Abridgment

Relationships Between Various Classes of Road Surface Roughness and Ratings of Riding Quality

Hugh J. Williamson, W. Ronald Hudson, and C. Dale Zinn, Center for Highway Research, University of Texas at Austin

This paper discusses the development of new methods for evaluating the riding quality of a road. Methods of this type are important because the ability to evaluate the present condition of a road is essential both for maintaining a system of high-quality roads now and for improving highway engineering practices in the future through research.

The new methods are based on evaluations of the quality of a road made by a panel using descriptors of different aspects of road roughness as predictor variables. Thus several predictive models are developed, each of which relates to a certain aspect of riding quality.

BACKGROUND

Serviceability

The present serviceability rating (PSR) introduced by Carey and Irick (1) is an evaluation of the present ability of a road to serve the public. The PSR is made by a panel of people and ranges from 0 (very poor) to 5 (very good).

Determining panel ratings, however, is very time-consuming. Another approach, which was introduced by Carey and Irick (1) and which has subsequently been taken by several other investigators (3, 4, 5), is to develop a regression model that can be used to predict PSR. The estimate of PSR so obtained is called the serviceability index (SI).

Roughness Measurement and Evaluation

A device such as the General Motors surface dynamics profilometer can be used to measure road surface elevation versus distance along the road in both the right and left wheel paths. Because of the large amount of data required to fully describe a road surface, most uses of the data require the calculation of a small set of characterizing measures of roughness.

In this study, the roughness was categorized on the basis of wavelength through digital filtering; four bands spanning the range from 1.219 to 30.48 m (4 to 100 ft) in wavelength were included. For each band, characterizing measures of both the most severe roughness and the average roughness of each road section were computed. The waves in both wheel paths were analyzed along with the surface profile elevation undulations of one wheel path relative to the other; the latter causes a vehicle rolling effect. The mathematical calculations are described explicitly elsewhere (6, 7).

RELATIONSHIP BETWEEN COMPONENTS OF ROUGHNESS AND PSR

An SI model provides a means for associating a riding quality index with a set of physical measurements and thus greatly facilitates interpretation of the measurements. Still, neither SI nor any other single number could reflect or characterize all of the important information in a measured road profile.

For this reason, a set of SI models was developed that can be used to transform the roughness measures corresponding to each wavelength band into a measure of riding quality that is directly related to PSR. This was achieved by regressing PSR on the roughness terms for each individual band. Then the model for 1.219 to 3.048-m (4 to 10-ft) wavelengths, for example, predicts whatever part of the variation in PSR is interpretable or explainable in terms of this class of roughness.

Separate models were developed for asphalt concrete (asphalt) and portland cement concrete (concrete) pavements. In addition to the roughness measures, the models also contain a dummy variable to account for any possible visual or auditory differences between types of pavements that may not be explainable in terms of roughness. The dummy variable was used to differentiate between continuous and jointed pavements in the concrete case and between surface-treated and hot-mix asphalt concrete pavements in the asphalt case.

The multiple correlations and other information about the models are given in Table 1. Space restrictions do

---

Publication of this paper sponsored by Committee on Pavement Condition Evaluation.

Table 1. Characteristics of the SI models.

Type of Pavement	Sample Size	Wavelength[a] (m)	Correlation With PSR	Standard Error	Number of Terms in Model[b]
Concrete	22	1.219 to 30.48 (overall)	0.91	0.32	6
		1.219 to 3.048	0.86	0.37	5
		3.048 to 7.620	0.85	0.38	4
		7.620 to 15.24	0.77	0.46	4
		15.24 to 30.48	0.75	0.46	3
Asphalt	50	1.219 to 30.48 (overall)	0.91	0.38	8
		1.219 to 3.048	0.86	0.45	6
		3.048 to 7.620	0.82	0.49	5
		7.620 to 15.24	0.81	0.52	6
		15.24 to 30.48	0.68	0.61	2

Note: 1 m = 3.28 ft.

[a] Type of roughness. [b] Including constant term.

not allow presentation of the models themselves here, but they are available elsewhere (7).

Stepwise regression, a method for choosing a subset of a collection of possible predictor variables, was used to develop the regression models (2). We note three points:

1. The multiple correlation of 0.91 for both overall models is very high, which indicates that there is a close relationship between roughness and PSR. This is consistent with other published results (1, 3, 4, 5).
2. For the models corresponding to the individual pass bands, the correlations decrease monotonically as wavelength increases. Although it is dangerous in general to assume automatically that a cause and effect relationship exists between two variables that are highly correlated, it seems reasonable in this case to infer from the correlations that the raters were more sensitive to short than to long waves. Further experimental work to assess the isolated effect of severe long waves caused by swelling clay would be valuable, however.
3. The correlation of 0.86 for both the concrete and asphalt models for 1.219 to 3.048-m (4 to 10-ft) wavelengths is almost as high as the 0.91 correlation for all roughness measures combined. This again suggests the close relationship between PSR and short waves.

Correlations among the roughness terms unquestionably cloud the relationships between PSR and individual types of roughness to some extent, but this problem would be difficult to eliminate.

TEST CASES

The SI models were applied to profiles measured on I-20 near Odessa, Texas, just before and just after a hot-mix overlay was performed. The overlay produced (a) an improvement of 1.12 in the overall SI value, (b) an improvement of 1.58 for 1.219 to 3.048-m (4 to 10-ft) wavelength roughness, and (c) steadily decreasing improvements [0.05 for 15.24 to 30.48-m (50 to 100-ft) wavelengths] for longer waves. The results are consistent with field observations, with effects seen in plots of the measured profiles, and with the nature of the roughness improvement that would be expected of any overlay performed with a 7.62-m (25-ft) skid.

This test case and others, along with the details of the model development, are discussed further elsewhere (7). Separate models for longitudinal and transverse roughness are also presented.

SUMMARY

This paper discusses the development and application of a set of riding quality indexes that characterize the road roughness with different ranges of wavelengths. The indexes are based on the relationship between road surface profile data and ratings made by a panel of riding quality and were derived through regression analysis.

ACKNOWLEDGMENTS

This study was carried out at the Center for Highway Research at the University of Texas at Austin. We wish to thank the sponsors, the Texas Department of Highways and Public Transportation and the Federal Highway Administration. The suggestions made by the Texas Department of Highways and Public Transportation contact representative, James L. Brown, have been very beneficial. The programming support provided by Randy Wallin and Jack O'Quin and the profile measurements made by Harold Dalrymple, Noel Wolf, and Leon Snider are also greatly appreciated.

The contents of this report reflect our views, and we are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration.

REFERENCES

1. W. N. Carey, Jr., and P. E. Irick. The Pavement Serviceability-Performance Concept. HRB, Bulletin 250, 1960, pp. 40-58.
2. N. Draper and H. Smith. Applied Regression Analysis. Wiley, New York, 1966.
3. L. F. Holbrook and J. R. Darlington. Analytical Problems Encountered in the Correlation of Subjective Response and Pavement Power Spectral Density Functions. HRB, Highway Research Record 471, 1973, pp. 83-90.
4. F. L. Roberts and W. R. Hudson. Pavement Serviceability Equations Using the Surface Dynamics Profilometer. Center for Highway Research, Univ. of Texas at Austin, Research Rept. 73-3, April 1970.
5. R. S. Walker and W. R. Hudson. Use of Profile Wave Amplitude Estimates for Pavement Serviceability Measures. HRB, Highway Research Record 471, 1973, pp. 110-117.
6. H. J. Williamson. Analysis of Road Profiles By Use of Digital Filtering. TRB, Transportation Research Record 584, 1976, pp. 37-54.
7. H. J. Williamson, W. R. Hudson, and C. D. Zinn. A Study of the Relationships Between Road-Surface Roughness and Human Ratings of Riding Quality. Center for Highway Research, Univ. of Texas at Austin, Research Rept. 156-5F, Aug. 1975.