Optimizing Road Intersection Design for Improved Traffic Management in Bucana, Gapan City, Nueva Ecija using PTV VISSIM

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Abstract: This study focuses on traffic congestion in the Philippines, particularly in cities such as Bucana, Gapan City, Nueva Ecija. Despite adjustments, the intersection continues to be inefficient, producing severe traffic congestion. This study examines how intersection design influences travel time, traffic flow, and safety. This study considered road widths, traffic volume, city ordinances, and traffic control devices. The study utilized PTV Vissim, a multimodal traffic simulation software, to analyze potential changes and offer long-term traffic control solutions. It examined travel durations, traffic volume, and safety measures to comprehensively describe the Level of Service (LOS) for efficient traffic management.

Keywords: Traffic policies, Level of Service, road intersection design, traffic management, multimodal traffic simulation software

1. INTRODUCTION

According to a recent report on traffic dynamics, the Philippines faces increasing congestion caused by vehicles, particularly in urban areas. Numbeo (2024) reported on their 2024 mid-year traffic index report that the Philippines placed second to the most pronounced vehicular congestion among six Southeast Asian nations and securing the 15th position globally. This demonstrates the urgent need to address this issue by examining the complicated interconnection of factors contributing to traffic patterns.

The current assessment of the Philippine Institute for Development Studies (PIDS) determined that the Philippines needs more adequate and better-quality road and rail transport infrastructure (Navarro & Latigar, 2022). With the current state of transportation facilities, transportation problems have been becoming severe, especially in road intersections, which are primarily vulnerable to transportation problems.

O'Flaberty (1997) defines intersections (where two or more roads meet) as vehicle conflict points. Similarly, Mchsane *et al.* (1998) noted that there are many potential and actual conflicts at no other location within the street and highway systems than at road intersections.

The study aims to comprehensively understand intersectional features on the road in Bucana, Gapan City, Nueva Ecija. As stated by Secretary Bonoan, DPWH projects in the city are crucial support to the rapid urbanization of Gapan City which is considered as the premiere city in Nueva Ecija's fourth congressional district (DPWH, 2024). Using a multimodal traffic simulation software, the improvement proposals on the highly congested intersection at Bucana, Gapan City, Nueva Ecija can be evaluated and used to assess improvement on the traffic characteristics of the intersection.

2. REVIEW OF RELATED LITERATURE

Traffic policies play a significant role in managing traffic flow in a roadway. The study by Bahrami and Roorda (2020) looks for ways traffic management will be uplifted in certain areas. These policies aim to reduce traffic jams and make a difference in the expectation of traffic. The study found that the best way to make traffic flow smoothly depends on traffic volume and capacity.

The current approach to developing and implementing traffic policies often involves direct experimentation on the streets. While government agencies have conducted infrastructure impact evaluations using traditional methods, the drawback is the need for an extended analysis period between the before and after stages. In the initial stages of planning new projects, there is a need for quick assessments to justify the endeavors, where advanced tools like simulation and software prove more practical and efficient than conventional methods, including direct experimentation (Regidor, 2004).

PTV VISSIM and other microscopic traffic flow models allow for a thorough examination of intersections and road networks. This software helps improve city logistics and develop sustainable urban traffic systems. PTV VISSIM assists in evaluating various intersection designs and developing effective traffic management methods by simulating real-world traffic. In order to assess the possible effects of intersection reconstruction on traffic flow and city logistics in the surrounding area, the study by Kucera and Chocholac (2021) focuses on using PTV VISSIM to build a simulation model for traffic infrastructure planning at a significant intersection in Pardubice, Czech Republic.

2.1 Synthesis and Justification

The viewpoint provided by the Federal Highway Administration (2009) regarding intersections in the United States is a valuable resource that emphasizes how vital well-designed intersections are for improving road safety and traffic management. The study will benefit from this global viewpoint in the Philippines. It will highlight the necessity of creating strong traffic laws based on national transportation laws like Republic Act No. 4136 and the National Transport Policy.

This study is informed by prior research from Indonesia, India, and Nigeria on the Level of Service (LOS) metric, which provides a consistent approach to evaluating intersection performance (Osuolale *et al.*, 2019). It illustrates how crucial it is to assess variables like delays and traffic congestion to determine how effective traffic management strategies are. The study integrates knowledge from previous research on road intersection design in Bangladesh, Nigeria, and Italy. These studies highlight the importance of geometric design for road safety and functionality and provide examples of potential solutions for complex intersection layouts.

The study's research approach is informed by multimodal traffic simulation software, as evidenced by studies conducted in the Philippines, Iraq, and the Czech Republic.

2.2 Theoretical Framework

Road intersection design optimization is significant, especially in metropolitan contexts with dense populations and diverse traffic dynamics, such as Bucana, Gapan City, Nueva Ecija. Reducing traffic, increasing safety, limiting environmental effects, and optimizing vehicle flow all depend on effective traffic management.

This research combines multiple disciplines, such as infrastructure engineering, traffic flow dynamics, and urban planning concepts, to create a comprehensive approach to road intersection design. This study aims to expand the understanding of how various design configurations and traffic management strategies affect overall traffic performance and user experience. Traffic flow theory, pioneered by visionaries like John Glen Wardrop in the mid-20th century, offers a theoretical foundation for understanding the complex interactions between vehicles, pedestrians, and the built environment.

This research will consider practical aspects, including traffic laws, regulatory structures, LOS requirements in road intersection design, and theoretical developments. It will analyze the current policies and regulations governing Bucana, Gapan City, Nueva Ecija traffic management. This study intends to identify opportunities for aligning proposed intersection designs with local legal and operational requirements, thereby ensuring the feasibility and sustainability of implementation.

2.3 Statement of the Problem

The main objective of this study is to propose enhancements to optimize the existing road intersection design and traffic management policies in Bucana, Gapan City, Nueva Ecija, addressing traffic congestion and validate the enhancements using multimodal traffic simulation software.

Specifically, this study aims to address the following:

1) Identify the traffic policies governing the road intersection design in Bucana, Gapan City, Nueva Ecija.
2) Classify the LOS resulting from the road intersection design in Bucana, Gapan City, Nueva Ecija in terms of travel time, traffic volume, and safety.
3) Analyze possible enhancements to the existing road intersection design in Bucana, Gapan City, Nueva Ecija to achieve more effective traffic management and alleviate congestion.
4) Create an optimized road intersection design improving the traffic management in Bucana, Gapan City, Nueva Ecija.
5) Evaluate the optimized road intersection design using the PTV VISSIM multimodal traffic simulation software in determining the effectiveness of optimizing the road intersection design in Bucana, Gapan City, Nueva Ecija.

2.4 Hypotheses of the Study

The following hypotheses are tentative answers expected in the study.

H_0: There is no significant difference in the LOS between the existing and optimized road intersection designs.

H_1: There is a significant difference in the LOS between the existing and optimized road intersection designs.

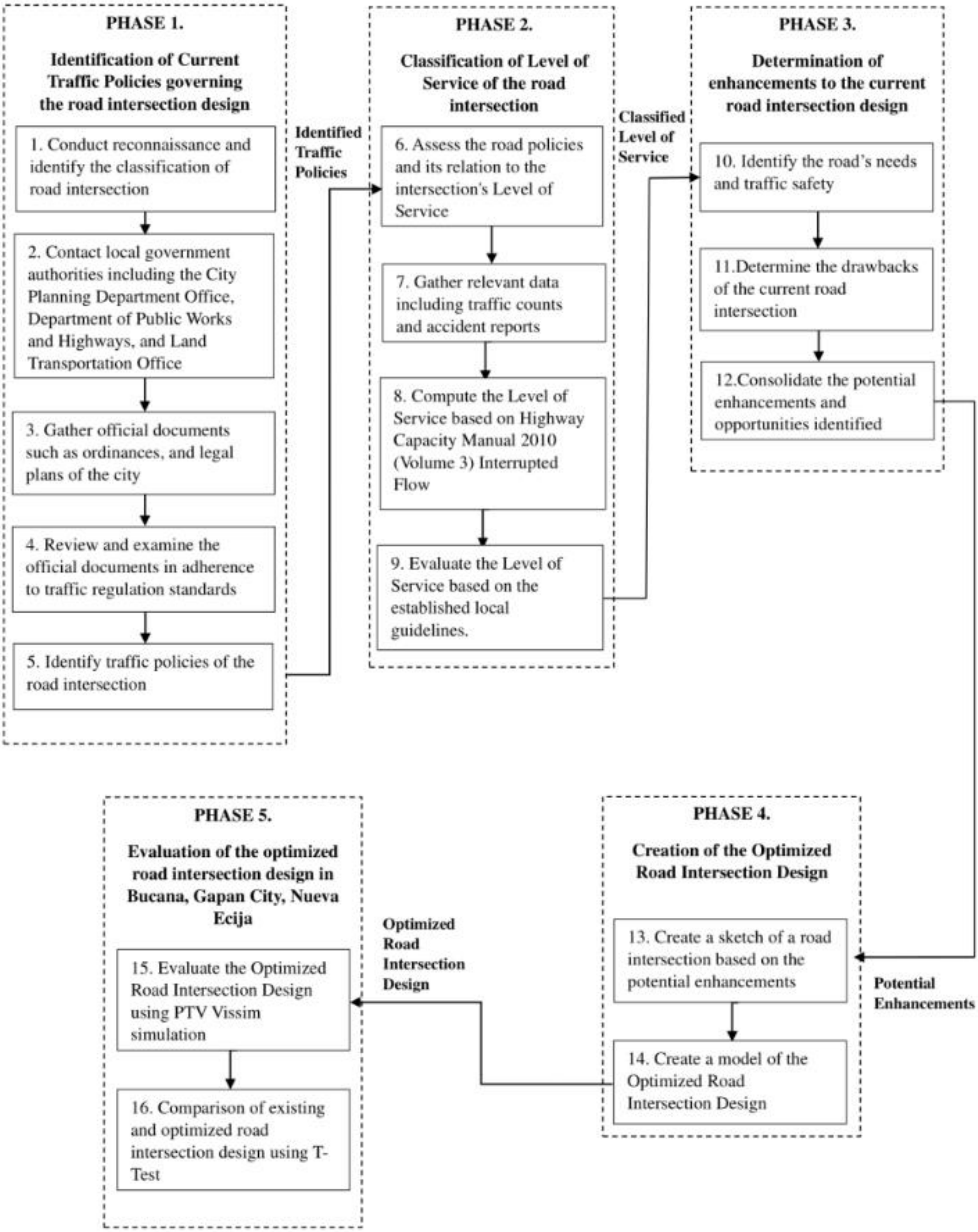

Figure 1. Conceptual framework

2.5 Significance of the Study

The result of the study will contribute statistics and benefit the various sectors as follows:

Engineers. Engineers will benefit from this research regarding guidelines and data to better understand road intersection designs. This will also provide them with guidelines for reducing risks associated with traffic, promoting a safer atmosphere, and improving traffic efficiency.

Community. This research will help improve traffic flow and lessen congestion. It can significantly improve the community's economic health, increase productivity, reduce fuel use, and lower overall expenses for commuters and companies.

Local Government. The optimized road intersection design can be used by the local government authorities to update traffic laws and policies better to reflect the demands and characteristics of the particular community.

Department of Public Works and Highways (DPWH) and other stakeholders. The study can become a guide for a strategic investment in transportation infrastructure. Stakeholders can allocate resources more effectively by prioritizing improvements to road intersection design based on the research findings, resulting in a more targeted and impactful use of public funds.

Future Researchers. Future researchers can use this study as a reference for their future manuscripts and as a basis for studies related to the optimization of road intersection design.

2.6 Scope and Limitation of the Study

This study focuses on understanding and examining the road intersection design and the current traffic flow patterns in Bucana, Gapan City, Nueva Ecija to provide an optimized road intersection design and traffic management validated through multimodal traffic simulation software. The study examined peak traffic hours, and assessed the current intersection layout. This study is conducted in the Academic Year 2023–2024.

The study's findings and recommendations are exclusive to Bucana, Gapan City, Nueva Ecija. These may not be applicable to other areas with distinct urban settings, infrastructure, or traffic patterns. The accuracy and credibility of the research outcomes are influenced by the quality and availability of local traffic documents and any pertinent data obtained from local authorities and agencies. Time restrictions can impact the study's scope and the complexity of its findings and recommendations. Although the study suggests potential improvements, it does not influence the development or regulation of traffic policies. Furthermore, the consequences of the proposed design on the specified environment are outside the scope of this study and require special attention.

Moreover, the accuracy of simulation results depends heavily on proper calibration of traffic flow models and driver behavior parameters. Although PTV VISSIM models driver behavior, it might not fully capture the nuances of human decision-making in real-world traffic situations.

3. METHODOLOGY

3.1 Identification of Current Traffic Policies Governing the Road Intersection Design

The researchers categorized the road intersection by investigating the physical features of the intersection, including the number of merging lanes, the type of roadway, the existence of pedestrian walkways, and the accessibility for bikes.

Through direct communication with officials and representatives from the City Planning Department Office, Department of Public Works and Highways, and Land Transportation Office, information on traffic policies, guidelines, and regulations about road networks and transportation systems in the study area were obtained, reviewed, and analyzed.

3.2 Classification of LOS of the Road Intersection

Through manual or on-site traffic surveys, the researchers obtained valuable data on vehicle classification, pedestrian volume, and bicycle traffic throughout a day. The researchers gathered the accident report documents from the City Police District Office.

3.2.1 LOS determination

The local rules served as the researchers' criteria and parameters for assessing the road intersection's LOS. Steps that were followed in computing the LOS of the intersection are:

a) Determine and Label Movement Priorities
b) Convert Movement Demand Volumes to Flow Rates
c) Determine Conflicting Flow Rates
d) Determine Critical Headways and Follow-Up Headways
e) Compute Potential Capacities
f) Compute Capacity Adjustment Factors
g) Compute Movement Control Delay
h) Determination of LOS

Below are the formulas utilized to compute the intersection LOS:

Conversion of movement demand to flow rates

$$v_i = \frac{V_i}{PHF} \quad (1)$$

where,

v_i : demand flow rate for movement i
V_i : demand Volume for movement i
PHF : Peak Hour Factor (0.92 - suggested default value by Highway Capacity Manual 2010)

Critical headways

$$t_{c,x} = t_{c,base} + t_{c,HV}P_{HV} + t_{c,G}G - t_{3,LT} \quad (2)$$

where,

$t_{c,x}$: critical headways for movement x (s)
$t_{c,base}$: base critical headway (s)
$t_{c,HV}$: adjustment factors for heavy vehicles (1.0 for major streets with one lane in each direction; 2.0 for major streets with two or three lanes in each direction (s)
P_{HV} : proportion of heavy vehicles for movement

$t_{c,G}$: adjustments factor for grade
G : percent grade
$t_{3,LT}$: adjustment factor for intersection geometry (0.7 for mino-street left-turn movement at three-leg intersections; 0.0 otherwise) (s)

Potential Capacities

$$c_{p,x} = v_{c,x} \frac{e^{-v_{c,x}t_{c,x}/3600}}{1-e^{-v_{c,x}t_{f,x}/3600}} \quad (3)$$

where,

$c_{p,x}$: potential capacity of movement x (veh/h)
$v_{c,x}$: conflicting flow rate for movement x (veh/h)
$t_{c,x}$: critical headway for minor movement x (s)
$t_{f,x}$: follow-up headway for minor movement x (s)

Capacity Adjustments

$$C_{SH} = \frac{\sum_y v_y}{\sum_y \frac{v_y}{c_{m,y}}} \quad (4)$$

where,

C_{SH} : Capacity of Shared Lane
v_y : flow rate of the y movement in the subject shared lane (veh/hr)
$c_{m,y}$: movement capacity of the y movement in the subject shared lane (veh/hr)

LOS Criteria: Automobile Mode

Table 1. LOS criteria

Control Delay (s/vehicles)	**LOS by Volume-to-Capacity Ratio**	
	v/c < 1.0	**v/c > 1.0**
0-10	A	F
>10-15	B	F
>15-25	C	F
>25-35	D	F
>35-50	E	F
>50	F	F

3.3 Determination of Enhancements to the Current Road Intersection Design

Identifying the road's needs and traffic safety, determining the drawbacks of the current road intersection, and consolidating the potential and possible enhancements and opportunities helped the researchers to assess what enhancements are appropriate and complement the existing road intersection design.

3.3.1 Identify the road's needs and traffic safety

The researchers analyzed the estimated vehicle volume to determine if the existing road intersection could accommodate a high volume or would cause frequent traffic jams for road users.

3.3.2 Determine the drawbacks of the current road intersection

Data on traffic flow, accident records, current surveys, and research about the design of road intersections were included in this step. The researchers pinpointed the precise time of day that traffic bottlenecks happened at the intersection.

3.3.3 Consolidate the potential enhancements and opportunities identified

After listing and evaluating the road's needs, traffic safety, and drawbacks, the researchers collaborated with experts in relevant fields, such as traffic management and urban design, who refined and validated the potential enhancements that complemented the existing road intersection design. The researchers ensured that the identified enhancements are aligned with long-term urban planning and transportation goals, considering the impact on future developments and evolving traffic patterns.

3.4 Creation of the Optimized Road Intersection Design

The researchers developed and created an optimized road intersection design model using PTV VISSIM. This phase aims to remedy the identified deficiencies while aligning them with long-term urban planning and transport objectives.

3.5 Evaluation of the Optimized Road Intersection Design in Bucana, Gapan City, Nueva Ecija

This phase evaluates the optimized road intersection design model. The efficiency and impact of planned traffic improvements are assessed systematically and comprehensively considering the following parameters: travel time, queue length, and interaction between vehicles. This step enables researchers to carry out an accurate and data-driven evaluation of optimized road intersection design through PTV VISSIM.

3.5.1 Comparison of existing and optimized road intersection design using T-Test

In order to justify whether the traffic management in the road intersection design has experienced improvement, the researchers used a T-test to evaluate the significance of the improvement. The researchers used the following formulas to conduct the T-test.

Pooled Variance Formula

$$S_p^2 = \frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2} \quad (5)$$

T-Distribution Formula

$$t = \frac{\bar{x}_1-\bar{x}_2}{S_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \quad (6)$$

3.6 Research Design

The study used the quasi-experimental approach to understand and examine the intersection. This research combined qualitative and quantitative methods to understand the research topic comprehensively. The researchers used a qualitative approach to collect traffic policies and intersection records. The quantitative approach was then utilized to understand traffic-related information and data, such as traffic flow analysis and the statistical analysis between the LOS of the existing and optimized road intersection designs. The integration of both approaches helps in creating a comprehensive data set for the study.

3.7 Research Setting

This study focuses on the five-leg intersection along the Maharlika Highway at Bucana, Gapan City, Nueva Ecija. Another national primary road, Jose Abad Santos Avenue, terminates at this intersection while two city roads, Delos Reyes St. (locally known as Inang Bayan St.) and Tinio St, comprises the remaining two legs (see Fig. 2). A mix of major supermarket, shopping center, retail and business establishments, and residential units have direct access around the intersection.

Based on the 2020 census, Gapan City has a total population of 122,968 with an annual population growth rate of 2.3%. Gapan City serves as the gateway between Nueva Ecija and Bulacan connecting two major urban areas of Cabanatuan City and San Miguel, Bulacan.

Figure 2. Location map of Bucana, Gapan City, Nueva Ecija

3.8 Data Gathering Procedure

The optimized road intersection design was developed with urban planners and traffic engineers. The design was implemented using PTV VISSIM, a multimodal traffic simulation software, to assess the effectiveness of the redesigned intersection. Simulations were run under the influence of traffic volume to determine queue length, delays, and the LOS, allowing for iterative design refinement if necessary.

3.9 Data Gathering Instruments

The first phase entails a thorough document review to systematically extract information from local documents, explicitly identifying traffic policies that influence road intersection design. Recent traffic data and accident reports were analyzed to classify the LOS of existing road intersections. Data extraction is formed to extract quantitative information on travel time, traffic volume, and safety metrics from available records.

PTV VISSIM is used to evaluate the optimized road intersection design. This tool implements optimized design and runs simulations under various scenarios, providing information on travel time, traffic volume distribution, and safety measures.

3.10 Statistical Treatment

This study used a T-test to test the hypothesis and determine if the results of the network performance of existing and optimized road intersection designs were significant. A T-test helped the researchers verify whether the null hypothesis must be rejected or accepted.

4. PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

4.1 Traffic Policies

The critical components of a complete traffic management framework as stated by Sitanggang and Saribanon (2018) are listed, along with the central policies and protocols that are strictly implemented at the Bucana, Gapan City intersection.

4.1.1 Right of way protocol

Authorities aim to reduce accidents due right-of-way violations and increase safer road use by enacting clear laws, such as those established in Republic Act No. 4136 or "Land Transportation and Traffic Code". Article III, Section 42 (Right of Way) of RA 4136, details the laws and regulations governing the right of way on the road, particularly at intersections. This policy establishes priority guidelines to decide which vehicles have the right of way at intersections.

4.1.2 Speed limit

The road users must comply with the enforced 30 kph speed limit within the city as indicated in RA 4136, Chapter 4, Article 1, Section 35 (Restriction as to speed) with few exemptions.

4.1.3 Prohibition of distracted driving

Anti-Distracted Driving Act bans activities like making or receiving calls, texting, reading or sending messages, playing games, watching videos, using social media, and other similar actions that could divert the driver's attention from the road. It aims to safeguard road users from the ruinous and extremely injurious effects of vehicular accidents due to distracted driving.

4.1.4 Enforcement and penalties

Traffic rules are strictly enforced to guarantee conformity with established policies. According to the Land Transportation Office (LTO), strict compliance with traffic laws is critical for maintaining order and increasing road safety.

4.1.5 Implementation of one-way street

The Gapan City Local Government has made the Peñaranda leg a one-way street, allowing vehicles to enter the intersection only from the other four legs. Vehicles on the Peñaranda leg are not permitted to enter the intersection between 6:00 AM and 9:00 PM.

4.2 Road Intersection Inventory

4.2.1 Pavement width

The road intersection is a five-leg intersection composed of three national roads and two city roads that accommodates a variety of traffic movements (see Appendix A). The southbound Maharlika Highway is 14.5 meter-wide with four lanes while the northbound route is slightly narrower, measuring 11.4 meter-wide, yet accommodates four lanes. The westbound Jose Abad Santos Avenue has a width of 8.8 meters with two lanes and the eastbound two-lane Tinio St. has a width of 8.5 meters also with two lanes. A 6.3 meter-wide minor street links southbound, northeastbound, and eastbound traffic. It has two lanes and a designated parking area adjacent the carriageway.

4.2.2 Traffic control devices

The intersection lacks appropriate warning and regulatory signs and traffic signals, which allow for uncontrolled ingress and egress from nearby commercial establishments and possibly dangerous turning movements due to poor pavement markings. Concerns over speed control are raised by the absence of traffic calming measures, especially in light of on-street parking, which could worsen traffic congestion and obstruct traffic flow. The poor pavement quality further compounds the intersection's general operational difficulties.

4.2.3 Pedestrian facilities

All five legs of the intersection feature pedestrian crossings. The location of designated loading and unloading zone and lack of handicapped-accessible curb-cut ramps for persons with disability (PWDs) are also observed. Poor lighting along the routes decrease visibility and safety not only for the pedestrians but the road users as well.

4.3 LOS Determination

4.3.1 Flow designation

A total of thirteen flows are assigned within the intersection as enumerated in Table 2 and depicted in Fig. 3.

Table 2. Designation of flow number to the area of flow

Flow Number	Area of Flow

1	Cabanatuan to Cabiao
2	Cabanatuan to Manila
3	Cabanatuan to Inang Bayan St., San Vicente
4	Cabanatuan to Peñaranda
5	Cabiao to Cabanatuan
6	Cabiao to Inang Bayan St., San Vicente
7	Cabiao to Peñaranda
8	Cabiao to Manila
9	Manila to Cabiao
10	Manila to Cabanatuan
11	Manila to Inang Bayan St., San Vicente
12	Manila to Peñaranda
13	Inang Bayan St., San Vicente to Peñaranda

4.3.2 Traffic count

Table 3 displays the number and classification of vehicles that pass the intersection during the morning and afternoon peak hours.

Table 3 Total movement from combined flows

Morning Peak Hour		Afternoon Peak Hour	
Vehicle Type	Movement	Vehicle Type	Movement
Car	211	Car	161
PUJ	19	PUJ	17
HOV/FX	0	HOV/FX	0
Taxi	0	Taxi	0
Utility Van	42	Utility Van	50
Mini Bus	0	Mini Bus	0
Large Bus	1	Large Bus	3
2-axle truck	28	2-axle truck	20
3-axle truck	11	3-axle truck	9
Articulated Cargo Truck	12	Articulated Cargo Truck	11
Tricycle	644	Tricycle	513
Motorcycle	416	Motorcycle	402
Total	1384	Total	1186

Table 4. Vehicle volume per leg

Vehicle Volume per Leg (15-Minute Duration)					
Morning Peak Hour			Afternoon Peak Hour		
Direction	Number of Vehicles	Percentage	Direction	Number of Vehicles	Percentage
North Leg	495	35.76%	North Leg	406	34.23%
South Leg	592	42.77%	South Leg	533	44.94%
East Leg	-	-	East Leg	-	-
West Leg	271	19.58%	West Leg	214	18.04%
North-East Leg	26	1.89%	North-East Leg	33	2.78%

- No traffic movement

Table 4 reveals a significantly higher volume of vehicles traversing each leg and the entire intersection during the morning peak hour compared to the afternoon peak hour.

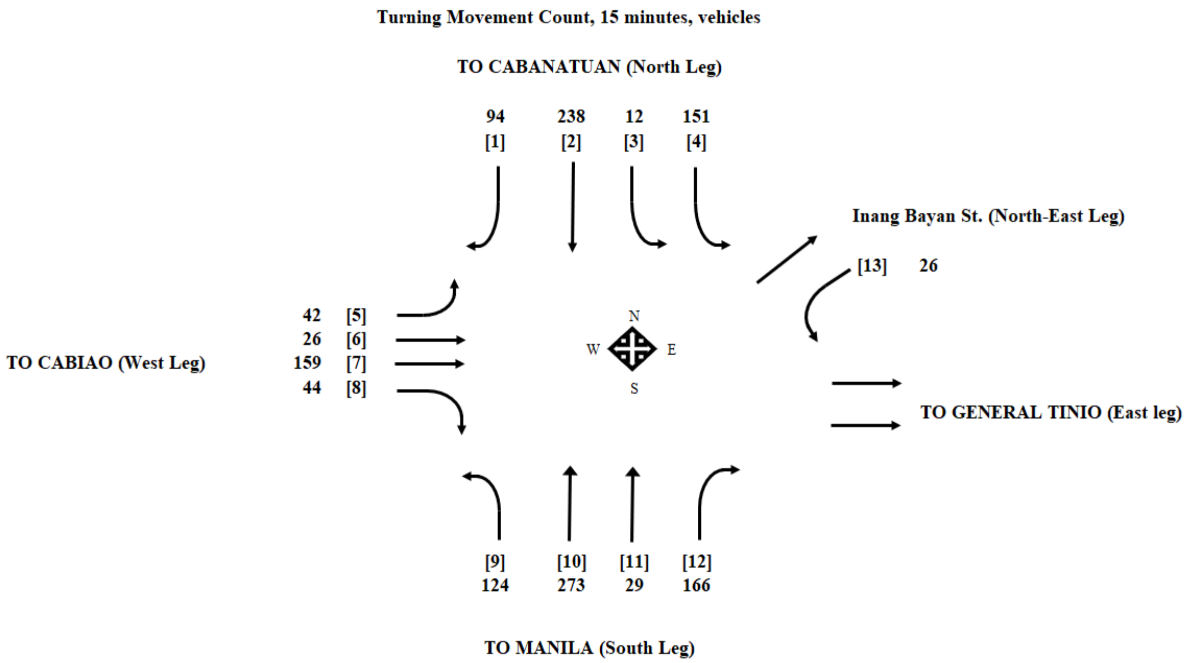

Figure 3. Turning movement count for each leg during the morning peak hour

4.3.3 Pedestrian count

Table 5. Pedestrian Volume per Leg

Pedestrian Volume per Leg (15-minute Duration)			
Morning Peak Hour		Afternoon Peak Hour	
Direction	Number of Pedestrian	Direction	Number of Pedestrian
North Leg	14	North Leg	12
South Leg	31	South Leg	28
East Leg	20	East Leg	19
West Leg	15	West Leg	14
North-East Leg	11	North-East Leg	8
Total	91	Total	81

4.3.4 Road crash data

The road crash incidents and accidents were the only reported cases in the City Police District Office from January 1, 2021 to January 29, 2024; it mainly focuses on the cases near the Bucana, Gapan City intersection.

Table 6. Road Crash Data

Road Crash Data		
Type	Number of Incidents and Accidents	Percentage
Fatal	27	2.75%
Serious Injury	955	97.25%
Total	982	100%

4.3.5 LOS analysis

Table 7 shows the values obtained from the LOS analysis using HCM 2010 Volume 3. The governing traffic volume from the conducted 15-minute traffic count in morning and afternoon peak hours is used in estimating the 1-hour traffic volume of the intersection. The demand flow rate and critical headways are calculated using Eq.s 1 and 2 respectively.

Table 7. Computation of Level of Service using HCM 2010 Volume 3

Computation of Level of Service						
Flow Number	15-minute Volume	1-hour volume	Demand Flow Rate	Conflicting Flow Rate (veh/hr)	Critical Headways (s)	Follow-up Headways (s)
1	94	376	408.696	-	-	-
2	238	952	1034.783	-	-	-
3	12	48	52.174	1357.043	4.175	2.234
4	151	604	656.522	1988.696	4.175	2.234
5	42	168	182.609	2716.522	7.175	3.538
6	26	104	113.043	1855.652	6.275	4.038
7	159	636	691.304	2460	6.275	4.038
8	44	176	191.304	1423.130	6.275	3.338
9	124	496	539.130	1503.478	4.175	2.234
10	273	1092	1186.957	-	-	-
11	29	116	126.087	-	-	-
12	166	664	721.739	-	-	-
13	26	104	113.043	44	7.175	3.538

- Not Relevant

Table 8. Determination of Level of Service

Determination of Level of Service					
Lane Designation	Flow Number	Potential Capacities (veh/hr)	Capacity Adjustment Factors (veh/hr)	Movement Control Delay (s)	Level of Service
North Lane	1	-	288.704	692.510	LOS F
	2	-			
	3	494.123			
	4	279.471			
West Lane	5	12.996	29.210	17955.631	LOS F
	6	71.526			
	7	29.381			
	8	162.549			
South Lane	9	433.440	433.440	155.685	LOS F
	10	-			
	11	-			
	12	-			
North-East Lane	13	952.503	952.503	9.288	LOS B
East Lane	-	-	-		LOS A

- Not Relevant

Referring to Table 1, LOS at each leg are determined based on the computed control delays. The table shows that the three major highways are operating on LOS F. This LOS represents the most congested and undesirable operating condition for a roadway or intersection.

4.4 Enhancements for the Intersection

Based on the findings, the following are the proposed enhancements to be considered in creating the optimized road intersection design (see Appendix B). These enhancements take part in the PTV VISSIM simulation.

1) Improvement and installation of traffic control devices
2) Improvement of pavement markings
3) Enhancement of lighting and visibility
4) Removal of loading and unloading zone
5) Widening of the lanes
6) Enhancement of pedestrian facilities
7) Removal of on-street parking

4.5 PTV VISSIM Simulation

Table 9 shows the PTV VISSIM results on the vehicle delay in seconds of the existing and optimized design.

Table 9. PTV VISSIM simulation results on vehicle delay

Flow Number	Vehicle Delay (s)	
	Existing Design	Optimized Design
1	82.789	22.424
2	115.849	23.294
3	114.554	21.181
4	70.467	19.418
5	49.958	6.106
6	67.636	7.905
7	54.278	6.484
8	31.932	6.950
9	49.995	14.879
10	38.815	13.373
11	128.747	17.495
12	71.778	11.050
13	5.465	1.239

It can be observed in Table 10 the positive impacts of the proposed enhancements in improving the intersections' LOS.

Table 10. PTV VISSIM simulation results on LOS

Flow Number	Existing Design		Optimized Design	
	Level of Service	LOS (Value)	Level of Service	LOS (Value)
1	LOS F	6	LOS C	3
2	LOS F	6	LOS C	3
3	LOS F	6	LOS C	3
4	LOS F	6	LOS C	3

5	LOS E	5	LOS A	1
6	LOS F	6	LOS A	1
7	LOS F	6	LOS A	1
8	LOS D	4	LOS A	1
9	LOS E	5	LOS B	2
10	LOS E	5	LOS B	2
11	LOS F	6	LOS C	3
12	LOS F	6	LOS B	2
13	LOS A	1	LOS A	1

4.6 Statistical Analysis

As shown in Table 11, the p-value computed from the simulation of the optimized design was < 0.01. Since the p-value is less than the significance level of 0.05, it indicates a significant difference between the LOS of the existing and optimized road intersection design. Through statistical data comparison, it is apparent that the intersection design in Bucana, Gapan City, Nueva Ecija achieved optimization with modifications to existing design and traffic policy considerations.

Table 11. T-Test results

	Existing	*Optimized*
Mean	5.231	2.000
Variance	2.026	0.833
Observations	13	13
Pooled Variance	1.429	
Hypothesized Mean Difference	0	
df	24	
t stat	5.762	
P(T<=t) two-tail	< 0.01	
t Critical two-tail	± 2.064	

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of Findings

The PTV VISSIM simulation results analysis reveals substantial improvements in the vehicle delay and LOS at the intersection when transitioning from the existing design to the optimized design across all flow numbers. Specifically, Flows 1 through 4 experienced a significant upgrade from LOS F (6) to LOS C (3), indicating a marked enhancement in service quality. Flow 5 showed impressive improvement from LOS E (5) to LOS A (1), showcasing excellent service. Similarly, Flows 6 and 7 progressed significantly, moving from LOS F (6) to LOS A (1). Flow 8 showed a substantial improvement from LOS D (4) to LOS A (1), reflecting a significant enhancement in service quality. Flows 9 and 10 also experienced notable improvements, transitioning from LOS E (5) to LOS B (2), indicating better traffic conditions. Flow 11 improved from LOS F (6) to LOS C (3), while Flow 12 advanced from LOS F (6) to LOS B (2). Notably, Flow 13 maintained its high level of service at LOS A (1) in both the existing and optimized designs.

5.2 Conclusion

Based on the results, the study reveals that the existing road intersection has the potential to have a more efficient transportation network. The proposed optimized road intersection design improves traffic management in Bucana, Gapan City, Nueva Ecija. This was supported by comparing the results of network performance simulation of the existing design and optimized design using PTV VISSIM.

The study reveals how traffic ordinances and regulations affect traffic congestion at intersections. As Bahrami and Roorda (2020) also stated, traffic policies play a significant role in managing traffic flow in a roadway.

It has been proven that the road intersection features an intricate design influenced by various factors, including road widths, traffic flow per lane, city ordinances, traffic control devices, and other variables documented in the inventory. The improvement in the vehicle delay and LOS was seen in Tables 10 and 11 respectively. As demonstrated by Lu and Yan (2019), this study can conclude a significant difference in the operating characteristics between the existing road intersection design and the proposed optimized road intersection design.

5.3 Recommendations

From the conclusions formulated, the researchers recommend the following for the furtherance of the study:

1) To the Local Government Unit
    a) City Engineers at the Municipal Planning and Development Council must have a consultation regarding the implementation of the proposed enhancements.
    b) Establish a dedicated City Traffic Management Office (CTMO) with the explicit mandate to comprehensively address and resolve traffic-related challenges within the city.
2) To Transportation Engineers
    a) Establish mechanisms for ongoing monitoring and evaluation of implemented intersection design.
3) To Future Researchers
    a) Utilize other traffic simulation software, such as PTV VISTRO, to pursue improved traffic management at the intersection.
    b) Conducting a comparative analysis of the Traffic Management of the intersection after the opening of various highway facilities such as the Cabiao-Gapan-Penaranda Bypass and Flood Control Wall on the San Leonardo-Gapan City Bridge as a bypass.

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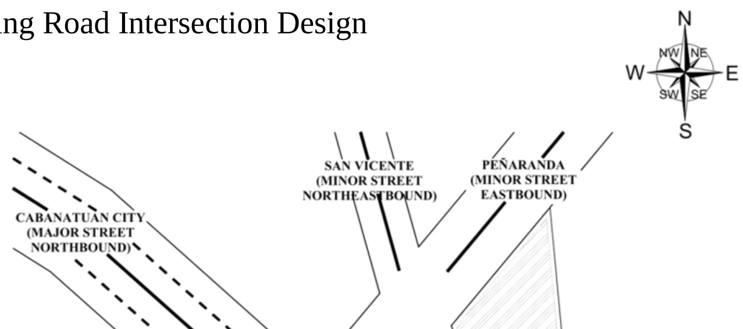
7. APPENDICES

Appendix A. Existing Road Intersection Design



Appendix B. Optimized Road Intersection Design

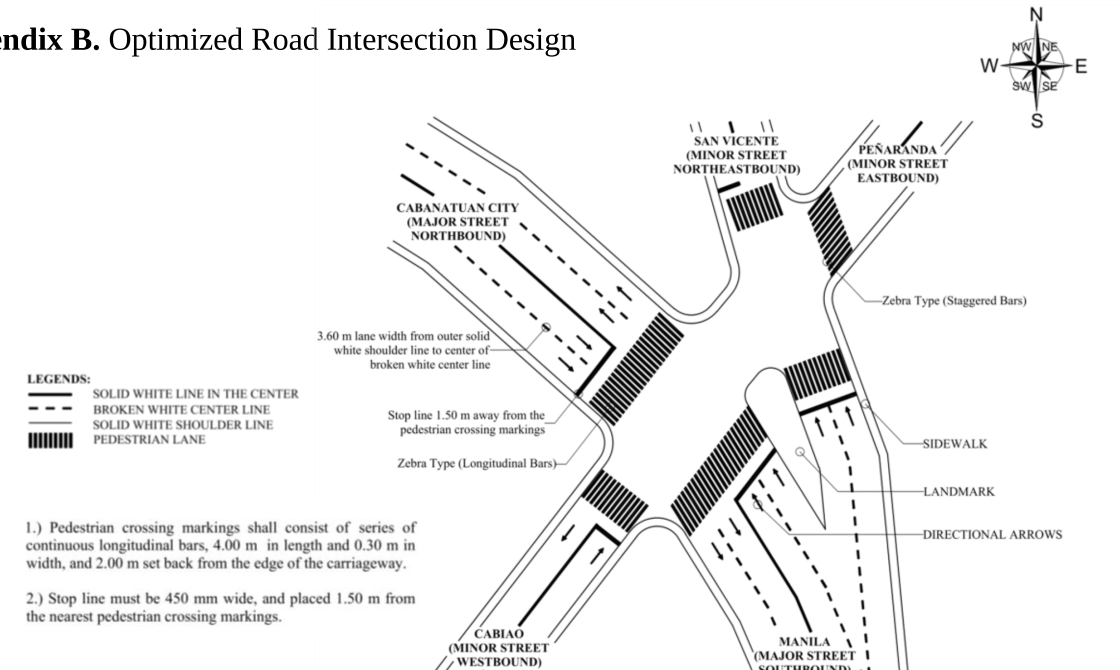


Figure 1B. CAD layout of the optimized road intersection design

Figure 2B. 3D-model of optimized road intersection design (from Manila POV)

Figure 2C. 3D-model of optimized road intersection design (from Cabiao POV)