 DYNAMEQ Flow Chart

3. RESEARCH METHODOLOGY

3.1 Data Acquisition

The data needed for the simulation of the network in this study were acquired though surveying of the volume counts per exit point and the traffic control systems at the adjacent local roads. This set of data was the initial requirement for the modeling software to be able to run the model and simulate the traffic condition in the Makati Skyway.

3.1.1 Volume Count

To identify all the possible problems that may cause the queuing in the exit points of the skyway, the survey period when vehicles have not yet started queuing must be determined. This allows the researcher to see precisely when the queuing will start and which factors have caused it to happen. From 6:00 am to 9:00 am, the appropriate time to count the vehicles exiting the Skyway was found to be during the 7:00 – 8:00 am period. From the period of observation, it was found that the vehicles start queuing at approximately 7:20 am. This period was chosen to investigate the other possible variables that may contribute to the congestion of the vehicles before and immediately after the congestion is in effect.

Before the surveying commenced, each exit point was analyzed to prepare for the number of surveyors required to accommodate all the movement happening in the adjacent intersections directly after the exit ramp. One person was assigned one traffic movement to accurately count all the vehicles entering and exiting the intersections. All entry and exit points of the Makati Skyway were surveyed simultaneously to have consistency in the total vehicle counts per entry and exit point.

There are seven traffic movements affecting the vehicles exiting the Skyway Buendia exit, as summarized in Figure 4.1. One person was stationed at points A (Skyway Buendia Entry movement), B (Skyway Buendia Exit), and C (South Luzon Expressway Exit) each. At Point F, Five people were tasked to survey four traffic movements, namely, South Luzon Expressway to Buendia, Skyway Exit to Buendia, Dela Rosa Street to Buendia, and passing through Dela Rosa Street, while the remaining person took down the traffic signal cycles for the Buendia intersection.

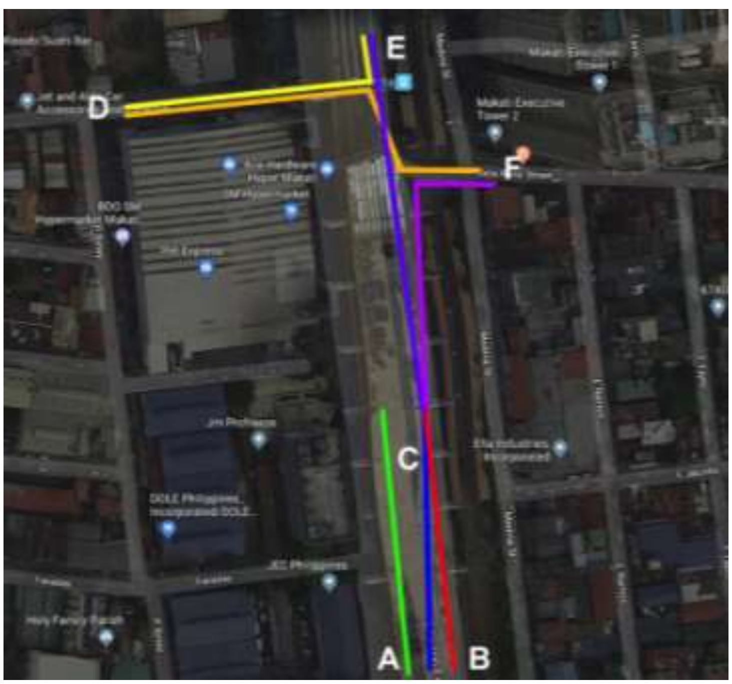


Figure 4.1 Buendia Entry and Exit Points (Google Maps)

There are six traffic movements affecting the vehicles exiting the Skyway Amorsolo exit, as summarized in Figure 4.2. One person was stationed at points A (Skyway Amorsolo Entry movement), and D (Gamboa Street to Amorsolo Street) each. At point B, four people surveyed the four traffic movements, namely, Skyway Amorsolo Exit to Amorsolo Street, Skyway Amorsolo Exit to Gamboa Street, passing through Amorsolo Street, and Amrosolo Street to Gamboa Street.

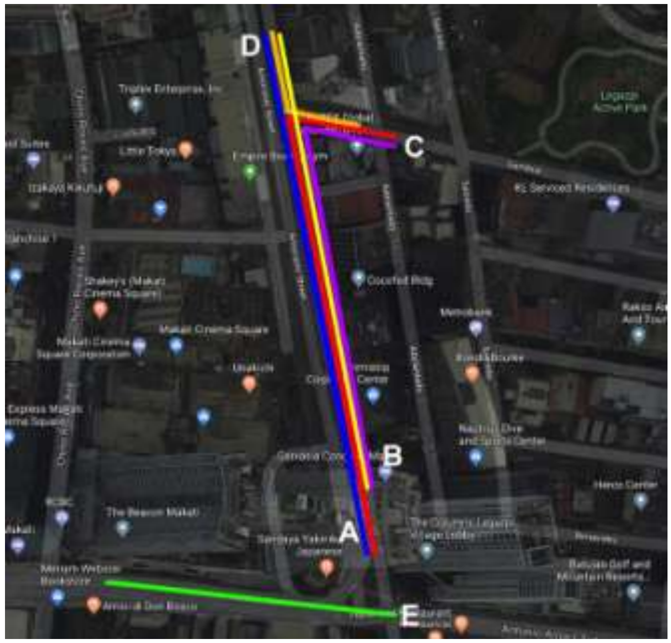


Figure 4.2 Amorsolo Entry and Exit Points (Google Maps)

There are eight traffic movements affecting the vehicles exiting the Skyway the Don Bosco exit, as summarized in Figure 4.3. One person was stationed at points A (Skyway Don Bosco Exit), B (South Luzon Expressway Exit), D (Estacion Street to Don Bosco Street), E (Chino Roces North Bound), and F (Chino Roces South Bound) each. At point C, two people surveyed the two traffic movements, Skyway Don Bosco Exit to South Luzon Expressway, and Passing through South Luzon Expressway.

Figure 4.3 Don Bosco Exit Point (Google Maps)

There are seven traffic movements affecting the vehicles exiting the Skyway the Magallanes exit, as summarized in Figure 4.4. One person was stationed at points A (Skyway Magallanes Exit), B (Skyway Magallanes Entry), C (South Luzon Expressway Exit), and F (Pasay Exit) each. At point D, two people surveyed the two traffic movements, Skyway Magallanes Exit to EDSA Freeway, and passing through South Luzon Expressway.

Figure 4.4 Magallanes Entry and Exit Point (Google Maps)

3.1.2 Plate Surveying

The data collected from volume surveying were found to have missing pieces of information. Since the number of surveyors was limited, the destinations of some exiting vehicles were not determined immediately, such as the vehicles exiting the Don Bosco off ramp and going towards either the north bound or south bound side of Chino Roces Avenue. Because of this, plate surveying was performed to estimate the percentage of vehicles going to the specific destinations. The vehicles that fell into the category of color black were surveyed.

3.1.3 Traffic Control System

The green times and the red times of the traffic signals were recorded. Three cycles of each traffic signal were averaged to get the precise time recording. Traffic signals were present in all the intersections in Amorsolo. However, the intersections in the other exit points, such as Buendia, Don Bosco, and Magallanes are all manned by traffic enforcers with varying green times in each traffic movement. To remedy this, the green times of the traffic enforcers in each intersection were averaged for each intersection to obtain the specific data sets for their traffic control plans without disregarding the actual conditions in each area.

3.2 Network Modeling

The Makati Skyway road network was traced in the DYNAMEQ software. Each road segment of the northbound and southbound side of the skyway from Magallanes to Buendia was modeled. The local roads and intersections adjacent to the exit points of the skyway were also included. The geometry and the number of lanes per road segment were adjusted according to the information in the software's open street maps and actual surveillance in Google maps.

The volume counts of each entry and exit point were placed in the O-D matrix of the software. The traffic signal data from each intersection was input in their respective traffic control plans. When the required data was placed in their respective fields, the model was run. After several iterations, the movement time series of each traffic moment in each intersection were obtained. This was done to compare the simulated volume counts to the actual volume counts conducted in each intersection.

3.3 Network Calibration

The simulated volume counts in the road segments of each intersection with a different traffic movement were compared to the actual volume counts. They were obtained from the movement time series section of the software. The percent difference of each simulated volume count to its actual count was obtained and was gradually minimized through the manipulation of the included road segments, travel speed, intersection attributes, and O-D matrix.

Once the network was calibrated, the congestions in the off ramps were analyzed and possible solutions were determined. The possible solutions were introduced to the network and the corresponding results were analyzed. The investigation was satisfied once the good solution for each exit point was obtained.

4. DATA RESULTS AND DISCUSSION

4.1 Buendia Exit

As shown in table 4.1, there is a difference in the volume count of point B and C as compared to their outflow counts going to point E and point F. This was caused by the bottlenecks that occurred in the area as the time reached the beginning of the peak hour. Since the heavy queuing of the vehicles in the area has slowed down the outflow of volumes coming from B and C to points E and F, only the volumes counted at B and C were considered. The vehicles of B to E/F and C to E/F were estimated with the help of plate surveying.

Table 4.1 Buendia Volume Count

Buendia	
Point	**Counts (veh)**
A	2970
B	1503
C	1644
B and C to E	759
B and C to F	388
D to F	489
D to E	697

Several factors contributed to the congestion at Buendia. Each of them had their own individual effects to the overall traffic flow in Buendia. The different factors affected different locations in the Buendia intersection.

Figure 4.1 Exiting Vehicles Unable to Merge

With the presence of an overwhelming number of vehicles utilizing the SLEX, the vehicles exiting the Skyway were met with the congestion that was already formed by the vehicles below the Skyway. The vehicles exiting the skyway had difficulty in merging with the existing traffic at the local road directly after the skyway exit. Because of this, the bottleneck carried over to the traffic at the off ramp of the Buendia Exit.

Figure 4.2 Pedestrians Crossing Dela Rosa Street

The pedestrians crossing the Dela Rosa Street, even though they were not a constant contributor to the congestion in the area, were also a key factor in the given situation. As shown in Figure 4.2, every time the pedestrians crossed the Dela Rosa Street, incoming vehicles were forced to stop for them even though they were in the green time. This prevented the vehicles from quickly passing through the intersection and hindered the queued vehicles to decrease in number.

Figure 4.3 Gridlock at Buendia Intersection

The left turning vehicles from Dela Rosa Street to Buendia Street also caused major problems. With the existing congestion from the number of vehicles coming from SLEX to Buendia Street, the left turning vehicles from Dela Rosa are unable to completely enter the road segment. As a result, they queue at the Buendia intersection. After their green time, the vehicles coming from the Skyway exit and the SLEX are unable to enter Buendia Street, thus contributing to a gridlock at the Buendia intersection.

4.2 Amorsolo Exit

The factors contributing to the congestion in the Amorsolo intersection is much more evident as compared to the other exit points. One of the problems observed at the exit of the Amosolo area is that the receiving lane of Gamboa Street only allots one lane for the right turning vehicles coming from the Amorsolo Skyway exit and the Amorsolo Street. The lane capacity of the Gamboa Street is unable to accommodate the large number of vehicles coming from the skyway exit and the service road. Another problem is the unruly pedestrians who cross the Gamboa Street even when the right turning vehicles are passing through. They cause the right turning vehicles to stop every time they cross the Gamboa Street, which contributes to the long queue along the skyway off ramp and the service road.

Table 4.2 Amorsolo Volume Count

Amorsolo	
Point	**Point**
A to C	520
A to D	1409
B to D	383
B to C	227
C to D	441
E	1873

4.3 Don Bosco Exit

One factor was observed to have contributed to the congestion at the Don Bosco exit. One problem is like the other exits, which is the presence of a great number of vehicles already utilizing the Chino Roces Avenue. The right turning vehicles from the skyway off ramp are queued, as they gradually are unable to proceed to Chino Roces Avuenue.

Table 4.3 Don Bosco Volume Count

Don Bosco	
Point	**Counts (veh)**
A	2337
B	2247
C	1624
D	361
E	1119
F	832

4.4 Magallanes Exit

One problem was observed to be causing the congestion at the Magallanes exit. The vehicles from the Magallanes off ramp going to the EDSA flyover are unable to exit the skyway, as there is an existing congestion on the flyover. This carries over to the skyway, as the vehicles have no choice but to queue along the skyway off ramp.

Table 4.4 Magallanes Volume Count

Magallanes	
Point	**Counts (veh)**
A	2893
B	2162
C	1877
D	1056
E	1301
F	736

4.5 Calibration

Model calibration is a crucial step in simulating traffic models. The actual volume counts surveyed in the actual roads must not stray very far from the simulated results so as to ensure the accuracy of the model. In Tables 4.5 to 4.8, the initial computations of the percentage differences of crucial road segments in the exit points are shown.

Table 4.5 Buendia Intersection Initial Count Comparison

Buendia Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Left Turn	436	452	552	552	498	697	597.5	33.31	28.55
Thru	304	296	388	456	361	489	425	30.12	26.18
Skyway SLEX Thru	580	808	712	656	689	1472	1080.5	72.47	53.19
Skyway SLEX Right	224	300	324	288	284	677	480.5	81.79	58.05

Table 4.6 Amorsolo Intersection Initial Count Comparison

Amorsolo Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Right Turn	172	268	180	224	211	227	219	7.31	7.05
Thru	312	444	324	352	358	383	370.5	6.75	6.53
Skyway Thru	512	256	684	360	453	1409	931	102.69	67.85
Skyway Right	332	184	360	272	287	920	603.5	104.89	68.80
Local Right	288	492	376	592	437	441	439	0.91	0.91

Table 4.7 Don Bosco Intersection Initial Count Comparison

Don Bosco Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Skyway SLEX Thru	2360	2316	1192	2016	1971	2688	2329.5	30.78	26.67
Skyway SLEX Right	904	1096	600	876	869	1897	1383	74.33	54.19
Local Left	344	340	384	380	362	362	362	0.00	0.00

Table 4.8 Magallanes Intersection Initial Count Comparison

Magallanes Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Right	872	1040	924	764	900	1110	1005	20.90	18.92
Thru	2432	2376	2392	1900	2275	2662	2468.5	15.68	14.54

From the tables above, there are road segments with high percentage difference that exceeds 50%. These percentage differences needed to be minimized as these invalidate the accuracy of the model. The values under the columns labeled as 1, 2, 3 and 4 in the tables indicate the number of vehicles that passes along the road segments in the simulation within the period of 7 am to 8 am in 15-minute intervals. The differences of their average to the count column are the remaining vehicles that are unable to enter the network as the congestion in the simulation prevents them to. This means that the road networks could not accommodate the number of vehicular volumes that was input in the origin-destination matrix.

Table 4.9 Buendia Intersection Modified OD and Lanes In/Out Count Comparison

Buendia Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Left Turn	416	468	544	588	504	551	527.5	8.91	8.53
Thru	328	380	420	400	382	387	384.5	1.30	1.29
Skyway SLEX Thru	468	816	784	628	674	840	757	21.93	19.76
Skyway SLEX Right	184	372	316	344	304	386	345	23.77	21.24

Table 4.10 Amorsolo Intersection Modified OD and Lanes In/Out Count Comparison

Amorsolo Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Right Turn	144	248	196	248	209	212	210.5	1.43	1.42
Thru	340	328	348	404	355	357	356	0.56	0.56
Skyway Thru	472	784	828	804	722	832	777	14.16	13.22
Skyway Right	360	252	564	420	399	543	471	30.57	26.52
Local Right	284	476	288	576	406	411	408.5	1.22	1.22

Table 4.11 Don Bosco Intersection Modified OD and Lanes InOut Count Comparison

Don Bosco Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Skyway SLEX Thru	1748	1760	1848	1784	1785	1844	1814.5	3.25	3.20
Skyway SLEX Right	1060	1148	1120	868	1049	1193	1121	12.85	12.07
Local Left	304	372	344	372	348	352	350	1.14	1.14

Table 4.12 Magallanes Intersection Modified OD and Lanes In/Out Count Comparison

Magallanes Intersection									
Movement	1	2	3	4	Average	Count	Average'	Percent Difference	Percent Error
Right	768	904	976	892	885	911	898	2.90	2.85
Thru	2072	2108	2136	2112	2107	2183	2145	3.54	3.48

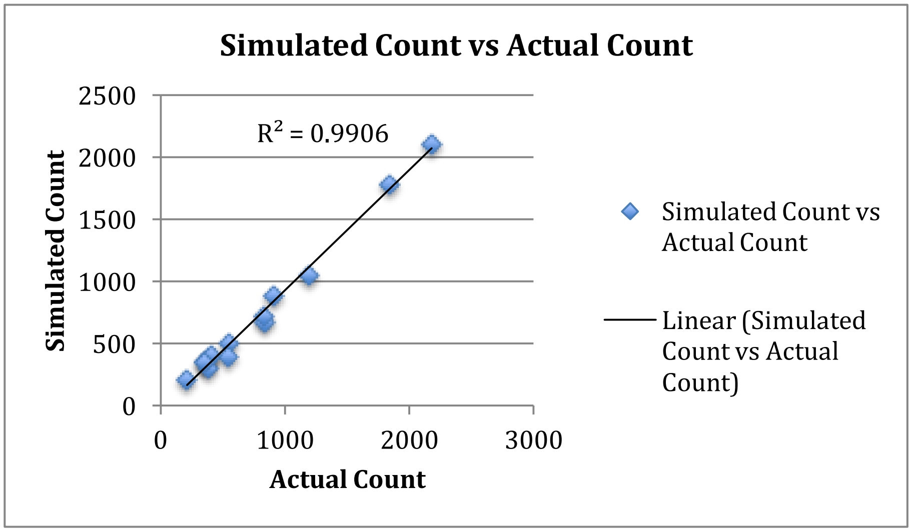


Figure 4.4 Simulated Volume Count vs Actual Volume Count

From the new set of comparisons of the simulation and actual volume counts, no percentage difference exceeds 50%. The highest percent difference is 30.57%, which can be considered since it is not high enough to make a significant influence in the model. In Figure 5.4, it shows that the r-squared value of the trend of the two variables is 0.9906.

Table 4.13 Congested Links Travel Delay and Level Of Service

From-Node	To-Node	Average Delay (s)	Level of Service	From-Node	To-Node	Average Delay (s)	Level of Service
29	24	93.94633	F	3	2	54.60268	D
57	48	191.83590	F	24	28	37.61413	D
12	20	106.97430	F	18	7	346.54575	F
4	20	119.48332	F	30	24	150.67803	F
15	18	39.33648	D	16	24	51.97423	D
5	3	111.74858	F	25	16	151.46025	F
20	3	123.77000	F	38	18	136.59818	F

In Table 4.13, the congested links are identified through the delay results simulated in the software. Using the classification of the Department of Transportation in Arizona, the congested links were classified under the D and the F level of service.

Once the congested links were identified, the traffic signal optimization feature of the software was used to determine the appropriate cycles for each traffic signal in the model with the consideration of the vehicular volume coming from different road segments. Given the huge number of vehicles using the EDSA freeway, a dummy traffic signal was placed on the interchange to simulate the real condition happening in that ramp. The average movement time of the queue was recorded and was made to be the green time of the vehicles using the interchange. Given that there are no alternative routes and traffic signals on the interchange, the problem lies on the EDSA freeway itself. The vehicles utilizing the freeway must be cut down. Another possible solution is securing a lane only for the vehicles exiting the Magallanes interchange to reduce the queue happening after the Magallanes exit. The optimized traffic control data of Buendia, Amorsolo, and Don Bosco were summarized in in Tables 4.14 to 4.19.

Table 4.14 Optimized Gil Puyat Traffic Signal

Gil Puyat Intersection		
Movements		
Green	139	25
Yellow	2	2
All Red	1	1

Table 4.15 Optimized Buendia Traffic Signal

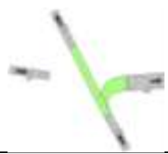
Buendia Intersection		
Movements		
Green	41	43
Yellow	2	2
All Red	1	1

Table 4.16 Optimized Rufino Traffic Signal

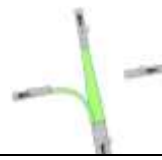
Rufino Intersection		
Movements		
Green	49	27
Yellow	2	2
All Red	1	1

Table 4.17 Optimized Amorsolo Traffic Signal

Amorsolo Intersection			
Movements			
Green	28	97	16
Yellow	2	2	2
All Red	1	1	1

Table 4.18 Optimized Gamboa Traffic Signal

Gamboa Intersection		
Movements		
Green	57	10
Yellow	2	2
All Red	1	1

Table 4.19 Optimized Chino Roces Traffic Signal

Chino Roces Avenue		
Movements		
Green	57	27
Yellow	2	2
All Red	1	1

From the optimized traffic control data, the cycle lengths were shortened in all the links. This was done to prevent long queues from different links. Allowing more cycles of green times will minimize the need for vehicles to fall in queues. In Table 4.20, the delay time of the links were improved.

Table 4.20 Optimized Model Link Delay Time

From-Node	To-Node	Average Delay (s)	Level of Service	From-Node	To-Node	Average Delay (s)	Level of Service
29	24	62.08625	E	3	2	5.170095	A
57	48	0.015335	A	24	28	11.40428	B
12	20	0.165624	A	18	7	10.41267	B
4	20	0.009622	A	30	24	14.70633	B
15	18	0.126029	A	16	24	62.55885	E
5	3	15.61258	B	25	16	12.9654	B
20	3	17.0053	B	38	18	0.287275	A

In Table 4.20, the level of service of most of the links improved to A’s and B’s meaning there is already no congestion present in the links. However, two links still have levels of service of E meaning there are still congestions within those two links. Upon reviewing the simulation animation, it was discovered that while there was still a significant delay in the two links, they do not have long queues like that of the congested model. The delay was merely caused by having longer red times to give way to the other links with greater vehicle demand.

The improvements of the data in the delay time were proofs that the optimization of the traffic control plans was effective. In addition to this, no new roads were needed. Aside from the need of constructing new traffic control plans in the Buendia Area, a change in the existing traffic signals is enough to relieve the capacity imbalance that is happening in the Makati Skyway exit points. Enforcing the importance of following pedestrian disciplines and signals can also help improve the traffic flow of the vehicles in these areas.

5. CONCLUSION AND RECOMMENDATION

Traffic congestion is evident in the exit points Makati Skyway and its adjoining local roads. With links having a travel delay ranging from 39 seconds to 350 seconds, assessing the road segments through model simulation was necessary to alleviate this heavy problem that the vehicle drivers are experiencing in Makati every day during weekdays.

Since there was a huge demand coming from the skyway and insufficient capacities from the local roads to absorb the vehicles, other solutions must be identified in order to compensate for the imbalance at the off ramps of the Makati Skyway. Traffic control plan optimization was an effective way of allowing the high demand coming from the skyway to smoothly exit the skyway without being bombarded with long queues. By modelling the Skyway and the local roads within the vicinity of its exit points, the software was able to take into consideration the vehicle demand coming from every traffic movement and adjust the traffic control plans based on them.

The main solution for Buendia, Amorsolo, and Don Bosco is to adjust the traffic signals into the optimized traffic signals in this study to remove the long queues that are already being carried over to the skyway itself. It is a cost-effective solution that will not be a burden to the economy in Makati City. For Magallanes, further studies must be done to relieve the congestion happening in the EDSA freeway. Only by relieving the congestion in EDSA can the congestion in the Magallanes Interchange be solved.

The researcher recommends for future studies to expand local roads included in the model. This can allow future researchers to look for more solutions that can still improve the small queues that still occurs in some links of the model. By doing this, future researchers will be able to take the analysis further and provide more specific solutions. Exploring other expressways is also a good way to identify other natures of congestion that is happening in the Philippines. This will help the country improve its transportation sector and, hopefully, be at par with the countries with exceptional transport networks.

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