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Research on the Correlation Between International Roughness Index (IRI) and Present Serviceability Index (PSI), Recommendations on Evaluation Rates in Vietnam's Conditions

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***Abstract* - PSI (Present serviceability index) is a general index determined by AASHTO experiment based on roughness, crack proportion, pavement area proportion in need of repair. It is typical for the quality of operating, using the pavement at the time of evaluation. IRI reflects the pavement roughness, commonly collected by using specialized equipment in direct or indirect measurement. The determination of the correlation between IRI and PSI will help to make the quality evaluation of asphalt concrete pavement faster, reduce related costs and efforts in collecting, analyzing and treating, determining the status of pavement damage. The article presents the outcome of the research on the correlation between the international roughness index (IRI) and the present serviceability index (PSI) of the pavement based on the experimental data collected using the ARRB - Australia's specialized and modern equipment (Hawkeye) in a number of asphalt concrete pavement national highway routes in the Northern Vietnam. The research outcomes show the close correlation between IRI and PSI with R^2 ranging from 0.8542 to 0.9405 (with significance rate α= 5%) and an adjusted coefficient (*k* =1) in the correlation equation shall be recommended in accordance with Vietnam's construction and operation conditions.**

***Key Words: International Roughness Index (IRI), Present Serviceability Index (PSI), Asphalt Concrete Pavement, Pavement Quality*.**

1. INTRODUCTION

Survey, evaluation of pavement conditions is an important task in order to come up with schedules and solutions of maintenance, operation to keep the road system in good conditions, timely repair road damages caused during operation process, with the impacts of travelling vehicles and unfavorable environment factors. In Vietnam, attention has not yet been properly paid to data collection and pavement evaluation; monitoring of technical conditions such as unevenness, roughness, crack and damages of the pavement, etc., mainly with single, manual methods or simple, inconsistent experimental equipment, the accuracy of which depends largely on subjective factors, the collection period lasts so long and prevents the traffic operation, the monitoring and evaluation criteria remain unclear. Frequent collection of pavement conditions will facilitate the determination of the pavement degradation status in order to make sound and effective decisions on maintenance, operation and repair, improvement of highways [1, 2, 4].

During the experimental process, AASHTO provided a 5-point rating scale of pavement conditions: PSI =5 for perfect pavement; 4-5 for very good; 3-4 for good; 2-3 for average; 1-2 for poor; 0-1 for very poor [6, 7]. Pavement quality evaluation by PSI (Present Serviceability Index) is based on the data of pavement roughness and damages. However, PSI is affected by subjective factors as the determination of the proportions of cracks, repairs is analyzed through images or by directly surveying sites, while IRI is not affected by subjective factors when direct measurement is applied [9, 15]. In order to minimize subjectivity in determining PSI, a number of critical researches announced the establishment of the relations between IRI using specialized measuring equipment (measuring unit m/Km) and PSI for asphalt concrete pavement, specifically below:

Paterson's research outcomes, W.D.O [8], proved the relation below:

$$PSI = 5.e^{-0.18.IRI} \quad (1)$$

Al-Omari and Darter [6], provided the relation equation below:

$$PSI = 5.e^{-0.26.IRI} \quad (2)$$

According to Hall, K.T., C.E.C. Munoz [7], with x=log(1+SV), SV is slop variance determined by IRI value, an equation between IRI and PSI can be presented as below:

$$PSI = 5 + 0.6046.x^3 - 2.2217.x^2 - 0.0434.x \quad (3)$$

In addition to the outcomes on the correlation between IRI and PSI, the determination of IRI-PCI correlation (pavement condition index) was carried out. Park and his coworkers [9] founded an exponential relationship between PCI and IRI by using data from nine states and provinces in the North America.

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Most of the announced researches [10, 11, 12] accept IRI as a parameter to foresee PSI or PCI of the pavement, as IRI is not a subjective measurement, compared with PSI, PCI.

Currently, Vietnam has specialized equipment named Hawkeyes allowing the collection, determination of IRI of the pavement by applying direct measurement and using the data of impressions, pot holes, cracks, images of pavement damages [1, 3]. Hence, it is necessary to research and develop the correlation between IRI and PSI to make the pavement quality evaluation faster, reduce related costs and efforts in collecting, analyzing and treating, determining the status of pavement damage in the current period, when 3-D technology allowing automatically determining the level of pavement damage has not been applied.

2. RESEARCH METHODOLOGY

2.1. Collection of IRI and PSI data

Using specialized pavement survey equipment named Hawkeye by ARRB, Australia (Figure 1) to conduct survey, collect data of the pavement conditions with distance parameters (DIM combined with GPS), international roughness index - IRI, wheel track rutting, roughness and pavement damages through videos with surveyed vehicle speed from 30-120km/h. Collecting data on pavement conditions at National Highway 2 (NH2), section from Km31+00 to Km 36+00; National Highway 5 (NH5) section from Km 12+00 to Km17+00; National Highway 6 (NH6) section from Km 38+00 to Km 43+00, surveying all travelling lanes, a data set is sufficient enough to ensure the statistical data analysis.

Figure 1. Pavement condition surveying car Hawkeye

2.2. Data processing

PSI is a general index determined by AASHTO experiments depending on roughness, crack proportion, pavement area proportion in need of fixing. For asphalt concrete pavement, PSI is determined according to the formula below:

$$PSI = 5{,}03 – 1{,}91 \log(1+\overline{SV}) – 1{,}38\overline{RD^2} – 0{,}01\sqrt{c+p} \quad (4)$$

In which: *c* – Pavement area proportion with grade 2 cracks and grade 3 cracks, in ($ft^2/1000ft^2$, equivalent to 92.29 m^2); *p* – repaired pavement area proportion ($ft^2/1000ft^2$); $\overline{RD}$ – average wheel ruts impression depth of 2 wheel ruts (inches); $\overline{SV}$ - average slope variance.

Processing the collected data in order to determine bidirectional average pavement roughness indexes, slope variance, wheel rutting depth, crack area proportion and repaired pavement area proportion of the sections (for each 100m, determining a measuring point), thus, each survey section has 50 measuring points.

2.3. Statistical analysis and correlation determination

The general analysis shows that, it is agreed to see IRI as a parameter to expect PSI. When IRI and PSI are considered as two independent variables, the least equation method shall be applied in developing the correlation between IRI and PSI. The statistical reliability of the regression coefficient of the outcome models was tested at the significance level of 5%. Testing the statistical hypothesis according to Kolmogorov to check the distribution of the sample sets, the outcomes show that IRI and PSI have lognormal distribution which is in consistent with the researches [1, 6, 7].

In Vietnam’s conditions, it is fairly hard to ensure average IRI ≤ 1 with the previous and existing construction technologies for asphalt concrete pavement in all routes in general and in highways in particular; concurrently, the pavement survey outcomes of a number of routes after construction show that average IRI > 1. Thus, to make it suitable with the actual operation, exponential models are used to determine the correlation between IRI and PSI in this research, the general formula is recommended as below:

$$PSI = A.\, e^{-x.(IRI-k)} \quad (5)$$

A, x are the values determined based on statistical data IRI, PSI of the experimental sections; k is adjusted value of IRI in accordance with Vietnam’s conditions.

3. RESULTS AND EVALUATION

3.1. Data processing results of IRI, PSI indexes

Data processing to determine the average IRI and PSI indexes at every 100m section of NH2, NH5 and NH6 routes, the results are shown in Figure 1 and Figure 2.

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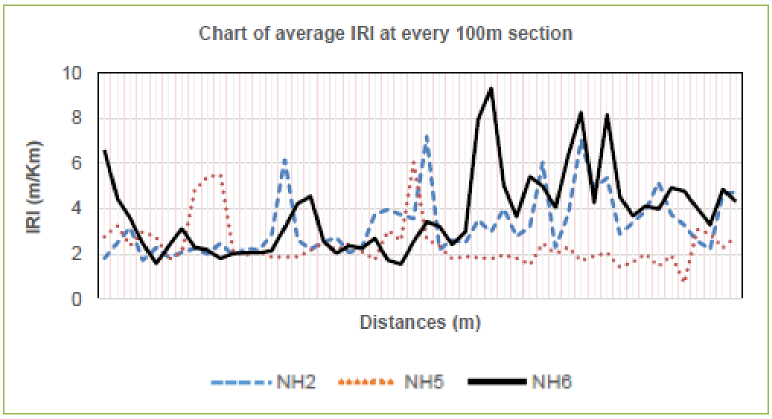

Figure 1. IRI values of surveyed sections

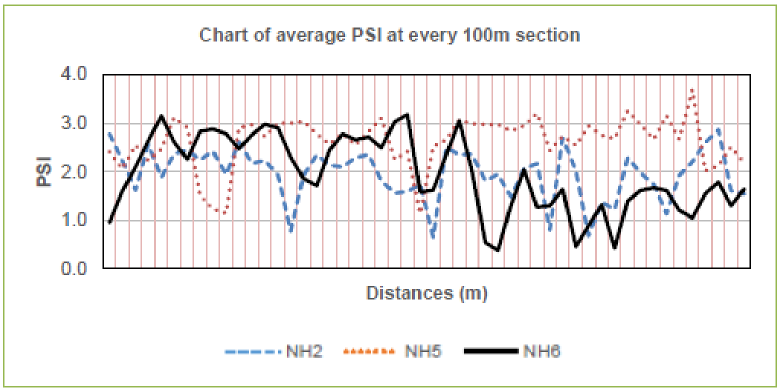

Figure 2. PSI values of surveyed sections

Based on the analysis results, among the surveyed sections, NH6 route has the highest average IRI (3.81) and the lowest PSI (1.94); NH5 route has the lowest average IRI (2.41) and the highest PSI (2.62). When evaluating under IRI criteria, the sections being exploited are graded "average", while evaluating under PSI, the NH2 and NH6 graded "poor", NH5 graded "average".

Table 1. Average values of IRI and PSI of surveyed sections

Average values	NH2	NH5	NH6
IRI (m/Km)	3.28	2.41	1.83
PSI	1.96	2.62	3.37

3.2. IRI and PSI correlation

Based on the values surveyed at 50 points for each section of NH2, NH5 and NH6 routes, correlation between IRI and PSI was determined by the log function as the general formula (7) as proposed. The analysis results of correlation for each section are shown in Figure 3, Figure 4 and Figure 5, and the analysis results of correlation between IRI and PSI for all 150 surveyed points of NH2, NH5, NH6 routes are shown in Figure 6.

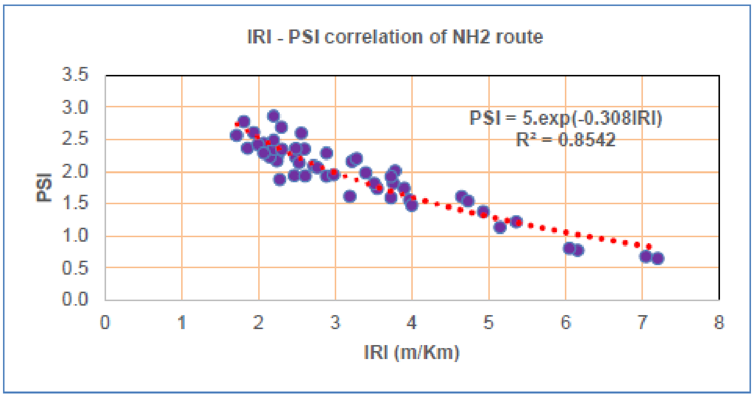

Figure 3. Diagram of IRI - PSI correlation of NH2 route

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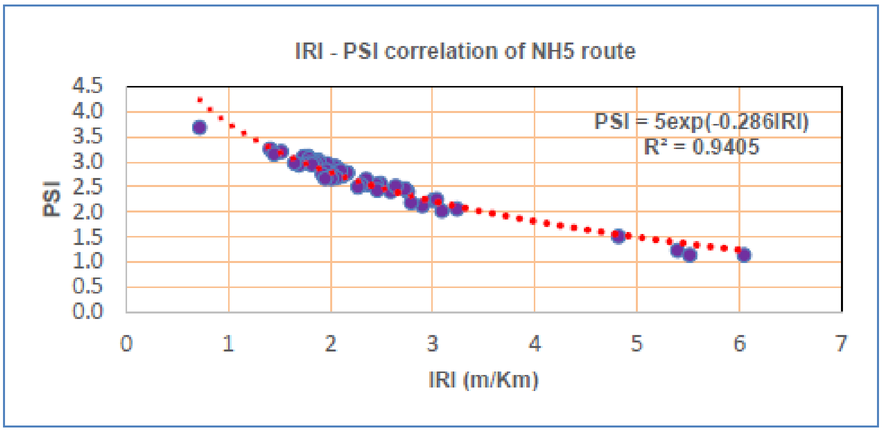

Figure 4. Diagram of IRI - PSI correlation of NH5 route

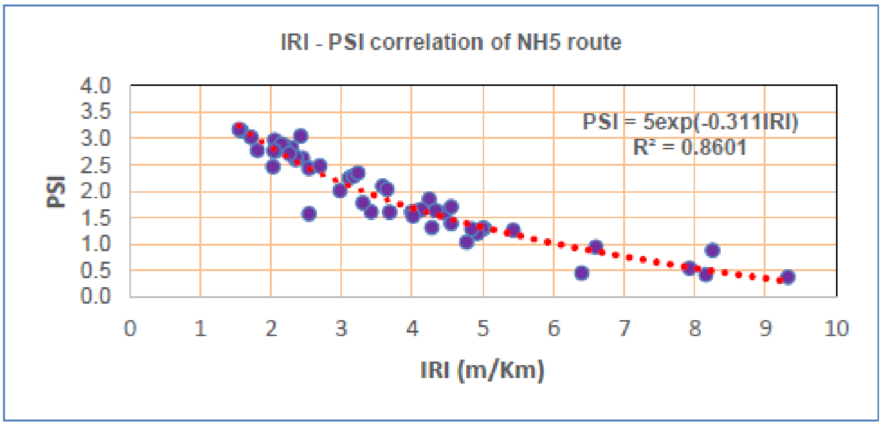

Figure 5. Diagram of IRI - PSI correlation of NH6 route

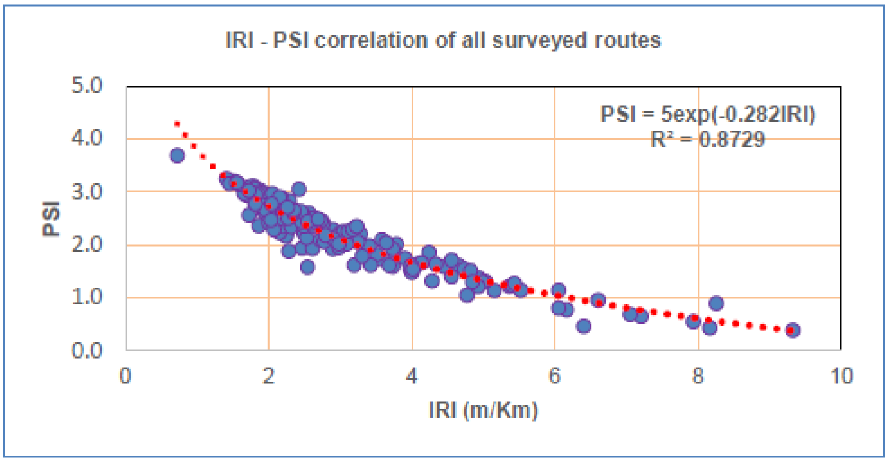

Figure 6. Diagram of IRI - PSI correlation of all surveyed routes

Based on statistical data and the IRI – PSI correlation of three Northern national highway routes for 150 surveyed points, the data show that in order to make it suitable for the conditions, the construction and mining technology level as well as asphalt concrete road pavement quality evaluation in Vietnam, the asphalt pavement is considered to be excellent when IRI = 1, corresponding to PSI = 5. From formula (5), when applying IRI = 1 and PSI = 5, we have k = 1. Using the correlation between IRI and PSI of all three surveyed sections with 150 points, combining the adjustment coefficient k in Vietnam's related conditions, the equation is defined as follows:

$$PSI = 5.e^{-282.(IRI-1)} \qquad (6)$$

In order to evaluate the suitability of the correlation model, the author compares the calculation results of the PSI using IRI under proposed formulas (6) and (1), (2), (3), the results are shown in Table 2 and Figure 7.

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Table 2. Evaluation of IRI - PSI correlation results

IRI (m/Km)	Under formula (1)	Under formula (2)	Under formula (3)	Under formula (6)
0	5.00	5.00	5.000	-
1	4.18	3.86	4.472	5.00
2	3.49	2.97	3.330	3.77
3	2.91	2.29	2.432	2.84
4	2.43	1.77	1.790	2.15
5	2.03	1.36	1.334	1.62
6	1.70	1.05	1.010	1.22
7	1.42	0.81	0.783	0.92
8	1.18	0.62	0.628	0.69

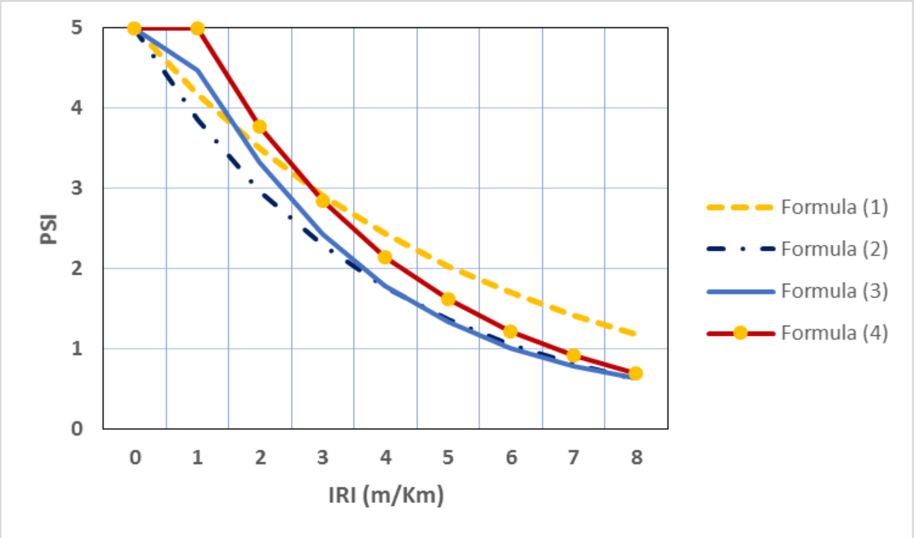

Figure 7. Comparison of IRI - PSI correlation results

Regression analysis results show that there is close correlation between IRI and PSI of each section of NH2, NH5, NH6 routes, R^2 of high values ranging from 0.8542 to 0.9405 with a reliability rate of 95%.

From formula 6, the research recommends the evaluation level of pavement quality being exploited in Vietnam by PSI, IRI as follows:

Table 3. Recommendation on the quality of asphalt concrete road pavement of national highways in the Northern Vietnam

PSI	Average IRI	Evaluation level
4-5	IRI ≤1.8	Very good
3-4	1.8<IRI≤2.8	Good
2-3	2.8<IRI≤4.3	Average
1-2	4.3<IRI≤6.8	Bad
0-1	IRI>6.8	Very bad

4. CONCLUSIONS AND RECOMMENDATIONS

From experimental research contents of determining the PSI and IRI values on 03 national highway routes in Northern Vietnam using the ARRB - Australia's specialized and modern equipment (Hawkeye) and statistical processing, establishing the relationship between IRI and PSI, the research results come to the following conclusions and recommendations:

Establishing the correlation between IRI and PSI will help to make the quality evaluation of asphalt concrete road pavement faster, reduce related costs and efforts in collecting, analyzing and treating, determining the status of pavement damage in the current period, when 3-D technology allowing automatically determining the level of pavement damage has not been applied.

The IRI and PSI indexes, when considered as two independent variables, it is clear from surveyed and processed data that they have the form of exponential distribution under the Kolmogorov statistic hypothesis testing, there is close correlation between PSI and IRI of the asphalt concrete road pavement of the surveyed national highway routes, with R^2 of high values ranging from 0.8542 to 0.9405.

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Given the pavement construction technology of national highway routes in the past and currently, in order to evaluate the quality of pavement in line with the reality, it is recommended to add and adjust the IRI to make it suitable with Vietnam's conditions by the coefficient k = 1.

It is proposed to use the formula (6) in evaluating the quality of asphalt concrete road pavement of the national highway routes under exploitation by IRI by direct or indirect measurement. It is recommended to evaluate the quality of asphalt concrete road pavement of national highways in the Northern Vietnam based on the values shown in Table 3.

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