Vol. 05, No. 2 (2023) 267-274, doi: 10.24874/PES05.02.009

Proceedings on Engineering Sciences

www.pesjournal.net

PREDICTION OF SERVICE LIFE BASE ON RELATIONSHIP BETWEEN PSI AND IRI FOR FLEXIBLE PAVEMENT

Muhammad Isradi[1]
Joewono Prasetijo
Yudi Dwi Prasetyo
Nurani Hartatik
Andri Irfan Rifai

Received 10.10.2022.
Accepted 14.03.2023.
UDC – 625.089.2

Keywords:

Remaining pavement life, International Roughness Index, Present Serviceability Index, Flexible pavement

A B S T R A C T

Uncertainty about the remaining service life of the pavement occurs in developing countries even though the structure is designed with the planned life. As a result, there is damage to the network and the structure and function of the road. Uncertainty in volume, traffic growth that exceeds the plan, and limited funds have a very strong influence on the shape of the road. This study aimed to determine the condition of the road surface and road service functions to find out the service life of the pavement and the relationship between the Present Serviceability Index value and the International Roughness Index on the flexible pavement. Secondary data collection such as IRI and traffic volume is used for modeling and reviewing road service functions. The results show that the remaining road life will end in year 8, a 2-year decrease from the 10-year plan. The relationship between PSI and IRI plans has an R2 value of 0.9981, while the actual condition has an R2 of 0.9976.

1. INTRODUCTION

The activity of moving people and goods requires an excellent level of road service. Damage can affect economic activity, quality of life, and the environment (Prasetyo et al., 2021). Pavement functions to spread wheel loads to the surface area, provide a strong structure to support traffic loads, and provide a flat surface and skid resistance (Isradi, Prasetijo, et al., 2021). Pavement damage is caused by loads that exceed the ability of each road pavement element (Saodang, 2005).

The use of sustainable roads will reduce pavement functions that are detrimental to users and the planned age of the road (Rochmawati, 2020) Road damage requires research to determine the road surface condition to remain prime to reduce the rate of road accidents (Dermawan et al., 2020). According to the World Health Organization (WHO), one million people die every year, three million people are seriously injured, and thirty million are injured in road accidents (Prasetijo et al., 2021). One of the things that cause rapid pavement damage is the lack of maintenance of the drainage system. Roads built without a

[1] Corresponding Author: Muhammad Isradi
Email: isradi@mercubuana.ac.id

good system have a faster speed of damage. As a result, the design life will be shorter than that built with a good drainage structure and other factors (Iskandar et al., 2020).

A common phenomenon in developing countries is the presence of excessive loads that damage the pavement structure before the design life is reached (Rifai et al., 2015), In addition, the traffic volume, which is difficult to predict (Isradi et al., 2020) causes the aging process to be non-linear. The overall decrease in road performance follows the function of increasing traffic volume and load (Haas et al., 1994).

Present Serviceability Index of the design life can be used to assess the performance of the pavement. It can also be used as an indicator of timing and maintenance requirements (Ratnasari & Suparma, 2021), to formulate the right strategy and obtain the best alternative to maintain the life of the plan.

This study aims to figure out the condition of the pavement structure for the coming years, the value of the Present Serviceability Index, and the effect of the relationship between PSI and IRI values.

2. METHOD AND DATA COLLECTION

Data collection techniques were carried out by direct observation, interviews, and the processing of primary data from field surveys (Firdaus et al., 2022). Researchers also collect some information as secondary data (Isradi, Molina, et al., 2021). This research was carried out on the 7.2 km Tanjung Sari national road in West Java (figure 1).

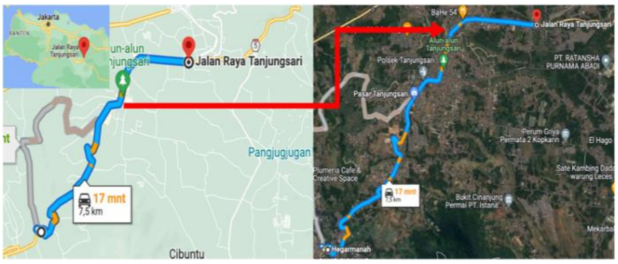

Figure 1. Study location

Average Daily Traffic (ADT) Data

Traffic volume is obtained by counting vehicles that pass a point on a road segment at certain time intervals expressed in passenger cars (PCU) (Direktorat Jendral Bina Marga, 2020). The 2018-2019 data used comes from the West Java National Road Implementation Center.

The ADT calculation in the coming year uses the vehicle growth factor value from the West Java regional planning, which is 4.8% (Direktur Jenderal Bina Marga, 2017). In addition, the actual traffic growth statistics from West Java Province of 5.85% are also used (BPS-Jawa Barat, 2020).

Table 1. Number of vehicles by type.

No	Type of Vehicle	Group	Total
1	Passenger car	2	16.859
2	Pick Up / Minibus	3	21.051
3	Small Truck	4	13.952
4	Small Bus	5b	872
5	Big Bus	6a	58
6	2Axle 6 Wheel Truck	6b	3.604
7	3 Axle 10 Wheel Truck	7a	988
8	Trailer Truck	7b	277
9	Semi Trailers	7c	523

CESAL

Researchers calculate the CESAL value, the CESAL value with the plan value, and the actual value based on the ADT data. The calculation results will then be used to project an increase in the traffic load every year (Direktur Jenderal Bina Marga, 2017).

Data Structural Number (SN) dan Structural Number Capacity (SNC)

It should be noted that reinforcement is required for paved roads when the damaged surface area reaches about 25% to 30% of the total. The average life of an asphalt road before periodic maintenance is needed about 11 to 13 years (Direktur Jenderal Bina Marga, 2017).

International Roughness Index (IRI)

The World Bank developed the International Roughness Index (IRI) in the 1980s. It is the unevenness parameter calculated from the cumulative amount of surface rise and fall in the longitudinal direction of the profile divided by the distance/length of the measured surface. It is used to describe a longitudinal profile of a road and is used as a standard for surface unevenness. The recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m) (Direktorat Jendral Bina Marga, 2020).

Its values have been developed for various pavement ages and speeds. IRI < 4 m/km can be traveled at a 100 km/hour speed for new roads, while IRI < 6 m/km can be traveled at about 80 km/hour. In other words, the IRI ranges from 1.75-3.5 m/km for new roads and 2.5-6.00 m/km for old roads (Sayers & Karamihas, 1998).

The data is obtained from the Westl Java National Road Implementation Center along the observed roads, and then the average IRI value of these roads is taken.

Present Serviceability Index (PSI)

The Present Serviceability Index (PSI) concept was developed through the AASHTO Road Test. It correlates subjective and objective assessments with roughness measurements, crack damage, fillings, and grooves into one equation. PSI values vary with a range from 0 to 5 (AASHTO, 1993).

The initial PSI value of the pavement at the time of construction is also called initial serviceability and is recommended at 4.2 for flexible pavement, and the minimum allowable limit is 2.0 (AASHTO, 1993). The values vary with a range from 0 to 5, as shown in Table 2 below.

Table 2. Rating serviceability.

No	Value	Rating
1	4 – 5	Very good
2	3 – 4	Well
3	3 – 2	Fair
4	2 – 1	Bad
5	0 – 1	Very bad

3. ANALYSIS AND DISCUSSION

The analytical study was done by developing a road condition performance model represented by IRI in the projections for the coming years. The stages of the analysis are the estimation of traffic volume with loading, the condition of the pavement (IRI), and the value of the Present Serviceability Index

Remaining Pavement Life, according to CESAL

Projected daily traffic volume (ADT) at the end of the year expressed in PCU/day. The results are important for road planning and observing trends with future volume evaluations. Table 2 below shows the projected ADT plan for the next 10 years, where the projected and actual traffic growth are 4.8% and 5.85%, respectively.

Table 3. LHR projection plan.

Road ID	Year	Traffic	Type of Vehicle									Total	
			Passenger cars	Pickup, minibus	Small Trucks	Small Bus	Big Bus	2Axle 6 Wheel Truck	3 Axle 10 Wheel Truck	Trailer Truck	Semi-Trailer	Plan (vehicles)	Actual (vehicles)
		Group	2	3	4	5b	6a	6b	7a	7b	7c		
		i	0,048	0,048	0,048	0,048	0,05	0,048	0,048	0,048	0,048	4,80%	5,85%
TANJUNG SARI	2019		16.859	21.051	13.952	872	58	3.604	988	227	523	58.135	58.766
	2020		17.668	22.061	14.622	914	61	3.777	1.036	238	548	60.925	61.507
	2021		18.516	23.120	15.324	958	64	3.959	1.085	249	575	63.850	65.074
	2022		19.405	24.230	16.060	1.004	67	4.149	1.138	261	602	66.915	68.849
	2023		20.337	25.393	16.830	1.052	70	4.348	1.192	273	631	70.127	72.842
	2024		21.313	26.612	17.638	1.102	73	4.557	1.249	287	661	73.493	77.067
	2025		22.336	27.889	18.485	1.155	77	4.775	1.309	300	693	77.020	81.536
	2026		23.408	29.228	19.372	1.211	81	5.004	1.372	315	726	80.717	86.266
	2027		24.532	30.631	20.302	1.269	85	5.245	1.438	330	761	84.592	91.269
	2028		25.709	32.101	21.277	1.330	89	5.496	1.507	346	798	88.652	96.563
	2029		26.943	33.642	22.298	1.394	93	5.760	1.579	362	836	92.907	102.163

The equivalent single axle load (ESAL) or vehicle damage factor (VDF) value is determined according to each type of vehicle's load and axle configuration from the planned and actual ADT data. The planned and actual CESAL values are as follows:

Table 4. Comparison of planned and actual CESAL scores.

Year	Planned ADT (vehicles)	Actual ADT (vehicles)	Planned CESAL	Actual CESAL
	4,80%	5,85%	4,80%	5,85%
2019	58.135	58.766	4,72	4,77
2020	60.925	61.507	10,13	10,28
2021	63.850	65.074	16,31	16,79
2022	66.915	68.849	23,34	24,38
2023	70.127	72.842	31,33	33,20
2024	73.493	77.067	40,38	43,42
2025	77.020	81.536	50,60	55,22
2026	80.717	86.266	62,13	68,82
2027	84.592	91.269	75,10	84,44
2028	88.652	96.563	89,68	102,36
2029	92.907	102.163	106,04	122,87

Furthermore, the calculation of the remaining pavement life is obtained, calculated based on the CESAL value, which is then used to obtain the remaining life value (RL) %.

$$RL = 100\left[1-\left(\frac{Np}{N_2}\right)\right] \qquad (1)$$

RL = Remaining Life %

Np = Total Traffic

N_2 = Total traffic at the end of the design life

The results can be seen in the following figure 2.

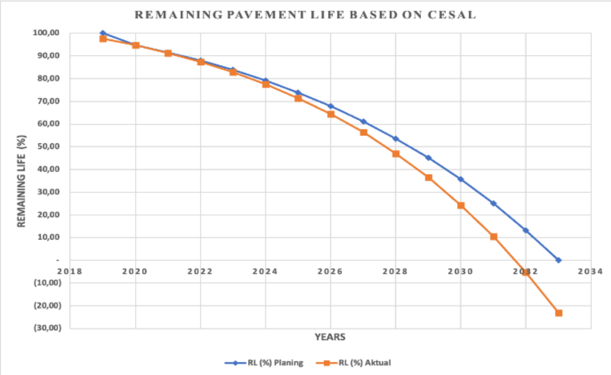

Figure 2. Graph of remaining pavement life based on CESAL

Figure 2 shows that the planned life will end in 2027, so the road life has decreased by 2 years from the design life based on loading and traffic volume.

Pavement Damage Model Development

The development of this optimization requires accurate and adequate data related to the pattern of road damage. Usually, the core process is to collect information on infrastructure and traffic data. Based on the above data, we know that the International Roughness Index (IRI) and Present Serviceability Index (PSI) are parameters that can be used to determine the functional performance of roads (Sandra & Sarkar, 2013).

The development of road surface roughness predicted by HDM-4 results from five components such as structural damage, cracks, grooves, holes, and environmental components (Jorge & Ferreira, 2012). The equation approach to predict pavement conditions represented by IRI through the HDM-4 approach is as follows:

$$IRI_t = e^{0,023.t}[IRI_0 + 263(1 + SNC)^{-5.NE4.t}] \quad (2)$$

Where:

IRI_0 = Initial roughness, IRI (m/km)
SNC = Structural Number Capacity
NE4t= cumulative standard axles million in year t (load damage power 4).

Meanwhile, researchers use the AASHTO equation to get the PSI value for flexible pavement as follows (AASHTO, 1993)

$$PSI_{Average} = 5{,}671 - 1{,}714\sqrt{IRI_{Average}} \quad (3)$$

Model lain yang telah dikembangkan untuk mendapatkan nilai PSI dari IRI mengikuti Paterson (Paterson, 1986)

$$PSI = 5\exp\left(-\frac{IRI}{5{,}5}\right) \quad (4)$$

Another model that has been developed to derive PSI values from IRI follows Paterson:

$$PSI = 5\exp(-0{,}24\,IRI) \quad (5)$$

The recommended initial PSI value of the pavement at the time of completion of construction, also known as the initial serviceability, is 4.2 for flexible pavements, with a minimum allowable limit of 2.0.

The results of the analysis using IRI_0 data in 2019 and the results of calculations for pavement predictions for the next 10 years are as follows.

Table 5. Pavement prediction.

Year	CESAL Planning (million)	CESAL Aktual (million)	SNC	e	IRI_0	IRI (Planning)	PSI (Planning)	IRI (Actual)	PSI (Actual)
2019	4,72	4,77	4,74	2,27	4,64	5,84	1,53	5,85	1,53
2020	10,13	10,28	4,74	2,27	4,64	6,12	1,43	6,13	1,43
2021	16,31	16,79	4,74	2,27	4,64	6,44	1,32	6,46	1,31
2022	23,34	24,38	4,74	2,27	4,64	6,79	1,20	6,85	1,19
2023	31,33	33,20	4,74	2,27	4,64	7,20	1,07	7,30	1,04
2024	40,38	43,42	4,74	2,27	4,64	7,66	0,93	7,82	0,88
2025	50,60	55,22	4,74	2,27	4,64	8,18	0,77	8,42	0,70
2026	62,13	68,82	4,74	2,27	4,64	8,77	0,59	9,11	0,50
2027	75,10	84,44	4,74	2,27	4,64	9,43	0,41	9,91	0,28
2028	89,68	102,36	4,74	2,27	4,64	10,18	0,20	10,82	0,03
2029	106,04	122,87	4,74	2,27	4,64	11,01	-0,02	11,87	-0,23

Table 5 shows the predicted and actual IRI values for the next 10 years. The actual IRI value in 2025 is 8.42 for road conditions, with an IRI value > 8 entering a mildly damaged phase, where road conditions change from steady to unstable conditions.

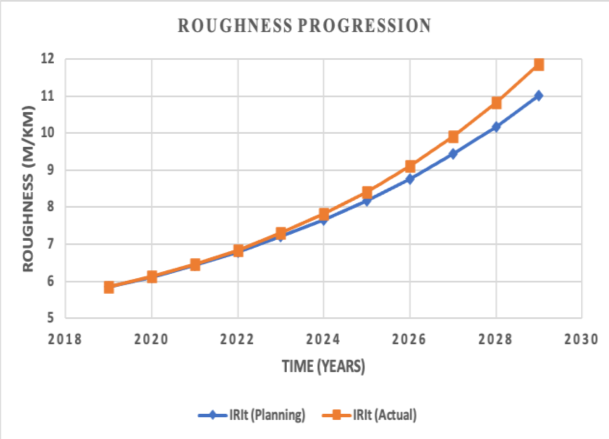

Figure 3. Roughness progression next 10 years

The recommended PSI value is 4.2, with a minimum limit of 2.0. The analysis results in the initial year of the plan reached 1.53. The PSI value has passed the minimum limit at the beginning of the calculation age. Then, the actual PSI value has reached -0.23 with very bad road conditions in the next 10 years.

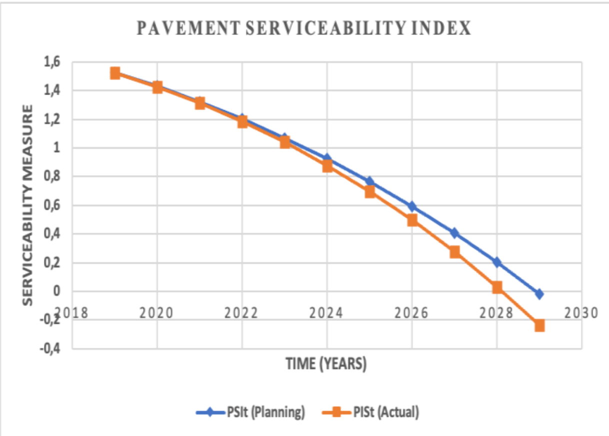

Figure 4. Serviceability index progress next 10 years

Correlation between IRI and PSI

The relationship between IRI and PSI values (figure 5) is based on the results of the calculations in table 5.

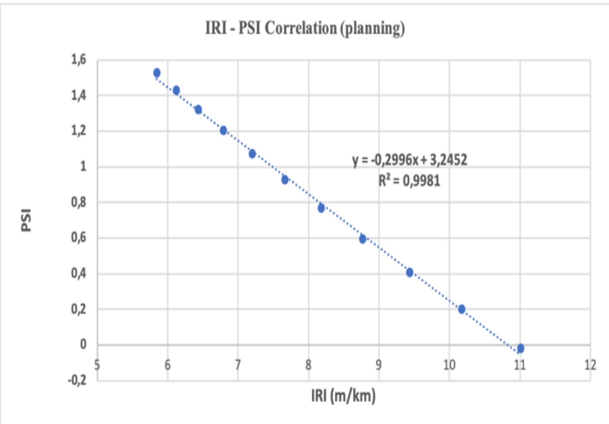

Figure 5. Correlation between IRI and PSI (plan)

Based on regression analysis, figure 5 shows a linear relationship between IRI and PSI. The obtained PSI = 3.2452-0.2996 x IRI, where the value of R2 is 0.9981. It means IRI affects PSI by 99.8%.

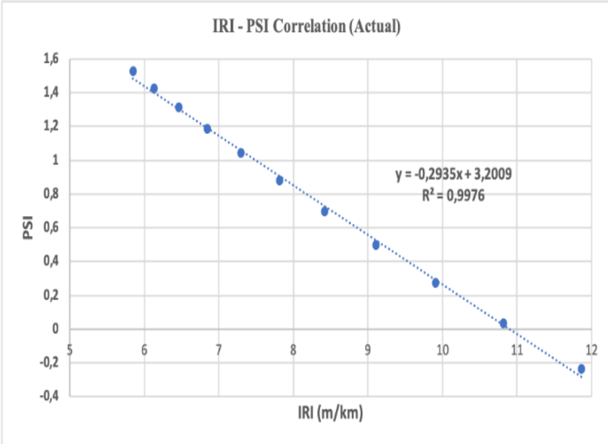

Figure 6. Correlation between IRI dan PSI (actual)

The correlation between IRI and PSI (actual) can be seen in Figure 6, where the results obtained are PSI = 3.2009-0.2935 x IRI, with an R2 value of 99.76%.

Comparison of PSI and IRI Model

Several estimates and projections of PSI values for IRI by combining several formulas for flexible pavements.

The following image (figure 7) is a comparison of them:

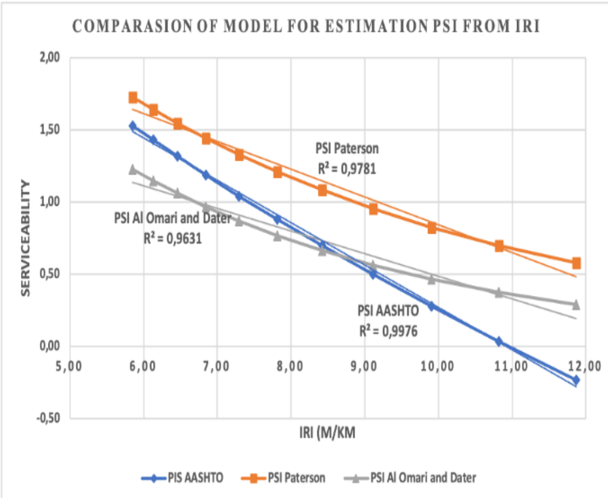

Figure 7. Comparison of PSI and IRI model

Estimating the three models above proves the correlation between PSI and IRI values. The R2 value for the PSI AASHTO model is 99.8%, where the road conditions will be very bad in 2024. The R2 value for the PSI Paterson model is 97.8%, with very bad road projections in 2026. Lastly, we get an R2 value of 96.3% for the Al Omari and Darter models, where the road condition will be very bad in 2022.

4. CONCLUSIONS

The analysis results explain that the Remaining Life (RL) model is appropriate and can be used to predict road life. Based on traffic volume loading, a decrease of 2 years from the design life is obtained. Prediction of IRI value for 10 years proves that road conditions will be damaged in the next 6 years with an IRI value > 8mm/km. Furthermore, the PSI value has passed the minimum value limit at the beginning of the calculation age. With very bad road conditions, the actual PSI value has reached -0.23 in the next 10 years. The R2 value of the relationship between IRI and PSI (actual) was 99.76%. The estimated correlation model projection between IRI and PSI of the three models shows the same strong correlation, where the AASHTO model has the strongest correlation value of 99.76%.

References:

Aashto. (1993). *Aashto Guide for Design of Pavement Structures*. American Association of State Highway and Transportation Officials.

BPS-Jawa Barat. (2020). *Statistik Transportasi Provinsi Jawa Barat 2020*, BPS-Jawa Barat, Ed.

Dermawan, W. B., Isradi, M., & Pawaztris, P. (2020). Analysis Of Accident Prone Areas Along Jenderal Ahmad Yani Road In Bekasi. *Journal of Applied Science, Engineering, Technology, and Education*, *1* (2), 124–130. https://doi.org/10.35877/454ri.asci1239

Direktorat Jendral Bina Marga. (2020). *Buku Kondisi Jalan Nasional*.

Direktur Jenderal Bina Marga. (2017). Manual Perkerasan Jalan (Revisi Juni 2017). In PUPR 1 (01).

Firdaus, H. Y., Isradi, M., Prasetijo, J., Rifqi, M., & Halim, H. (2022). Analysis of Transjakarta Service Performance on the Cibubur-BKN by Servqual Method. *European Journal of Science, Innovation and Technology*, *2*(1), 113–123.

Haas, R., Hudson, W., & Zaniewski, J. (1994). Modern Pavement Management. In *Krieger Publishing Company*. https://doi.org/10.1073/pnas.0409727102

Iskandar, D., Hadiwardoyo, S. P., Sumabrata, R. J., & Fricilia, M. (2020). The Correlation between Drainage Condition and Pavement Performance. *International Journal of Innovative Technology and Exploring Engineering*, *9* (4), 1333–1337. https://doi.org/10.35940/ijitee.c8413.029420

Isradi, M., Arifin, Z., & Sudrajat, A. (2020). Analysis of the Damage of Rigid Pavement Road by Using Pavement Condition Index (PCI). *Journal of Applied Science, Engineering, Technology, and Education*, *1* (2), 193–202. https://doi.org/10.35877/454ri.asci1242

Isradi, M., Molina, P., Rifai, A. I., Mufhidin, A., & Prasetijo, J. (2021). Evaluation of Performance and Services of Integrated Transportation System (Case Study : Connecting Line between MRT Dukuh Atas Station and KRL Sudirman Station). *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 496–507.

Isradi, M., Prasetijo, J., Hartatik, N., Abidin, Z., & Arifin, Z. (2021). Analysis of Urban Road Damage Assessment Using Surface Distress Index (SDI), Pavement Condition Index (PCI), and International Roughness Index (IRI) Methods. *RIGEO Review of International Geographical Education*, *11* (2), 699–715. https://doi.org/10.33403/rigeo

Jorge, D., & Ferreira, A. (2012). Road Network Pavement Maintenance Optimisation Using the HDM-4 Pavement Performance Prediction Models. *International Journal of Pavement Engineering*, *13* (1), 39–51. https://doi.org/10.1080/10298436.2011.563851

Paterson, W. D. O. (1986). International Roughness Index: Relationship To Other Measures of Roughness and Riding Quality. *Transportation Research Record*, *8*, 49–59.

Prasetijo, J., Zhang, G., Jawi, Z. M., Mahyeddin, M. E., Zainal, Z. F., Isradi, M., & Muthukrishnan, N. (2021). Crash model based on integrated design consistency with low traffic volumes (due to health disaster (COVID-19)/movement control order). *Innovative Infrastructure Solutions*, *6* (1), 22. https://doi.org/10.1007/s41062-020-00388-7

Prasetyo, Y. D., Isradi, M., & Hartatik, N. (2021). Analisis Penilaian Kondisi Kerusakan Jalan Dengan Metode International Roughness Index Dan Pavement Condition Index Pada Ruas Jalan Panglima Sudirman Kabupaten Tuban. *Jurnal EXTRAPOLASI*, *18* (02), 39–51.

Ratnasari, H., & Suparma, L. (2021). Prediksi Present Serviceability Index untuk Analisis Sisa Umur Layan Perkerasan Lentur. *HPJI (Himpunan Pengembangan Jalan Indonesia)*, *7* (2), 153–162.

Rifai, A. I., Hadiwardoyo, S. P., Correia, A. G., Pereira, P., & Cortez, P. (2015). The Data Mining Applied for the Prediction of Highway Roughness Due to Overloaded Trucks. *International Journal of Technology*, *6* (5), 751–761. https://doi.org/10.14716/ijtech.v6i5.1186

Rochmawati, R. (2020). Studi Penilaian Kondisi Kerusakan Jalan Dengan Metode Nilai International Roughness Index (IRI) Dan Surface Distress Index (SDI)(Studi Kasus Jalan Alternatif Waena _ Entrop). *Dintek*, *13* (02), 7–15.

Sandra, A. K., & Sarkar, A. K. (2013). Development of a model for estimating International Roughness Index from pavement distresses. *International Journal of Pavement Engineering*, *14* (8), 715–724. https://doi.org/10.1080/10298436.2012.703322

Saodang, H. (2005). Konstruksi Jalan Raya Buku 2 Perancangan Perkerasan Jalan Raya. In *Nova, Bandung*. https://doi.org/10.1017/CBO9781107415324.004

Sayers, M. W., & Karamihas, S. M. (1998). The Little Book of Profiling. In *Basic Information about Measuring and Interpreting Road Profiles* (Issue September).

Muhammad Isradi
Department of Transportation Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Panchor, Johor, Malaysia & Department of Civil Engineering, Faculty of Engineering, Universitas Mercu Buana Jakarta, Indonesia
isradi@mercubuana.ac.id
ORCID 0000-0003-2942-0503

Joewono Prasetijo
Department of Transportation Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Panchor, Johor, Malaysia
joewono@uthm.edu.my
ORCID 0000-0002-8608-2240

Yudi Dwi Prasetyo
East Java-Bali National Road Implementation Center Indonesia
yudiprasetyo875@pu.go.id
ORCID 0000-0001-6935-9933

Nurani Hartatik
Department of Transportation Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Panchor, Johor, Malaysia
nuranihartatik@untag-sby.ac.id
ORCID 0000-0002-1472-8997

Andri Irfan Rifai
Department of Transportation Engineering, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Panchor, Johor, Malaysia
andri.irfan@uib.ac.id
ORCID 0000-0003-4333-8450