Re-designing of the bottleneck on Suryanata Street Samarinda City East Kalimantan

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Abstract. Some indicators of traffic problems like congestion, pollution and accident become the benchmark to evaluate the infrastructure performance. One kind of problem that often happened are the Bottleneck problems. In this kind of condition, the capacity of one side of the road is lower than before condition. On the other hand, in the process of landscape design of bottleneck deciding only by the availability of the space and those kinds of condition are not getting research by some specialist. The purpose of this research is to analyze the design parameter to enhance the capacity so case we can decreasing the number of congestion in a significant way. This research has taken place in Suryanata Street, Samarinda City. This research uses the model of Greenshield Linear, Greenberg Logarithmic, and Exponential Underwood to state the relationship between the performance of Traffic, Volume, Speed, and Density so we can decide the best model to analyze the shock wave that is using to design the parameter that effecting the design of bottleneck road area. Meanwhile, the pollution that can identify it consist of: CO (in the part of Per Million / PMM), NOX (calculate in Cubic meter / M3) and level of smoke (calculate in Cubic Meter / M3) with using the model of Hobbs (1979). Re-designing will be implemented to get the optimal performance infrastructure in the research location, and evaluate those kinds of terms. The result of the research got three design parameters in the Bottleneck area. There are track width, length of the road, and traffic volume. From the result analysis, the researcher is doing the Re-designing in the bottleneck area of the research location by using the parameter performance of congestion, specifically on delayed and pollution, like CO, NOX and level of smoke. Based on the re-designing, we can be decreasing the delay in the amount of 29.31% decreasing the number of NOX by 25.03% on CO we can be decreasing in the amount of 14.88% and also decreasing the level of smoke by 11.94%.

Keywords: Bottleneck, CO, Delayed, Delayed, Level of Smoke, NOX, Shock Wave

1. Background
In general, the problem of road narrowing (bottleneck) is a traffic problem in urban areas [1]. The road narrowing results from changes in road dimensions, both width and number of lanes [2]. No exception to the road narrowing on Suryanata Street, Samarinda City, performance traffic problems arise due to road narrowing, a section of the road with the road type 4/2 D becomes 2/2 UD, in other words the condition of the traffic capacity afterwards is smaller than the entrance section (before) so that there will be a decrease in traffic performance. Indicators of traffic problems in road narrowing (Bottlenecks) include: congestion, pollution and accidents used as benchmarks in evaluating infrastructure performance. Meanwhile, in terms of the design (landscape) road narrowing has not been studied much, it arises because of the lack of land, while the optimization of existing infrastructure has never been studied and applied in its application [3].

The purpose of this study is to determine the design parameters to increase service
capacity so that it can significantly reduce congestion by using the analysis of the relationship between traffic flow performance on roads and the effect of road narrowing, as well as implementing the results of research on narrowing on Suryanata Street Samarinda City.

The benefit of research is availability of road narrowing design parameters from the results of the analysis of the traffic flow performance relationship that can be used in overcoming congestion caused by road narrowing, as well as the implementation of the results of the design planning analysis as a solution to the problem of road narrowing at the study location.

2. Research methodologi

The methods of collecting data are divided into 2 (two), namely:

a) Secondary Data,

b) Primary Data, including [4]:

1) Segment geometric data,
2) Traffic volume data,
3) Speed data and vehicle travel time,
4) Vehicle Queue Data.

In road narrowing, design variables that can be used as candidate variables include variables from road characteristics and traffic characteristics. The characteristics of the road include: The initial road length and the final road width or the number of initial and final lanes, and the length of the road connecting the initial and final road segments. While the road characteristics variable.

Here is a few variables which affects the design on the Bottleneck:

1) Lane Width
2) Traffic Flow Performance
3) Length of the road on Suryanata Street Segment 2

The method for analyzing the relationship between volume, velocity, and density uses a data distribution chart. Furthermore, the method used to analyze the mathematical relationship between the three parameters of traffic performance parameters using three types of models, namely the Greenshield Model, Greenberg Model, and Underwood Model [5]. Shock wave analysis using the results of the selected model. Analysis of vehicle exhaust emissions using the Hobbs air pollution regression model [6].

3. Research result

Road geometric that affects road capacity and performance, namely the type of road that determines the difference in traffic loading, traffic lane width, which can affect the value of free-flow speed and capacity. The geometric characteristics of the road are from the road conditions (4/2 T) to (2/2 T).

3.1. Traffic performance analysis

The goal is to measure traffic performance and identify problems that occur on roads and traffic space usage. The traffic flow performance analyzed are volume, speed and density [7].
Figure 1 The fluctuation of traffic volume on Suryanata Street road segment between standard and narrow

Figure 2 The fluctuation of traffic speed on Suryanata Street road segment between standard and narrow
3.2. Analysis of the Relationship of Speed, Density and Volume
The choice of the traffic volume (V) and speed (S) data relationship model using the Greenshield, Greenberg and Underwood methods. From the field data, the relationship between volume and speed is obtained as in Table 1.

Table 1 The value of R^2 Suryanata Street Determination for the three segments in the three models

| Condition                              | Relationship | Greenshield | Greenberg | Underwood |
|----------------------------------------|--------------|-------------|-----------|-----------|
| Normal road direction out of town      | SD           | 0.952       | 0.869     | 0.876     |
|                                        | VD           | 0.986       | 0.986     | 0.988     |
|                                        | VS           | 0.829       | 0.740     | 0.727     |
|                                        | Average      | 0.858       | 0.865     | 0.864     |
| Normal road direction to enter the city| SD           | 0.910       | 0.842     | 0.845     |
|                                        | VD           | 0.962       | 0.975     | 0.971     |
|                                        | VS           | 0.583       | 0.560     | 0.642     |
|                                        | Average      | 0.818       | 0.793     | 0.819     |
| The road between normal and narrow roads out of town | SD           | 0.950       | 0.825     | 0.877     |
|                                        | VD           | 0.979       | 0.981     | 0.982     |
|                                        | VS           | 0.714       | 0.568     | 0.747     |
|                                        | Average      | 0.881       | 0.791     | 0.869     |
| The road between normal and narrow roads in the direction of entering the city | SD           | 0.942       | 0.774     | 0.797     |
|                                        | VD           | 0.972       | 0.977     | 0.976     |
|                                        | VS           | 0.596       | 0.471     | 0.622     |
|                                        | Average      | 0.837       | 0.740     | 0.798     |
| The road between normal and narrow roads out of town | SD           | 0.927       | 0.850     | 0.857     |
|                                        | VD           | 0.985       | 0.991     | 0.988     |
|                                        | VS           | 0.631       | 0.711     | 0.681     |
|                                        | Average      | 0.848       | 0.851     | 0.842     |
| The road between normal and narrow roads in the direction of entering the city | SD           | 0.966       | 0.852     | 0.911     |
|                                        | VD           | 0.987       | 0.989     | 0.990     |
|                                        | VS           | 0.782       | 0.677     | 0.818     |
|                                        | Average      | 0.912       | 0.839     | 0.906     |

Based on the largest coefficient of determination, the selected model is the Greenshield model.
3.3. Shock wave analysis
Shock waves can be described as movements in traffic volume due to traffic density changes and volume values. The shock wave on the road occurred due to the incident’s impact so that the traffic volume was disturbed, resulting in the blocking of part or all of the road lanes [8].

By using the shock wave method, the values are obtained:

a. The shock wave (ω) is calculated using the formula, the value ω = -1.38 km/hour is obtained. A negative value indicates a shock wave backward forming in the direction of the vehicle’s arrival.

b. According to the formula, the number of vehicles in the queue will get N = 260.25 pcu.

c. The time it took for the last vehicle to leave the last queue was 20.83 minutes.

3.4. Selection of variables that affect the performance of the Bottleneck area
There are three candidate variables observed, namely road width, bottleneck area length and traffic volume. The method used to assess the effect is by using the variable sensitivity method on traffic performance [9].

From the sensitivity graph, it is obtained the relationship between candidate variables that affect traffic performance in the form of delays. So that the three candidate variables affect on traffic performance in the bottleneck area.
4. Design planning

From the results of the analysis of variable selection obtained variables: road lane width, bottleneck area length, and traffic volume. These three variables are used as a proposed improvement by changing the geometric shape of the road length in the narrowing area so that a geometric repair proposal is obtained for the narrowing area as follows:

The results of field observations (existing conditions) obtained data on the length of the bottleneck area, namely 12 m, with an angle $\alpha$ of 19°. as in the picture beside.

![Figure 6 Existing and Road Area Planning Narrowing](image)

To redesign the bottleneck on Suryanata Street by looking at the density of land use and traffic conditions, it is not possible to change the road width variable, and it is also difficult to control the amount of traffic volume so that the proposed change in the length of the bottleneck area becomes a mishandling of the design. The method used to propose changes in the length of the bottleneck area that can be proposed is by changing the length of the bottleneck area by using trial-error and measuring the traffic performance. The bottleneck area length assumption is accepted if the speed and density in the bottleneck area are close to the traffic flow on the standard road segment (without narrowing).

From the trial-error result, it is obtained that the bottleneck area length is 22 m with angle $\alpha$ is 90°. It is sufficient to say that the speed and density of the bottleneck area and the standard road area are the same.

Design the narrowing area after the proposed improvements are as follows:
5. Delay analysis
Delays are obtained from the calculation results by comparing the travel time required by vehicles to cross narrowed roads and normal roads. The following is the result of the calculation of delay analysis [8].

![Table 2 The result of the existing delay calculation](image)

|       | Existing |       |       |
|-------|----------|-------|-------|
|       |          | T3-T2 (minutes) | T4-T2 (minutes) |
| Delay | T3-T2 (minutes) | 6.31 | 13.57 |
|       | T4-T2 (minutes) | 7.26 | 13.57 |
|       | (minutes / Pcu) | 378.6 | 814.2 |
|       | (sec / Pcu) | 267.6 | 593.4 |
|       | (minutes / Pcu) | 4.46 | 9.89 |
|       | (sec / Pcu) | 267.6 | 593.4 |

The amount of delay will be obtained from the travel time on narrow roads reduced by travel time on normal roads calculated from the beginning of the narrowing to the end of the narrowing, while the travel time on normal roads is calculated on roads that do not experience narrowing.
6. **Emission calculation analysis**

From the results of the redesign of the design in the constriction area, there were several changes in the results of the analysis of vehicle exhaust emissions [10], to determine the relationship between traffic volume and air pollution, among others, presented by Hobbs (1979) which are summarized in the table below:

**Table 3 Calculation results with the Air Pollution Regression Model [6]**

| Types of Pollutants | Regression Formulas                        | Information                        | Survey Results | Survey Time | Traffic Volume (Pcu) | Concentration of Gas |
|---------------------|--------------------------------------------|------------------------------------|----------------|-------------|----------------------|----------------------|
| CO concentration   | \[C = 2.96 + 0.00032V + 0.0000005V^2\]     | Out of Town Directions             | 07.00 - 10.00  | 10455.1     | 60.96                |
|                     |                                            | Directions to Enter the City       | 14.00 - 17.00  | 15107.7     | 121.92               |
| Nox Concentration   | \[N = 46.9-0.036T + 0.00004T^2\]           | Out of Town Directions             | 07.00 - 08.00  | 5379.4      | 1010.76              |
|                     |                                            | Directions to Enter the City       | 16.00 - 17.00  | 6111.3      | 1320.81              |
| Smoke Rate          | \[S = 9.49 + 0.022 V\]                    | Out of Town Directions             | 07.00 - 08.00  | 5379.4      | 127.84               |
|                     |                                            | Directions to Enter the City       | 16.00 - 17.00  | 6111.3      | 143.94               |

**Proposal**

| Types of Pollutants | Regression Formulas                        | Information                        | Survey Results | Survey Time | Traffic Volume (Pcu) | Concentration of Gas |
|---------------------|--------------------------------------------|------------------------------------|----------------|-------------|----------------------|----------------------|
| CO concentration   | \[C = 2.96 + 0.00032V + 0.0000005V^2\]     | Out of Town Directions             | 07.00 - 10.00  | 9608.6      | 52.20                |
|                     |                                            | Directions to Enter the City       | 14.00 - 17.00  | 13840.1     | 103.16               |
| Nox Concentration   | \[N = 46.9-0.036T + 0.00004T^2\]           | Out of Town Directions             | 07.00 - 08.00  | 4615.4      | 732.82               |
|                     |                                            | Directions to Enter the City       | 16.00 - 17.00  | 5410.2      | 1022.94              |
| Smoke Rate          | \[S = 9.49 + 0.022 V\]                    | Out of Town Directions             | 07.00 - 08.00  | 4615.4      | 111.03               |
|                     |                                            | Directions to Enter the City       | 16.00 - 17.00  | 5410.2      | 128.51               |

The reduction of pollution with a change in the length of the bottleneck area from the existing to the standard conditions can be seen as follows:
Table 4 Calculation results the reduction of pollution

| Types of Pollutants | Decline | Percentage reduction |
|---------------------|---------|----------------------|
| CO concentration (ppm) | Out of Town Directions | 8.76 | 14.37% |
|                     | Directions to Enter the City | 18.75 | 15.38% |
|                     | Total | 27.51 | 14.88% |
| Nox Concentration (m³) | Out of Town Directions | 277.94 | 27.50% |
|                     | Directions to Enter the City | 297.87 | 22.55% |
|                     | Total | 575.81 | 25.03% |
| Smoke Rate (m³) | Out of Town Directions | 16.81 | 13.15% |
|                     | Directions to Enter the City | 15.42 | 10.72% |
|                     | Total | 32.23 | 11.94% |

7. Conclusion
The variables that affect traffic performance in the bottleneck area are variable: road lane width, bottleneck area length, and traffic volume. In the study area, the geometric road improvements were carried out by changing the length of the bottleneck area. The length of the bottleneck area in the existing 12 meters was changed to 22 meters. From the results of the redesign of the narrowing area in the study location with performance parameters in the form of a decrease in performance delay from 378.6 sec/pcu in the existing condition to 267.6 sec/pcu for the proposed condition or by 29.31% and a decrease in NoX of 25.03%. Co is 14.88% and the smoke level is 11.94%.

8. Suggestion
For the further studies related to the addition of other candidate variables that affect the performance of the bottleneck area, especially those related to the percentage of heavy vehicles and motorbikes.

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