

## THE IMPACT OF ON-STREET PARKING AND AN OFF-STREET PARKING RELOCATION SCENARIO ON TRAFFIC PERFORMANCE AND PEDESTRIAN DYNAMICS IN AN URBAN TOURISM AREA: A CASE STUDY OF THE JALAN DANAU TAMBLINGAN CORRIDOR, SANUR

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### ABSTRACT

On-street parking is widely deployed along urban tourism corridors to accommodate short-term accessibility demand, yet the practice tends to erode effective road capacity, intensify side friction, and reallocate road space away from pedestrians. This study examines the effects of on-street parking and a proposed off-street parking relocation scenario on traffic performance and pedestrian dynamics along the Jalan Danau Tamblingan corridor in the Sanur tourism area of Denpasar, Indonesia. A comparative quantitative approach was applied by integrating three analytical layers: road segment performance evaluation based on the Indonesian Highway Capacity Guidelines (PKJI 2023), microscopic traffic simulation using PTV Vissim, and pedestrian dynamics assessment through walkability perception surveys and pedestrian crossing demand analysis using the PV<sup>2</sup> criterion. The results indicate that, under existing conditions, the corridor operates at Level of Service D with a weekend degree of saturation of 0.82 and a substantial directional disparity in operating speeds, which is attributable to the asymmetric distribution of on-street parking. The off-street parking relocation scenario reduces the degree of saturation to 0.72, raises operating speeds to between 23 and 26 km/h, and yields a more uniform directional flow. However, these improvements coincide with intensified pedestrian crossing activity, signaling a shift in the locus of conflict from parking–vehicle interactions toward vehicle–pedestrian interactions. The findings suggest that off-street parking relocation is an effective traffic management measure, but its implementation must be coordinated with pedestrian facility planning to preserve safety and comfort along urban tourism corridors.

Keywords: on-street parking; off-street parking; traffic performance; pedestrian dynamics; urban tourism area

### INTRODUCTION

Urban tourism corridors face compound pressures on road space arising from the convergence of three overlapping movement systems: through traffic, short-duration parking activity, and pedestrian mobility that constitutes a defining feature of the visitor experience. The sustained growth of global tourism over the past decade has increased curbside parking demand and intensified the competition for road space between vehicles and pedestrians (Mesfin et al., 2024; Kong et al., 2024). Within this context, parking policy can no longer be treated as a purely operational matter; rather, it must be understood as a strategic instrument that shapes the performance of the broader urban transport system. On-street parking along tourism corridors is often justified as a practical response to space constraints and customer accessibility requirements. The literature, however, documents several systemic externalities of the practice. (Sha et al., 2024) found that reallocating curbside parking to travel lanes, cycle lanes, or public space in Leicester reduced travel time by 27–30%, delays by 43–47%, vehicle emissions by more than 90%, and crash risk by up to 94%. Empirical evidence from arterial corridors in India reinforces these findings: (Srivastava & Kumar, 2023a) reported that on-street parking, alongside non-motorized vehicles and pedestrian crossings, consistently erodes capacity and operating speeds in mixed-traffic conditions. A subsequent study on Varanasi's urban arterials identified on-street parking as one of the most significant sources of side friction affecting the level of service of road segments (Srivastava & Kumar, 2023b).

The effects of on-street parking extend well beyond vehicular performance. Parked vehicles at the curbside obstruct sightlines, narrow the effective walking space on sidewalks, and amplify uncertainty in pedestrian crossing decisions. (Gore et al., 2021) demonstrated quantitatively that on-street parking lowers the average walking speed and shifts pedestrian level of service to a lower tier, while Kim et al. (2023) found that perceived pedestrian safety is strongly shaped by the joint characteristics of adjacent traffic and walking infrastructure. On-street parking thus generates two distinct types of conflict simultaneously: a physical conflict with the vehicle flow and a perceptual conflict with pedestrians who feel displaced from their circulation space.

In the policy discourse, relocating parking to off-street facilities is frequently promoted as an elegant resolution to this dilemma. The standard argument holds that separating parking from the primary traffic stream restores effective road capacity and mitigates the cruising-for-parking phenomenon long identified as a substantial contributor to congestion and emissions (Bayih & Tilahun, 2024; Shoup, 2024). Recent studies, however, have begun to caution that the transition to off-street parking is not a neutral intervention with respect to the pedestrian environment. Kuo et al. (2024) modeled off-street parking dynamics in Taipei and found that relocation alters the walking patterns to and from parking facilities, producing new crossing points that were not previously anticipated. Mesfin et al. (2024), in a comparative study of Shanghai and Zurich, observed that the elasticity of the system in response to parking policy is highly dependent on existing infrastructure characteristics; identical interventions can yield divergent outcomes when the pedestrian dimension is not considered explicitly.

The urban tourism context introduces additional analytical complexity. Visitor movement in such areas is heterogeneous, often circular, and frequently departs from the structured travel patterns observed in non-tourism settings. (Amen et al., 2023) showed that walkability quality is a key determinant of the visitor experience in historical urban districts, while Mukherjee et al. (2024) argued that PV<sup>2</sup>-based pedestrian crossing warrants remain relevant but require recalibration for the mixed-traffic conditions typical of developing countries. Studies focused on Bali specifically indicate that parking pressure and tourism density have become priority transport issues, yet integrated analyses combining vehicular performance with pedestrian dynamics in major tourism corridors remain scarce (Atmajaya et al., 2023; (Suartawan et al., 2022).

The Indonesian road performance assessment framework has also undergone a substantial update. The Indonesian Highway Capacity Guidelines 2023 (Pedoman Kapasitas Jalan Indonesia, PKJI 2023) replaced the long-standing MKJI 1997 and introduced recalibrated parameters that are more responsive to the contemporary traffic mix in Indonesia, including motorcycle dominance and high levels of side friction (Pedoman Kapasitas Jalan Indonesia, 2023; Nuhun et al., 2026). Initial studies applying PKJI 2023 report that the new guidelines produce more conservative capacity estimates under high-side-friction conditions, which warrants empirical testing of its implications for parking-related analyses.

The research gap addressed by this study lies in the limited number of studies that integrate three analytical layers — segment performance evaluation based on the latest national standard, microscopic simulation to capture operational behavior, and pedestrian dynamics assessment — within a single empirical framework applied to an Indonesian urban tourism corridor. Accordingly, this study aims to: (1) evaluate the existing traffic performance of the Jalan Danau Tamblingan corridor under on-street parking conditions; (2) analyze pedestrian dynamics and crossing facility demand in the existing condition; and (3) assess the impact of an off-street parking relocation scenario on traffic performance and its implications for pedestrians. The findings are expected to provide an empirical basis for the formulation of integrated parking policy in urban tourism areas, while enriching the transport engineering literature on tourism contexts in Southeast Asia.

## **METHODS**

### **Study Site and Scope**

This study was conducted along the Jalan Danau Tamblingan corridor in Sanur Sub-district, South Denpasar District, Denpasar City, Bali. The corridor was selected because it constitutes one of the principal tourism axes linking accommodation areas, commercial facilities, and beach access points in Sanur, and thus represents the typical characteristics of urban tourism corridors in Indonesia. The road is classified as a two-lane two-way undivided segment (2/2 UD), with on-street parking activity on both sides of the carriageway and sidewalks of varying width. The analytical scope focused on a one-kilometer segment that exhibits a high intensity of tourism, commercial, and pedestrian activity (Figure 1).



Figure 1. Study site along the Jalan Danau Tamblingan corridor, Sanur tourism area, Denpasar City

The study employed a comparative quantitative approach (Hafram et al., 2023) that contrasts two conditions: the existing condition with on-street parking and a scenario in which parking is relocated to off-street facilities. Three analytical layers were applied sequentially to produce a comprehensive performance picture. The first layer is a macroscopic analysis of segment performance based on PKJI 2023; the second is microscopic simulation using PTV Vissim to capture operational vehicle behavior; and the third is the assessment of pedestrian dynamics through walkability perception and pedestrian crossing demand analysis using the  $PV^2$  criterion.

### Field Data Collection

Primary data were collected through four complementary field surveys. First, classified traffic volume counts were carried out on weekdays and weekend days during the morning (07:00–10:00), midday (12:00–14:00), and afternoon (16:00–19:00) peak periods, in order to capture temporal variation in flow. Second, on-street parking characteristic surveys recorded accumulation, parking duration, and turnover rate for the two dominant modes — motorcycles and passenger cars. Third, pedestrian surveys included counts of crossing volumes per 100-meter segment, walking speeds, and walkability perceptions collected through a short questionnaire administered to pedestrians within the corridor. Fourth, geometric measurements were taken to verify the effective road width, sidewalk width, and the physical position of parked vehicles relative to the carriageway. Particular attention was paid to documenting the geometric configuration and the inter-side distribution of parking demand, as earlier studies have indicated that asymmetric on-street parking distribution is one of the principal explanations for directional performance disparities (Al-Yasee et al., 2025; Mansour & Al-Jameel, 2023).

### Segment Performance Analysis Based on PKJI 2023

The primary performance indicators computed were the degree of saturation (DS), Level of Service (LOS), and operating speed, following the PKJI 2023 procedure (Pedoman Kapasitas Jalan Indonesia, 2023). Adjustment factors included the effective lane width, directional split,

side friction, and city size class. The side friction class was determined from the frequency of parking events, vehicles entering and exiting roadside premises, pedestrian movements, and slow-moving vehicles per 200-meter segment per hour. PKJI 2023 was selected because it provides parameter values that have been recalibrated to reflect the contemporary Indonesian traffic mix, and recent studies in Indonesia indicate that capacity estimates derived from PKJI 2023 tend to be more conservative than those produced by MKJI 1997 under high-side-friction conditions (Nuhun et al., 2026).

### **Microscopic Simulation with PTV Vissim**

Microscopic simulation was undertaken in PTV Vissim to capture operational behavior that is not readily revealed by macroscopic analysis, in particular the interactions between traffic flow and parking maneuvers, as well as the spatial distribution of speeds along the corridor. The car-following behavior was modeled using the Wiedemann 74 framework, which is appropriate for urban traffic conditions of moderate to high density (Hafram et al., 2023). The desired speed distribution, fleet composition, and input flows were derived from the field survey results, while the spatial positions of parking events in the model were calibrated to match the existing geometry. Model calibration involved comparing the simulated operating speeds and flow volumes against field measurements; validation was based on the Geoffrey E. Havers (GEH) statistic, with an acceptance threshold of  $GEH < 5$  commonly applied in international practice (Hafram et al., 2023). In the present study, calibration emphasized the driver behavior parameters that are most sensitive to heterogeneous traffic, including average following distance, additive safety distance, and lane-changing aggressiveness. Two simulation scenarios were modeled: the existing condition with on-street parking and a full off-street parking relocation scenario.

### **Pedestrian Dynamics and Crossing Demand Analysis**

Pedestrian dynamics were evaluated through two complementary instruments. First, walkability perception was assessed through a brief questionnaire measuring pedestrians' levels of comfort, perceived safety, and overall satisfaction with the corridor environment. The instrument design drew on contemporary walkability literature emphasizing perceptual dimensions as a complement to physical measurement (Mesfin et al., 2024; Kim et al., 2023). Second, pedestrian crossing facility demand was assessed using the  $PV^2$  criterion, which is the product of the hourly pedestrian crossing volume ( $P$ ) and the square of the bidirectional traffic volume ( $V^2$ ); the resulting values were compared with the thresholds adopted in Indonesian crossing facility guidelines. While the  $PV^2$  criterion has attracted criticism regarding its sensitivity to mixed-traffic conditions, it remains the principal reference in Indonesian planning practice (Hariani et al., 2024; Mukherjee & Kumar, 2024).

### **Synthesis Framework**

The three analytical layers were synthesized within a comparative framework that contrasts the key performance indicators between the existing condition and the relocation scenario. The synthesis explicitly examines the trade-off between improvements in vehicular performance and the consequences arising in the pedestrian domain, in line with recent literature that advocates a multimodal approach to parking policy evaluation (Kong et al., 2024). The overall research workflow is shown in Figure 2.

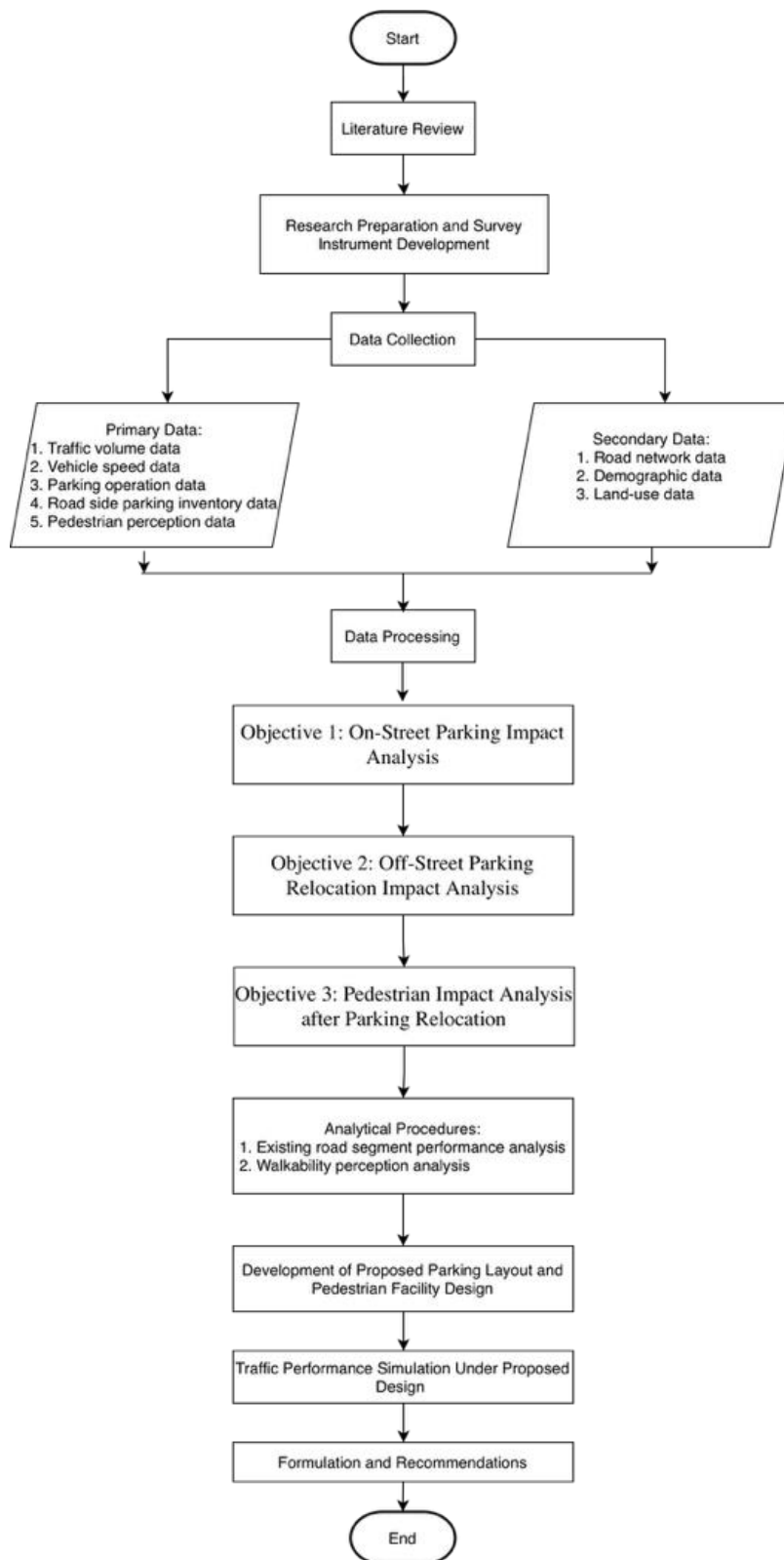


Figure 2. Research methodology lowchart

## RESULTS AND DISCUSSION

### Impact of On-Street Parking on Traffic Performance

The segment performance analysis indicates that the Jalan Danau Tamblingan corridor operates at the upper bound of Level of Service D under existing conditions, with a weekend peak-hour degree of saturation of 0.82 (Table 2). This value exceeds the performance threshold prescribed in Minister of Public Works and Housing Regulation No. 5 of 2023 ( $DS \leq 0.85$ ), placing the corridor close to saturation. On weekdays, the degree of saturation was 0.74, which still falls within Level of Service D but with a relatively narrow margin before transitioning to LOS E.

The most striking feature of the existing condition is the directional disparity in operating speed, as shown in Table 1. The mean speed in the south–north direction was only 13.49 km/h, whereas the north–south direction reached 29.51 km/h. This more than two-fold difference cannot be explained by traffic volume alone, since the directional split is relatively balanced. A more consistent explanation, supported by the literature, is that the disparity originates from the asymmetric distribution of on-street parking and from the differing intensity of parking maneuvers on either side of the carriageway. Mansour & Al-Jameel (2023) documented empirically that on-street parking on one side of an undivided road generates a disproportionate lateral encroachment effect, forcing the adjacent travel direction to operate at lower speeds because of reduced lateral clearance.

Table 1.

Operating speed performance under existing conditions	
Direction	Mean Speed (km/h)
South–North	13.49
North–South	29.51

Source: PTV Vissim simulation results, 2025

Table 2.

Degree of saturation and Level of Service under existing conditions			
Condition	Peak Volume (pcu/hour)	DS	LOS
Weekday	877.25	0.74	D
Weekend	971.15	0.82	D

Source: PKJI 2023 analysis results, 2025

Beyond the static measures, the presence of on-street parking creates conditions conducive to cruising-for-parking behavior, in which drivers slow down or circulate in search of an available space. Shoup (2024) emphasized that this behavior generates additional, unproductive traffic load because such vehicles occupy road space without contributing to primary movement. In a tourism corridor such as Sanur, the sharp temporal fluctuations in parking demand reinforce this effect, consistent with patterns observed in high-demand urban contexts including Shanghai (Mesfin et al., 2024). The findings are also consistent with the Indonesian literature. Reports indicate that relocating on-street parking along Jalan MT Haryono in Balikpapan reduced the degree of saturation from 0.89 to 0.85 (Octavia et al., 2024), and a similar effect was observed at the Penglipuran tourism corridor in Bali. This convergence of findings strengthens the external validity of the interpretation offered here.

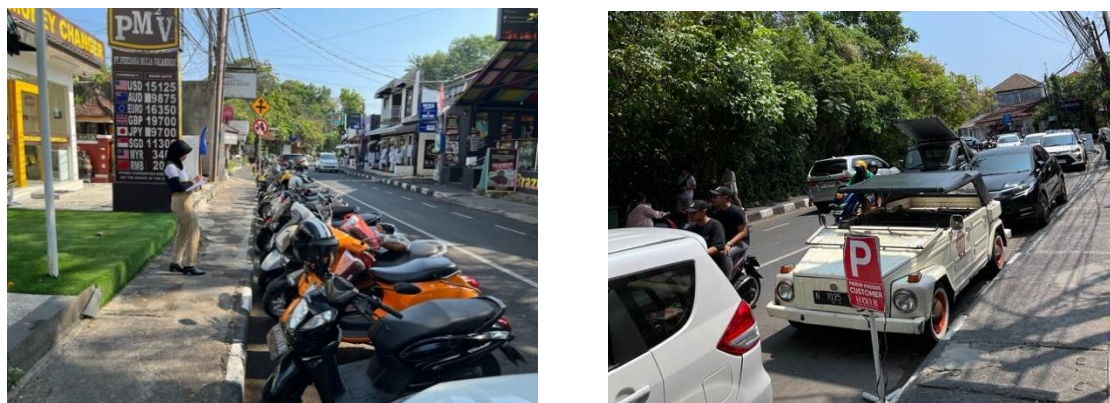


Figure 3. On-street parking narrows the effective road width and intensifies side friction

### On-Street Parking Characteristics and Spatial Implications

The parking characteristic surveys revealed two contrasting patterns of space utilization between cars and motorcycles (Table 3). Motorcycles recorded a peak accumulation of 154 vehicles with a static capacity utilization of 89%, approaching full occupancy and indicating a demand that is barely accommodated. Cars displayed a much lower peak accumulation of 14 vehicles with utilization of 61%, but with substantially longer dwell times — exceeding three hours per vehicle — so that each car consumed road space and generated lateral obstruction over an extended period. This pattern implies that the two modes exert different forms of pressure on road space: motorcycles through volume and proximity to pedestrian areas, and cars through prolonged lateral blockage of the carriageway.

Table 3.

Spatial utilization characteristics of on-street parking under existing conditions			
Aspect	Cars	Motorcycles	Implication
Peak Accumulation	14 vehicles	154 vehicles	Motorcycles dominate parking space use
Static Capacity Utilization	61%	89%	Motorcycle parking approaches full capacity
Dwell-Time Pattern	Long (>3 hours)	More dynamic	Cars generate prolonged obstruction
Friction Character	Reduces effective road width	Compresses pedestrian area	Two spatially distinct sources of conflict

Source: Field survey results, 2025

The policy implication is substantive: a single, undifferentiated intervention risks missing the root of the problem. Policies focused solely on reducing on-street car parking, while leaving the very high accumulation of motorcycle parking unaddressed, may merely transfer the problem to the pedestrian domain, where sidewalks come under increasing pressure from motorcycle parking — a pattern that has been documented in side-friction studies across developing-country cities (Al-Yasee et al., 2025; Srivastava & Kumar, 2023a).

### Pedestrian Dynamics under Existing Conditions

The perception survey results indicate that on-street parking lowers both comfort and perceived safety among pedestrians along the corridor. Respondents consistently identified three principal sources of disruption: blockage of sightlines by parked vehicles, particularly when crossing the road; compression of the walking space by motorcycles parked on or near the sidewalk; and uncertainty arising from vehicles entering and exiting parking spaces. These observations align

with the findings of Kim et al. (2023), who documented that pedestrian safety perception is highly sensitive to the combined characteristics of traffic and walking infrastructure, and with Meir & Oron-Gilad (2025), who demonstrated empirically that low-walkability street environments degrade pedestrian crossing performance.

Crossing facility demand analysis using the  $PV^2$  criterion showed that several segments of the corridor have already reached the threshold associated with the need for formal pedestrian crossing facilities. In a tourism setting, this demand is further amplified by the dispersed nature of pedestrian movement, which does not concentrate at a single point but rather spreads along the corridor in accordance with the spatial pattern of tourism and commercial activity. Mukherjee & Kumar (2024) confirmed that the  $PV^2$  criterion remains a valid instrument for selecting crossing facility types, but emphasized that it should be complemented by context-specific considerations of pedestrian behavior, such as gap acceptance and waiting time.

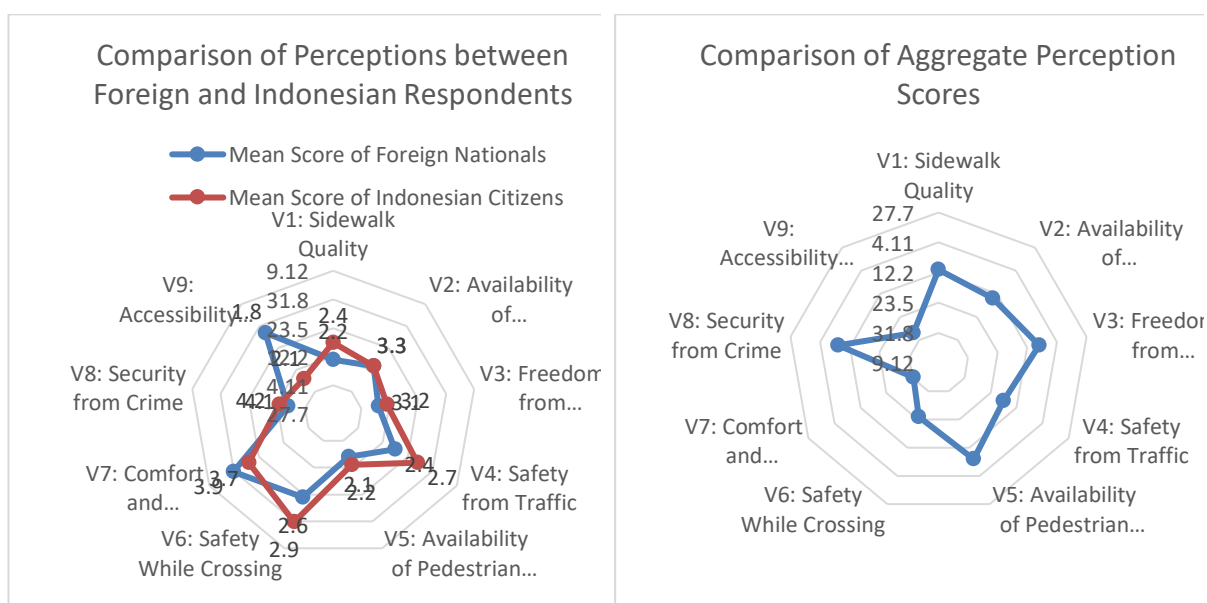


Figure 4. Survey results show that on-street parking reduces pedestrian comfort and perceived safety

### Evaluation of the Off-Street Parking Relocation Scenario

The simulation of the off-street parking relocation scenario produced consistent and measurable improvements in traffic performance. The degree of saturation decreased from 0.82 to 0.72 on the weekend peak, shifting the level of service from the upper bound of D into a more stable LOS C/D range. More importantly, the operating speeds revealed a clear distributional improvement: the south–north speed increased from 13.49 km/h to between 23 and 26 km/h, while the north–south speed remained essentially unaffected, holding steady at 28–30 km/h (Table 4). A key implication is the restoration of inter-directional speed uniformity, which is a hallmark of a well-functioning two-way road (Sha et al., 2024).

Table 4.

Traffic performance comparison between existing conditions and the off-street parking relocation scenario

Performance Indicator	Existing	Off-Street Relocation	Change
Degree of Saturation (PKJI 2023)	0.82 (LOS D)	0.72 (LOS C/D)	Reserve capacity restored
South–North Speed (Vissim)	13.49 km/h	23–26 km/h	Increase of 70–92%
North–South Speed (Vissim)	29.51 km/h	28–30 km/h	Stable; no adverse effect
Inter-Directional Imbalance	High	Substantially reduced	Flow more uniform

Source: PKJI 2023 analysis and PTV Vissim simulation results, 2025

These performance gains are consistent with international evidence that the reallocation of curbside parking to other functions substantially improves operational indicators. Sha et al. (2024) estimated delay reductions of 43–47% along the Leicester corridor after parking reallocation, while Mesfin et al. (2024) demonstrated significant system elasticity in response to parking regulation in Shanghai's central business district. Domestic studies adopting similar frameworks have reported directionally consistent improvements, although the magnitude varies with context (Atmajaya et al., 2023; Octavia et al., 2024).

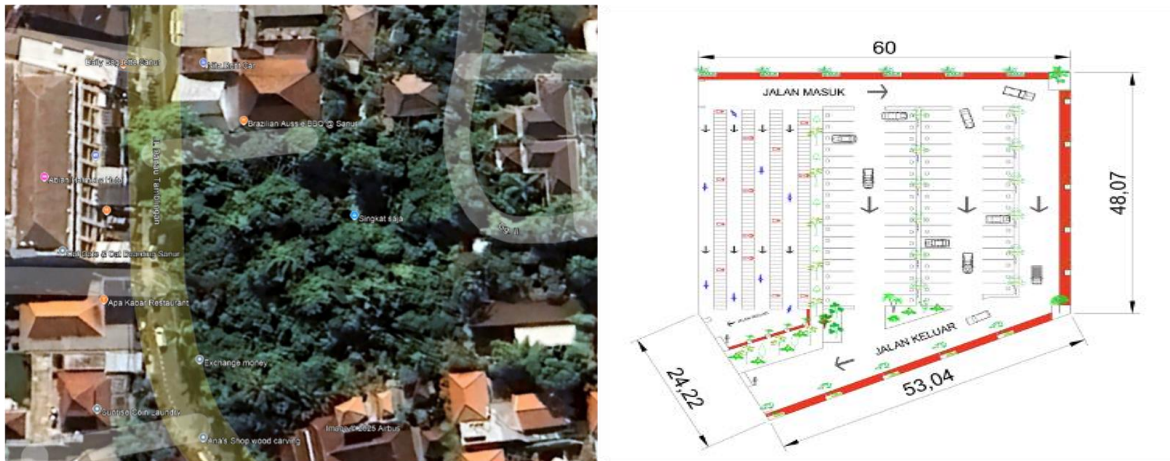


Figure 5. Proposed location and layout of the off-street parking facility

### Shifting Pedestrian Dynamics after Relocation

A more nuanced finding emerges when the pedestrian analysis is extended to the relocation scenario. The transfer of parking to off-street facilities, located beyond the primary corridor, inherently generates new crossing demand because visitors must walk to and from concentrated parking points. This pattern is reinforced by the character of tourism activity, which spreads along accommodation, retail, and beach access points. The walking routes that emerge are therefore not concentrated between a single origin–destination pair but distributed along the corridor.

The practical consequence is the emergence of new conflicts, manifested as increased demand for formal pedestrian crossing facilities at locations not previously identified as critical points. This finding is consistent with the analytical framework developed by Kuo et al. (2024), which explicitly modeled the redistribution of pedestrian crossing demand following off-street parking relocation in Taipei. A broader implication is that parking interventions cannot be evaluated solely on the basis of traffic efficiency; a fair assessment must account for the transfer of risk from parking–vehicle conflicts to vehicle–pedestrian conflicts. Kong et al. (2024) describe this as the "mixed outcomes" dimension of parking reform, which helps explain why parking policies in many jurisdictions fail to achieve the dual objectives of traffic performance and pedestrian safety simultaneously.



Figure 6. The off-street parking relocation alters pedestrian movement patterns and creates new crossing points

### **Policy Implications for Parking Management in Tourism Corridors**

The synthesis of results suggests that off-street parking relocation is an effective but incomplete intervention. Three policy implications can be drawn. First, parking relocation should be designed as a paired intervention with the provision of formal pedestrian crossing facilities, whether zebra crossings with pedestrian refuges, pelican crossings, or geometric design elements that support safe crossing behavior. Second, the location of off-street facilities should be determined by an analysis of pedestrian origin–destination patterns rather than purely by land availability, in order to keep walking distances within acceptable comfort thresholds for the tropical climate context (Huang et al., 2024; Amen et al., 2023). Third, on-street parking pricing should be considered as a complementary instrument, given that the literature shows that prices set close to off-street levels eliminate the incentive to cruise for parking (Bayih & Tilahun, 2024; Shoup, 2024). The Sanur context adds further contextual nuance. Visitors who rely on walking as the primary mode of destination exploration make the walkability dimension more central than in ordinary urban corridors. Consequently, the success of parking policy cannot be evaluated independently of pedestrian experience quality, which is itself an essential asset for the sustainability of tourism destinations (Amen et al., 2023).

### **CONCLUSION**

This study integrated three analytical layers — segment performance evaluation based on PKJI 2023, microscopic simulation in PTV Vissim, and pedestrian dynamics analysis using the  $PV^2$  criterion and walkability perception — to evaluate the impact of on-street parking and an off-street parking relocation scenario on the Jalan Danau Tamblingan corridor in the Sanur tourism area. The findings show that, under existing conditions, on-street parking causes the corridor to operate at the upper bound of Level of Service D, with a degree of saturation of 0.82 and a substantial directional disparity in operating speeds attributable to the asymmetric distribution of parking and the differing intensity of side friction on each side of the carriageway.

From the pedestrian perspective, on-street parking lowers sidewalk user comfort and perceived safety, and several corridor segments have already reached the  $PV^2$  threshold for formal crossing facilities. The off-street parking relocation scenario produces measurable improvements in traffic performance, reflected in a decrease in the degree of saturation to 0.72, a 70–92% increase in south–north operating speed, and the restoration of inter-directional uniformity. These gains, however, are accompanied by a shift in the locus of risk into the pedestrian domain through the emergence of new formal crossing demand, which is a direct consequence of concentrating parking points outside the primary corridor.

The principal contribution of this study is the integrated empirical evidence that the success of off-street parking relocation in an urban tourism corridor depends on the design of an intervention package that combines parking reform with adequate pedestrian facility provision.

The study also demonstrates that the three-layer analytical framework can be adapted to similar corridors in Southeast Asian tourism destinations, where multimodal pressures and strong pedestrian dynamics demand evaluation instruments that are sensitive to safety and walking quality dimensions. The study is subject to limitations. The temporal coverage of the field data is limited to a single weekly cycle, and only a single relocation scenario was considered. Future research is encouraged to examine partial relocation scenarios, the integration of parking pricing policy, and the seasonal effects of tourism demand fluctuation, so that policy recommendations can become increasingly contextual and adaptive.

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