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VISSIM-Based assessment of road performance under proposed bicycle lane scenarios: Case study Adi Sumarno Road in Karangayar

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Abstract

The integration of bicycle infrastructure into existing road networks presents significant challenges for urban transportation planners, particularly in developing countries where road space is limited. This study assesses the impact of implementing dedicated bicycle lanes on road performance using VISSIM microsimulation modeling, taking Adi Sumarmo Road in Karanganyar Regency, Indonesia as a case study. The methodology involved comprehensive data collection followed by VISSIM model development, calibration, and validation through GEH statistics and MAPE values. Two scenarios were evaluated: Type A (protected on-road) and Type B (sidewalk) bicycle lanes. The microsimulation results revealed that both scenarios would maintain acceptable road performance levels. Type A implementation showed minimal changes in average travel speed (from 40 km/h to 39 km/h) and travel time (maintained at 44 seconds), with a degree of saturation increase from 0.22 to 0.30. Type B demonstrated slightly better performance with average speeds of 39.4 km/h and a lower degree of saturation of 0.29. These findings suggest that dedicated bicycle infrastructure can be successfully implemented on urban arterial roads without significantly compromising traffic flow performance, with sidewalk-level facilities offering particular advantages.

Keywords

VISSIM microsimulation, Bicycle lane design, Road performance analysis, Sustainable transportation

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Introduction

The integration of bicycle lanes into existing road networks has become an increasingly important issue for urban planners and transportation engineers. As cities aim to promote sustainable mobility, reduce traffic congestion, and improve public health, providing safe and efficient infrastructure for cyclists is crucial [1]. However, the introduction of bicycle lanes often raises concerns about their potential impact on overall road performance and traffic flow [2]. To address these concerns, researchers have employed various simulation tools to assess the feasibility and effectiveness of different bicycle lane scenarios [3].

Previous studies have utilized microscopic traffic simulation software, such as VISSIM, to evaluate the performance of road networks with the addition of bicycle lanes. For instance, [4] used VISSIM to investigate the impact of different bicycle lane configurations on traffic operations at signalized intersections. Their results indicated that the implementation of exclusive bicycle lanes improved cyclist safety but led to increased delays for motorized vehicles. Similarly, [5] employed VISSIM to assess the effect of shared bicycle lanes on road capacity and level of service in an urban corridor. While their findings suggested that shared lanes could be a viable option in low-speed, low-volume roads, they also highlighted the need for further research on the optimal design and placement of bicycle lanes in different road environments.

Despite the valuable insights provided by these studies, there remains a need for a comprehensive assessment of road performance under various bicycle lane scenarios, particularly in the context of developing countries like Indonesia. The unique characteristics of Indonesian roads, such as high traffic density, diverse vehicle types, and limited road space, present additional challenges for the integration of bicycle lanes [6]. Therefore, this study aims to evaluate the impact of different bicycle lane configurations on the performance of a selected Indonesian road using the VISSIM microscopic traffic simulation software. By comparing multiple scenarios, including protected bicycle lane on road, bicycle lane on sidewalk, and no bicycle lane options, this research seeks to provide recommendations for optimal bicycle lane design and implementation strategies that balance the needs of all road users while promoting sustainable transportation.

Method

This study focuses on Jalan Adi Sumarmo, a main road located in Karanganyar Regency, Central Java, Indonesia. The road has a length of approximately 900 meters and a width of 15.3 meters, with a 4/2 UD (4 lanes, 2 directions, undivided) configuration. The road serves as a crucial link for daily activities, connecting residential areas, schools, and businesses.

Primary data was collected through field surveys, including road geometry measurements, traffic volume counts, and vehicle speed observations. Road geometry data, such as lane width, median presence, and sidewalk dimensions, were obtained using a walking measure and recorded in a standardized form. Traffic volume data was collected during peak hours on both weekdays and weekends using manual counting methods and classified into three vehicle categories: motorcycles (MC), light vehicles (LV), and heavy vehicles (HV). Vehicle spot speeds were measured using a radar gun for a sample of vehicles in each category. Bicycle lane scenarios were developed based on the Indonesian guidelines for bicycle facility design [7].

The microscopic traffic simulation software VISSIM (version 11.0) was used to model and evaluate the performance of Jalan Adi Sumarmo under the different bicycle lane scenarios. The base model was developed using the collected road geometry, traffic volume, and vehicle speed data. The model was calibrated by adjusting driver behavior parameters, such as average standstill distance, additive part of safety distance, and lane change distance, to match the observed traffic conditions. The calibrated model was then validated using the Geoffrey E. Havers (GEH) statistic and the mean absolute percentage error (MAPE) for traffic volume and vehicle speed, respectively. The results of simulation compared to the Indonesian standards for urban road performance to assess the acceptability of each scenario.

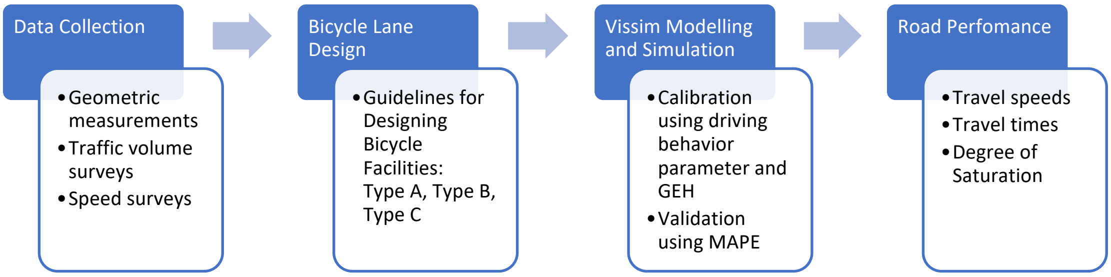

Figure 1. Research Flow

Results and Discussion

Geometric, Volume, and Speed

Jalan Adi Sumarmo has a total length of 900 meters and a width of 15.3 meters, with four lanes (two in each direction) and no median. The sidewalks on the western side of the road have a width of 1.7 meters, while the eastern side has road shoulders with a width of 1.3 meters. The traffic volume during peak hours was found to be 1,241 vehicles per hour (vph) for Northbound and 1,1180 vph for Southbound as shown in Figure 2, with motorcycles (MC) comprising the majority of the traffic (approximately 60%), followed by light vehicles (LV) and heavy vehicles (HV).

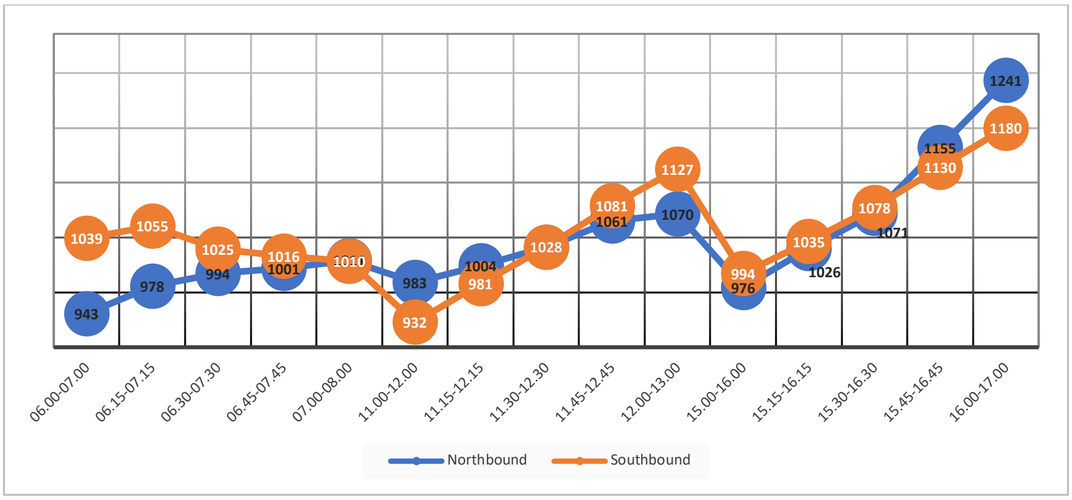

Figure 2. Traffic Volume

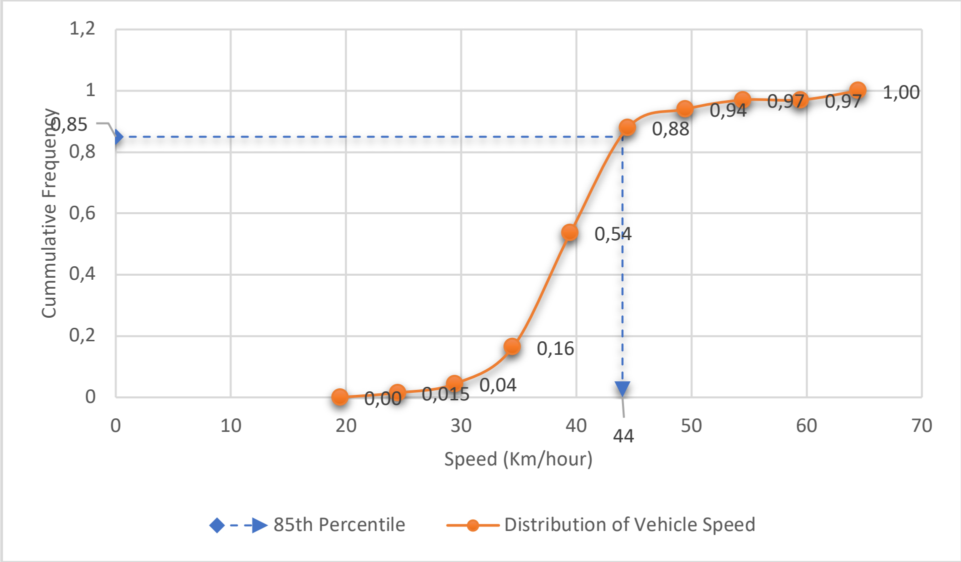

Figure 3. Cumulative frequency curve for spot speed

Based on the speed survey and data processing using cumulative frequency distribution graphs of vehicle speeds, the 85th percentile speed was found to be 44 kilometers per hour (Figure 3). This value represents the speed at or below which 85% of vehicles travel under free-flowing conditions, serving as a key metric for evaluating traffic flow characteristics and determining appropriate design parameters for the bicycle lane implementation on Adi Sumarmo Road.

Bicycle Lane Type Selection

Based on the analysis of traffic volume and 85th percentile vehicle speeds, the study established two viable bicycle facility designs: Type A and Type B (Figure 4). Type A consists of a protected bicycle lane on the roadway with physical separation using curbs, while Type B features a bicycle lane integrated with the sidewalk area. This determination aligns with the bicycle facility design guidelines which recommend Type A or Type B facilities for roads with observed traffic volumes of 1,241 vehicles per hour and 85th percentile speeds of 44 kilometres per hour, ensuring appropriate separation between cyclists and motorized traffic while maintaining operational efficiency.

Scenario 1 (Type A) implemented a protected on-road bicycle lane by reducing the main road width from 14m to 12m to accommodate a 1.44m dedicated bicycle lane with a 0.42m physical barrier (double kerb), while adjusting the sidewalk width to 1.5m and modifying shoulder use. In contrast, Scenario 2 (Type B) placed the bicycle lane at sidewalk level, featuring a 1.44m wide bicycle lane with a 0.30m minimum safety buffer before the kerb edge, maintaining a minimum pedestrian path width of 1.5m and utilizing existing shoulder space and remaining land.

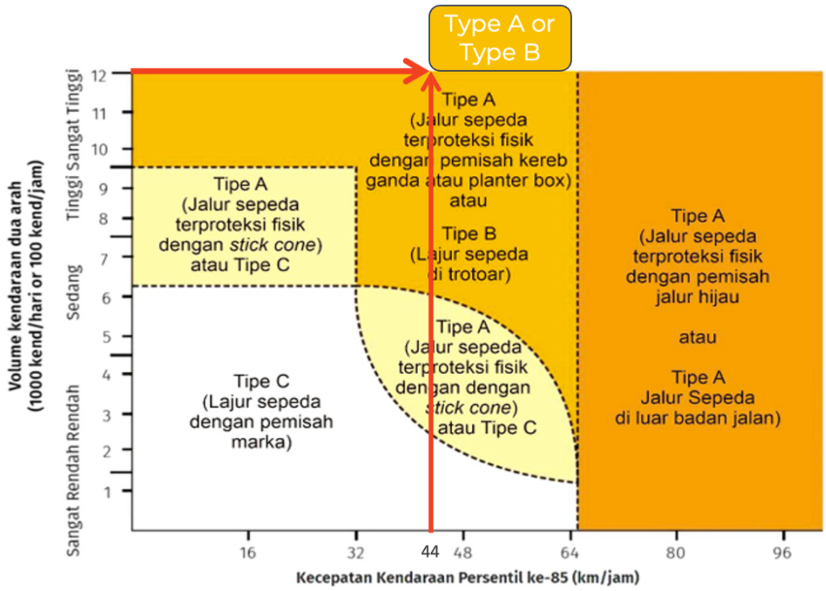

Figure 4. Bicycle lane type selection

Road Performance

Road performance values are labeled by traffic direction and segment. "Northbound" means traffic heading north, and "Southbound" means traffic heading south. Numbers (1 and 2) indicate different segments in each direction. The analysis of degree of saturation (Dj) across different scenarios reveals distinct patterns between northbound and southbound traffic flows (Figure 5). In the existing conditions, southbound consistently showed higher saturation levels (0.30) compared to northbound (0.13-0.14). When bicycle lane modifications were implemented, the impact varied by direction and scenario type. The northbound direction experienced more pronounced changes in saturation levels, with Type A (Scenario 1) implementation showing the most significant increase to 0.30 from the baseline of 0.13-0.14. This substantial increase can be attributed to the reduction in effective road width when implementing the protected bicycle lane on the road. In contrast, Type B (Scenario 2) maintained better performance with saturation levels reaching 0.28, suggesting that sidewalk-level bicycle lanes have less impact on motorized traffic flow.

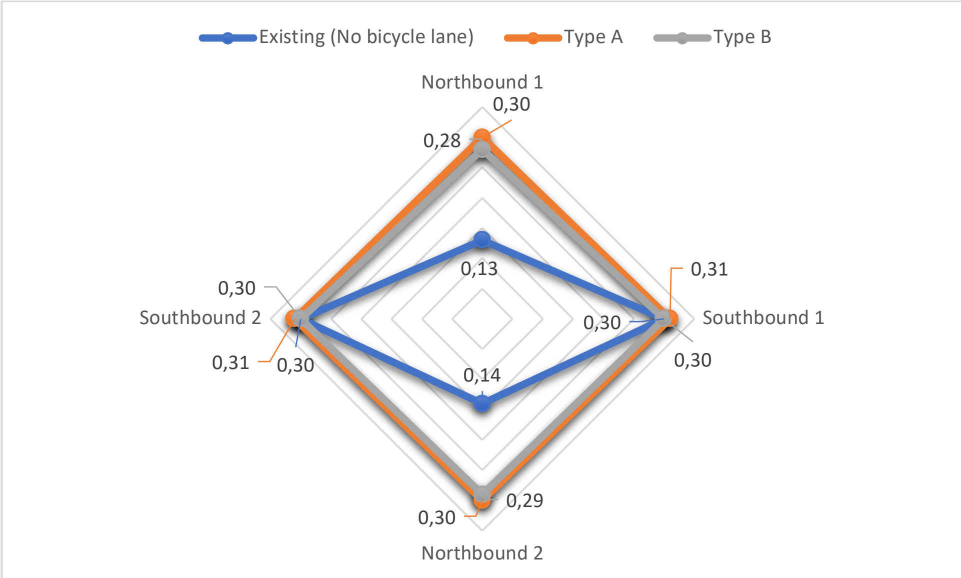

Figure 5. Degree of Saturation

The travel speed analysis following VISSIM simulation revealed distinct patterns of impact across the two proposed bicycle lane scenarios (Figure 6). Scenario 1 (Type A protected on-road bicycle lanes) resulted in a moderate reduction in travel speeds, showing decreases of less than 10% from baseline conditions (34,52 km/h). In contrast, Scenario 2 (Type B sidewalk-level bicycle lanes) demonstrated notably better performance in maintaining traffic speeds, with changes less than 5% from existing conditions (36,53 km/h). Directional analysis revealed that the southbound traffic flow exhibited greater sensitivity to the modifications, likely due to its existing geometric constraints and higher utilization rates.

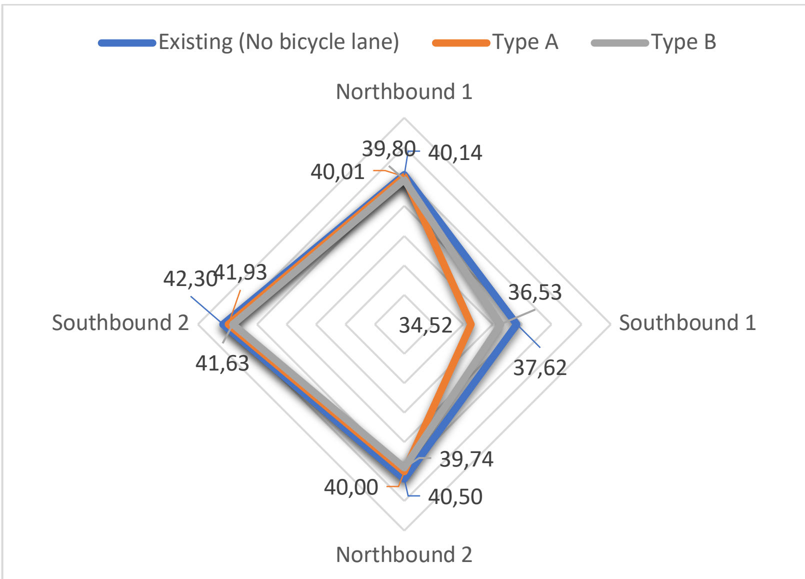

Figure 6. Travel speed

Analysis of travel times across implementation scenarios revealed relatively minor impacts on overall traffic performance (Figure 7). After implementing Scenario 1 (Type A protected on-road bicycle lanes), travel times showed a modest increase of less than 5% compared to baseline conditions, at 44 seconds on average. Similarly, Scenario 2

(Type B sidewalk-level bicycle lanes) demonstrated comparable patterns, with minimal increases in travel time that closely matched those observed in Scenario 1.

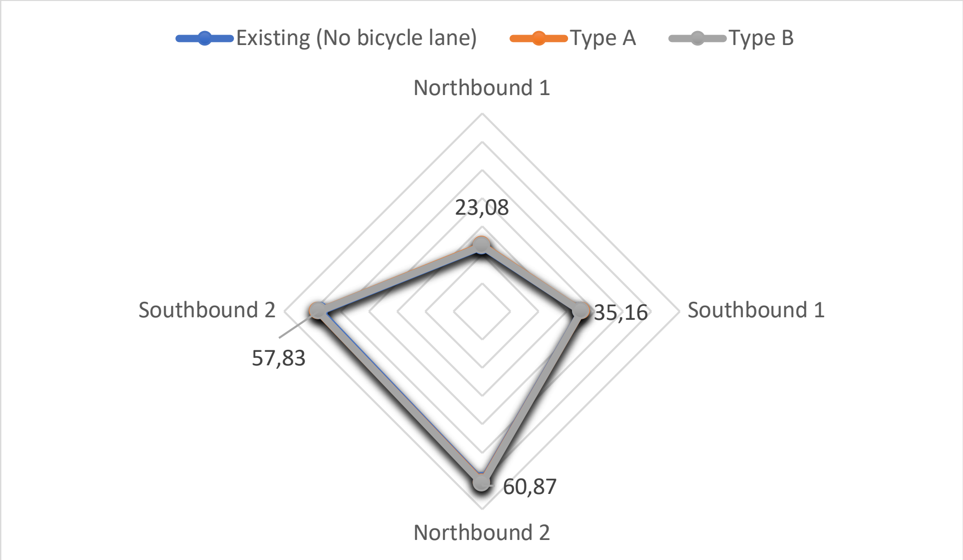

Figure 7. Travel times

Discussion

The existing road performance analysis showed relatively low degree of saturation (DJ) values ranging from 0.14 to 0.33, indicating good operational capacity. This aligns with Ratnaningsih's findings that proper bicycle lane implementation can be achieved without significantly compromising road performance when initial saturation levels are moderate [8]. The VISSIM simulation validated these results through GEH values < 5.0 and MAPE values within acceptable ranges (8-12%), comparable to validation metrics reported by [9] in their VISSIM studies of Indonesian traffic conditions.

The study found that geometric changes required for bike lane implementation, particularly for Type A facilities, led to increased saturation levels but remained within acceptable limits. This provides important practical insights missing from previous research about the trade-offs between different bicycle facility types. The findings suggest that while both Type A and Type B implementations are feasible from a traffic performance perspective, Type B offers slightly better overall performance while still meeting safety objectives. These findings complement [10] research on non-motorized transportation benefits and align with [11] work on urban bike lane planning in smart cities. Similar to [12] simulation-based findings, this study reveals that selective implementation of protected cycling lanes on suitable streets resulted in only minor impacts on vehicle travel times (approximately 7% increase). The implementation of physical separators between cycling and vehicle lanes in Karanganyar corresponds with [13] finding that protected bicycle lanes completely eliminated the risk of unsafe passing distances under 1m. This physical separation approach appears more effective than painted lines alone, supporting [14] conclusion that separated lanes were strongly preferred by cyclists.

Though limited to a specific road segment and time period, this study makes several unique contributions including the first application of microsimulation modeling for bicycle lane evaluation in Karanganyar. The results demonstrate that proper bicycle infrastructure can be achieved without significantly compromising road performance when following a systematic approach: beginning with comprehensive traffic performance analysis to establish baseline conditions, carefully measuring key metrics including saturation levels, travel speeds and travel times, and considering sidewalk-level (Type B) bicycle lanes as primary option as they show minimal impact on traffic flow. This evidence-based methodology, supported by microsimulation modeling, provides a practical framework for governments to evaluate and implement sustainable transportation infrastructure while maintaining acceptable road network performance. The approach can be adapted for different urban contexts, helping agencies make informed decisions about bicycle lane integration that balance mobility needs with infrastructure capacity.

Conclusion

The existing road demonstrated good operational characteristics with degree of saturation values of 0.14-0.33, which provided a foundation for evaluating two bicycle lane implementation scenarios: Type A (protected on-road) and Type B (sidewalk-level). Through VISSIM simulation analysis, while both scenarios maintained acceptable performance levels, Type B implementation proved optimal with lower degree of saturation (0.28-0.30 vs 0.30-0.31) and better travel speeds (36-42 km/h vs 34-42 km/h) compared to Type A. These results demonstrate that implementing bicycle lanes on Adi Sumarmo Road is feasible, with Type B recommended as the preferred solution, providing an optimal balance between traffic performance and cyclist safety. This research contributes valuable quantitative evidence through microsimulation modelling to the growing body of knowledge on bicycle infrastructure integration in Indonesian cities, while also providing practical guidance for transportation planners and engineers working to implement sustainable mobility solutions. For successful implementation, it is recommended to establish regular monitoring programs and develop supporting policies to ensure proper usage and maintenance of the bicycle infrastructure.

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