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Analysis of the Effect of Road Damage Conditions on Vehicle Speed (Case Study of Road Sections in Tanjungbalai City)

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Abstract

Economic growth and technological advancements have increased mobility in various aspects of life, with land transportation being the primary choice for daily activities. In this context, the availability of good road infrastructure is crucial for ensuring the smooth operation of transportation systems. The condition of road pavement is a key factor that influences how efficiently the system operates, as poor pavement conditions can lead to longer vehicle travel times. A comprehensive analysis can help identify specific components that contribute to changes in road conditions over time. According to the Road Law (2004), public roads are classified based on their function into arterial roads, collector roads, local roads, and environmental roads, each with different characteristics in terms of travel distance and average speed. Road damage is generally divided into structural damage, which occurs when the pavement can no longer support traffic loads, and functional damage, which compromises the safety and comfort of road users, thereby increasing operational costs. Several factors contributing to road pavement damage include increased traffic loads, poor drainage systems, construction materials, unstable subgrade conditions, and Indonesia's tropical climate, characterized by high air temperatures and rainfall. Research conducted in Tanjung Balai City shows a correlation between road pavement conditions and vehicle speed; as pavement conditions deteriorate, vehicle speeds decrease. The results indicate a significant relationship, with an R2 value of 0.92, meaning a 92 percent correlation.

Keywords: *Vehicle Speed, Travel Time, Road Pavement*

1. INTRODUCTION

Along with economic growth and technological advances, people's mobility in various areas of life increases. Land transportation is the main choice for many people and businesses to carry out daily activities. In circumstances like this, the availability of good road infrastructure is very important to ensure the transportation system operates smoothly.

The condition of the road pavement is an important factor that influences how smoothly the transportation system runs. Road pavement, as the main structure of highways, is very important to provide travel comfort and stability. Road infrastructure policy and planning relies on a deep understanding of how road pavement conditions affect vehicle travel times; Poor pavement conditions can cause many problems, such as longer vehicle travel times. Comprehensive analysis can help find specific components that contribute to changes over time. Jalan SMA 3.

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Understanding the Road

A road is a means of land transportation that covers all parts of the road, including supporting structures, which are on the ground surface, above the ground surface, below the ground surface and above the water surface, except for railways and cable roads (Regulation of the Director General of Land Transportation regarding technical maintenance of complementary roads article 1, 2017).

Benefits of the Road

Based on the road law on roads (2004), public roads according to their function are divided into arterial roads, collector roads, local roads and environmental roads as follows:
Arterial roads are public roads that function to serve the main transportation with the characteristics of long-distance travel, high average speed, and the number of access roads is limited in an efficient manner.
Collector roads are public roads that function to serve collector or share transportation with the characteristics of medium distance travel, medium average speed and limited entry limits.
Local roads are public roads that function to serve local transportation with the characteristics of short distance travel, low average speed, and an unlimited number of access roads.
Environmental roads are public roads that function to serve environmental transportation with the characteristics of short distance travel and low average speeds (Silvia S, 2015).
The differences in road function are in the primary road network, so roads can be further differentiated into primary arterial, primary collector and primary local roads. In accordance with Minister of Public Works Regulation No 03/PRT/M/2021, road functions in the primary road network system and secondary road network system can be differentiated as in table 1

Table 1. Road Function in the Road Network System

Primary network system	Secondary network roads
Primary arterial road	Secondary arterial road
Primary collector road-1	Secondary collector road
Primary collector road-2	
Primary collector road-3	
Primary collector road-4	
Primary local road	Secondary local roads
Primary neighborhood road	Secondary neighborhood road

Source: Minister of Public Works Regulation No. 03, 2012

C. Road Classification
Based on government function and administration, road classification is as follows:

a. National roads are arterial roads and also collector roads that connect two provincial capitals and toll roads.

b. Provincial roads are collector roads that connect the provincial capital with the district/city capital, or between the capital of one district/city and the capital of another district/city.
c. Regency roads are local roads in the primary road network system which do not include roads connecting the district capital with the sub-district capital, between sub-district capitals, district capitals and local activity centers, between local activity centers, as well as public roads in the secondary road network system within the district area, and district strategic road.
d. City Roads are highways that connect service centers within the city,
e. Village roads are public roads that connect areas and/or between one settlement and another in a village. [DGH, 1990)

D. Road Damage

Road damage is caused, among other things, by excessive repetitive traffic loads, heat or air temperature, water and rain, as well as poor initial product quality. Routine and periodic road maintenance needs to be carried out to maintain road safety and comfort for users and maintain its durability until its design life. (Suwardo and Sugiharto, 2004).

Types of Road Damage

Broadly speaking, damage is divided into two parts, namely:
Structural damage includes pavement failure or damage to one or more pavement components resulting in the pavement no longer being able to accommodate traffic loads.
Functional damage results in the safety and comfort of road users being disrupted so that operational costs increase. (Sihombing, A. T., 2021).

Factors Causing Road Damage

According to Sukirman (1992), damage to road pavement construction can be caused by several factors as follows:
Traffic, which can take the form of load increases and load repetitions
Water, which can come from rainwater, poor road drainage systems and rising water due to capillarity.
Pavement construction materials, this factor can be caused by the nature of the material itself or can also be caused by a poor processing system.
Climate, Indonesia has a tropical climate where air temperatures and rainfall are generally high which is one of the causes of road damage;
Unstable subgrade conditions, this factor may be caused by a poor implementation system or it could also be caused by poor subgrade.
The process of compacting the layer above the base soil is not good.

E. Road Pavement

Definition and Function of Road Pavement

Road pavement is a part of a highway that is hardened with asphalt aggregate or cement (Portland Cement) as a binding material so that a certain construction layer, which has a certain thickness, strength and stiffness, as well as stability, is able to distribute the traffic load above it to the subgrade safely. The main function of the pavement itself is to spread

or distribute the wheel load over a surface area of the subgrade that is wider than the contact area of the wheel with the pavement, thereby reducing the maximum stress that occurs in the subgrade. Pavement must have the strength to support traffic loads. The surface of the pavement must be flat but must have hardness or skid resistance on the surface of the pavement. Pavement is made from various considerations, such as: structural requirements, economy, durability, convenience, and experience (Hardiyatmo, 2007).

Types of Road Pavement

Types of road pavement based on binding material

According to Sukirman (1992), based on the binding material, road pavement construction can be divided into:

Flexible pavement construction (Flexible Pavement), namely pavement that uses asphalt as a binding material. The pavement layers carry and spread the traffic load.

Rigid pavement construction (Rigrid Pavement), namely pavement that uses cement (Portlan Cement) as a binding material. Concrete slabs with or without reinforcement are placed on the subgrade with or without a sub-base layer. Most of the traffic load is borne by the concrete slab.

Composite pavement construction (Composite Pavement), namely rigid pavement combined with flexible pavement, can be in the form of flexible pavement over rigid pavement, or pavement over flexible pavement in the field.

Road Pavement Evaluation Criteria

There are 19 types and levels of road damage, according to Shahin (1994). These include alligator cracking, bleeding, block cracking, bums and sags, corrugation, depression, edge cracking, join reflection, lane/shoulder drop off, longitudinal and transverse cracking, rutting, shoving, slippage cracking, swell, weathering, and raveling.

Treatment without damage evaluation will be ineffective because identification of pavement damage requires looking at the source of the damage as the cause. Otherwise, it will not be able to carry out proper repairs. To achieve this goal, it is necessary to carry out surveys and inspections of damage to identify pavement conditions and create appropriate solutions for handling road damage.

F. Vehicle Speed

Definition and Factors that Influence Vehicle Speed

Speed

A movement to move from one place to another requires effort, but also requires speed. Vehicle speed is the average distance that can be traveled by a vehicle on a road section in a certain unit of time (Hobbs, 1995). The influence of speed, especially on vehicles, is the behavior of drivers who adjust the speed of the vehicle on a road section to travel at a certain speed. Generally there is a difference in vehicle speed. The difference in vehicle speed can be divided into:

Local speed, namely instantaneous speed. This speed is obtained from measurements on a road section using a radar system. One of these radar tools is a radar gun.

Average local speed, namely the average local speed at the same place.

Space average speed, namely speed which is generally measured by aerial photography.

Travel speed, namely the speed measured by the distance traveled, which includes the time the vehicle stops and the time the vehicle slows down.
Average travel speed, namely the average value of travel speed.
Travel speed, namely speed that is like travel speed, but in calculating travel time, movement speed is taken into account when the vehicle is moving.
Average movement speed, namely the speed of the average value of movement speed.
Design speed, which is used in planning road sections or road geometrics.

According to Hobbs, FD (1995) speed is generally divided into 3 types, namely:
Instantaneous speed (spot speed) is the speed of a vehicle at a time measured from one place.
Running speed is the average vehicle speed in a lane when the vehicle is moving, which is calculated by dividing the length of the lane divided by the length of time the vehicle travels along that lane.
Travel speed is the effective speed of a vehicle moving between two places.
The average traffic flow speed (km/hour) is calculated by dividing the length of the road section divided by the average vehicle travel time (MKJI).

$V = \frac{s}{(t2-t1)}$ ……………………………………………………………… 1

The average speed is obtained by adding up the speed for a certain period of time and dividing it by the amount of data used, as in the following equation:

$V \text{ average} = \frac{v1+v2+vn}{n}$ …………………………………………... 2

a vehicle on a road section in a certain unit of time.

V=TTL ……………………………………………………………. 3

Where:
V = Average speed of LV space (km/h)
L = Segment length (km)
TT = Average LV travel time throughout the segment (hours)

Free Flow Speed

Free flow velocity (FV) is defined as the speed at zero flow level. Free flow speed has been observed through field data collection where the relationship between free flow speed and geometric conditions and environmental conditions has been determined using the regression method. The free flow speed of light vehicles has been chosen as the basic criterion for the performance of a road segment at a flow equal to zero (= 0). Free flow speeds for heavy vehicles and motorbikes are also given as a reference. The free flow speed for passenger cars is usually 10-15% higher than for other types of light vehicles. The equation for determining the free flow speed has the following general form:

FV = (FVo + FVW) x FFVSF x FFVCS ……………………………… 4

Where:
FV = Free flow speed of the vehicle in field conditions (km/hour)
FVo = Basic free flow speed of vehicles on the observed road
FVW = Speed adjustment factor for road width (km/hour)
FFVSF = Speed adjustment factor for side obstacles and shoulder width or barrier carriage distance
FFVCS = Speed adjustment factor for city size

G. Regression Analysis

Statistical regression analysis examines the causal relationship between certain variables and other variables. The "causal" variable is referred to by various terms, such as explanatory variable, explanatory variable, dependent or independent variable, and independent variable X (which is represented by the horizontal axis or X in the graph). The affected variable is also referred to as the affected variable, dependent variable, or Y variable, and both of these variables can be random, but the assigned variable must always be a random variable. This research uses regression analysis, which is one of the most widely used analyses. You could almost say that regression analysis can be used in almost any field of science. These correlations are associated with each regression, but are not always associated with the regression. If the correlation between two variables does not have a causal or functional relationship, then correlation is not necessary

Simple Linear Regression Analysis

According to Yusra, C., Isya, M., & Anggraini, R. (2018), linear regression analysis is an analysis of the dependence of a variable called the dependent variable on another variable called the independent variable. Regression analysis can be used to calculate the magnitude of the influence of a change in one variable on other variables.

Linear regression can also form a linear relationship between the independent variable and the dependent variable. In simple regression analysis, the dependent variable Y depends only on one variable, whereas in multiple regression, the dependent variable Y depends on two or more independent variables X. The regression line is the line X that connects the average of Y and all possible values. X is a variable whose value can be determined, and the dependent variable Y is the result of changes in the independent variable. The general form of a simple regression equation is:

$Y i = \beta 0 + \beta 1 X i + \varepsilon i ; i = 1,2, \ldots\ldots\ldots, k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$

Where

$Y i$ = Dependent variable for the ith observation
$\beta 0$ and $\beta 1$ = Regression model parameters
Xi = ith independent variable
εi = Residual

2. METHOD

Authors use this type of quantitative research, which usually consists of two research designs: survey or experiment. In this research, the author used a survey design using direct observation methods in the field to assess road damage and vehicle speed on several roads in the research location, namely Tanjung Balai City.

A. Research Procedures

The procedures carried out in this research were carried out by implementing several steps, the research steps are as follows:

Preliminary Survey

To find out the situation in the field, a preliminary survey must be carried out. The things that need to be done and paid attention to in the preliminary survey are:

1. processing permits or notification/coordination with local road builders,
2. observation and determination of survey posts,

3. recruitment/mobilization of personnel/survey officers,
4. training for survey officers, as a provision in survey procedures.

Data Collection Survey
This data collection includes primary data regarding asphalt road damage and vehicle speed. Primary data is obtained from direct surveys in the field and recorded by surveyors according to time, location and type of damage. Recording was carried out on several roads in Tanjung Balai City.

Analysis of Average Vehicle Speed Calculations
Speed is the average distance that can be traveled by a vehicle on a road section in a certain unit of time. In this study, the length of the observation section of 500 m was used. By obtaining the travel time and travel distance, the travel speed of a vehicle can be calculated by looking at formula (2) (Wirnanda, I., Anggraini, R., & Isya, M., 2018).

Analysis Prerequisite Test
1. *Normality Test*
The normality test is used to determine whether the data distribution for each variable is normally distributed or not. If the significance value of each variable is greater than 0.05 or 5%, then the research variable is considered to be normally distributed, whereas if the value is lower than 0.05 or 5%, then the research variable is considered not to be normally distributed. If the data distribution is normal, data analysis can continue (Purnomo, A., 2017). Normality test used the Kolmogorov-Smirnov test and SPSS program analysis.

2. *Linearity Test*
Linearity calculations are used to determine whether the independent variable data predictor is related to the dependent variable linearly or not. The purpose of the linearity test is to determine whether there is a linear relationship between two variables. To test linearity, variance analysis is applied to the regression line, and the calculated F value is consulted with the F table at the 5% level. The relationship between the two variables is considered linear if the calculated F value is smaller than the table F value, and vice versa, the relationship between the two variables is not linear. This calculation was carried out using SPSS.

Simple Regression Analysis
In this analysis, the effect of road damage on vehicle speed is studied. Equation (5) was obtained using the SPSS program. The values of the correlation coefficient (R), coefficient of determination (R), ANOVA, and hypothesis t are sought.

3. RESULTS AND DISCUSSION

The results of observations of vehicle speeds at the study location can be seen in the following table.

Table 2. Average speed on each road section

No	Research Location Road Section	Average Speed (km/hour)
1	Husni Thamrin	25
2	SMA 3	24.82
3	Prof, Dr, Ir. Sutami	17.21
4	Abd Rahman	21.25

Source: Researcher Analysis Results, 2024

To determine the relationship between road pavement conditions and vehicle speed, ANOVA test analysis is needed. Pavement condition results for each road section are included in this analysis, and pavement condition data are taken from previous research, as shown in table 3.

Table 3. Assess the condition of the road pavement on each road section

No	Research Location Road Section	PCI Road Pavement Condition Value (%)
1	Husni Thamrin	39
2	SMA 3	37.25
3	Prof, Dr, Ir. Sutami	73.25
4	Abd Rahman	60.75

Source: Alexander TS & Rifqy A, 2022

Using SPSS software, analysis was carried out to determine the relationship between road pavement conditions and vehicle speed. The results can be seen in the following table.

Table 4. Results of Analysis of the Relationship between Road Pavement Conditions and Vehicle Speed

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.438 a	.92	-.212	266,002

The R 2 (R Square) obtained was 0.92. This means that the relationship between road damage and travel speed is 92%. From the graph of the relationship between the level of road damage and speed, it can be concluded that the higher the level of damage, the more influence it will have on vehicle speed.

4. CONCLUSION

The research results show that the condition of the road pavement at the study location in tanjung balai city is correlated with vehicle speed; if the road pavement condition is poor, the vehicle speed decreases. The results, namely an r2 value of 0.92, or a significant relationship of 92 percent, show this.

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