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Evaluate the accuracy of vehicle type on road surface condition survey using roadroid application

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Abstract. Poor road surface conditions influence the continuity of sustainable transportation such as congestion, the assessment stages road surface conditions are by evaluating the existing road conditions. One of the pavement performance parameters that can be determined objectively is International Roughness Index (IRI). Nowadays, the cheap and reliable technology used to measure IRI value is Roadroid which is an Android application developed from a company in Sweden by using a built-in vibration sensor on a smart phone which is placed on the vehicle and the old manual method is called Surface Distress Index (SDI) which is based on visual observations using the RCS method. With the variation of flexible and rigid pavement consist of good and bad road conditions and using motorcycle, sedan and sport utility vehicle, it is found that the correlation between the IRI value using Roadroid and SDI value using visual observation shows high correlation where the highest r2 values by using Sport Utility Vehicle (SUV) compare to small car and motorcycle. It concludes that Roadroid can be used as database for road maintenance planning purposes.

Keywords: vehicle type accuracy, road surface condition, roadroid application

1. Introduction

Road surface conditions influences the continuity of traffic flow. On bad road condition, drivers tend to slow down the speed and may decrease road capacity of the road and increase the risk of traffic congestion. Traffic congestion also imposes direct economic and health costs on users and non-users in the form of wasted time and money, stress and other illnesses. Transport system also make a significant contribution to global warming through emissions of carbon dioxide (CO2) and other greenhouse gases [1]. It is important to assess the road surface conditions by evaluation the existing road conditions [2].

The International Roughness Index (IRI) is one of the parameters of unevenness which is calculated from the cumulative number of rise and fall of the surface in the direction of the elongated profile divided by the distance or surface length measured. The usual recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m) [3]. The IRI value is obtained based on the roughness characteristics using a roughness measurement tool that is classified by the ASTM E 950-94 standard into four groups based on the level of accuracy and the method used in determining IRI shown in (Table 1) [4].

Table 1. Descriptions of Roughness Measurement Tools in Each Class

Level	Method	Tools	Advantages	Deficiency
Class I	Laser Scanner Technology	Hawkeye	Very high precision, Inter-point close intervals, Low operational costs	Expensive, Cannot work when it rains, Cannot go through narrow roads, Long survey time
Class II	Complex Profilometer	MERLIN, CHLOE Profilometer, NAASRA	Dynamic, Medium precision	Relatively expensive, Long survey time
Class III	Correlation Method	ROMDAS, Roughometer, Bump Integrator, Roadroid, Roadmaster.	Cheap enough, Medium precision, Portable, can be used on non-paved roads, Low maintenance costs, 100 km / day survey capacity	It needs to be calibrated, Sensitive to the influence of the vehicle and GPS
Class IV	Visual Observation	-	Easy, Not expensive	Accuracy depends on subjective surveyors, need to convert to IRI values

In Indonesia, mostly the local government still in level Class III and Class IV but only few in level I and II for economic reason. One of the disadvantages of class III is sensitive to the vehicle used. In the overwhelming of smartphone era, using this technology to assess the road condition may lower the capital and maintenance cost of the equipment. For Android based smartphones, the Roadroid is a famous application developed in 2012 from a Swedish company and in 2014 won the 2014 IRF Global Road in Technology, Equipment and Manufacturing [5], works by using mobile vibration sensor that is placed on a vehicle to collect road surface condition data [6]. There are four choices of vehicle types namely bicycle, small car, medium car, four-wheel drive jeep [7]. This research will find out the different of IRI from Roadroid between motorcycle, small car and medium car. For road type and surface variations, the road surface divided into asphalt (flexible pavement) and concrete (rigid pavement) and in good and bad condition, respectively.

Besides Roadroid, the manual method is used to closely view by visual observation along the road. This visual observation is still used by some of Public Work Agency in local government. This SDI value is the output of this method and then convert to IRI for the research purposes.

2. Methods

The research explores the accuracy of 3 of the 4 types of vehicles (as seen in Figure 1), namely motorcycle (Honda Beat 110 cc automatic transmission), small car (Daihatsu Ayla 998 cc manual transmission with ground clearance of 18 cm,) and medium car (Mitsubishi Xpander Sport 1500 cc automatic transmission with ground clearance 24 cm).

Figure 1. Vehicles Used in Research

The location of the research is conducted on flexible pavement and rigid pavement. The flexible pavement road was Jalan Kaliabang Tengah Road, Bekasi City along 1 km with bad and good condition and the rigid pavement was Jalan Inspeksi Kanal Timur Road, North Jakarta City along 1 km with bad and good condition. It is important to make an interval during the surveys of distances of every 20 m, 50 m, 100 m per length of road 1 km to find out whether the distance interval may affect the IRI value.

To determine the SDI value obtained using the RCS (Road Condition System) program. RCS is one part of the IRMS (Integrated Road Management System) application and is one of the parameters used to assess a road condition where the survey is conducted by observation visualization of a road section in flexible pavement with measurements of every 100 m interval and RCS generates values in SDI units use shown in (Table 2) [8].

Table 2. SDI Value According to RCS

Road Surface Conditions	SDI Value
Good	0 – 50
Medium	50 – 100
Lightly Damaged	100 – 150
Heavily Damaged	>150

To minimize surveyor subjectivity the value from this survey was an aggregate from 3 surveyors, carried out on foot since the length of the road is only 1 km.

3. Results and discussion

Using the same approach, study from Batubara compares IRI value using Roughometer on the Sport Utility Vehicle (SUV) and SDI value from visual observation, and it recommends the relationship between IRI and SDI for rigid and flexible pavement are IRI = 1.24 + 0.03*SDI and IRI = 2.67 + 0.054*SDI respectively and show that the different of IRI value for flexible and rigid even though the surface conditions is the same (shown in Table 3) [3].

Table 3. The Correlation between IRI Value and SDI Value in Rigid Pavement and Flexible Pavement According to Previous Research Results [3]

SDI Value	IRI Value Roughometer Tool		Road Surface Conditions
	Flexible Pavement	Rigid Pavement	
0 - 50	2,6 - 5,3	1,2 - 2,7	Good
51 - 100	5,4 - 8	2,8 - 4,2	Medium
101 - 150	8,1 - 10,7	4,3 – 5,7	Lightly Damaged
> 151	> 10,8	> 5,8	Heavily Damaged

Based on the information provided in Table 3, the survey is made to find the SDI value and calculate the IRI value then the results will be validated using regression and compare with the Table 3 and get the result of rigid pavement has r2 value of 0.91 and flexible pavement has r2 value of 0.78. The result shows that IRI values using a Roughometer tool [3] and our SDI values of visual observations have a high correlation therefore the SDI values from the observation can be used as a benchmark for further research.

Table 4 shows the result of IRI values from Roadroid using different types of vehicles with various interval for bad condition of rigid pavement. It shows that the best result is for 50 and 100 m interval due to since this is the poor condition of the road. The other result shown that SUV car make a good result to show that the road is poor condition.

Table 4. Comparison of IRI Values Roadroid Based on Distance Intervals and Vehicle Type on a Rigid Pavement Bad/Poor Condition

Interval Distance of 20 m				**Interval Distance of 50 m**				**Interval Distance of 100 m**				**Documentation Per 100 m**
Distance (m)	**IRI Values Roadroid Application**			**Distance (m)**	**IRI Values Roadroid Application**			**Distance (m)**	**IRI Values Roadroid Application**			
	SUV Car	**City Car**	**Motorcycle**		**SUV Car**	**City Car**	**Motorcycle**		**SUV Car**	**City Car**	**Motorcycle**	
0 - 20	1.4	1	2.87	0 – 50	4.53	2.19	4.62					
20 - 40	2.5	2.22	7.32									
40 - 60	2.1	3.43	6.26					0 - 100	2.19	1.93	4.12	
60 - 80	2.29	2.42	3.49	50 - 100	4.98	2.03	3.97					
80 - 100	2.41	1.51	3.03									
Average per 1 km	**5.39**	**1.77**	**3.81**	**Average per 1 km**	**6.23**	**1.79**	**3.81**	**Average per 1 km**	**5.42**	**1.75**	**4.84**	
Explanation	**Not Ok**	**Good**	**Not Ok**	**Explanation**		**Good**	**Not Ok**	**Explanation**		**Good**	**Not Ok**	

In addition to using the r2, the p-value parameter is used to determine the statistically significance of the data. Then a decent data can be made a regression equation with r2 value parameter and p-value parameter. Table 5 shows both types of road surfaces have high r2 values and high correlation. This shows that > 88% of the value of road unevenness (IRI) affects the value of road damage (SDI). While the remaining 12% can be influenced by the type of vehicle used, the behavior of the driver of the vehicle and the condition of the busy road or there are side obstacles or there are intersections. The best results on each type of road surface for damaged condition is using a SUV Car, because all parts of the SUV Car can pass through the damaged condition compared to City Car and Motorcycle. The majority of city car and motorcycle will avoid these damaged conditions.

Table 5. Comparison of IRI Value Equations Against SDI Value Between Rigid Pavement and Flexible Pavement

Type	**Condition**	**Vehicle**	**Type of Regression**	**Regression Equation**	**r^2**	**The Highest Interval Distance With r^2**	**p - value**
Rigid Pavement	**Bad**	**SUV Car**	**Linear**	**SDI = 0.39 + 12.43*IRI**	**0.889**	**50 meter**	**0.000**
	Good	SUV Car	Quadratic	SDI = -7.44 + 12.20*IRI + 0.41*(IRI)²	0.723	50 meter	0.04
Flexible Pavement	**Bad**	**SUV Car**	**Linear**	**SDI = 10.39*IRI – 7.48**	**0.997**	**100 meter**	**0.000**
	Good	SUV Car	Quadratic	SDI = -25.98 + 11.2*IRI + 1.57*IRI²	0.996	100 meter	0.000

More practical information can be drawn from the result of the analyses by making a graph that corresponds to the regression equation with the highest r2 value on each type of road surface use shown in Figure 2 and 3 and Table 6.

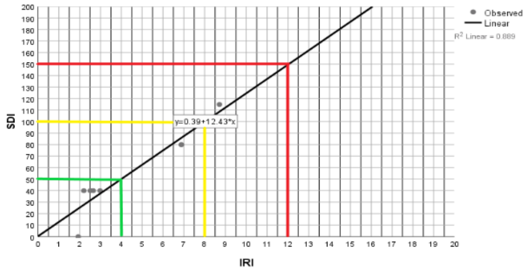

Figure 2. Regression Equation Between IRI Value to SDI Value in The Rigid Pavement

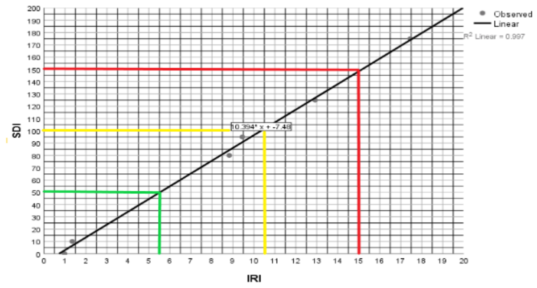

Figure 3. Regression Equation Between IRI Value to SDI Value in The Flexible Pavement

Table 6. The Correlation between IRI Value and SDI Value in Rigid Pavement and Flexible Pavement According to the Authors Research Results

IRI Roadroid Rigid Pavement	IRI Roadroid Flexible Pavement	SDI Value	Road Surface Conditions	Road Surface Conditions Roadroid	Color Indicator Roadroid
< 4	<5,5	0 – 50	Good	Good	
4,1 – 8	5,6 - 10,5	51 – 100	Medium	Ok	
8,1 – 12	10,6 – 15	101 – 150	Lightly Damaged	Not Ok	
>12	>15	>150	Heavily Damaged	Poor	

Table 5 shows that flexible pavement get the maximum r2 values linear regression equation is 0.997 with high correlation and higher than the results of previous study. But for rigid pavement, the maximum r2 values linear regression equation is 0.889 with high correlation and lower than the results of previous study. It shows that between IRI values using a Roadroid application to the SDI values of visual observations have a high correlation. In accordance with the RCS method, that SDI assessment is more suitable for flexible pavement than rigid pavement which have strongly influenced by the crack area and crack width. In flexible pavement, SDI and IRI values are strongly influenced by the number of holes and wheel depth.

Validation is done to determine the difference in the results between the SDI values of visual observations and IRI values using Roadroid and IRI values using Roughometer tool on each type road surface. The results use shown in Figure 4 and 5 and Table 7.

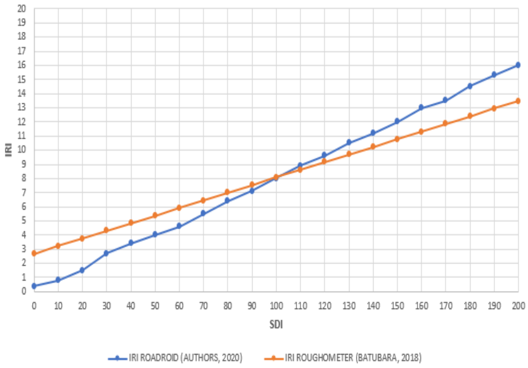

Figure 4. Validation Equation Between Authors Research Results and Previous Research Results in The Rigid Pavement

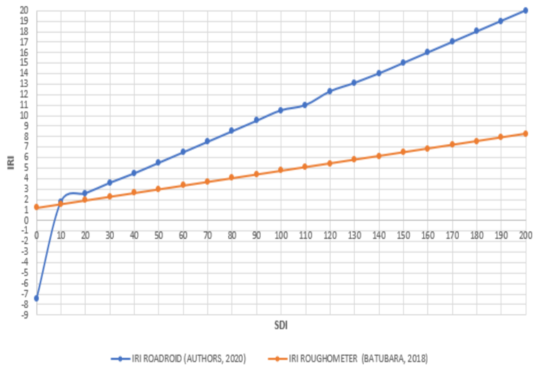

Figure 5. Validation Equation Between Authors Research Results and Previous Research Results in The Flexible Pavement

Table 7. Comparison of Equation Validation Results

Road Surface Condition	SDI Value	Rigid Pavement			Flexible Pavement		
		IRI Value Roadroid Application (Author, 2020)	IRI Value Roughometer Tool (Batubara, 2018)	Percentage Difference IRI Value	IRI Value Roadroid Application (Author, 2020)	IRI Value Roughometer Tool (Batubara, 2018)	Percentage Difference IRI Value
Good	0	0.39	2.67	-585%	-7.48	1.24	117%
	10	0.8	3.21	-301%	1.8	1.59	12%
	20	1.5	3.75	-150%	2.6	1.94	25%
	30	2.7	4.29	-59%	3.6	2.29	36%
	40	3.4	4.83	-42%	4.5	2.64	41%
	50	4	5.37	-34%	5.5	2.99	46%
Medium	60	4.6	5.91	-28%	6.5	3.34	49%
	70	5.5	6.45	-17%	7.5	3.69	51%
	80	6.4	6.99	-9%	8.5	4.04	52%
	90	7.1	7.53	-6%	9.5	4.39	54%
	100	8	8.07	-1%	10.5	4.74	55%
Lightly Damaged	110	8.9	8.61	3%	11	5.09	54%
	120	9.6	9.15	5%	12.3	5.44	56%
	130	10.5	9.69	8%	13.1	5.79	56%
	140	11.2	10.23	9%	14	6.14	56%
	150	12	10.77	10%	15	6.49	57%
Heavily Damaged	160	13	11.31	13%	16	6.84	57%
	170	13.5	11.85	12%	17	7.19	58%
	180	14.5	12.39	15%	18	7.54	58%
	190	15.3	12.93	15%	19	7.89	58%
	200	16	13.47	16%	20	8.24	59%
		Average Percentage		**54%**	**Average Percentage**		**53%**

And one important parameter besides r2 value is the p-value. If the p-value ≤ 0.01, the test is significant and if the p-value > 0.01, the test is not significant. The correlation between IRI and SDI for rigid pavement and flexible pavement has a lowest p-value of 0.000. From Table 7, the difference may be higher because of differences method of taking IRI values on road surface damage. The Roughometer tool is mounted on the axle axis needed help from other components such as GPS, power cables, inertial sensors, DMI, and the controller [3]. While the Roadroid only needs to use an Android handphone accelerator and installed on the dashboard of the vehicle [6]. Validation was done and using regression equation between IRI values of Roadroid from results (yellow color) and IRI values from Roughometer tool (green color). The results use shown in Table 8.

Table 8. IRI Value Regression Equation Between Roadroid and Roughometer on Rigid and Flexible Pavement

Rigid Pavement IRI Roughometer = 2.6 + 0.68*IRI Roadroid r^2 value = 0.999; p-value = 0.000				**Flexible Pavement IRI Roughometer = 1.67 + 0.31*IRI Roadroid r^2 value = 0.940; p-value = 0.000**			
Roadroid		**Roughometer**		**Roadroid**		**Roughometer**	
IRI Value	**Road Surface Conditions**	**IRI Value**	**Road Surface Conditions**	**IRI Value**	**Road Surface Conditions**	**IRI Value**	**Road Surface Conditions**
0		2.6		0		1.67	
1	Good	3.28	Good	1		1.98	
2		3.96		2	Good	2.29	
3		4.64		3		2.6	Good
4		5.32		4		2.91	
5	Ok	6	Medium	5		3.22	
6		6.68		6		3.53	
7		7.36		7		3.84	
8		8.04		8	Ok	4.15	
9	Not Ok	8.72		9		4.46	
10		9.4		10		4.77	
11		10.1	Lightly Damaged	11		5.08	
12		10.7		12	Not Ok	5.39	
13		11.4		13		5.7	
14		12.1		14		6.01	Medium
15		12.8		15		6.32	
16	Poor	13.4		16		6.63	
17		14.1	Heavily Damaged	17	Poor	6.94	
18		14.8		18		7.25	
19		15.5		19		7.56	
20		16.2		20		7.87	

The correlation between the IRI from Roadroid to IRI from Roughometer for rigid pavement shows the results of equation IRI Roughometer = 2.6 + 0.68*IRI Roadroid with a highest r2 value is 0.999 and has a p-value of 0.000. While for flexible pavement the equation is IRI Roughometer = 1.67 + 0.31*IRI Roadroid with r2 value of 0.94 and has p–value of 0.000. It shows that IRI values using Roadroid and IRI values using Roughometer have a high correlation and statistically significant parameter. Meanwhile, the other research has IRI Roughometer = 0.57 + 0.89*IRI Roadroid with a r2 value is 0.83 [6].

4. Conclusions and suggestions

Road surface conditions influences the IRI value and SDI value. These values have a high correlation and statistically significant. While the highest IRI and SDI values indicate that the road surface conditions are damaged, then the lowest IRI and SDI values indicate that the road surface conditions are good. These possibilities can be affected the continuity of sustainable transportation such as congestion or road safety. Roadroid application and visual observation can be used to determine IRI value with good results and statistically significant that may be compared with the Roughometer. For further research purposes, it is expected to be carried out on local roads which often have heavy damage on the road surface due to poor maintenance.

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