Effects of Road Shoulder Width and Speed Bump Dimensions on Motorbike Speed Reduction

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Abstract. This study aims to obtain the characteristics of a decrease in motorbike speed before speed bump and a model of the relationship between a decrease in motorbike speed, dimensions of the speed bump and the width of the shoulders on local roads in residential areas. Data collection technique with artificial lines from vehicle recording before passing speed bumps using a Yi-4k action camera. Motorcycle speed data is used to analyse the decrease in speed to be made a mathematical model of the relationship of motorcycle speed, dimensions of speed bumps, and road shoulder width. It can be concluded that the speed bump can reduce the speed up to 72.18% from the average normal speed of the road under study, with decelerate moving from 0.38 m/s² to 0.30 m/s² at a distance of 16 meters before the speed bumps arrive at over speed bump. The model chosen for the relationship of decreasing speed, dimensions of speed bump and shoulder width at a distance of 8 meters before speed bump \((Y_1)\) is \(Y_1 = 13.615 - 0.090X_2 + 0.038X_3\), while at a distance of 16 meters before speed bump \((Y_2)\), chosen equation \(Y_2 = 15.403 - 0.639X_1 + 0.042X_3\), \(R^2 = 0.976\), with \(X_1\) (High Speed bumps), \(X_2\) (Speed bumps width), \(X_3\) (Width of the shoulder), \(Y_1\) (Varea 8 m), \(Y_2\) (Yard) Varea 16 m).

1. Introduction
Factors causing accidents with the highest percentage (93.52%) were drivers who described drivers as being careless, sleepy, unskilled, drunk, high speed and not maintaining distance (Department of Transportation, 1998). A traffic accident is an unexpected and unintentional road event involving a vehicle with or without other road users resulting in human casualties and / or property loss (UU No. 22, 2009). Therefore setting speed limits needs to be done to prevent accidents and fatalities. Speed limitation is very necessary especially on local roads. Speed limit on local roads in residential areas is at a maximum of 30 km / hour (Transportation Minister Regulation No. 111, 2015); (Government Regulation No 79, 2013).

In Indonesia, including Surakarta City, there are many concrete speed bumps installed on local roads. The dimensions of speed bumps installed in the field are very diverse with varying installation distances [1]. Installation without rules by the community is intended to reduce the speed of vehicles passing through the location of their settlements, in order to reduce the potential for accidents. The uncertainty of the size of the speed bump dimension on a particular road size has more impact on causing road user inconvenience.

Research on the influence of speed control devices is carried out among others in the campus, Lampung University, Bandar Lampung which mentions the existence of speed humps which can
reduce vehicle speed. Likewise, in Korea which examined speed control devices by comparing speed humps, speed tables and chicane, the results of which stated that speed humps were only able to reduce speed by around 18% [2]. Different from the results of research conducted in Belgrade, Spain, which examined speed bumps with 3 different dimensions, namely 3 cm, 5 cm, and 7 cm where the result is a decrease in vehicle speed is influenced by the height of speed bumps with the largest percentage of reduction namely for high speed bumps 7 cm can reduce speed by 35% [3]. In the city of Surakarta itself, the relationship of vehicle speed with the dimensions of speed bumps has been analysed, the width of the road on speed bumps results in a significant difference between speed before passing speed bumps and when crossing speed bumps [4]. In Denmark using the method of floating car data (FCD) and Global Navigation Satellite System (GNSS) states that the speed control device in the form of speed humps can reduce speed by 85% from normal speed above speed humps (Agerholm et al, 2017). In Istanbul, Turkey examines the optimal design of speed bumps that can reduce vehicle speed significantly and does not jeopardize road safety, stating that the optimal dimensions are 2.8 cm high by 5 cm wide [5].

This study has similarities with previous studies, namely the variable studied is a decrease in vehicle speed and dimensions (length and width) speed bumps, but no one has included a variable shoulder. The existence of the shoulder of the road influences changes in the speed of vehicles passing on the road [6-8]. Therefore, this study aims to obtain the characteristics of a decrease in motorcycle speed before speed bumps and a model of the relationship between a decrease in motorcycle speed, dimensions of the speed bump and the width of the road shoulder on a local road in a residential area.

2. Method

The study was conducted in 5 locations in Surakarta City (Table 1) with notation \( W \): Width of the Road (m), \( H \): Heigh of Speed Bump (cm), \( B \): Width of Speed Bump (cm), and \( S \): Shoulder Width (Right + Left)/2 (cm). The research location has criteria: asphalt road, located in a residential area, is a local road with a width of ±3 m, has shoulder lanes, and speed bumps installed are made of concrete material. The method used is by recording vehicles, especially motorcycles before passing speed bumps using a Yi-4k action camera that is installed as far as 2 times the value of Perception Reaction Time (PRT). The value of PRT or commonly referred to as PIEV time taken in planning distance and traffic signs is 1 second and this value applies to approximately 90 percentiles [9]. Using the PRT value of 1 second multiplied by the normal speed obtained from a speed survey using a speed gun obtained an average speed at 90 percentile motorbikes that is 34.51 km/h (Table 2), the observation area is 8 m and 2 times the distance is 16 m before speed bumps. Speed data collection area can be seen in Figure 1.d bump and shoulder width on local roads in residential areas.

| No | Road Nama                  | \( W \) | \( H \) | \( B \) | \( S \) |
|----|----------------------------|--------|--------|--------|-------|
| 1  | Jl. Sekar Jagad IV, Pajang | 3.2    | 6.5    | 50     | (60+50)/2 = 55 |
| 2  | Jl. Kampung Kadirejo, Gandekan | 3  | 3.5    | 33     | (30+30)/2 = 30 |
| 3  | JL Kampung Sewu, Gandekan | 3      | 5.5    | 57     | (100+50)/2 = 75 |
| 4  | Jl Parang Kusumo, Sondakan, Laweyan | 2.9 | 3      | 32.6   | (100+100)/2 = 100 |
| 5  | Jl Merapi II, Nusukan, Banjarsari | 3    | 3.85   | 38.3   | (40+30)/2 = 35 |

The data collection technique in this study is the same as the research [10] by using an artificial line from vehicle recording before passing speed bumps using a Yi-4k action camera.
Table 2: Research Sites

| No | Road Name                     | Width of the Road (m) | Height of Speed Bump (cm) | Width of Speed Bump (cm) | Shoulder Width (Right + Left)/2 (cm) |
|----|-------------------------------|-----------------------|---------------------------|--------------------------|--------------------------------------|
| 1  | Jl. Sekar Jagad IV, Pajang JL | 3.2                   | 6.5                       | 50                       | (60+50)/2 = 55                        |
| 2  | Kampung Kadirejo, Gandekan JL | 3                     | 3.5                       | 33                       | (30+30)/2 = 30                        |
| 3  | Kampung Sewu, Gandekan JL Parang Kusumo, Sondakan, Laweyan JL Merapi | 3 | 5.5 | 57 | (100+50)/2 = 75 |
| 4  | Jl Parang Kusumo, Sondakan, Laweyan JL Merapi | 2.9 | 3 | 32.6 | (100+100)/2 = 100 |
| 5  | Jl Merapi II, Nusukan, Banjarsari | 3 | 3.85 | 38.3 | (40+30)/2 = 35 |

Figure 1: Observation Area
as shown in Figure 2. Provision of artificial lines is done to obtain vehicle time data while on the artificial line which is then processed to obtain motorcycle speed data at each location. This motorcycle speed data is then used to analyze the decrease in speed and is modeled to find a mathematical model of the relationship of motorcycle speed, dimensions of speed bumps, and shoulder width.

### 3. Results and Discussions

#### 3.1. Decreasing Speed and Deceleration

Characteristics of motorcycle speed reduction in approaching speed bump in 5 research locations can be seen in Table 2. Vehicle speeds that occur in the area of 16 meters before speed bump can reduce the speed from the average normal speed of 34.51 km/h to 15.03 km/h (56.45%). The average speed that occurs above the speed bump is 9.60 km/h, which means it can reduce the speed by 72.18% from the average normal speed of the road under study. From the speed condition data, it can be calculated the vehicle deceleration when approaching the speed bump shown in Table 3. The slowing of the car that occurred on the road on the study location when approaching the speed bump is around 0.38 m/s\(^2\) to 0.30 m/s\(^2\). With the highest deceleration when approaching the point 16 meters from the speed bump and the lowest at a distance of 8 meters from the speed bumps.

From the data in Table 4, a correlation test was performed to determine the value of the relationship between the variables before then a regression analysis was performed to obtain the model, the results of the correlation test analysis can be seen in Table 6. The dependent variable was used, namely the speed at the distance of the "PRT" of 8 m before the speed bumps then given a name (\(Y_1\)) and a distance of \(2 \times \text{PRT}\) which is 16 m before the speed bumps which are then named (\(Y_2\)). The independent variables are the dimensions of height speed bumps (\(X_1\)),
width of speed bumps ($X_2$), and shoulder width of road ($X_3$).

From Table 5 it was found that a strong correlation was seen in the independent variable shoulder width ($X_3$) with the dependent car speed variable at a distance of 8 m ($Y_1$) and 16 ($Y_2$) before speed bumps with correlation values of 0.661 and 0.794. The high correlation between the
dependent variable and the independent variable shows the potential of the model which is quite feasible to be followed up. From the correlation analysis it was also found that the independent variables of the height of the speed bumps ($X_1$), and the speed and width of the speed bumps ($X_2$) with the dependent variable car speed at a distance of 8 m ($Y_1$) had a moderate relationship with the correlation of -0.536 and -0.564 and the dependent variable the speed of the car at a distance of 16 m ($Y_2$) is -0.628 and -0.429. A moderate relationship still has enough potential to be followed up as a model. In other cases, a high correlation (0.884) between the independent variable $X_1$ (high speed bump) and $X_2$ (wide speed bump), indicates that both have a large mutually influential correlation in terms of speed reduction, so that the model has the potential for only one variable to appear in the final model to be chosen.

The results of the regression analysis carried out using the data in Table 4, obtained a model of the relationship of speed reduction with the dimensions of speed bumps and the width of the shoulder of the road looks like in Table 6. The model obtained shows the variables $X_1$ (High Speed bumps), $X_2$ (Width Speed bumps), and $X_3$ (width of the shoulder of the road) affect the dependent variable $Y_1$ ($V$ area 8 m) and $Y_2$ ($V$ area 16 m) where the value of $R^2$ > 0.5. For the next discussion, we will discuss models obtained at a distance of 8 meters and a distance of 16 meters, as well as models with large values of determination which are all at a distance of 16 meters.

From the results of the regression analysis that has been delivered solidly in Table 6, it is obtained that at a distance of 8 meters before the speed bump ($Y_1$), the model with the largest determination value ($R^2$) is obtained from the equation $Y_1 = 13.615 - 0.090X_2 + 0.038X_3$, $R^2$ equal to 0.873, which it means that 87.3% decrease in motorcycle speed that occurs can be represented by variable width speed bumps and road shoulder width. At a distance of 16 meters before the speed bump ($Y_2$), the equation $Y_2 = 15.403 - 0.639X_1 + 0.042X_3$ is chosen with the $R^2$ value of 0.976, which means that 97.6% decrease in speed can be represented by variable height of speed bumps and shoulder width.

It can be seen from the model obtained, at $Y_2$ (distance of 16 meters before speed bump) the high dimension ($X_1$) has more influence on the decision to decrease the speed that occurs because, this condition is possible because the high dimension is more captured by the driver’s senses at a distance of 16 meters. Unlike the model with the dependent variable $Y_1$ (distance of 8 meters before speed bump), it turns out that the dimension of the speed bump width ($X_2$) is more influential. This is possible at a distance of 8 meters before the speed bump, the driver’s senses capture the width variable rather than height, although the value of the variable representation (determination) obtained tends to decrease.

Of the two models that have the highest determination value, both at $Y_1$ and $Y_2$, both of them have a free variable shoulder of the road with a positive value, which means the wider the shoulder of the road will further increase the speed of the vehicle that occurs. This shows that the existence of the shoulder of the road is very important to be considered for the desired speed reduction at a location even though there is a speed control device in the form of a speed bump. This is consistent with the results of the study (Liu, S., Wang, J., & Fu, T., 2016), which states

| No | Regression analysis results | $R^2$ |
|----|-----------------------------|------|
| 1  | $Y_1 = 12.404 - 0.501X_1 + 0.032X_3$ | 0.689 |
| 2  | $Y_1 = 13.615 - 0.090X_2 + 0.038X_3$ | 0.873 |
| 3  | $Y_2 = 15.403 - 0.639X_1 + 0.042X_3$ | 0.976 |
| 4  | $Y_2 = 15.606 - 0.081X_2 + 0.048X_3$ | 0.925 |
that the width of the shoulder of the road positively affects speed. The effect of road shoulder width on speed affects the speed of the vehicle on the left lane but does not affect the vehicle speed at the centre of the lane. Testing was done with the results and participants were driving very fast on the road with a large shoulder width of the road. Wide shoulders provide a safe perception of the driver and reduce the proposition of dangerous displacement, for example, the driver crosses lanes. Likewise (Ben-Bassat, T., & Shinar, D., 2011) who conveyed the results of the study that the width of the road shoulder significantly influences the actual speed, lane position and driving speed.

4. Conclusion

From the results of the analysis and discussion it can be concluded: Speed bump can reduce speed up to 72.18% from the average normal speed of the road under study, with deceleration from 0.38 m / s² to 0.30 m / s² at a distance of 16 meters before the speed bumps up to above speed bump. The model chosen for the relationship of speed reduction, speed bump dimensions and shoulder width at a distance of 8 meters before speed bump (Y₁) is \[ Y_1 = 13.615 - 0.090X_2 + 0.038X_3, \] with \( R^2 = 0.873 \), while at a distance of 16 meters before speed bump (Y₂), chosen equation is \[ Y_2 = 15.403 - 0.639X_1 + 0.042X_3 \] with an \( R^2 \) value of 0.976. With \( X_1 \) (High Speed bumps), \( X_2 \) (Width Speed bumps), \( X_3 \) (Width of the shoulder), \( Y_1 \) (Varea 8 m), \( Y_2 \) (Varea 16 m). This model applies to high speed bumps of 3.0 - 6.5 cm and road shoulder widths of 30 - 100 cm on road width ± 3 m.

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