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Testing of Ultrasonic Sensor Components on the "Ultrasonic Surface Rough Meter" Prototype

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Based on Government policies that continue to encourage increased use of domestic products (P3DN) and enlarge the level of domestic components (TKDN) to realize the independence of the domestic industrial sector, we are trying to make an instrument that will be implemented to determine the level of road damage, with accelerometers, ultrasonic sensors and GPS which become a unit in the instrument that we will make under the name "Ultrasonic Surface Rough meter". To find out the success of the prototype product "Ultrasonic Surface Rough meter" carried out various tests and one of them was the prototype component test "Ultrasonic Surface Rough meter" which consisted of ultrasonic sensor component tests, accelerometer component tests and Global Positioning System (GPS) tests and here only focused on ultrasonic sensor tests. The results of vertical distance measurements using the prototype "Ultrasonic Surface Rough meter" carried out by statistical analysis on all tests using ultrasonic sensors can be said to be "Valid and correct".
Keywords: roughness meter; IRI; road maintenance; Descriptive Statistics.

1. Introduction

Roads are a form of transportation infrastructure with all its equipment above or below the surface, which is part of traffic, including above or below the water surface except railway tracks and so on. Meanwhile, roads play an important role in realizing balanced inter-regional development and for equitable distribution of results and maintaining national stability and security in order to realize national development.(Irianto and Reny Rahmawati, 2020).(Pemerintah Republik Indonesia, 2004)

To see road conditions is to calculate the cumulative length of road surface fluctuations per unit length, which can be referred to as the value of road surface unevenness, or better known as the International Roughness Index (IRI). Mathematically, the IRI is the ratio between the cumulative length of damaged/potholed roads (in m) to the total road length (in km). So, the greater the IRI value (in units of m / km), the worse the condition of the road surface. Based on PUPR Open Data that in 2022 the surface condition of National Roads is Good Condition 17684.25km 37.65%, Medium Condition 25616.80 km 54.55%, Light Damaged Condition 2556.95 km 5.44%, Heavily Damaged Condition 1105.96 km 2.35% and Total Length 46963,960 km(Direktorat Jenderal Bina Marga, 2023)

To be able to see road conditions, a tool is needed to be used to measure these conditions and in Pd-01-2021-BM it is also stated that the IRI measuring instruments used are divided into four classes based on the level of accuracy, namely: Class 1 precision profilometers, examples of Hawkeye laser profilers. While profilometer devices both APL, optics and inertia are categorized as Class 2, while the Class 3 category is, Rough meter, rolling straightedge. Class 4 subjective assessment/measurement without calibration, an example of visual inspection with Road Condition Index (RCI) method according to PUPR Regulation No. 13/PRT/M/2011. (Menteri Pekerjaan Umum, 2011; Nyoman Suaryana, 2021)

Based on Government policies that continue to encourage increased use of domestic products (P3DN) and enlarge the level of domestic components (TKDN) to realize the independence of the domestic industrial sector, we are trying to make an instrument that will be implemented to determine the level of road damage, with accelerometers, ultrasonic sensors and GPS which become a unit in the instrument that we will make under the name "Ultrasonic Surface Rough meter".

The main objective of the "Ultrasonic Surface Rough meter" prototype is to improve the design of the "Ultrasonic Surface Rough meter" model into a device that can meet user demands, and users can participate in the process specially to participate in evaluating and feedback. Feedback and ideas provided by users will be useful to add features that complement the tool "Ultrasonic Surface Rough meter".

To find out the success of the prototype product "Ultrasonic Surface Rough meter" carried out various tests and here focuses on the prototype component test "Ultrasonic Surface Rough meter" which consists of ultrasonic sensor component tests, accelerometer component tests and Global Positioning System (GPS) tests and here only focuses on ultrasonic sensor tests.

2. Literature Review

The IRI is a standard that represents the length profile of roads and measures the roughness of the road surface. The calculation of roughness involves the cumulative number of surfaces rising and falling along the profile, which is then divided by the surface length (For Testing and Material’s, 1998) [5]. Tools such as rough meters are one of the instruments used to calculate the level of unevenness on the road surface (Irianto and Reny Rahmawati, 2020) (Sayers, 1995).

From several references to previous research, both national and international, it can be seen that there are various kinds of methods and equipment, both very simple such as visual methods more complex methods such as using Mobile Laser Scanner surveys which are definitely expensive both in operation and maintenance. Some things that can be underlined are that from all the results of these studies no one has developed a prototype of a road surface unevenness measuring instrument that uses ultrasonic sensors for models or prototypes of road surface unevenness measuring instruments. (Suwardo and Heru Budi Utomo, 2020)(Sayers, Gillespie and Paterson, 1986).

Prototype Ultrasonic Surface Rough meter which has been designed and designed using the HC-SR04 Ultrasonic Sensor and combined with Arduino Due which is a microcontroller board based on Atmel SAM3X8E ARM Cortex-M3 CPUs. The workings of the Ultrasonic sensor in the Ultrasonic Surface Rough meter instrument are as follows, first of all the ultrasonic transmitter emits a signal with a frequency of 340 kHz, the signal propagates as a wave with that speed and frequency will hit the object or object and then the signal will be reflected. The reflected signal will be captured by the ultrasonic receiver and will be processed and calculated the distance of the object to the ultrasonic tool.

3. Research Method

Analysis of ultrasonic sensor Test Data used descriptive statistical methods that have the aim to describe or illustrate the results of ultrasonic sensor Test Data. One method of description involves a form of numerical measurement obtained from the results of processing ultrasonic sensor Test Data. To calculate the value of ultrasonic sensor Test Data using descriptive statistical analysis, with the following formula:

Average (Mean)

What is meant by Mean is the average of the total number of data values divided by the amount of data (Dr. H. Mundir, 2012)(Dr. Molli Wahyuni, 2020).

$$x = \frac{\sum i}{\eta} \qquad 1$$

Information:

x = Average rating

$\sum i$ = Number of data values i

η = Lots of data

To speed up calculations using the AVERAGE function, which is one of the Microsoft Excel functions used to calculate the average of a group of argument values given to some cell or range of data. Examples of its use are as follows

= AVERAGE (number1, [number2], 2

The Middle value (Median)

The median is the midpoint of the entire data. Therefore, 50% of data that are below or equal to that value and there are 50% more data that are above or equal to the data.(Hogg, McKean and Craig, 2019) (Dr. Molli Wahyuni, 2020).

The median formula for n is even $Me = \frac{x_{\frac{n}{2}} + x_{\frac{n}{2}+1}}{2}$ 3

The median formula for n is odd $Me = x_{\frac{n+1}{2}}$ 4

Information:

Me = Median

x = Date as of –

n = Total number of frequencies

To speed up calculations using the MEDIAN () function in Microsoft Excel is to return or generate "statistical" median or middle value from a series of values provided. The MEDIAN function () is one of the functions defined (built-in function) and belongs to the category of statistical functions of Microsoft Excel. Examples of its use are as follows:

= MEDIAN (number1, [number2], ...) 5

Frequently appearing values (Mode)

Mode is a term in statistics that refers to the value that appears most often or has the highest frequency of occurrence(Larose and Freeman, 2014) (Dr. Molli Wahyuni, 2020). To speed up calculations using the MODE () function in Microsoft Excel (TeachUcomp, 2012). Examples of its use are as follows:

= MODE (number1, [number2], ...) 6

Standard Deviation

Standard deviation (Ion POHOAȚĂ et al., 2023) is a value that indicates the degree or degree of variation of a group or standard measure of deviation from its mean.(Dr. Molli Wahyuni, 2020; Ruwah Ibnatur Husnul et al., 2020).

$$\sigma = \sqrt{\frac{\sum x^2}{n} - \left(\frac{\sum x^2}{n}\right) 2^2} \quad 7$$

Information:

σ = Standard deviation

n = Number of samples

x = average

To speed up calculations using the STDEV Function. P () in Microsoft Excel, Examples of its use are as follows:

= STDEV.P(number, [number2], ...) 8

Variance or Sample Variance

Variance is a function to determine the level of spread or variation of data. The symbol of Population variance is σ^2 or s^2. (Larose and Freeman, 2014)(Dr. Molli Wahyuni, 2020).

$$s^2 = \sigma^2 \quad (9)$$

Information:

s^2 = Varian's sample

X_i = The Data i

Me = Sample average

n = Number of samples

To speed up the calculation using the VAR Function. P () in Microsoft Excel, examples of its use are as follows:

= VAR.P(number1, [number2], ...) 10

The Range Difference

Range difference is the difference between the largest value and the smallest value in a data group (Larose and Freeman, 2014) (Dr. Molli Wahyuni, 2020).

$$R = X_{max} - X_{Min}. \quad (11)$$

Information:

R = range difference

X_{max} = greatest value

X_{min} = smallest value

To speed up calculations using MAX () Function and MIN () function in Microsoft Excel, examples of their use are as follows:

= MAX (number1, [number2], ...) – MIN (number1, [number2], ...) 12

Confidence Interval with Confidence Level 95%

A confidence interval (CI) is a range of values used to estimate population parameters with a certain confidence level, usually 95% or 99%. In statistics, CI is used to determine the boundary at which the value of a population parameter is likely to be, based on the sample data we have. The confidence interval provides information about how accurate our estimates are against population parameters as well as the possible variations in those estimates.(Dr. Molli Wahyuni, 2020).

$$CI = Me \pm z \left(\frac{\sigma}{\sqrt{n}}\right) \quad (13)$$

Information:

CI = Confidence interval

z = Confidence Level Value

σ = Population

s = Sample

n = Sample size

Correlation

Correlation is a reciprocal or causal relationship, which is used for the strength of relationships between variables and a way to find out whether there is a relationship between variables with analysis.

By using the Pearson Product Moment Correlation (PPM) equation assuming: the sample is taken randomly (random), the data of each variable is normally distributed, a form of linear regression, and used for interval / ratio data(Hogg, McKean and Craig, 2019). They are as follows:

$$R\,xy = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}} \quad 14$$

(Hogg, McKean and Craig, 2019)

To speed up the calculation using the Difference from the CORREL () function in Microsoft Excel is to calculate the correlation value of two variables. Examples of its use are as follows:

= CORREL (array 1, array 2) 15

Consistency

Data consistency refers to uniform, accurate, and coherent data quality across different databases, systems, and applications within an organization. By using the following formula:

$$Cu = \frac{\sqrt{\sigma}}{x} < 5\,\% \quad 16$$

Where: Cu is the correlation, σ is the standard deviation and x is the mean value.

Another way is to use Cronbach's alpha which is a measure of internal consistency, which is how closely related a set of items are as a group. It is considered a measure of scale reliability. Which is formulated as follows:

$$\alpha = \frac{n * x}{s + (n-1) * x} \quad 17$$

where α is Cronbach's alpha, n is the amount of data, x is the average value and s is the variance value (Larose and Freeman, 2014)(Hogg, McKean and Craig, 2019).

Cronbach's Alpha value greater than 0.9 Internal Consistency is called "Excellent", Values between $0.8 \leq \alpha < 0.9$ are called "Good", values $0.7 \leq \alpha < 0.8$ are called "Acceptable", values $0.6 \leq \alpha < 0.7$ are called "Questionable", values $0.5 \leq \alpha < 0.6$ are called "Poor" and values below 0.5 are called "Unacceptable". (Hogg, McKean and Craig, 2019).

4. Result and Discussion

Measuring objects under the Ultrasonic Surface Rough meter, with different treatment of measured objects and measuring instruments. Measurements were carried out as many as 15 treatments with the number of data collection as many as 100 times in each treatment and compared with the measurement results with standard length measuring instruments, namely rulers / bars. The conditions of the treatment of objects and measuring instruments carried out are as shown in the table below:

Table 1. Conditions for treating objects and measuring instruments Ultrasonic Surface Rough meter

No	Description	Object	Object Treatment	Tool Treatment
1	Data 1	Point		Not moving
2	Data 2	Point		Not moving
3	Data 3	Point		Not moving
4	Data 4	Point	Added water 2.9 cm	Not moving
5	Data 5	Point		Not moving
6	Data 6	Line		Horizontal moves
7	Data 7	Line		Horizontal moves
8	Data 8	Line		Horizontal moves
9	Data 9	Line		Horizontal moves
10	Data 10	Line		Horizontal moves
11	Data 11	Line		Horizontal moves
12	Data 12	Line	Added water 2.9 cm	Horizontal moves
13	Data 13	Line	Added water 2.9 cm	Horizontal moves
14	Data 14	Line	Added water 2.9 cm	Horizontal moves
15	Data 15	Line	Added water 2.9 cm	Horizontal moves

The object being measured is a stationary point and the Ultrasonic Surface Rough meter measuring the instrument is also stationary, while the standard instrument measurement result is 17.5 cm (look at the image below).

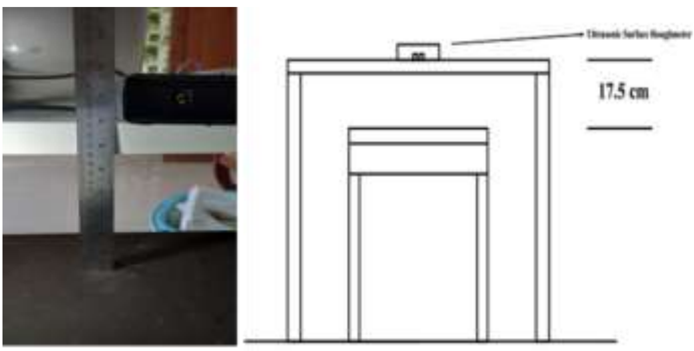

Figure 1. Image of the measured object from the object to the Ultrasonic Sensor on the Ultrasonic Surface Rough meter, Instrument

The measurement results in the Data 1 treatment are seen in the picture below

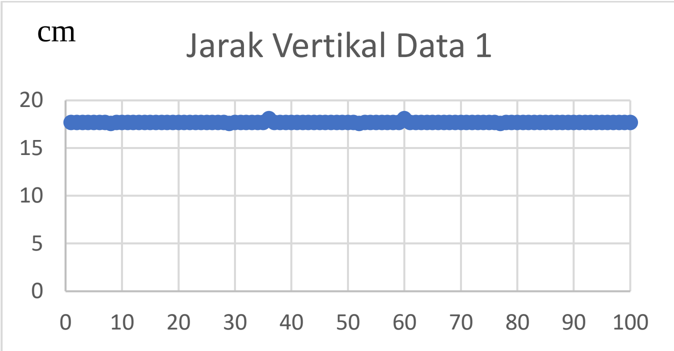

Figure 2. Graph of measurement results with The Ultrasonic Surface Rough meter, Instrument

Table 2. Descriptive Statistical Value of Ultrasonic Surface Rough meter, Tool Test on Data 1

No	Descriptive Statistics	Value
1	Average (Mean)	17.6944
2	Middle value (Median)	17.7
3	Frequently appearing values (Mode)	17.7
4	Standard Deviation	0.063927
5	Variance or Sample Variance	0.004128
6	Range Difference	0.53
7	Minimum	17.58
8	Maximum	18.11
9	Confidence Level	97%
10	The Correlation of Vertical Distance with difference	100.00%
11	Consistency	1.43%
12	Cronbach's alpha	1.00

From Table 2 it can be seen that the results of Descriptive Statistical Analysis in Test 1 of vertical distance measurement with The Ultrasonic Surface Rough meter obtained a Confidence Level of 97% which shows a confidence level above 90%, Vertical Distance Correlation with a difference of 100.00% which means that the results of Vertical Distance measurement data with differences have a strong relationship, and the Consistency value < 5% means that it can be said to have a level of "consistent" and Cronbach's alpha of "1.00" so it can be categorized under Excellent Internal consistency. With the results of Descriptive Statistical Analysis, it means that the results of vertical distance measurements in Test 1 can be said to be "Valid and correct".

The results of Descriptive Statistical analysis on Test Data 1 to Test Data 15 are in Table 3 below.

Table 3 Recapitulation of Descriptive Statistical Values Test of Ultrasonic Surface Rough meter, Tool

No	Description	Mean	Median	Mode	Standard Deviation	Varians Sample	Range	Minimum	Maximum	Confidence Level	Correlation of Vertical Distance with difference	Consistency	Cronbach's alpha
1	Data 1	17.69	17.7	17.7	0.06	0	0.53	17.58	18.11	97.07%	100.00%	1.43%	1.00
2	Data 2	17.33	17.27	17.27	0.12	0.01	0.49	17.26	17.75	97.24%	100.00%	1.99%	1.00
3	Data 3	16.9	16.97	16.98	0.16	0.03	0.47	16.56	17.03	97.24%	100.00%	2.36%	1.00
4	Data 4	14.05	14.03	14.03	0.04	0	0.13	14.01	14.14	99.08%	100.00%	1.40%	1.00
5	Data 5	17.2	17.2	17.2	0	0	0.03	17.19	17.22	99.83%	100.00%	0.27%	1.00
6	Data 6	17.23	17.27	17.44	0.34	0.12	1.29	16.8	18.09	92.87%	100.00%	3.38%	1.00
7	Data 7	17.4	17.53	17.56	0.22	0.05	0.64	16.97	17.61	96.37%	100.00%	2.73%	1.00
8	Data 8	17.4	17.53	17.56	0.22	0.05	0.64	16.97	17.61	96.37%	100.00%	2.73%	1.00
9	Data 9	16.99	16.92	16.92	0.4	0.16	1.76	16.16	17.92	90.18%	100.00%	3.72%	1.00
10	Data 10	17.2	17.09	16.85	0.48	0.23	1.72	16.25	17.97	90.43%	100.00%	4.02%	1.00
11	Data 11	16.97	16.92	16.92	0.29	0.09	1.7	16.03	17.73	90.41%	100.00%	3.18%	1.00
12	Data 12	14.32	14.33	14.55	0.23	0.06	1.23	13.63	14.86	91.72%	100.00%	3.37%	1.00
13	Data 13	14.02	14.01	13.91	0.25	0.06	1.27	13.55	14.82	91.43%	100.00%	3.56%	1.00
14	Data 14	14.28	14.29	14.26	0.17	0.03	1	13.91	14.91	93.29%	100.00%	2.87%	1.00
15	Data 15	14	14.14	13.67	0.27	0.07	0.95	13.67	14.62	93.50%	100.00%	3.69%	1.00

From Table "3" it can be seen that the results of Descriptive Statistical Analysis on the entire vertical distance measurement test with Ultrasonic Surface Rough meter obtained an average Confidence Level of 94.47% which shows a confidence level above 90%, Vertical Distance Correlation with an average difference of 100.00% which means that the results of Vertical Distance measurement data with differences all have a strong relationship, and an average Consistency value < 5% means that it can be said has a "consistent" level and Cronbach's alpha average of "1.00" so it can be categorized under Excellent Internal consistency. With the results of Descriptive Statistical Analysis, it means that the results of vertical distance measurements on all tests can be said to be "valid and correct".

5. Conclusion

Based on the results of data analysis using descriptive statistical analysis methods, it can be concluded that typical overall result values Vertical distance measurement test with Ultrasonic Surface Rough meter obtained an average Confidence Level of 94.47% which shows a confidence level above 90%, Vertical Distance Correlation with an average difference of 100.00% which means that the results of Vertical Distance measurement data with the difference all have a strong relationship, and an average consistency value of < 5% means that it can be said to have a level of "consistent" and Cronbach's alpha average of 1.00 so that it can be categorized under Excellent Internal consistency. With the results of Descriptive Statistical Analysis means that the results of vertical distance measurements on all tests can be said to be "Valid and correct".

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