Traffic Condition and Proposed Traffic Management Strategies at Banlic-Mamatid Intersection in Cabuyao City, Laguna, Philippines

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Abstract: A large amount of traffic volume on the road can cause problematic traffic flows and not functional intersections especially in peak hours. Interventions are necessary to alleviate such conditions. This study evaluates the traffic condition at Banlic-Mamatid Intersection in Cabuyao City, Laguna. Traffic management strategies were also assessed whether these will help improve the traffic condition. Results showed that the intersection operates at a level of service (LOS) F. Strategies evaluated to address the congestion were the optimization of signal timing, traffic signalization, and banning of heavy vehicles. The optimization of results showed an improvement in its LOS. However, the other lane groupings had an increase in their delay. For the heavy vehicle restriction, there are improvements in most of the movements. Lastly, for the prohibition of left-turn, there were no changes in the lane groupings' delay since only southbound was prohibited from the left-turning movement.

*Keywords***:** level of service, PTV VISSIM, traffic management

1. INTRODUCTION

The efficiency and safety levels of intersections can affect the operational performance of the whole system. The functioning of major intersections controls roadway systems. This avoids conflicting movements of vehicles and other users. The highest demand for vehicles passing through a given area happens during peak hour periods. The number of vehicles that can be accommodated at the intersection decreases whenever intersection failure happens during peak hours. Thus, the volume of traffic during peak hours is usually considered for the design of the serviceability of an intersection as these can be considered as the worst-case scenario. LOS describes the operational conditions in traffic and the behavior of motorists and passengers. This varies with volumes of traffic. It is also referred to as the level of satisfaction that can be obtained from different operating characteristics and traffic volumes. It has six different levels, LOS A for free flow, to LOS F for break downflow. LOS becomes extremely poor when the volume of traffic is nearing the capacity of the road under ideal roadway and traffic conditions. Additionally, vehicle speed slows down, delay, and frequency of stops increases.

In the Philippines, most of the intersections in the urban areas are generally characterized by congestion and delays. This is due to the increase in traffic volume, driver behavior, and no signalized traffic control system. One of these intersections is Banlic-Mamatid Intersection in Cabuyao City, Laguna. As observed, it is experiencing severe congestion, especially during peak hours. This is due to its huge population as well as its neighbors. This generates a huge traffic volume that causes serious congestion. There is a need to assess the traffic condition of the intersection. This so proper strategies for traffic management can be established.

This study evaluates the LOS of the current signalized Banlic-Mamatid Intersection. Additionally, strategies towards improving the LOS were assessed including optimization of signal timing, traffic signalization, and addition of lane. In the establishment of simulation models and assessing the LOS and performance of the intersection with proposed strategies, PTV VISSIM tool was used.

2. LITERATURE REVIEW

This section presents the literature and discusses past results from similar studies on assessing the LOS of intersections. This section also highlights the theoretical basis of this study.

2.1 Signalized Intersection Level of Service

Studies have been conducted to showcase different methods in determining the LOS of signalized intersections. Ezat (2008) analyzed two signalized intersections, the Maysaloon and Alabayda's are in Baghdad City to improve its performance operation. The required field data were collected manually, analysis throughout the study were performed using HCS-2000 to determine the existing LOS of the intersections. The highest average delay is shown at the Mohammed Alqasem Street with 76.2 sec/veh and LOS E. The approach from Al-Baladiyat has the lowest average delay with 22.7 sec/veh and LOS C. The approach from Dorah expressway has the poorest performance with an average delay of 117.4 sec/veh and LOS F. On the other hand, the approach from Alneariya has the best performance with an average delay of 27.7 sec/veh and LOS C. Two-decades of data were predicted using HCS program by calculating capacity, delay, and LOS for all approaches and the entire intersection. It was found that Maysaloon and AlBayda'a Sq. is under LOS E. Additionally, the congestion is from Palestine St. and Maysaloon Sq. and in the approach coming from Dorah expressway. AlBayda'a Sq.

Moreover, Awad *et al.* (2010) assessed the Al-Zeoat intersection in Al-Ramadi City. The authors assessed the intersection using the SIDRA traffic program. Results showed that the approaches were operating at LOS F except for the Al-Maeradth St. approach which was operating at LOS E. The major flow of traffic was concentrated along the Al-Mohafadha St. to Al-Mahkama St. In addition, Gangopadhyay et al. (2013) assessed an intersection in Ahmedabad City, India. The study area was selected since several Special Economic Zones were being proposed in this region, which was expected to produce rapid growth in population and travel demand. From the classified traffic volume count data, it was determined that the most dominant vehicle composition is motorized two-wheelers. The travel speed characteristics were evaluated using a 4.9-km section resulting in average journey speed is 19 kph and 20 kph during morning and evening peak respectively. For morning and evening periods, the average running speed was 26 kph. Furthermore, it was observed that the cause of delays was the traffic signal and merging of traffic at the intersection.

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2.2 Strategies for Improvement of Traffic Condition

Traffic management aims at achieving a balance between demand and supply in a transportation system considering that users with different characteristics share limited space of available transportation infrastructure. Traffic management systems are sets of applications and tools that are utilized to improve traffic efficiency and safety within transportation systems. It gathers information from different sources. Then, use this information to control potential hazards and untoward incidents in the system (Souza *et al.*, 2017). The efficient, less polluting, and safe transportation of people and goods requires the use of the infrastructure with the appropriate application of traffic control measures. Efficient traffic control is directly related to the efficiency and relevance of control methodologies (Papageorgiou *et al.*, 2004). Traffic lights are the major control measure installed to ensure movement and safety of crossing pedestrians. They may lead to efficient network operations with increasing traffic volume. However, their optimal control strategy must exist to minimize the total time spent by all vehicles in the network (Papageorgiou *et al.*, 2004).

An intersection usually has approaches and the crossing area included. Approaches are used by corresponding streams of traffic. The movement of vehicles in various approaches can be managed using a traffic signal. The following can influence traffic conditions via traffic lights operation that involves large streams of traffic. They are split, cycle time, and offset. Split is the relative duration of green time as a percentage of the whole cycle time. To increase the capacity of an intersection, the cycle time is usually increased. However, it may increase delays in undersaturated intersections because of longer waiting times during the red phase. Offset is the phase difference between cycles for successive intersections that may give rise to a “green wave” along an arterial. This is ideally considered the existence of vehicle queues (Papageorgiou *et al.*, 2004; Saha *et al.*, 2019).

Control strategies have several categories depending on the time of the day, and the number of intersections. Fixed-time strategies normally consider a given time of day such as morning and afternoon peak hours. Also, optimization codes are applied based on historical travel demands as well as stream turning rates, which are normally offline. Traffic-responsive strategies, however, make use of measurements done real-time. This allows the calculation of real-time to achieve signal settings that are appropriate to the traffic condition of the stream. On the other hand, isolated strategies are used in single intersections while coordinated strategies are for an urban zone and network with multiple intersections. Most control strategies are appropriate for undersaturated traffic conditions. In this case, vehicle queues are formed during red phases and dissipate during green phases. Few traffic control strategies apply for oversaturated conditions (Papageorgiou *et al.*, 2004). One way to improve the capacity of an intersection during congestion times is to increase the number of lanes for either the left-turn or through vehicles (Bie *et al.*, 2017).

Two active traffic management strategies at saturated and/or oversaturated intersections are developed and experimentally validated as a signal phase and timing application. The first strategy is to allocate as much green time as possible to approaches with higher saturation discharge rate, such as summation of saturation flow rate across all lanes, to reduce delay. For the second approach, green times are distributed to balance queue lengths of major and minor streets to prevent queue spillback or gridlock. Two strategies are validated through field vehicle trajectory data. Based on the results, the proposed strategies effectively manage queue lengths of major and minor streets as well as reduce delays (Huang *et al.*, 2015). Moreover, optimization of signal timing, heavy vehicle restriction, prohibition of left-turning at all approaches is potential strategies for improving traffic conditions. On, optimization of signal timing, Abojaradeh *et al.* (2016) suggested a couple of alternatives for the improvement of the

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traffic conditions in the Al-Shmesani District. These were changing traffic signal timing and modifying the geometric condition of the intersection. This is seen to reduce delay and fuel consumption. Heavy vehicle restriction is considered the most efficient strategy. Heavy vehicles cause an average delay of -17.82%. Thus, restricting all heavy vehicles in the road section yields to the improvement of traffic conditions in the road (Al Eisaei *et al.*, 2017).

In addition, prohibiting left turns on all approaches allows the through movements on all lanes of each direction to operate on two phases instead of four splitting phases with a 190-sec cycle length. According to Abojaradeh *et al.* (2014), the total intersection delay can improve from 318.3 to 102.2 sec/veh. However, this strategy might produce more delays and back of the queue on downstream traffic signals. Villegas *et al.* (2018) found that the geometry of traffic signal phasing highly affects the handling of the intersection in terms of capacity and safety. Results show that conflicting points for the movement of vehicles exist in the case of the Philippines when having double turn lanes without median-turn lane markings. Conflicts among the turning vehicles can be serious and harm the speed and saturation flow rates. While in Japan, turn lane markings provide a positive impact on mobility.

3. METHODOLOGY

In this section, details presented include that of the study area, processes of data collection, and analysis. Traffic data and highway geometric information data were gathered. Then, the LOS of the intersection was analyzed. After analyzing the LOS, different strategies were proposed for the improvement of the traffic condition. Then, simulations of proposed strategies were done using PTV VISSIM. Lastly, from the simulation done by the software, the best improvement strategy was selected.

3.1 Banlic-Mamatid Intersection

The focused intersection is the Banlic-Mamatid located in Cabuyao City, Laguna. Cabuyao City is one of the top cities in the province of Laguna, declared as a city in 2010. As a counterpart of being one of the successful cities in Laguna, this also led to a growing population, which has resulted in daily traffic congestion on the roads of the city. Mamatid for example is one of the barangays in the city with an increasing population. It is currently the most populous barangay in Cabuyao City. According to the 2015 Census, it has a population of 55,803, which grew from 50,213 in the 2010 Census. Banlic-Mamatid Intersection, located in Mamatid, Cabuyao City, is one of the busiest intersections in the city. It is the meeting point of roads coming from Checkpoint, Calamba, Barangay San Isidro, and a majority from villages and subdivisions surrounding the Banlic-Mamatid Intersection.

Figure 1 shows the assigned geometric layout of the Banlic-Mamatid Intersection. In this study, the road from Cabuyao City is in the north direction, while the road from Calamba City is towards the south. On the other hand, the road from Bermuda-Camella is towards the West direction, while the road from Banlic-Mamatid is due East. The intersection is not a perpendicular intersection where the two-lane highway has different lane widths and is not aligned with each other. The Banlic-Mamatid road has a total span length of 7.182 meters, with its lane width as 5.182 meters and shoulder-width at 1 meter on both sides. On the other hand, the Bermuda-Camella road has a total span length of 9.069 meters, where its lane width is 5.349 meters and shoulder width of 1.860 meters on both sides. The national highway has a total span length of 17.376 meters where its lane width is 14.326 meters and has a shoulder width of 1.525 meters. When it comes to the pedestrian, the crosswalk width on the North is

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4.250 meters while on the South, the crosswalk width is 4 meters.

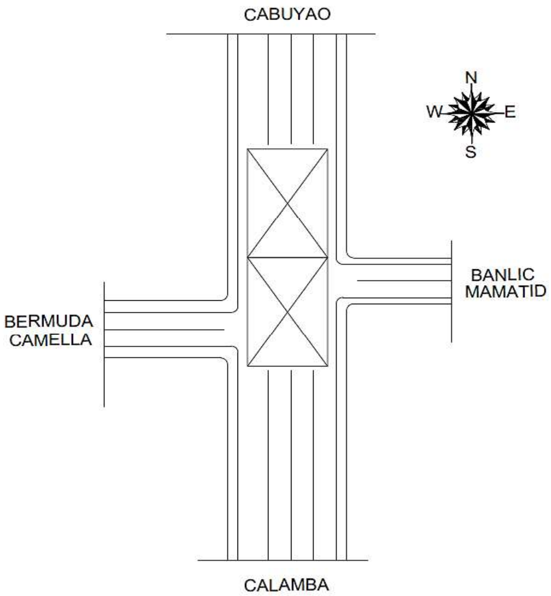

Figure 1. Assigned Geometric Layout of Banlic-Mamatid Intersection

Figure 2 shows the lane groupings at Banlic-Mamatid Intersection. The vehicles coming from Cabuyao are referred to as SB (Southbound), while the vehicles from Calamba are NB (Northbound). On the other hand, the vehicles coming from Bermuda-Camella are referred to as EB (Eastbound), while the vehicles from Banlic-Mamatid are WB (Westbound). The Banlic-Mamatid Intersection has four phases which are: Phase 1 is SB through or right (T/R) and NB T/R; Phase 2 is WB left (L)/T/R; Phase 3 is EB L/T/R, and Phase 4 is SB L and NB L.

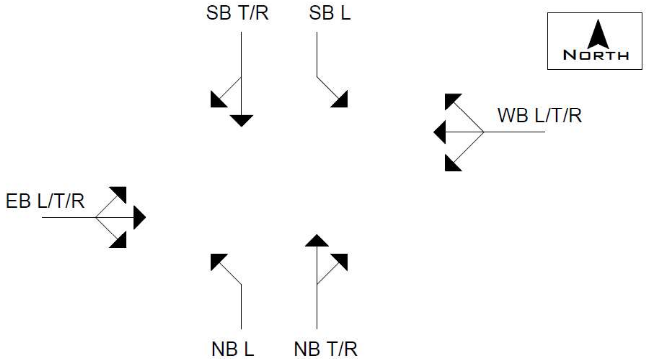

Figure 2. Lane Groupings at Banlic-Mamatid Intersection

The traffic flow was recorded using video cameras for 1 hour. This is coupled with a tally counter to count the traffic volume and the number of pedestrians. A paper and pen were used to note the green, yellow, and red times for each phase. A measuring tape was used to measure the lane width for each lane with the assistance of the assigned traffic enforcer. Data were observed and gathered for four consecutive Saturdays. The traffic volume of the study area was observed using a video camera and the videos were viewed in slow motion by a media player to ensure that the exact number of vehicles was manually counted and noted. The video cameras for the intersection and Banlic-Mamatid road were installed on the 4th floor of the Mang Inasal Banlic Building, while the video camera for the Bermuda – Camella

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road was installed beside 7-Eleven Banlic (see Figure 3).

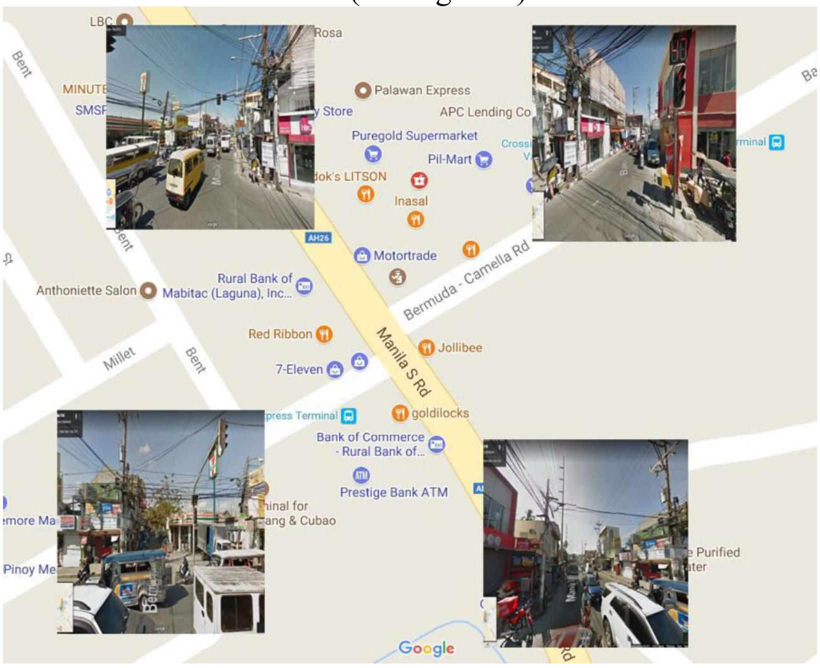

Figure 3. Location Map of the Selected Study Area at Cabuyao, Laguna

An hourly variation was done on October 7, 2017, from 17:00 to 20:00 to determine the peak hours for Saturday evenings. The peak hour was found to be between 17:00 to 18:00. However, it was decided to do an observation from 17:30 to 18:30 instead. As every vehicle has a different effect on the traffic, a Passenger Car Equivalent (PCE) factor must be multiplied by the volume of each vehicle type to determine the number of PCs displaced by a specific vehicle. The PCEs for motorcycle, tricycle, PC/van, jeepney/light truck, and heavy vehicle (HV)/bus was based on research conducted by the National Center for Transportation Studies of University of the Philippines Diliman last 2008. Meanwhile, the PCE for a bicycle was based on the Cycling Embassy of Great Britain. These PCE factors are shown in Table 1.

Table 1. Type of Vehicles and Their Corresponding PCE

Type of Vehicle	PCE
Bicycle	0.2
Motorcycle	0.5
Tricycle	0.8
PC/Van	1.0
Jeepney/Light Truck	1.5
HV/ Bus	2.2

3.2 Determination of Signalized Intersection LOS

The following were accomplished to determine the LOS of a signalized intersection according to Highway Capacity Manual (2010). First, the steady-state headway is determined using equation 1, where, h is the steady-state headway (sec/veh); t_L is the time of last stopped vehicle (sec); t_4 is the time of 4th vehicle (sec), and v_n is the vehicle position of the last vehicle (veh). Then the saturation flow rate was determined for every movement in each phase of the intersection. The saturation flow rate for each subject lane group in vehicle/hour is equal to

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3600 divided by the steady-state headway (in seconds/vehicle) that was determined earlier using equation 1.

$$h = \frac{t_L - t_4}{v_n - 4} \tag{1}$$

After determination of the saturation flow rate, it was adjusted using equation 2, where, s is the adjusted saturation flow rate for subject lane group, expressed as total for all lanes in lane group (veh/h); s_o is the base saturation flow rate per lane (pc/h/ln); N is the number of lanes in lane group; f_w is the adjustment factor for lane width; f_{HV} is the adjustment factor for heavy vehicles in traffic stream; f_g is the adjustment factor for approach grade; f_p is the adjustment factor for existence of a parking lane and parking activity adjacent to lane group; f_{bb} is the adjustment factor for blocking effect of local buses that stop within intersection area; f_a is the adjustment factor for area type; f_{LU} is the adjustment factor for lane utilization; f_{LT} is the adjustment factor for left turns in lane group; f_{RT} is the adjustment factor for right turns in lane group; f_{Lpb} is the pedestrian adjustment factor for left-turn movements; and f_{Rpb} is the pedestrian-bicycle adjustment factor for right-turn movements. Adjustment factors for saturation flow rate were applied based on the highway capacity manual 2010 (TRB 2010). Table 2 shows the adjustment factors used for the saturation flow rate while Table 3 is used for default values for utilization of adjustment factors.

$$s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb} \tag{2}$$

Table 3. Default Utilization Adjustment Factors

Lane Group Movements	No. of Lanes in Lane Group	Traffic in Most Heavily Traveled Lane	f_{LU}
Through or	1	100.0	1.000
Shared	2	52.5	0.952
	3	36.7	0.908
Exclusive Left	1	100.0	1.000
Turn	2	51.5	0.971
Exclusive	1	100.0	1.000
Right Turn	2	56.5	0.885

Source: TRB (2010)

The flow rate is then adjusted accordingly using equation 3, where, V_p is the adjusted flow rate for lane group i (veh/h), and V_{15} is the 15-minute volume of peak period (veh/h). Capacity per lane group is then calculated using equation 4, where, c_i is the capacity of lane group i (veh/h); s_i is the saturation flow rate for lane group i (veh/r), and g_i/C is the effective green ratio for lane group i.

$$V_p = 4 * V_{15} \tag{3}$$

$$c_i = S_i \frac{g_i}{C} \tag{4}$$

The volume to capacity ratio is calculated using equation 5, where X_i is the ratio for lane group i; v_i is the demand flow rate for lane group i (veh/h); s_i is the saturation flow rate for lane group i (veh/h); g_i is the effective green time for lane group i (s), and C is the cycle

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length (s).

$$X_i = \left(\frac{v}{c}\right)_i = \frac{v_i}{S_i \frac{g_i}{C}} = \frac{v_i C}{S_i g_i} \tag{5}$$

Then, the control delay per vehicle is calculated using equation 6, where, *d* is the control delay per vehicle (s/veh); d_1 is the uniform control delay assuming uniform arrivals (s/veh); PF is the uniform delay progression adjustment factor, which accounts for effects of signal progression; d_2 is the incremental delay to account for the effect of random arrivals and oversaturation queues, adjusted for duration of analysis period and type of signal control (s/veh); and d_3 is the initial queue delay, which accounts for a delay to all vehicles in analysis period due to initial queue at the start of the analysis period (s/veh). The control delay consists of the uniform delay d_1, random delay d_2, and d_3. Uniform delay and incremental delay are calculated using equations 8 and 9, respectively while d_3 is assumed to be 0 for an intersection that is isolated.

$$d = d_1(PF) + d_2 + d_3 \tag{6}$$

The uniform delay, d_1 is calculated using equation 7 where, *C* is the cycle length (s); cycle length used in pre-timed signal control or average cycle length for actuated control; *g* is the effective green time for lane group (s); green time used in pre-timed signal control, or average lane group effective green time for actuated control; and *X* is the v/c ratio or degree of saturation for lane group.

$$d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left[\min(1, X)\frac{g}{C}\right]} \tag{7}$$

While the incremental delay is calculated using equation 8, where, d_2 is the incremental delay to account for the effect of random arrivals and oversaturation queues, adjusted for duration of analysis period and type of signal control; this delay component assumes that there is no initial queue for lane group at the start of the analysis period (s/veh). T is the duration of the analysis period (h); *k* is the incremental delay factor that is dependent on controller settings; I is the upstream filtering/metering adjustment factor; *c* is the lane group capacity (veh/h), and *X* is the lane group v/c ratio or degree of saturation.

$$d_2 = 900T\left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8kIX}{cT}}\right] \tag{8}$$

Total delays are then aggregated for each approach using equations 9 and 10, where d_A is the delay for approach A (s/veh); d_i is the delay for lane group *i* (on approach A) (s/veh); v_i is the adjusted flow for lane group *i* (veh/h); d_I is the delay per vehicle for intersection (s/veh), and v_A is the adjusted flow for approach *A* (veh/h).

$$d_A = \frac{\sum d_i v_i}{\sum v_i} \tag{9}$$

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$$d_I = \frac{\sum d_A v_A}{\sum v_A} \quad (10)$$

Table 4 shows the LOS criteria for signalized intersections. The LOS for a signalized intersection is directly related to the average control delay value per vehicle.

Table 4. LOS Criteria for Signalized Intersections

LOS	Average Control Delay (s/veh)	Description
A	≤ 10	free flow / insignificant delays
B	> 10 – 20	stable operation / minimal delays
C	> 20 – 35	stable operation / acceptable delays
D	> 35 – 55	approaching unstable / tolerable delays
E	> 55 – 80	unstable operation / significant delays
F	> 80	forced flow / excessive delays

Source: TRB (2010)

3.3 Analysis of the Impacts of Proposed Strategies

Based on the literature, strategies that are explored here to evaluate whether LOS of the intersection is improved or not include the following:

- **Optimizing signal timing.** The researchers determined the effective green time of all the lane groups for the current cycle length by using the equations shown.
- **Heavy vehicle restriction.** The researchers restricted the heavy vehicles from passing through the intersection.
- **Prohibiting left turning.** The researchers prohibited left turning by disregarding the volume of the left-turning vehicles that came from SB direction.

Traffic simulation software was used to assess various scenarios and visualize current traffic conditions (Hongxu *et al.* 2013; Li *et al.* 2015; Aldrete *et al.* 2016). PTV VISSIM is a traffic simulation software that is widely used in assessing traffic conditions in studies (e.g. Al Eisaeia *et al.* 2017; Abao *et al.* 2014; Gao *et al.* 2013). PTV VISSIM simulations were used effectively in this study for the researchers to visualize each strategy made and to choose what is the most effective strategy based on what is seen in the simulations. Different modes of transport can be included within the model such as bicycles, light, and vehicles, public transport. Various outputs can be generated from the simulation which varies between traffic engineering, urban planning, and 3D visualization. Signal timing and intersection design are also features that can be employed. Also, VISSIM's capabilities in analyzing traffic characteristics and driving behavior in both interrupted and uninterrupted traffic flows are crucial. The following inputs were added to the simulation:

- **Geometric data.** Roads were laid out according to the actual measurements and connections in each road according to each route given in four directions. Conflict Areas and Reduced Speed Area were also set.
- **Base data.** The 2D/3D models such as bicycle, motorcycle, tricycle in PCE value, PC/van, jeepney/light truck, bus, and heavy trucks were set with its corresponding desired speed of 15, 30, 25, 40, 40, 30, and 30 kph, respectively.
- **Vehicle and pedestrian input.** This was done through the calculation of the relative flow of each direction and its corresponding routes. The relative flow was calculated

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by dividing each vehicle by the total volume of each direction. For the pedestrian, the greatest number of pedestrians was added.

- **Static vehicle route.** After inputting the volume of vehicles, the static vehicle was set according to the phase of each intersection.
- **Signal control.** Given the existing traffic signals in Banlic-Mamatid intersection, the green, red, and yellow time of each phase, were added to the signal control parameter of the program.

After setting all the needed inputs, a simulation was done to visualize the impacts of the strategies in the study area. Under scenario management, each strategy was inputted to compare the changes that have been made given a specific scenario or strategy.

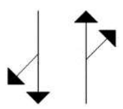
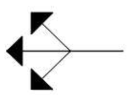
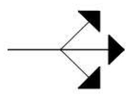
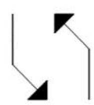
4. RESULTS AND DISCUSSIONS

4.1. Traffic Data

The researchers decided to make a traffic count from 5:30 p.m. to 6:30 PM on a Saturday. Based on the following reasons: (1) From the graph shown, the data between 5:00 PM. to 6:00 PM and 6:00 PM to 7:00 PM. have very close values so the researchers have decided to take average counts; (2) most of the commuters end their work at 5 PM and add some more minutes to fix their things before leaving their company, or school. Then, at 5:30 PM, they are already on the road traveling back to their homes along or through Banlic-Mamatid Intersection.

Based on the observed traffic volume on October 21, 2017, the road from Cabuyao (SB) had the highest volume of vehicles passing the intersection with 1530 veh/hr, followed by the vehicles from Calamba (NB) with 1503 veh/hr. The vehicles from Bermuda-Camella (EB) had the lowest volume with only 114 veh/hr. Vehicles coming from Banlic-Mamatid (WB) had the highest volume that turned left with 218 veh/hr while the road from Calamba (NB) had the highest volume of vehicles that turned right with 202 veh/hr. Table 5 shows the signal phasing and cycle time of the observed traffic for October 21, 2017. Phase 1 had the longest green time with 95 s due to the heavy amount of traffic volume coming from SB and NB. Phase 3 had the shortest green time with 10 s due to the low traffic volume coming from EB.

Table 5. Actual Cycle Time of Each Phase

Phase 1		Phase 2		Phase 3		Phase 4	
SB T/R	NB T/R	WB L/T/R		EB L/T/R		SB L	NB L
							
Green	95 s	Green	50 s	Green	10 s	Green	20 s
Red	89 s	Red	134 s	Red	174 s	Red	66 s
Yellow	3 s	Yellow	3 s	Yellow	3 s	Yellow	3 s
Cycle Length				191 s			

4.2 LOS of the Intersection

The analysis in this section shows the current LOS of the study area. For the intersection, the

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data gathered on October 21, 2017, was used in computing its LOS. Table 6 shows the 15-minute interval of the volume of vehicles passing the intersection on October 21.

Table 6. 15-minute Interval of Volumes Passing Through Each Movement in PCE

BOUND	NB			SB			WB			EB		
Period (min)	T	L	R	T	L	R	T	L	R	T	L	R
15	237	10	36	244	38	13	18	35	29	12	15	9
30	248	11	30	256	21	8	15	36	23	7	5	4
45	235	3	37	252	36	10	6	38	30	11	10	6
60	253	2	49	254	38	14	7	46	31	8	11	2
TOTAL	973	26	152	1006	133	45	46	155	113	38	41	21

(NB=Northbound; SB=Southbound; WB=Westbound; EB=Eastbound; T=Through; L=Left; R=Right)

EB L/T/R has the highest delay with 495.694 s/veh, operating on LOS F. Meanwhile, SB T/R has the lowest delay with 53.960 s/veh, operating on LOS D. Table 7 shows the aggregated delays and corresponding LOS of the intersection. Approach EB has the highest delay with 495.694 s/veh while SB has the lowest delay with 62.102 s/veh. Approach NB and EB are both operating on LOS F, while approach SB and WB are operating on LOS E. Result shows that the overall intersection is operating on LOS F and has excessive delays.

Table 7. Aggregated Delays and Corresponding LOS of Banlic-Mamatid Intersection

Approach	Average Delay per Vehicle (s/veh)	LOS
SB	62.102	E
NB	122.053	F
WB	74.356	E
EB	495.694	F
Intersection Delay (s/veh)		Intersection LOS
104.070		F

The simulation is done on PTV VISSIM and Table 7 shows that the traffic is severe, and it is very important to propose strategies to improve the present condition of the intersection. The researchers observed the long queue of vehicles and the people passing through the pedestrian crossing without following the proper time to move. Also, because of heavy vehicles passing through NB, there is a problem with the left turning of vehicles from SB. Also considering the short width lane of the Banlic-Mamatid road; there is a huge effect on the vehicles passing through the intersection because of difficulty in right turning and left turning to this road.

4.3 Analysis of the Impact of Strategies in Improving LOS

Analysis in this section shows the impact of these strategies in the LOS of the study area.

4.3.1. Optimization of signal timing

Table 8 shows the effective green time for each lane group. Phase 1 has an effective green

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time of 106 seconds, which is greater than its actual green time of 95 seconds. Phase 2 and Phase 4 have an effective green time of 40 seconds and 18 seconds, respectively. On the other hand, Phase 3 has an effective green time of 13 s which is also greater than its actual green time of 10 seconds.

Table 8. Summary of Results on the Effective Green Time of Each Phase

	X_c	Effective Green, g (s)	Actual Green (s)
Phase 1	0.5078	106	95
Phase 2	0.1900	40	50
Phase 3	0.0610	13	10
Phase 4	0.0844	18	20

X_c (intersection) = 0.9203
C (actual) = 191 s
C (effective) = 193 s

SB T/R, NB T/R, and EB L/T/R show a huge decrease in its delay, with NB T/R having an improvement on its LOS, from LOS F to LOS E. On the other hand, WB L/T/R, SB L, and NB L had an increase in its delay, with WB L/T/R and NB L operating from LOS E to LOS F. Table 9 shows the aggregated delays and corresponding LOS of the intersection from the optimization of signal timing. All approaches except WB had an improvement in its delay and LOS. The overall intersection delay and LOS also showed an improvement, from a delay of 104.070 s/veh, operating on LOS F, the intersection would have a delay of 67.093 s/veh on LOS E.

Table 9. Aggregated Delays and Corresponding LOS on Optimization of Signal Timing

Approach	Average Delay per Vehicle (veh/s)	LOS
SB	55.038	E
NB	55.605	E
WB	117.181	F
EB	188.126	F

Intersection Delay (s/veh)	Intersection LOS
67.093	E

4.3.2. Heavy vehicle restriction

The 15-minute interval of the volume without any heavy vehicles passing the intersection. SB T/R and NB T/R showed an improvement in this strategy, with NB T/R now operating on LOS E. Meanwhile, all other lane groupings showed no change in their delay and LOS since there is originally no HVs passing on those lanes. Table 11 shows the aggregated delays and corresponding LOS of the intersection from the heavy vehicle restriction. Only SB and NB showed an improvement in their delay, with NB now operating on LOS E. Also, the intersection had a decrease in its delay, from 104.070 s/veh to 77.620 s/veh, operating on LOS E.

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Table 11. Aggregated Delays and Corresponding LOS on HV Restriction

Approach	Average Delay per Vehicle (veh/s)	LOS
SB	59.323	E
NB	60.587	E
WB	74.356	E
EB	495.694	F
Intersection Delay (s/veh)	Intersection LOS	
77.620	E	

4.3.3. Prohibiting left turning at approach SB

Table 12 shows the aggregated delays and corresponding LOS of the intersection from the prohibition of left-turning on SB. SB had an increase in its delay and LOS, from 62.102 s/veh to 53.960 s/veh, now operating on LOS D. There were no changes in the other approaches since only SB was prohibited from left turning. The intersection had a slight decrease in its delay, from 104.070 s/veh to 103.214 s/veh, still operating on LOS F.

Table 12. Aggregated Delays and Corresponding LOS on Prohibit of Left Turning

Approach	Average Delay per Vehicle (veh/s)	LOS
SB	53.960	D
NB	122.053	F
WB	74.356	E
EB	495.694	F
Intersection Delay (s/veh)	Intersection LOS	
103.214	F	

4.4 Analysis of the Impact of Strategies

The sections above show the results of the analysis of the performance of the intersection according to proposed traffic control strategies. For the optimization of results, SB T/R, NB T/R, and EB L/T/R showed an improvement in its LOS. However, the other lane groupings had an increase in their delay. For the heavy vehicle restriction, SB T/R and NB T/R showed a significant amount of decrease in its delay, with NB T/R improving its LOS from LOS F to LOS E. Lastly, for the prohibition of left-turn at approach SB, there were no changes in the lane groupings' delay since only SB was prohibited from the left-turning movement.

5. CONCLUSIONS AND RECOMMENDATIONS

This study evaluated the LOS of the Banlic-Mamatid intersection in Cabuyao City, Laguna. Data were gathered during a Saturday peak from 17:30 to 18:30. LOS of the current system was analyzed and the impact of the proposed strategies for the Banlic-Mamatid Intersection was evaluated. PTV VISSIM was used in simulating and visualizing the strategies to identify the best possible strategy to improve traffic conditions. Analysis of the Banlic-Mamatid intersection shows that it is currently operating under LOS F. This is attributed to excessive

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delays and forced flow that exists. Results for Eastbound movements showed that even though the approach has a low volume, it is operating at LOS F due to the current insufficient green time allocated.

To improve the traffic condition at Banlic-Mamatid Intersection, traffic control strategies were analyzed to determine its impact on the LOS of the intersection including optimization of the signal timing, heavy vehicle restriction, and prohibiting left-turning at Southbound movements. Based on the optimization of signal timing at the intersection, the proposed cycle time of 193 seconds improved the intersection LOS from F to E. However, the optimized signal timing greatly increased the delay during the assigned Phase 2 and Phase 4 traffic movements. The second strategy assessed was the restriction of HVs. The HV restriction improved the intersection LOS from F to E. This shows that heavy vehicles should pass through the intersection after 7 p.m. Restriction of HVs at the observed time and day gives enough space for occupancy of other smaller vehicles. As seen in the observations, most of the vehicles coming from the Northbound are HVs, which take a large amount of time to pass through the intersection and difficulty of doing right turn movements which affect the whole intersection. Thirdly, the narrow road on WB greatly affects turning movements as it takes time for the vehicle to do right-turn movements. For the vehicles turning left, a domino effect happens because of the vehicles' difficulty in turning right on this road. Lastly, the prohibition of left-turn movements at SB shows a decrease in delay. However, this strategy did not show an improvement in the intersection's LOS.

Every evaluated strategy for the improvement of traffic conditions has its advantages and disadvantages. Traffic conditions improved in some traffic directions, while worse in other directions. Based on the results of this study, it is recommended that the phasing of traffic movements be revised and further analyzed. This is easier to implement and takes a shorter period to implement. If this is proven effective, improvement for the traffic condition in Banlic-Mamatid Intersection will be easier. Additional lanes must be built on both sides of the Banlic-Mamatid road to improve the traffic condition on the WB road. In doing this, further planning and preparation need to be done for detailed design and costing, budgeting, securing of right of way, and other necessary works. Although this solution is more tedious to implement than other softer solutions such as the other strategies explored in this study, it may provide even a long-term solution.

Despite these results, it is recommended that further research be done that focuses on the calibration of the input parameters to the study area context. Only the speed parameters were considered in this context. Future research may include conducting a study for the behavior of motorists and pedestrians since people display a variety of behavior including greedy and unexpected biases for the implementation of the traffic rules. Moreover, it is that investigation that considers different times and days to understand further the condition of the Banlic-Mamatid Intersection. Also, assessment of LOS according to the standards set in HCM 2010 developed in the context of the United States may not be the best to use for assessment in the current study context. The traffic conditions in developing countries like the Philippines are exclusively different from those in the US. The development of LOS standards according to the country's context should be developed and used. A methodology for its development may be explored in research.

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