Development of Road Network Traffic Model in Bandung City

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Abstract. The city of Bandung is a city with a higher number of movements; thus, it allows congestion on certain road segments. Constructing and widening new roads do not become the only solutions, but also by improving the traffic management on these roads. With the study area in some segments of Wastu Kencana Street, Cihampelas, Pajajaran, Pasir Kaliki, Kebon Kawung, and Cicendo, some of which have frequent congestion. Several alternatives have been assessed to implement traffic management policies. The solution alternatives are do nothing and do something. Do nothing alternative means the existing road conditions at the time of the study. Do something alternative consists of three traffic management scenarios: Alternative 1, changing traffic direction but not changing the existing one-way system; Alternative 2, applying a combination of one-way systems with two-way systems; and alternative 3, applying a condition of traffic management using two-way system in all roads. Whereas to evaluate network performance, the cost parameters of the trip, the average Volume Capacity Ratio (V/C), and the average speed are employed. The best policy alternative is Alternative 1 where the V/C value is 0.72, average speed of 27.57 km/hour, and cost of travel of IDR 9,370.87 million/hour.

Keywords: traffic management, road network, vehicle operating costs, V/C (Volume Capacity Ratio), average speed, travel costs.

1. Introduction

The city of Bandung as one of big cities in Indonesia is also inseparable from the transportation problems. At first, Bandung was only planned as a city of settlements and resorts. After the Independence of the Republic of Indonesia, this city becomes the capital of West Java Province, starting to be burdened with various functions and its population growth. Based on data from Bandung Statistics Center in 2017, there are around 2.5 million people living in an area of 167.31 km$^2$. This condition is exacerbated by the annual pace of road growth which is much smaller than the annual growth of vehicles. Even the width of roads in Bandung does not reach 20% of the city. In addition, geographical factors which are difficult for urban expansion become the supporting factors making traffic problems in Bandung difficult to overcome.

Solving transportation problems can be exercised from its physical aspects or traffic management application. Physical breakdown can be conducted by building a new road or by widening the available...
road; therefore, it can accommodate the volume of existing traffic. Traffic management can take form in the provision of traffic signs, directional arrangements, traffic lights, etc.

Physical problem solving will cost more and requires larger area, so solving problems with traffic management offers more preferable option for large areas and more economic. Traffic management which applies to an area depends on the policy of the region which usually considers the traffic conditions of the region concerned.

The objectives in this study are:
1. To evaluate the performance of the road network in the study area under existing conditions (do nothing).
2. To evaluate the performance of the road network in the study area upon conducting any action which consists of changes in the direction of movement or in traffic management.

2. Methods

2.1 Traffic Management
Traffic management is the application to control certain traffic on a road segment or several road segments in a certain area to achieve certain objectives [5]. In broadly speaking, road traffic management
can be categorized into management against time and on traffic space. Basically, congestion occurs because of the movement towards the same point and at the same time. To overcome the problem of congestion, arrangements need to be made in such a way that the movement does not occur at the same time and in the same space.

2.2 Volume Capacity Ratio (V/C)
V/C is one indicator to measure road network performance [2].

\[ \text{Average } V/C = \frac{\sum(V/C_{\text{segment}} \times \text{length}_{\text{segment}})}{\sum \text{length}_{\text{segment}}} \]  

Limits on the value of applied V/Cs as indicators of road network performance are presented in Table 1.

| Volume Capacity Ratio | Level of Road Service | Information |
|-----------------------|-----------------------|-------------|
| < 0.60                | A                     | Smooth flow, low volume, and high speed |
| 0.60 – 0.70           | B                     | Stable flow, limited speed, and volume suitable for road outside the city |
| 0.70 – 0.80           | C                     | Stable flow, speed affected by traffic, and the volume suitable for city roads |
| 0.80 – 0.90           | D                     | Approaching unstable flow, and low speed |
| 0.90 – 1.00           | E                     | Unstable flow, low speed, and solid volume or near capacity |
| > 1.00                | F                     | Obstructed flow, low speed, volume above capacity, and many stops |

Source: Tamin and Nahdalina, 1998 as referenced in Tamin, 2006

2.3 Average Speed
Related to the calculation of the average V/C, the speed on each road segment is obtained from the result of loading the Origin Destination Matrix on the road network database using SATURN program. The speed on each of these roads will be used to calculate the average speed in the study area, using the equation as follows:

\[ \text{Average Speed} = \frac{\sum(\text{speed}_{\text{segment}} \times \text{length}_{\text{segment}})}{\sum \text{length}_{\text{segment}}} \]  

2.4 Travel Costs
Travel costs are the sum of two cost components: Vehicle Operating Costs and time value costs. The model used is a calculation developed by PCI as a result of a study conducted by LAPI ITB (1997)[7].

The components employed in the calculation of Vehicle Operating Costs in this study are only calculated from the cost of fuel consumption. The component of fuel consumption costs can be formulated as follows:

\[ \text{Fuel Consumption Costs (FCC)} = \text{FCC}_{\text{basic}} \times \left( 1 \pm (k_s + k_t + k_f) \right) \]  

FCC_{basic} class I vehicle = 0.0284v^2 - 3.0644v + 141.68  
FCC_{basic} class IIA vehicle = 2.26533 \times (\text{FCC}_{\text{basic}} \text{ class I vehicle})  
FCC_{basic} class IIB vehicle = 2.90805 \times (\text{FCC}_{\text{basic}} \text{ class I vehicle})  
k_s = \text{correction factor for slope}  
k_t = \text{correction factor for traffic flow}
k_r = correction factor for road roughness
v = vehicle speed (km/hour)

\[
VOC = \sum_{i=1}^{n} (FCC_i \times L_i \times V_i) \times Rp 7,800.00
\]

\( (4) \)

VOC = Vehicle Operating Costs (Rp/year)
L_i = length of road segment i (km)
V_i = traffic volume at road segment i (pcu)
IDR 7,800.00 = fuel price (perialite) per liter in 2018

Costs for time values are calculated based on the following equation:

\[
C = 600 \times \text{total travel time}
\]

\( (5) \)

C = costs for time values
6000 = time values in Bandung

### Table 2. Correction Factor of Basic Vehicle Consumption.

| correction factor for negative slope (k_r) | g < -5% | -0.337 |
| correction factor for positive slope (k_r) | -5% ≤ g < 0% | -0.158 |
| correction factor for traffic flow (k_l) | 0% ≤ V/C < 0.6 | 0.050 |
| correction factor for traffic flow (k_l) | 0.6 ≤ V/C < 0.8 | 0.183 |
| correction factor for traffic flow (k_l) | V/C ≥ 0.8 | 0.253 |
| correction factor for road roughness (k_r) | < 3 m/km | 0.035 |
| correction factor for road roughness (k_r) | ≥ 3 m/km | 0.085 |

\( g = \text{slope} \)

\( V/C = \text{Volume Capacity Ratio} \)

**Source**: LAJI-ITB (1997)

### 3. Results and Discussions

#### 3.1 Review Some Related Research about Time Values

Several studies assessing time values based on Jasa Marga's formula by considering studies of the value of time have been carried out in several cities in Indonesia. The following Table 3 are basic time values of several studies which have been conducted.

### Table 3. Time Values of Several Studies.

| Reference | Time Value (Rp/hour/veh) |
|-----------|-------------------------|
|           | Class I | Class IIA | Class IIB |
| PT. JasaMarga (1990-1996), Formula Herbert Mohring | 12,287 | 18,534 | 13,768 |
| Padalarang-Cileunyi (1996) | 3,385 – 5,425 | 3,827 – 38,344 | 5,716 |
| Semarang (1996) | 3,411 – 6,221 | 14,541 | 1,506 |
| IHCM (1995) | 3,281.25 | 18,212 | 4,971.20 |
| PCI (1979) | 1,341 | 3,827 | 3,152 |
| JIUTR northern extension (PCI 1989) | 7,067 | 14,670 | 3,659 |
| Surabaya-Mojokerto (JICA 1991) | 8,880 | 7,960 | 7,980 |

**Source**: Highway Economics Module-Kartika, 2006
The amount of Minimum Time Value is presented by Table 4.

### Table 4. Minimum Time Values (IDR/Hour).

| Regency/City | JasaMarga   | JIUTR   |
|--------------|-------------|---------|
|              | Class I     | Class IIA | Class IIB | Class I     | Class IIA | Class IIB |
| DKI Jakarta  | 8,200       | 12,369   | 9,188     | 8,200       | 17,022    | 4,246     |
| Other than DKI | 6,000       | 9,051    | 6,723     | 6,000       | 12,455    | 3,170     |

Source: Highway Economics Module-Kartika, 2006

The formula used is as follows:

\[
\text{Time Values} = \max\{K \times \text{Basic Time Values}, \text{Minimum Time Values}\}
\]

While the value of K can be seen in the following Table 5.

### Table 5. K Values for Several Cities.

| No. | Regency/ City | K values |
|-----|---------------|----------|
| 1   | Jakarta       | 1.00     |
| 2   | Cianjur       | 0.15     |
| 3   | Bandung       | 0.39     |
| 4   | Cirebon       | 0.06     |

### 3.2 Data

#### 3.2.1 Traffic Volumes

Traffic volume surveys were carried out by collecting data with manual calculations directly on the specified road segments on weekdays and weekends. The survey of traffic volume on weekdays was carried out on Wednesday, May 16, 2018. The surveys at the end of the week were conducted on Saturday, May 19, 2018. The data from the survey during the morning and evening rush hours on some roads are presented in Table 6.

### Table 6. Traffic Volumes.

| Name of Roads | Survey Point          | Direction of Movement | Volume (pcu/hour) |
|---------------|-----------------------|-----------------------|-------------------|
|               |                       | Weekdays | Weekend | Weekdays | Weekend |
| Pajajaran 1   | Kimia Farma Lab.      | East- West |          | 2,923     | 2,547     |
| Pajajaran 2   | Pajajaran Stadium     | West- East |          | 2,730     | 2,446     |
| Ciconeo       | Cicendo Eye Clinic    | North- South |        | 2,846     | 2,632     |
| Kebon Kawung  | Ampera Restaurant     | East- West |          | 3,055     | 3,225     |
| Pasir Kaliki  | Jelita Parahyangan Hotel | North- South | | 2,390    | 2,568  |
| Wastu Kencana | Kembang Market        | North East–South East | 4,077    | 3,200     |
| R.E. Martadinata | Cibeunying Tax Office | West- East |          | 3,251     | 2,749     |

### 3.3 Road Network Performance

To obtain the modeling results, the OD Matrix cannot stand alone, meaning that the OD Matrix must be charged to the road network which has been prepared using the iteration method to reach equilibrium conditions. Loading is carried out for three road network conditions, which are the existing road network, road network after the implementation of traffic management, and road network before the present conditions. The balance method used is User Equilibrium Method, as suitable for urban areas with high congestion levels such as Bandung. This loading process is carried out using SATURN program.
3.3.1 Do Nothing Alternative
Do nothing alternative employs the existing road network system, a one-way system. There are two one-way road loops in this condition, Pajajaran St.–Cihampelas St. – Wastu Kencana St. and Pajajaran St.–Cicendo St. – Kebon Kawung St. - PasirKaliki St. Figure 2 inform details on the direction of movement on the road network of the existing study area. Each road has different characteristics, both capacity and length of segments.

3.3.2 Do Something Alternative
Do something alternative is the condition of the road network where changes are made to road arrangements by altering direction of movement, as well as road management changes into two directions on road networks in the study area to increase road network performance. In this study, three scenarios of do something alternative were carried out in an attempt to improve road performance, which are Alternative 1, Alternative 2, and Alternative 3.

A. Alternative 1
The system used in alternative 1 preserves the existing condition, a one-way management system, but some directional changes are implemented to the road network, such as part of Pajajaran St., Pasir Kaliki St., Cicendo St. and Kebon Kawung St. and removal of road dividers on some roads on Wastu Kencana St. Changes in direction in the road segment result in a change in direction on the loop of the road network. Figure 2 presents more noticeable direction of movement in the road network of Alternative 1. The removal of road dividers on some roads on Wastu Kencana St. will increase the capacity of the road; therefore, changes to the road segments are needed.
B. Alternative 2
In alternative 2, there are some of the road segments in the study area modified using a 2-way system, a part of Pajajaran St. and Cihampelas St. Other road segments still use a one-way system. As in Alternative 1, Alternative 2 also removes road dividers on some roads on WastuKencana St. The direction of road network in Alternative 2 is illustrated in Figure 2. The system changes will change road capacity of the road segments which undergo system changes.

C. Alternative 3
In the scenario of Alternative 3, road network condition is returned as a condition before the application of one-way system (existing condition), using two-way system. All roads on the road network in this study area use a two-way system. The direction of movement can be examined in Figure 2. In the two-way road system, the road capacity is smaller, but more road alternatives to pass.

3.4 Analysis
To analyze the road network performance is conducted by comparing the three parameters in the study area between Alternative 1, Alternative 2, and Alternative 3 to the existing condition (do nothing). The
best road network condition is the condition where the study area network has lowest travel costs, smallest average V/C, and highest average speed.

3.4.1 Average V/C
Each road network condition has a different average V/C. The average V/C value describes the state of the road network under evaluated conditions. Figure 3 presents the average V/C value.

![Average V/C Chart](image)

**Figure 3.** Average V/C Chart.

3.4.2 Average Speed

Like the average V/C, every road network condition has different average speeds. The existing condition and Alternative 1 condition have higher average speed when compared to Alternative 2 condition. It is driven by the existing road network segment, and Alternative 1 has more one-way roads which has higher design speed than the two-system direction. However, two-way system has more delays caused by setting traffic signals. The average speed is presented by Figure 4.

![Average Speed Chart](image)

**Figure 4.** Average Speed Chart.

3.4.3 Travel Cost
Travel costs are the sum of vehicle operating costs and the cost of time value. Travel costs are mostly influenced by the combination of V/C and speed. High V/Cs and low speeds will make traveling costs higher. The travel cost chart is presented in Figure 5.
4. Conclusions
From the analyzes performed on the predetermined parameters, the mean V/C, and the average speed, it can be concluded that the condition of the existing road network condition is unstable with the intersection only at Pajajaran St. – PasirKaliki. In Alternative 1 and Alternative 2, the study area network is in stable condition with interrupted intervals at Alternative 1 at the intersection of Pajajaran St. - Cicendo - Cihampelas, Pajajaran St. – Pasir Kaliki, Kebon Kawung St. – Pasir Kaliki, at the intersection of Kebon Kawung St. - Cicendo, at Alternative 2 at the intersection of Pajajaran St. - Cicendo - Cihampelas, Pajajaran St. – Pasir Kaliki, and Cihampelas St. - Abdul Rivai – Wastu Kencana. The road network performance of the study area on Alternative 3 is in poor condition where the performance of road segments cannot be calculated due to the length of queue at Pajajaran St.intersection - Cicendo - Cihampelas, Pajajaran St. intersection – Pasir Kaliki, and Kebon Kawung St. intersection – Pasir Kaliki. The length of queue in those intersections exceeds the length of the segment affecting to other segments.

Alternative 1 gives a better road network performance on the evaluated parameters, rather than Alternative of Do Nothing, Alternative 2 and Alternative 3. Hence, the scenario of Alternative 1 is regarded as the best solution in this study.

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