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Policy Analysis Approach to Mitigate Traffic Congestion at a Four-Way Intersection in Cacutud, Arayat, Pampanga for an Efficient Traffic Flow System

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Abstract:

Traffic congestion stems from high demand on roads, leading to inconvenience, economic losses, pollution, and diminished quality of life. The Four-Way Intersection with several side streets in Cacutud, Arayat, Pampanga, serves as a hub for essential institutions and facilities, significantly impacting the surrounding area. Policy analysis lays the groundwork for crafting effective traffic management policies, providing decision-makers with valuable insights, and facilitating ongoing evaluation and enhancement of strategies. The researchers have identified four potential transport policies to tackle these challenges: Intelligent Transport Systems (ITS), Unified Vehicular and Volume Reduction Program (UVVRP), Strict enforcement of basic transportation laws, and Re-routing of key vehicles at the Intersection. In evaluating these policies, the Level of Service (LOS) and control delay—defined as the time vehicles wait at a controlled intersection—were calculated. Through a combination of traffic simulation and Level of Service analysis, it was discovered that ITS implementation led to a significant average improvement of 20-30% in intersection performance. Survey results reveal motorists and PUV operators support smart traffic lights and strict law enforcement. Pedestrians and business owners lack understanding of these transport policies, indicating a necessity for enhanced education on these measures. Despite concerns, there's overall willingness to adopt congestion-alleviating measures.

Keywords **—Traffic Congestion, Four-Way intersection, Traffic Simulation, Policy Analysis**

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I. INTRODUCTION

Traffic congestion is a complex problem that manifests in various forms, including gridlocked streets during peak hours, protracted commute times, and the deterioration of air quality. Its repercussions extend far beyond inconveniences, encompassing economic inefficiencies, heightened pollution levels, and a decline in urban residents' overall quality of life [1].

In 2014, the Japan International Cooperation Agency (JICA) revealed that traffic congestion in Metro Manila costs the Philippine economy at least PHP 2.4 billion per day. This figure represents the quantifiable value of time lost because of delays, expenditures on fuel, adverse effects on public health, and environmental degradation, among other factors. JICA projects that the capital's ongoing urbanization could potentially result in associated expenses of PHP 6 billion by 2030, barring the implementation of efficient measures. JICA estimates that Filipinos spend approximately PHP 5.5 billion annually on the infamous traffic congestion on Epifanio de Santos Avenue [2].

Various factors contribute to traffic congestion in urban areas, which can be classified into two types: recurring and nonrecurring congestion. Recurring congestion occurs regularly, primarily due to a high volume of vehicles during peak hours. On the other hand, unpredictable events like weather, work zones, incidents, and special events cause nonrecurring congestion. According to the United States Department of Transportation Federal Highway Administration (DOT-FHWA), nonrecurring congestion accounts for over 50% of all traffic congestion, causing 40% of the total congestion [3].

Effectively addressing traffic congestion necessitates a multifaceted strategy that includes significant investments in public transportation, promoting alternative modes of transportation such as cycling and pedestrian-friendly infrastructure, and integrating cutting-edge intelligent transportation technologies. Furthermore, urban planning should prioritize mixed-use developments to reduce the need for long commutes and encourage the use of public transportation networks. Sustainable urban design, combined with sustained research and innovation in transportation systems, can ameliorate traffic congestion and create more habitable and resilient urban environments for all residents. As cities evolve, they must adapt their transportation strategies to effectively confront the challenges of a world marked by escalating mobility and consumption [4].

Mitigating traffic congestion within a community, particularly in a third-world country, goes beyond being a mere inconvenience; it substantially influences the community's economic, social, and environmental facets. Considering the impracticality of extensive structural road redesign in such circumstances, the researchers adopted a policy analysis approach to address these issues comprehensively.

Policy analysis systematically evaluates and assesses proposed or existing policies to understand their implications, effectiveness, feasibility, and potential impact on various stakeholders [5]. It involves rigorous research, data analysis, and critical evaluation to provide evidence-based recommendations for policymakers and stakeholders, aiding in informed decision-making and policy formulation. Policy analysis in the context of traffic control becomes essential when engineering solutions are unfeasible, particularly in situations involving public participation, adding complexity to the issue. Engineering adjustments, such as road reshaping or expansion, can remediate some congested 4-way highways, but others face challenges due to a significant influx of pedestrians or establishments that attract crowds, further contributing to traffic issues. We need to revise traditional engineering solutions in such cases. Policy analysis manages public behavior and movement, establishing regulations that significantly alleviate congestion caused by vehicular and pedestrian traffic [6].

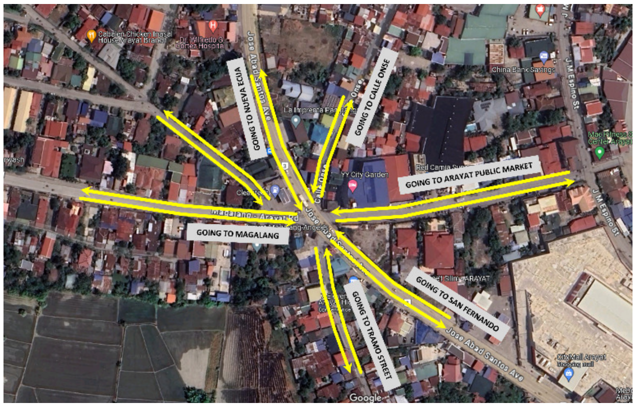

Fig. 1 Cacutud Intersection

This study examines a four-way intersection located in Cacutud, Arayat, Pampanga, which serves as a critical junction point connecting several side streets and providing essential access routes to various destinations. This intersection is a significant thoroughfare, functioning as a crucial link to San Fernando, Pampanga; Magalang, Pampanga; and Nueva Ecija. Despite its status as a national road, the intersection lacks traffic lights, with traffic flow being managed instead by traffic enforcers.

The absence of traffic lights significantly contributes to traffic congestion, particularly during peak hours, resulting in inefficient traffic flow management. This intersection is strategically important as it connects roads leading to a public market and a nearby school, thus experiencing high volumes of both pedestrian and vehicular traffic during specific times. The lack of adequate traffic control infrastructure at this intersection presents significant challenges in managing traffic flow effectively. High congestion levels during peak hours can lead to delays, commuter frustration, and potential safety hazards.

This study seeks to conduct an in-depth exploration of traffic congestion and its management. By synthesizing existing literature, the researchers aim to develop a comprehensive understanding of traffic congestion's economic, social, and technological dimensions. The study focuses on evaluating the effectiveness of existing policies, exploring innovative solutions, and examining the integration of community engagement and behavioral insights for sustainable traffic management.

II. METHODOLOGY

A. *Methodological Framework*

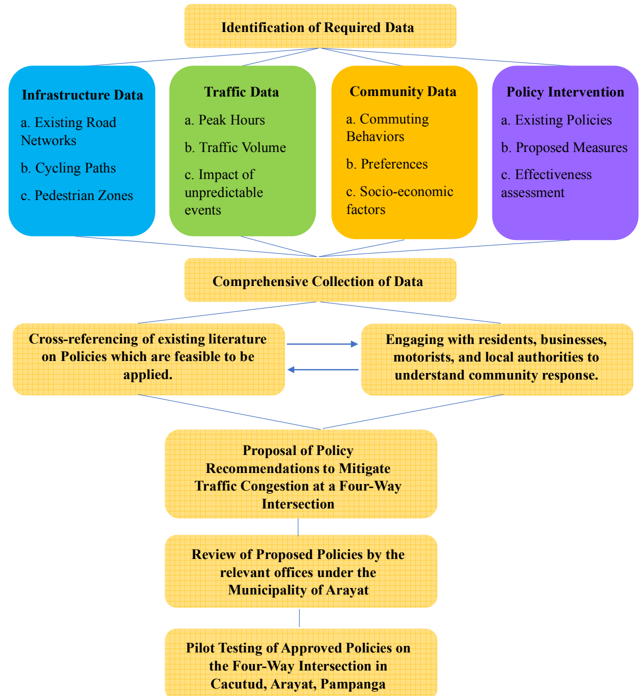

Fig. 2 Theoretical Framework

The proposed methodological framework for traffic congestion policy analysis adopts a systematic approach to address the issue comprehensively. Initially, key data categories, including infrastructure, traffic, community, and policy intervention data, are identified to lay the groundwork for a thorough analysis. Subsequently, a meticulous data collection process ensues, gathering information on road networks, peak hours, commuting behaviors, existing policies, and more. This data collection phase aims to provide a nuanced understanding of traffic congestion's complexities.

The framework then integrates a two-fold literature review and stakeholder engagement approach. The literature review seeks effective policies from existing sources while engaging with stakeholders, such as residents, businesses, motorists, and local authorities, ensuring a holistic understanding of community perspectives. This dual approach acknowledges the importance of both theoretical foundations and practical, community-specific considerations.

Crucially, the framework emphasizes seeking a two-way agreement or approval from stakeholders before proposing policies. This collaborative approach ensures that the proposed interventions align with the needs and expectations of the community. By systematically progressing from data identification to stakeholder engagement and agreement, the framework strives to develop policies that are theoretically sound, practically viable, and acceptable to the community, thereby enhancing the likelihood of successful policyimplementation.

B. *Research Design*

Integrating a Quantitative Approach within the established methodological framework gains heightened relevance considering the existing transport data obtained by researchers, specifically indicating a relatively slow traffic flow.

The quantitative dimension, rooted in actual road data, allows for a detailed quantitative assessment of the Level of Service (LOS) for roads, particularly those experiencing slower traffic. Involving engagement with pedestrians and community membersadds a contextual layer to this study. It enables the researchers to delve into the human experiences associated with the observed slow traffic, uncovering nuanced insights that numerical data alone may not capture.

By integrating the manual counting of vehicle volume as the quantitative approach and the qualitative engagement, the researchers not only leverage precise location data but also gain a comprehensive perspective on the challenges of slow traffic flow. This combined approach, grounded in quantitative and qualitative evidence, enriches the analysis by providing a nuanced understanding of the impact on pedestrians and the community. Consequently, the researchers can formulate well-informed policy recommendations that address the quantitative evidence of slow traffic flow, as indicated by the results of the manual counting as well as Google Maps data, and the qualitative dimensions of its impact on the local community.

1) ***Level of Service:***Level of Service (LOS) serves as a measurement tool employed to assess the excellence of operational circumstances within a flow of traffic. Its primary emphasis lies in the examination of elements such as speed, duration of travel, the extent of maneuvering freedom, occurrences of traffic disruptions, and factors associated with the overall comfort and convenience of the transportation experience [7]. The concept of LOS aims to capture how a traveler perceives the quality of service offered at a specific intersection or segment of a roadway. This assessment is made by considering the standard of free-flowing automobile traffic. In simpler terms, LOS provides a way to measure and express the satisfaction or experience of individuals using a particular road section or intersection, with an emphasis on how well traffic moves without significant disruptions or delays. The focus is on understanding the traveler's perspective in terms of the ease, efficiency, and overall quality of their journey through that specific part of the transportation network.

2) ***Signalized Intersection:***A signalized intersection is a type of road intersection where traffic is regulated by traffic signals or traffic lights. These intersections use signal lights to control the flow of vehicles and pedestrians, ensuring the safe and efficient movement of traffic. The signal lights typically include red, yellow, and green lights, each indicating specific instructions to drivers and pedestrians. In a signalized intersection, the traffic signals are programmed to allocate right-of-way to different directions at specific intervals. The use of signalized intersections helps manage traffic flow, reduce congestion, prevent collisions, and provide safe opportunities for pedestrians to cross the road. The control of traffic lights is often coordinated with nearby intersections to optimize the overall traffic network's efficiency. Signalized intersections are common in urban areas and busy roadways where managing traffic movements is crucial.

TABLE 1
LEVEL OF SERVICE FOR SIGNALIZED INTERSECTION

LOS	CONTROL DELAY PER VEHICLE (s/veh)	DESCRIPTION
A	Control delay no higher than 10 s/veh and a volume-to-capacity ratio no higher than 1.0. Typically assigned when progression at the intersection is exceptional with high arrival on green or there is a very short cycle length.	No vehicle waits longer than one signal.
B	*Control* delay between 10 and 20 s/veh and a volume-to-capacity ratio no higher than 1.0. Assigned when there is exceptional progression at the intersection or there is a short cycle length. More vehicles have to stop than LOS A.	On a rare occasion, vehicles wait through more than one signal indication.
C	Control delay between 20 and 35 s/veh and a volume-to-capacity ratio no higher than 1.0. Typically assigned when progression at the intersection is good or the cycle length is average. Many vehicles have to stop, and individual cycle failures may start to occur.	Intermittently, vehicles wait more than one signal indication. Occasionally, backups may develop, traffic flow still stable.
D	Control delay between 35 and 55 s/veh and a volume-to-capacity ratio no higher than 1.0. Typically assigned when progression is not effective or there is a long cycle length. Many vehicles have to stop, and individual cycle failures happen more regularly.	Delays at intersections may become extensive, but enough cycles with lower demand occur to permit periodic clearance, preventing excessive backups.
E	Control delay between 55 and 80 s/veh and a volume-to-capacity ratio no higher than 1.0. Typically assigned when progression is not ideal and there is a long cycle length. Individual cycle failures happen frequently.	Long queues create lengthy delays.
F	The control delay is over 80 s/veh, or the volume-to-capacity ratio is higher than 1.0. Typically assigned when progression is very bad and there is a long cycle length. Most cycles are not able to clear the queue.	Backups from locations downstream restrict or prevent movement of vehicles, creating a "gridlock" condition.

*3) **Unsignalized Intersection:***An unsignalized intersection is a road junction or crossing where traffic flow is not controlled by traffic signals or lights. Drivers rely on standard right-of-way rules, traffic laws, and often common courtesy to navigate through the intersection safely. At unsignalized intersections, drivers must exercise caution and yield the right of way to vehicles approaching from certain directions, as specified by traffic regulations. At unsignalized intersections, drivers must exercise caution and yield the right of way to vehicles approaching from certain directions, as specified by traffic regulations. Typically, the first vehicle to arrive at the intersection has the right of way, and if two vehicles arrive simultaneously, standard rules or local regulations determine who proceeds first.Unsignalized intersections are common in less densely populated areas or in situations where traffic volumes are not high enough to warrant the installation of traffic signals.

The Level of Service (LOS) of an unsignalized intersection is determined using the volume to capacity ratio (v/c).

Alternativey, Control delay for unsignalized intersection is solved using the formula:

$$d = \frac{3600}{c_{m,x}} + 900T\left[\frac{v_x}{c_{m,x}} - 1 + \sqrt{\left(\frac{v_x}{c_{m,x}} - 1\right)^2 + \frac{\left(\frac{3600}{c_{m,x}}\right)\left(\frac{v_x}{c_{m,x}}\right)}{450T}}\right] + 5$$

Where:

d = control delay (s/veh)

v_x = flow rate for movement x (veh/h)

$c_{m,x}$ = capacity of movement for x (veh/h)

T = analysis time period (h); T = 0.25 for a 15-minute period

TABLE 2
LEVEL OF SERVICE FOR UNSIGNALIZED INTERSECTION

LOS	V/C RATIO	DESCRIPTION
A	< 0.20	Free flow
B	0.21 – 0.50	Stable flow (slight delays)
C	0.51 – 0.70	Stable flow (acceptable delays)
D	0.71 – 0.85	Approachable unstable flow
E	0.85 – 1.00	Unstable flow
F	> 1.00	Forced flow (congested and queues fail to clear)

*4) **Existing Transport Data:***The obtained transport data from manual counting of traffic volume plays a foundational role in the quantitative dimension of the study. This dataset, reflective of real-time traffic conditions, especially in areas with slow flow, establishes a tangible basis for evaluating the Level of Service for roads. Integrated seamlessly into the Quantitative Approach, this existing transport data ensures precision in quantitative assessments and alignment with observed traffic patterns within the community. This integration fosters a cohesive and well-informed research design, where the quantitative insights derived from Google Maps data harmonize with the qualitative aspects, offering a comprehensive understanding of the dynamics of traffic congestion. Additionally, the researchers' firsthand experience with heavy/slow traffic in the area further substantiates and contextualizes the quantitative findings. This experiential insight contributes a valuable layer of understanding, enhancing the overall credibility and depth of the research design.

C. Research Intruments

*1) **Survey Questionnaires:***Design and distribute surveys to residents, commuters, and businesses in Mangga-Cacutud to gather information on their commuting habits, peak travel times, and perceived traffic issues. Include questions on public transportation usage, the frequency of private vehicle use, and suggestions for improvement. Analyze survey data to identify patterns, preferences, and common concerns related to traffic.

*2) **Interviews:***Conduct interviews with key stakeholders, including local authorities, traffic enforcers, and community leaders, to gain insights into existing traffic management strategies, challenges faced, and proposed solutions. Explore the perspectives of public transport operators, considering their experiences and potential contributions to traffic management.

*3) **Ocular Inspection:***Physically visit key traffic junctions, intersections, and bottlenecks in Mangga-Cacutud during peak and off-peak hours. Assess the infrastructure, road conditions, signage, and overall traffic flow. Document observations related to pedestrian safety, parking areas, and the efficiency of existing traffic management infrastructure.

D. Data Collection Methods

*1) **Sample Size:*** The researchers administered survey questionnaires among the designated participants to obtain firsthand data for the study. This method facilitated a systematic accumulation of information, guaranteeing a thorough and direct understanding of the study. In 2020, as reported by the Philippine Atlas, the population of Cacutud, Arayat was recorded at 10,996. The sample size was calculated through the help of Raosoft, incorporating a 5% margin of error and a 90% confidence level. The researchers determined a sample size of 265, with respondents comprising of residents, pedestrians, motorists, and business owners at the four-way intersection in Cacutud, Arayat [8].

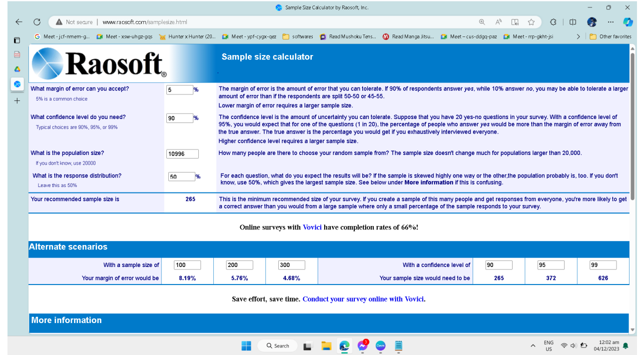

Fig. 3 Raosoft Sample Size Calculator

*2) **Sampling Strategy:***The researchers utilized a simple random sampling method, ensuring that everyone within the target population has an equal opportunity to be chosen for the study. Simple random sampling is employed when dealing with people characterized by a high degree of homogeneity, selecting research participants randomly to engage in the study [9]. This strategy guarantees a representative and unbiased sample, thereby augmenting the applicability of the results to a broader population.

*3) **Primary and Secondary Data Acquisition Methods:***The researchers wrote a formal letter requesting specific data on traffic congestion at the Four-Way Intersection in Cacutud, Arayat. This letter will be directed to the Regional Office of the Department of Public Works and Highways—Pampanga 1st District Engineering Office (DPWH—Pampanga 1st DEO) and the Physical and Infrastructure Sector of the Municipality of Arayat. The objective is to obtain comprehensive data that will contribute to a thorough understanding of the traffic dynamics in this area, supporting the research's broader goals.

E. Data Analysis

The existing traffic congestion analysis relies heavily on basic statistics and traditional traffic flow data, possibly neglecting real user experiences and the influence of public transport. Its limitations in examining localized patterns over time could restrict precise policy suggestions. Moreover, it needs an in-depth exploration of correlations with external factors and predictive models for future scenarios,hinderingcomprehensive understanding of congestion influencers. In contrast, the proposed analysis involves stakeholders actively and incorporates public opinions via qualitative methods like stakeholder interviews and feedback analysis. This inclusive approach aims to grasp policy effectiveness better and enhance decision-making processes' inclusivity.

Its primary objective is to develop a comprehensive policy analysis framework to tackle traffic congestion at a specific four-way intersection. This approach aims to gain a thorough understanding of the phenomenon. The quantitative aspect involves statistical measures, employing survey questionnaires with Likert scales to analyze public opinions on traffic policies. Simultaneously, the qualitative component utilizes thematic analysis, delving into nuanced themes via observation and open-ended interviews. Key stakeholders, such as transportation officials and urban planners, were interviewed to glean qualitative insights into policy effectiveness and potential enhancements. This synthesis of methodologies aims to fuse numerical precision with the richness of qualitative insights, offering a deeper understanding of the research context [10].

The Likert scale is a widely used tool in surveys and research, offering a method to measure attitudes, opinions, or perceptions on a scale, typically ranging from strongly agree to strongly disagree. It employs a numerical scale assigned to each response category, allowing for quantification of subjective data [11]. The researchers employed a 4-point Likert scale to assess the consensus among the population regarding various statements related to traffic complexities in the study locale. Omitting the neutral option in a typical Likert scale is a frequently employed technique to prompt a clear opinion from study participants. This scale encompasses the following response options: (1) Strongly Disagree; (2) Disagree; (3) Agree; (4) Strongly Agree, providing a nuanced perspective on participant opinions. To calculate the needed margin of error in a survey, one can use the formula: Margin of Error = $1/\sqrt{n}$, where 'n' represents the sample size. This formula helps determine the range within which the true population value is likely to fall based on the survey results.

A one-sample t-test is a statistical hypothesis test used to determine whether the mean of a single sample is significantly different from a specific hypothesized population mean. This test becomes particularly valuable when the actual population mean is uncertain, but there exists a reasonable estimation of what it could be. To calculate the T-test one can use the formula: $t = (\bar{x} - \mu 0) / (s / \sqrt{n})$. The sample mean (x) refers to the average of all the data points within your sample, while the hypothesized population mean (μ0) represents the specific value against which the sample mean is being compared. The sample size (n) denotes the total number of data points present in the sample.

III. RESULTS AND DISCUSSION

A. Road Network

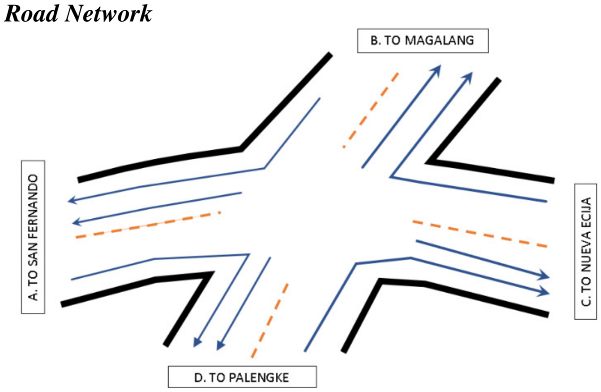

Fig. 4 Road Network

B. Traffic Count

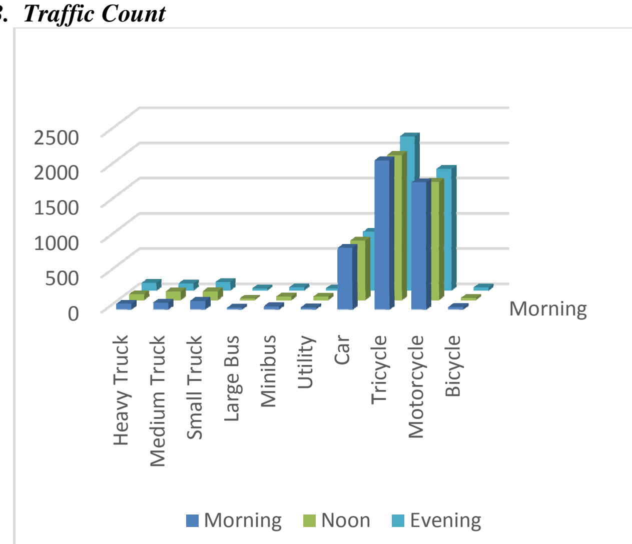

Fig. 5 Average Traffic Count

Figure 5 presents a graphical depiction of the Average Traffic Counts as observed by the researchers. During the morning period, the mean traffic counts were recorded as follows: 78.3333 for heavy trucks, 95 for medium trucks, 120.333 for small trucks, 23 for large buses, 44.3333 for minibuses, 28 for utility vehicles, 872 for private cars, 2116.33 for auto rickshaws, 1803.33 for motorcycles, and 32.6667 for bicycles. At noon, similar observations were made, with mean traffic counts as follows: 78.3333 for heavy trucks, 121 for medium trucks, 121.667 for small trucks, 18 for large buses, 46.6667 for minibuses, 45 for utility vehicles, 840.333 for private cars, 2057.33 for auto rickshaws, 1676 for motorcycles, and 25.6667 for bicycles. Lastly, during the evening hours, the mean traffic counts were documented as: 104.667 for heavy trucks, 95.6667 for medium trucks, 116 for small trucks, 26.6667 for large buses, 41.6667 for minibuses, 27 for utility vehicles, 829 for private cars, 2184.67 for auto rickshaws, 1724.33 for motorcycles, and 40 for bicycles.

C. Growth Rate

TABLE 3
GROWTH RATE

Direction	Peak Hour Volume		Yearly Growth Rate Factor
	2022	2024	
Arayat – San Fernando	1175	1487	**12.5%**
San Fernando - Arayat	994	1614	**27.5%**
Arayat - Magalang	1083	1390	**13.3%**
Magalang - Arayat	1198	1716	**19.7%**
Arayat - Nueva Ecija	1050	1465	**18.1%**
Nueva Ecija - Arayat	1382	1725	**11.7%**
Arayat – Town Proper	609	805	**15%**
Town Proper - Arayat	369	63	**-**

The researchers have examined data spanning from 2022 to 2024. They have identified a growth rate factor for these intersections, which can be utilized to forecast future traffic volumes. The average growth rate factor, as indicated in Table 4, stands at 16.83% per lane. However, it is important to note that this growth rate factor does not apply to the Town Proper – Arayat lane, due to a significant reduction in traffic volume resulting from recent changes in traffic policies in that area.

Growth Rate Factor Formula:

$$Growth\ Factor = \left(\frac{present}{past}\right)^{\frac{1}{n}} - 1$$

D. Population Growth

TABLE 4
POPULATION GROWTH

Direction	Current Population	Growth Factor	In 5 Years	In 10 Years
Arayat – San Fernando	1487	12.5%	2680	4829
San Fernando – Arayat	1614	27.5%	5439	18324
Arayat – Magalang	1390	13.3%	2596	4846
Magalang – Arayat	1716	19.7%	4217	10363
Arayat – Nueva Ecija	1465	18.1%	3366	7733
Nueva Ecija – Arayat	1725	11.7%	3000	5216
Arayat – Town Proper	805	15%	1620	3257
Town Proper - Arayat	63	-	-	-

To accurately gauge the efficacy of various proposed solutions, whether they are structural or policy-oriented, researchers rely on simulations. These simulations project the potential outcomes of implementing these solutions. However, to forecast the effectiveness of these policies down the line, researchers must first establish future population data to input into the simulations. This future population data is derived from the growth rate factor, which is detailed in Table 3.5, and further computed in Table 3.6 as the Calculated Population Growth. This process ensures a comprehensive understanding of how proposed policies might impact populations in the future, aiding in informed decision-making and strategy development.

Future Population Formula:

$$Future\ Population = past(1 + Growth\ rate\ factor)^{n}$$

E. Level of Service

The researchers manually counted the number of vehicles over a weekwith one-hour intervals spanning from morning through noon to the evening. For Monday, Tuesday, Saturday and Sunday, the researchers computed the projected traffic volume count using the growth rate factor. The type of vehicles was categorized into heavy truck, medium truck, small truck, large bus, minibus, utility, car, auto rickshaw, motorcycle, and bicycle. The researchers utilized the volume to capacity ratio ($\frac{v}{c}$) formula to ascertain the Level of Service (LOS) for each route. This method provided a structured approach for evaluating traffic performance and informing transportation planning decisions.

TABLE 5
MORNING PEAK HOUR (7:00 AM TO 8:00 AM)

DAYS	A-D B-D	D-C A-C	B-A C-A	C-B D-B
1	647	1396	1624	1076
2	598	1240	1322	860
3	542	1266	1516	1008
4	610	1278	1456	1024
5	592	1245	1538	1098
6	446	1223	1340	821
7	312	1074	1290	720
AVERAGE (V_x)	535.29	1246	1440.86	943.86
VOLUME TO CAPACITY RATIO ($\frac{v}{c}$)	0.359	0.836	0.967	0.633
LEVEL OF SERVICE	B	D	E	C

For Route A-D and B-D (Going to Arayat Public Market), a volume to capacity ratio of 0.359 was obtained, resulting in a Level of Service (LOS) classification of B. Route D-C and A-C (Going to Nueva Ecija) recorded aratio of 0.836, leading to a Level of Service (LOS) rating of D. Route B-A and C-A (Going to San Fernando) registered a ratio of 0.967, thereby yielding a Level of Service (LOS) rating of E. Lastly, for Route C-B and D-B (Going to Magalang), theratio was 0.633, resulting in a LOS classification of C.

TABLE 6
AFTERNOON PEAK HOUR (11:00 AM TO 12:00 PM)

DAYS	A-D B-D	D-C A-C	B-A C-A	C-B D-B
1	673	1504	1523	1114
2	528	1425	1512	1031
3	997	1599	1603	1404
4	874	1467	1456	1386
5	1049	1599	1603	1404
6	386	1178	1273	874
7	395	1198	1273	952
AVERAGE (V_x)	700.29	1424.29	1463.29	1166.43
VOLUME TO CAPACITY RATIO ($\frac{v}{c}$)	0.470	0.956	0.982	0.783
LEVEL OF SERVICE	B	E	E	D

For Route A-D and B-D (Going to Arayat Public Market), a ratio of 0.470 was obtained, resulting in a Level of Service (LOS) classification of B. Route D-C and A-C (Going to Nueva Ecija) recorded a ratio of 0.956, leading to a Level of Service (LOS) rating of E. Route B-A and C-A (Going to San Fernando) registered aratio of 0.982, thereby yielding a Level of Service (LOS) rating of E. Lastly, for Route C-B and D-B (Going to Magalang), theratio was 0.0.783, resulting in a LOS classification of D.

TABLE 7
EVENING PEAK HOUR (11:00 AM TO 12:00 PM)

DAYS	A-D B-D	D-C A-C	B-A C-A	C-B D-B
1	696	1513	1612	1658
2	451	1298	1356	734
3	782	1621	1611	1691
4	941	1446	1549	1603
5	854	1658	1550	1379
6	498	1366	1401	772
7	443	1405	1468	817
AVERAGE (V_x)	666.43	1472.43	1506.71	1236.29
VOLUME TO CAPACITY RATIO ($\frac{v}{c}$)	0.447	0.988	1.011	0.830
LEVEL OF SERVICE	B	E	F	D

For Route A-D and B-D (Going to Arayat Public Market), a ratio of 0.447 was obtained, resulting in a Level of Service (LOS) classification of B. Route D-C and A-C (Going to Nueva Ecija) recorded aratio of 0.988, leading to a Level of Service (LOS) rating of E. Route B-A and C-A (Going to San Fernando) registered a ratio of 1.011, thereby yielding a Level of Service (LOS) rating of F. Lastly, for Route C-B and D-B (Going to Magalang), theratio was 0.830, resulting in a LOS classification of D.

F. *Policy Guidelines for Proposed Policies*

1) *Intelligent Transport Systems (ITS):*

a)Closure of Calle Onse: This closure aims to improve traffic flow, enhance pedestrian safety, and reduce congestion at the intersection. Prioritize alternative routes and ensure proper signage and communication to inform drivers about the closure.

b)Intelligent Traffic Light System Installation: Smart traffic lights equipped with sensors, cameras, and communication devices at the 4-way intersection. These smart traffic lights will dynamically adjust signal timing based on real-time traffic conditions, optimizing traffic flow, and minimizing delays.

c) Adaptive Signal Control: Utilize adaptive signal control algorithms within the Smart Traffic Lights system to dynamically adjust signal timing at the Main Intersection and surrounding roads. This adaptive control will optimize traffic flow by allocating green light time based on traffic demand, time of day, and other relevant factors.

d) Priority for Main Intersection: Given the Main Intersection's importance, prioritize its signal timing to ensure the efficient movement of vehicles and pedestrians. Adjust the "Go time" frequency at the Main Intersection to be more frequent during peak hours, especially when traffic congestion is expected due to activities at the public market.

e) Real-time Monitoring and Adjustment: Implement a system for real-time monitoring of traffic conditions and performance of the Smart Traffic Lights system. Utilize data analytics and traffic management software to analyze traffic patterns, identify congestion points, and adjust signal timing and traffic flow strategies.

f) Regular Maintenance and Updates: Establish a schedule for regular Smart Traffic Lights system maintenance to ensure its optimal performance. Additionally, plan for periodic updates and upgrades to incorporate advancements in ITS technology and address evolving traffic management needs.

2) Unified Vehicular and Volume Reduction Program (UVVRP):

a) Prohibited Periods: Establish prohibited periods during which vehicles covered by the Number Coding System are restricted from operating on specified roads. The prohibited periods shall be from 7:00 AM to 8:00 PM on weekdays (Monday to Friday), excluding holidays.

b) Prohibited Days Based on Plate Endings:

- Monday: Vehicles with license plate numbers ending in 1 and 2 are prohibited from operating within designated areas.
- Tuesday: Vehicles with license plate numbers ending in 3 and 4 are prohibited.
- Wednesday: Vehicles with license plate numbers ending in 5 and 6 are prohibited.
- Thursday: Vehicles with license plate numbers ending in 7 and 8 are prohibited.
- Friday: Vehicles with license plate numbers ending in 9 and 0 are prohibited.

c) Exemptions and Exceptions:

- Emergency vehicles such as ambulances, fire trucks, and police vehicles are exempt from the UVRRP restrictions.
- Vehicles used for public transportation services, including buses and taxis, may be exempt from certain restrictions or subject to alternative regulations.
- Special permits may be granted for vehicles engaged in essential services or activities during restricted hours, subject to approval by relevant authorities.

d) Public Awareness and Education:Conduct comprehensive public awareness campaigns to inform motorists about the UVRRP regulations, including prohibited days and times, consequences of non-compliance, and available exemptions.Utilize various communication channels such as social media, radio broadcasts, road signs, and informational materials distributed through government agencies and community organizations.

3) Strict enforcement of all basic transportation laws:

a) Community Engagement Strategy:Conduct seminars and workshops on basic transportation laws and road safety practices in each barangay in the Municipality of Arayat.Collaborate with local government units, community organizations, and educational institutions to organize and facilitate these seminars.Provide informative materials such as brochures, pamphlets, and educational videos to supplement seminar sessions.Empower barangay officials and community leaders to promote awareness and compliance with transportation laws within their communities.

b) Awareness Campaigns at the Intersection:Utilize various communication channels, including digital displays, banners, and posters, to convey messages about road safety and adherence to transportation laws.Engage with motorists and pedestrians through interactive activities, such as distributing educational materials, conducting safety demonstrations, and organizing community events focused on road safety.

c) Addition of Traffic Signs:Identify locations where the addition of traffic signs such as speed limit signs, stop signs, yield signs, and other regulatory signs is necessary to improve traffic control and enhance road safety.Install and maintain traffic signs in accordance with established standards and guidelines, ensuring their visibility, readability, and compliance with relevant regulations.Supplement traffic signs with road markings, pavement symbols, and other visual cues to effectively reinforce traffic regulations and guide motorists.

d) Enforcement Mechanisms:Strengthen enforcement efforts through increased patrols, checkpoints, and surveillance operations conducted by traffic law enforcement agencies.Implement stringent penalties for traffic violations, including fines, license suspension, and vehicle impoundment, to deter non-compliance with transportation laws.Utilize CCTV cameras, automatic license plate recognition systems, and mobile applications to enhance monitoring and enforcement capabilities.

4) Re-routing of key vehicles in the Intersection:

a) Traffic Re-Routing Objective: The primary objective of the proposed re-routes is to optimize traffic flow, reduce congestion, and improve connectivity between San Fernando and Nueva Ecija and between Magalang and San Fernando. These bidirectional re-routes aim to provide commuters with efficient travel options while minimizing disruptions to existing road networks.

b) Infrastructure Preparation:Identify and prepare designated entry and exit points for each re-route, ensuring safe and efficient access for motorists.Install appropriate signage, road markings, and traffic control devices to guide vehicles along the designated routes and prevent confusion or congestion.

G. Re-routing Options

The researchers have pinpointed three alternative routes to divert private cars, motorcycles, and tricycles from traversing the Cacutud, Intersection. These routes offer viable detours to alleviate traffic congestion and enhance vehicle flow.

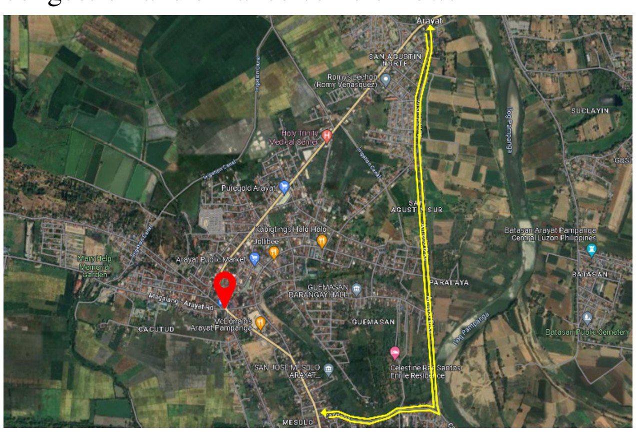

Fig. 6 Re-route from Brgy. San Jose Mesulo to San Agustin Norte

Starting from San Fernando, vehicles enter at San Jose Mesulo Street, pass through Barangay Paralaya, traverse Arnedo Dike and exit at San Agustin Norte. Conversely, vehicles from Nueva Ecija can enter at San Agustin Norte and exit at San Jose Mesulo Street.

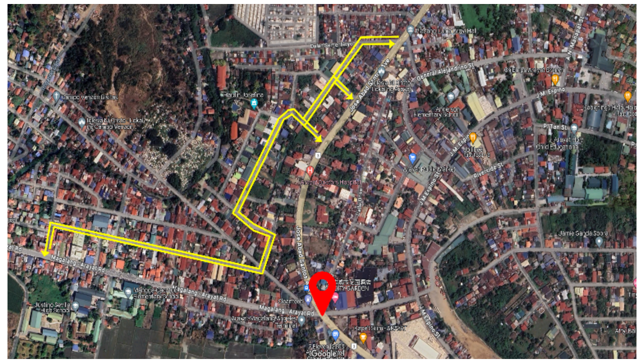

Fig. 7 Re-route from Magalang Road to JASA (towards Nueva Ecija)

For vehicles originating from Magalang, an entry point is positioned near the Cabs Korean Restaurant, with three exit points leading towards Jose Abad Santos Avenue (JASA). Similarly, vehicles from Arayat can access these entry points from JASA and can utilize the exit point near the Cabs Korean Restaurant to travel towards Magalang.

Fig. 8 Re-route from Magalang Road to JASA (towards San Fernando)

Vehicles originating from San Fernando can enter at the street next to Flying V gas station and exit onto Magalang road. Similarly, vehicles traveling from Magalang to San Fernando can access the route by entering from the Magalang road to reach the Flying V gas station.

H. Simulation

PTV Vissim, the leading traffic simulation software, digitally replicates real-world traffic dynamics at a granular level, enabling informed planning decisions. By optimizing the performance of transportation infrastructure, it proactively addresses issues such as congestion, emissions, and equitable road space distribution. The data collected from manual intersection traffic counts over a three-day period was input and integrated into PTV Vissim for analysis and simulation. In the context of a four-way intersection, traffic counts were recorded for 12 total directions: A-D, B-D (TO PALENGKE), D-C, A-C (TO NUEVA ECIJA), B-A, C-A (TO SAN FERNANDO), and C-B, D-B (TO MAGALANG). PTV Vissim conducted a total of 35 simulations at hourly intervals. The simulation data generated by PTV Vissim includes various metrics such as Qlen, QlenMax, Vehs(All), Pers(All), LOS, LOSval(All), VehDelay(All), Stopdelay(All),Stops(All),EmissionCo, EmissionsNOx, EmissionsVOC, and FuelConsumtion.The trend observed in the comparison of data indicates significant improvements ranging from 20% to 30% across key metrics. Notably, there was a 24.66% enhancement in the LOS value, signifying a considerable improvement in the level of service. Additionally, there was a 27.4% reduction in average vehicle delay, leading to smoother traffic flow. Moreover, there were improvements of 25.43% in PERSdelay and 27.32% in STOPdelays, further enhancing overall traffic management efficiency.

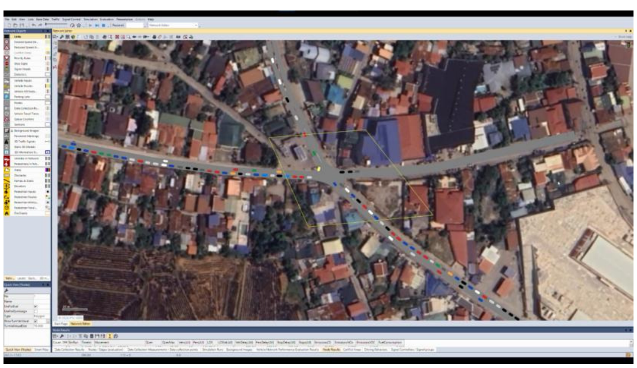

Fig. 9PTV VISSIM Simulation Unsignalized

TABLE 8
PTV VISSIM RESULTS UNSIGNALIZED

	TIMEINT	MOVEMENT	QLEN	QLENMAX	VEHS(ALL)	PERS(ALL)	LOSVAL(ALL)	VEHDELAY(ALL)	PERSDELAY(ALL)	STOPDELAY(ALL)	STOPS(ALL)
AVG	0-3600	1-1: D@149.6-4@40.0	12.33	40.3	2	2	4	152.36	152.36	143.18	6.95
AVG	0-3600	1-1: D@149.6-6@27.4	11.63	37.84	3	3	5	152.36	121.96	117.62	0.88
AVG	0-3600	1-1: D@149.6-8@23.1	12.24	40.26	3	3	5	168.82	168.82	162.83	1.45
AVG	0-3600	1-3: A@207.6-2@45.8	153.12	210	4	4	5	114.51	114.51	107.37	0.94
AVG	0-3600	1-3: A@207.6-6@27.4	153.3	209.19	60	60	2	34.67	34.67	31.82	1.83
AVG	0-3600	1-3: A@207.6-8@23.1	153.41	209.32	35	35	5	139.27	139.27	128.9	21.56
AVG	0-3600	1-5: C@160.4-2@45.8	68.1	131.34	22	22	1	4.06	4.06	2.84	0.86
AVG	0-3600	1-5: C@160.4-4@40.0	65.74	127.41	111	111	1	4.46	4.46	3.53	0.09
AVG	0-3600	1-5: C@160.4-8@23.1	64.69	127.6	114	114	2	6.11	6.11	5.15	0.18
AVG	0-3600	1-7: B@251.5-2@45.8	114.61	223.91	99	99	4	124.99	124.99	112.47	3.66
AVG	0-3600	1-7: B@251.5-4@40.0	123.82	233.14	82	82	4	123.08	123.08	109.88	3.27
AVG	0-3600	1-7: B@251.5-6@27.4	125.27	234.61	79	79	3	111.45	111.45	102.01	2.04
AVG	0-3600	1	90.26	251.06	614	614	2	18.39	18.39	16.25	0.47
			88.348	**159.691**	**94.462**	**94.462**	**3.308**	**88.810**	**86.472**	**80.296**	**3.398**

The Unsignalized PTV Vissim result shown in table 8 yielding an average of 88.35 Qlen , Qlenmax of 159.69, VEHS/PERS(ALL) 94.46, LOS VALUE OF 3.31, VEHDELAY OF 88.81, PERSDELAY OF 86.47, STOPDELAY OF 80.3, and VEH stops of 3.4.

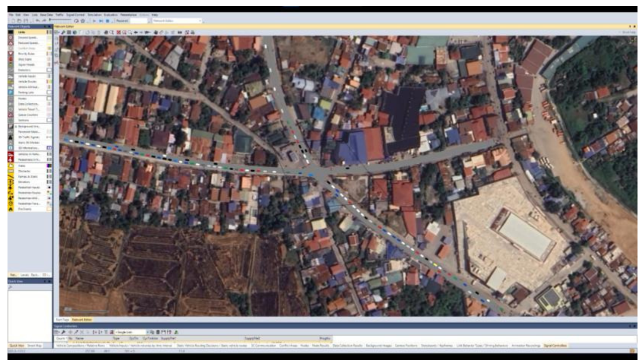

Fig. 10 PTV VISSIM Simulation Signalized

TABLE 9
PTV VISSIM RESULTS SIGNALIZED

	TIMEINT	MOVEMENT	QLEN	QLENMAX	VEHS(ALL)	PERS(ALL)	LOSVAL(ALL)	VEHDELAY(ALL)	PERSDELAY(ALL)	STOPDELAY(ALL)	STOPS(ALL)
AVG	0-3600	1-1: D@149.6-4@40.0	1.37	10.85	4	4	3	27.8	27.8	24.91	0.48
AVG	0-3600	1-1: D@149.6-6@27.4	1.37	10.85	3	3	4	47.47	47.47	43.02	0.76
AVG	0-3600	1-1: D@149.6-8@23.1	1.37	10.85	6	6	2	15.51	15.51	12.02	0.48
AVG	0-3600	1-3: A@207.6-2@45.8	182.74	249.76	6	6	6	86.75	86.75	80.01	1.29
AVG	0-3600	1-3: A@207.6-6@27.4	182.74	249.76	103	103	5	73.13	73.13	66.25	1.27
AVG	0-3600	1-3: A@207.6-8@23.1	182.74	249.76	53	53	5	74.62	74.62	67.51	1.31
AVG	0-3600	1-5: C@160.4-2@45.8	133.54	193.13	17	17	5	73.01	73.01	66.75	1.18
AVG	0-3600	1-5: C@160.4-4@40.0	108.57	164.86	77	77	5	64.09	64.09	58.66	1
AVG	0-3600	1-5: C@160.4-8@23.1	133.54	193.13	82	82	5	65.17	65.17	59.77	1
AVG	0-3600	1-7: B@251.5-2@45.8	190.09	272.38	53	53	4	79.37	79.37	71.36	1.32
AVG	0-3600	1-7: B@251.5-4@40.0	190.09	272.38	46	46	4	77.15	77.15	69.09	1.23
AVG	0-3600	1-7: B@251.5-6@27.4	190.09	272.38	42	42	4	84.81	84.81	76.53	1.31
AVG	0-3600	1	123.26	272.38	492	492	5	69.32	69.32	62.84	1.14
			124.732	**186.344**	**75.692**	**75.692**	**4.385**	**64.477**	**64.477**	**58.363**	**1.059**

The Unsignalized PTV Vissim result shown in table 9 yielding an average of 124.73 Qlen, Qlenmax of 186.34, VEHS/PERS(ALL) 75.69, LOS VALUE OF 4.38, VEHDELAY OF 64.48, PERSDELAY OF 64.48, STOPDELAY OF 58.36, and VEH stops of 1.

I. Survey Results

The researchers conducted a survey to assess the approval of stakeholders withinCacutud, Arayat, Pampanga, regarding proposed policy measures aimed at mitigating traffic congestion at the intersection of a four-way road with multiple adjacent side streets. In the conducted survey, the respondents were classified into motorists, PUV Operators, Pedestrian, and Business Owners.

The survey's findings, derived from four Likert-type scales, are utilized to analyze respondents' responses using numerical equivalents and interpretations: 1 signifies "strongly disagree," 2 indicates "disagree," 3 implies "agree," and 4 denotes "strongly agree."

Interpreting a 4-point scale involves assigning point values to each response, ranging from 1 (lowest) to 4 (highest), based on response frequencies. The scale's range is calculated by subtracting 1 from 4 (yielding 3) and dividing by four, since it is the maximum value (3 ÷ 4 = 0.75). Subsequently, the lowest value on the scale, 1, is added to determine the maximum, and 0.1 is added to the maximum to establish the next minimum value.

The intervals are defind as follows:

Scores from 1 to 1.75 correspond to "Strongly Disagree."

Scores from 1.85 to 2.6 correspond to "Disagree."

Scores from 2.7 to 3.45 correspond to "Agree."

Scores from 3.55 to 4.3 correspond to "Strongly Agree."

1) Motorists:In this section, a group comprising seventy (70) motorist respondents were examined.

TABLE 10
MOTORISTS AWARENESS OF TRANSPORT POLICIES

Statement	Weighted Mean	Verbal Interpretation
Awareness of Smart Traffic Lights	3.34	Agree
Function of Smart Traffic Lights	3.27	Agree
Awareness of UVVRP	3.55	Strongly Agree
Regulations and Guidelines of UVVRP	3.22	Agree
Implementation of Traffic Laws	3.06	Agree
Redirecting/rerouting Traffic	3.6	Strongly Agree

TABLE 11
MOTORISTS PERSONAL EXPERIENCE AND PERCEPTION

Statement	Weighted Mean	Verbal Interpretation
Experienced Smart Traffic Lights	3.76	Strongly Agree
Positive impact of UVVRP	3.17	Agree
Necessity of Traffic Laws	3.5	Agree
Experienced rerouting of Traffic	3.73	Strongly Agree
Closing of Roads for alleviating Traffic	3.79	Strongly Agree

TABLE 12
MOTORISTS PARTICIPATION WILLINGNESS LEVEL

Statement	Weighted Mean	Verbal Interpretation
Willingness to participate in seminars	2.8	Agree
Integration of traffic policies	3.47	Agree
Implementation of Smart Traffic Lights	3.67	Strongly Agree
Implementation of UVVRP	2.71	Agree
Strict implementation of traffic laws	3.61	Strongly Agree
Implementation of Rerouting	3.73	Strongly Agree
Closing of Calle Onse during peak hours	2.7	Agree

2) Public Utility Vehicle Operators:Onto the next classification of respondents, were the results of seventy-five (75) PUV Operators' response to the conducted survey.

TABLE 13
PUV OPERATORS AWARENESS OF TRANSPORT POLICIES

Statement	Weighted Mean	Verbal Interpretation
Awareness of Smart Traffic Lights	3.81	Strongly Agree
Function of Smart Traffic Lights	3.79	Strongly Agree
Awareness of UVVRP	3.72	Strongly Agree
Regulations and Guidelines of UVVRP	3.68	Strongly Agree
Implementation of Traffic Laws	3.76	Strongly Agree
Redirecting/rerouting Traffic	3.83	Strongly Agree

TABLE 14
PUV OPERATORS PERSONAL EXPERIENCE AND PERCEPTIONS

Statement	Weighted Mean	Verbal Interpretation
Experienced Smart Traffic Lights	3.73	Strongly Agree
Positive impact of UVVRP	2.73	Agree
Necessity of Traffic Laws	3.56	Strongly Agree
Experienced rerouting of Traffic	3.84	Strongly Agree
Closing of Roads for alleviating Traffic	3.87	Strongly Agree

TABLE 15
PUV OPERATORS PARTICIPATION WILLINGNESS LEVEL

Statement	Weighted Mean	Verbal Interpretation
Willingness to participate in seminars	3.95	Strongly Agree
Integration of traffic policies	3.92	Strongly Agree
Implementation of Smart Traffic Lights	3.87	Strongly Agree
Implementation of UVVRP	3.12	Agree
Strict implementation of traffic laws	2.96	Agree
Implementation of Rerouting	2.47	Disagree
Closing of Calle Onse during peak hours	2.31	Disagree

*3) **Pedestrians:***The next classification of respondents is seventy (70) Pedestrians, these are the results of their response to the survey.

TABLE 16
PEDESTRIANS AWARENESS OF TRANSPORT POLICIES

Statement	Weighted Mean	Verbal Interpretation
Awareness of Smart Traffic Lights	3.01	Agree
Function of Smart Traffic Lights	2.97	Agree
Awareness of UVVRP	2.46	Disagree
Regulations and Guidelines of UVVRP	2.46	Disagree
Implementation of Traffic Laws	3.39	Agree
Redirecting/rerouting Traffic	2.83	Agree

TABLE 17
PEDESTRIANS PERSONAL EXPERIENCE AND PERCEPTIONS

Statement	Weighted Mean	Verbal Interpretation
Experienced Smart Traffic Lights	3.3	Agree
Positive impact of UVVRP	2.54	Disagree
Necessity of Traffic Laws	3.67	Strongly Agree
Experienced rerouting of Traffic	2.63	Disagree
Closing of Roads for alleviating Traffic	3.43	Agree

TABLE 18
PEDESTRIANS PARTICIPATION WILLINGNESS LEVEL

Statement	Weighted Mean	Verbal Interpretation
Willingness to participate in seminars	3.44	Agree
Integration of traffic policies	3.61	Strongly Agree
Implementation of Smart Traffic Lights	3.34	Agree
Implementation of UVVRP	3.09	Agree
Strict implementation of traffic laws	3.53	Agree
Implementation of Rerouting	2.96	Agree
Closing of Calle Onse during peak hours	2.49	Disagree

4) ***Business Owners:***Lastly, a group comprising fifty (50) business owner respondents were examined.

TABLE 19
BUSINESS OWNERS AWARENESS OF TRANSPORT POLICIES

Statement	Weighted Mean	Verbal Interpretation
Awareness of Smart Traffic Lights	3.56	Strongly Agree
Function of Smart Traffic Lights	3.48	Agree
Awareness of UVVRP	2.6	Agree
Regulations and Guidelines of UVVRP	2.48	Disagree
Implementation of Traffic Laws	3.3	Agree
Redirecting/rerouting Traffic	3.06	Agree

TABLE 20
BUSINESS OWNERS PERSONAL EXPERIENCE AND PERCEPTION

Statement	Weighted Mean	Verbal Interpretation
Experienced Smart Traffic Lights	3.1	Strongly Agree
Positive impact of UVVRP	2.56	Disagree
Necessity of Traffic Laws	3.62	Strongly Agree
Experienced rerouting of Traffic	2.62	Disagree
Closing of Roads for alleviating Traffic	3.16	Agree

TABLE 21
BUSINESS OWNERS PARTICIPATION WILLINGNESS LEVEL

Statement	Weighted Mean	Verbal Interpretation
Willingness to participate in seminars	3.58	Strongly Agree
Integration of traffic policies	3.64	Strongly Agree
Implementation of Smart Traffic Lights	3.38	Agree
Implementation of UVVRP	3.48	Agree
Strict implementation of traffic laws	3..48	Agree
Implementation of Rerouting	2.7	Agree
Closing of Calle Onse during peak hours	2.68	Disagree

IV. CONCLUSIONS

A. Simulation and Level of Service

The level of service at an intersection or on any road is the most effective means of determining congestion. Through simulation, the Unsignalized Level of Service yielded an average of 3.308 LOSVAL. Comparing this to the 4.385 LOSVAL from the data, we can conclude that there is a 24.66% improvement in the LOS value. However, the intersection's rating is still considered to be F.

To sum up, the average improvement of the implementation of ITS in the four-way intersection ranges from 20-30 percent throughout the different aspects of the four-way intersection. These findings collectively affirm the efficacy of ITS in optimizing traffic management and enhancing overall intersection performance.

B. Survey Results and Proposed Policies

Personal experiences and perceptions among motorists and PUV operators highlight a mixed response to congestion alleviation measures. While there is agreement on the effectiveness of smart traffic lights, opinions vary on the impact of the UVVRP. Nonetheless, there is widespread support for strict enforcement of traffic laws and road closures during peak hours. However, the survey also reveals concerns among a subset of respondents, particularly regarding proposed rerouting strategies such as the potential closure of Calle Onse.

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