Analysis Of Road Traffic Flow on The Capitol-Lazatin Junction And Providing Appropriate Traffic Control Measures Using Deterministic Simulation Modelling

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Abstract: - Traffic congestion is generally a major problem in big and growing cities around the world. Pampanga, a developing province in the Philippines, has been struggling to keep its roads and highways free from congested traffic such as at the Capitol-Lazatin Junction located in the capital city of Pampanga, the City of San Fernando. This study aims to assess the road traffic flow on the Capitol-Lazatin Junction and provide appropriate traffic control measures in order to alleviate the traffic problem at the study area using a deterministic simulation modelling. Manual counting method was carried out in collecting primary data through closed-circuit television (CCTV) to execute traffic assessment of the intersection. All the collected data were then utilized using Synchro 8 to determine the intersection delay and level of service in accordance with the Highway Capacity Manual 2010. The generated result for level of service came up as F or "Failure" on all the approaches, and the intersection itself. As such, it was deemed that the existing operating condition causes lengthy delays to motorists passing through it. Consequently, four proposed scenarios were tested to determine the appropriate solution to this problem. Repeated test track trials were carried out in controlled settings and adequate data for determining the appropriate traffic countermeasure was produced with the aid of Synchro 8. The results indicate that the Scenario 4 yields the optimum performance of the intersection in terms of level of service and intersection delay. However, it was revealed during the traffic survey that the heavy vehicles passing through the junction was only 1% in majority of the approaches. With that preface, Scenario 3 was deemed as the appropriate countermeasure as it befits the given condition of the study area. Also, to test the sustainability of the proposed solution, traffic projection was conducted. It was revealed that there is only 8.4 seconds deviation between the performance of this control type at the present condition and the potential future condition. This ascertained that making the intersection into a signalized junction with a fully-actuated control system is both efficient and sustainable.

Key Words: — ***Control Measure, Intersection Delay, Level of Service, Simulation, Synchro 8, Traffic Congestion, Traffic Signal System.***

I. INTRODUCTION

Urbanization in the Philippines has resulted in more movement and attraction to the people. Pampanga, a developing province that attracts a lot of new businesses and investments, has been struggling to keep its roads and highways free from congested traffic. Cities in Pampanga, especially San Fernando, have been receiving new investments resulting in rapid urbanization. Due to this, transportation problems arose in the province, such as large vehicular volumes that sometimes cannot be accommodated by our roads efficiently.

In Capitol-Lazatin Junction, there are establishments that attract people to go in this area such as Lelut Baculud, a Kapampangan

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restaurant that is known among the locals and The Orchid Gardens, a recreational complex that has a modern resort, hotel, event center and restaurant. But the biggest development in this area would be the Capital Town Pampanga, the first-ever township in Central and Northern Luzon that is slated to become the Central Business District of the North. The 35.6-hectare township is situated in the City of San Fernando, which main entry points come from Capitol Boulevard, Lazatin Boulevard, and Jose Abad Santos Avenue. With the emergence of Capital Town Pampanga, it is expected to result in heavy traffic around these areas. However, among the three mentioned roads, only Capitol Boulevard is a 2-lane road. So, vehicles traversing this boulevard are expected to experience heavier traffic due to its lower road capacity. At the present time, even though the Capitol Town Pampanga is yet to be fully realized, there are already several conflicting movements at the junction of Capitol Boulevard and Lazatin Boulevard, which causes inconvenience to many road users.

A variety of problems can stem from traffic congestion, including economic costs associated with delayed travel times, higher fuel usage, air pollution, and accidents. Being stuck in traffic can also induce mental stress to road users, which can contribute to different health problems. With the current tide of commerce and investments in the City of San Fernando, urban traffic congestion should really be of concern to the transportation sector.
Consequently, this study was conducted to assess the current intermittent traffic congestion present along the junction of Capitol Boulevard and Lazatin Boulevard. It also aims to project the possible traffic situation on the study area that will be ensued from the emerging township project, along with the existing commercial area, to ultimately formulate a sound solution that will alleviate the traffic problem.

1.1 General Objective

- The study intends to assess the current and possible future traffic situation along the intersection of Lazatin Boulevard and Capitol Boulevard in the City of San Fernando Pampanga.

1.2 Specific Objectives

- To assess the current operating conditions of the study area by Level of Service (LOS) and intersection delay (sec/veh).
- To formulate traffic control measures and evaluate its impact on traffic flow through the utilization of a simulation system.
- To determine the sustainability of the proposed control measure by forecasting the future traffic demand that ensued from the developing nearby area using the growth factor method.

II. METHODOLOGY

2.1 Research Design

This research is quantitative in nature since it systematically evaluates the phenomenon of traffic in the Capitol-Lazatin Junction by collecting quantifiable data and employing computational, mathematical, and statistical methods. With that preface, a measurable data collection, analysis, and interpretation were done by the researchers in order to achieve the objectives of this study.

Also, quantitative research can use simulation models to represent a real system and to test different scenarios in that system. A simulation modelling process consists primarily of feeding a model with quantitative data in a structured procedure to produce quantitative outputs. In this study, the acquired data and the necessary tools were utilized to assess the problem and to determine the optimal countermeasures in the Capitol-Lazatin Junction.

2.2 Software Used in the Study

Synchro 8 is a deterministic software for traffic simulation that is primarily used in optimizing traffic signal timing. Deterministic software uses various formulas, such as the Intersection Capacity Utilization method and Highway Capacity Manual (HCM) method in this case, that produce one specific answer to a given set of conditions. The formulas being used are products of years of research on actual driving conditions hence outcomes with a high degree of confidence can be ensured.

Generally, Synchro and its suites of applications can be used in analyzing existing and future traffic conditions. It helps in analyzing, designing, modelling, simulating, and animating both signalized and unsignalized intersections, roundabouts, arterials, and corridors. Moreover, it aids in determining their level of service, queue, delays, capacity, lengths, splits, and offsets. Thus, it aids users, especially engineers and transportation planners, in developing and implementing new or alternative traffic signal timing schemes.

These are actually the reasons as to why the researchers have decided to use Synchro 8 in this study. Aside from it being proven and tested by many experts, it is very straightforward and easy to use. With its modelling capabilities, it helped the researchers create a model which can be saved in a comprehensive and standardized file format. They were able to test or predict the efficiency of the model, increasing the confidence and credibility of the results of the study.

2.3 Data Collection

Roadway conditions are the factors describing a particular stretch of a road in a particular locality. It includes the geometric design of the road, which pertains to the dimensions and arrangements of the visible features of a roadway. This aspect is of importance for this study as this served as input data to model the road network in the simulation software. In this regard, the researchers requested the following data to the Department of Public Works and Highways (DPWH):

- Area type
- Number of lanes
- Lane width (in feet)
- Alignment

Traffic conditions refer to the amount of network traffic and how it is distributed spatially throughout the road network. The researchers primarily gathered data on traffic conditions by performing manual counting method, which can be done by counting either physically on the site or through digital means such as traffic cameras. In that regard, there are closed-circuit television (CCTV) present in the study area so the researchers requested access to its footage from the City Public Order and Safety Coordinating Office (CPOSCO) and used it to perform counting of traffic volume more efficiently.
The types of vehicles passing on every lane at the junction were also classified. This traffic survey was separated into a 15-minute time interval during the peak hour. Consequently, the following data were obtained simultaneously in this method:

- Distribution of vehicle types
- Amount and distribution of traffic in available lanes

Control conditions pertain to all countermeasures taken to distribute and manage the flow of traffic on roads in a given space and time. The following data on control condition were obtained by mere observation in the study area:

- Barricades
- Pavement Markings
- Traffic Signs

2.4 Proposed Simulation Model Scenarios

A simulation modelling of traffic control measures was carried out in different scenarios to determine the most appropriate solution in alleviating the traffic congestion at the intersection. The proposed scenarios are as follows:

Scenario 1: Introducing a pretimed traffic signal at the junction, in which the cycle length is fixed and all phases have a maximum recall.

Scenario 2: Providing a semi-actuated traffic signal at the junction, wherein on the basis of vehicle detection, it may gap-out or skip other assigned phases while recalling the major street through phases to their maximum values.

Scenario 3: Applying a fully-actuated traffic signal at the junction, wherein all phases are actuated and no recalls are set. This control type will also be uncoordinated, which allows the cycle length to vary depending on vehicle detection every cycle.

Scenario 4: Implementing a truck ban ordinance at peak hours to reduce the volume of traffic passing through the junction, in addition to the optimal traffic control type among the three scenarios above.

2.5 Traffic Growth Rate

The future traffic volumes anticipated to use the facility should be taken into consideration when making improvements or modifications to the existing road networks. As such, the researchers adopted a methodology for traffic forecasting that incorporates growth rate based on the economic growth as well as variations in transportation demand on a certain area over a period of time. Hence, future traffic volume was approximated using the transportation demand (number of registered vehicles in the region) and the economic growth factor (gross regional domestic product) that influences the former. Vehicle registration data serves as a key measure for traffic growth and this data was collected from the Land Transportation Office (LTO). On the other hand, Gross Regional Domestic Product (GRDP) is an indicator of the economic strength of any region that also reflects the growth of traffic and overall economic performance of that region. In this regard, GRDP data was obtained from Philippine Statistics Authority (PSA).

Then, in order to obtain the annual rate of traffic growth, the researchers used an econometric model with the aid of regression analysis that was formulated using Spreadsheet to ensure the accuracy of data. Using the available data on number of registered motor vehicles and GRDP of the study region, an econometric model as shown below can be yield:

$$\log_e P = A_0 + A_1 \log_e (\% \text{ GRDP})$$

Where:

P: Traffic Volume

A_0: Regression Constant

A_1: Regression Coefficient

GRDP: Gross Regional Domestic Product

The value of A_1 is also the Elasticity Coefficient. This is a measurement of the percentage change in the factors affecting the demand (GRDP) relative to the percentage change in the transportation demand (number of registered motor vehicles). This Elasticity Coefficient is the value that needs to be multiplied to the GRDP growth rate to get the traffic growth rate. The predictor formula of traffic growth rate is as below:

$$r = A_1 \times \text{GRDP growth rate}$$

Where:

r: Traffic Growth Rate

A_1: Elasticity Coefficient

The forecasting of traffic volume is commonly done with a time horizon of 10 to 20 years in order to economically justify any changes to the current situation. With this preface, the necessary computation for the projected traffic volume in year 2033 is shown below:

$$V_n = V_0 \times TPF$$

$$TPF = (1+r)^n$$

Where:

V_n: Future Traffic Volume (2033)

V_0: Current Traffic Volume (2023)

TPF: Traffic Projection Factor

r: Traffic Growth Rate

n: Design Life

2.6 Data Analysis

In this section, the values of control delay per vehicle can be determined based on the results obtained using the software. The researchers identified the scale of level of service in the research location using the criteria displayed in the following table as defined by HCM 2010.

Table.1. Level of Service Criteria for Unsignalized and Signalized Intersection

Level of Service	Average Control Delay (sec/veh)		Traffic Condition	Description
	Unsignalized	Signalized		
A	≤ 10	≤ 10	Excellent	No vehicle waits for more than one red light and no approach period is used completely.
B	11 to 15	11 to 20	Very Good	Drivers begin to feel somewhat confined among groups of vehicles as an occasional approach phase is completely exploited.
C	16 to 25	21 to 35	Good	Drivers may occasionally have to wait through more than one red light; backups may form behind turning vehicles.
D	26 to 35	36 to 55	Fair	Delays may be significant during rush hour, but there are enough lower volume periods to allow clearing of emerging queues, preventing major back-ups.
E	36 to 50	56 to 80	Poor	Represents the maximum number of cars that intersection approaches can tolerate; extensive lines of waiting vehicles may form over numerous signal cycles.
F	> 50	> 80	Failure	Back-ups from surrounding places or on cross streets may limit or prevent vehicles from exiting intersection approaches. Massive delays due to ever-increasing queue lengths.

SOURCE: Highway Capacity Manual, HCM 2010.

2.7 Comparative Analysis

The performance of the intersection using the existing model and the different simulation model scenarios were compared to one another in terms of vehicular delay (sec) and their corresponding Level of Service rating. Then, after determining the optimal traffic control measure, the performance of the intersection was also assessed using the projected traffic volume in 2033 to evaluate its effectiveness and efficiency in the future.

III. RESULTS AND DISCUSSIONS

3.1 Phase 1: Analysis of Road Traffic Flow on the Capitol-Lazatin Junction

The primary data instrument used was the traffic survey, which was conducted by manually counting the traffic volume and classifying the vehicles per lane movement through closed-circuit television (CCTV) footage over the course of 7 days and during the peak traffic hour from 5:00 PM to 6:00 PM. With that, the following data entry for the Synchro 8 settings were obtained and computed:

Table.2. Synchro 8 Data Entries for Evaluating the Current Unsignalized Intersection

Approach	Southbound			Westbound			Northbound			Eastbound		
Lane Group	RT	TH / LT		RT / TH / LT			RT / TH / LT			RT / TH / LT		
Traffic Volume (veh/hr)	279	206	417	584	196	34	26	180	103	132	225	250
Lane Width (ft)	11	11		11			8			11		
Peak Hour Factor	0.97	0.96		0.96			0.95			0.96		
Percent Heavy Vehicles (%)	2	1		1			1			1		
Adjacent Parking	✓		✓	✓						✓		
Parking Maneuvers	29		18	9						9		

In addition, the percentage distribution of the vehicle types with their corresponding dimensions were used as data inputs for the vehicle parameters feature of Synchro 8.

Table.3. Synchro 8 Data Entries for Vehicle Parameters

Vehicle Type	Percentage (%)	Vehicle Length (ft)	Vehicle Width (ft)
Others (Bicycles & E-bikes)	5.41	5	2
Motorcycle	38.39	6	2.6
Tricycle	14.13	6	3.5
Passenger Car	36.26	15	6
Passenger Utility	2.82	16.5	6.5
Goods Utility	1.74	20	6.5
Small Bus	0.18	20	7.2
Large Bus	0.02	35	8
Rigid 2-Axle Truck	0.50	20	7.8
Rigid 3-Axle Truck	0.41	40	8.2
Rigid +4-Axle	0.02	42.5	8.2
Trailer 3,4-Axle	0.05	52.5	8.2
Trailer +4-Axle	0.05	65	8.2

The values summarized in Table 2 and Table 3 were utilized in the software. The Synchro 8 software, which is integrated with HCM formulas, generated the performance of the intersection by multiple criteria, most important of which are the intersection delay and level of service rating.

Table.4. Evaluation Result Summary for the Current Unsignalized Intersection

Approach	Delay (sec)	Level of Service
Southbound	272.2	F
Westbound	191	F
Northbound	53.9	F
Eastbound	52.8	F
Intersection Delay (sec): 170.6		
Intersection Level of Service: F		

3.2 Phase 2: Determining the Optimal Traffic Control Measure

After verifying the poor traffic condition of the study area, four model scenarios, all of which involve a traffic signal system, were tested using the same software under similar traffic conditions. Hence, values used in the model scenarios are the same to that of values used in assessing the current unsignalized intersection. But some data entries were added for determining the best model scenario which are as follows.

Table.5. Additional Synchro 8 Data Entries for Evaluating the Proposed Signalized Intersection

Approach	Southbound			Westbound			Northbound			Eastbound		
Lane Group	RT	TH / LT		RT / TH / LT			RT / TH / LT			RT / TH / LT		
Turn Type	Pm	-	Pm +Pt	Pm	-	Pm +Pt	Pm	-	-	Pm	-	Pm +Pt
Yellow Time (sec)	4	4		4			4			4		
All-Red Time (sec)	1	1		1			1			1		
Minimum Split (sec)	9	9		9			9			9		
Vehicle Extension (sec)	3	3		3			3			3		
Minimum Gap (sec)	3	3		3			3			3		
(for Scenario 4 only)												
Modified Traffic Volume (veh/hr)	268	205	414	578	193	34	26	177	102	130	221	243
Percent Heavy Vehicles (%)	0	0		0			0			0		

Some data entries were chosen at the discretion of the researchers, but in accordance with the Synchro 8 manual and other relevant references. Consequently, all the defined and computed values were used in testing the different model scenarios. The following table is the results of every scenario proposed, including the current performance of the junction.

Table.6. Comparative Analysis of the Existing Condition and Four Model Scenarios

Approach	EXISTING CONDITION		SCENARIO 1		SCENARIO 2		SCENARIO 3		SCENARIO 4	
	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS
Southbound	272.2	F	44.9	D	51.3	D	37	D	31.6	C
Westbound	191	F	22.7	C	17.4	B	21.4	C	22.6	C
Northbound	53.9	F	16.2	B	28.6	C	26.8	C	25.5	C
Eastbound	52.8	F	58.8	E	46	D	50.4	D	53.1	D
Intersection Delay (sec) and LOS	**170.6**	**F**	**37.8**	**D**	**36.9**	**D**	**34.1**	**C**	**33**	**C**

The results indicate that Scenario 4 offers the optimum performance in terms of intersection delay and level of service. However, the conducted traffic survey revealed that the heavy vehicles passing through the junction was only 1% in majority of the approaches. Enforcing a truck ban ordinance would be inefficient in reality as it would only improve the performance of the intersection by a little. With that preface, Scenario 3 was deemed as the most appropriate countermeasure as it befits the given condition of the study area.

3.3 Phase 3: Assessing the Sustainability of the Appropriate Traffic Control Measure Proposed

In order to determine the effectiveness of the suggested solution, traffic projection was carried out and was utilized in testing the performance of the intersection when subjected to projected traffic. Through an econometric model and regression analysis, a traffic growth rate of 5.97% was computed. This value was then used to forecast the traffic volume in 2033 as shown in the table below.

Table.7. Projected Traffic Volumes for 2033

Approach	Southbound			Westbound			Northbound			Eastbound		
Lane Group	RT	TH	LT	RT	TH	LT	RT	TH	LT	RT	TH	LT
Traffic Volume (veh/hr)	279	206	417	584	196	34	26	180	103	132	225	250
Projected Traffic Volume (veh/hr)	296	219	443	620	208	37	28	191	110	140	239	265

Using the projected traffic volume, the performance of the intersection after 10 years was assessed using the Synchro 8. Table 8 presents the performance results of the optimal countermeasure at the present time and after 10 years.

Table.8. Comparative Analysis of the Effectiveness of the Proposed Solution

Approach	Scenario 3 Using Present Traffic Volume		Scenario 3 Using Projected Traffic Volume	
	Delay	LOS	Delay	LOS
Southbound	37	D	54.1	D
Westbound	21.4	C	24.6	C
Northbound	26.8	C	34.5	C
Eastbound	50.4	D	53.6	D
Intersection Delay (sec) and LOS	**34.1**	**C**	**42.5**	**D**

This means that the traffic condition using the present traffic volume was “Good” having only a 34.1 seconds average intersection delay while the traffic condition using the projected traffic volume was “Fair” having a 42. 5 seconds average intersection delay. This ascertained that proposing an actuated-uncoordinated traffic signal is both efficient and sustainable.

IV. CONCLUSION

Through the gathered data and utilization of a deterministic simulation software, the hypothetical traffic problem was proven as the existing operating condition of the Capitol-Lazatin junction causes lengthy delays to motorists passing through it. Using the same simulation tool, the performance of the intersection under various scenarios relating to the proposed feasible solutions were evaluated as well. Repeated test track trials were carried out in controlled settings and adequate data for determining the appropriate traffic countermeasure was produced with the aid of Synchro 8. The results indicate that the Scenario 4 yields the optimum performance of the intersection in terms of level of service and intersection delay. However, it was revealed during the traffic survey that the heavy vehicles passing through the junction was only 1% in majority of the approaches. With that preface, Scenario 3 was deemed as the most appropriate countermeasure as it befits the given condition of the study area. It was also tested using the projected traffic volume after 10 years to justify the solution being proposed, and it came out to have a fair performance in terms of intersection delay and level of service. Therefore, it was concluded that the proposed system is effective to alleviate the traffic congestion not only at the present time, but also at the potential future traffic situation of the study area.

REFERENCES

[1]. Adnan, M. (2014). Passenger car equivalent factors in heterogenous traffic environment. Procedia Engineering, 77, 107-108.
[2]. Federal Highway Administration. (2021). Traffic signal timing manual. U.S. Department of Transportation.
[3]. Institute of Transportation Engineers. (2015). Guidelines for determining traffic signal change and clearance intervals.
[4]. Japan International Cooperation Agency. (2013). Traffic demand forecast.
[5]. Mututantri, P. L., Abeysinghe, W. D. P., Wijewardena, L. S. S., & Weerasekera, K. S. (2015). Design of a flyover and roundabout underneath it to ease the traffic congestion at the Rajagiriya junction. Engineer, 48(4), 34-38.
[6]. Spack, M. (2016). How to decide when you need micro-simulation analysis.
[7]. Trafficware. (2011). Synchro Studio 8 user guide. Trafficware, Ltd. Retrieved from:

[8]. Yulianto, B. (2020). Traffic management and engineering analysis of the Manahan flyover area by using traffic micro-simulation VISSIM. IOP Conference Series: Materials Science and Engineering, 852(1), p. 012005.