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Evaluation of Ride Equation Using Current Profiler Systems and New Sensor Technology

This report describes the research performed to evaluate the current ride equation used by the Texas Department of Transportation (TxDOT). The existing equation for determining Present Serviceability Index (PSI) from measured profile is based on ride measurements obtained from a rating session conducted in the late 1960s. Since its original development over 30 years ago, a number of changes have occurred that require a re-evaluation of the current equation. These include such things as changes in vehicle design, and the switch from the predominantly large automobiles to the smaller and more fuel efficient mid-sized and compact cars of today. Additionally, TxDOT has changed the PSI reporting interval from 0.2- to 0.1-mile.

The current ride equation is considerably different from the original equation used by TxDOT for estimating PSI from profile data obtained with the Surface Dynamics Profilometer (SDP). The original model was developed from a rating session that was held in the late 1960s. In that rating session, the profile of each section was measured and various statistics computed. Included in these statistics were the amplitudes and wavelengths, or spectral estimates that make up the road profile. The first model related these estimates to the ride ratings. Since the time this first equation was developed, several modifications were made. The first occurred in the early part of the 1980s, at which time a model was developed that would include a better relationship for calibrating the less expensive Mays Ride Meter. About 1995, a model was developed that related the PSI from the profile measurements to the International Roughness Index, or IRI. This model was later refined in 1996 and is in current use today.

What We Did…

Researchers conducted two ride surveys that provided data for evaluating the correlation between subjective ratings of ride quality, and the predicted ratings determined using the current equation. For this purpose, researchers and TxDOT personnel established 0.1-mile test sections of varying roughness levels on which inertial profile measurements and ride panel ratings were made. The first survey, conducted in 1999, involved panel ratings on asphalt and Portland cement concrete (PCC) test sections located in Brazos, Madison, and Montgomery counties. The second survey, conducted in 2000, was organized to verify the effect of pavement type. This second survey primarily covered PCC sections located in the Dallas/ Fort Worth areas, and was

intended to supplement the data collected from the first survey where the majority of sections were asphalt concrete pavements. In both surveys, participants were asked to rate the ride quality of each section on a 0 to 5 scale, with 0 representing an extremely rough pavement, and 5 representing an extremely smooth pavement.

Researchers analyzed the data to establish the effects of a number of factors on user perception of ride quality and to evaluate the current ride equation through comparisons of the predicted ratings with those from the ride panel. These efforts led to the development of a new ride model that is documented in Research Report 4901-1, and briefly described in this document. The main findings from analyses of the ride survey data are summarized in this document.

What We Found…

The Current Ride Equation

Differences between the predicted PSIs from the current ride equation and the mean panel ratings on a number of sections were found to be statistically significant. This fact is not surprising, considering the PSI equation is directly related to IRI and not the Present Serviceability Rating (PSR). Texas is not the only state to use an IRI-based ride equation. The equations developed from two recent studies (see Transportation Research Record #1435), by Al-Omari, et al., and by Sedat, et al., were compared with the Texas ride equation. These comparisons showed that the current IRI-based

equation is as good as those developed in these two other studies. Thus, if the goal is to have a ride equation based on IRI, the current TxDOT equation appears suitable.

New Ride Model

Because of the need to relate the ride equation directly to road user perception of ride quality, a new equation was developed from the 1999 and 2000 rating sessions. Similar to the model developed from the rating session in the late 1960s, the new model directly relates the road profile spectral density characteristics to the mean panel ratings. The wavelengths found correlated to ride ranged from 1 to 8 meters, or about 3 to 26 ft. For the new model, the power spectral estimates are calculated from the measured profile and are used to obtain the PSI. This new model is of the form:

$$\text{PSI} = 5\, e^{-\sqrt{\alpha P}}$$

where PSI denotes the predicted PSR and αP is given by:

$$\alpha P = \alpha_1 P_1 + \alpha_2 P_2 + \dots + \alpha_8 P_8$$

Each P_i term represents a power spectrum for each frequency component, i.e., 1 to 8 meter wavelengths. The set of "α" coefficients was derived from regression analysis of the power spectral estimates and the mean panel ratings. Figure 1 illustrates the relationship between the mean panel ratings, the predicted ratings from the current IRI-based model, and the ratings from the new model. Figure 1 shows

that the new model more closely follows the panel ratings than does the IRI-to-PSI model currently used by TxDOT. Specifically, this figure shows that the IRI-based model tends to overrate the smoother pavements and underrate the rougher pavements.

Summary of Findings

Following is a summary of the findings and conclusions from this research:

1. The panel ratings from both the 1999 and 2000 surveys appear to be spatially independent even though the sections were rated in a certain sequence.

2. The effects of the following factors on subjective ratings of ride quality were found to be significant at a confidence level of 95 percent or higher:
   a. Section roughness, which showed a noticeable correlation with the panel ride ratings;
   b. Vehicle type;
   c. The individual rater.

3. Using the data from both surveys, there was inconclusive evidence to support the need to include a blocking factor for pavement type in the ride equation. Thus, the same equation can be used for flexible and rigid pavements.

4. The ratings from both surveys indicate that the existing ride equation tends to overestimate user opinions of ride quality for smooth pavements and underestimate user opinions of ride quality for rough pavements. This
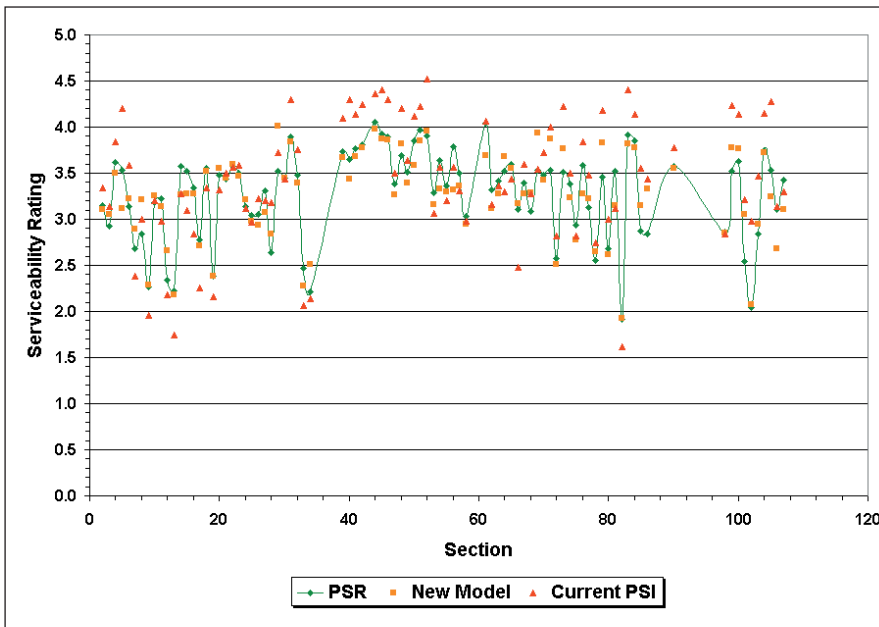
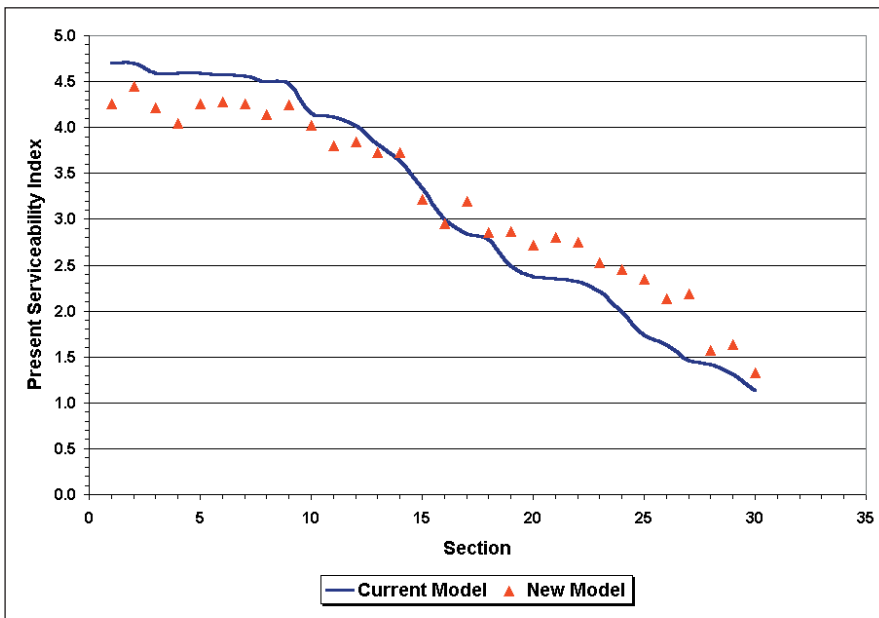Figure 1. Comparison of Models with Panel Ratings

Figure 2. New and Current Model Comparisons for the Austin Test Sections

finding supported the need for calibrating or revising the existing ride equation to improve the agreement with the panel ratings from the surveys conducted. Thus, researchers developed a new model.

5. The current equation that directly relates ride to IRI is as good as two other models developed in two independent studies done in other states.

6. Relative to the current ride equation, a ride model was developed that shows improved correlation with mean panel ratings, and that relates panel ratings directly to the physical or spectral characteristics of road profile.

The Researchers Recommend…

1. Application of the new model to evaluate ride quality on the Austin calibration sections maintained by TxDOT provided the results shown in Figure 2. This figure illustrates that the IRI-based model gives higher ratings for smoother roads and lower ratings for rougher roads than the new ride model.   This observation is consistent with the general trend noted in Figure 1. Researchers recommend further field evaluations to assess the potential impact of using the new model on pavement management needs due to the expected shift in the ride scores that will result as TxDOT switches from the old to the new ride model.

2. Researchers recommend that TxDOT consider using the new ride statistic to evaluate initial surface smoothness for quality assurance testing, and to report the ride quality of Texas highways in the Pavement Management Information System database.

For More Details...

The research is documented in Report 4901-1, *Evaluations of Ride Equation.*

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TxDOT Implementation Status—December 2003

The new ride equation developed in this project will be implemented in the PMIS by the Construction Division without an implementation project. The new equation is being evaluated for final implementation with a larger data set.

For more information, contact Dr. German Claros, P.E., Research and Technology Implementation Office, at (512) 467-3881 or by email at gclaros@dot.state.tx.us.

Disclaimer

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement. The engineer in charge of the project was Dr. Roger S. Walker, P.E. (Texas, Serial No. 3154).