Level of service for roads with motorcycle lane or without motorcycle lane in Denpasar

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Abstract. Denpasar is the capital of Bali and the main gateway to the island. The increasing number of vehicles in Denpasar City reach 7% annually. The negative impact of the high number of motorcycles is decrease of road performance, especially causing low travel speed and high potential of traffic conflict. To minimize that problem, motorcycle lane was applied to make homogeneity movement of motorcycles in the city of Denpasar. The methods by analysed of road performance on the motorcycle lanes by using MKJI 1997 (Indonesia Road Capacity Manual). The analysis shows that the application of motorcycle lane has an influence to improvement road traffic. That is indicated by the VCR value for road with motorcycle lane facilities are 0.42 and 0.54. Meanwhile without motorcycle lane is 0.34 and 0.43. The level of service on Puputan Rd, Cok Agung Tresna Rd and Sudirman Rd (north direction) is “B”. Its mean traffic flow is stable, but travel speed began to be limited by traffic conditions. Meanwhile on Sudirman Rd (south direction), the level is service mostly is C. Its mean Traffic flow is stable, but the travel speed and vehicle movement is controlled

1. Background

Easy and fast transportation at the present time is a major public needs. Motorcycles is a popular modes of transportation due to affordable price and faster in travel time that private car or public transportation. The needs of motorcycles increased because of high level of congestion in the major cities and lack of punctuality service of public transportation in Indonesia. Thus, motorcycle becomes one of the proper transportation choices at the present time.

Demand of motorcycles are still continues and increase from year to year. This is because motorcycles are favorite modes of transportation that most people choose, especially in the major cities that have high levels of congestion. The use of motorcycles as is very helpful to increase people mobility within the city. By using the motorcycle will become more practical in terms of travel time saving because motorcycles mostly could avoid traffic jams. In additions, motorcycles has more economic value because it is more efficient that using a private car or public transportation. It’s cheep in operational cost because petrol price was subsidized by government.

Denpasar is the capital city of Bali and the main gateway to the island. The city is also a hub for other cities in the Lesser Sunda Island. With the rapid growth of the tourism industry in Bali, Denpasar has encouraged and promoted business activities and ventures, contributing to it having the highest growth rate in Bali Province. The population of Denpasar was 897,300 in 2017. It’s increased from 788,445 at the 2010 Census. The surrounding metropolitan area has roughly 2 million residents. There were rapid increase of the number of population and increase of traffic density. Trend of increasing traffic density on the roads especially in school zone, offices center and major tourist areas. The number of motorcycles in Denpasar increase up to 7 percent per year. The number of motorcycles in 2013 as much as 1,654,313 [1], then in year 2014 is expected to increase up to 112,000 motorcycles. The population of motorcycles is shown in Figure 1.
Increased ownership of motorcycles leads to decreased road capacity and increased travel time and increased number of accidents. One solution to reduce traffic conflicts and traffic accidents is to separate motorcycle with other types of vehicles. Law number 22 year 2009 which states that the motorcycle operates on the left lane of the road to provide a safe and comfort for motorcycle when driving on the road. Therefore, to force motorcycle to be on the left lane, it’s needed a motorcycle lane.

2. Motorcycle Lane

Motorcycle lane is divided into two types namely inclusive motorcycle lane and exclusive motorcycle lane. Inclusive motorcycle lanes are installed on the existing road and are usually located on the inside of the main carriageway for each direction of traffic flow. Motorcycle lanes may be separated from the rest of the road by painted road marking lines. At the inclusive motorcycle lanes, sometimes motorcycles and other types of vehicles could rejoin on the main carriageway due to lack of discipline and crashes can occur. Meanwhile exclusive motorcycle lanes require a carriageway completely separate from that used by other vehicles. Separate motorcycles physically from other types of vehicles by using a curb separator, so that other types of vehicle does not mix with motorcycles. Exclusive motorcycle lanes minimise crashes on the road between motorcycles and other types of vehicles [4].

Motorcycle lanes are required if the number of motorcycles is greater than 600 motorcycles/hour/lane. This number is obtained from determining the headway times between motorcycles when driving on urban roads is at least 6 seconds. If converted into hours, then get 600 motorcycles/hour/lane. Aim to provide motorcycles lanes is to reduce accidents. If the amount of accidents is greater than 40 accidents/km/year or the accident rate is greater than 100, then motorcycle lane is needed to reduce motorcycle accidents [5].

The placement of motorcycles lanes must meets with same criteria, ie motorcycles lanes are priority lane than other vehicles lane on the road, motorcycles lanes in urban arterial roads or suburban arteries which have urbanized travel characteristics. Motorcycles lanes in the urban arterial road are on the left side and should be separated from the lane of four-wheeled vehicles by using road marking or curb separator [5].

Figure 1. Motorcycle Population in Denpasar
3. Methods

3.1. Methods of Collecting Data
Traffic volume and travel speed data collection was conducted in mid July 2016 in four places, there were Puputan Niti Mandala Renon Road (Road with motorcycle lane), Cok Agung Tresna Road (road without motorcycle lane) and Sudirman Road way to south (road with motorcycle lane) and Sudirman Road way to the north (road without motorcycle lane) in Denpasar City. Data were collected during morning, noon and afternoon sessions. Each sessions was taking for two hours of data with intervals of five minutes. The data was taken by the surveyor by using traffic counter equipment to collect traffic volume data and speed gun equipment to collect travel speed data. Motorcycles lanes on Puputan road and Sudirman road which have width 2.5 meter were divided into 2 lanes in one direction. In addition, there are 2 lanes for other types of vehicles with a width of 3.5 meters. The data collection surveys is shown in Figure 4 also the roads survey condition is shown in Table 1.
**Table 1. Roads Survey Condition**

| Location                  | Criteria                  | Number of Lanes | Roads Classification [6] | Road Width | Remarks       |
|---------------------------|---------------------------|-----------------|--------------------------|------------|---------------|
| Puputan Niti Renon Road   | With Motorcycle Lane      | 3 lanes         | Arterial Secondary       | 9 meter    | Location 1    |
| Cok Agung Tresna Road     | Without Motorcycle Lane   | 3 lanes         | Arterial Secondary       | 9 meter    |               |
| Sudirman Road (way to the south) | With Motorcycle Lane     | 2 lanes         | Local Primary            | 8 meter    | Location 2    |
| Sudirman Road (way to the north) | Without Motorcycle Lane | 2 lanes         | Local Primary            | 8 meter    |               |

3.2. Methods of Data Analysis

3.2.1. Traffic Capacity

Capacity is the ability of a road to accommodate traffic volume. It is the maximum hourly rate at which vehicles can reasonably be expected to cross a point on a roadway during a given time period under prevailing traffic roadway and control condition. For undivided roads, the analysis is carried out in both directions of traffic. Meanwhile for divided roads, the analyzes are measured separately in each direction of traffic. Capacity calculation methods is using the MKJI 1997 (Indonesia Road Capacity Manual). MKJI 1997 was obtained by multiplying the value of basic capacity with geometric and the road environmental factors on the road [2]. The equation to calculate capacity is shown below.

\[
C = C_0 \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS}
\]  

whereas:
- \(C\) = Capacity (pce/hour)
- \(C_0\) = Basic capacity (pce/hour)
- \(FC_W\) = Factor of width adjustment
- \(FC_{SP}\) = Factor of separator adjustment
- \(FC_{SF}\) = Factor of side obstacles and roadside adjustment
- \(FC_{CS}\) = Factor of city size adjustment
3.2.2. Degree of Saturation.
Degree of saturation is a measure of how much demand it is experiencing compared to its total capacity. The degree of saturation (%) is a ratio of demand to capacity on each approach to the junction, with a value of 100% meaning that demand and capacity are equal and no further traffic is able to progress through the junction or road. Degree of saturation can be determined by using traffic flow and capacity which is stated in pce/hour [6]. Degree of saturation shows whether the road already has traffic capacity problems not. Degree of saturation is theoretically no more than 1 value which means if the value to close to 1 then the traffic condition is close to saturation, and visually it can be seen that traffic speeds on the road at the low speed [3]. Equation to calculate degree of saturation as shown below.

\[
DS = \frac{Q}{C}
\]  

whereas:

\[DS = \text{Degree of saturation}\]
\[Q = \text{Traffic Flow (pce/h)}\]
\[C = \text{Capacity (pce/h)}\]

3.2.3. Level of Service
Level of service states the level of traffic quality and the actual traffic going on. Level of service is rated by the driver or passenger based on the feeling of easily, secure and comfort of driving. The assessment of level of service is based on freedom of choice of operational travel speed and freedom of movement or maneuver. This service level is divided into six categories such as from “A” for the best condition up to “F” for the worst condition [2]. The scope of the V/C ratio for each level of service along the characteristic is shown in Table 2.

| Table 2. Service level based on V/C Ratio value (MKJI, 1997) |
|---------------------|-----------------|------------------|
| Level of Services   | Criteria                     | V/C Ratio value   |
| A                   | Free traffic flow conditions with high travel speed and low traffic volume | 0.00 – 0.20       |
| B                   | Traffic flow is stable, but the travel speed began to be limited by traffic conditions | 0.20 – 0.44       |
| C                   | Traffic flow is stable, but the travel speed and vehicle movement is controlled | 0.45 – 0.74       |
| D                   | Traffic flow is close to stable but the travel speed can still be controlled, V/C ratio is still tolerable | 0.75 – 0.84       |
| E                   | Traffic flow is unstable, sometimes flow stops and traffic demand is approaching capacity | 0.85 – 1.00       |
| F                   | Traffic Flow is forced. There is low speed, traffic volume above capacity and long queue (traffic jam) | ≥ 1.00            |

4. Data Processing
In this research data processing was done by converting traffic volume data. Convert vehicle/hour to passenger car equivalents (pce/hour). Then the data was divided per lane. Based on the result of data processing, it’s shown that traffic flow at the roads with motorcycle lane facility are higher than roads without motorcycle lane. At the location of Raya Puputan Rd (with motorcycle lane) the traffic volume in the morning and afternoon session sessions is 7822 pce/hour/lane and 560 pce/hour/lane higher than Cok Agung Tresna Rd (without motorcycle lane) by 536 pce/hour/lane and 457 pce/hour/lane respectively. In the afternoon the traffic volume on Cok Agung Tresna Rd (without motorcycle lane) is
636 pce/hour/lane higher than the traffic volume in Raya Pupuptan Rd (Figure 5) which is 586 pce/hour/lane.

In location 2 on Sudirman Rd (south) and Sudirman Rd (north), the traffic flow on the roads with motorcycle lane is higher than on the roads without motorcycle lane at all sessions. The traffic flow on the road with the motorcycle lane facilities is approximately 25% larger than the road without the motorcycle lane facilities as shown in Figure 6. The largest traffic flow on the road with the motorcycle lane facilities in the morning session by 1109 pce/hour/lane. Meanwhile the largest traffic volume on the road without motorcycle lane is 885 pce/hour/lane.

Data processing of travel speed at location 1 (Raya Puputan Rd and Cok Agung Kresna Rd) in Figure 7, Puputan Rd (with motorcycle lane) has highest travel speed with an average by 55.67 km/hour. Meanwhile on Cok Agung Kresna Rd (without motorcycle) the average travel speed is 44.67 km/hour.
In addition, data processing of travel speed at location 2 in Figure 8, Sudirman Rd (south direction) with motorcycle lane has the highest travel speed with an average 49 km/hour. Meanwhile on Cok Agung Kresna Rd (without motorcycle) the average travel speed is 40 km/hour.

**Figure 7.** Travel Speed on Location 1

**Figure 8.** Travel speed on location 2

5. **Analysis**
The calculation of the road capacity measure by using the Manual of Indonesia Road Capacity Manual (1997) is shown in Table 3. Capacity in location 1 is 4374 pce/hour while for location 2 is 3082 pcu/hour.
### Table 3. Road Capacity

| Observation Location | Location                        | Co  | FCw | FCsp | FCsf | FCcs | C (pcu/hour) |
|----------------------|---------------------------------|-----|-----|------|------|------|-------------|
| Location 1           | Puputan Rd ; motorcycle lane    | 4950| 1   | 1    | 0.94 | 0.94 | 4374        |
|                      | Cok Agung Tresna Rd ; without   | 4950| 1   | 1    | 0.94 | 0.94 | 4374        |
|                      | motorcycle lane                 |     |     |      |      |      |             |
| Location 2           | Sudirman Rd (South Direction) ; | 3300| 1.08| 1    | 0.92 | 0.94 | 3082        |
|                      | motorcycle lane                 |     |     |      |      |      |             |
|                      | Sudirman Rd (North Direction) ; | 3300| 1.08| 1    | 0.92 | 0.94 | 3082        |
|                      | without motorcycle lane         |     |     |      |      |      |             |

Based on Table 4. It can be seen that the level of service on Jalan Puputan Rd, Cok Agung Tresna Rd and Sudirman Rd (north direction) is “B”. Its mean traffic flow is stable, but travel speed began to be limited by traffic conditions. Meanwhile on Sudirman Rd (south direction), the level is service mostly is C while some others got B. It’s mean traffic flow is stable, but the travel speed and vehicle movement is controlled.

### Table 4. Level of Service

| Location                        | Time    | V (pcu/hour) | C  | VC | Level of Services |
|---------------------------------|---------|--------------|----|----|-------------------|
| Puputan Rd ; motorcycle lane    | 07.00- 08.00 | 1858        | 437 | 4  | 0.42 B            |
|                                 | 08.00- 09.00 | 1473        | 437 | 4  | 0.34 B            |
|                                 | 11.00- 12.00 | 1248        | 437 | 4  | 0.29 B            |
|                                 | 12.00- 13.00 | 1393        | 437 | 4  | 0.32 B            |
|                                 | 15.00- 16.00 | 1239        | 437 | 4  | 0.28 B            |
|                                 | 16.00- 17.00 | 1378        | 437 | 4  | 0.32 B            |
| Cok Agung Tresna Rd ; without   | 07.00- 08.00 | 1508        | 437 | 4  | 0.34 B            |
| motorcycle lane                 | 08.00- 09.00 | 1344        | 437 | 4  | 0.31 B            |


At location 1 on Puputan Rd and Cok Agung Tresna Rd, the analysis result shows that VCR value on road with motorcycle lane is higher than on the road without motorcycle lane. Average value of VCR on Puputan road (with motorcycle lane) is 0.32 while on Cok Agung Tresna Rd (without Motorcycle lane) is 0.29. Both of these roads have service level B. The traffic flow is stable, but travel speed began to be limited by traffic conditions. Although the average value of VCR is on road with motorcycle lane is higher than on the road without motorcycle lane, the travel speed is higher by 56 km/h, compared with road without motorcycle lane is 44 km/h. The highest VCR on Puputan Rd during morning session is 0.42

At location 2 on Sudirman Rd (south direction) and Sudirman road (north direction), analysis result obtained that value of VCR on road with motorcycle lane is higher than on the road without motorcycle lane. The average VCR value on Sudirman Rd with motorcycle lane is 0.45 while on Sudirman Rd without motorcycle lane is 0.35. Sudirman Rd (south direction) mostly has a level of service C. So traffic flow is stable, but the travel speed and vehicle movement is controlled. In addition Sudirman road (north direction) has service level B, So The traffic flow is stable, but travel speed began to be limited by traffic conditions. Same with location 1, in location 2 the average travel speed of road with motorcycle lane is higher than road without motorcycle lane by 49 km/h and 40 km/h respectively. Resume of VCR and travel Speed are shown in Table 5. The highest VCR on Sudirman Rd during morning session is 0.54
### Table 6. Resume of VCR Value and Travel Speed

| Observation Location | Location          | Criteria                  | VCR | Travel Speed (km/hour) |
|----------------------|-------------------|---------------------------|-----|------------------------|
| Location 1           | Puputan Rd        | With Motorcycle Lane      | 0.42| 56                     |
|                      | Cok Agung Tresna Rd | Without Motorcycle Lane  | 0.34| 44                     |
| Location 2           | Sudirman Rd (South direction) | With Motorcycle Lane | 0.54| 49                     |
|                      | Sudirman Rd (North direction) | Without Motorcycle Lane | 0.43| 40                     |

### 6. Conclusion

The conclusion that can be taken on this research is as follows:

1. Traffic flow on Puputan Rd with motorcycle lane is higher than on Cok Agung Tresna Rd without motorcycle lane by average 639 pce/hour compared to 543 pce/hour. Meanwhile on Sudirman Rd (South direction) with motorcycle lane is higher than Sudirman Rd (north direction) without motorcycle lane by 1022 pce/hour compared to 767 pce/hour.

2. Travel speed Puputan Rd with motorcycle lane has highest travel speed with an average by 55.67 km/hour. Meanwhile on Cok Agung Kresna Rd without motorcycle is 44.67 km/hour. In addition, on Sudirman Rd (south direction) with motorcycle lane has the highest travel speed with an average 49 km/hour while Cok Agung Kresna Rd (without motorcycle) is 40 km/hour.

3. Level of service on Jalan Puputan Rd, Cok Agung Tresna Rd and Sudirman Rd (north direction) is “B”. Its mean traffic flow is stable, but travel speed began to be limited by traffic conditions. Meanwhile on Sudirman Rd (south direction), the level is service mostly is C while some others got B. It’s mean.

4. Traffic flow is stable, but the travel speed and vehicle movement is controlled.

### References

[1] Board of Bali Statistics Center 2014 *Number of Vehicle in Denpasar City.*

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