

A Study on Correlation between International Roughness Index and Present Serviceability Rating

Kundan Hallur¹, Dr L Manjesh²

M.E Student (Highway Engineering), Department of Civil Engineering, University Visvesvaraya College of Engineering, Bengaluru, Karnataka, India ¹

Associate Professor, Department of Civil Engineering, University Visvesvaraya College of Engineering, Bengaluru, Karnataka, India ²

ABSTRACT: The roughness index is a function of the smoothness of the pavement, comfort and safety to the road user. Traditionally the assessment of road roughness has been based on the riding quality measured by an instrumented car or other suspension-type response instruments. Such devices are, however, neither time-stable in themselves nor consistent between similar vehicles. It is therefore necessary for their output to be calibrated against a standard roughness scale, such as the profile-based International Roughness Index (IRI). The various equipments available for measuring roughness are Meter Straight Edge, Dipstick Profiler, Profilographs, Rod and Level Survey and Response Type Road Roughness Measuring Systems. MERLIN, MWUI, VMBI and FWBI are categorised under RTRRMS. In the present study an attempt is made to measure unevenness of pavement using MWUI, Bump integrator - ROMDAS equipments for the selected study stretches with varying pavement condition. IRI values from various equipments are developed. The calibrations of these equipments are done using the standard equipment TRL MERLIN. An attempt is also made to determine the correlation between Present Serviceability Rating and International Roughness Index using different models.

KEYWORDS: IRI, UNEVENNESS, MERLIN, ROUGHNESS, VMBI, MWUI, FWBI, PSR.

I. INTRODUCTION

The function of pavement condition evaluation is to assess as to whether and to what extent a pavement is adequate for the purpose of or which it is intended so as to enable timely planning and execution of appropriate maintenance and strengthening measures. Serviceability rating is based on recognition of the fact that more often than not the engineers and the road users look at a pavement from different angles. Engineers are mainly concerned with structural adequacy of the pavement and its component, and the extent of structural or other damage that has occurred to the pavement in the form of cracks, surface deterioration etc. the serviceability rating technique emphasis that highway are for the comfort and convenient of the travelling public, and such as advocates user based evaluation of pavement condition

In order to evaluate pavement performance, present Serviceability Index is used. Pavement Serviceability represents the level of services that pavement structures offer users. This indicator first appeared as a rating made by users with respect to the state of the road, particularly the road surface. This rating is represented by a subjective index called Present Serviceability Rating' (PSR). A quantitative relationship is established between this Serviceability rating and certain parameters that measure physical distress of pavement surface.

A pavement, which is structurally sound to sustain heavy load repetitions, may even be unserviceable functionally if its surface is rough and distressed. Roughness of a road is an important parameter which not only indicates the comfort level of ride over a pavement surface, but is also related to vehicles vibration while in motion, the vehicle operating

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

speed, wear and tear of the wheels with time, affects the road user cost to a significant extent. The roughness index is a function of the smoothness of the pavement, comfort and safety to the road user.

International Roughness Index (IRI) and Present Serviceability index (PSI) are the parameters which are used to represent the smoothness and the performance of pavement. Modeling the relationships between Present Serviceability Rating (PSR) and International Roughness Index (IRI) are useful for efficient pavement management system.

1.1 Need for measurement of pavement surface Unevenness

Pavement unevenness is the most significant factor governing riding quality. Hence it is necessary to measure or evaluate the pavement surface unevenness.

The study of pavement unevenness is important from the following aspects:

- To judge the quality of construction.
- To assess the need for renewal of pavement surfacing.
- To create a healthy competition in the road construction industry to provide better riding quality.
- To create good public relations as the road users will judge the quality of construction mainly from the riding qualities of the pavement.

The method of measurement of pavement surface unevenness and the equipment should be simple and fairly fast so that the highway engineers could make use of them both during construction as a quality control check and also for carrying out surface condition surveys before deciding the maintenance measures.

1.2 Machine for Evaluating Roughness using Low cost Instrument (MERLIN)

MERLIN is simple equipment to measure the unevenness of pavement surface more accurately. This equipment measures the vertical displacement between the road surface under the probe and Centre point of an imaginary line joining the two points where the road surface is in contact with the two feet. By plotting the displacements as a histogram on chart mounted on the equipment, the spread can be measured and it has been found to correlate well with the road roughness.

1.3 Multiple Wheel Unevenness Indicator (MWUI)

MWUI is simple equipment used to measure unevenness of road surface and consists of 8 bogie wheels, connected through hinges to a datum frame. The bogie wheels are provided to achieve fixed datum. The probe wheel (cycle wheel) is centrally placed, which acts as a medium to measure the response to the road roughness. The unevenness values of pavement surface are expressed in terms of Unevenness Index in mm/km road length.

1.4 Fifth Wheel Bump Integrator (FWBI)

Fifth Wheel Bump Integrator is a single wheel trailer unit hauled by suitable vehicle at the specified uniform speed. The vertical oscillations are integrated with the help of an Integrator Unit. The unevenness values of pavement surface are expressed in terms of Unevenness Index or Roughness Index in mm/km road length.

1.5 Vehicle Mounted Bump Integrator (VMBI)

Vehicle Mounted Bump Integrator consists of an integrating unit which is mounted on the rear axle of jeep. The differential movement between the rear axle and the body of the vehicle due to road unevenness is measured by the upward vertical motion of a wire which is transmitted into unidirectional rotatory movement of the pulley of the integrator unit. The unevenness values of pavement surface are expressed in terms of Unevenness Index or Roughness Index in mm/km road length.

II. OBJECTIVES

- Measurement of unevenness using various equipments such as MERLIN, MWUI, and VMBI.
- Calibration of Roughness measuring equipment such as MWUI, and VMBI using MERLIN.
- Subjective rating of the pavement stretches by visual and ride rating technique.
- Development of models for correlation between IRI and PSR.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

III. FIELD INVESTIGATIONS

3.1 Selection of Study Stretches

For the study, five road stretches each of length 400m with varying surface condition from good to very poor are selected in Jnanabharathi Campus, Bangalore University. The following criteria were used for the selection of the test stretches.

- The test stretches are straight without horizontal curves and steep gradient.
- The test stretches have uniform riding quality and uniform surface throughout the stretch
- Cross drainage works, over-bridges are to be avoided within the test stretch.

The test stretches selected in the present study are shown in Table 3.1

Table 3.1 Selected Test Stretches for the present study

Stretch No	Name of the Stretch	Nomenclature of stretches	Condition
1	Mariappanpalya Road	Stretch A	Good
2	University Main Road	Stretch B	Good
3	Girls Hostel Road	Stretch C	Fair
4	Boys Hostel Road	Stretch D	Fair
5	Statistics Department Road	Stretch E	Poor

The pavement surface unevenness of selected study stretches are measured using following equipment

- a) Machine for Evaluating road roughness using Low cost Instrumentation (MERLIN)
- b) Vehicle Mounted Bump Integrator (VMBI)
- c) Multiple Wheel Unevenness Indicator (MWUI)

3.2 Unevenness Measurement Using MERLIN

IRI values of study stretches are shown in the Table 3.2.

Table 3.2 IRI values calculated using MERLIN

Stretch	IRI values for test stretches, m/km				Average IRI, m/km
	LHS		RHS		
	Trial 1	Trial 2	Trial 1	Trial 2	
A	3.85	3.88	3.83	4.00	3.89
B	3.65	3.55	3.70	3.70	3.65
C	5.25	5.15	5.17	5.22	5.20
D	5.48	5.44	5.54	5.50	5.49
E	6.70	6.68	6.72	6.62	6.68

Table 3.3 Comparison of IRI values

Stretch	IRI values for test stretches, m/km				
	Nov 2014	March 2015	August 2015	January 2016	May 2016
A	3.37	3.55	3.74	3.80	3.89
B	3.08	3.21	3.48	3.60	3.65
C	4.64	4.86	5.06	5.16	5.20
D	4.86	5.01	5.28	5.34	5.49
E	6.01	6.17	6.48	6.61	6.68

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

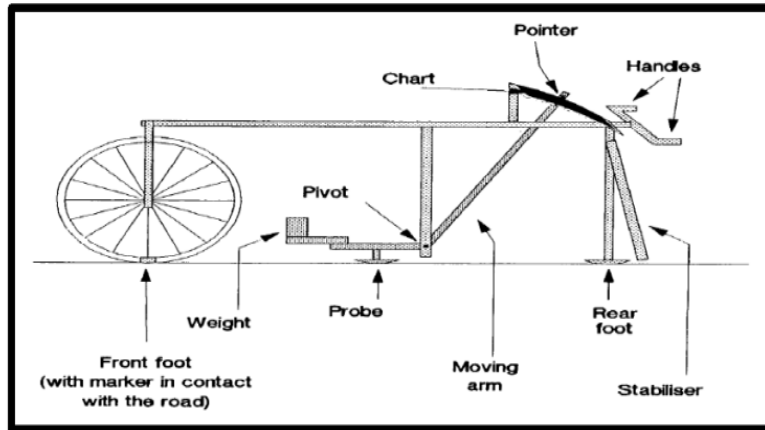


Figure 3.1: Various Components of MERLIN

3.3 Unevenness measurement using VMBI

Table 3.3 Bump Counts measured by VMBI

Stretch	Number of Raw Bump Counts per km				Average Raw Bumps per km
	Trial 1	Trial 2	Trial 3	Trial 4	
A	1422	1420	1425	1429	1424
B	1279	1280	1268	1265	1273
C	1730	1740	1735	1747	1738
D	1860	1875	1849	1858	1861
E	2550	2569	2554	2545	2555

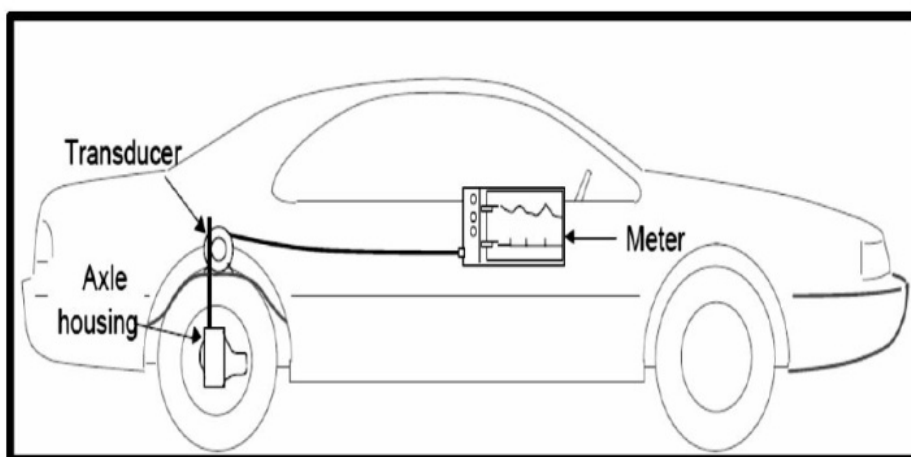


Figure 3.2 Schematic diagram of VMBI

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

3.4 Multiple Wheel Unevenness Indicator (MWUI)

Roughness of study stretches is measured using MWUI with integrator unit in terms of bump counts are shown in Table 3.4.

Table 3.4 Bump Counts measured by MWUI

Stretch	Number of raw bump counts per km				Average bump counts per km
	Trial 1	Trial 2	Trial 3	Trial 4	
A	1960	1965	1955	1962	1961
B	1880	1877	1920	1926	1901
C	2318	2322	2318	2324	2321
D	2650	2638	2663	2680	2658
E	3265	3274	3258	3282	3270

IV. CALIBRATION OF VMBI AND MWUI

The pavement unevenness of selected section is measured using roughness measuring equipment such as MWUI and VMBI in terms of bump counts. These equipment are calibrated using MERLIN. Table 4.1 shows calibration equation of equipment.

Table 4.1 Calibration Equation developed for Equipment

Equation No	Equipment	Calibration Equation	R ² Value
3.3	VMBI	$y = 2.658x + 328.4$	0.9680
3.4	MWUI	$y = 2.108x + 164.9$	0.9530

y= IRI m/Km,

x= Number of Raw Bump Counts per km

V. RATING STUDIES

To carry out the PSR studies, three panels were constituted viz highway, mixed and non- highway panels with six raters in each panel. An initial Orientation Program was conducted for the raters for assessing the pavement by both riding rating technique and visual rating technique. The raters were trained to rate the pavement surface for typical road stretches.

5.1 Visual Rating Technique

The members of the rating panel were trained to walk along the left and right wheel paths on the selected stretches and condition of the pavements was assessed based on the visual judgment of surface characteristics. The rating scale suggested by AASHO for the visual assessment of pavement is shown in Table 5.1.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Table 5.1 Description of Visual Rating Scale

Sl.No.	Description Based on Visual Rating	Numerical Scale
1	Perfectly even surface Without undulations, Cracking, Patching	4-5
2	Slightly uneven surface with some undulations, no pot holes and slight cracking	3-4
3	Moderately uneven surface, Visible patching and medium Cracking	2-3
4	Uneven surface with improper patched potholes, medium to high cracking	1-2
5	Uneven surface with different type of undulations, badly patched potholes, high cracking	0-1

5.2 Ride Rating Technique

For the rating by riding technique the raters were taken in test vehicle driven along the stretches at a speed of 30 kmph and are trained to assess the PSR value according to comfort condition. The rating scale adopted for the ride assessment of pavement is shown in Table 5.2.

Table 5.2 Description of Ride Rating Scale

Sl No	Description Based on Ride Rating	Numerical Scale
1	Without discomfort perfect smoothness	4-5
2	Little distortion, fairly smooth riding	3-4
3	Medium distortion fair to uneven riding	2-3
4	Heavy distortion uncomfortable riding	1-2
5	Intolerable, very discomfort in riding	0-1

5.3 Analysis of present serviceability ratings

The data were analyzed statistically to estimate the mean and standard deviation of rating values for each pavement section both for ride and visual rating techniques. The same data were analyzed for the estimation and removal of errors in the rating and the true ratings are presented in table 5.3 to 5.6.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Table 5.3 True Rating Using Visual Rating Technique – Highway Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.29	4.15	4.15	4.25	4.13	4.04	4.17
B	4.20	4.33	4.43	4.13	4.31	4.22	4.27
C	3.75	3.79	3.70	3.68	3.86	3.95	3.79
D	3.29	3.07	3.16	3.23	3.23	3.14	3.19
E	2.21	2.35	2.26	2.33	2.14	2.33	2.27

Table 5.4 True Rating Using Visual Rating Technique – Mixed Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.33	4.28	4.15	4.37	4.10	4.37	4.27
B	4.42	4.37	4.42	4.28	4.46	4.46	4.40
C	3.70	3.83	3.88	3.83	3.92	3.83	3.83
D	3.15	3.20	3.34	3.20	3.29	3.11	3.21
E	2.70	2.66	2.52	2.57	2.48	2.57	2.58

Table 5.5 True Rating Using Visual Rating Technique – Non Highway Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.25	4.14	4.34	4.16	4.32	4.30	4.25
B	4.43	4.23	4.25	4.43	4.50	4.21	4.34
C	3.89	3.96	3.98	3.80	3.77	3.85	3.87
D	3.26	3.42	3.08	3.17	3.14	3.30	3.23
E	2.35	2.42	2.45	2.62	2.51	2.49	2.47

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Table 5.6 True Rating Using Ride Rating Technique – Highway Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.15	4.10	4.15	4.24	4.06	4.08	4.13
B	4.24	4.19	4.06	4.15	4.24	3.99	4.15
C	3.61	3.56	3.70	3.61	3.61	3.72	3.63
D	3.07	3.11	2.88	2.97	2.98	3.09	3.00
E	2.43	2.48	2.61	2.43	2.43	2.46	2.47

Table 5.7 True Rating Using Ride Rating Technique – Mixed Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.23	4.27	4.27	4.27	4.29	4.32	4.28
B	4.32	4.45	4.36	4.36	4.39	4.23	4.35
C	3.77	3.73	3.73	3.73	3.75	3.59	3.72
D	3.05	3.01	3.01	3.10	3.12	3.14	3.07
E	2.51	2.46	2.47	2.46	2.31	2.60	2.47

Table 5.8 True Rating Using Ride Rating Technique – Non Highway Panel

Stretch No.	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Mean
A	4.36	4.36	4.32	4.43	4.41	4.34	4.37
B	4.45	4.36	4.50	4.52	4.41	4.34	4.43
C	3.82	3.82	3.69	3.71	3.87	3.80	3.78
D	3.10	3.10	3.24	2.99	3.05	3.17	3.11
E	2.47	2.47	2.42	2.54	2.42	2.54	2.48

5.4 Summary of relation between IRI and PSR

An attempt is made to develop relation between PSR and IRI data. Six different models are developed out of which two models, square root and linear shows best correlation between IRI and PSR with R² value 0.9420 and 0.9590 respectively. By using one of these models we determine the Present serviceability index of pavement from IRI data. Table 5.9 shows the summary of the selected 7 model results.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Table 5.9 Summary of the selected six model results

SI No	Model	Equation	R ² Value
1	Linear	$y = -0.593x + 6.621$	0.9590
2	Exponential	$y = 8.549 e^{(-0.17x)}$	0.9280
3	Logarithmic	$y = -2.89\ln(x) + 8.242$	0.9240
4	Power	$y = 13.64 x^{(-0.84)}$	0.8850
5	Square root	$y = -2.633x + 9.506$	0.9420
6	Log (1+x)	$y = -8.071x + 9.872$	0.9300

VI. DISCUSSIONS AND CONCLUSIONS

6.1 Results and Discussions

- From the roughness test result it was observed that IRI value of test stretch varies from 3.65 to 6.68 m/km using standard equipment MERLIN.
- Based on the IRI values and FHWA guidelines the roughness of test stretches can be classified under moderate to rough.
- The calibration equation for VMBI using MERLIN is $IRI, m/Km = 2.658(\text{Number of Raw Bump Counts per km}) + 328.4$ and $R^2 = 0.9680$
- The calibration equation for MWUI using MERLIN is $IRI, m/km = 2.108(\text{Number of Raw Bump Counts per km}) + 164.9$ and $R^2 = 0.9530$
- From the test result it was observed that bump counts were more in MWUI compared to VMBI. Because probe wheel of MWUI traverses through every smaller undulation on pavement, where in VMBI instrument skips undulations under high speed.
- The rating studies were carried out by constituting 3 panels. Viz: Highway panel, mixed panel and Non-Highway panel for the six selected pavement stretches. The mean visual rating values varied from 2.27 to 4.27 for Highway panel, 2.58 to 4.27 for mixed panel and 2.47 to 4.25 for Non-Highway panel. The mean ride rating value varied from 2.47 to 4.13 for Highway panel, 2.48 to 4.28 for mixed panel and 2.47 to 4.37 for Non-Highway panel.
- Non-Highway panel members were over sensitive to variation in pavement distress and riding comfort. They tend to rate with higher values when compared to other two panels for the same condition of the pavement.
- To correlate IRI with Present Serviceability Rating (PSR), different models are developed out of which square root and liner showed better correlation than remaining models with R^2 value 0.9590 and 0.9420 respectively.

6.2 Conclusions

- The R^2 value for VMBI is found to be greater than that of MWUI. It can be concluded that VMBI is more suitable for measurement of pavement roughness.
- As the ageing increases there is an increase in roughness, this may be due to increase in the occurrence of other distresses which are the functions of IRI viz. ravelling, settlement, cracking, patching etc.
- The models developed for the relationship between PSR and IRI show that visual rating and ride rating are a function of unevenness as it has a direct effect on the rating.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

REFERENCES

1. Sayers M. W., Gillespie T. and Paterson W. D. O, "Guideline for Calibrating Road Roughness Measurements", World Bank Technical Report 46, The World Bank: Washington D.C, 1986.
2. Cundill M. A. „The MERLIN Road Roughness Machine: User Guide”, Transport Research Laboratory Report 301, 1991.
3. IRC Sp-16-2004, "Guidelines for Surface Evenness of Highway Pavements" First Revision, New Delhi, 2004.
4. Yusak O, Bambang I. and Hendarto, "The comparison of roughness measurement between NAASRA, ROMDAS and MERLIN devices" Centre for Research on Transportation and Communication (PPTK-ITB), Indonesia, Nov 2001.
5. Perera, R. W. and Kohn, S. D." LTPP Data Analysis: Factors Affecting Pavement Smoothness". NCHRP Web Document 40 (Project 20-50[8/13]): Contractor's Final Report, Transportation Research Board, PP 248,2001.
6. Morrow G, "Comparison of Roughness Measuring Instruments" Department of Civil and Environmental Engineering, Auckland, May 2006.
7. Hudson, W. R. and Hain, R. C. "The Calibration and Use of the Bureau of Public Roads Roughometer at the AASHO Road Test," presented at the Annual Meeting of the Highway Research Board, January 1961.
8. Paterson. "International Roughness Index: Relationship to other Measures of Roughness and Riding Quality." Transportation Research Record 1084, TRB, National Research Council, Washington, DC, pp 49-59, 1986.
9. Mrawira D. and Haas R. "Calibration of the TRRL's Vehicle-Mounted Bump Integrator" Department of Civil Engineering Waterloo, Ontario, Canada, 1996.
10. Srikantha M K "Pavement Condition Evaluation of Selected Stretches", Bangalore University, Bengaluru, India, 2015.

BIOGRAPHY



Kundan Hallur
MISCA
P.G Student



Dr L Manjesh
M.E, PhD, MIRC, MIGS, MISTE