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Performance Analysis and Traffic Flow Simulation of Tukad Pakerisan Road Segments Using VISSIM in South Denpasar

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ABSTRACT

The increasing ownership of motor vehicles has significantly contributed to heightened levels of traffic congestion. This study was conducted on Tukad Pakerisan Road in Denpasar City and aims to evaluate the current performance of the road segment by employing traffic modeling through Vissim software. The research adopts the Indonesian Highway Capacity Guidelines (PKJI) as the methodological framework. Data collection was carried out via a 12-hour on-site survey across two road segments of Tukad Pakerisan. The analysis revealed that the traffic flow volume reached 2025.45 Passenger Car Station/hour on Segment A and 1865.65 Passenger Car Station/hour on Segment B. The respective road capacities were 1877.669 Passenger Car Station/hour and 1671.583 Passenger Car Station/hour. The degree of saturation was found to be 1.08 on Segment A and 1.12 on Segment B, indicating Level of Service (LOS) F—characterized by severe traffic congestion. The simulation indicates significant future congestion, with projected saturation levels exceeding 1.5, underscoring the need for integrated mitigation strategies such as adaptive signal control and vehicle restriction policies. A five-year performance projection further suggests a continual increase in the degree of saturation, surpassing the acceptable limit of 0.85 as stipulated in PKJI 2023. These findings underscore the urgent need for capacity enhancement on Tukad Pakerisan Road. The study recommends the installation of additional traffic signage and the implementation of traffic engineering strategies to mitigate congestion along this critical corridor in South Denpasar.

Keywords: Road Segment Performance; PKJI 2023; Vissim Software

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1. INTRODUCTION

Traffic congestion in Denpasar has had wide-ranging social and economic implications. According to data from the Denpasar City Transportation Agency, average travel time in key corridors has increased by over 25% between 2018 and 2023, particularly during peak hours. This results in significant productivity losses, increased transportation costs, and elevated levels of stress among commuters. Small businesses and service-based industries have also reported decreased customer accessibility due to chronic congestion. From an environmental standpoint, prolonged vehicle idling exacerbates air pollution and increases greenhouse gas emissions, further stressing urban sustainability.

This research introduces methodological innovation by combining the newly issued PKJI 2023 guidelines with detailed microsimulation modeling using Vissim. While previous studies have commonly relied on older national standards such as MKJI 1997 or PKJI 2014, the adoption of PKJI 2023 ensures alignment with the latest definitions of capacity, saturation, and traffic behavior characteristics under Indonesian road conditions. Vissim provides a high-resolution, vehicle-by-vehicle simulation platform that allows for calibration of local driving behavior, something rarely implemented in prior local studies. This integrated approach not only enhances the precision of the performance analysis, but also provides a predictive framework for policy testing and future infrastructure planning in fast-growing cities like Denpasar.

Transportation plays a crucial role in supporting the economic activities of society [1]. The growing ownership of motor vehicles has significantly contributed to rising levels of traffic congestion. To ensure smooth and efficient mobility for the population, the availability of adequate and well-maintained transportation infrastructure is essential. One of the main contributors to traffic congestion is the increased traffic volume along road segments [2]. Congestion occurs when the volume of traffic exceeds the capacity of the road, leading to reduced travel speeds—often approaching zero—and causing vehicle queues. Such conditions frequently result in widespread traffic problems [3].

Congestion is most commonly observed on arterial roads that function as primary access routes for urban activity [4]. A growing population intensifies local activity levels, which, in turn, increases mobility and demand for transportation services [5]. Consequently, the increased use of both public and private transport modes, when not supported by adequate road capacity, results in an imbalance that causes traffic volumes to exceed road limits [6]. This situation leads to several issues, including vehicle accumulation, longer travel times, delays, queuing, and a declining level of service [7].

This research is conducted on Tukad Pakerisan Road, located in South Denpasar District, Denpasar City, Bali Province [8]. The study focuses on two segments of this road, which functions as a primary collector road with a 2/2 undivided cross-section (2/2 UD) [9]. Due to its strategic role in regional mobility, Tukad Pakerisan Road often experiences heavy traffic loads and recurrent congestion [10]. The main causes include the surge in private vehicle ownership—recorded at 1,540,337 vehicles in 2023 by the Denpasar City Central Bureau of Statistics (Bali, 2024)—and high levels of daily population mobility [11]. Additionally, roadside friction contributes to traffic delays, causing bottlenecks at several points along the corridor [12].

The objective of this study is to analyze the existing performance of Tukad Pakerisan Road and to project its operational performance over the next five years using the Indonesian Highway Capacity Guidelines (PKJI) 2023 [13]. Unlike previous studies, which relied on older methodologies such as MKJI 1997 or PKJI 2014, this research adopts the most recent PKJI 2023 framework [14]. Furthermore, this study introduces a different case study location and incorporates both current analysis and future projections, offering a comprehensive assessment of urban road performance under evolving traffic conditions [15].

Unlike prior research that primarily employed MKJI 1997 or PKJI 2014, this study introduces a methodological advancement by integrating the latest PKJI 2023 guidelines with detailed microsimulation modeling using Vissim. The research contributes new insights into the operational challenges of urban collector roads by applying localized calibration of driver behavior and conducting a five-year performance projection. This approach remains limited in existing literature, particularly in the context of developing cities like Denpasar.

From the perspective of information technology, this research underscores the significance of simulation modeling and statistical validation in traffic performance analysis. By integrating Vissim's microsimulation capabilities with statistical tools such as SPSS, the study highlights the crucial role of computational modeling in transforming raw field data into predictive insights. This reflects the growing interdisciplinary application of computational methods in solving urban infrastructure challenges.

2. RESEARCH METHOD

The researcher uses the Indonesian Highway Capacity Guidelines (PKJI) 2023 as the primary reference and guideline, as issued by the government to analyze the performance of road segments in Indonesia [16]. Through PKJI 2023, the researcher conducts a series of measurements and data recordings on key performance indicators of the road segments under study [17]. The data collected and analyzed include traffic flow volume (q), road capacity (C), degree of saturation (DS)—which is the ratio between volume and capacity—travel time (TT), travel speed (TS), and free-flow speed (FFS) [18]. The use of Vissim software in this study is based on its ability to simulate multimodal vehicle flows at a microscopic level [19]. All types of vehicles can interact within traffic streams at both segments and intersections [20]. The software’s driver behavior settings enable adjustments to be made that reflect real-world traffic conditions [21]. These capabilities make Vissim a reliable tool for calibrating simulation results with field survey data [22]. Calibration in the Vissim simulation is performed by adjusting driver behavior parameters to align with actual on-site conditions [23]. The calibration variables used include: Desire Position at Free Flow, Overtake at Same

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Line, Distance Standing, Distance Driving, Average Standstill Distance, Additive Part of Safety Distance, Multiplicative Part of Safety Distance, Waiting Time Before Diffusion, Minimum Headway (Front/Rear), and Safety Distance Diffusion Factor [24]. Validation is employed to determine the tolerance range between field survey results and Vissim simulation outputs [25]. This is performed using the Independent T-Test in SPSS, applying a significance level of 95%. This study was conducted on Tukad Pakerisan Road, South Denpasar, Bali. The research location was limited to Tukad Pakerisan Road, focusing on two road segments: Segment A, which extends from the Waturenggong intersection to the Tukad Shangyang intersection, and Segment B, which spans from the Tukad Pancoran intersection to the Tukad Petanu intersection, as shown in Figure 1.

The development of the Vissim simulation model commenced with the creation of a digital road network that faithfully replicates the geometric layout of Tukad Pakerisan Road. Traffic input data included vehicle classifications (e.g., motorcycles, light vehicles, heavy vehicles), traffic composition, volume distribution, and observed travel speeds. In addition, signal timing, phase duration, and intersection geometry were incorporated based on primary field surveys. All simulation scenarios were configured using a 60-minute simulation time with 15-minute warm-up periods.

To ensure the accuracy of the simulation, model calibration was undertaken to align the Vissim outputs with real-world field data. Calibration focused on driver behavior parameters within Vissim, particularly those influencing headway, following distance, overtaking tendencies, and standstill behavior. These parameters were not arbitrarily selected; rather, they were derived through iterative trial-and-error simulations informed by direct roadside observations in Denpasar. For example, local driver tendencies such as frequent lane changing and minimal headway during congestion were mirrored in the simulation by lowering the *Minimum Headway* and *Additive Part of Safety Distance* values.

Validation was conducted using an Independent Samples T-Test to assess statistical consistency between the field data and simulation results. The significance level ($\alpha = 0.05$) was used as the decision threshold. The resulting *p-values* exceeded 0.95, and *t* values remained below the critical threshold ($t_{0.05} = 2.306$), indicating that there is no statistically significant difference between the simulated and observed traffic performance metrics. This confirms that the Vissim model accurately reflects the traffic conditions of Tukad Pakerisan Road.

This study adopts the Indonesian Highway Capacity Guidelines (PKJI) 2023 as the primary methodological reference for assessing road performance. The collected parameters include traffic flow volume (q), capacity (C), degree of saturation (DS), travel time (TT), average travel speed (TS), and free-flow speed (FFS). Field data were obtained through a 12-hour traffic survey conducted on two segments of Tukad Pakerisan Road in South Denpasar, Bali.

To simulate and project traffic performance, this study employs PTV VISSIM—a microsimulation software renowned for its high precision in modeling urban traffic. The simulation model was constructed using geometric data and signal timing from field observations. Simulation was configured for 60 minutes with a 15-minute warm-up. Calibration was performed by adjusting local driver behavior parameters, such as minimum headway and safety distance factors, based on field conditions in Denpasar. The final settings ensured realistic replication of local traffic dynamics.

Validation was carried out using an Independent Samples T-Test with a 95% confidence interval. The statistical comparison between field data and simulation outputs showed no significant difference ($p > 0.95$), confirming that the VISSIM model is reliable for assessing the current and projected performance of Tukad Pakerisan Road.

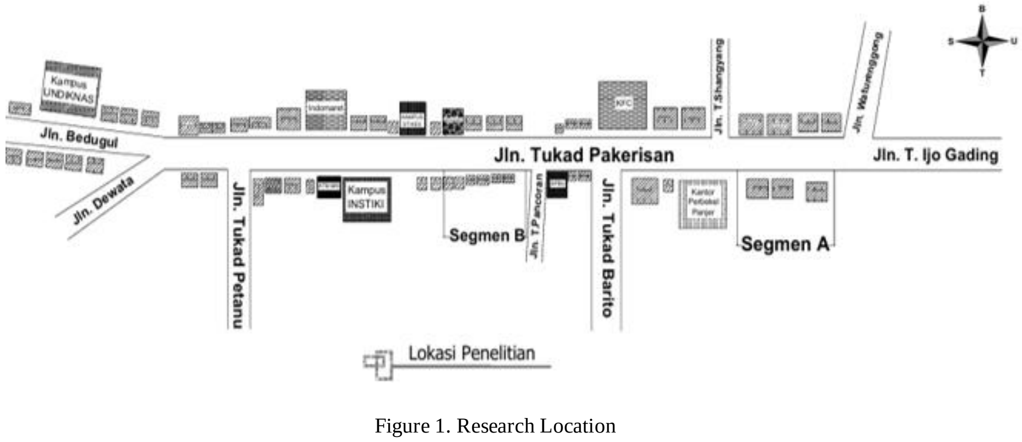

Figure 1. Research Location

3. RESULTS AND DISCUSSION

3.1. Geometric Road Conditions

To facilitate identification in this study, Tukad Pakerisan Road in Denpasar is divided into two segments. Both segments represent road sections between intersections along Tukad Pakerisan Road, namely: the segment from the Waturenggong Intersection to the Tukad Barito Intersection, and the segment from the Tukad Barito Intersection to the Tukad Petanu Intersection.

Table 1. Geometric Road Conditions

Segment Code	Data Type	Description
Segment A	Road Type	Road Type 2/2-TT
	Lane Width	6.00 meters
	Lane Width	3.00 meters
	Shoulder	0.30 meters
	Sidewalk	1.00 m
Segment B	Road Type	Road Type 2/2-TT
	Lane Width	7.00 meters
	Lane Width	3.50 meters
	Shoulder	0.30 meters
	Sidewalk	1.00 meters

3.2. Traffic Volume During Peak Hours

1. Segment A (Waturenggong Junction-Tukad Barito Junction)

From the analysis results, the value of the existing total two-way traffic flow volume at the observation point segment A was 4939 vehicles/hour, which was converted into passenger car units to 2022.95 Passenger Car Station/hour.

Table 2. Traffic Volume During Peak Hours Segment A (Waturenggong Junction-Tukad Barito Junction)

Direction	Vehicles/hour	PCA/hour	Vehicles/hour	PCA/hour	Vehicles/hour	PCA/hour	Direction, %	Vehicles/hour	PCA/hour
1	2	3	4	5	6	7	8	9	10
S-U	438	438	9	10.8	2059	720.65	50%	2506	1169.45
U-S	3	3	0	0	2430	850.5	50%	2433	853.5
1+2	441	441	9	10.8	4489	1571.15	100%	4939	**2022.95**
					Directional separation, PA=q1/(q1+q2)			50%	
							Passenger Car Unit Factor, F_{SMP}=		**0.40959**

2. Segment B (Tukad Barito Junction-Tukad Petanu Junction)

From the analysis results, the value of the existing total two-way traffic flow volume at the observation point segment B was 5404 vehicles/hour, which was converted into passenger car units to 1837 Passenger Car Station/hour.

Table 3. Traffic Volume During Peak Hours Segment B (Tukad Barito Junction-Tukad Petanu Junction)

Direction	Vehicles/hour	PCA/hour	Vehicles/hour	PCA/hour	Vehicles/hour	PCA/hour	Direction, %	Vehicles/hour	PCA/hour
1	2	3	4	5	6	7	8	9	10
S-U	252	252	4	4.8	2331	582.75	50%	2587	839.55
U-S	382	382	6	7.2	2433	608.25	50%	2821	997.45
1+2	634	634	10	12	4764	1191	100%	5408	**1837**
					Directional separation, PA=q1/(q1+q2)			50%	
							Passenger Car Unit Factor, F_{SMP}=		**0.40959**

3.3. Road Capacity Analysis

Table 4. Road Capacity Segment A (Waturenggong Junction-Tukad Barito Junction)

Direction	Basic capacity C_0	Adjustment factor for Capacity				Capacity C (8)x(9)x (10)x(11)x(12)
		Path width FC_{LJ}	Directional separation FC_{PA}	Side obstacles FC_{HS}	City size FC_{UK}	
	Tabel 2.5 Passenger Car Station/hour	Tabel 2.6	Tabel 2.7	Tabel 2.8	Tabel 2.10	
				Tabel 2.9		
7	8	9	10	11	12	13
1	2800	0,87	1	0,82	0,94	**1877,669**

.

Table 5. Road Capacity Segment B (Tukad Barito Junction-Tukad Petanu Junction)

Direction	Basic capacity C_0	Adjustment factor for Capacity				Capacity C (8)x(9)x (10)x(11)x(12)
		Path width FC_{LJ}	Directional separation FC_{PA}	Side obstacles FC_{HS}	City size FC_{UK}	
	Tabel 2.5 Passenger Car Station/hour	Tabel 2.6	Tabel 2.7	Tabel 2.8	Tabel 2.10	
				Tabel 2.9		
7	8	9	10	11	12	13
1	2800	0,87	1	0,73	0,95	**1671,583**

3.4. Vissim Simulation Model Development

The development of the Vissim simulation model begins with creating a road network, vehicle input data in the form of vehicle type, vehicle model, vehicle model distribution, vehicle class, traffic composition, speed distribution, and driver behavior settings. On each road section, the phase and cycle time of the road section are set, the data for which is obtained from primary data. The Vissim Simulation Model is shown in the figure 2.

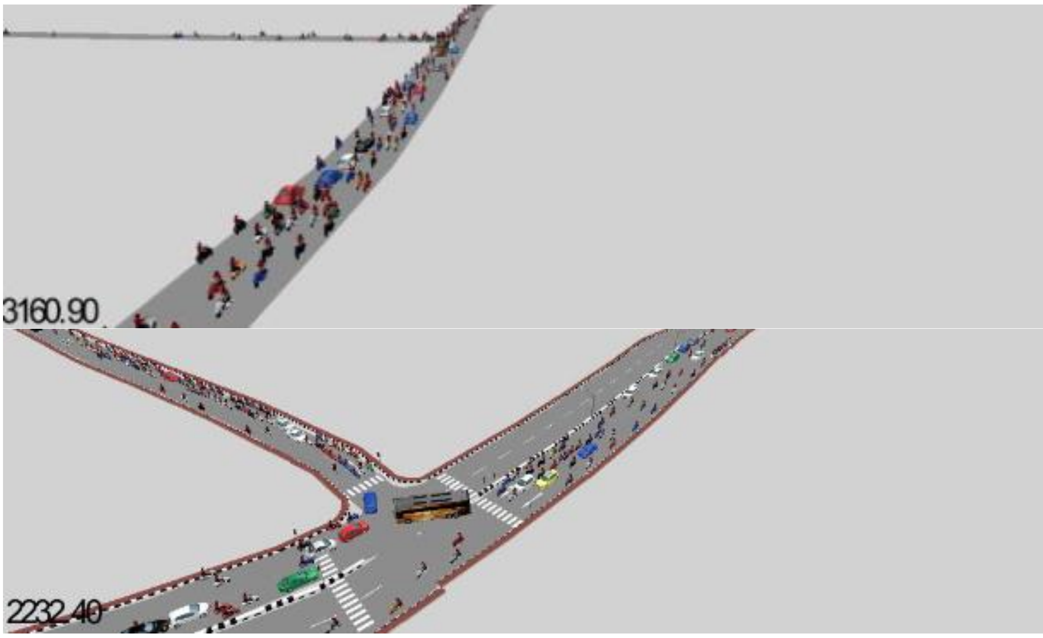

Figure 2. Vissim Simulation Model

3.4.1 Modeling Calibration

In the calibration process before the release, the driving behavior settings obtained can be seen in Table 6.

Table 6. Driver behavior settings in Vissim modeling

Number	Parameter	Value	Unit
1	Desire position at free flow	Any	
2	Overtake at same line	On	On left and right
3	Distance Standing	0.4	Meter at 0 kilometer/hour
4	Distance Driving	0.4	Meter at 50 kilometer/hour
5	Average Standstill distance	0.4	Meter
6	Additive part of safety distance	0.4	
7	Multiplicative part of safety distance	0.8	
8	Waiting time before diffusion	20	Second
9	Min headway (front/rear)	0.4	Meter
10	Safety distance diffusion factor	0.4	

3.4.2 Model Validation

Validation is used to compare the results of field surveys with the output of Vissim simulations by using SPSS software to perform a T-Test analysis through the Independent T-Test method with a 95% significance level. The validation for Tukad Pakerisan Road in Denpasar was conducted on Segment A and Segment B, which represent the vehicle entry and exit segments along this road.

Table 7. Results of the Independent T-Test analysis

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Output	Equal variances assumed	.006	.941	.003	8	.998	4.000	1560.484	-3594.484	3602.484
	Equal variances not assumed			.003	7.978	.998	4.000	1560.484	-3596.484	3604.217

Independent Samples Test

In Table 7, the degrees of freedom (df) and the significance level of 5% yield a t-table value of 2.306. Based on the calculated t-value: H_0 is accepted if ($0.003 \leq 2.306$) Based on the significance probability value: H_0 is accepted if $0.998 > 0.05$ (significance level) Based on these statements, the decision from the independent samples t-test can be concluded as follows:H_0 is accepted, indicating that there is no significant difference between the observed field traffic volume and the Vissim simulation results.

3.5 Five-Year Performance Projection

To forecast the traffic performance over the next five years, a traffic growth model was employed using a compound annual growth rate (CAGR) based on historical vehicle population data in Denpasar City obtained from the Central Bureau of Statistics (BPS Denpasar, 2018–2023). The average annual vehicle growth rate was found to be approximately 6.2% per year, which aligns with the urbanization trends and increasing private vehicle ownership in the region.

The projected traffic volume Qt for each segment was calculated using the formula:

$$Qt = Qo\ x\ (1 + r)^t \tag{1}$$

Where:

Qt = traffic volume in year t

Q0 = base year traffic volume (measured in 2023)

r = annual growth rate (6.2%)

t = number of years ahead (in this case, 5)

Using this formula, the projected traffic volume for **2028** was estimated for both Segment A and Segment B. These projected volumes were then applied to the existing road capacity (C) to calculate the future Degree of Saturation (DS) using:

$$\text{DS} = \frac{Qt}{C} \tag{2}$$

The results indicated that the DS values will continue to rise, reaching approximately 1.45 for Segment A and 1.58 for Segment B by 2028, significantly exceeding the acceptable threshold of 0.85 as outlined in PKJI 2023. This underscores the urgency of implementing traffic mitigation strategies to maintain acceptable service levels.

Given the projected increase in traffic congestion over the next five years, it is imperative to propose comprehensive mitigation strategies. Potential engineering solutions include road widening, implementation of adaptive signal control systems, and redesigning intersections to improve traffic flow efficiency. From a policy perspective, encouraging the use of public transportation through subsidies and service improvements, as well as implementing vehicle restriction measures during peak hours (e.g., odd-even license plate rules), can significantly reduce private vehicle dependency. Furthermore, demand management strategies such as congestion pricing or the development of non-motorized transport infrastructure (e.g., pedestrian and cycling lanes) should be considered to promote modal shift and sustainable mobility. Future research should model these interventions in Vissim to assess their effectiveness before actual implementation.

4. CONCLUSION

The performance analysis of Tukad Pakerisan Road was conducted on two segments. In Segment A, which spans from the Waturenggong intersection to the Tukad Barito intersection, the traffic flow volume (q) was found to be 2025.45 Passenger Car Station/hour, with a road capacity of 1877.669 Passenger Car Station/hour. The free-flow speed (FFS) was measured at 31.939 kilometer/hour, the degree of saturation (DS) was 1.08, the average speed (VMP) was 20 kilometer/hour, and the travel time (TT) was 0.0100 hours or 36 seconds, with a high level of side friction (T). The calculated degree of saturation of 1.08 Passenger Car Station/hour places this road segment at Level of Service (LOS) F, which indicates a condition where vehicles experience significant delays, very low speeds, and long queues. According to PKJI standards, if the degree of saturation is ≤ 0.85, the road is considered acceptable. Therefore, based on these results, Tukad Pakerisan Road Segment A is categorized as inadequate and requires improvement measures. For Segment B, which extends from the Tukad Barito intersection to the Tukad Petanu intersection, the traffic flow volume (q) was 1865.65 Passenger Car Station/hour, the road capacity was 1671.583 Passenger Car Station/hour, and the free-flow speed (FFS) was 30.514 kilometer/hour. The degree of saturation (DS) was calculated at 1.12, the average speed (VMP) was 18 kilometer/hour, and the travel time (TT) was 0.0111 hours or 40 seconds, with a very high level of side friction (ST). The resulting degree of saturation of 1.12 Passenger Car Station/hour again indicates a Level of Service F, meaning vehicles move slowly, frequently stop, and experience significant delays and long queues. Since the acceptable threshold for saturation is ≤ 0.85, Segment B is also considered to be in an inadequate condition. Based on the analysis of both segments, it can be concluded that Tukad Pakerisan Road is currently experiencing a decline in performance and does not meet acceptable operational standards, highlighting the need for immediate intervention and road management strategies.

This study not only evaluates the current road performance but also highlights the added value of combining PKJI 2023 and Vissim simulations for forecasting future traffic conditions. The calibrated driver behavior parameters tailored to Denpasar's local context and the five-year projection contribute to a more dynamic and predictive framework for traffic planning, which could be adapted for other urban collector roads in similar developing regions.

Beyond its civil engineering scope, the research also contributes to the application of computational modeling and data analysis in urban mobility studies. It showcases how simulation tools like Vissim, combined with rigorous statistical validation, can serve as decision-support systems for traffic management. This underlines the importance of interdisciplinary approaches in the field of information technology, particularly in the context of smart urban planning.

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

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