Evaluating Traffic Signal Implementation at Sta. Ana, Pampanga T-Intersection Along Jose Abad Santos Avenue

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***Abstract*: Traffic congestion is one of the most common social and economic transportation problems in urban areas, and it affects the economy, environment, and daily lives of the people. The congestion at the three-way junction or T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga dramatically affects the residents of Santa Ana and the nearby towns such as Arayat and Candaba. This study aimed to determine if installing traffic lights will improve traffic flow in the T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga. The researchers focused on evaluating the effectiveness of installing traffic lights during peak hours provided by the municipal ordinance in Sta Ana, Pampanga, to provide comprehensive data and an understanding of the traffic conditions at the T-intersection. To determine the effectiveness of the traffic lights, the researchers analyzed and compared the data needed, which is traffic volume data, specifically the Level of Service (LOS) of the current T-Intersection and compared it with signalized intersections through computer simulation using PTV Vissim. Based on findings, the data showed that the unsignalized T-intersection has a LOS Rating F and VCR greater than 0.60 and the signalized T-intersection through simulation in PTV Vissim has a LOS rating E. The researchers concluded that the installation of the traffic light would improve the traffic flow of the T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga, as the LOS rating of the intersection improved from F to E after installing the traffic light in the T-Intersection but the overall traffic in the T - Intersection was not fully controlled according to several traffic standards.**

***Keywords*: Computer Simulation, Cycle length, Intersection delay, Level of Service (LOS), Phase Time, PTV Vissim, Volume Capacity Ratio, (VCR).**

1. Introduction

Traffic Congestion is a major transportation problem worldwide, Traffic Congestion is a major transportation problem worldwide, especially in developing third-world countries. Severa (2023) stated several negative impacts of traffic congestion on the daily lives of commuters and business owners, such as reduced productivity and increased operational costs of business industry due to higher fuel consumption.

Jose Abad Santos Avenue is a two to thirteen-lane main road covering provinces from Zambales, Bataan, Pampanga, and Nueva Ecija. The road is 118 kilometers long and was named after Former Chief Justice of the Philippines, Jose Abad Santos. Jose Abad Santos Avenue is the main mode of transportation in the places covered by this road. Specifically, the T-intersection Traffic Congestion is a major transportation problem worldwide, especially in developing third-world countries. Severa (2023) stated several negative impacts of traffic congestion on the daily lives of commuters and business owners, such as reduced productivity and increased operational costs of business industry due to higher fuel consumption.

Jose Abad Santos Avenue is a two to thirteen-lane main road covering provinces from Zambales, Bataan, Pampanga, and Nueva Ecija. The road is 118 kilometers long and was named after Former Chief Justice of the Philippines, Jose Abad Santos. Jose Abad Santos Avenue is the main mode of transportation in the places covered by this road. Specifically, the T-intersection at Jose Abad Santos Avenue in Santa, Pampang, serves as the main route for commuters of citizens of Arayat, Santa Ana, and Candaba to access the City of San Fernando, where most of the economic activity of the area occurs. According to the Department of Public Works and Highways (2023), Jose Abad Santos Avenue sectioning from San Fernando to Santa Ana, Pampanga, has an Annual Average Daily Traffic ranging from 21,028 vehicles on station K0073 + 0, 28,229 vehicles on station K0073 + 0, 34,996 vehicles on station N06639LZ + 0 and 40,183 vehicles on station K0069 + 0.

In the Philippines, the town of Santa Ana, Pampanga, experiences heavy traffic during peak hours; one particular road is the three-way junction or T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga, located in front of Santa Ana Parish Church, Santa Ana Public Market, and Samson Building. The congestion at this intersection dramatically affects not only the residents of Santa Ana but also the nearby towns such as Arayat and Candaba, which causes delays that affect their daily activities, productivity, and mobility.

The condition of the T-intersection in Santa Ana, Pampanga, contributes significantly to the traffic congestion in the area. In the T-intersection, no traffic lights or signs indicate the right of way. The road that leads to Candaba is narrow. Moreover, the streets leading to Arayat and Mexico have two lanes. Still, the absence of proper sidewalks and parking spaces results in vehicles parking in the second lane, reducing the functional capacity of the road. Additionally, heavy pedestrian traffic from nearby establishments such as Santa Ana Parish Church, Santa Ana public market, and Samson building contributes to the congestion, as pedestrians are forced to share the roads with vehicles because of poor sidewalks. These road conditions create congestion, disrupting the movement of commuters and impacting their daily activities.

Traffic lights are an efficient method of controlling traffic on road structures like intersections. Traffic lights signal messages using three different colors, specifically red, amber, and green. These signals assign the right of way of vehicles in an intersection with specific time intervals in a particular section of the intersection. These signals of traffic lights can provide smooth movement of traffic flow in the area (Land Transportation Office, 2023).

This study aimed to determine if installing traffic lights improve traffic flow in the T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga. The overhead traffic lights were placed directly above the stop line on each approach to the road. The effectiveness of the traffic lights was determined by evaluating traffic data specifically ADT (Average Daily Traffic), PCU (Passenger Car Unit), PCEF (Passenger Car Equivalent Factors), and VCR (Volume Capacity Ratio) to calculate the equivalent LOS (Level of Service) of the current T-Intersection in Jose Abad Santos Avenue in Santa Ana, Pampanga and comparing it with signalized intersections through computer simulation using PTV Vissim.

The main objective of this study is to analyze the effectiveness of installing traffic lights in a T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga. This study aims to achieve the following:

- To compute for the Level of Service (LOS) of the unsignalized T-intersection at Jose Abad Santos Avenue in Santa Ana, Pampanga, through manual computation.
- To determine the Level of Service (LOS) of the signalized T-intersection at Jose Abad Santos Avenue in Santa Ana, Pampanga, through computer simulation using PTV Vissim.
- To assess and compare the Level of Service (LOS) of the unsignalized and signalized T-intersection at Jose Abad Santos Avenue in Santa Ana, Pampanga.
- Identify the Optimal cycle length of the traffic signal lights that provides the minimum delay.

2. Methodology

The researchers used a quantitative (Data Collection, Numbers) methods and experimental methods to determine the effectiveness of installing traffic lights in the T-intersection at Jose abad Santos in San Joaquin Santa Ana, Pampanga through digital Simulation, it refers to a systematic approach where it collects and analyze numerical data aiming to quantify and examine variables patterns or relationship, often using statistical method to conclude (Scribbr, 2020)

This study aimed to evaluate if installing traffic lights improve traffic flow in the T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga through computer simulation. The study used a comparative analysis design to determine if traffic lights can improve traffic flow in the area. A systematic approach used to compare two or more entities, variables, or options to determine their similarities, differences, and patterns is called comparative analysis. It is a process of evaluating and assessing the variables to make informed choices, identify patterns, and support problem-solving. (Appinio, 2023)

A. Research Locale

The Municipality of Santa Ana, Pampanga, located in the province of Pampanga in Central Luzon, Philippines, has a total land mass of 15.38 square miles. Which only has a small authority with a percentage of 1.99%, the Traffic congestion in the municipality is prone to congestion, where the primary route connecting Santa Ana to other municipalities in Pampanga (Candaba, Arayat) in Central Luzon, prone to congestion is accrued during the rush hours (6:00 AM - 9:00 AM and 3:00 PM - 7:00 PM) based on the Municipal Order No. 1. Due to current high volume of the vehicles, especially buses and trucks, the Santa Ana Public market is the main focal point of heavy traffic in the municipality the San Fernando- Santa Ana Road is more often congested due to large numbers of vehicles that travel between the two cities.

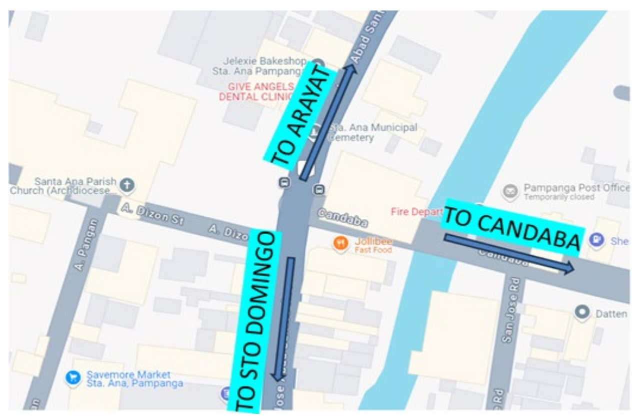

Fig. 1. Coordinates of T-Intersection in jose abad santos avenue in santa ana, pampanga: 15°05'42"N 120°46'11"E

B. Research Instruments

The researchers used personal video recording devices to count traffic volume at the T-intersection in Jose Abad Santos Avenue in Santa Ana, Pampanga, and steel tape measures to measure the road width at the T-intersection. The researchers also used traffic engineering software like PTV Vissim to assess and evaluate traffic data through digital simulation.

1) PTV VISSIM

The researchers used and utilized PTV VISSIM as software to simulate the traffic by gathering data through manual counting to analyze traffic flow at unsignalized intersections in urban areas with variable traffic conditions (Nyame-Baafi et al., 2022); its purpose is to determine the level of service, to analyze intersections and corridors, to determine the traffic signal timings and the cycle lengths and its split offsets. PTV VISSIM is primarily used for traffic signal progressions and its optimization and also in maximizing the complexities of road networks; based on the studies conducted by Atrish (2022), software like PTV VISSIM replicated the movement that allows the user to stimulate and evaluate traffic road accurately. Resolves and addresses the problem in traffic, making effective traffic management plans; overall, the researchers used a PTV VISSIM, which is a powerful tool to improve the flow of traffic on Jasa Road and for potential impact on traffic management in the Area of Santa Ana Pampanga.

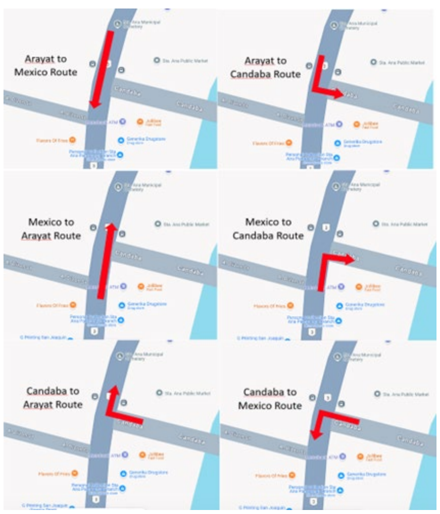

Fig. 2. Routes of T-Intersection in jose abad santos avenue in santa ana, pampanga

C. Data Collection

The data was gathered by submitting a Letter of Intent and requesting Municipal Order No. 1 from the municipality of Santa Ana, which contains the peak hours of Santa Ana, Pampanga. The researchers proceeded by recording the intersection using a recording camera for peak hours from 6:00 AM - 9:00 AM and 4:00 PM - 7:00 PM. The researchers proceeded by manually counting the vehicles in each path of the Intersection for one week and also measured the width of the carriageway of the connecting roads in the intersection. The researchers interpreted the video recording twice to avoid errors and increase the accuracy of the data in the video recording. The computed Average Hourly Volume per route was inputted to PTV Vissim to simulate traffic flow in the Intersection and compare simulated traffic at signalized and unsignalized intersections.

D. Data Analysis

The researchers used quantitative data gathered from the manual counting of vehicles using personal video recording devices from Monday to Sunday during peak hours due to the high volume of vehicles and heavy traffic, specifically from 6:00 AM - 9:00 AM and 4:00 PM - 7:00 PM, based on the given Municipal Ordinance in Sta Ana. Pampanga. The researchers also used traffic assessment standards based on Department Order No.22, Series of 2013 by the Department of Public Works and Highways (DPWH) and in the Highway Capacity Manual to assess and analyze the quantitative data gathered from manual counting procedures.

1) Analysis of Unsignalized Intersection

Average Daily Traffic (ADT) is the number or volume of vehicles in a lane of a road per day in hours at a specific time period ranging from 7 days or less. The following specific formula can compute average daily traffic:

Average Hourly Volume = Total number of vehicles / Total number of hours

ADT = Average Hourly Volume in Peak Hours / Expansion Factors

According to the Highway Capacity Manual, the K factor is the proportion of Average Daily Traffic to the volume present in the analysis hour. K factor or expansion factors differ depending on whether the area is rural or urban. Below are the K-factor equivalents, depending on the area:

Table 1
Relationship of K- K-Factor and area type

Area Type	**K-factor**
Urbanized	0.091
Urban	0.093
Transitioning Urban	0.093
Rural Developed	0.095
Rural Undeveloped	0.100

According to the Department Order No.22, Series of 2013 by the Department of Public Works and Highways (DPWH) (2013), Passenger Car Equivalent Factor and Basic Hourly Car Capacity are constant values used in computing the volume capacity ratio of the traffic flow in a road. Below are the values listed of specific PCEF of each type of vehicle and PCU depending on the road width:

Table 2
Basic hourly car capacity

Carriage Width	**Hourly PCU**	
	Urban	**Rural**
Single < 4 meters	600	600
4 - 5 meters	1200	1200
5.1 to 6 meters	1600	1900
6.1 to 6.7 meters	1700	2000
6.8 to 7.3 meters	1800	2400
2 x 6.7 or 2 x 7.3 meters	6900	7200

Table 3
Passenger car equivalent factor

Vehicle Type		
No.	Description	PCEF
1	Motor and tricycle	2.5
2	Passenger car	1.0

3-5	Passenger bus, good utility bus, and small bus	1.5
6	Large bus	2.0
7	Rigid truck, 2 axles	2.0
8	Rigid truck, 3+ axles	2.5
9	Truck semi-trailer, 3 and 4 axles	2.5
10	Truck semi-trailer, 5+ axles	2.5
11	Truck trailers, 4 axles	2.5
12	Truck trailers. 5+ axles	2.5

Basic Hourly Car Capacity depends on the hourly vehicle capacity of a road depending on the width of the road, and Passenger Car Equivalent Factor depends on the friction of a specific vehicle on the road caused by several loads present in the vehicle. PCEF ranges from 1(lowest friction) to 2.5 (highest friction). A Passenger Car Unit (PCU) is used to compute the capacity of a road. The formula can compute PCU:

PCU = ADT x PCEF

Volume Capacity Ratio (VCR) is a traffic capacity parameter primarily used to identify the capacity and number of vehicles passing a specific road lane or all road lanes on a specified hourly format (at least one hour). According to the Department Order No.22, Series of 2013 by the Department of Public Works and Highways (DPWH) (2013), the ideal Volume Capacity Ratio of a road must have a value of less than or equal to 0.60 as prescribed in the Department's Highway Planning Manual and also road width must have a minimum length of 3.05 meters. The Volume Capacity Ratio can be computed by the formula:

VCR = (PCU*0.08)/BHCC

Legend:

ADT = Average Daily Traffic

BHCC = Basic Hourly Car Capacity (in PCU)

Hourly Design Volume = 8% of ADT in PCU

PCU = Passenger Car Unit

PCEF = Passenger Car Equivalent Factors

VCR = Volume to Capacity Ratio

The Department of Public Works and Highways (DPWH) (2013) stated that a VCR of 0.60 or greater in an area must be given action to solve traffic, like traffic signals and signs, road widening or other traffic engineering infrastructures to be implemented over five years to solve traffic congestion in the area.

Level of Service (LOS) is a qualitative measure used in transportation engineering to evaluate the operational conditions of a roadway or intersection and assess and identify the quality of a road condition as stated in the Highway Capacity Manual. LOS is used to assess and analyze road and traffic conditions like speed, density and delay. Below is a table showing the relationship between VCR and traffic conditions which is used to identify LOS.

Table 4
Level of service

Level of Service	Traffic Condition	VCR
Level A	free-flowing traffic, unimpeded free-flow speed (FFS) with vehicles able to maneuver with almost no obstruction.	less than 0.20
Level B	relatively free-flowing traffic, FFS is maintained, and motorists are only slightly restricted from being able to maneuver between lanes.	between 0.21 and 0.50
Level C	moderate traffic, driver speeds are near the FFS, and maneuvering requires driver focus and care	between 0.51 and 0.70
Level D	Moderate/heavy traffic, density increases faster, and speed begins to decline. There is limited ability for drivers to maneuver, and drivers experience reduced comfort	between 0.71 and 0.85
Level E	Heavy traffic, Traffic is operating at near capacity, and there is little to no room for drivers to maneuver between lanes. Any changes, such as merging vehicles, will cause upstream disruption	between 0.86 and 1.00
Level F	Saturation traffic volumes, stop-and-go situations, there is breakdown of traffic and unstable flow resulting from a bottleneck at a downstream point	greater than 1.00

Table 5
Level of service for signalized intersection

Level of Service	Delay (SECS.)	Description
LOS A	<10.00	Free Flow/Insignificant Delays - it is a representation correlated to free flow conditions in any insignificant delays, or minimal delays. where no vehicle waits or most of the vehicle don’t stop
LOS B	10.1-20.0	Stable operation/Minimal Delays - infrequently approach phases that are fully utilized, a stable operation with a minimal delay, and drivers approaches on restriction.
LOS C	20.1-35.0	Stale Operation/Acceptable Delays - stable operation with acceptable delays, delays are more moderated and major phases are being fully utilized, cycle failures start to appear at the level with its significant number of vehicles.
LOS D	35.1-55.0	Approaching Unstable/Tolerable Delays - it approaches the instability of the delays where drivers wait through the red lights, and where the congestion starts to show.
LOS E	55.1-80.0	Unstable Operation/Significant Delays - operation where it is in an unstable state with its significant delays in vehicles in signal cycles.
LOS F	>80.0	Forced Flow/Excessive Delays - forced flow with excessive delays, conditions are jammed, traffic arrivals are greater than intersection capacity, leading to constrained delays, contributing to factors that include poor signal progression.

2) Analysis of Simulated Signalized Intersection

The researchers used traffic engineering software, specifically PTV Vissim, to evaluate and assess traffic data gathered in the T-Intersection on Jose Abad Santos Avenue in Santa Ana, Pampanga. The software was able to locate the exact location of the area and edit road features of the intersection, specifically road length and width. The software was also able to simulate and provide accurate traffic flow based on traffic data gathered like Level of Service and interpret intersection delays in the intersection. In addition, in simulating signalized intersections, specific cycle lengths were assessed and applied to the signal lights to compare traffic simulations with different cycle lengths. Lastly, the researchers compared and evaluated the effectiveness of signal lights in the traffic flow in the simulation under signalized intersections. After the simulation of signalized and unsignalized intersections, traffic data, specifically LOS and intersection delay was presented. The data presented was assessed and evaluated depending on the LOS (A to F) and the severity of the intersection delays.

Table 6
Maximum green light of a cycle length

Phase Volume per Lane (veh/hr/lane)	**Cycle length, s**							
	50	**60**	**70**	**80**	**90**	**100**	**110**	**120**
	Maximum Green, s							
100	15	15	15	15	15	15	15	15
200	15	15	15	15	16	18	`19	21
300	15	16	19	21	24	26	29	31
400	18	21	24	28	31	34	38	41
500	22	26	30	34	39	43	47	51
600	26	31	36	41	46	51	56	61
700	30	36	42	48	54	59	65	71
800	34	41	48	54	61	68	74	81

acceleration delay, the evaluation of signal intersection involves in calculating level of service (LOS) it also referred to the control or signal delay. Below are all the levels of delay and their correlation with the LOS ratings.

According to US Department of Transportation (2021), each cycle length can be used depending on the volume of vehicles passing per hour. Each volume has a corresponding maximum green light time on planning the cycle length of a signal light. Also, the minimum allowable yellow light used in speed caution is 3 seconds.

3. Results and Discussion

The results of the study aimed to present the data gathered from the manual counting method in the T-intersection in Jose Abad Santos Avenue in Santa Ana, Pampanga at peak hours from 6:00 AM - 9:00 AM and 4:00 PM - 7:00 PM for one week. The researchers inputted the data gathered in specialized traffic engineering software to simulate the traffic in an signalized intersection. The results presented in the simulation was assessed and evaluated to determine if installing traffic lights in the intersection can improve the traffic flow.

A. Area and Traffic Analysis

The researchers used a manual counting method to identify and assess traffic volume in the T- Intersection of Jose Abad Santos Avenue in Santa Ana, Pampanga, at peak hours from 6:00 AM - 9:00 AM and 4:00 PM - 7:00 PM based on the Municipal Order No. 1 from the municipality of Santa Ana. Based on the manual counting method, the average volume of vehicles observed in one week on 6 available routes- Arayat to Mexico, Arayat to Candaba, Candaba to Mexico, Candaba to Arayat, Mexico to Arayat and Mexico to Candaba are 650, 456, 649,532, 540 and 537, respectively. The data represents that at least 450 vehicles are crossing per route per hour and at least 1000 vehicles are crossing per entry point per hour at the intersection. In the T-intersection, the estimated road width of the carriageway at Mexico, Arayat and Candaba are 4.5 meters, 6 meters and 3.15 meters, respectively, which are used on the Basic Hourly Car Capacity stated in Table 2.

Table 7
Level of service of candaba as an entry point

Type	**ADT**	**PCEF**	**PCU**
Motorcycle	2560	2.5	6400
Tricycle	2603	2.5	6508
Passenger Car	861	1	861
Passenger, Goods Utility andd Small (Carmexss) Buses	194	1.5	291
Large Bus	0	2	0
Rigid Truck (2Axles)	108	2	216
Rigid and Trailer Truck (3+ Axles)	54	2.5	135
TOTAL:	6380		14411

Intersections connect several road sections in other directions at a main point. With this, vehicles in intersections often reduce speed or completely stop to give way to other vehicles. The sudden reduction in speed and stop in an intersection in a vehicle while in an intersection is called an intersection delay. Intersection delay can be influenced by vehicles passing and giving way to each other, pedestrians crossing the intersection, and signal lights. The delay includes vehicle movements at slower speeds or stopping at an intersection as vehicles approach factors like other vehicles, pedestrian crossing, stop-and-go yields and signal lights. Delays in an intersection can identify the level of service (LOS) of a unsignalized and signalized intersection (Highway Capacity Manual 2000, n.d.).

According to Highway Capacity Manual, the signalized intersection, is being determined by the experienced of the average vehicle delay that currently entering the intersection, this includes delay on several factors, such as the move up time,

Moreover, the T-Intersection of Jose Abad Santos Avenue in Santa Ana, Pampanga, is located at San Joaquin, Sta Ana, Pampanga. According to the Philippine Statistics Authority (2024), Brgy. San Joaquin in Sta Ana, Pampanga, is considered an urban area with a population of 3,143 residents in 2020.

Table 9
Level of service of aray at as an entry point

Type	ADT	PCEF	PCU
Motorcycle	2646	2.5	6615
Tricycle	1925	2.5	4813
Passenger Car	1011	1	1011
Passenger, Goods Utility and Small (Carmexss) Buses	183	1.5	275
Large Bus	44	2	88
Rigid Truck (2Axles)	130	2	260
Rigid and Trailer Truck (3+ Axles)	44	2.5	110
TOTAL:	5983		13172

Thus, the K-Factor used according to Table 1 is 0.093 or 9.3% and the urban counterpart or road width per lane was used in the Basic Hourly Car Capacity in Table 2.

B. Computation and Presentation of Level of Service of Unsignalized Intersection

VCR = (PCU*0.08)/BHCC
Carriageway Length = 3.15 meters
BHCC(Urban) = 600

Table 8

VCR	1.92
LOS	F

Based on the data presented in Table 7, the Volume Capacity Ratio of Candaba as an entry point is 1.92 with a corresponding Level of Service of F based on Table 4. This indicates that the entry point experiences saturated traffic volumes and breakdown of traffic and unstable flow. Also, the computed VCR in the entry point is greater than 0.60, which indicates that the area must implement traffic congestion solutions in the next five years to solve traffic congestion in the area.

VCR = (PCU*0.08)/BHCC
Carriageway Length = 6 meters
BHCC(Urban) = 1600

Table 10

VCR	0.66
LOS	C

Based on the data presented in Table 9, the Volume Capacity Ratio of Arayat as an entry point is 0.66 with a corresponding Level of Service of C based on Table 4. This indicates that the entry point experiences moderate traffic with driver speeds are near the free-flow speed. Also, the computed VCR in the entry point is greater than 0.60, which indicates that the area must implement traffic congestion solutions in the next five years to solve traffic congestion in the area.

VCR = (PCU*0.08)/BHCC
Carriageway Length = 4.5 meters
BHCC(Urban) = 1200

Table 12

VCR	0.85
LOS	D

Table 11
Level of service of mexico as an entry point

Type	ADT	PCEF	PCU
Motorcycle	2280	2.5	5700
Tricycle	2011	2.5	5028
Passenger Car	1011	1	1011
Passenger, Goods Utility and Small(Carmexss) Buses	259	1.5	389
Large Bus	44	2	88
Rigid Truck (2Axles)	162	2	324
Rigid and Trailer Truck (3+ Axles)	65	2.5	163
TOTAL:	5832		12703

Based on the data presented in Table 9, the Volume Capacity Ratio of Mexico as an entry point is 0.85 with a corresponding Level of Service of D based on Table 4. This indicates that the entry point experiences moderate to heavy traffic, with density increases faster and speed begins to decline. Also, the computed VCR in the entry point is greater than 0.60, which indicates that the area must implement traffic congestion solutions in the next five years to solve traffic congestion in the area.

As presented by the data shown by three entry points in the intersection in Table 10, the Volume Capacity Ratio of Candaba, Arayat and Mexico as entry points are 1.92, 0.66 and 0.85 and LOS rating of F, C and D. The overall average Volume Capacity Ratio of the T - Intersection is 1.14 with LOS rating

Table 13
Average volume capacity ratio and level of service of entry points in the intersection

Entry Point	VCR	LOS
Candaba as Entry Point	1.92	F
Arayat as Entry Point	0.66	C
Mexico as Entry Point	0.85	D

Road	Average Volume Capacity Ratio	Level of Service
T - Intersection at Jose Abad Santos in San Joaquin, Sta Ana, Pampanga	1.14	F

of F. This indicates that the T- intersection experiences saturated traffic volumes and breakdown of traffic and unstable flow. Also, the computed VCR in the T - Intersection is greater than 0.60, which indicates that the area must implement traffic congestion solutions and traffic mitigation practices on the next five years to solve and alleviate traffic congestion in the area.

C. Presentation of Level of Service of Simulated Signalized Intersection

The researchers used the average volume of vehicles per hour for the simulation of signalized intersection using PTV Vissim. Vehicle types present in the manual counting procedure was assessed in the simulation. Furthermore, after editing and optimizing road and vehicle parameters in the software, signal lights was added with different cycle lengths and phase times. Cycle lengths of 60, 90, and 120 seconds was used in the simulation, which is based and adapted from the National Association of City Transportation Officials, in order to find the optimal cycle length needed for a traffic light to control traffic in the area. The specific time allotted from red, amber, and green signals of a traffic light was identified and entered in the software which is based on Table 5 and the Federal Highway Association, and signal groups were assigned in each route in the T - Intersection. Phase time or green time of a traffic depends on the number of vehicles present in a signal group or entry points, thus, phase times for each group differ depending on the number of vehicles present in each entry point for more accurate and optimal results of the simulation. The simulation of the T - Intersection was to identify LOS and intersection delay based on Table 5 which was used to compare the LOS of the unsignalized intersection and the signalized simulation of the intersection with specific cycle lengths and phase times and the. Below are the different phases used in the study to identify and optimize the LOS and intersection delay:

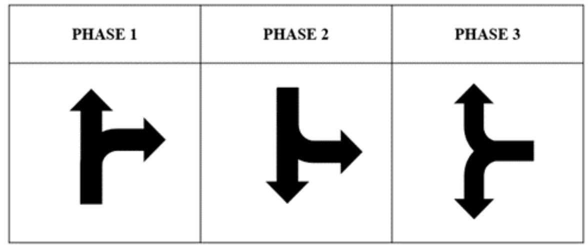

Fig. 3. Phase movement per entry point

Based on the data presented in Table 14, the average intersection delay of the T- Intersection is 72.66 seconds with a corresponding Level of Service of E. According to Highway Capacity Manual, this indicates that the simulated signalized intersection with a cycle length of 60 seconds can have a volume near the road capacity and vehicles may wait for signal cycles.

Based on the data presented in Table 15, the average intersection delay of the T- Intersection is 74.70 seconds with a corresponding Level of Service of E. According to Highway Capacity Manual, this indicates that the simulated signalized intersection with a cycle length of 90 seconds can have a volume near the road capacity and vehicles may wait for signal cycles.

Based on the data presented in Table 16, the average intersection delay of the T- Intersection is 76.57 seconds with a corresponding Level of Service of E. According to Highway Capacity Manual, this indicates that the simulated signalized intersection with a cycle length of 120 seconds can have a volume near the road capacity and vehicles may wait for signal cycles.

Table 14
PTV VISSIM Simulation results (60-second cycle length)

Route	**Phase Time (in seconds)**	**Intersection Delay (in seconds)**	**Level of Service**
Mexico to Candaba	18	78.30	E
Mexico to Arayat	18	86.30	F
Candaba to Mexico	24	55.62	E
Candaba to Arayat	24	55.61	E
Arayat to Candaba	18	82.59	F
Arayat to Mexico	18	92.69	F

Road	Average Intersection Delay (in seconds)	Level of Service
T - Intersection at Jose Abad Santos in San Joaquin, Sta Ana, Pampanga	72.66	E

Table 15
PTV VISSIM Simulation results (90-second cycle length)

Route	Phase Time (in seconds)	Intersection Delay	Level of Service
Mexico to Candaba	27	82.67	F
Mexico to Arayat	27	82.57	F
Candaba to Mexico	36	65.85	E
Candaba to Arayat	36	63.47	E
Arayat to Candaba	27	76.05	E
Arayat to Mexico	27	84.68	F

Road	Average Phase Time (in seconds)	Level of Service
T - Intersection at Jose Abad Santos in San Joaquin, Sta Ana, Pampanga	74.70	E

Table 16
PTV VISSIM Simulation results (120-second cycle length)

Route	Phase Time (in seconds)	Intersection Delay	Level of Service
Mexico to Candaba	37	76.39	E
Mexico to Arayat	37	83.13	F
Candaba to Mexico	46	64.63	E
Candaba to Arayat	46	70.25	E
Arayat to Candaba	37	88.59	F
Arayat to Mexico	37	82.86	F

Road	Average Phase Time (in seconds)	Level of Service
T - Intersection at Jose Abad Santos in San Joaquin, Sta Ana, Pampanga	76.57	E

1) Comparison of Level of Service of Unsignalized and Simulated Signalized Intersection

Table 17
Comparison of level of service of unsignalized and simulated signalized intersection

Cycle Length	Level of Service
0 seconds (unsignalized)	F
60 seconds	E
90 seconds	E
120 seconds	E

As presented by the data shown by Tables 14-16 and Table 14, the Level of Service of the unsignalized intersection is F and the Level of Service and intersection delay of the simulated signalized intersection are: E with delay of 72.66 seconds for 60-second cycle length, E with delay of 74.70 seconds for 90-second cycle length, and E with delay of 76.57 seconds for a 120 - second cycle length. It is shown that a cycle length of 60 seconds with a Level of Service of E with a delay of 72.66 seconds is the most suitable option among the analysis of three proposed cycle lengths. A study conducted by US Department of Transportation (2021) stated that the use of shorter cycle length is one of the most effective methods in controlling oversaturated traffic conditions. Reduced cycle duration allows for more frequent servicing of all traffic movements, with only a slight increase in lost time during peak hours. The shorter cycle gives more equal servicing of all movements as it allows drivers to visibly observe progress even if it takes multiple cycles to be served at a given intersection This indicates that the simulated signalized intersection can have a volume near the road capacity and vehicles may wait for signal cycles based on the Highway Capacity Manual. According to Thurston Regional Planning Council (2020), A Level of Service of C or lower is recommended in rural areas, a Level of Service of D or lower for transitioning areas and urban areas and a Level of Service of E or lower on urbanized or urban-centered areas like a metropolis. Even though the Level of Service of the simulated signalized intersection, which is E, compared to the Level of Service of the unsignalized intersection, which is F, the intersection experiences almost full or near capacity of volume of vehicles. there is little to no room for drivers to maneuver between lanes and vehicles may wait for signal cycles. This proves that the overall level of service of the T - Intersection improved from F to E based on the cycle length of 60 seconds, overall traffic of the area has not yet fully controlled based on the regional Level of Service standards of Thurston Regional Planning Council.

4. Summary, Conclusion and Recommendations

This chapter aimed to present the summary and conclusion of the results of unsignalized intersection and signalized intersection with specific cycle lengths and phase times through simulation in PTV Vissim. Also, the researchers suggested recommendations for the improvement and optimization of related studies in the future that are inclined with this topic.

A. Summary

The researchers gathered data from a manual counting method in the T-Intersection at Jose Abad Santos Avenue in Sta. Ana, Pampanga. The data gathered was used to compute the VCR and LOS of the actual intersection and average volume was used for simulation of signalized intersection with different cycle lengths in PTV Vissim.

The overall T - Intersection has an average volume vehicles per hour of 650, 456, 649,532, 540 and 537 on routes: Arayat to Mexico, Arayat to Candaba, Candaba to Mexico, Candaba to Arayat, Mexico to Arayat and Mexico to Candaba. The Volume Capacity Ratio of Candaba, Arayat and Mexico as entry points are 1.92, 0.66 and 0.85 and LOS rating of F, C and D with an average VCR of 1.14 and LOS of F in the T- Intersection. This indicates that the actual T- Intersection experiences saturation traffic volumes with stop-and-go situations,

In the simulation of signalized intersection in PTV Vissim, 60, 90 and 120 second-cycle length was used. The Level of Service and intersection delay of the simulated signalized intersection are: E with delay of 72.66 seconds for 60-second cycle length, E with delay of 74.70 seconds for 90-second cycle length, and E with delay of 76.57 seconds for a 120-second cycle length, with the 60-second cycle length being the most suitable cycle length.

B. Conclusion

Based on the findings, the unsignalized T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga, has a VCR 1.14 and LOS Rating F. LOS Rating F based on table 4.0 indicates that the traffic flow is forced with excessive delays. The conditions are jammed, traffic arrivals rated are greater than the intersection capacity, leading to constrained delays, contributing to the factors that include signal progression. Also, this proves that the actual T- Intersection has a VCR greater than 0.60, thus suggesting that the intersection requires traffic mitigation measures like traffic signals and signs, road widening or other traffic engineering infrastructures to be implemented over five years to solve traffic congestion in the area.

On the other hand, the signalized T-Intersection at Jose Abad Santos in San Joaquin, Santa Ana, Pampanga, through simulation in PTV Vissim, with a cycle length of 60 seconds, 90 seconds, and 120 seconds, has an LOS rating E and the 60-second cycle length shows the optimal result. LOS rating E based on Table 4.0 indicates that the traffic flow is Heavy, the traffic is operating at near capacity, and there is no little to no room for driver for changing lanes and any changes, such as merging vehicles cause upstream disruption and vehicles may experience several signal cycles before crossing the desired route. Based on the simulation results, the 60-second cycle length achieved the optimal results among the three cycle lengths and this proves that shorter cycle lengths can improve traffic flow more efficiently according to the US Department of Transportation.

The results concludes that the data supports the assumption, that the installation of traffic lights at the T- Intersection at Jose Abad Santos Avenue in Santa Ana, Pampanga, as tested in the simulation improve the traffic flow of the intersection as the LOS rating of the intersection improved from F to E after installing traffic light in the T-Intersection. Even though that the LOS improved from F to E, the simulated signalized intersection operates at near capacity and installation of traffic lights in the area reduces delay and optimize the condition of traffic in the area but the overall traffic of the area has not yet fully controlled based on the regional Level of Service standards of Thurston Regional Planning Council.

C. Recommendations

1. It is recommended that future researchers utilize the use of the full version of PTV Vissim for the full potential of the study.
2. It is recommended that future researchers collect traffic volume data over a continuous 24-hour period which could help in traffic signal assessment.
3. It is recommended that future researchers include the manual counting of pedestrian activity together with the motorized vehicles which can provide insights into how traffic signals impact both vehicles and pedestrians.
4. It is recommended that future researchers design a traffic signal program that suits the three (3) roads of the intersection which can make the level of service of the road better.
5. To reduce high traffic, the Municipality of Sta. Ana, Pampanga should enforce a strict policy regarding parking regulations to maximize road capacity.
6. The Municipality of Santa Ana, Pampanga should assign traffic and/or police officials to regulate the parking of other vehicles and vendors on one side of the street.

References

[1] J Appinio Blog. (2023). What Is Comparative Analysis and How to Conduct It? Appinio Blog. https://www.appinio.com/en/blog/market-research/comparative-analysis.

[2] Bee Maps. (2024). “How Long Is the Wait at a Typical Traffic Light?” https://beemaps.com/blog/how-long-are-traffic-lights.

[3] Cabrera, R., et al. (2020). Traffic signal synchronization and its impact on traffic flow. Pampanga Traffic Management Office.

[4] City of Elmira. (2024). Why Do I Have to Wait so Long after I Stop at a Specific Signal. https://www.cityofelmira.net/FAQ.aspx?QID=86.

[5] Department of Public Works and Highways. (2013). DO_022_S2013. Retrieved from https://www.dpwh.gov.ph/dpwh/sites/default/files/issuances/DO_022_S2013.pdf

[6] Dizon, C., & Ramos, J. (2020). The impact of traffic volume on the effectiveness of traffic light systems. University of the Philippines Traffic Studies.

[7] Garcia, F., et al. (2020). Adoption of adaptive traffic systems: A case study in San Fernando. Pampanga City Planning Office.

[8] LTO Philippines. (n.d.). Retrieved from https://lto.gov.ph/wp-

[9] Manila LGU. (2025). No apprehension during rush hour. Philippine News Agency. Retrieved from https://www.pna.gov.ph/articles/1230816

[10] Miguel, C. G. B. (2023) EDSA traffic advisory: Peak hours, rules, estimated travel time & more. Retrieved from https://philkotse.com/safe-driving/edsa-traffic-advisory-peak-hours-rules-estimated-travel-time-more-5752

[11] Muchlisin, I. T., & Widodo, W. (2020). Optimization model of unsignalized intersection to signalized intersection using PTV VISSIM: Study case in Imogiri Barat and Tritunggal intersection, Yogyakarta, Indonesia.

[12] Mutcd. (2023.). 11th Edition MUTCD. Retrieved from https://mutcd.fhwa.dot.gov/pdfs/11th_Edition/mutcd11thedition.pdf

[13] Navarro, S. J. (2008). Highway Capacity Manual. Retrieved from https://sjnavarro.wordpress.com/wp-content/uploads/2008/08/highway_capacital_manual.pdf

[14] Othayoth, D., & Rao, K. K. (2020). Investigating the relation between level of service and volume-to-capacity ratio at signalized intersections under heterogeneous traffic conditions. Transportation Research Procedia, 48, 2929-2944.

[15] Pangilinan, M., et al. (2020). Smart traffic systems in Pampanga: Benefits and challenges. Angeles City Traffic Bureau.

[16] Penny, S. (2021). Level of service: Defining scores for different transportation facilities. SMATS. Retrieved from https://www.smatstraffic.com/2021/07/26/level-of-service/

[17] Philippine Statistics Authority. (2024). Barangay classification. Retrieved from https://psa.gov.ph/classification/psgc/barangays/0305419000

[18] Plocova, K., & Fibich, D. (2020). Design traffic lights for atypical intersection. International Multidisciplinary Scientific GeoConference: SGEM, 20(6.1), 531-538.

[19] Raghu, K., Kumar, R., & Singh, A. (2020). Comparative analysis of signalized and unsignalized T-intersections in urban settings. Journal of Transportation Engineering, https://www.researchgate.net/publication/376547553_Signalized_and_Unsignalized_Road_Traffic_Intersection_Models_A_Comprehensive_Benchmark_Analysis/reference

[20] Ramos, A. (2020). Urban design and traffic light efficiency in high-traffic areas of Pampanga. Metro Manila Transport Research.

[21] Santos, B., et al. (2020). Effectiveness of traffic light synchronization in urban areas. Angeles City Transport Research.

[22] Santos, B., et al. (2020). Public perception and effectiveness of traffic signal synchronization in San Fernando. Angeles City Transport Research

[23] .Scribbr (2020) What is Quantitative Research? Definition, Uses and Methods Scribbr https://www.scribbr.com/methodology/quantitative-research/

[24] Signal Cycle Lengths. North American Cities and Transit Agencies (NACTO) (2025),

https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/traffic-signals/signal-cycle-lengths/.

[25] Think Transportation. (2025). Traffic simulations software: A comparison of SUMO, PTV VISSIM, Aimsun, and Cube. Retrieved from https://thinktransportation.net/traffic-simulations-software-a-comparison-of-sumo-ptv-vissim-aimsun-and-cube/

[26] Traffic Signal Timing Manual: Chapter 5 - Office of Operations. (2021). Federal Highway Administration. Retrieved from https://ops.fhwa.dot.gov/publications/fhwahop08024/chapter5.html

[27] Thurston Regional Planning Council (2020), WA. Retrieved from https://www.trpc.org/.

[28] Villaluz, A. J. A. (2023, June). Efficient utilization of traffic lights in common congested areas. Transportation Research Part C: Emerging Technologies, 2020, Mobile Crowdsourcing, Intelligent Transport System, Intersection Congestion.

[29] Washington State Department of Transportation (2021). Traffic Signals. Retrieved from https://wsdot.wa.gov/travel/operations-services/traffic-signals