Evaluating the Impact of Dedicated Bicycle Lane on Urban Traffic Dynamics

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Abstract: The growing interest in sustainable urban mobility has led to the widespread implementation of bicycle lanes in cities worldwide. However, the impact of these bicycle lanes on vehicular traffic flow remains a critical concern for urban planners and policymakers. This study employs microsimulation techniques to explore the effects of these infrastructure on urban traffic systems, specifically focusing on vehicle speed, delay and overall traffic Level of Service (LOS). Using traffic simulation model, various scenarios involving the integration of bicycle lanes into existing road networks were analysed. Our findings suggest that although the introduction of bicycle lanes reduces the available road space for vehicles, their presence does not necessarily result in significant increases in travel delay. In fact, the bicycle lanes contribute to improved vehicle speeds and LOS. The results contribute valuable insights into the role of cycling infrastructure in promoting sustainable transport while maintaining efficient traffic operations in urban areas.

Keywords: Bicycle Lanes, Traffic simulation, Speed, Delay, Level of Service (LOS)

1. INTRODUCTION

In the Global Bicycle Cities Index 2022, Hangzhou emerges as the most bicycle-friendly city in Asia, achieving an index score of 52.55 out of 100 (Table 1). This comprehensive index assesses cycling conditions across 90 cities worldwide, including 10 in Asia. Based on six key indicators—climate, cycling trends, safety measures, infrastructure quality, bicycle rental facilities, and cycling-focused events such as car-free days—the index provides a detailed evaluation of cycling viability.

Table 1. Asia Most Bicycle Friendly Cities, 2022 (Seasia Stats 2024)

No	Country	Index
1	Hangzhou	52.55
2	Tokyo	40.26
3	Beijing	35.91
4	Shanghai	32.51
5	Singapore	31.62
6	Seoul	27.67
7	New Delhi	23.96
8	Hong Kong	22.24
9	Jakarta	21.66
10	Bangkok	18.9

Notably, however, no Malaysian cities were included in the ranking, despite efforts in urban centres such as Kuala Lumpur, Shah Alam, and Johor Bahru to implement bicycle lanes in recent years. For instance, Kuala Lumpur introduced its first bicycle lane in 2015, a 5.5 km route connecting Mid Valley to Dataran Merdeka, designed to reduce traffic congestion and promote cycling as a sustainable commuting alternative. Similarly, Shah Alam has integrated cycling lanes into its urban corridors, such as Persiaran Perbandaran, to accommodate growing demand for non-motorised transport, particularly amid rising e-scooter usage as highlighted in the study of (Mustafa, Yasmin Soraya, et al., 2024). Johor Bahru has also prioritised cycling infrastructure as part of its urban development strategy, albeit on a smaller scale. Table 2 further details the existing and planned lengths of cycling infrastructure across these cities. As of 2023, Kuala Lumpur has constructed approximately 32.9 km of bicycle lanes, with plans to expand this network by an additional 15 km by 2025. Shah Alam's current network comprises 15 km of shared bicycle lanes, focusing on key commercial areas in the city centre and surrounding residential zones. Johor Bahru, while lagging behind with only 15 km of existing lanes, has outlined ambitious targets to develop 30 km of cycling routes by 2030, aligning with national sustainability goals. These efforts reflect a growing recognition of cycling's role in addressing urban congestion and emissions, though challenges persist in achieving the infrastructure quality and connectivity seen in higher-ranked cities like Hangzhou.

Table 2. Cities and Their Existing Bicycle Lane

City	**Existing Cycle Lane (km)**	**References**
Kuala Lumpur	32.9	(Dewan Bandaraya Kuala Lumpur, 2019)
Johor Bahru	15	(Nordin, 2023)
Putrajaya	180	(Perbadanan Putrajaya, 2022; Smart Putrajaya, 2021)
Shah Alam	15	(Dewan Negeri Selangor, 2017)

The rapid pace of urbanisation, coupled with growing environmental concerns and the need to improve public health outcomes, has compelled cities across the globe to adopt more sustainable and innovative strategies to address the complex challenges associated with urban mobility. Among these strategies, the provision and implementation of dedicated cycling lanes have emerged as a promising approach to encouraging active transportation, reducing greenhouse gas emissions, and improving the overall quality of life in urban environments. By creating safer and more accessible infrastructure for cyclists, cities aim to shift travel behaviour towards more sustainable modes, thereby reducing dependence on private motor vehicles and contributing to broader climate and liveability goals. However, integrating cycling lanes into existing and often already congested road networks is not without its challenges. Such interventions can introduce a number of operational and design complexities, particularly in densely populated urban areas where road space is a limited and highly contested resource. One of the principal concerns is the potential reduction in road space available for motorised traffic, which may result in increased congestion, longer travel times, and elevated vehicle emissions. These impacts are especially pronounced in corridors with high traffic volumes or limited right-of-way, where the reallocation of space may necessitate the removal of traffic lanes or parking provisions. The degree to which cycling infrastructure affects urban traffic dynamics is influenced by a multitude of factors, including the composition of vehicular traffic, road geometry, signal timings, and overall network configuration. As such, there is a pressing need for a deeper and more nuanced understanding of how the inclusion of cycling lanes interacts with existing traffic systems, both to maximise the benefits of sustainable transport infrastructure and to mitigate unintended negative consequences. To address these concerns, this study utilises microsimulation modelling techniques to evaluate the effects of cycling lanes on urban traffic performance. By simulating real-world traffic conditions under different infrastructure scenarios, the study aims to generate empirical evidence on the impact of dedicated cycling infrastructure on key traffic performance indicators, including average vehicle speed, traffic delays, and overall flow level of service. These insights are intended to support more informed and balanced decision-making in urban transport planning, ensuring that efforts to promote cycling are harmonised with the broader objective of maintaining efficient and resilient urban mobility systems.

2. LITERATURE REVIEW

2.1 Overview of Bicycle Lane

A bicycle lane is a type of cycling network infrastructure designed to connect key origin and destination points over longer distances, offering high-quality connections for safe and enjoyable cycling (Grigoropoulos et al., 2021). (Liu et al., 2019) define bicycle lanes as “fast cycle routes,” referring to long, high-quality cycling routes intended for commuting in urban areas. These lanes are specifically designated for bicycles but may also be shared with pedestrians, forming part of urban cycling networks (Abdullah et al., 2020). Bicycle roads were first constructed in Tilburg and The Hague, the Netherlands, during the early 1980s to alleviate congestion on the nation’s overcrowded road networks. The Netherlands was the first country to propose the concept of a bicycle highway, enabling commuters to travel up to 15 km securely and efficiently by bicycle(Grigoropoulos et al., 2021). Additionally, the first bike lane integrated into a vehicular route was created in July 1967 on Sycamore Lane in New York City. In Malaysia, the first bicycle lanes were introduced in 2015 in Kuala Lumpur, featuring a 5.5 km stretch from Mid Valley to Dataran Merdeka. This route passes through the Klang River, Brickfields, the Kompleks Dayabumi compound, and Lebuh Pasar Besar (Jonathan, 2015). The initiative aimed to provide an alternative mode of transport within the city to reduce traffic congestion and pollution. It also sought to encourage cycling among Malaysians, aligning with Kuala Lumpur’s tourism strategy to promote itself as a modern, health-conscious city and the government’s FitMalaysia campaign for a healthier nation. Table 3 presents the standard bicycle track widths as specified by the Department of Works Malaysia. Concurrently, Kuala Lumpur City Hall has developed its own set of design guidelines for cycle infrastructure (Dewan Bandaraya Kuala Lumpur, 2019). Figure 1 provides a detailed example of a road design with a designated speed limit of 50 km/h, showcasing the integration of bicycle tracks within the roadway infrastructure.

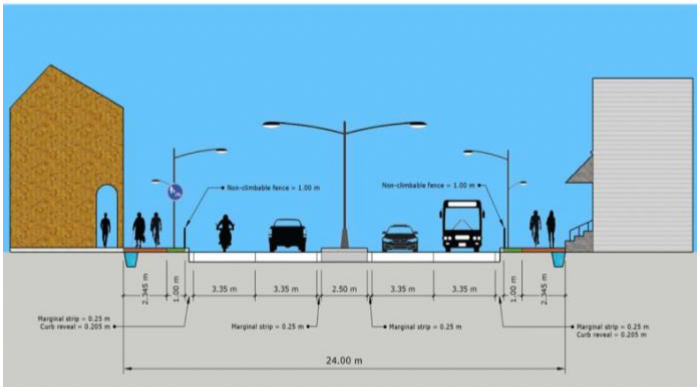

Figure 1. Design DU4-1 for ROW U4 = 80 ft./24 m (50 km/h) (Dewan Bandaraya Kuala Lumpur, 2019)

Table 3. Width of cycle track (Jabatan Kerja Raya Malaysia, 2018)

Types of cycle track		**Width (m)**	
		Minimum	**Desirable**
Exclusive	One way	1.5	2.0
	Two way	2.5	3.0
Non-exclusive	One way	1.5	3.0

The width of a bicycle track is determined by the type of facility, whether exclusive or non-exclusive, as specified in the Arahan Teknik Jalan (ATJ) Manual –Table 3. Non-exclusive bicycle tracks must be separated from the main carriageway by a minimum of 0.7 m, typically using a chevron-marked separator. Meanwhile, (Pucher & Buehler, 2017) observe that the bicycle lanes are being developed in cities worldwide to encourage the use of bicycles, e-bikes, and other small-wheeled vehicles for urban transport. Similarly, European cities have invested in a range of infrastructure and policies to enhance the attractiveness of cycling, with the objectives of reducing car dependency, promoting physical activity, fostering environmental sustainability, stimulating economic growth, and improving accessibility (Buekers et al., 2015). (Madsen & Lahrmann, 2017) argue that cycling facilities, such as dedicated bicycle tracks and lanes, are often constructed to enhance cyclists' perceived safety and security. Previous studies indicate that cyclists are more likely to sustain injuries requiring hospitalisation compared to other road users. Moreover, bicycle lanes are frequently incorporated into intervention strategies aimed at modifying commuter behaviour, rather than simply expanding road infrastructure to accommodate anticipated increases in traffic volume (Skov-Petersen et al., 2017). A study by (Mai et al.) in a Sydney sub-regional city found that despite strong investment, poor design such as steep gradients, narrow widths, and poor intersection priority led to low cycling uptake. Using Sustainable Mobility Theory, the study identified key infrastructure gaps and stressed that even well-intended policies can fail without proper design and institutional support, especially in car-centric cities.

2.2 Bicycle Lane and Its Impact

Cycling has gained increasing prominence as a sustainable mode of transportation, offering benefits in terms of reduced emissions, improved public health, and enhanced urban liveability with low cost (Karanikola et al., 2018). As cities strive to address environmental concerns and traffic congestion, the implementation of cycling lanes has become a common strategy to promote active mobility and encourage the adoption of cycling. Several studies have explored the impact of cycling infrastructure on urban traffic systems, revealing both potential benefits and challenges. While some research has highlighted the positive effects of cycling lanes on reducing vehicle emissions, improving road safety, and promoting a modal shift towards active transportation, other studies have raised concerns about the potential impact on vehicular traffic flow and congestion (Nanayakkara et al., 2022). In India, the Covid-19 pandemic led to a rise in cycling and spurred the development of dedicated infrastructure. A study by (Monga & Sadhukhan, 2024) in Patna proposed a user perception-based Bicycle Level of Service (BLOS) framework, using a Discrete Choice Experiment and Random Parameter Logit Model to evaluate service levels. This approach ensures infrastructure is assessed in line with users' actual experiences and preferences. In addition, recent study by (Chiou & Wu, 2024) in Taipei on YouBike found that income, riding distance, and public transport use strongly affect bikesharing–transit transfers. It recommends placing bikes haring stations near transit hubs and ensuring bike availability and safe lanes for popular short trips.

Cycling is an active mode of travel that is reliable, practical, and efficient for shorter journeys, contributing to reductions in traffic, carbon emissions, and noise pollution (Nanayakkara et al., 2022). Enhancements in active travel across European metropolitan areas have delivered significant lifetime carbon emission benefits, with walking and cycling already accounting for a substantial share of overall transport in these regions(Brand et al., 2021). Furthermore, findings from three studies by (Green et al., 2021) indicate that the physical activity benefits of active travel often outweigh concerns regarding air pollution exposure. A meta-analysis of 39 studies examining the relationship between transport modes and air pollution exposure found that car travel consistently results in the highest levels of exposure.

Bicycles, in particular, offer numerous advantages in urban settings, including reduced traffic congestion, minimal space requirements, lower environmental pollution, and improved public health (Grigoropoulos et al., 2021). Addressing climate and air pollution challenges necessitates an immediate reduction in emissions from motorised transport, particularly private vehicles. According to the (World Health Organization, 2022), there is growing evidence highlighting the value of active mobility in mitigating climate change. For instance, walking for 30 minutes or cycling for 20 minutes on most days reduces mortality risk by at least 10%. While cycling and walking cannot replace all car trips, there remains substantial potential to reduce emissions. Beyond the environmental benefits, cycling provides immediate health advantages, mitigating the impacts of climate change on human health by reducing premature deaths, heart disease, cancer risks, and obesity (Maizlish et al., 2017). In the study of (Willberg et al., 2023), although noise exposure from cycling exceeds healthy thresholds, cyclists can mitigate their exposure through careful route selection. In the study by (Antón-González et al., 2023), a conclusion was made where the primary focus of many studies was on the structural factors influencing cycling in urban environments, particularly the development of infrastructure and facilities to encourage cycling among users. While these structural enhancements were identified as key to promoting cycling, the study found that the associated health benefits, though acknowledged, were considered a secondary concern. This suggests that urban cycling policies and planning efforts prioritise accessibility and convenience over direct health outcomes, highlighting the need for a more integrated approach that balances infrastructure development with public health considerations.

Cycling infrastructure such as dedicated bicycle lanes have gained prominence as a tool for reducing automobile use, promoting active transportation, and creating more sustainable urban mobility systems. However, the integration of cycling infrastructure into existing road networks can have complex implications for overall traffic performance and few studies examine the effects of specific lane designs. A study by (Li & Chen, 2025) in Taipei addressed this gap by analysing six cycle lanes using both citywide and road-specific data. It found that longer, wider, and better-connected lanes particularly those near metro stations and with higher bikeshare density led to significant increases in ridership. These findings highlight the importance of context-specific infrastructure planning to support the goals of Sustainable Development Goal 11. Research has shown that the implementation of cycling lanes can have both positive and negative impacts on urban traffic dynamics. On the one hand, the provision of cycling infrastructure can encourage more people to commute by bicycle, leading to a modal shift away from private vehicles and potentially reducing congestion and emissions. On the other hand, the reallocation of road space to cycling lanes can result in reduced capacity for motorised vehicles, potentially increasing travel times, delays, and emissions in the short term (Egan & Caulfield, 2024).

A study by (Lee et al., 2024) examined the impact of bicycle infrastructure on safety and operations using a microsimulation approach. The researchers found that the introduction of cycling lanes resulted in safer travel through the network during the peak hour period without any apparent deterioration in delays. The study highlighted that despite reallocating road space to accommodate bicycle lanes, there was no significant increase in vehicular delays. This suggests that well-planned bicycle infrastructure can enhance road safety without negatively impacting traffic flow. Recent Malaysian research has begun to address not only the physical gaps in cycling infrastructure but also the behavioural risks linked to different facility types. (Rusli et al., 2023) observed cyclist behaviours in Kuala Lumpur across four settings: shared paths, one-way and two-way lanes, and roads without cycling facilities. Using binary logistic regression, they found the highest risk-taking such as riding against traffic or encroaching on pedestrian areas occurred where no dedicated lanes existed, followed by shared paths. In contrast, well-designed lanes were associated with notably safer cyclist behaviour.

Furthermore, the design and integration of cycling infrastructure can play a crucial role in determining its impact on urban traffic systems. Proper signage, lane markings, and the separation of cycling and motorised traffic can help to minimise conflicts and improve the overall efficiency and safety of the transportation network (Autelitano & Giuliani, 2021). A study by (Xu & Zuo, 2024) found that the introduction of bike-sharing services significantly reduces short-term traffic congestion, with the initial deployment having the greatest impact, while subsequent expansions yield diminishing returns; however, the availability of dedicated bicycle lanes is essential to support and enhance the effectiveness of these services. In addition, a study in Charlotte by (Preston & Pulugurtha, 2021) evaluated a Protected Intersection Design (PID) using Vissim and SSAM. The PID had no adverse effect on traffic performance, while bicycle related conflicts decreased by up to 80% when cycling volumes exceeded 10%. The findings suggest that PIDs enhance cyclist safety without compromising traffic efficiency, particularly in areas with higher cycling demand. Besides, a study by (Nurfaizi & Sari, 2021), aligned with Indonesia's Regulation No. 22 of 2009, identified the need for dedicated pedestrian and cycling paths in Kampung Inggris, Pare District. Due to mixed traffic and the lack of bike lanes, three alternative routes were proposed using stochastic traffic assignment. The study also recommended supporting facilities such as signage, markings, and bicycle parking to improve safety and air quality.

A research gap exists in understanding the comprehensive impact of bicycle lanes on urban settings, particularly in terms of safety, traffic operations, and environmental benefits. While previous studies have examined the effects of bike-sharing services and general cycling infrastructure, there is limited research assessing the impact of bicycle lanes on overall urban traffic performance. Therefore, further investigation is warranted to examine how dedicated bicycle lanes influence urban traffic flow to inform more effective urban transport policies and infrastructure planning.

2. METHODOLOGY

The designation of a bicycle lane formally recognises cycling as a mode of transport, potentially fostering more predictable interactions between cyclists and motorists; however, conflicts may still occur, particularly in high demand corridors with high traffic volumes and speeds. Given that a dedicated bicycle lane, marked in blue at the edge of the road, is introduced, our hypothesis is that it will reduce vehicle speeds, potentially resulting in queue formation and increased traffic congestion. This effect is expected due to the reallocation of road space, which may lead to a narrower carriageway for motorised vehicles, thereby reducing their ability to manoeuvre freely. Additionally, the presence of a dedicated lane may encourage a higher volume of cyclists, increasing interactions at intersections and driveways, which could further contribute to delays. The study area for the bicycle lane is situated along a critical route through the heart of Shah Alam city centre, specifically at Persiaran Perbandaran and the four-way intersection of Persiaran Bandar Raya in Section 14 (Figure 2 and Figure 3). The intersections are surrounded by several commercial centres, contributing to the increasing traffic volume in the area. The cycling lane in this region is significant, as the community utilises it for both business related activities and recreational purposes in Section 14. The study utilises defined traffic data from a location with an existing dedicated bicycle lane to construct an accurate microscopic traffic model.

Figure 2. Study area with existing bicycle lane

Figure 3. Bicycle lane merging area

The road network configuration used in this study closely replicates the actual layout, covering a stretch of approximately 200 metres. The network consists of dual carriageways with two lanes in each direction, incorporating varying lane allocations across both sides, resulting in a total cross-sectional width of 4 metres. Traffic volume and composition are generated using hypothetical inputs within the simulation environment, allowing for a range of traffic conditions to be tested across different levels of service. The simulated traffic includes a mix of light-duty vehicles, motorcycles, and non-motorised modes such as bicycles, with flexible configurations to reflect diverse urban traffic scenarios. Two primary scenarios are examined: one incorporating dedicated cycling lanes and one without, both implemented at intersection approaches in both directions. These scenarios enable a comparative assessment of the impact of cycling infrastructure on overall traffic performance. Table 4 presents the details of the simulated scenarios, while Figure 4 provides a visual representation of the modelled traffic network within the Aimsun platform. The choice of Aimsun as the simulation tool aligns with the methodological approach adopted by (Mustafa, Shahfuan Hakimi, et al., 2024) in previous studies, although Vissim was used in some of that research, such as in one particular study.

Table 4. Traffic Volume and Traffic Configurations for Scenario 1 and 2

Scenario	**Traffic Volume (Veh/hr)**	**Traffic Configurations (%)**
With and without bicycle lane	500	70% PC, 20% MC, 10% BC
		60% PC, 10% MC, 30% BC
		45% PC, 5% MC, 50% BC
	1000	70% PC, 20% MC, 10% BC
		60% PC, 10% MC, 30% BC
		45% PC, 5% MC, 50% BC
	1300	70% PC, 20% MC, 10% BC
		60% PC, 10% MC, 30% BC
		45% PC, 5% MC, 50% BC
	1500	70% PC, 20% MC, 10% BC
		60% PC, 10% MC, 30% BC
		45% PC, 5% MC, 50% BC
	2000	70% PC, 20% MC, 10% BC
		60% PC, 10% MC, 30% BC
		45% PC, 5% MC, 50% BC

The study further investigates the impact of varying cycle lengths for the cycling lanes on the operational performance at the four-leg intersection. To simulate realistic traffic conditions, we tested different cycle length settings for the cycling lanes at the intersection. The overall cycle time for the intersection was set at 120 seconds, with the cycle length for the bicycle lanes varied at 10, 30, and 60 seconds.

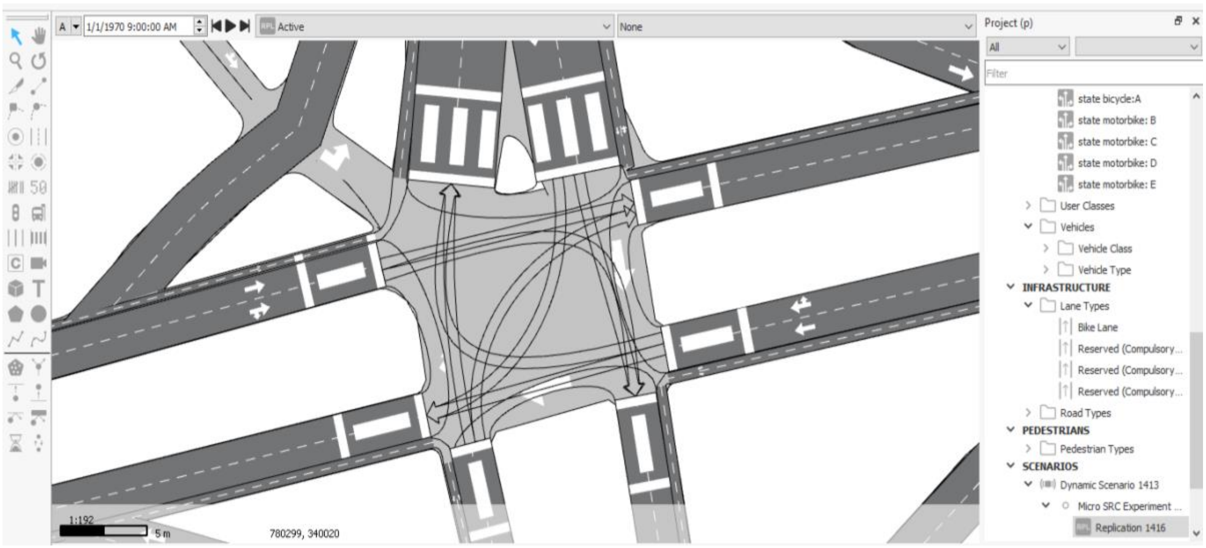

Figure 4. Examples of Road Network in Aimsun

4. RESULTS AND DISCUSSIONS

Table 5 presents a detailed comparison of vehicle speeds and Level of Service (LOS) across different traffic configurations, highlighting the significant improvements observed with the introduction of a dedicated bicycle lane marked in blue at the edge of the road. The simulation results indicate that the segregation of bicycles from the main traffic stream minimises conflicts between cyclists and motorised vehicles, leading to more stable traffic conditions, smoother vehicle movements, and improved overall traffic performance. The presence of a dedicated bicycle lane results in noticeable enhancements in vehicle speed across all traffic volumes. Under light traffic conditions (500–1000 vehicles per hour), average vehicle speeds increase by approximately 3–13%, depending on the proportion of bicycles in the traffic stream. The lower end of this improvement is observed in scenarios dominated by passenger cars (PC), where fewer bicycles (BC) are present. However, as traffic volume increases, the benefits of the dedicated bicycle lane become even more apparent. At higher traffic volumes (1500–2000 vehicles per hour), the dedicated lane ensures that bicycles no longer mix with motorised traffic, preventing unnecessary speed reductions and maintaining more stable traffic flow.

A particularly striking effect is observed when bicycles constitute a substantial portion of the traffic stream. In scenarios where bicycles make up 50% of total traffic, the average vehicle speed increases dramatically from 28.06 km/h to 52.43 km/h, an improvement of nearly 87%. This substantial gain is attributed to the reduction in friction between different modes of transport, as the dedicated lane allows cyclists to travel at their own pace without impeding vehicular movement. Additionally, the improvement in LOS is evident across all traffic conditions. At lower traffic volumes, LOS improves from categories C or D to A, indicating a more fluid and efficient traffic flow. At higher volumes, the presence of a dedicated bicycle lane prevents severe congestion, maintaining LOS at more acceptable levels, typically B or C, instead of E or F, which would be expected without lane separation. This suggests that the dedicated lane effectively mitigates the negative impact of increased bicycle presence on motorised traffic performance.

These findings highlight the critical role of dedicated bicycle infrastructure in supporting urban mobility, particularly in cities promoting cycling as a sustainable mode of transport. By reducing conflicts and improving operational efficiency, bicycle lanes help maintain overall traffic performance, reinforcing the need for their integration into urban transport planning. Conflicts between cars and bicycles primarily occur at locations where their trajectories intersect, particularly in mixed-traffic conditions where no dedicated cycling infrastructure is provided. These conflicts are most prominent at merging zones, driveways, and turning points, where motorised vehicles are required to adjust their speeds or change lanes to accommodate cyclists. The absence of dedicated lanes results in frequent speed fluctuations, sudden braking, and increased travel time, contributing to overall traffic turbulence and congestion. However, the introduction of a dedicated bicycle lane effectively mitigates these disruptions by providing a segregated space for cyclists, reducing vehicle-bicycle interactions and enhancing traffic flow stability.

The findings align with previous research by.(Schaefer et al., 2020), indicating that the presence of 22 bicycles is unlikely to significantly impact passenger vehicle travel speed, despite variations in performance characteristics and the absence of dedicated bicycle lanes. The results of the t-tests and the 95% confidence intervals suggest that, in most cases, the differences in vehicle speed are not statistically or practically significant. However, the analysis identified a few instances where measurable variations in speed were observed, highlighting the need for further investigation into specific traffic conditions that may influence these effects.

Table 5. Vehicle Speed and Level of Service (LOS) for Different Traffic Configuration

Traffic Volume (Veh/hr)	**Traffic Configuration (%)**	**Vehicle Speed (km/hr)**	**LOS**	**Vehicle Speed (km/hr)**	**LOS**	**Percent Improvement in Speed**
		Without Bicycle Lane		With Bicycle Lane		
500	70% PC, 20% MC, 10% BC	77.40	A	79.52	A	2.7
	60% PC, 10% MC, 30% BC	56.65	C	63.81	A	12.6
	45% PC, 5% MC, 50% BC	51.31	B	56.35	C	9.8
1000	70% PC, 20% MC, 10% BC	74.57	A	78.42	A	5.2
	60% PC, 10% MC, 30% BC	48.49	D	62.71	A	29.3
	45% PC, 5% MC, 50% BC	42.21	E	54.98	C	30.3
1300	70% PC, 20% MC, 10% BC	71.65	A	77.52	A	8.2
	60% PC, 10% MC, 30% BC	42.45	E	61.49	A	44.9
	45% PC, 5% MC, 50% BC	37.74	E	54.11	C	43.4
1500	70% PC, 20% MC, 10% BC	69.61	A	76.62	A	10.1
	60% PC, 10% MC, 30% BC	39.65	E	60.27	B	52.0
	45% PC, 5% MC, 50% BC	34.37	E	54.03	C	57.2
2000	70% PC, 20% MC, 10% BC	62.34	A	73.45	A	17.8
	60% PC, 10% MC, 30% BC	33.55	E	56.70	C	69.0
	45% PC, 5% MC, 50% BC	28.06	F	52.43	D	86.8

In addition, these findings are contradicted with the study by (Nanayakkara et al., 2022) where with 9600 cars and 2400 cyclists in the network, they observed a significant reduction in the average speed of vehicles. The results also contradicted the study by (Younes et al., 2024), which found that the impact of the delineator-protected bicycle lane (marked with traffic cones and plastic delineators) was associated with a 28% reduction in average maximum speeds and a 21% decrease in average speeds for vehicles making right turns. The bicycle lanes reduce conflicts between cyclists and motorised vehicles by providing a separate space for cyclists, preventing them from weaving through mixed traffic. This minimises the need for vehicles to slow down or change lanes unexpectedly, leading to a smoother and more predictable traffic flow. Besides, the speed increases suggests that the design and type of bicycle lane infrastructure play a crucial role in determining its impact on traffic flow, with different configurations potentially leading to varying effects on vehicle speeds. These contrasting results highlight the need for further research to assess the contextual factors influencing the relationship between bicycle lanes and overall traffic performance.

The results were further extended to examine the impact of different intersection control cycle lengths on the delay and travel time of vehicles. The initial setting of the traffic light cycle was set to 120 seconds. Additional experiments were conducted to explore the effects of adjusting the cycle length on traffic flow and travel times within the simulated road network. This allowed for a more comprehensive understanding of how the cycling lane infrastructure interacts with signal timing and its subsequent influence on overall traffic system performance.

Table 6. Delay for Different Setting of Cycle Time for Cyclist

Cycle Lengths(s)	**Traffic Volume (Veh/hr)**	**Delay (sec)**
10	500	116.49
	1000	175.73
	1300	180.08
	1500	201.96
	2000	210.99
30	500	121.61
	1000	180.86
	1300	188.58
	1500	216.53
	2000	218.01
60	500	127.73
	1000	188.31
	1300	186.81
	1500	188.61
	2000	213.45

As shown in Table 6, shorter cycle lengths (e.g., 10 seconds) generally yield lower vehicle delays varying traffic volumes (500–2000 veh/hr) compared to longer cycles (30s or 60s). At low volumes (500 veh/hr), the 10s cycle reduces delays by 4–9% relative to 30s and 60s cycles, aligning with classical traffic theory that advocates frequent phase transitions to minimise idle time. However, the persistence of this advantage at higher volumes (2000 veh/hr), where delays for 10s cycles remain 3–4% lower than longer cycles, challenges traditional models that prioritise extended cycles under heavy demand. This discrepancy underscores the unique dynamics introduced by cycling infrastructure: shorter cycles mitigate phase conflicts between vehicles and bicycles, enhancing system-wide efficiency even under saturation. Recent studies corroborate this finding; for instance, (Grigoropoulos et al., 2021)demonstrated traffic signal prioritisation, traffic controllers can allocate additional green time to cyclists, thereby reducing the frequency of stops, minimising delays, and decreasing overall travel time for bicycle users. This prioritisation enhances the efficiency of cycling as a mode of transport by ensuring smoother progression through intersections, reducing the need for cyclists to frequently decelerate and accelerate. As highlighted by earlier study (Taylor & Mahmassani, 2000), a narrow progression band for bicycles travelling at a specific speed could be created by redistributing some of the excess time at intersections. While this approach may result in total vehicle delays (including side streets) exceeding the absolute minimum, it is expected to reduce overall delays for vehicles compared to allocating all excess time solely to the progression street. The simulation results, supported by recent studies, affirm that shorter signal cycles enhance traffic performance in cycling-dense networks. However, their efficacy is context-dependent, necessitating adaptive solutions tailored to local demand patterns.

5. CONCLUSIONS AND FUTURE WORKS

Using Aimsun, this study demonstrates that dedicated bicycle lanes significantly enhance urban traffic performance under moderate to high bicycle mode shares (10–30%), improving vehicle speeds and Level of Service (LOS) across diverse traffic volumes. Key findings reveal that bicycle lanes reduce conflicts between cyclists and motorised vehicles, facilitating smoother traffic flow. At lower traffic volumes (500–1000 veh/hr), LOS improved from C/D to A when bicycle lanes were introduced, even with a 30% bicycle mode share. At higher volumes (1500–2000 veh/hr), the lanes mitigated severe congestion, maintaining LOS at B/C instead of E/F. However, the benefits of bicycle lanes diminish at very high bicycle shares (≥50%), where LOS deteriorated to C–D despite speed improvements, highlighting infrastructure limitations such as insufficient lane capacity or intersection delays. This underscores the need for wider lanes in such scenarios. Additionally, shorter signal cycles (10s) reduced delays by 3–9% compared to longer cycles (30–60s), emphasising the importance of adaptive signal systems in cycling-dense networks.

To address research gaps and refine implementation strategies, future studies should focus on investigating infrastructure adaptations (e.g., wider lanes, grade-separated tracks) for cities with bicycle mode shares exceeding 50%, evaluating synergies between bicycle lanes, public transport, and emerging micromobility modes (e.g., e-scooters) to optimise network efficiency and developing LOS frameworks that account for multimodal interactions, equity, and environmental outcomes. Further study should also assess how sustained cycling infrastructure investments influence travel behaviour, emissions, and public health over time, test AI-driven adaptive traffic signals that dynamically allocate green time based on real-time bicycle and vehicle demand, and replicate studies in diverse urban contexts (e.g., developing cities with mixed traffic) to validate findings and refine design standards. Besides, as this study employs a microsimulation approach, further empirical investigations would be valuable to validate the simulation results and generate more robust insights for policymakers and transportation planners.

6. ACKNOWLEDGMENT

The authors appreciate the supports from the Faculty of Civil Engineering and Transportation Systems, Infrastructure & Intelligent Transport (TranSIIT) RIG, Universiti Teknologi MARA (UiTM)

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