INVESTIGATING THE RELATIONSHIP BETWEEN PAVEMENT ROUGHNESS AND FREE FLOW SPEEDS (FFS) OF ROADWAYS FOR FFS TO BE USED AS A NETWORK LEVEL PAVEMENT PERFORMANCE EVALUATION METRIC.

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ABSTRACT

Road agencies require regularly updated pavement condition data for effective maintenance planning and network-level asset management. The International Roughness Index (IRI) is widely used to evaluate pavement roughness; however, conventional roughness surveys require dedicated equipment and are often costly to repeat frequently over large networks. This study investigated whether 85th percentile Free Flow Speed (V85) can be used as a supplementary indicator for network-level pavement performance screening. IRI data were collected using the RoadLab Pro smartphone application, while speed data were extracted using the Google Maps Distance Matrix API. Five selected two-lane road sections were analyzed at 100 m, 200 m, and 500 m segment lengths. Linear regression was first used to explore the IRI–V85 relationship, and Kruskal–Wallis testing was then applied to determine whether V85 differed significantly between IRI categories. Most regression models showed negative slopes, indicating that speed generally reduced as IRI increased. However, R^2 values were weak to moderate. The pooled Kruskal–Wallis p-values were 0.300, 0.181, and 0.075 for 100 m, 200 m, and 500 m segments, respectively. Therefore, statistically significant V85 differences between IRI categories were not confirmed. The study concludes that V85 should not replace IRI but may support preliminary pavement screening. Future research can be conducted by controlling for mode mix, land use characteristics, traffic volume, and other factors that influence vehicle speed to better evaluate the relationship between V85 and pavement condition.

Keywords: free flow speed, international roughness index, Kruskal–Wallis test, pavement roughness, road asset management

1. INTRODUCTION

Pavement condition is an important factor affecting road user comfort, vehicle operating cost, safety, and travel efficiency. Pavement roughness is one of the most widely used functional pavement performance indicators because it represents the unevenness of the pavement surface experienced by road users. The International Roughness Index (IRI) is commonly used to quantify pavement roughness and is widely applied in pavement performance evaluation, maintenance planning, and rehabilitation prioritization.

In pavement asset management, regular roughness data are required to identify deteriorated sections, prioritize maintenance, and allocate limited resources effectively. However, conventional pavement roughness surveys generally require specialized equipment, trained operators, and dedicated survey vehicles. Therefore, frequent network-level IRI data collection can be costly and difficult to maintain, particularly where agencies need rapid preliminary screening over large road networks.

With the increasing availability of digital transport data, Free Flow Speed (FFS) may provide useful supplementary information for pavement performance screening. Under free-flow conditions, drivers are less constrained by surrounding traffic, and their speed selection may be influenced by roadway conditions. Rougher pavement may increase vibration and reduce ride comfort, which can lead drivers to reduce operating speed. Previous research has shown that pavement roughness can influence vehicle free-flow speed, although the magnitude of the effect

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may be small within limited IRI ranges (Wang et al., 2014).
However, speed is influenced by many factors other than pavement roughness, including road geometry, access density, roadside friction, speed limits, traffic environment, and driver behavior. Therefore, FFS cannot be directly assumed as a pavement condition indicator. This study evaluates whether 85th percentile Free Flow Speed (V85) can be used as a supplementary network-level pavement performance screening metric for selected two-lane road sections.

2. LITERATURE REVIEW

IRI is commonly used to quantify pavement roughness and is widely applied in pavement performance evaluation, maintenance planning, and rehabilitation prioritization (Sayers et al., 1986). Research mapping of IRI studies shows that IRI remains a key measure in pavement roughness evaluation and road infrastructure performance assessment.
Several studies have examined the relationship between pavement roughness and operating speed. Wang et al. (2014) and Yu and Lu (2014) investigated the impact of pavement roughness on vehicle free-flow speed and found that pavement roughness had a small effect on free-flow speed within the roughness range considered in their study. This finding is important because it suggests that the roughness–speed relationship may not always be strong, especially where the IRI range is limited.
A local study by Abeygunawardhana et al. (2020) identified relationships between road roughness and vehicle speed patterns on different roadway segments. Smartphone-based roughness measurement has also been investigated as a cost-effective alternative for pavement condition assessment. Sandamal and Pasindu (2020) demonstrated the applicability of smartphone-based roughness data for pavement evaluation.
Although previous studies indicate that roughness may influence speed, the relationship depends on road type, traffic environment, roughness range, and analysis segment length. In addition, smartphone-based IRI measurements and digital speed data require careful interpretation because they are suitable mainly for preliminary screening. Therefore, this study contributes by evaluating IRI–V85 relationships at 100 m, 200 m, and 500 m segment levels and by applying category-based statistical testing to determine whether IRI category changes produce significant speed differences.
This section should critically review relevant literature to establish the current state of knowledge and position the study within existing research. It should identify key findings, methodologies, and limitations in prior work, leading to a clear articulation of the research gap addressed by the present study. The review should be concise and focused, while maintaining relevance to the research objectives.

3. METHOD

This study was conducted on five selected two-lane road sections: Old Galle Road, Moratuwa Section; Borupana Road; Colombo–Hanwella Low Level Road; Rathmalana–Mirihana Road; and New Negombo Road in the Colombo harbour area. These roads were selected to represent different urban, suburban, industrial, and port-access road environments.
Pavement roughness data were collected using the RoadLab Pro smartphone application. The same test vehicle was used during the survey to improve consistency, and the smartphone position was kept fixed. Surveys were carried out during low-traffic or night-time periods to reduce the influence of congestion on speed behavior. Global Positioning System coordinates were recorded for each segment, and abnormal or inconsistent records were removed during data cleaning.
Free Flow Speed data were extracted using the Google Maps Distance Matrix API. Travel time data were collected for each road segment, and speed was calculated using segment length and travel time. For each segment, repeated speed observations were used to calculate the 85th

percentile speed, V85. The IRI and V85 datasets were matched using segment coordinates.

The road sections were analyzed at three segment lengths: 100 m, 200 m, and 500 m. Linear regression was first used to explore the relationship between IRI and V85 using the equation below.

$$V_{85} = a + b(IRI)$$

Where $V_{85}$is the 85th percentile Free Flow Speed, $IRI$is the International Roughness Index, $a$is the intercept, and $b$is the slope. A negative slope indicates that speed tends to reduce as pavement roughness increases.

Since regression results were not sufficient to confirm the relationship statistically, IRI category-based analysis was conducted. IRI values were grouped into roughness categories using approximately 2 m/km intervals: IRI below 2, 2–<4, 4–<6, 6–<8, and IRI ≥ 8. The Kruskal–Wallis test was then used to test whether V85 values differed significantly between IRI categories. Road-normalized Kruskal–Wallis analysis was also conducted by subtracting each road's mean V85 from individual segment V85 values to reduce road-to-road speed differences.

4. RESULTS AND DISCUSSION

The regression analysis showed that most road sections produced negative slopes, indicating that V85 generally tended to reduce as IRI increased. However, the R^2 values were weak to moderate and inconsistent across roads and segment lengths. As summarized in Table 1, the average R^2 values were 0.168 for 100 m segments, 0.272 for 200 m segments, and 0.319 for 500 m segments. Although 500 m segments gave the highest average R^2, the median R^2 was only 0.139, and the number of observations was limited. The 100 m segment level provided greater spatial detail but showed higher scatter. The 200 m segment level provided the most practical balance between local pavement detail and stable speed representation. Therefore, 200 m was identified as the most practical segment length for network-level screening in this study.

Table 5.Summary of Segment-Level Regression Performance

Segment Length	Total Data Points	Average R^2	Median R^2	General Interpretation
100 m	158	0.168	0.187	Higher spatial detail, but more scatter
200 m	79	0.272	0.241	Most practical balance between detail and stability
500 m	31	0.319	0.139	Smoother results, but fewer observations

The IRI category summary showed that mean V85 did not reduce consistently across all IRI categories. This was mainly due to uneven sample sizes, particularly in the higher roughness categories. Therefore, visual comparison alone was insufficient, and statistical testing was required. The pooled Kruskal–Wallis test results are presented in Table 2. The test produced p-values of 0.300, 0.181, and 0.075 for 100 m, 200 m, and 500 m segment lengths, respectively. Since all p-values were greater than 0.05, statistically significant differences in V85 between IRI categories were not confirmed. The 500 m pooled result was closest to significance, but it still did not satisfy the 5% significance level.

Table 6.Pooled Kruskal–Wallis Test Results

Segment Length	n	IRI Groups	H Statistic	p-value	Result
100 m	158	4	3.668	0.300	Not significant
200 m	79	4	4.871	0.181	Not significant
500 m	31	3	5.169	0.075	Not significant

Road-normalized Kruskal–Wallis analysis was conducted to reduce the influence of different road operating environments. The p-values were 0.446, 0.391, and 0.530 for 100 m, 200 m, and 500 m segment levels, respectively. Therefore, even after normalization, statistically significant V85 differences between IRI categories were not confirmed. These findings do not prove that pavement roughness has no effect on speed. Instead, they indicate that the current dataset was not strong enough to statistically confirm the effect. The main reasons were limited IRI variability, small sample sizes in higher roughness categories, and the influence of other speed-controlling factors such as road geometry, access density, roadside friction, speed limits, traffic environment, and driver behavior. This agrees with previous findings that roughness may have only a small impact on free-flow speed within some IRI ranges (Wang et al., 2014).From a pavement asset management perspective, the method is more suitable for preliminary screening than final rehabilitation design. Road sections showing both high IRI and reduced V85 may be flagged for detailed pavement investigation. Therefore, FFS can support IRI-based pavement management but should not replace direct pavement roughness measurements.

5. CONCLUSION

This study evaluated the relationship between pavement roughness and 85th percentile Free Flow Speed for five selected two-lane road sections. Pavement roughness was measured using the RoadLab Pro smartphone application, while speed data were extracted using the Google Maps Distance Matrix API. The analysis was conducted at 100 m, 200 m, and 500 m segment levels.

The regression results showed generally negative slopes, indicating that V85 tended to reduce as IRI increased. However, the R^2 values were weak to moderate and inconsistent. Among the segment lengths considered, 200 m provided the most practical balance between local pavement detail and stable speed representation.

The Kruskal–Wallis tests did not confirm statistically significant differences in V85 between IRI categories. The pooled, road-normalized, and road-wise analyses all produced p-values greater than 0.05. Therefore, the current dataset does not provide sufficient statistical evidence to confirm that higher IRI categories produce significant reductions in V85.

The study concludes that V85 should not be used as a direct replacement for IRI. However, it has potential as a supplementary network-level pavement screening indicator. Future studies should collect more data from roads with wider IRI variation, especially IRI values around 8–9 m/km, validate smartphone-based IRI measurements using profiler-based surveys, and include additional explanatory variables such as road geometry, access density, roadside friction, speed limits, and land use.

6. REFERENCES

1. Abeygunawardhana, C., Sandamal, R. M. K., & Pasindu, H. R. (2020). *Identification of the impact on road roughness on speed patterns for different roadway segments*. MERCon 2020: 6th International Multidisciplinary Moratuwa Engineering Research Conference.
2. Sandamal, R. M. K., & Pasindu, H. R. (2020). Applicability of smartphone-based roughness data for rural road pavement condition evaluation. *International Journal of Pavement Engineering*. https://doi.org/10.1080/10298436.2020.1765243
3. Sayers, M. W., Gillespie, T. D., & Queiroz, C. A. V. (1986). The International Road Roughness Experiment: A basis for establishing a standard scale for road roughness measurements. *Transportation Research Record, 1084*, 76–85.
4. Wang, T., Harvey, J., Lea, J., & Kim, C. (2014). Impact of pavement roughness on vehicle free-flow speed. *Journal of Transportation Engineering, 140*(9). https://doi.org/10.1061/(ASCE)TE.1943-5436.0000689
5. Yu, B., & Lu, Q. (2014). Empirical model of roughness effect on vehicle speed. *International Journal of Pavement Engineering, 15*(8), 737–747. https://doi.org/10.1080/10298436.2013.792931