The Analysis of Service Level on Diponegoro Road, Pasar Aceh: Comparing The Existing Condition and with on-Street Parking Restriction

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Abstract. Traffic congestion is a major problem in cities, especially on the main roads in the Central Business District (CBD) area, as occurred on Diponegoro Road in Banda Aceh, Indonesia. This problem has economic, social, and environmental impacts, such as fuel wastage, longer travel times, and air pollution from vehicle exhaust gases. Factors causing traffic congestion include side friction, such as road crossings (Pedestrian/PED), parking and stop vehicles (PSV), entry and exit vehicles (EEV), and slow-moving vehicles (SMV). Diponegoro Road is a three-lane one-way road (3/1 TT). However, only one lane is effective during peak hours, while the other is used for vehicle parking. Therefore, this study aims to analyze the service level of Diponegoro Road under existing conditions and with the implementation of on-street parking restrictions. The road performance was calculated using the Indonesian Road Capacity Guidelines (PKJI) 2023 method. The data needed are traffic volume, road geometrics, side friction, and population. The study results show that the road's service level on weekdays (Monday and Thursday) is on level C, indicating that traffic conditions limit the speed and movement of vehicles, and the drivers are restricted in choosing the desired speed. On Sunday mornings, the road level of service is on level B, while in the afternoon, it becomes level D. This difference in service level occurs because there is no activity to access schools or workplaces on Sunday mornings. On Sunday afternoons, most citizens go shopping or sightseeing, causing volume and roadside friction to increase and road performance to drop. The level of road service with the implementation of on-street parking restrictions shows a good level (A and B), with an indication of stable traffic flow, and drivers are free to choose their driving speed. Thus, this research recommends maximizing off-street parking to limit on-street parking.

1 Introduction

The number of vehicles increasing in an area is generally due to population and economic growth. It is followed by people's need to make movements to fulfil their life needs. Without proper traffic infrastructure management, vehicle growth will reduce road service levels and lead to congestion. Traffic congestion is a serious problem in the transportation system in developing cities, which has a negative impact on the comfort of urban life. Ensuring a continuous and collision-free flow of vehicle traffic requires proper management of control infrastructure and parking lots, which are often located in the...
immediate vicinity of highways [1]. Dipenogoro Road is located in the CBD (Central Business District) area of Pasar Aceh, which attracts many people and vehicle trips to and from the area, causing this road to be frequently congested. Diponegoro Road is a three-lane one-way road (3/1 TT). However, only one lane is effective during peak hours, while the other is used for parking vehicles, exacerbating the congestion. This road is an alternative mobility space for students, workers, and the public, especially from Kuta Raja and Baiturrahman sub-districts to various government centres, education, tourist destinations, and other functions. Therefore, a study is needed to evaluate the performance of Diponegoro Road, and the results become a reference that will improve the road's performance. Road performance is a quantitative value that describes the operational conditions of a traffic infrastructure[2]. This study aims to analyze the service level of Diponegoro Road, Pasar Aceh, Banda Aceh, on the existing conditions and with on-street parking restrictions. A method based on the Indonesian Road Capacity Guidelines 2023 [3] was used to calculate the analysis of the road section. The performance of the road section is assessed based on the degree of saturation value related to road geometric conditions, vehicle volume, and side friction factors that occur. Side friction is a factor influenced by activities that often occur on the side of the road [4]. Side friction can reduce road capacity and performance and affect vehicle speed [5]. The research results are expected to be evaluation material for related agencies in policy decision-making.

2 Research Methodology

2.1 Data Collection

Field data needed to analyze this research was obtained by collecting information on traffic volume and site friction types on Diponegoro Road. Data collection was conducted for three days, on weekdays (Monday and Thursday) and holidays (Sunday). The days' selection was based on the consideration that these days can represent working days and holidays. Field observations were conducted during the morning, afternoon, and evening peak hours at 07:30-09:30, 11:30-13:30, and 16:30-18:30 WIB (Western Indonesian Time).

a. Road Geometric Data

Road geometric data was obtained by measuring road, lane, and shoulder widths using tape. This data is needed to obtain the road capacity correction factor, as shown in Table 1.

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Effective Road Width (m)</th>
<th>FC_w</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/2-T, 6/2-T, 8/2-T atau Jalan satu-arah</td>
<td>L_{LE} = 3,00</td>
<td>0,92</td>
</tr>
<tr>
<td></td>
<td>3,25</td>
<td>0,96</td>
</tr>
<tr>
<td></td>
<td>3,50</td>
<td>1,00</td>
</tr>
<tr>
<td></td>
<td>3,75</td>
<td>1,04</td>
</tr>
<tr>
<td></td>
<td>4,00</td>
<td>1,08</td>
</tr>
<tr>
<td>2/2-TT</td>
<td>L_{LE2 arah} = 5,00</td>
<td>0,56</td>
</tr>
<tr>
<td></td>
<td>6,00</td>
<td>0,87</td>
</tr>
<tr>
<td></td>
<td>7,00</td>
<td>1,00</td>
</tr>
<tr>
<td></td>
<td>8,00</td>
<td>1,14</td>
</tr>
<tr>
<td></td>
<td>9,00</td>
<td>1,25</td>
</tr>
<tr>
<td></td>
<td>10,00</td>
<td>1,29</td>
</tr>
<tr>
<td></td>
<td>11,00</td>
<td>1,34</td>
</tr>
</tbody>
</table>
b. Traffic Volume Data
Traffic volume data, or the number of vehicles passing through the observation point, was collected using a Handycam. Calculations were made by counting and noting all motorized vehicles passing through the road for six hours of observation (morning, afternoon and evening) based on vehicle classifications: light vehicles, heavy vehicles and motorcycles.

c. Side Friction Data
Side friction data was obtained by calculating the various activities that occurred around the road at the research location consisting of road crossings (Pedestrian/PED), parking and stop vehicles (PSV), entry and exit vehicles (EEV), and slow-moving vehicles (SMV). Data was recorded on survey forms every 15 minutes in the morning, afternoon, and evening sessions for two hours each.

d. Total population
The total city population of the research location was obtained from the Central Bureau of Statistics (BPS), Banda Aceh City. This data is required to calculate the road capacity correction factor, as shown in Table 2.

Table 2. The Capacity correction factor due to city size

<table>
<thead>
<tr>
<th>City Size (Million people)</th>
<th>City class/city category</th>
<th>City size correction factor (FCCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0,1</td>
<td>Very Small</td>
<td>0,86</td>
</tr>
<tr>
<td>0,1-0,5</td>
<td>Small</td>
<td>0,90</td>
</tr>
<tr>
<td>0,5-1,0</td>
<td>Medium</td>
<td>0,94</td>
</tr>
<tr>
<td>1,0-3,0</td>
<td>Large</td>
<td>1,00</td>
</tr>
<tr>
<td>&gt;3,0</td>
<td>Very large</td>
<td>1,04</td>
</tr>
</tbody>
</table>

Data Analysis

a. Traffic Volume
The volume of vehicles passing the observation point was summed up by vehicle type (light vehicles, heavy vehicles, motorcycles) in one-hour intervals. The volume was then converted into passenger car units (PCU) by multiplying the volume of each vehicle type by a conversion factor, the passenger car equivalent (emp), according to Table 3. These traffic volume values are used to calculate the degree of saturation (Dj) as a road performance parameter. Road performance is used to obtain the service level of the road. Details of the road level of service are given in Table 3.

Table 3. The Passenger Car Equivalent

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Total two-way traffic volume (vehicle/hour)</th>
<th>EMP MV</th>
<th>EMP MC</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/2-T or 2/1</td>
<td>&lt; 1050</td>
<td>1,3</td>
<td>0,40</td>
</tr>
<tr>
<td></td>
<td>≥ 1050</td>
<td>1,2</td>
<td>0,25</td>
</tr>
<tr>
<td>6/2 T or 3/1</td>
<td>&lt; 1100</td>
<td>1,3</td>
<td>0,40</td>
</tr>
<tr>
<td></td>
<td>≥ 1100</td>
<td>1,2</td>
<td>0,25</td>
</tr>
</tbody>
</table>

b. Side Friction
The amount of side friction on a road section was calculated by summing up the total weight of each side activity. These roadside activities consist of road crossings (Pedestrian/PED), parking and stop vehicles (PSV), entry and exit vehicles (EEV), and
slow-moving vehicles (SMV). The results were then multiplied by the weight factor of each activity (Table 4).

### Table 4. The Weight Factor of Side Friction

<table>
<thead>
<tr>
<th>No.</th>
<th>Jenis hambatan samping utama</th>
<th>Bobot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pedestrians on the road and crossing</td>
<td>0,5</td>
</tr>
<tr>
<td>2</td>
<td>Parking and other stopped vehicles</td>
<td>1,0</td>
</tr>
<tr>
<td>3</td>
<td>exit and entry the vehicle from the side of the road</td>
<td>0,7</td>
</tr>
<tr>
<td>4</td>
<td>Slow vehicle flow (un-motorized vehicles)</td>
<td>0,4</td>
</tr>
</tbody>
</table>

All activities' total side friction value was then interpreted to obtain the side friction classification (Table 5).

### Table 5. The Side Friction Criteria

<table>
<thead>
<tr>
<th>Side Friction Level</th>
<th>The sum of the frequency values of events (on both sides of the road) times the weight</th>
<th>Area Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>&lt;100</td>
<td>Residential areas, frontage roads are available</td>
</tr>
<tr>
<td>Low (L)</td>
<td>100-299</td>
<td>Residential areas there are several public transportation (city transportation)</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>300-499</td>
<td>Industrial area, there are several shops along the side of the road</td>
</tr>
<tr>
<td>High (H)</td>
<td>500-899</td>
<td>Commercial Area, there is activity on the high side of the road</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>≥900</td>
<td>Commercial area, there is market activity on the side of the road</td>
</tr>
</tbody>
</table>

After the side friction classification was obtained, the data was used to calculate the road capacity with the side friction correction factor shown in Table 6.

### Table 6. Capacity correction factor due to side friction with the curb, FC_{SF}

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Side Friction Class</th>
<th>Fi_{SF}</th>
<th>The distance from the curb to the nearest obstacle, L_{KP}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>4/2-D</td>
<td>Very low</td>
<td>0.95</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0.94</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.91</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.86</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Very high</td>
<td>0.81</td>
<td>0.85</td>
</tr>
<tr>
<td>2/2-UD or a one-way street</td>
<td>Very low</td>
<td>0.93</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>0.86</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.78</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>Very high</td>
<td>0.68</td>
<td>0.72</td>
</tr>
</tbody>
</table>

c. **Road Capacity**
The road capacity was calculated using Equation 1. The grade separation correction factor is assumed to be 1 with the criteria provided in Table 7.
Table 7. Capacity correction factor due to separation on undivided road types, $\text{FC}_{SP}$

<table>
<thead>
<tr>
<th>PA %-%</th>
<th>50-50</th>
<th>55-45</th>
<th>60-40</th>
<th>65-35</th>
<th>70-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{FC}_{PA}$</td>
<td>1.00</td>
<td>0.97</td>
<td>0.94</td>
<td>0.91</td>
<td>0.88</td>
</tr>
</tbody>
</table>

$$C = C_0 \times FC_W \times FC_{SP} \times FC_{SF} \times FC_{CS}$$  \hspace{1cm} (1)

d. Road Performance
The road performance parameter used in this study is the degree of saturation ($D_j$), describing the ratio between total traffic volume ($Q$) and road capacity ($C$) (Equation 2).

$$D_j = \frac{Q}{C}$$  \hspace{1cm} (2)

e. Road Service Level
The service level of the road was obtained based on the degree of saturation ($D_j$) values, as shown in Table 8, and is used to analyze road conditions [6].

Table 8. Urban Road Service Level Criteria

<table>
<thead>
<tr>
<th>Service Level</th>
<th>Traffic Flow Condition</th>
<th>Degree of Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Free flow at high speed, drivers free to select desired speed without delay</td>
<td>0.00 – 0.20</td>
</tr>
<tr>
<td>B</td>
<td>Steady flow, speed starts to be limited by traffic conditions, and the freedom to select desired speeds is relatively unaffected.</td>
<td>0.23 – 0.44</td>
</tr>
<tr>
<td>C</td>
<td>Steady flow, but vehicle speed and motion are limited by traffic conditions. Drivers are restricted to choosing their preferred speed</td>
<td>0.45 – 0.74</td>
</tr>
<tr>
<td>D</td>
<td>Flow is almost unstable, traffic flow conditions limit the driving speed, and the Q/C ratio is still tolerable</td>
<td>0.75 – 0.84</td>
</tr>
<tr>
<td>E</td>
<td>Traffic volume is near the road’s capacity, flow is unstable, and vehicle speed sometimes stops</td>
<td>0.85 – 1.00</td>
</tr>
<tr>
<td>F</td>
<td>Traffic flow is congested, speeds are low, queues are long, and bottlenecks or delays are large</td>
<td>&gt;1.00</td>
</tr>
</tbody>
</table>

Source: Morlok (1998)[6]

3 Result and Discussion

3.1 Diponegoro street geometric
This research is located on Diponegoro Road, the CBD area of Banda Aceh, Indonesia. The road has a length of ± 250 m and is a three-lane, one-way type with a road cross-section width of 11.5 m. However, this road only has one effective lane with a width of 3.75 m because both sides are utilized as on-street parking for two and four-wheeled vehicles.
3.2 Traffic Volume

The traffic volume was recorded at 15-minute intervals and then converted from vehicles per hour to Passenger Car Units (PCU) per hour. The results of the traffic volume calculation are given in Figure 1.

![Traffic Volume Graph](image)

Fig. 1. Traffic Volume

The results show that the peak hour occurred in the afternoon for all three days of observation. On weekdays (Monday), the peak hour was 17.30 - 18.30 WIB, while weekdays (Thursday) are the same as holidays (Sunday), which occurred at 18.30 - 19.30 WIB. The highest volume occurred on Sunday, whereas the peak hour traffic was 1051 PCU/hour. In the morning, the traffic volume was low because trade activities, which are the dominant activities, have not yet operated. The community uses this road for school, work and other destinations. The lowest volume occurred on Sunday morning, which was only 395 PCU/hour, due to the absence of school and work activities and the non-operation of Pasar Aceh in the morning.

1. Side Friction

Side friction data was collected at the same time as traffic volume data. Determination of the side friction classification was obtained from the total sum of each event per hour after multiplying by each weight. Furthermore, the interpretation of the results was based on Table 5. The results show that Diponegoro Road's highest side friction value occurred in the afternoon. The side friction value shows an increasing trend. In the morning, it is categorized as low, then increased to medium during the day, and the highest occurred in the afternoon with a value of 500 - 900. The types of side friction, including parking and stopped vehicles (PSV) and entry and exit Vehicle (EEV), dominate at the research location. Figure 2 provides more details of the side friction values.

2. Road Capacity and Performance

Data processing results revealed that the highest road capacity was obtained in the morning at 1528 PCU/hour for the three days of observation. It was due to the low value of side friction in the morning, as given in Figure 3.
The highest side friction occurred in the afternoon, causing the road capacity to decrease. It impacted the degree of saturation (Dj) value being low. The lowest Dj did not occur at the highest capacity (07:30-08:30) but at 08:30-09:30. It happened because, at that hour, the traffic volume and side friction were low with high road capacity. Based on the degree of saturation value, the road service level in six hours of observation was in the B, C, and D categories. Still, C was more dominant, as shown in Table 9 to 11. It indicates a condition where traffic flow is stable, vehicle speeds begin to be limited by traffic conditions, and drivers are free to choose the desired speed (B), but at the level of service C, drivers are limited in choosing speed. At the level of service D, the traffic flow is unstable, and traffic conditions limit the driving speed.
### Table 9. Degree of Saturation of Monday

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Traffic Volume (Q) (pcu)</th>
<th>Capacity (C) (pcu)</th>
<th>Degree of Saturation (Dj) (2/3)E (2/3)A</th>
<th>Level of Service existing alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.30 - 08.30</td>
<td>876</td>
<td>1,464</td>
<td>0.60</td>
<td>C B</td>
</tr>
<tr>
<td>08.30 - 09.30</td>
<td>688</td>
<td>1,400</td>
<td>0.49</td>
<td>C B</td>
</tr>
<tr>
<td>11.30 - 12.30</td>
<td>883</td>
<td>1,400</td>
<td>0.63</td>
<td>C B</td>
</tr>
<tr>
<td>12.30 - 13.30</td>
<td>751</td>
<td>1,400</td>
<td>0.54</td>
<td>C B</td>
</tr>
<tr>
<td>17.30 - 18.30</td>
<td>909</td>
<td>1,400</td>
<td>0.65</td>
<td>C B</td>
</tr>
<tr>
<td>18.30 - 19.30</td>
<td>897</td>
<td>1,289</td>
<td>0.70</td>
<td>C B</td>
</tr>
</tbody>
</table>

### Table 10. Degree of Saturation of Thursday

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Traffic Volume (Q) (pcu)</th>
<th>Capacity (C) (pcu)</th>
<th>Degree of Saturation (Dj) (2/3)E (2/3)A</th>
<th>Level of Service existing alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.30 - 08.30</td>
<td>822</td>
<td>1,464</td>
<td>0.56</td>
<td>C B</td>
</tr>
<tr>
<td>08.30 - 09.30</td>
<td>670</td>
<td>1,400</td>
<td>0.48</td>
<td>C B</td>
</tr>
<tr>
<td>11.30 - 12.30</td>
<td>799</td>
<td>1,289</td>
<td>0.62</td>
<td>C B</td>
</tr>
<tr>
<td>12.30 - 13.30</td>
<td>738</td>
<td>1,400</td>
<td>0.53</td>
<td>C B</td>
</tr>
<tr>
<td>17.30 - 18.30</td>
<td>845</td>
<td>1,289</td>
<td>0.66</td>
<td>C B</td>
</tr>
<tr>
<td>18.30 - 19.30</td>
<td>885</td>
<td>1,289</td>
<td>0.69</td>
<td>C B</td>
</tr>
</tbody>
</table>

### Table 11. Degree of Saturation of Sunday

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Traffic Volume (Q) (pcu)</th>
<th>Capacity (C) (pcu)</th>
<th>Degree of Saturation (Dj) (2/3)E (2/3)A</th>
<th>Level of Service existing alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.30 - 08.30</td>
<td>395</td>
<td>1,464</td>
<td>0.27</td>
<td>B A</td>
</tr>
<tr>
<td>08.30 - 09.30</td>
<td>607</td>
<td>1,400</td>
<td>0.43</td>
<td>B A</td>
</tr>
<tr>
<td>11.30 - 12.30</td>
<td>954</td>
<td>1,289</td>
<td>0.74</td>
<td>C B</td>
</tr>
<tr>
<td>12.30 - 13.30</td>
<td>817</td>
<td>1,400</td>
<td>0.58</td>
<td>C B</td>
</tr>
<tr>
<td>16.30 - 17.30</td>
<td>951</td>
<td>1,289</td>
<td>0.74</td>
<td>C B</td>
</tr>
<tr>
<td>17.30 - 18.30</td>
<td>1051</td>
<td>1,289</td>
<td>0.82</td>
<td>D B</td>
</tr>
</tbody>
</table>

In general, the central business district (CBD), fails to provide sufficient space for off-street parking, thus tending to increase the number of on-street parking requests in the area. This has negatively impacted traffic in most metropolitan cities across the world, including in India[7]. This also happens in Indonesia. Abuse of traffic lanes for parking, as in the city of Banda Aceh, also occurs in many other cities in the world. In the downtown areas of almost all major cities, on-street parking has been used to capacity throughout the day, and
in many cities, the capacity utilization rate of on-street parking exceeds 100% due to double parking, and illegal parking on the side of the road, roads, and parking lots on the sidewalk [8][9].

The results of this study indicate that parking restrictions on highways can improve road performance. The same opinion that parking on the road has an influence on performance on the road [10]. Based on [11], a policy of increasing parking rates, time restrictions [12][13], developing off/on-parking infrastructure [14] and expanding shared parking capacity [15][16] can also be implemented. In Amsterdam, the increase in parking prices caused overall hourly on-street parking demand to decrease by around 17% and the number of arrivals to decrease by 9% [17]. However, City governments and city planners are often hesitant to implement parking restriction policies because the public often opposes changes to on-street parking spaces [13]. Lack of public district parking lots increased the pressure on the on-street parking capacity and sustainability of streets. A case study parking survey in a large city center shows that parking demand is exceeding the capacity by 166% for average daily occupancy on weekdays and 111% on weekends in 2022, compared to 61% in 2015 [18]. However, this policy must be implemented as an effort to cultivate the use of public transportation so that it can reduce traffic volume which will have an impact on improving road performance.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Based on the research results and data analysis that has been carried out, the following conclusions are drawn:

1. The traffic volume passing through the Diponegoro road section was higher on Sunday afternoon at 1051 PCU/hour, while it was lower on weekdays at 909 PCU/hour on Monday and 885 PCU/hour on Thursday. This result is due to most Banda Aceh citizens using holidays to shop in the CBD area-Pasar Aceh, located on Diponegoro Road.

2. In the existing condition, the highest degree of saturation was obtained on Sunday afternoon at 0.82. This value shows that the performance of Diponogoro Road in existing conditions was poor with a level of service category D, meaning that the traffic flow is close to unstable, and traffic flow conditions still control the speed, so it is necessary to optimize the level of service to improve its performance.

3. Implementing the on-street parking restriction scenario on the Diponegoro road section, Pasar Aceh, resulted in the highest degree of saturation of 0.41. This optimization effort can improve road performance by Dj < 0.75.

4.2 Recommendations

Based on the research results, the following recommendations were made:

1. The government immediately must make a policy to improve the Diponegoro Road service level, considering that this road is located in the CBD area and used as an alternative road for the citizens to access various vital destinations in Banda Aceh City.
2. The provision of off-street parking locations within the Pasar Aceh and the Baiturrahman Grand Mosque buildings must be optimized to reduce vehicle parking on the road. Thus, the level of road service can be improved more optimally.

3. Future researchers are expected to analyze the effect of side friction types on vehicle speed to determine what type of side friction needs to be considered so as not to hamper road performance.

Thanks to “Ministry of Research, Technology and Higher Education” that has funded this research [grant numbers: 222/UN11.2.1/PT.01.03/PNBP/2023] and the surveyors who have helped in the process of data collection as well as all those who have helped make this research completed

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