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Provision Impact Analysis of Motorcycle Exclusive Lanes on the Performance of Road Sections Using the Method MKJI 1997 and Vissim Software (Case Study of Margonda Road, Depok)

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ABSTRACT

Purpose: This study aims to determine the performance of the road before and after the provision of motorcycle lanes. It also aims to determine the lane effect on vehicle speed and alternative solutions.

Design/methodology/approach: In this study, MKJI 1997 and Vissim Software were used as the research methods.

Findings: The results of the existing road performance showing that the vehicle speed, DS, and level of service were 38.66 km/h, 0.84, and D, respectively. This indicated that the provision of motorcycle lanes was effective in improving road performance, due to the level of service for the LV and HV lanes increasing from D to B, with a speed increasing from 36.99 km/h to 40.25 km/h. The results showed that the level of service for the motorcycle lane increased from D to C and the vehicle speed was 49.92 km/h. While the level of service for LV and HV lanes being consistent with B and the vehicle speed was 40,04 km/h.

Research limitations/implications: The level of service for the motorcycle lanes decreased from D to F with the speed decreased from 46.13 km/h to 41.23 km/h, subsequently indicating that the alternative solution was to widen the motorcycle lane.

Practical implications: Margonda Road is one of the congestion points in Depok City. Margonda Road connecting Depok and Jakarta. The composition of motorcycles on Margonda Road reach more than 80% of the traffic flow. This conditions has an impact on decrease the road performance. In this study, the provision of motorcycle lanes will be carried out using the Vissim Software simulation, where the application of lanes is considered to be the solution to this problem.

Originality/value: This paper is original

Paper type: a Research Paper

Keyword: *Motorcycle Exclusive Lane, DS, Level of Service, Road Performance, Margonda Road*
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I. INTRODUCTION

Indonesia reportedly needs high transportation facilities for mobility, due to its rapid population growth. Consequently, a motorcycle is one of the modes of transportation widely used by most of the population within the country. In Indonesia, Depok is a buffer city rapidly growing in the business, economic, and property sectors, respectively, due to an increase in population. The population of this city is observed at 2.41 million, with the Beji sub-district having the second-highest density level (Badan Pusat Statistik Kota Depok, 2020). This leads to an increase in the volume of vehicles in Depok City, subsequently causing congestion problems. Subsequently, Margonda Road is found to be one of the congestion points within this city.

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Margonda Road is secondary artery road that connecting Depok and Jakarta (Isradi & Putri, 2021). Along this road, shopping, residential, commercial, and educational areas are observed. The composition of motorcycles on Margonda Road in 2018 found to be 72% of the total vehicles passing through the section (Dinas Perhubungan Kota Depok, 2018) .This indicates that the high composition of motorcycles in the traffic flow leads to a decrease in the level of road service, due to the movement of two wheels in mixed traffic. The movement of these flexible vehicles is found to also affect the smooth flow of traffic, regarding the utilization of the space traversed by changing lanes, which then leads to disturbances for other vehicle users.

Therefore, a solution is needed to improve road performance, by implementing a motorcycle lane on Margonda Road. The implementation of the motorcycle lane will be simulated using Vissim Software to get the value of the vehicle speed after the motorcycle lane. Meanwhile, road performance analysis uses the Indonesian Road Capacity Manual (MKJI) 1997.

The aims of this research was to determine the motorcycle volume effect on the existing performance of Margonda Road, to determine the motorcycle lanes effect on vehicle speed based on Vissim simulations, to determine the performance of Margonda Road after the motorcycle lanes application, and to provide alternative solutions in improving the performance of Margonda Road after the application of motorcycle lanes.

II. LITERATURE REVIEW

A. Motorcycle Exclusive Lanes

These are the special lanes used by motorcycle riders to facilitate traffic flow and reduce the occurrence of accidents. The classification of motorcycle lanes is divided into two types, namely inclusive and exclusive motorcycle lanes. Inclusive motorcycle lanes are motorcycle lanes which uses road markings/traffic signs as lane barriers. Exclusive motorcycle lanes are motorcycle lanes which uses separators/curbs as lane barriers (Le & Nurhidayati, 2016).

B. Road Performance

This is a quantitative measure describing traffic operational conditions, whose assessment based on the MKJI 1997 (Kementrian Pekerjaan Umum Dan Perumahan Rakyat Direktorat Jenderal Bina Marga, 1997) are as follows,

a. Free Flow Speed (FV)
   This is the speed of traffic at density = 0 (i.e., no passing vehicles), or the speed of vehicles that are not affected by other vehicles (Khisty & Lall, 2005). The general equation is shown as follows,
   $FV = (FV_o + FV_W) \times FFV_{SF} \times FFV_{CS}$
b. Capacity (C)
   Road capacity is the maximum volume that can be accommodated by a road segment and maintained per unit hour under specific conditions (Roess et al., 2011). The basic equation for determining this parameter is as follows,
   $C = C_O \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS}$
c. Degree of Saturation (DS)
   This is defined as the ratio of traffic flow to capacity. The degree of saturation states the level of density that occurs due to the movement of vehicles that pass the road (Isradi et al., 2020). The basic equation is observed as follows,
   $DS = Q/C$
d. Travel Speed
   This is the average speed (km/h) of traffic flow, determined by the mean space velocity of light vehicles (LV) along a road segment.
e. Level of Service
   Level of Service is a quantitative and qualitative measure describing traffic operational conditions (Peraturan Menteri Perhubungan Nomor PM 96 Tahun 2015, 2015). This is used to assess road performance, which is found to be an indicator of congestion. It is also classified from categories A to F, with secondary arterial roads having a minimum level of C (Manajemen Dan Rekayasa Lalu Lintas Di Jalan, 2006).

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C. Vissim Software

Vissim is a microscopic traffic simulation modelling software used to model urban transportation. This is useful for evaluating various types of transportation engineering, traffic management, and the most effective level of planning. It is also a program developed by PTV (Planung Transport Verkehr AG) in Karlsruhe, Germany, due to representing *Verkehr In Städten Simulations Model*, which indicates city traffic simulation modelling. (Fahmi et al., 2020).

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III. RESEARCH METHODOLOGY

The study method is show in Fig. 1.

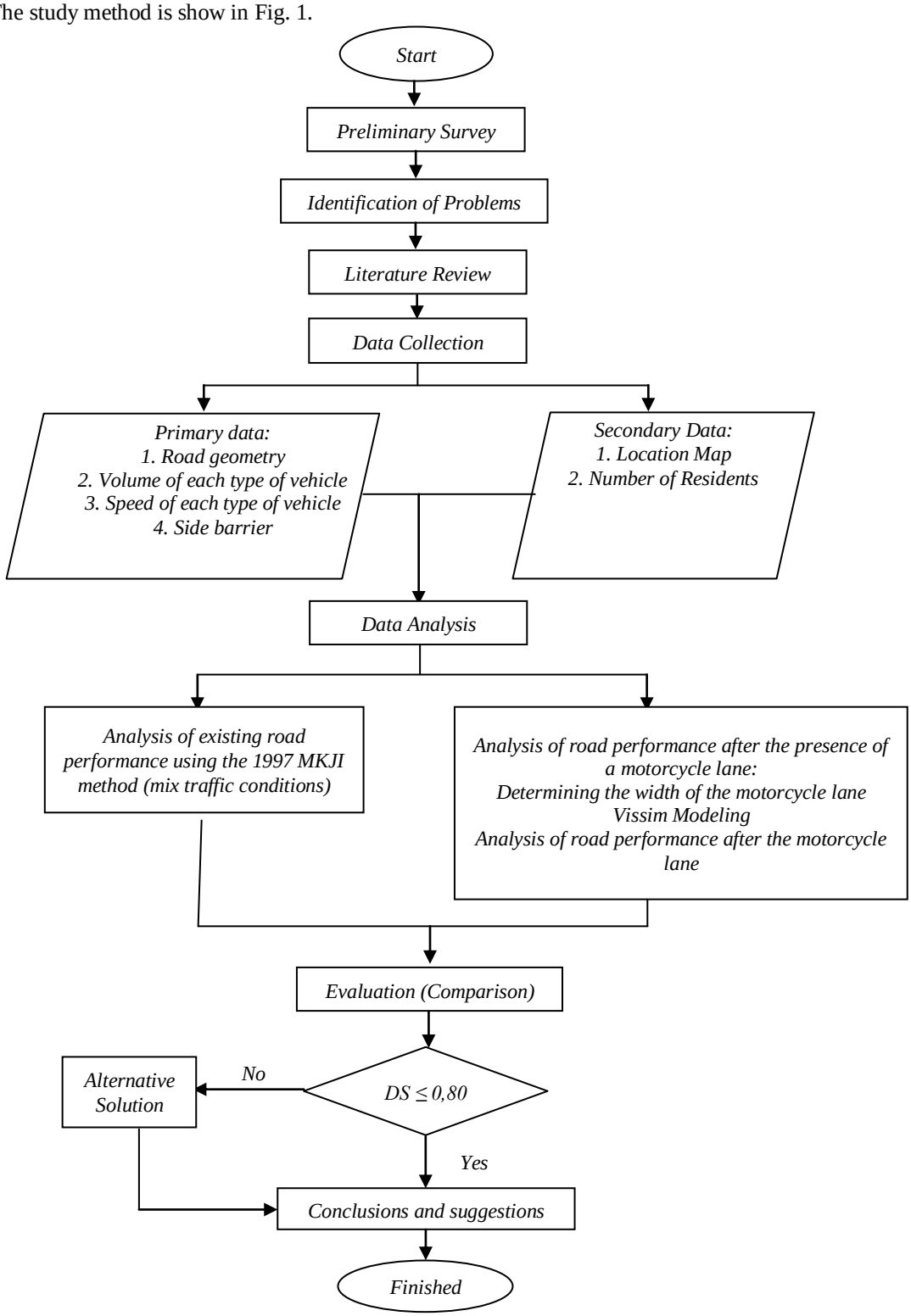

***Figure 1**. The Research Flowchart*

(Source: Author's Processing Results, 2022)

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The study location is Margonda Road, which is a secondary arterial connection in the direction of Jakarta and Depok Cities. The road segment being reviewed was also 200 meters long from the Margonda Residence to Domino's Pizza, due to the frequent occurrence of traffic jams during peak hours. Furthermore, the vehicles passing through Margonda Road were dominated by motorcycles, based on data obtained from the Depok City Transportation Service in 2018, which stated that the composition of motorcycles was observed at 72%.

The study period was carried out with the following details,

a. Tuesday and Friday = 06.30 – 08.30 AM
   04.00 – 06.00 PM
b. Monday = 07.00 – 09.00 AM
   03.45 – 05.45 PM

Based on this study, the calculation of road performance was also divided into motorcycle lane, as well as LV and HV lanes after the proposed motorcycle application. The characteristics observed as follows,

a. Motorcycle Lane = one-way road type
b. LV and HV lanes = road type 4-lane-2-way divided (4/2 D)

The arrangement of these lanes was subsequently divided into 2 conditions as follows,

a. Condition A, where the composition is grouped into motorcycle lanes, as well as LV and HV lanes.
b. Condition B, where the composition is divided into mixed lanes (motorcycles and 10% LV), as well as LV and HV lines.

IV. DATA COLLECTION

A. Primary Data

Primary data was directly obtained by conducting observations or surveys at the study location, subsequently indicating the following,

1. Road Geometric Data

   The geometric data of Margonda Road based on the field survey were,

   a. Road Type = 6-lane-2-way divided (6/2 D)
   b. Width Road:
      Jakarta Direction =12 meters
      Depok Direction = 7 meters and 5 meters (fast lanes and slow lanes)
   c. Sidewalk Width = 2.3 meters and 2 meters (towards Depok and Jakarta Direction)

   The section of Margonda Road is shown in Fig. 2.

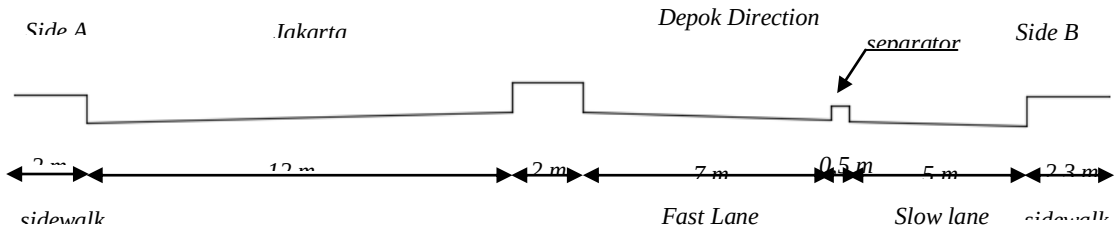

***Figure 2**. The Section of the Margonda Road*

(Source: Author Survey Results, 2022)

2. Volume data for each vehicle type

   Based on the MKJI 1997, the characteristics of the measured vehicles in this study are as follows,

   a. Light Vehicle (LV)
   b. Heavy vehicle (HV)
   c. Motorcycle (MC)

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Meanwhile, the classification of the utilized Vissim-based vehicles were motorcycles, cars, public transportation, pick-ups, 2 and 3 axle trucks, as well as small, medium, and large buses, respectively. The observation period for the vehicle volume was also carried out at a peak of 2 hours, using a video recorder.

3. Speed data for each vehicle type
   The measurement of the actual speed was carried out using a speed gun, with the data being classified according to the vehicle type. This was due to being used to input the desired speed distribution data for Vissim modelling.

4. Side barrier data
   This was obtained by recording the activities causing side obstacles within a 200 meters range at the study location. The side resistance events observed are as follows,
   a. Pedestrians.
   b. Vehicles stopping and parking.
   c. Vehicles entering and leaving the side of the road.
   d. Slow vehicle.

B. Secondary Data

The secondary data in this study were the population information and locations obtained from the Central Statistics Agency and Google Maps, respectively.

V. RESULTS AND ANALYSIS

A. Traffic Volume Analysis

Based on the volume survey, the highest traffic flow to Jakarta and Depok occurred on Tuesday, May 4, 2021, at 06.30-07.30 and 16.45-17.45, respectively, as shown in Table 1.

Table 1. The Highest Traffic Volume on Margonda Road

Vehicle Type	*Light Vehicle*		*Heavy Vehicle*		*Motorcycle*		*Total Traffic Flow Q*	
emp	*LV :*	*1,00*	*HV:*	*1,20*	*MC:*	*0,25*		
Direction	*vehicle/hour*	*smp/ hour*	*vehicle/ hour*	*smp/ hour*	*vehicle/ hour*	*smp/ hour*	*vehicle/hour*	*smp/hour*
Jakarta	*1,923*	*1,923*	*29*	*34.8*	*9,897*	*2,474.25*	*11,849*	*4,432.05*
Depok	*2,051*	*2,051*	*21*	*25.2*	*8,803*	*2,200.75*	*10,875*	*4,276,85*

Source: Processing By Author (2022)

B. Side Barrier analysis

Based on this analysis, the Jakarta and Depok directions of Margonda Road were included in the medium (M) and high (H) side resistance, respectively.

C. Road Performance Analysis Existing Condition

The road performance analysis of the existing lane conditions included the calculation of free-flow speed, road capacity, degree of saturation, actual speed, and level of service. This indicated that the values of the free flow speed in the Jakarta and Depok directions were 64.48 km/h and 62.92 km/h, respectively, as shown in Table 2.

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Table 2. Margonda Road Performance of Existing Condition

Direction	*Day*	*Volume (Q) smp/hour*	*Capacity (C) smp/hour*	*Actual Speed km/hour*	*Degree of Saturation (DS)*	*Service Level (LOS)*
Jakarta	*Tuesday*	*4,432.05*	*5,260.46*	*38.66*	*0.84*	*D*
Depok	*Tuesday*	*4,276.95*	*5,132.16*	*22.73*	*0.83*	*E*

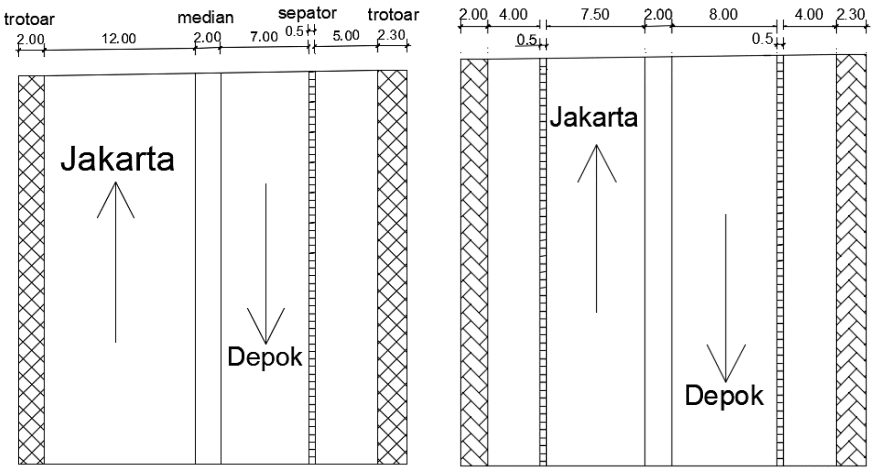
Source: Processing By Author (2022)

D. Analysis of the Impact of Motorcycle Volume on Road Performance

To determine the impact of motorcycle volume on road performance, the elimination of the motorcycles volume from the calculation was conducted. This implied that the DS values for the Jakarta and Depok directions were 0.84 to 0.37 and 0.83 to 0.40, respectively. Therefore, the impact of motorcycle volume was very large on road performance, due to reducing the degree of saturation value.

E. Determination of Motorcycle Lane Width

Based on this analysis, the width of the existing and proposed roads after the application of the motorcycles lane did not change in the study location. This signified that the width of the motorcycle lane was 4 meters for both the Jakarta and Depok directions on Margonda Road, as shown in Fig. 3.



(a) *(b)*

Figure 3. (a) Margonda Road Existing Condition (b) Margonda Road with Motorcycle Lane

(Source: Author's Processing Results, 2022)

F. Vehicle Speed Analysis of Vissim Simulation Results After the Provision of Motorcycle Lane

Based on the Vissim simulation, the comparison of vehicle speed in the existing road and after the provision of motorcycle lane (Condition A) is shown in Table 3.

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Table 3. The Comparison of Existing Vehicle Speeds with Vehicle Speeds After the Provision of Motorcycle Lane (Condition A)

Vehicle Type	Vehicle Speed (km/h)			
	Jakarta Direction		Depok Direction	
	Existing	After	Existing	After
Car	42.13	43.89	24.35	25.28
Public transportation	31.99	33.70	22.35	22.93
Pick Up	40.97	42.97	25.23	26.24
Small Bus	39.56	38.18	19.00	20.71
Medium Bus	39.32	41.86	23.50	22.02
Big Bus	34.50	36.58	21.50	22.46
2 Axle Truck	36.43	38.89	19.97	21.40
3 Axle Truck	31.00	33.47	28.00	28.54
Average Speed of MC	46.13	40.98	26.53	17.53
Average Speed of LV and HV	36.99	38.69	22.99	23.70

Source: Processing By Author (2022)

According to Table 3, the vehicle speed was observed to decrease and increase. The average speed values of the motorcycles was significantly decreased, and the average speed values of the LV and HV was increased. This showed that the provision of motorcycle lane increased vehicle speed in the LV and HV lanes.

The speed comparison in the existing road and after the provision of motorcyle lane mixed condition (Condition B) is shown in Table 4, through the Vissim simulation.

Table 4. The Comparison of Existing Vehicle Speeds with Vehicle Speeds After the Mixed Condition Motorcycle Lane (Condition B)

Vehicle Type	Vehicle Speed (km/h)			
	Jakarta Direction		Depok Direction	
	Existing	After	Existing	After
Motor (mixed lane)	46.13	41.23	26.53	17.18

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Car (mixed lane)	*42.13*	*39.56*	*24.35*	*17.48*
Car	*42.13*	*45.25*	*24.35*	*26.51*
Public transportation	*31.99*	*34.75*	*22.35*	*23.97*
Pick Up	*40.97*	*45.03*	*25.23*	*27.65*
Small Bus	*39.56*	*39.90*	*19.00*	*21.85*
Medium Bus	*39.32*	*42.96*	*23.50*	*23.31*
Big Bus	*34.50*	*37.42*	*21.50*	*23.55*
2 Axle Truck	*36.43*	*42.30*	*19.97*	*25.73*
3 Axle Truck	*31.00*	*34.39*	*28.00*	*29.95*
Average Speed of Mixed Condition MC Lane	*46.13*	*41.23*	*26.53*	*17.18*
Average Speed of LV and HV	*36.99*	*40.25*	*22.99*	*25.31*

Source: Processing By Author (2022)

According to Table 4, the vehicle speed was observed to decrease and increase. The average speed values of the motorcycles was significantly decreased, and the average speed values of the LV and HV was increased. This showed that the provision of motorcycle lane increased vehicle speed in the LV and HV lanes.

G. Road Performance Analysis After the Provision of Motorcycle Lane (Condition A)

The road performance analysis after the application of the motorcycle lane included the calculations of road capacity, degree of saturation, and level of service. This indicated that differences were observed in the road capacity for MC, LV, and HV lanes, respectively. The results of the motorcycle lane performance are shown in Table 5.

Table 5. The Motorcycle Lane Road Performance (Condition A)

Direction	*Day*	*Volume (Q) smp/hour*	*Capacity (C) smp/hour*	*Motor speed km/hour*	*Degree of Saturation (DS)*	*Level of Service (LOS)*
Jakarta	*Tuesday*	*2,474.25*	*1,675.08*	*40.98*	*1.48*	*F*
Depok	*Tuesday*	*2,200.75*	*1,568.60*	*17.53*	*1.40*	*F*

Source: Processing By Author (2022)

Based on this study, the level of service of the motorcycle lane was found in category F, due to the high volume of the vehicle. This denoted that the motorcycle lane capacity with a 4 meter width was insufficient for very high volumes. Additionally, the results of the LV and HV lanes performances are shown in Table 6.

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Table 6. The LV and HV Lane Road Performances (Condition A)

Direction	*Day*	*Volume (Q) smp/hour*	*Capacity (C) smp/hour*	*LV and HV speed km/hour*	*Degree of Saturation (DS)*	*Level of Service (LOS)*
Jakarta	*Tuesday*	*1,957.8*	*3,363.36*	*38.69*	*0.58*	*C*
Depok	*Tuesday*	*2,076.2*	*3,385.80*	*23.70*	*0.61*	*E*

Source: Processing By Author (2022)

H. Road Performance Analysis After the Mixed Condition of Motorcycle Lane (Condition B)

The road performance analysis after the motorcycle lane application included the calculations of road capacity, degree of saturation, and level of service. This showed that differences were observed in the road capacity of mixed-condition motorcycle lanes, as well as the LV and HV lanes. The results of the mixed-condition motorcycle lane performance are shown in Table 7.

Table 7. The Mixed Condition Motorcycle Lane Road Performance (Condition B)

Direction	*Day*	*Volume (Q) smp/hour*	*Capacity (C) smp/hour*	*Motorcycle Speed km/hour*	*Degree of Saturation (DS)*	*Level of Service (LOS)*
Jakarta	*Tuesday*	*2,666.55*	*1,675.08*	*40.40*	*1.59*	*F*
Depok	*Tuesday*	*2,405.85*	*1,568.160*	*17.33*	*1.53*	*F*

Source: Processing By Author (2022)

From this analysis, the service level of the mixed-condition motorcycle lane was categorized as F, due to the high volume of the blended vehicles. This revealed that the lane capacity was insufficient to accommodate the volume of the vehicle. Subsequently, the performance results for the LV and HV lanes are shown in Table 8.

Table 8. The LV and HV Lane Road Performance (Condition B)

Direction	*Day*	*Volume (Q) smp/hour*	*Capacity (C) smp/hour*	*LV and HV Speed km/hour*	*Degree of Saturation (DS)*	*Level of Service (LOS)*
Jakarta	*Tuesday*	*1,765.5*	*3,363.36*	*40.25*	*0.53*	*B*
Depok	*Tuesday*	*1,871.1*	*3,385.80*	*25.31*	*0.55*	*D*

Source: Processing By Author (2022)

I. The Road Performance Comparison of the Existing Road and Motorcycle Lane

The road performance comparison of the existing road and motorcycle lane (condition A) are shown in Table 9.

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Table 9. The Road Performance Comparison (Condition A)

Direction	Existing Condition			After the Provision of Motorcycle Lane					
	Mix Traffic			Motorcycle Lane			LV and HV Lanes		
	DS	Speed	LOS	DS	Speed	LOS	DS	Speed	LOS
Jakarta	0.84	38.66	D	1.48	40.98	F	0.58	38.69	C
Depok	0.83	22.73	E	1.40	17.53	F	0.61	23.70	E

Source: Processing By Author (2022)

According to Table 9, the level of service for the LV and HV lanes was becoming better, indicating that the Jakarta direction was increased from D to C, and the Depok direction was remaining the same with E. Meanwhile, the level of service for the motorcycle lanes for Jakarta and Depok became worse, decreasing from D to F. This indicated that the implementation of motorcycle lanes was sufficiently effective in improving road performance, based on the better level of service for LV and HV lanes.

The road performance comparison of the existing road and mixed condition motorcycle lane (Condition B) are shown in Table 10.

Table 10. The Road Performance Comparison (Condition B)

Direction	Existing Condition			After the Provision of Motorcycle Lane					
	Mix Traffic			Motorcycle Lane			LV and HV Lane		
	DS	Speed	LOS	DS	Speed	LOS	DS	Speed	LOS
Jakarta	0.84	38.66	D	1.59	40.40	F	0.53	40.25	B
Depok	0.83	22.73	E	1.53	17.33	F	0.55	25.31	D

Source: Processing By Author (2022)

From Table 10, the level of service for the LV and HV lanes was better than the existing condition, indicating the increase of categories from D to B for Jakarta directions and E to D for Depok directions. However, the level of service of the motorcycle lanes for Jakarta and Depok was worse than the existing condition, decreasing from D to F. This indicated that the application of motorcycle lanes was quite effective in improving road performance, according to the better level of service for the LV and HV lanes.

J. Alternative Solution for Motorcycle Lanes (Condition A)

The alternative solution applied to improve the performance of Margonda Road was based on road widening, to enlarge the motorcycle lane. The width of the Margonda Road towards Jakarta directions were 6.5 meters for motorcycle lanes and 6 meters for LV and HV lanes. Meanwhile, the width of Margonda Road towards Depok directions were 6 meters for motorcycle lanes and 6.5 meters for LV and HV lanes. From the Vissim simulation, the comparison of the vehicle speed in the existing conditions and with alternative solutions (Condition A) are shown in Table 11.

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Table 11. The Vehicle Speed Comparison (Condition A)

Vehicle Type	Vehicle Speed (km/h)			
	Direction to Jakarta		Direction to Depok	
	Existing	Alternative	Existing	Alternative
Car	42.13	42.45	24.35	25.06
Public Transportation	31.99	32.09	22.35	22.85
Pick Up	40.97	40.47	25.23	25.53
Small Bus	39.56	38.95	19.00	19.82
Medium Bus	39.32	39.48	23.50	21.93
Big Bus	34.50	34.72	21.50	20.73
2 Axles Truck	36.43	36.61	19.97	19.41
3 Axles Truk	31.00	30.48	28.00	26.94
Average Speed of MC	46.13	48.15	26.53	28.28
Average Speed of LV and HV	36.99	36.90	22.99	22.78

Source: Processing By Author (2022)

According to Table 11, the vehicle speed increased and decreased, indicating that the average speed of motorcycles had increased in the Jakarta and Depok directions, at 4.4% and 6.6%, respectively. Meanwhile, the average speed of the LV and HV lanes for Jakarta directions decreased at 0.22% and for Depok directions decreased at 0.89%. This indicated that the application of alternative solutions increased the vehicle speed in the motorcycle lanes and maintained the vehicle speed in the the LV and HV lanes.

The road performance comparison of the existing road and after implementation of alternative solutions (Condition A) are shown in Table 12.

Table 12. The Road Performance Comparison (Condition A)

Direction	Existing Condition			After Implementation of Alternative Solutions					
	Mix Traffic			Motorcycle Lanes			LV and HV Lanes		
	DS	Speed	LOS	DS	Speed	LOS	DS	Speed	LOS
Jakarta	0.84	38.66	D	0.80	48.15	C	0.66	36.90	C
Depok	0.83	22.73	E	0.76	28.28	D	0.69	22.78	E

Source: Processing By Author (2022)

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Based on Table 12, the level of service for the LV and HV lanes was better than the existing condition, indicating the increase of category from D to C in the Jakarta direction, and the Depok direction was remaining the same with E. Also, the level of service for the motorcycle lane was subsequently better, indicating the increase of categories from D to C for Jakarta directions and E to D for Depok directions. This indicated that the implementation of alternative solutions was effective in improving road performance, according to the better level of service for motorcycle lanes, and LV and HV lanes.

K. Alternative Solution for Mix Condition of Motorcycle Lanes (Condition B)

The alternative solution applied to improve the performance of Margonda Road was based on road widening, to enlarge the motorcycle lanes. The width of the Margonda Road towards Jakarta directions were 7 meters for motorcycle lanes and 6 meters for LV and HV lanes. Meanwhile, the width of Margonda Road towards Depok directions were 6.5 meters for motorcycle lanes and 6.5 meters for LV and HV lanes. From the Vissim simulation, the comparison of the vehicle speed in the existing conditions and with alternative solutions (Condition B) are shown in Table 13.

Table 13. The Vehicle Speed Comparison (Condition B)

Vehicle Type	*Vehicle Speed (km/h)*			
	Direction to Jakarta		*Direction to Depok*	
	Existing	*Alternative*	*Existing*	*Alternative*
Motorcycle (mix lane)	*46.13*	*49.92*	*26.53*	*30.25*
Car (mix lane)	*42.13*	*42.39*	*24.35*	*25.04*
Car	*42.13*	*44.90*	*24.35*	*26.30*
Public Transportation	*31.99*	*34.46*	*22.35*	*23.79*
Pick Up	*40.97*	*44.91*	*25.23*	*27.49*
Small Bus	*39.56*	*39.72*	*19.00*	*21.66*
Medium Bus	*39.32*	*42.79*	*23.50*	*23.16*
Big Bus	*34.50*	*37.29*	*21.50*	*24.12*
2 Axles Truck	*36.43*	*42.10*	*19.97*	*25.52*
3 Axles Truck	*31.00*	*34.18*	*28.00*	*28.14*
Average Speed of Mixed Condition MC Lane	*46.13*	*49.92*	*26.53*	*30.25*
Average Speed of LV and HV	*36.99*	*40.04*	*22.99*	*25.02*

Source: Processing By Author (2022)

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According to Table 13, the vehicle speed of motorcycle, LV and HV had increased, indicating that the average speed of motorcycles had increased in the Jakarta and Depok directions, at 8.2% and 14%, respectively. Meanwhile, the average speed of the LV and HV lanes for Jakarta directions increased at 8.26% and for Depok directions increased at 8.84%. This indicated that the application of alternative solutions increased the vehicle speed in the motorcycle lanes and LV and HV lanes.

The road performance comparison of the existing road and after implementation of alternative solutions (Condition B) are shown in Table 14.

Table 14. The Road Performance Comparison (Condition B)

Direction	*Existing Condition*			*After Implementation of Alternative Solutions*					
	Mix Traffic			*Motorcycle Lanes*			*LV and HV Lanes*		
	DS	*Speed*	*LOS*	*DS*	*Speed*	*LOS*	*DS*	*Speed*	*LOS*
Jakarta	*0.84*	*38.66*	*D*	*0.82*	*46.15*	*C*	*0.59*	*40.04*	*B*
Depok	*0.83*	*22.73*	*E*	*0.80*	*27.65*	*D*	*0.62*	*25.02*	*D*

Source: Processing By Author (2022)

Based on Table 14, the level of service for the LV and HV lanes was better than the existing condition, indicating the increase of category from D to C for Jakarta direction, and from E to D for Depok direction. It also showed that the level of service of the motorcycle lanes was better, indicating the increase of categories from D to C for Jakarta directions and E to D for Depok directions. Therefore, the application of alternative solutions was effective in improving road performance, according to the better level of service for motorcycle lanes, LV and HV lanes.

CONCLUSION

Based on this study, the following conclusions were observed:

1. The impact of motorcycle volume on road performance are:
   a. Road performance of the existing condition for Jakarta direction, produced vehicle speeds 38.66 km/h, degree of saturation 0.84, and level of service D.
   b. Road performance of the existing condition for Depok direction, produced vehicle speeds 22.73 km/h, degree of saturation 0.83, and level of service E.
   c. When motorcycles volume were eliminated, a decrease was then observed in the degree of saturation values of the Jakarta directions from 0.84 to 0.37 and Depok directions from 0.83 to 0.40.
2. Based on Vissim simulation, the effect of motorcycle lanes on vehicle speed are as follows,
   a. In the motorcycle lane, a speed decrease was observed at 26.53-17.53 km/h (33% decrease) and 46.13-40.98 km/h (11% decrease) in the Depok and Jakarta directions, respectively.
   b. In the LV and HV lanes, there was a speed increase from 22.99-23.70 km/h (up 3%) and 36.99-38.69 km/h (up 5 %) in the Depok and Jakarta directions, respectively.
   c. For the mixed-condition motorcycle lane, a speed decrease was also observed from 26.53-17.18 km/h (down 35%) and 46.13-41.23 km/h (down 11%) in the Depok and Jakarta directions, respectively.
   d. From the mixed-condition LV and HV lanes, there was an increase in speed from 22.99-25.31 km/h (up 10%) and 36.99-40.25 km/h (up 9%) in the Depok and Jakarta directions, respectively.
   e. This indicated that the presence of lane separation increased the speed of LV and HV vehicles.
3. The performance comparison of the existing road and after the provision of a motorcycle lane is described as follows,
   a. The performance of motorcycle lanes was found to be worse, where the biggest DS increase was 0.84 to 1.48 at the Jakarta direction, with the LOS decreasing from D to F.

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b. In this analysis, better performance of the LV and HV lanes was observed, where the biggest DS decrease was 0.84 to 0.58 at the Jakarta direction, with the LOS increasing from D to C.
c. Worse performance was also observed for the mixed-condition motorcycle lane, where the biggest DS increase was 0.84 to 1.59 at the Jakarta direction, with the LOS decreasing from D to F.
d. For the mixed-condition LV and HV lanes, better performance was observed, where the biggest DS decrease was 0.84 to 0.53 at the Jakarta direction, with the LOS significantly increasing from D to B.

4. Based on the application of the alternative solution (road widening), the following results were obtained,
   a. Better performance was observed in the motorcycle lanes, where the biggest DS decrease was 0.83-0.76 at the Depok direction, with the LOS increasing from E to D.
   b. The performance of the LV and HV lanes was also found to be better, where the biggest DS decrease was 0.84-0.66 at the Jakarta direction, with the LOS increasing from D to C.
   c. In the mixed-condition motorcycle lane, better performance was observed, where the biggest DS decrease was 0.83-0.80 at the Depok direction, with LOS increasing from E to D.
   d. In the mixed-condition LV and HV lanes, better performances were also observed, where the biggest DS decrease was 0.84-0.59 at the Jakarta direction, with LOS significantly increasing from D to B.

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