Route Selection For Pile Distribution And Intersection Performance Analysis Along The Route

I Gusti Raka Purbanto[1*], I Wayan Suweda[1], I Gede Restu Anggandika[1]

[1]Civil Engineering Udayana University, Bali, Indonesia

[*]E-mail address: rakapurbanto@unud.ac.id

ABSTRACT

The distribution of piles to the installation site requires consideration of various factors, including travel time and route conditions to allow delivery vehicles to maneuver freely. This research aims to determine the optimal time and alternative routes for delivering piles from PT. Satriacipta Astakencana, located at Jl. Prof. Dr. Ida Bagus Mantra Km. 14.5, Sukawati, Gianyar, to the NUGRAA Apartment project site on Jl. Pantai Batu Bolong Canggu. This is due to considerations of distance and delivery time, as well as the frequent traffic conflicts at the unsignalized intersection of Jl. Raya Canggu and Jl. Pantai Berawa. This study uses a method of collecting field survey data, observation, and literature studies. Based on the analysis, the alternative route via Route 1 from PT. Satriacipta Astakencana - Jl. Gatot Subroto-Jl. Raya Kerobokan - Jl. Raya Canggu - Jl. Pantai Batu Bolong to the delivery location, with a distance of 26.7 km, travel time of 49 minutes, and the selected departure time of 05.00 WITA, is recommended. The analysis shows that the intersection performance during peak hours (07.00-08.00 WITA) has an average delay of 40.42 seconds/smp at intersections I and II. The queue probability at both intersections has exceeded 100% with a level of service of E. Therefore, the suitable time to pass through the intersection is between 05.00-06.00 WITA.

Keywords: Distribution, Intersection Performance, Piles, Unsignalized Intersection.

1. INTRODUCTION

In the production process, the distribution of goods plays a crucial role in the overall success of material trade. Any delay in material distribution can result in setbacks in ongoing construction projects. PT. Satriacipta Astakencana, the only company in Bali that manufactures prestressed precast concrete, is located at Jln. Prof. Dr. Ida Bagus Mantra Km. 14.5, Sukawati, Gianyar. This company produces various precast concrete products, including piles, beams, columns, half slabs, and others, with piles as the primary product. Product distribution to project sites, such as the NUGRAA Apartment project on Jl. Pantai Batu Bolong, Canggu, is an essential part of the production process. Traffic congestion can significantly prolong delivery time and lead to fuel wastage, ultimately resulting in financial losses[1]. Therefore, route selection, delivery timing, and vehicle condition are critical considerations to ensure

efficient and timely delivery. According to [2], travel cost is a key factor in route selection. Furthermore,[3] emphasize that traffic flow smoothness also influences route choice.

The road network in this area is relatively narrow with many curves, which requires special attention during the delivery process, especially when using large vehicles such as pile transport trucks. Deliveries often pass through multiple intersections, and one of the key intersections studied in this research is the unsignalized intersection at Jl. Raya Canggu – Jl. Pantai Berawa, which frequently experiences congestion and traffic conflicts.

Several previous studies have addressed route selection and intersection performance. For instance, [4] used a causal-comparative research methodology to determine the optimal route, while [5] reported that the current condition of the Jl. Raya Canggu – Jl. Pantai Berawa intersection exhibits a high saturation level, with a degree of saturation (DS) reaching 2.6 and a Level of Service (LOS) of F, indicating very poor traffic conditions.

An intersection is defined as an area where two or more roads meet, merge, intersect, or cross, either at-grade or grade-separated, at a point within the road network where vehicle paths conflict [6]. In the delivery process from PT. Satriacipta Astakencana to the project site, route selection must consider the large size and volume of delivery vehicles, which limits accessible routes. Among several intersections encountered along the route, the unsignalized Jl. Raya Canggu – Jl. Pantai Berawa intersection presents a significant bottleneck. Traffic conflicts at this intersection often disrupt vehicle maneuvers and hinder smooth travel.

Based on previous studies, it is crucial for PT. Satriacipta Astakencana to consider optimal delivery timing to avoid severe congestion at the unsignalized Jl. Raya Canggu – Jl. Pantai Berawa intersection. This study aims to identify the most efficient route and delivery schedule for transporting piles to ensure smooth and timely arrival at the project site, while avoiding peak traffic hours that could lead to delays and increased logistics costs.

2. THEORY AND METHODS

2.1 Basic Theory

A nominated route is defined as a route that may be chosen during a journey[7]. In this context, it refers to the movement from an origin zone to a destination zone, where multiple route options may exist; however, only a few alternative routes are considered "reasonable" and likely to be chosen. The objective of route selection serves as a basis for modeling travel behavior in order to determine the optimal route. Travel time and travel distance are key parameters used by road users in selecting the most efficient route.

Transport and distribution management

Distribution is the process of delivering goods or production outputs from a company or producer to personal or industrial consumers. The main challenge in distribution lies in aligning the quantity of available products with the demand at the destination. The transportation system, first developed by F.L. Hitch Cock in 1941, focuses on moving products from multiple sources to various destination points. The speed and consistency of transportation services are crucial to ensure timely deliveries between two locations. Fundamentally, distribution and transportation serve the function of moving products from the place of production to the place

of use. This activity may be carried out directly by the manufacturing company or through third-party services, depending on the company's chosen logistics strategy [8].

Definition of intersection

An intersection is the meeting, merging, crossing, or diverging point of two or more road segments. It can be defined as the point at which two or more roads meet, whether at-grade or grade-separated, forming a junction within the road network. Common issues associated with intersections include traffic capacity and volume, sight distance, geometric design, queue length, and traffic behavior. Intersections are classified into two types based on control mechanisms [6]: (1). Signalized Intersections, (2) Unsignalized Intersections.

Unsignalized Intersections

An unsignalized intersection refers to a junction not equipped with traffic signals, where drivers must make their own decisions regarding when it is safe to proceed. The control measures used at unsignalized intersections include: a) Priority Rules; b) Signs and Markings; c) Channelization.

Theoretical Basis of Unsignalized Intersections

In analyzing unsignalized intersections, the following standard forms are used:

1. USIG-I Form: Records traffic flow and geometric data.
2. USIG-II Form: Analyzes intersection type, approach width, capacity, and traffic behavior.

The performance evaluation of an unsignalized intersection refers to the procedures outlined in Indonesia Highway Capacity Manual (MKJI) 1997, starting with the collection of input data through field surveys, including:

a) Geometric Conditions: Sketching the geometric layout of the road, including road width and shoulders, and identifying major and minor roads.

b) Traffic Conditions: Determined based on the Design Hour Volume or the Annual Average Daily Traffic (LHRT), converted into hourly traffic flow.

Capacity (C)

The capacity of an intersection is defined as the maximum ability of an intersection to accommodate traffic flow. The formula used to calculate intersection capacity is given in Equation (1), where several adjustment factors are applied:

$$C = CO \times FW \times FCS \times FM \times FRSU \times FLT \times FRT \times FMI \quad (1)$$

Where:

- C = Capacity (smp/hour)
- CO = Basic Capacity (smp/hour)
- FW = Adjustment Factor for Approach Width
- FCS = Adjustment Factor for City Size
- FM = Adjustment Factor for Median Width
- FRSU = Adjustment Factor for Type of Roadside Use
- FLT, FRT, FMI = Other adjustment factors depending on local intersection characteristics.

Degree of Saturation (DS)

The Degree of Saturation (DS) is the ratio between traffic flow and capacity, serving as a key indicator for evaluating the performance level of an intersection or road segment. Once the DS value is determined, traffic problems within a given road segment can be identified. The formulas used to calculate DS are shown in Equations (2) and (3):

$$DS = (Qv \cdot P)/C \quad (2)$$

$$DS = Q/C \quad (3)$$

Where:

- DS = Degree of Saturation
- Qv = Total entering traffic (vehicles/hour)
- P = Passenger car equivalent factor (SMP factor)
- Q = Total flow (smp/hour)
- C = Capacity (smp/hour)

Delay

Average delay (D) is defined as the sum of geometric delays at the intersection and the traffic delays that occur. The formula used to calculate intersection delay is shown in Equation (4):

$$D = DG + DT1 \quad (4)$$

Where:

- DG = Geometric delay at the intersection (seconds/smp)
- DT1 = Traffic delay at the intersection (seconds/smp)

Queue Probability

Empirical curves or tables relating queue probability to the degree of saturation [9] can be used to estimate the likelihood of queuing. The following empirical formulas provide estimates for queue probability based on the DS value:

- Lower bound:
  $QP\% = 9{,}02 \times DS + 20{,}66 \times DS2 + 10{,}49 \times DS3 \quad (5)$
- Upper bound:
  $QP\% = 4{,}71 \times DS - 24{,}68 \times DS2 + 56{,}47 \times DS3 \quad (6)$

Level of Service at Intersections

The Level of Service (LOS) is a quantitative measure that describes the quality of traffic conditions experienced by road users at intersections. It considers factors such as traffic density, delays, comfort, safety, speed, and travel time [10].

Table 1. Level of Service at Intersections

Delay (sec/smp)	**Service Level**
< 5	A
> 5,00 – 15,00	B
> 15,00 – 25,00	C
> 25,00 – 40,00	D
> 40,00 – 60,00	E
> 60,00	F

2.2 Research Method

Research Population and Sample

This study consists of sample units for route selection and intersection analysis as follows:
Route Analysis:

1. Delivery schedule samples obtained from the company.
2. Distance and travel time data.

Intersection Analysis

1. The selected sample location is the unsignalized intersection at Jl. Raya Canggu – Jl. Pantai Berawa.
2. The sample time frame is based on morning delivery hours.
3. The sample population consists of three vehicle types:
    - Motorcycles (MC)
    - Light Vehicles (LV)
    - Heavy Vehicles (HV)

Data Analysis

This study utilizes primary data in the form of traffic volume obtained through manual traffic counting surveys, intersection geometry, and land use characteristics. Secondary data includes the study area map, departure times, company-selected delivery routes, and road network maps. For route analysis, location maps and route selection are based on Google Maps data. Intersection performance analysis is conducted using the methodology outlined in Indonesia Highway Capacity Manual (MKJI) 1997 [9].

3. RESULTS AND DISCUSSION

Delivery Data

For the NUGRAA Apartment construction project, a total of 73 precast concrete piles were used, consisting of 25 piles measuring 0.3 x 0.3 x 5 meters and 48 piles measuring 0.3 x 0.3 x 6 meters. The delivery of these piles was divided into four separate shipments, as shown on Table 1.

Table 2. Delivery data of NUGRAA Apartment

LAPORAN PENGIRIMAN APARTEMEN BATU BOLONG
BULAN OKTOBER 2023

Tanggal	No SJ	Tiang Pancang TP. 30x30		Lainnya		Tujuan	Mobil	Supir
		5m Polos	6m Polos	Jml	Type			
11 Oktober 2023	23. 1275		**20**	20		**Villa Panta nyanyi**	Hino 1	**Gabreil**
16 Oktober 2023	23. 1279	**25**		25			Hino 3	**Riko**
18 Oktober 2023	23. 1283		25	25			Hino 3	**Riko**
18 Oktober 2023	231.285		3	3			Dyna Crane	Oka
				0				
				0				
	JUMLAH	25	48	73				
	TOTAL							

Route Analysis

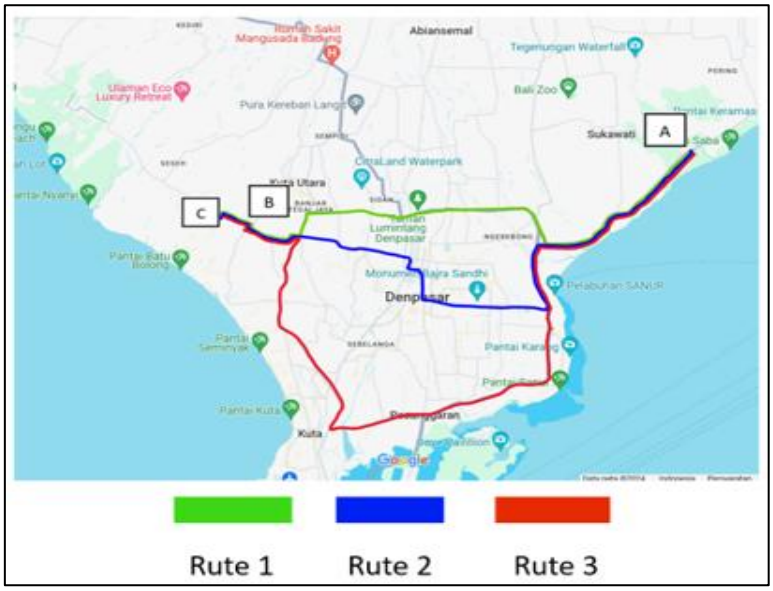

Figure 1. Delivery Route to Batu Bolong Apartment (NUGRAA Apartment)

Where: A = PT. Satricipta Astakencana; B = Unsignalized intersection at Jl. Raya Canggu – Jl. Raya Padonan and intersection at Jl. Raya Canggu – Jl. Pantai Berawa; C = NUGRAA Apartment (delivery location).

No	Period	Route	Distance (A - B) (km)	Total (min)	Distance (A -C) (km)	Total (min)
		1	22,8	42	26,7	47
1	05.00-06.30	2	26,2	44	28,8	49
		3	36,9	57	38,9	62
		1	22,8	60	26,7	77
2	08.30-11.45	2	26,2	67	28,8	84
		3	36,9	88	38,9	105
		1	22,8	61	26,7	80
3	13.00-16.00	2	26,2	68	28,8	87
		3	36,9	90	38,9	109
		1	22,8	70	26,7	85
4	15.00-18.45	2	26,2	73	28,8	88
		3	36,9	100	38,9	115

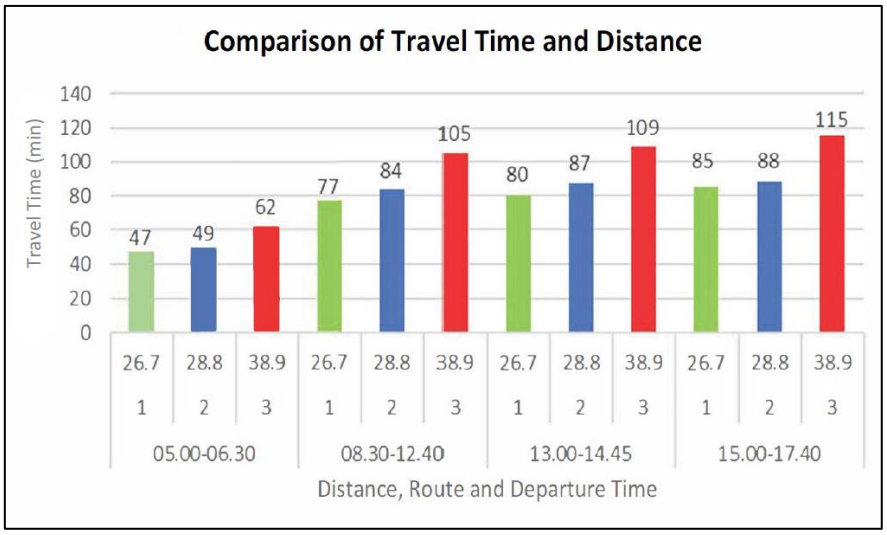

Figure 2. Comparison of Travel Time and Distance

Based on the route analysis, considering both travel time and distance, Route 1 (Northern Ring Road) was selected as the alternative route. This route was chosen for its efficiency, offering a shorter travel time and relatively shorter distance. Additionally, the geometric conditions of the road were favorable, which is important due to the large dimensions of the delivery vehicles, allowing for better maneuverability. Therefore, Route 1 is considered the most optimal option to minimize travel time and improve overall route efficiency. However, this route includes one intersection that is prone to vehicle conflict, which can contribute to delivery delays from PT. Satricipta Astakencana.

Intersection Performance Analysis

The intersection at Jl. Raya Canggu – Jl. Pantai Berawa is classified as an unsignalized staggered T-intersection, with a spacing of 75 meters between the two component intersections. Due to the separation distance being more than 40 meters, the intersection cannot be analyzed as a single unit. Therefore, the performance analysis is divided into two separate intersections:

- Intersection I: Jl. Raya Canggu – Jl. Raya Padonan
- Intersection II: Jl. Raya Canggu – Jl. Pantai Berawa

This intersection analysis takes into account the interaction between both intersections, considering the approach conditions of an unsignalized T-intersection.

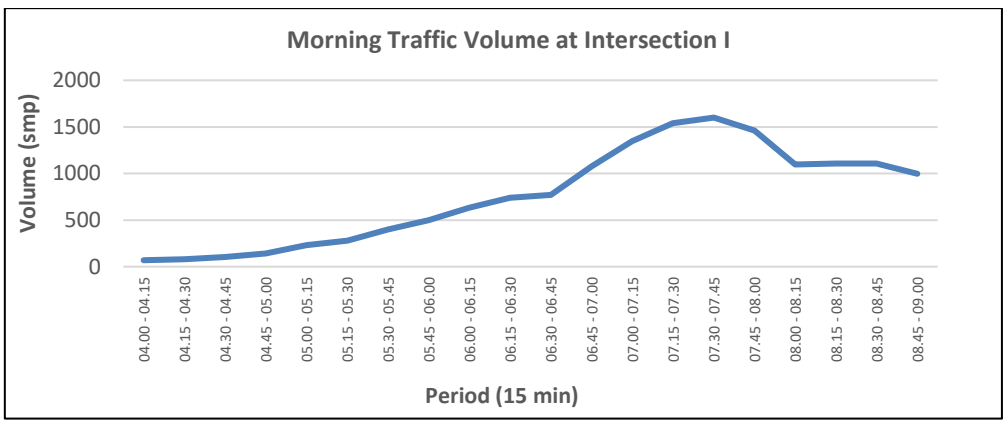

Figure 2. Morning Traffic Volume at Intersection I (Jl. Raya Canggu – Jl. Raya Padonan)

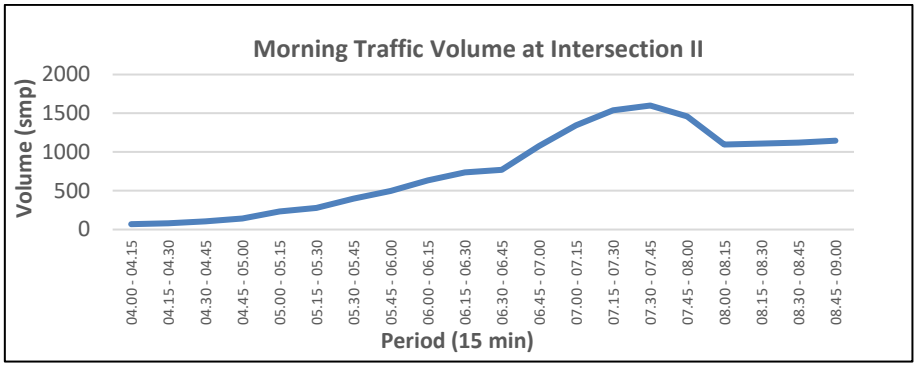

Figure 3. Morning Traffic Volume at Intersection I (Jl. Raya Canggu – Jl. Pantai Berawa)

Table 2. Summary of Intersection Performance at Intersection I (Jl. Raya Canggu – Jl. Raya Padonan) and Intersection II (Jl. Raya Canggu – Jl. Pantai Berawa) During Peak Hours

Intersection	Peak Hour	Qtotal smp	C (smp/h)	DS	D (s/smp)	QP (%)	TP
I	Morning (07.00-08.00)	4867,6	1894,18	2,570 1,2	-1,05 40,42	1243-337 190-58	E
II	Morning (07.00-08.00)	4833,8	2591	1,865 1,2	-4,11 40,42	157-370 190-58	E

Table 3. Summary of Intersection Performance at Intersection I (Jl. Raya Canggu – Jl. Raya Padonan) and Intersection II (Jl. Raya Canggu – Jl. Pantai Berawa) at 05.00 to 06.00.

Intersection	Peak Hour	Qtotal smp	C (smp/h)	DS	D (s/smp)	QP (%)	TP
I	Pagi (05.00-06.00)	1165,6	1860	0,627	10,82	16-53	B
II	Pagi (05.00-06.00)	1152,5	1962	0,587	10,12	14,5-48	B

Based on the intersection performance analysis conducted during the time range of 04:00–09:00 WITA, it was determined that the most suitable delivery time falls between 05:00–06:00 WITA. This time window allows for timely arrival at the project site, enabling unloading activities to proceed without delay. However, if the objective is to identify the optimal traffic conditions for delivery, then midnight deliveries would offer the best travel time. Nevertheless, this comes with the limitation that unloading cannot be performed upon arrival due to the absence of on-site workers during those hours.

4. CONCLUSIONS

Based on the analysis results, it can be concluded that the selected delivery route from the company is not the only viable option for transporting precast piles to the project site there are still other alternative routes that may be considered. However, after analyzing the chosen route, it was found that the route selected by the company is indeed optimal in terms of distance. On the other hand, the delivery schedule (specifically the departure time) was found to be less effective. The analysis indicates that the optimal departure time along Route 1 is at 05:00 WITA.

This finding aligns with the results of the intersection performance analysis at the Jl. Raya Canggu – Jl. Pantai Berawa intersection, where the average delays recorded were 10.82 seconds/smp at Intersection I and 10.12 seconds/smp at Intersection II. These delay values suggest that 05:00 WITA is a favorable time for traversing the intersection with minimal congestion.

Based on the analysis, the following recommendations can be made:

- For future research on alternative route selection, it is recommended to conduct further analysis and incorporate simulation of the distribution process for each potential route.
- Moving forward, it is important to reassess the intersection at Jl. Pantai Berawa – Jl. Raya Canggu, especially considering the presence of a shortcut in the area. In addition, nearby intersections within the same road network that may influence delivery routes to similar project locations should also be analyzed.

REFERENCES

[1] M. Aulia, “Analisis Dampak Sosial Ekonomi Pengguna Jalan Akibat Kemacetan Lalu Lintas Di Banda Aceh,” *Aceh J. Ekon. dan Kebijak. Publik*, vol. 3, no. 1, pp. 26–33, 2016.

[2] I. Reny Rochmawati, “STUDI PEMILIHAN RUTE PERJALANAN DARI SENTANI KE KOTA JAYAPURA,” *J. Portal Civ. Eng. Vol*, vol. 2, no. 2, 2019.

[3] I. Caesariawan, D. N. Rizky, I. Ismiyati, and E. E. Yulipriyono, “Pengaruh Nilai Waktu Pada Biaya Operasional Kendaraan (BOK) Mobil Penumpang Dalam Pemilihan Rute Jalan Eksisting dan Jalan Lingkar Ambarawa,” *J. Karya Tek. Sipil*, vol. 4, no. 4, pp. 304–312, 2015.

[4] F. Budiman, K. Erwan, and others, “Analisis Kinerja Simpang Stagger Pada Jl. Sultan Abdurrahman--Jl. Johan Idrus--Jl. Putri Candramidi Kota Pontianak,” *JeLAST J. Tek. Kelautan, PWK, Sipil, dan Tambang*, vol. 1, no. 1.

[5] I. G. R. Purbanto, *Permasalahan Pada Kinerja Simpang Tak Bersinyal dan Alternatif Solusi*. 2021.

[6] E. K. Morlok and J. K. Hainim, *Pengantar teknik dan perencanaan transportasi*. 1985.

[7] T. AKIYAMA, “The proposal of fuzzy traffic assignment models,” *Proc. Third East. Asia Soc. Transp. Stud.*, 1999.

[8] I. N. Pujawan and Mahendrawathi, *SUPPLY CHAIN MANAGEMENT*. 2010.

[9] D. J. B. Marga, “Manual Kapasitas Jalan Indonesia (MKJI),” 1997.

[10] K. Perhubungan, “Peraturan Menteri Perhubungan Nomor KM 14 Tahun 2006,” 2006.