Traffic Management for Jalan Kayu Ayu in Seminyak Area, Badung Regency

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Abstract: The usage of land for commercial purpose along the side of the road often causes conflicts. One of the areas in Badung Regency, namely along the road called Jalan Kayu Ayu, is an attractive tourism area, the passageway is quite large, while on the other hand the effective width of the road is only 5 meters. The purpose of this study is to analyze the performance and the current condition of the road as well as to analyze alternative solutions for improvement. Based on the results of the analysis, the peak hours at Jalan Kayu Ayu Badung Regency is at 23.15-00.15 WITA, with a traffic volume of 1,078 pcu / hour, road capacity of 1236.51 pcu / hour, actual speed of 19.26 km / h and a saturation level is 0.87 and an F for the level of road service. The analysis results of alternative 1 with the arrangement of side barriers shows that the traffic volume becomes 1,078 pcu / hour. The road’s capacity is 1404.43 pcu / hour, the actual speed is 27.23 km / h and the saturation level is 0.77 with a C for the level of road service. While the analysis of alternative 2 with the application of one-way roads results in a traffic volume of 550.2 pcu / hour, the capacity of the road’s passage is 1407.06 pcu / hour, the actual speed is 27.23 km / h and saturation level is 0.77 with a road service level of B.

Keywords: road performance, side obstacle

1. Introduction

Badung Regency is among the Regencies in Bali Province which is active in the trade, agriculture and tourism sectors. The tourism sector is the main economic activity in the Southern Badung region, mainly in Kuta District. One of the locations with a high density of visits from local and foreign tourists is Jalan Kayu Ayu. There are many facilities that support the tourism activities in this area such as hotels, restaurants, cafes and art shops, which have a positive impact on the increase in the number of tourist who visits.

The increase in economic activity in the areas of Jalan Kayu Ayu has lead to an increase in the road traffic volume. The utilization of land for commercial purposes along the sides of the road creates various problems[1]. The land along the sides of the road is generally used by pedestrians (both walking on and crossing), non-motorized vehicles, access for vehicles from the road side, and there are also vehicles that stop and park on the street. The various activities has caused side friction conflicts[2,3].

The main problem in Jalan Kayu Ayu Badung Regency is the tall barriers on the road side. While the width of the road is narrow, it only has an effective width of 5m. So that traffic delays often occur due to the high side barriers on these roads.

Based on the background of the traffic problems in Jalan Kayu Ayu, this study will examine the extent of the influence of side barriers on the road performance along with alternative solutions. This research is the first study to analyze side barriers in the areas of Jalan Kayu Ayu.

2. Materials And Method

2.1. Side Obstacles

Many transportation problems are linked to the problems of delays that occur during the trip. [4,5] These problems are caused by vehicles entering and exiting the road, vehicles that park on the roadside, pedestrians using the road bodies, and non-motorized vehicles [6]. These are what are called side obstacles. Side obstacles in certain circumstances may result in a temporary travel delay and also cause traffic jams (Table 1, 2).
Table 1. Side Barriers based on the Classifications of City Size

| Total Population of The Regency (Million People) | Classification of City Size (CS/ City Size) |
|--------------------------------------------------|-------------------------------------------|
| CS < 0.1                                         | Very Small                                |
| 0.1 ≤ CS < 0.5                                  | Small                                     |
| 0.5 ≤ CS < 1.0                                  | Medium                                    |
| 1.0 ≤ CS < 3.0                                  | Large                                     |
| 3.0 ≤ CS                                         | Very Large                                |

Source: Departemen Pekerjaan Umum, 1997 [7]

Table 2. Factor Weightage for each type of events on the side barrier

| Types of Side Obstacles          | Symbol | Factor Weightage |
|----------------------------------|--------|------------------|
| Pedestrian                       | PED    | 0.5              |
| Parking and Stop Vehicle         | PSV    | 1.0              |
| Enter and Escape Vehicle         | EEV    | 0.7              |
| Unmotorized                      | UM     | 0.4              |

Source: Departemen Pekerjaan Umum, 1997 [7]

2.2. Traffic Volume

In MKJI, the traffic flow value (Q) is expressed in passenger car units (pcu). All traffic flow values (per direction and total) are converted into passenger car units by multiplying the number of vehicles with passenger car equivalents (pce) (Table 3) which are derived empirically based on vehicle type [7]. According to Putranto, the definition of traffic flow / volume is the number of vehicles passing a point on a cross section of a road within a certain time frame [8].

The research results volume can be calculated using the following equation:

\[ Q = \frac{n}{T} \]

The equivalence of passenger cars (imp) for each type of vehicle depends on the road type and total traffic flow expressed in the vehicle / hour.

Table 3. Passenger Car Equivalent (PCE) on undivided city roads

| Type: Undivides Road | Total Two Ways Traffic Flow (Vehicle/ Hour) | pce | Width of the Traffic Path (m) |
|----------------------|---------------------------------------------|-----|-------------------------------|
|                      | HV                                          | MC  | ≤ 6              | > 6              |
| Undivided Two Paths  | 0 – 1800                                     | 1.3 | 0.5                        | 0.40             |
| (2/2 UD)             | ≥ 1800                                      | 1.2 | 0.35                       | 0.25             |
| Undivided Four Paths | 0 – 3700                                     | 1.3 | 0.40                       |
| (2/2 UD)             | ≥ 3700                                      | 1.2 | 0.25                       |

Source: PU Department, 1997

2.3. Basic Capacity

Capacity is expressed in passenger car units (pcu). The basic equation to determine capacity is:

\[ C = C_0 \times F_{Cw} \times F_{Csp} \times F_{Csf} \times F_{CCs} \]

2.4. Free Flow Velocity

Free flow velocity is defined as the velocity in which there are no obstacles on the road, depending on the speed that the driver choose driving a motorized speed without obstruction of other motorized vehicles on the road (i.e. when the current = 0). The free flow velocity of passenger cars is usually 10-15% higher than other types of vehicles. The equation to determine the free flow velocity on urban roads is as follows:

\[ F_{V} = (F_{Vo} + F_{Vw}) \times F_{FVsf} \times F_{FFVs} \]

The road side performance is quantitative measure to improve the operational conditions of the traffic facility, such as what was evaluated by Bina Marga [7]. The road side performance is measured using five indicators, namely volume, capacity, travel speed, degree of saturation and level of service.
2.5. Speed

Time Mean Speed is the average speed of all vehicles that cross a point on the road within a certain period of time, while Space mean speed is the average speed of all vehicles occupying a piece of road within a certain period of time. In this study, the mean space speed is used to calculate the average velocity value. Space Mean Speed is calculated using the following formula:

\[ V_s = \frac{n \cdot d}{\sum t_i} \]

2.6. Degree of Saturation

Degree of Saturation (DS) is defined as the ratio of the current (Q) to the capacity (C), used as the main factor in determining the level of performance of intersections and road segments. The DS value indicates whether the road segment has a capacity problem or not. Formula to calculate the Degree of saturation:

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

2.7. Level of Service

The concept of service level is used to measure the quality of the road service. Measures that are suitable for determining the level of service can be by identifying the speed of vehicles passing a highway and/or the volume of vehicles on the road. The level of road service is a quantitative measure that reflects the driver's perception of the road quality related to the vehicle. Level of road service can be classified from service level A to F, which is measured from the V/C ratio as shown in Table 4 where V is the flow or current (pcu/hour) and C is the capacity (pcu.hour).

| Level of Service | Actual Conditions | V/C Ratio     |
|------------------|-------------------|---------------|
| A                | Free flow allowing drivers to choose any speed they want without any delay | 0 < A ≤ 0.20 |
| B                | Stable flow, speed may be limited due to traffic conditions, driver has enough liberty to choose their speed | 0.20 < B ≤ 0.45 |
| C                | Stable flow, but speed and vehicle movement may be limited due to traffic conditions, driver’s ability to choose there are limited | 0.45 < C ≤ 0.75 |
| D                | The flow is close to unstable, speed is still controlled by traffic conditions, V/C ratio is still tolerable | 0.75 < A ≤ 0.85 |
| E                | Traffic volume is near its capacity, unstable flow, speed occasionally goes down to zero | 0.85 < A ≤ 100 |
| F                | Traffic flow congested, low speed, long lines of vehicles and large amount of obstacle | F ≥ 100 |

Source: Morlok, 1984
3. Research Design

The steps to conduct the research are shown in Figure 1 as follows:

- Pre-study examination and Location Selection
- Problem Identification and Determining the Objective
- Literature Review
- Data Collection
- Primary Data
- Secondary Data

- Road Geometry Survey Data: Road Length, Path Width, Roadside Width, Road Median, Pedestrian Facility, Total Paths
- Traffic Volume Survey Data
- Side Obstacles Survey Data
- Pilot Survey: Location Map, Total Population
- Road Speed Survey Data
- Road Performance Analysis

- With Side Obstacles
  - Vehicle Volume
  - Road Capacity
  - Vehicle Volume
  - Space Mean Speed
  - Service Level
- Without Side Obstacles
  - Vehicle Volume
  - Road Capacity
  - Vehicle Volume
  - Space Mean Speed
  - Service Level

Alternative Solution
- Management of Side Obstacles
- One Way Road

Conclusion and Recommendation

Figure 1. Research Design

The criteria considered in choosing the location of this study are: there must be pedestrians that walk on and cross the road, vehicles are able to enter and exit the road from the shopping area along the sides of the road, there are vehicles that stop or park on the road, there are non-motorized vehicles, and there are no signs or information regarding parking or stop restrictions on the road despite being a shopping district with high traffic activity.

Collecting primary data in this study was done using manual methods and digital methods. The manual method is by collecting data directly at the study location that involves several people to record the needed data. The data needed are road geometry data, side obstacle data, volume data, traffic speed...
data, and side obstacle data. Digital methods are used to determine the traffic volume data. Data collection is conducted on days when tourism is busy, which was on weekends. The time in which the traffic volume survey on Jalan Kayu Aya in Badung Regency was carried out was on Saturday, January 19, 2019 for 16 hours without pause. The survey was conducted in conjunction with the survey regarding side barriers and speed but by using different methods.

4. Results And Discussion

4.1. Total Population of People

The total population in Badung Regency in 2018 is 643,500 people and this is used as a reference for analysis [9].

4.2. Side Obstacle Analysis

The peak hours of the side obstacles in Jalan Kayu Aya, Badung Regency, adjusted for the peak hours of the traffic on this road, is from 23.15-00.15. The results of the side obstacle analysis conducted during the peak hours are shown in Table 5.

| Types of Side Obstacles       | Symbol | Factor Weightage | Frequency of Occurrences in the Field (per hour/200m) | Weighted Frequency (per hour/200m) |
|-------------------------------|--------|------------------|-------------------------------------------------------|-----------------------------------|
| Pedestrian                    | PED    | 0.5              | 205                                                   | 102                               |
| Parking and Stop Vehicle      | PSV    | 1                | 218                                                   | 218                               |
| Enter and Escape Vehicle      | EEV    | 0.7              | 264                                                   | 184.8                             |
| Unmotorized Vehicle           | SMV    | 0.4              | 1                                                     | 0.4                               |
| **Total Occurrence (per hour/200m)** |       |                  | **505.7**                                             |                                   |

Source: Analysis Results, 2019

4.3. Spot Speed Analysis

Spot speed is the speed of a vehicle at a certain time measured starting from a specified place. Spot speed is among the various types of speed in the science of traffic. There are two types of velocities obtained in the study of traffic flow velocity, namely Time Mean Speed ($V_t$) and Space Mean Speed ($V_s$) where both are part of Spot Speed. The speed calculation used is the average space speed (space mean speed), in which the vehicle speed at Jalan Kayu Aya in Badung Regency is calculated using Equation 4.2.

$$V_s = \frac{\sum_{i=1}^{n} (25d/1000)}{(598.43 dt/3600)}$$

$$= 19.26 \text{ km/jam}$$

The average speed of light vehicles at Jalan Kayu Aya Badung Regency is 19.26 km/hour.

4.4. Analysis on the Current Road Performance Traffic Volume

From the fluctuation in the graph, the peak hour is at 23.15-00.15 where the total volume is 1575 vehicles/hour and $Q = 1078$ pcu/hour. The next analysis conducted is the direction separator analysis, in order to calculate the percentage of direction separators. The calculation is displayed in Table 6.
Table 6. Direction Separator

| Direction      | Type | Arus (Kend/Jam) | Vehicle Type | Total Flow (pcu/hour) |
|----------------|------|-----------------|--------------|-----------------------|
|                |      | MC LV HV        | 0.35 x MC    | 1.0 x LV 1.2 x HV     | 1575 | 137.2 413 0 | 550.2 | 1078     |
| East to West   |      | 392 413 0       | 805          |                       |      |                |      |          |
| West to East   |      | 373 397 0       | 770          |                       |      |                |      |          |

Percentage of the Direction Separation

- East to West: 0.511
- West to East: 0.489

Source: Analysis Results, 2019

4.4.1. Current Capacity

To calculate the capacity during the traffic peak hours at Jalan Kayu Aya, Badung Regency, the following equation is utilized:

\[ C = C_0 \times FC_w \times FC_p \times FC_s \times FC_s \]

\[ = 2900 \times 0.56 \times 1.00 \times 0.94 \times 0.81 \]

\[ = 1236.51 \text{ pcu/hour} \]

4.4.2. Degree of Saturation

After conducting the traffic volume survey and the results of road capacity analysis is obtained, the degree of saturation (DS) analysis can afterwards be conducted. To find the degree of saturation of Jalan Kayu Aya in Badung Regency, the following equations are used:

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

\[ DS = \frac{1078}{1236.51} = 0.87 \times \frac{SMP}{Jam} \]

4.4.3. Speed

The method used to analyze the speed of vehicles at Jalan Kayu Aya in Badung Regency is the space mean speed method. The space mean speed of vehicles at Jalan Kayu Aya in Badung Regency is 19.26 km/hour. After the speed is calculated, the next step is to determine the level of service.

4.4.4. Level of Service

Jalan Kayu Aya, Badung Regency, is a local road which has a width of 5 meters. The initial plan was so that the speed on the flat terrain of this road is 40 km/h [10]. The relationship between planned speed, actual speed, degree of saturation, and level of road service is shown in Figure 2.

Figure 2. Existing Level of Service
4.5. Alternative Performance Analysis 1: Managing the Side Obstacles

In assessing the solutions, there are some side obstacles which can be assumed to have no weightage value.

| Types of Side Obstacles       | Symbol | Factor Weightage | Frequency of Occurrences in the Field (per hour/200m) | Weighted Frequency (per hour/200m) |
|-------------------------------|--------|------------------|------------------------------------------------------|-----------------------------------|
| Pedestrian                    | PED    | 0.5              | 0                                                    | 0                                 |
| Vehicle, Parking and Stop     | PSV    | 1                | 0                                                    | 0                                 |
| Vehicle Enter and Exiting    | EEV    | 0.7              | 264                                                  | 184.8                             |
| Unmotorized Vehicle           | SMV    | 0.4              | 0                                                    | 0                                 |

Table 7. Side Obstacle Reduction Analysis

Source: Analysis Results, 2019

Based on the results of the analysis above, the level of the road side barriers is low (L) with an FCsf value = 0.92. Even by managing the side obstacles, vehicles coming in and out cannot be significantly reduced because the road does not allow for slow lanes to be constructed.

4.5.1. Traffic Volume

The traffic volume utilized to measure the performance of the road is the traffic volume during the peak hours. From the fluctuation graph, the peak hour is found to be from 23.15 – 00.15 in which the total volume is 1575 vehicles/hour and the Q = 1078 pcu/hour.

4.5.2. Capacity

\[
C = C_0 \times FC_w \times FC_{sp} \times FC_{cs} \times FC_{sf}
\]

\[
= 2900 \times 0.56 \times 1.00 \times 0.94 \times 0.92
\]

\[
= 1404.43 \text{ pcu/hour}
\]

4.5.3. Degree of Saturation

Below is the equation used to analyze the degree of saturation due to the reduction of side obstacles:

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

\[
DS = \frac{1078}{1404.43} SMP/\text{jam} = 0.77 SMP/\text{jam}
\]

4.5.4. Speed

Afterwards, the speed of vehicles at Jalan Kayu Aya is analyzed. The FVo in this study is not from the by the PU Department, 1997, but it is the planned speed which 40 km/hour [10].

\[
FV = (FVo + FVw) \times FFV_{sf} \times FFV_{cs}
\]

\[
FV = (40+(-9.5)) \times 0.95 \times 0.94
\]

\[
FV = 27.24 \text{ km/jam}
\]

Based on the calculations above, the speed of vehicles at Jalan Kayu Aya is calculated to be 27.24 km/hour.

4.5.5. Level of Service

The service level of the road after assuming that the side obstacles has decreased with a DS = 0.77 and Vs = 27.23 km/h, is at the service level C, and this can be seen in Figure 3.
4.6. Analysis of Performance Alternative 2: One Way Road System

It is recommended for Jalan Kayu Aya Badung Regency to be a one-way road from East to West. This can be seen from the results of the analysis of the direction separation factors which is 50% from the east and 50% from the west. Viewed from the volume of vehicles, a larger proportion are from the east so that one direction movement is determined to be from the east to the west.

4.6.1. Traffic Volume

During the highest peak hours of Jalan Kayu Aya in Badung Regency, from east to west, which is the at 23:15-00:15, the total volume of cars is 805 (vehicles / hour) with a One Direction Q = 550.2 pcu / hour.

4.6.2. Capacity

In the performance analysis of the one-way road here, the correction factor for the side obstacle is used for the correction of the existing condition. To determine the basic capacity, in this calculation Jalan Kayu Aya, Badung Regency was changed to a one-way road, because currently it has two lanes. The capacity was multiplied by the number of lanes. The calculation is as follows: Co = 2x 1650 pcu / hour.

Calculation of the One Way Road Capacity: C

\[ C = C_0 \times F_{cw} \times F_{cs} \times F_{sp} \times F_{sf} \]
\[ = (2 \times 1650) \times 0.56 \times 0.90 \times 0.94 \times 0.81 \]
\[ = 1407.06 \text{ pcu/hour} \]

4.6.3. Speed

In the speed analysis of the one-way road version of Jalan Kayu Aya in Badung Regency, the FVo is not derived from the tables of the Department of Public Works, 1997, but the planned speed of 40 km/h (Saodang, H, 2005) is utilized:

\[ FV = (FVo + FVw) \times F_{FVs} \times F_{FVcs} \]
\[ FV = (40+(-9.5)) \times 0.95 \times 0.94 \]
\[ FV = 27.23 \text{ km/jam} \]

Based on the calculations above, the free flow speed at Jalan Kayu Aya, Badung Regency is 27.23 km/hour.

4.6.4. Degree of Saturation

The following equation is used in the analysis of the one-way road’s degree of saturation:

\[ DS = \frac{Q_{puncak \ 1 \ arah}}{C} \]

\[ DS = \frac{550.2}{1407.06} \text{ SMP/jam} = 0.39 \text{ SMP/jam} \]

\[ = 0.39 \]
After analyzing the one way road performance alternative, the degree of saturation is 0.39. This means that the road can still accommodate 61% more vehicles than the road’s capacity. In contrast with the current capacity of Jalan Kayu Aya, Badung Regency, which can only accommodate vehicles at 11% of the road’s capacity.

4.6.5. Service Level

The level of road service has a purpose to determine the degree of the road’s performance that is calculated based on the level of road usage, speed, density, and obstacles that occur. To calculate the level of service, some data are needed, namely the optimum speed, travel speed, and degree of saturation. The service level of the road segment, after assuming that the road is a one-way, is service level B with a DS = 0.39 and Vs = 27.23 km/h. This can be seen in Figure 4.

![Figure 4. The Service Level of the One-Way Road](image)

After obtaining the results of the road performance analysis, the comparison table was constructed and is displayed in Table 8 as follows.

| Road Performance | Existing/ Current | Alternative I | Alternative II |
|------------------|-------------------|---------------|---------------|
| V (Volume)       | 1078 pcu/hour     | 1078 pcu/hour | 550.2 pcu/hour|
| C (Capacity)     | 1236.51 pcu/hour  | 1404.43 pcu/hour | 1407.06 pcu/hour |
| DS (Degree of Saturation) | 0.87           | 0.77            | 0.39          |
| Vs (Space man Speed) | 19.26 km/hour | 27.23 km/hour   | 27.23 km/hour |
| Level of Service | F                 | C              | B             |

Source: Analysis Results, 2019

5. Conclusion And Recommendation

5.1. Conclusion

From the results of the study regarding Jalan Kayu in Badung Regency, the conclusions are as follows:

1. The current performance of Jalan Kayu Aya in Badung Regency is:
   1. Volume = 1078 pcu/jam
   2. capacity = 1236.51 pcu/jam
   3. Degree of Saturation = 0.87
   4. Speed = 19.26 km/jam
   5. Level of Service = F

2. From the two alternative proposed for Jalan Kayu Aya in Badung Regency, the results are as follows:
   a. The road performance of alternative 1, which is by managing the traffic, is:
      - Volume = 1078 pcu/hour
      - capacity = 1236.51 pcu/hour
      - Degree of Saturation = 0.77
      - Speed = 27.23 km/jam
- Level of Service = C

b. The road performance using alternative 2, which is the one-way road system, is as follows:
   - Volume = 550,2 pcu/hour
   - capacity = 1407,06 pcu/hour
   - Degree of Saturation = 0,39
   - Speed = 27,23 km/jam
   - Level of Service = B

5.2. Recommendation
The recommendations based on the study results are as follows:
1. The management of the traffic flow in the study location should be done at the earliest.
2. To solve the issue of cars parking on the road body of Kayu Aya Road, a central parking area should be constructed as there are still vacant land which can be used for a parking area.
3. If alternative 2 is selected, namely the one way road system, the road traffic flow circulation must be modified.

6. Acknowledgement
This article was presented at the 2nd International Conference on Smart City INNOVATION (ICSCI) 2019, jointly held by Universitas Indonesia and Universitas Diponegoro. ICSCI conferences have been supported by the United States Agency for International Development (USAID) through the Sustainable Higher Education Research Alliance (SHERA) Project for Universitas Indonesia’s Scientific Modelling, Application, Research, and Training for City-centered Innovation and Technology (SMART CITY) Center for Collaborative Research, administered through Grant #AID-497-A-1600004, Sub Grant #IIE-00000078-UI-1.

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