



Research Article

Evaluation of Roundabout Performance in the Sudirman Central Business District (SCBD), Jakarta

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Abstract

The Sudirman Central Business District (SCBD) in Jakarta is characterized by high-intensity, mixed-use activities that generate substantial traffic demand throughout the day. This study evaluates the operational performance of the Lot 13 roundabout, one of the district's critical internal nodes, using a combination of field observations, analytical assessment, and a microscopic simulation model developed in PTV Vissim. The simulation approach was selected because similar roundabout studies in Indonesia remain largely dominated by analytical capacity assessment, with fewer calibrated microsimulation-based evaluations in dense CBD environments characterized by mixed traffic and high roadside friction. Traffic data were collected at 15-minute intervals during peak periods and used to construct a detailed behavioural model calibrated to local driving characteristics, including short headways and aggressive merging behaviour typical of mixed traffic in Indonesia. The results reveal severe oversaturation on the Sudirman–Grand Lucky and Sudirman–BEI legs, where maximum queue lengths exceed 550 meters, delays surpassing 70–100 seconds per vehicle, and circulating speeds reduced to 12–18 km/hour, placing the roundabout at Level of Service F. Geometric constraints, high roadside friction, and unbalanced approach volumes further degrade operational capacity, demonstrating that the current unsignalized configuration is insufficient to accommodate prevailing demand. The findings suggest that adaptive signal control or metering signals may represent promising options for further operational performance by creating controlled entry gaps and reducing conflict intensity. The study provides a site-specific operational diagnosis of the Lot 13 roundabout and highlights the combined role of unbalanced approach demand, limited effective entry capacity, and roadside friction in shaping queue formation, delay, and flow breakdown in a dense CBD setting. Recommendations for future research include the evaluation of multi-scenario design alternatives and the assessment of broader network-level impacts to support long-term mobility planning in SCBD.

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Keywords: Central Business District, Road Capacity, Roundabout, Traffic Management, Vissim.

1. INTRODUCTION

The Sudirman Central Business District (SCBD) is one of Jakarta's most prominent urban economic centers, encompassing major office complexes, commercial developments, retail clusters, and recreational facilities. Its location along primary arterial corridors, including *Jenderal Sudirman Street*, *Gatot Subroto Street*, and *Senopati Street*, creates substantial travel demand across the day. The concentration of mixed land-use functions, high trip generation rates, and pronounced temporal activity patterns produce highly fluctuating traffic flows that frequently exceed roadway capacity, especially during morning and evening peak periods. These dynamics place significant operational pressure on

internal network elements, particularly roundabouts and intersections that serve as key connectors among mobility nodes within the district. Ensuring efficient mobility in this constrained environment requires traffic management strategies that are adaptive, evidence-based, and sensitive to the behavioural complexity of urban road users.

Among these network elements, the Lot 13 roundabout represents one of the most critical bottlenecks within the SCBD road system. The roundabout accommodates converging flows from multiple high-volume corridors, yet its operational performance is often undermined by unbalanced approach flows, high motorcycle penetration, mixed vehicle classes, and the predominance of weaving and merging manoeuvres. These factors contribute to

long queues, substantial delays, and breakdowns in circulating flow. Prior studies show that roundabouts located in dense urban environments are highly susceptible to oversaturation and may experience rapid performance degradation if approach demands are not uniformly distributed or if geometric constraints limit entry capacity [1], [2]. This is evident in Asian metropolitan contexts where mixed traffic, shorter headways, and heterogeneous driving behaviour challenge the assumptions of traditional capacity models.

In recent years, the literature has increasingly emphasized the importance of microscopic simulation as a state-of-the-art tool for evaluating the performance of intersections and roundabouts in complex, heterogeneous traffic environments. Traditional macroscopic approaches, such as those embedded in the Indonesian Highway Capacity Manual [3], operate under simplified behavioural assumptions that often fail to capture the granular dynamics of vehicle–vehicle interactions, gap acceptance variability, and queue evolution [4]. Microscopic models, by contrast, offer higher fidelity in representing driver heterogeneity, mixed-traffic interactions, and the stochasticity of urban movement patterns [5]. Rodegerdts et al. [6] further strengthened the basis for roundabout simulation by validating microscopic model outputs against field observations, highlighting the essential role of calibration and accurate behavioural parameter settings in evaluating operational performance. This has led to their adoption in a wide range of contemporary studies. Trinh [7] demonstrated the effectiveness of heterogeneous microscopic modeling for roundabouts in Asian mixed-traffic environments, while Taglieri [8] conducted a comparative simulation-based analysis of roundabouts and signalized intersections to evaluate their relative operational efficiency. At a broader policy level, Gautam et al. [9] explored the relative benefits of grade separation versus roundabout solutions in central business districts.

Despite this rapidly advancing body of knowledge, studies on roundabout performance in the Indonesian context remain largely dependent on analytical evaluations based on the Indonesian Highway Capacity Manual [3] and its updated successor, the Indonesian Road Capacity Guidelines [10]. Research by Dharmawan et al. [11], Putra and Purwanti [12], and Sukmawati et al. [13] has provided insights into roundabout capacity in Indonesia, yet these studies offer limited representation of the behavioural complexity associated with mixed traffic, short headways, pedestrian interaction, and roadside friction typical of Jakarta's CBD environments. Accordingly, there

remains a need for more detailed simulation-based operational assessments of roundabouts in Indonesia, particularly at critical urban nodes such as the SCBD Lot 13 roundabout.

In response to this need, the present study conducts an operational evaluation of the Lot 13 roundabout using microscopic simulation in PTV Vissim, complemented by analytical benchmarks from the Highway Capacity Manual [14]. By capturing detailed interactions such as lane-changing, gap acceptance, weaving conflicts, queue spillback potential, and speed dynamics under fluctuating demand, this approach enables a more detailed representation of observed operating conditions than conventional analytical methods alone. The resulting findings are intended to support context-sensitive traffic management evaluation, including possible geometric refinements, adaptive control, metering signals, or demand management interventions, aimed at enhancing mobility performance in SCBD and similar high-density urban districts.

2. METHODOLOGY

The research methodology was structured to provide a systematic analytical framework for evaluating the operational performance of the roundabout. The methodological design incorporates both analytical and simulation-based approaches to ensure a comprehensive assessment of the system's behaviour under existing traffic conditions.

Research Design

This study adopts a quantitative traffic engineering research design aimed at evaluating the operational performance of a roundabout-type intersection under real-world mixed-traffic conditions. The research process consists of three sequential and interrelated stages.

First, empirical traffic data and geometric characteristics of the study location were collected and systematically processed. This stage involved obtaining classified traffic volumes, turning movement counts, temporal flow variations, and detailed measurements of approach geometry, all of which form the foundational inputs for subsequent analyses. Second, an analytical performance evaluation was conducted using procedures defined in the Highway Capacity Manual [14]. This step provided baseline capacity estimates, control delay calculations, queue length approximations, and level-of-service classifications, enabling an initial understanding of the roundabout's operational adequacy relative to established theoretical standards. Third, a microscopic simulation model was developed using PTV Vissim to dynamically assess traffic operations under existing conditions.

This approach allowed for the incorporation of local driver behaviour, gap acceptance patterns, lane-changing tendencies, and interactions among heterogeneous vehicle types, factors that are not fully captured through conventional analytical methods. The simulation results were subsequently used to validate analytical findings and to provide nuanced insights into system performance under complex traffic scenarios. Collectively, these three stages establish a robust research design that integrates empirical observation, analytical rigor, and behaviourally realistic modelling to evaluate the performance of the Lot 13 roundabout.

Overview of the SCBD Traffic Environment

The SCBD area exhibits highly complex traffic characteristics resulting from intense office, commercial, and recreational activities that occur continuously throughout the day. The diversity of land-use functions creates persistent activity patterns, making SCBD one of the urban zones with the highest vehicle movements in central Jakarta. During the morning peak hours, traffic flows are dominated by commuting trips entering the district. By midday, increasing volumes are influenced by retail activities, lunchtime travel, and inter-office movements.

As the day transitions into the late afternoon and evening, the dominant traffic flows gradually shift toward outbound commuting movements, visits to culinary destinations, and extended recreational activities that often continue late into the night. Overall, the temporal distribution of traffic within the SCBD area reflects a recurring pattern comprising several distinct yet interrelated flow periods. The morning hours are marked by substantial inbound commuter movements between 07:00 and 09:00, representing the main influx of workers entering the district. This is followed by a midday period from 10:00 to 15:00, during which off-peak commercial, service-related, and inter-office activities generate moderate and relatively stable traffic volumes.

As the afternoon progresses, outbound flows become dominant between 16:00 and 19:00, coinciding with the end of business operations and the onset of evening activity cycles. After 19:00, traffic intensity is increasingly shaped by night-time entertainment and dining-related travel, resulting in continued activity levels well beyond conventional peak hours. These distinct flow profiles illustrate the persistent, high-frequency, and fluctuating travel demand characteristic of SCBD's mixed-use environment. Such fluctuations create sustained traffic pressure not only during traditional peak periods but also throughout transitional and late evening hours, thereby placing considerable strain on strategic intersections within the district, including

the Lot 13 roundabout. Serving as one of the key access points within the internal SCBD road network, the Lot 13 roundabout connects four major corridors and thus plays a crucial role in accommodating and regulating these highly variable flows (see Figure 1).

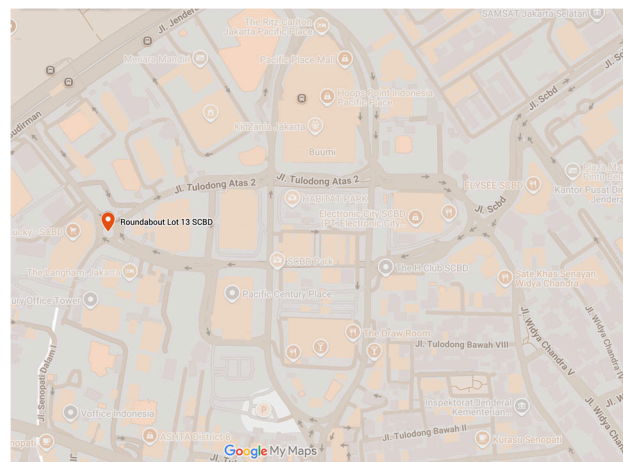


Figure 1. The Lot 13 Roundabout (Google My Maps [15])

As illustrated in Figure 2, traffic enters the Lot 13 roundabout from three primary directions. From the north, vehicles approach via *Jenderal Sudirman Street*, a major urban arterial that consistently carries high traffic volumes throughout the day. From the west, flows originate from *Tulodong Atas 2 Street*, which provides access to several office clusters within SCBD. From the south, substantial traffic is generated by the Grand Lucky–Equity corridor, a major trip generator with intensive inbound and outbound movements associated with parking activity and commercial functions. In contrast, no inbound flow is present from the east, as *Jalan Tulodong Atas 2* operates as a one-way westbound link. The combination of these approaches creates a high-intensity, cross-directional traffic environment characterized by frequent weaving, merging, and gap-acceptance interactions that shape the operational dynamics of the roundabout.



Figure 2. Geometric layout (Google Maps [16])

Data Collection

Traffic data were obtained through on-site surveys using manual traffic counts conducted at 15-minute intervals. The data collection was concentrated on the morning peak period (06:00–10:00 WIB; UTC+7) and the evening peak period (15:00–19:00 WIB; UTC+7), ensuring that the full range of fluctuations in traffic demand during high-intensity periods could be accurately captured. The survey recorded classified traffic volumes, including

motorcycles, light vehicles, and heavy vehicles, along with the detailed turning movement patterns at each roundabout approach. In addition, temporal variations in flow intensity throughout the observation period were documented to capture changes in demand distribution across different times of day. Figure 3 presents a summary of the temporal traffic volume patterns observed at the roundabout during the survey periods. The detailed survey data were subsequently used as inputs for the microsimulation model.

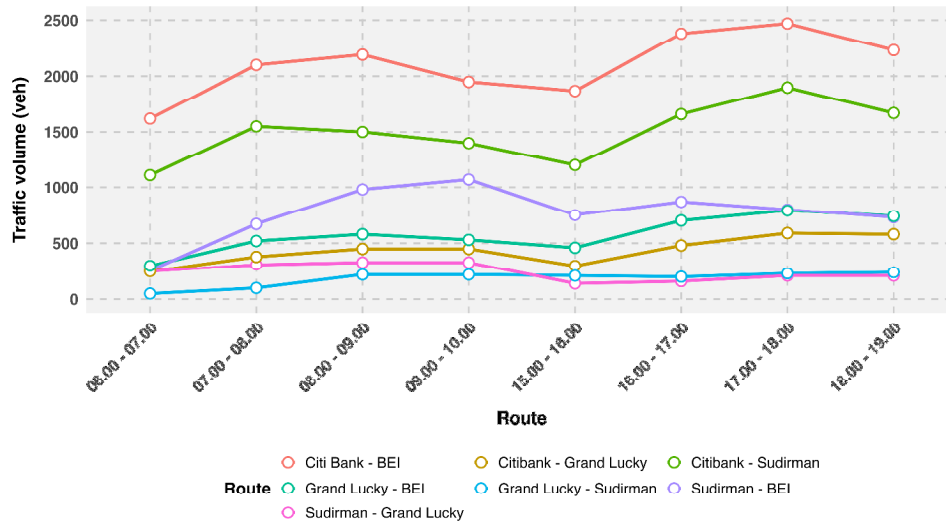


Figure 3. Aggregated traffic volumes at the roundabout

Roundabout Performance Analysis

Roundabout performance was evaluated to determine operational effectiveness using several key parameters widely adopted in traffic engineering:

- 1) Queue Length, measured at each approach to determine the extent of vehicle accumulation prior to entering the circulating lane. Longer queues indicate increased stress on the roundabout's entry capacity.
- 2) Delay, defined as the additional travel time experienced by a vehicle when entering the roundabout relative to free-flow entry conditions. The mean delay per vehicle (D) was calculated as the arithmetic average of individual vehicle delays, as expressed in Equation (1):

$$D = \frac{1}{n} \sum_{i=1}^n D_i \quad (1)$$

where D_i denotes the delay experienced by the i -th vehicle (s), and n is the number of observed or simulated vehicles included in the approach analysis. In this study, delay values were obtained from the calibrated microsimulation model and used as one of the principal indicators of roundabout operational performance.

- 3) Circulating Speed, represents the speed at which vehicles travel within the roundabout's circulating lane, reflecting internal operational efficiency.
- 4) Weaving Conflicts, occur when entering vehicles merge with circulating traffic or when exiting vehicles cross paths with entering flows. The number of vehicles involved in weaving manoeuvres within one cycle is used as an indicator of conflict intensity.

Microscopic Simulation

Given the traffic characteristics of the SCBD area, which is dominated by high-volume flows and complex cross-directional manoeuvres, microscopic modelling is the most appropriate approach for capturing operational dynamics that cannot be adequately represented by conventional analytical methods. As shown in Figure X, the framework integrates the existing SCBD traffic conditions, the roundabout's operational constraints, and the microscopic simulation model's inputs, culminating in the assessment of roundabout performance outcomes, including queue length, delay, and circulating speed.

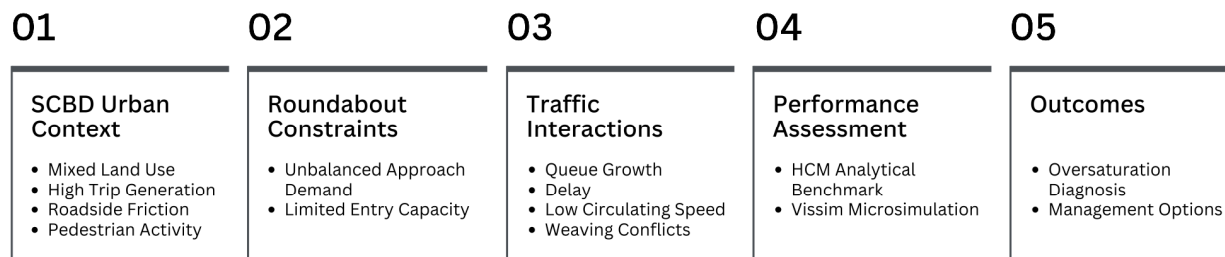


Figure 4. Conceptual framework for evaluating roundabout performance at Lot 13 SCBD.

The simulation software employed in this study is PTV Vissim, a behaviour-based microscopic simulation platform capable of representing detailed vehicle interactions, including route-choice decisions, car-following behaviour, lane-changing manoeuvres, and driver responses to dynamic traffic conditions [17]. Furthermore, recent findings by the study of Fadilah et al. [18] underscore that microscopic models are particularly effective in environments with high conflict intensity, as they can more accurately reflect the influence of driver behaviour on operational performance compared with macroscopic approaches.

Model development began with the incorporation of the existing geometric characteristics of the roundabout, including approach widths, circulating lane radii, lane configurations, entry/exit alignment, and all turning movements recorded during field observations. These geometric elements were supplemented with empirical traffic inputs, including entering traffic volumes, vehicle composition, observed speed distributions, and temporal arrival patterns, thereby ensuring that the model reflected the actual operating conditions.

A key component of Vissim's modelling framework is the Wiedemann 74 car-following model, which governs longitudinal vehicle interactions. In this study, several Wiedemann parameters, such as standstill distance, safety distance factors, following variation, and oscillation thresholds, were calibrated to reflect the driving characteristics typical of dense Indonesian urban traffic, where headways are short, and drivers exhibit relatively aggressive lane-changing behaviour. Lane-changing behaviour parameters, including look-back distance, lane-change aggressiveness, and accepted deceleration of trailing vehicles, were also adjusted to match field observations. Gap-acceptance behaviour at roundabout entries was calibrated using critical gap and follow-up time estimates derived from observed entry behaviour, ensuring a realistic representation of entry dynamics.

Calibration was carried out iteratively using a trial-and-error approach, in which model outputs, particularly flow rates, queue lengths, and delay values, were systematically compared with observed

conditions. Adjustments were made until the simulated results fell within acceptable tolerances and reproduced the empirical behaviour of drivers in the mixed-traffic system. This iterative calibration process was crucial in ensuring that the model captured complex phenomena such as forced merging, motorcycle filtering, short headways, and aggressive lane occupation.

Following calibration, the model underwent a formal validation process, where simulated and observed traffic volumes were compared using statistical goodness-of-fit indicators, including the coefficient of determination (R^2). The model was considered valid once deviations between simulated and observed values were within established thresholds commonly applied in traffic simulation research. As Vissim is inherently stochastic, multiple simulation runs were performed using different random seeds to account for variability in driver behaviour and vehicle interactions. Averaging results across these runs minimized the influence of stochastic anomalies and ensured the reliability and reproducibility of the performance measures. Only after achieving consistent outputs across multiple seed values were the simulation results adopted as the basis for evaluating the operational performance of the roundabout.

3. MODELLING

Microscopic simulation modelling was conducted using the PTV Vissim software to replicate, in detail, the operational conditions of the Lot 13 roundabout. The modelling process consisted of three primary components: network development, incorporation of traffic input parameters, and calibration-validation of driver behaviour settings to ensure that the simulated dynamics accurately reflected real-world conditions.

Network Model Development

The modelling process began with the construction of the road network based on the actual geometric configuration obtained from satellite imagery and on-site field surveys. The geometric features incorporated into the network included the roundabout layout, circulating lane width, approach

lengths, and complementary elements such as pedestrian crossings. This network model was designed to represent the existing physical conditions of the Lot 13 roundabout and its surrounding road environment, as illustrated in Figure 5.

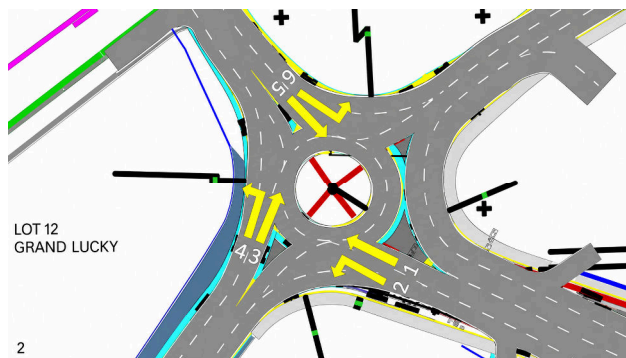


Figure 5. Road network model of the roundabout

Traffic Input Parameters

Traffic volume data collected at 15-minute intervals during field observations were converted into hourly flow rates and entered into the model as traffic inputs. Vehicle composition consisted of light vehicles, motorcycles, and heavy vehicles, with proportions aligned with empirically observed distributions in the SCBD area. Desired speed distributions were assigned based on observed operating speeds, set at 25–40 km/h for light vehicles, 20–35 km/h for motorcycles, and 15–25 km/h for heavy vehicles. In areas characterized by high roadside friction, particularly near pedestrian zones and the Grand Lucky parking access, reduced-speed areas were implemented, with speeds restricted to 10–15 km/h. This adjustment was necessary to ensure that acceleration–deceleration patterns, platoon behaviour, and speed variability within the simulation reflected real-world traffic dynamics.

Driver Behaviour Configuration

Driver behaviour parameters were calibrated using the Wiedemann 74 car-following model, which governs longitudinal interactions in Vissim. The Wiedemann 74 model represents driver behaviour through threshold-based longitudinal responses, allowing vehicles to alternate between free driving, approaching, following, and braking states in response to surrounding traffic conditions. This modelling framework is relevant for the present study because it can represent the short headways, frequent speed adjustments, and close vehicle interactions observed under mixed-traffic urban conditions.

Calibration was essential due to the observed characteristics of urban traffic in Jakarta, where drivers tend to maintain short headways, exhibit frequent lane changes, and adopt relatively aggressive behaviour when identifying acceptable

gaps. The calibration process involved adjusting several critical parameters, including the look-ahead distance, standstill distance, additive and multiplicative safety distance factors, and the observe adjacent lane behaviour governing lateral awareness.

An iterative trial-and-error procedure was employed, systematically refining these parameters until key simulation outputs closely matched observed field data within a predefined tolerance (<10%). The final calibrated parameters indicated a reduced standstill distance of 0.6 m and decreased additive and multiplicative safety margins (0.6 and 1, respectively). These values reflect the characteristics of Indonesian mixed traffic, where short headways and elevated risk tolerance are commonplace. Additionally, same-lane overtaking behaviour was enabled to simulate the manoeuvring flexibility typical of motorcycles in mixed-traffic environments.

Model Validation

Model validation was performed using hourly flow rates and the coefficient of determination (R^2) as accuracy indicators. A comparison between simulated outputs and observed traffic volumes yielded an R^2 value of 0.803 (see Figure 6), demonstrating that the microscopic simulation model provides a satisfactory representation of existing operational conditions at the Lot 13 roundabout.

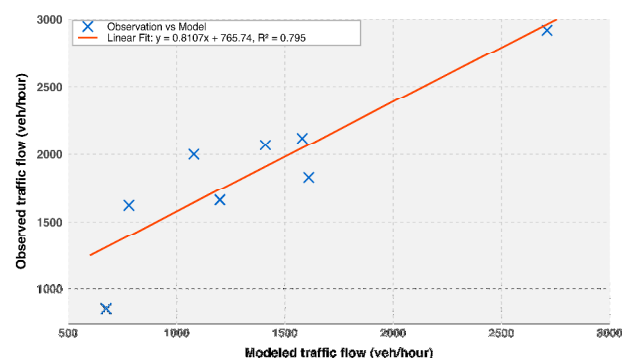


Figure 6. Validation of the microscopic simulation model

4. ROUNDABOUT PERFORMANCE ANALYSIS

The performance analysis of the Lot 13 roundabout was conducted to assess existing operating conditions and to determine the extent to which the roundabout is capable of accommodating current traffic demand within the SCBD area. The evaluation consists of a geometric assessment followed by a detailed examination of operational performance using outputs from the calibrated microscopic simulation model.

The performance indicators selected were queue length, delay, circulating speed, and weaving conflict intensity. These indicators were chosen because they directly reflect the operational manifestations of

oversaturation in a mixed-traffic roundabout environment and can be captured consistently through the calibrated microsimulation model. Queue length and delay represent the most immediate measures of entry inefficiency and service deterioration, while circulating speed reflects internal flow stability. Weaving conflict intensity was included because interaction complexity is a defining feature of roundabout operations under heterogeneous traffic conditions.

Geometric Analysis

The geometric analysis aims to evaluate whether the physical configuration of the roundabout supports optimal operational performance. As highlighted by Dharmawan et al. [11], inadequate geometric design, such as narrow entry widths or insufficient flare, may contribute to reduced operating speeds and the formation of long queues, ultimately degrading the performance of the entire roundabout. The Lot 13 roundabout is generally compact, with a central island measuring about 20 meters in diameter and a circulating lane width ranging from 5 to 6 meters. This configuration resembles a compact roundabout, which is typically suitable for low to moderate traffic volumes but may struggle to accommodate high-intensity flows, especially during peak hours.

Although most approaches appear to have two marked entry lanes, the operational capacity does not reflect true two-lane entry behaviour. The absence of adequate entry flares results in lane convergence near the roundabout throat, forcing vehicles to enter in a single-file formation. This geometric bottleneck restricts entry capacity, reduces queue discharge rates, and exacerbates delays during peak periods. Additional physical constraints, such as medians, pedestrian crossings, and nearby curb-side elements, further limit vehicle manoeuvrability near the entry points. From the perspective of the Highway Capacity Manual [14], these characteristics classify the entries effectively as single-lane entries, which are highly sensitive to increases in traffic volume. Consequently, the roundabout is prone to congestion when subjected to the high and fluctuating demand typical of the SCBD area.

Moreover, the roundabout is located adjacent to areas with high roadside friction, particularly near the Grand Lucky commercial complex. Frequent entering and exiting manoeuvres from parking areas, drop-off and pick-up activity, and intensive pedestrian movement contribute to additional interruptions in traffic flow. Pedestrian crossings located close to the roundabout exits further force approaching vehicles to decelerate, thereby reducing circulating speeds and prolonging queue discharge times. Although the geometric capacity of the

roundabout may be theoretically adequate under ideal conditions, these external influences significantly reduce its effective operational capacity.

Microsimulation-Based Performance Assessment

Operational performance was further evaluated using a calibrated PTV Vissim microscopic simulation model, which provides detailed insights into traffic behaviour under mixed-traffic conditions typical of Jakarta. Key performance indicators assessed include queue length, delay, circulating speeds, and vehicle conflict patterns.

Simulation results reveal severe oversaturation during peak periods, as reflected in the performance outcomes summarized in Table 1.

Table 1. Operational performance of the existing roundabout

Approach	Queue Length (m)	Delay (sec)
1	558.77	109.24
2	561.95	70.38
3	26.82	34.03
4	9.95	0.23
5	176.36	31.97
6	168.45	5.49

Approach Flows 1 (Sudirman Street–Grand Lucky) and 2 (Sudirman Street–BEI Building) exhibit maximum queue lengths of 558.77 meters and 561.95 meters, respectively, which far exceed typical thresholds for operational stability. In roundabout analysis, queue lengths beyond 150 meters are indicative of oversaturated entry conditions, where available capacity is insufficient to serve incoming demand. The excessive queues on these approaches demonstrate both structural flow imbalances and prolonged difficulty in securing acceptable entry gaps. In contrast, approaches 3 (Citibank–BEI Buildings) and 4 (Citibank Building–Sudirman Street) experience significantly shorter queues of 26.82 meters and 9.95 meters, respectively, suggesting that these approaches benefit from more favourable gap availability due to their minor-flow status. Approaches 5 and 6 show moderate congestion levels, with queues of 176.36 meters and 168.45 meters, indicating that although these approaches are impacted by circulating flows, their demand is not as dominant as Approaches 1 and 2.

Delay results reinforce these observations. Approaches 1 and 2 record delays of 109.24 seconds and 70.38 seconds, reflecting severe operational hindrance. Delays above 40 seconds per vehicle correspond to Level of Service (LOS) F based on HCM [14], signalling unacceptable performance. Approach 3, with a delay of 34.03 seconds, experiences moderate congestion, while Approach 4's delay of 0.23 seconds indicates free-flow

conditions. Approaches 5 and 6 experience delays of 31.97 and 5.49 seconds, respectively, representing mild to moderate congestion levels. A summary of the performance results is listed in Table 1.

Further, circulating speeds experience substantial reductions during peak periods, with average speeds falling to 12–18 km/h, a clear indication of flow breakdown. The drop in circulating speed reduces the likelihood of gap formation for entering vehicles, thereby reinforcing the high delay and queue growth observed on dominant approaches.

Taken together, the aforementioned indicators confirm that the Lot 13 roundabout is operating at a poor to very poor level of service (LOS F) based on the performance thresholds established in HCM [14]. Multiple operational indicators collectively confirm the presence of severe performance degradation, including major-approach queue lengths consistently exceeding 200 meters, average control delays surpassing 40 seconds per vehicle, pronounced imbalances in demand-to-capacity ratios across approaches, and circulating as well as entry capacities that are insufficient to accommodate prevailing traffic loads. These combined conditions reflect a systemic and sustained oversaturation of the roundabout under existing traffic demand.

5. DISCUSSION

Findings from the calibrated microscopic simulation indicate that the Lot 13 roundabout is functioning under severe oversaturation conditions during peak hours, particularly on the major inflows from Approach Flow 1 and Approach Flow 2 (see Figure 4). Excessive queue lengths exceeding 550 meters and delays surpassing 70–100 seconds per vehicle indicate that the current geometric and operational configuration is unable to accommodate prevailing traffic demand.

These findings confirm that the roundabout has reached, and in some cases exceeded, its practical capacity limits. The excessive queues exceeding 550 m are likely the result of a combined mechanism rather than demand alone. Sustained high inflow from the dominant Sudirman approaches interacts with limited effective entry capacity, insufficient flare utilization, and high roadside friction near the Grand Lucky corridor. Under these conditions, entry vehicles experience prolonged difficulty in securing acceptable gaps, causing queues to accumulate rapidly and, during peak periods, to propagate upstream as spillback. These long queues may also have implications beyond the roundabout itself. Given the constrained spacing of internal SCBD links and the concentration of commercial and office access points near the roundabout, upstream queue spillback can interfere with adjacent approaches and

disrupt progression on nearby links. Similarly, downstream disturbances associated with parking access, pedestrian crossings, and curbside activity may reduce discharge efficiency and further amplify delay at the roundabout entries.

The pronounced disparity between major and minor approach performance highlights a structural imbalance in flow distribution. Since roundabout operations rely on gap acceptance, continuous high-volume circulating flows from dominant approaches substantially limit entry opportunities for vehicles on minor approaches. This asymmetry in priority not only generates disproportionate delays but may also trigger unstable traffic conditions, including queue spillback, forced merging, and increased risk of conflict points, phenomena widely documented in high-density urban roundabouts [1], [19].

The simulation results align with earlier findings by Manage et al. [20], who emphasized that roundabouts perform most effectively under low to moderate traffic volumes, and that their efficiency deteriorates rapidly when demand approaches or exceeds capacity. In contexts such as SCBD, where traffic conditions are characterized by high-intensity commuting flows, mixed vehicle types, aggressive driving patterns, and substantial roadside friction, conventional non-signalized roundabouts face inherent limitations. Given these constraints, several studies have advocated the implementation of adaptive control measures, most notably the introduction of traffic signals at roundabout entries. Signalized metering has been shown to create controlled entry gaps, regulate circulating flow, and reduce delays under oversaturated conditions [1]. Al-Haideri et al. [21] and Diwakar and Ghosal [22] further highlight that signalization can reduce priority violations, minimize complex interactions in mixed traffic, and enhance overall safety performance. In environments with elevated pedestrian activity, such as near the Grand Lucky commercial zone, signal control can also improve multimodal coordination, as demonstrated by Subotić et al. [23] and Sánchez-Mateo et al. [24]. Moreover, Vasconcelos et al. [19] reported that the introduction of signal control at oversaturated roundabouts can increase practical capacity by 10–20%, particularly where approach volumes are highly unbalanced.

Signalization can also mitigate weaving conflicts by eliminating the need for entering vehicles to identify natural gaps in circulating flows; instead, controlled release mechanisms synchronize entries and reduce stochastic conflict patterns. Although safety performance was not quantified using formal conflict or surrogate safety indicators in this study, the observed and simulated operating conditions suggest elevated safety concern. Severe queueing,

forced merging, short accepted gaps, and frequent weaving interactions increase the likelihood of traffic conflicts, particularly in mixed-traffic conditions dominated by motorbikes. This indicates that future research should incorporate explicit safety analysis, such as conflict-based or trajectory-based surrogate measures, to complement the operational assessment.

While signalization presents a promising solution, its effectiveness depends heavily on the design of the signal timing plan. Inefficient cycle lengths or poorly optimized phasing may inadvertently worsen congestion or cause spillback into upstream links, an outcome that would be counterproductive in the already constrained SCBD network. Therefore, adaptive or traffic-responsive signal control may be considered as one of the potential strategies to accommodate temporal variations in flow intensity. During peak hours, greater green splits could be allocated to dominant approaches, whereas off-peak cycles may be shortened to ensure efficient flow for lower-demand movements.

The results of this study also suggest important implications for long-term traffic management within SCBD. The observed performance deficits indicate that geometric redesign alone, such as widening entries or modifying approach curvature, may not sufficiently resolve systemic congestion. Instead, a combination of signal metering, pedestrian flow regulation, enforcement of roadside activity, and possibly multi-modal demand management may be required to achieve meaningful improvement. Such an integrated approach aligns with contemporary urban mobility strategies that emphasize coordinated, adaptive, and context-sensitive traffic control measures. Overall, the discussion highlights that the Lot 13 roundabout, under its current configuration, is not capable of supporting the traffic demand characteristic of SCBD's dynamic urban settings. Signalization appears to be one potential intervention option that warrants further scenario-based evaluation; if implemented, it should be carefully calibrated, continuously monitored, and integrated with broader management initiatives.

6. CONCLUSION

This study evaluated the operational performance of the Lot 13 roundabout within Jakarta's SCBD using a combination of field data, analytical assessment, and validated microscopic simulation. The results demonstrate that the roundabout is operating under severe oversaturation, particularly on the two dominant approaches originating from Sudirman Street–Grand Lucky Supermarket and Sudirman Street–BEI Building. Excessive queue lengths exceeding 550 meters, delays surpassing 70–100 seconds per vehicle and circulating speeds

reduced to 12–18 km/h collectively confirm that the current roundabout configuration is no longer capable of accommodating existing traffic demand during peak periods. These operational deficiencies place the roundabout within LOS F according to HCM [14] thresholds. The findings further indicate that geometric constraints, such as insufficient entry flare, narrow effective throat width, and high roadside friction, contribute to reduced entry capacity and unstable flow conditions. The significant imbalance between major and minor approaches highlights the limitations of a fully unsignalized roundabout in environments with high and fluctuating traffic volumes. Given these conditions, the study indicates that adaptive traffic signal control or metering signals may be considered as candidate mitigation options for further engineering evaluation. Previous research and the simulation results suggest that signalization can improve entry gaps, reduce excessive delays, and enhance overall operational stability, particularly in highly unbalanced and conflict-prone traffic environments. However, effective implementation requires optimized, traffic-responsive cycle timing to prevent unintended spillback or secondary congestion.

While the results indicate for the need for operational interventions, the study is limited by the use of static demand inputs and behavioural approximations inherent to microscopic simulation. Future research should incorporate real-time demand variation, evaluate multi-scenario design alternatives (e.g., partial signalization, geometric redesign, multi-lane expansion), and integrate multi-modal considerations such as pedestrian prioritization and Transportation Demand Management (TDM) policies. Expanding the analysis to corridor-level impacts and long-term mobility strategies for SCBD would also offer valuable insights for policymakers and urban transport planners. Overall, the study concludes that the Lot 13 roundabout, in its current form, is not operationally sustainable under existing traffic conditions and that targeted, data-driven interventions are likely necessary to improve operational reliability within the SCBD network.

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