Evaluation of Subjective Rating of Unpaved County Roads in Indiana

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Counties and other local highway agencies continually use visual or subjective rating systems for routine and periodic road inspections. In a study of unpaved roads in Indiana, a subjective rating of unpaved roads was evaluated. Using a rating scale ranging from 0 to 5 for worsening road condition, regression relationships were determined among a panel condition rating and measured road roughness number, average rater speed and visually rated corrugation, potholes, rutting and gravel looseness. As expected, the panel condition rating worsened with increasing roughness, and average rater speed decreased with increasing panel condition rating. However, because most of the roads studied were in reasonable condition, considerable reduction in average speed was not experienced. An examination of road distresses also showed that corrugations and potholes were more related to panel condition rating than the other distresses. The results were used to suggest a basis for selecting maintenance activity based on the panel condition rating, present serviceability rating, roughness, and average speed. A comparison of ratings by the study panel from Purdue and panels from two countries indicated that the county panels generally rated their roads to be in better condition than the Purdue panel. However, in any subjective rating, consistency within any group is the most important consideration.

Over the years visual or subjective assessment of road condition has been the traditional method of inspection by highway engineers. Application of a visual assessment procedure requires experience and a knowledge of maintenance and improvement practices that apply to identified distresses. Several attempts have been made to quantify these visual ratings by using numeric ratings to represent pavement and surface conditions. Such subjective numeric ratings have also been related to measure roughness and other measurable road surface distresses, such as cracking and patching, as well as rut depth *(1–7)*.

Carey and Irick defined the concepts of present serviceability index (PSI) as a result of work at the AASHO Road Test *(1)*. These concepts involved the road user who determined whether or not the road condition was satisfactory. The PSI was obtained by correlating user opinions with objective measurements of road roughness (using AASHO slope profilometer) and the extent of cracking and patching as well as rutting in asphalt pavements. A rating scale from 0 to 5 representing the range from "impassable pavement" condition to a "perfectly smooth" pavement was used by a panel of road users who drove and rated selected road sections. The individual panel member's average ratings for any section, designated the present serviceability rating (PSR), was correlated to the objective measurements applying regression techniques. The rating calculated using the resulting regression equation is the PSI *(4)*. Separate equations relating PSI and roughness have been derived in Indiana for rigid and flexible pavements *(7)*; however, different equations are required if these concepts are to be applied in evaluating unpaved roads.

Hutchinson *(8)* cautioned the use of subjective rating systems, and Weaver *(3)* reported application of psychophysical principles to the quantification of the attribute of pavement serviceability. As a result of Weaver's work, a rating procedure using these principles is currently being used by the New York State Department of Transportation for the evaluation of the state highway system. The extent of some of these developments was outside the scope of the needs of typical county highway departments and was not considered in this study.

In this paper a subjective rating using ride comfort (PCR) on county gravel and stone roads in Indiana is evaluated. The purpose of the analysis was to determine the relationship between average PCR and measured roughness, average rater speed, as well as visually assessed road distresses and cross-sectional characteristics.

SELECTION OF COUNTIES AND ROADS

The five Indiana counties selected were Bartholomew, Huntington, Jasper, Tippecanoe, and Warrick (Figure 1). Their locations were chosen to cover the major engineering soil groups in the state and also to represent the major climatic zones within the state. Both the subgrade soils and the weather were expected to highlight basic differences in unpaved road performance in Indiana.

DETERMINATION OF SIZE OF RATING PANEL

The number of raters is important for reducing errors in the rating. Nakamura *(9)* proposed that if an error of 1.0 can be permitted, just two or three raters would be required. It was shown, however, that as a rule, a panel of 5 to 10 members would be necessary for a representative rating of roads. The use of rating schemes involving panels of 10 or more on a routine

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FIGURE 1 Location of study counties in the state of Indiana.

basis at the local level may present resource and management problems. Such larger-size panels could be used periodically to determine road needs for preparation of road plans. Nevertheless, some form of rating system would still be required for the local highway staff to determine on routine inspection the condition of paved and unpaved roads in their network. Five panel members were in this study.

COMPOSITION OF STUDY RATING PANELS

Raters differ in their perception of road condition, and differences can occur among raters of different professions and backgrounds. Lay raters were found to rate pavements higher than highway engineers *(9)*. This finding was later supported by Yoder and Milhous *(4)*.

In this study, unpaved road sections were rated by two panels. The first panel consisted of five graduate and research engineers from Purdue University who assessed the condition of all roads in each of the five counties. The second panel was expected to be a team of at least three officials, including the engineer, supervisor, or foreman or other county highway official as appropriate; however, only Huntington and Bartholomew counties were able to form rating panels for this study.

Each panel member undertook an independent road condition assessment based on criteria presented after an initial training session.

ASSESSMENT OF RIDEABILITY, DISTRESSES, AND AVERAGE SPEED

Each panel member rated the rideability (ride comfort) of the road surface and assessed the rating and percentage of road surface covered by corrugations, potholes, rutting, gravel loss and looseness, cross section, camber or cross slope, and side drainage. Each member's average travel speed over the section was also calculated. The rating form completed by the panel is shown in Figure 2, and the rating criteria for assessing rideability and gravel road surface distresses are given in Table 1.

Rideability

Rideability was assessed while the rater maintained a speed of 40 mph (64 kph) on each section unless prevailing road conditions required a reduction in speed. This speed was chosen because it was considered the lowest speed limit that an average automobile travels on a good gravel or stone road in Indiana. Most automobiles can usually travel faster than 40 mph. In rating the rideability of the road, care was taken to consider ride comfort alone to avoid any influence of road surface conditions. It was also important that unpaved roads be rated in their own right without comparing the ride with expectations on paved roads. This was emphasized because of the possibility that people not accustomed to driving on gravel and stone roads might rate such roads poorer than individuals with experience of rating or driving on unpaved roads. This aspect was investigated further when the ratings by local officials and the panel from Purdue University were compared.

Ride quality in Table 1 was defined as high, medium, or low as follows:

1. *High.* Vehicle vibrations are noticeable, but no reduction in speed is necessary for comfort and safety; or individual bumps or settlements cause the vehicle to bump slightly with little discomfort.
2. *Medium.* Vehicle vibrations are significant and some reduction in speed is necessary (by up to 10 mph or 15 kph) for safety and comfort; or individual bumps or settlements cause the vehicle to bounce significantly, creating some discomfort.
3. *Low.* Vehicle vibrations are so excessive that speed must be reduced considerably [by 15 mph (25 kph) or more up to 20 mph (32 kph) or less] for safety and comfort; or individual bumps or settlements cause the vehicle to bounce excessively, creating substantial discomfort or a safety hazard or high potential for vehicle damage.

Average Rater Speed

Average rater speed was tested as a possible rating criterion and it was assumed that vehicles will reduce speeds below 40 mph

HIGHWAY EXTENSION RESEARCH PROJECT FOR INDIANA COUNTIES AND CITIES
SCHOOL OF CIVIL ENGINEERING, PURDUE UNIVERSITY

GRAVEL ROAD CONDITION RATING FORM

COUNTY ________ ROAD NAME/NO. ________ NAME OF RATER ________ DRIVER 1 ________

DATE ________ WEATHER ________ DRIVER 2 ________

ODOMETER READING/ DISTANCE	SECTION NUMBER	TRAVEL TIME (SECS)	RIDE COMFORT (PCR)	CORRUGATIONS		RUTTING		POTHOLES		GRAVEL LOOSENESS		SIDE DRAINAGE		CAMBER/ CROSSFALL	
				RATING	PERCENT SECTION	RATING	PERCENT SECTION	RATING	PERCENT SECTION	RATING	PERCENT SECTION	RATING	PERCENT SECTION	RATING	PERCENT SECTION

FIGURE 2 County unpaved road condition rating form.

TABLE 1 DESCRIPTION OF RATING SPECIFICATIONS

Distress Type	No. Rating	Description	Distress Specification
Rideability	5	Very poor	Ride was very uncomfortable, with several speed changes. Vehicle operation was at low speeds of about 20 mph.
	4	Poor	Ride was uncomfortable. Speed changes of more than 10 mph occurred.
	3	Fair	Speed changes up to 10 mph occurred but ride quality was medium.
	2	Good	Very little speed change on the ride (less than 5 mph) at few locations only.
	1	Very good	It is possible to operate at 40 mph with no change. Ride quality is high.
Corrugation	5	Very severe	Corrugations are more than 2 in. deep. Ride quality is low.
	4	Severe	Corrugations are 1.5 to 2 in. deep. Ride quality is low to medium.
	3	Moderate (fair)	Corrugations are about 1 in. deep. Ride quality is medium.
	2	Slight (good)	Corrugations have just begun. (About ½ in. deep.) Ride quality is medium to high.
	1	Very good	Corrugations are not noticeable. Ride quality is high.
Rutting	5	Very severe	Ruts with mean depth greater than 2 in. Ruts are so bad that vehicles are forced to use ruts or choose other paths.
	4	Severe	Ruts are between 1.5 and 2 in. Vehicle paths are forced.
	3	Moderate	Ruts about 1 in deep. Vehicle paths may be forced.
	2	Slight	Ruts are about 0.5 in. deep. Vehicle paths are barely affected.
	1	Very good	Ruts are barely noticeable or absent.
Potholes	5	Very severe	More than 40 holes within 100 yd or meters. Ride quality low.
	4	Severe	Between 30 and 40 holes in 100 yd or meters. Ride quality is low to medium.
	3	Moderate (fair)	About 20 to 30 holes in 100 yd or meters. Ride quality is medium.
	2	Slight	About 10 holes in 100 yd or meters. Ride quality is medium to high.
	1	Very good	Fewer than 10 holes in a 100 yd or meter section. Ride quality is high.
Gravel looseness	5	Very loose	Gravel or stone is in place but not compacted. Ride quality is low.
	4	Loose	Gravel or stone is in place but is only slightly compacted. Ride quality is low to medium.
	3	Moderate	Gravel is fairly compacted in wheel paths with few loose stones. Ride quality is medium.
	2	Slight (good)	Gravel or stone surface has good compaction with few loose gravel or stone. Ride quality is medium to high.
	1	Very good	Gravel or stone is well compacted. Very little loose gravel exists. Ride quality is high.

(64 kph) if the road condition is poor. Average rater journey speed over the section was determined by measuring the time taken to travel a particular section length. The vehicle odometer was used to determine distances between intersections marking the beginning and end of study road sections. Each gravel road section in the five study counties was rated during field surveys in the summer of 1983. Sections in Tippecanoe county were rated again in 1984.

Roughness Measurements

A portland cement association (PCA) roadmeter supplied by the Division of Research and Training (DRT) of the Indiana Department of Highways (IDOH) was used by DRT staff for measuring roughness on the study road sections. Roughness unit was "counts per mile" measured at a speed of 20 mph (32 kph), which was found to create fewer instrumental problems compared with a speed of 50 mph (80 kph) normally used for PCA roadmeter measurements. Measurements were made over an entire 1-mi (1.6 km) section following the normal practice by the DRT of measuring roughness on 1-mi sections on the state highway network. Calibration was provided from measurements by the DRT on an existing paved road section as well as other measurements relating roughness at various measuring speeds *(10)*.

RESEARCH DESIGN AND STATISTICAL ANALYSIS

The statistical design of the experiment was a Nested Factorial Design with unequal cells. Based on the selection of roads and the panel condition rating procedure adopted, an experimental layout is shown in Figure 3 for Huntington County. A similar design applies to Bartholomew County, which also formed a rating panel. Experimental layout for the other three counties is similar, but excludes county raters.

The dependent variable PCR was tested first for normality then analysis of covariance (ANCOVA) was conducted to determine the effect of counties, roads within counties, sections within roads, and individual raters using the general linear model procedure of the Statistical Analysis System (SAS) computer package *(11)*. The Statistical Package for Social Sciences (SPSS) was used in all other statistical analyses *(12)*.

The analysis of variance showed the interaction between individual panel members and counties to be significant at an α-level of 0.05, thus violating the assumption of additivity required for analysis of variance *(10, 14)*. This interaction was further investigated by plotting the average PCR for each rater in each county. The resulting graph is shown in Figure 4 for the three counties—Bartholomew, Jasper, and Tippecanoe—for which concurrent roughness measurements were taken with panel condition ratings. The crossing of the lines between Raters 1 and 2 depicts some rating inconsistencies introduced by differences in ratings by both Raters 1 and 2 compared with ratings by other panel members. Apart from individual variation in rating by Rater 1, a difference may have been introduced by Rater 2 as a result of a panel member substitution in 1984 for rating assessments in Tippecanoe County. Because the results were inconsistent across counties, the data were analyzed separately.

ROADS / SECTIONS		PANELS							
		PURDUE					COUNTY		
		1	2	3	4	5	1	2	3
R1	S1	1*	1	1	1	1	1	1	1
	S2								
R2	S1								
	S2								
R3	S1								
	S2								
R4	S1								
	S2								
	S3								
R5	S1								
	S2								
	S3								
R6	S1								
	S2								
	S3								
	S4								
R7	S1								
	S2								
R8	S1								
	S2								

* NOTE: One rating per panel member on each section

FIGURE 3 Experimental layout—Huntington County example.

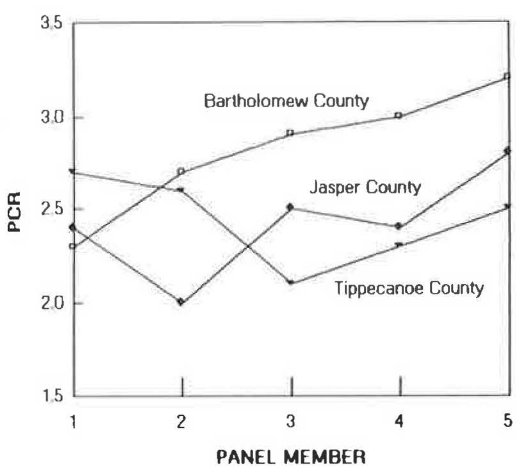

FIGURE 4 Average individual panel member ratings in three study counties.

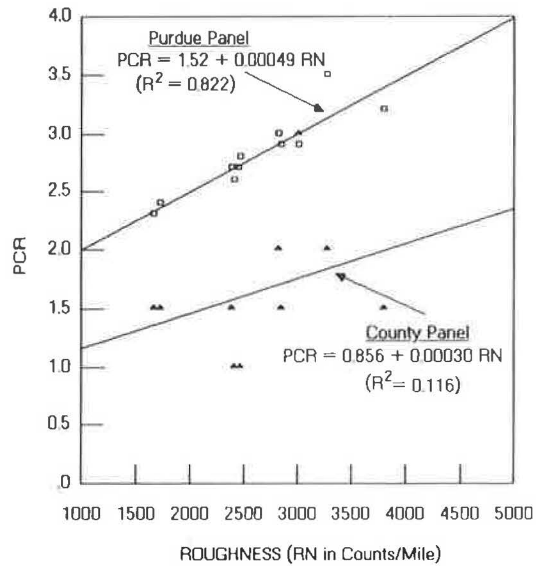

FIGURE 5 PCR versus roughness—Bartholomew County.

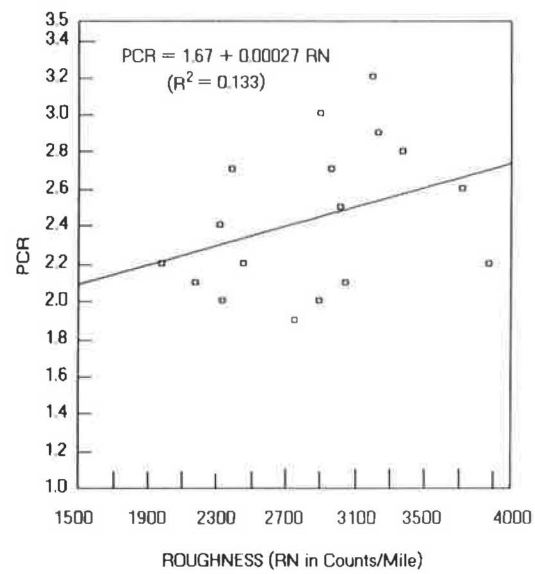

FIGURE 6 PCR versus roughness—Jasper County.

DISCUSSION OF REGRESSION ANALYSIS RESULTS

PCR, a dependent variable, was analyzed in regression, and roughness number (RN), distress rating variables, and average rater speed were analyzed as independent variables. The results of the analyses are discussed next.

PCR and Roughness

The equations relating PCR and roughness are shown in Figures 5 to 7 for Bartholomew, Jasper, and Tippecanoe Counties, respectively. It should be noted, however, that the PCR rating used in this study provides a higher value with worsening rideability (0 to 5). Hence, a perfect road has an effective rating of 0, representing a condition for which the rater feels zero or no discomfort. A very rough pavement approaches a rating of 5. The preceding rating scheme was adopted and considered acceptable after discussions with rating panel members and county highway officials.

A relationship between PCR and the present serviceability rating of AASHO *(1)* is shown in Equation 1.

$$PSR = 5 - PCR \tag{1}$$

In all three counties, there appeared to be a logical relationship between PCR and roughness. PCR increased with roughness as expected. However, the R^2 for Jasper County data was a low of 0.133 compared with ratings for Bartholomew and

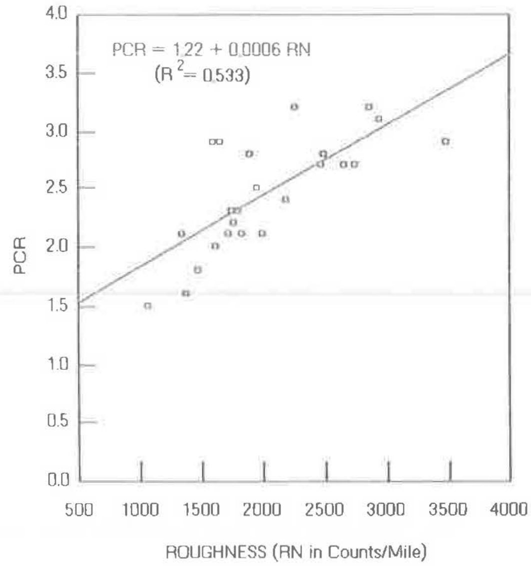

FIGURE 7 PCR versus roughness—Tippecanoe County.

Tippecanoe Counties with R^2 values of 0.822 and 0.533, respectively. The higher variability in Jasper County could be the result of saturated subgrades prevalent in most parts of the county that tended to create an uneven ride and distort the perception of ride comfort.

PCR and Average Rater Speed

The regression relationships between PCR and average rater speed are shown in Figures 8 to 10 for three counties. In general, R^2 values for the PCR and average rater speed relationships ranged from 0.05 to about 0.50 for the five counties. Although vehicle speed is affected by worsening road conditions, it was not clearly demonstrated in two of the counties with R^2 values of 0.05 and 0.1. The R^2 values of 0.49 and 0.50 in two counties have demonstrated that a relationship exists between average PCR and average rater speed. However, a wider range of gravel road condition would be required to show the true effect of road condition on speed. The range of unpaved road condition encountered during the studies did not affect speeds enough to highlight any differences.

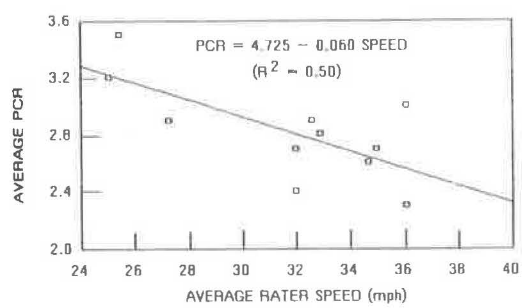

FIGURE 8 Average PCR versus average rater speed—Bartholomew County.

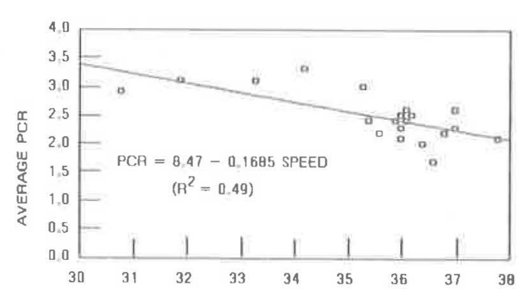

FIGURE 9 Average PCR versus average rater speed—Huntington County.

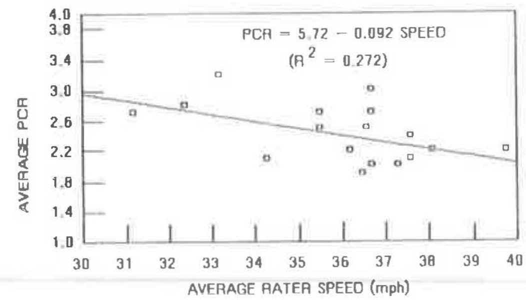

FIGURE 10 Average PCR versus average rater speed—Jasper County.

PCR and Visual Rated Distresses

Visually rated distresses included in the analysis were corrugations, extent of rut development, potholes, and gravel looseness. Each distress condition was given a rating together with an assessment of the percentage of the road section covered by the distress. It was assumed that the remainder of the section had a distress rating of 1 (very good). Equation 2 was used to calculate new ratings.

$$\text{New rating} = \frac{\text{Rating} \times \text{\% area}}{100} + (1 - \text{\% area}/100) \qquad (2)$$

New rating values ranging between 1 and 5 were estimated for their relationship to PCR.

Effect of Unpaved Road Surface Distresses

The results of regression analysis showing regression constant (β_0), coefficient (β_1), and R^2 values for each distress type are given in Table 2. Visual rating for corrugations exhibited the best relationship to average PCR. PCR increased with worsening or increasing corrugation rating. Similar relationships were obtained for average pothole ratings and gravel looseness. However, the relationships to PCR were not as clearly defined for ruts and gravel looseness as for corrugations. A decrease in PCR values occurred with increasing gravel looseness rating in some counties. The latter may be because gravel or stone is usually applied loose on unpaved county roads. A decrease in gravel looseness as defined in Table 1 depicts improved compaction or dispersal of loose gravel to expose a hardened unpaved road surface crust that would improve the PCR rating. The higher constant and coefficient values for the relationship of PCR to ruts in Bartholomew County could be the result of other factors that were not analyzed.

TABLE 2 REGRESSION OF PCR VERSUS DISTRESS RATINGS FOR FIVE STUDY COUNTIES IN INDIANA

County	β_0	β_1	R^2
Corrugation			
B[1]	1.043	1.206	.705
H	.865	.957	.475
J	.736	1.112	.265
T	.663	1.267	.325
W	1.716	.831	.427
Potholes			
B	1.146	1.330	.254
H	1.424	.872	.100
J	.661	1.433	.564
T	.088	2.105	.302
W	1.874	.876	.456
Ruts			
B	7.479	-4.509	.160
H	2.146	.315	.007
J	-.841	3.168	.163
T	1.330	.881	.070
W	1.893	1.207	.135
Gravel Looseness			
B	5.149	1.071	.217
J	1.597	.454	.238
H	1.989	.183	.038
T	1.566	.427	.066
W	3.557	-.167	.038

1. B = Bartholomew; H = Huntington; J = Jasper; T = Tippecanoe; W = Warrick

Visual conditions ratings were made from a moving vehicle and as a result, ruts shallower than 2 in. (5 cm) and gravel looseness could not be easily identified. However, ruts deeper than 2 in. (5 cm), which are usually signs of a failing unpaved road surface condition, can be identified more easily from a moving vehicle. Similarly, potholes and corrugations are two easily identifiable distresses that can be visually rated from a moving vehicle even in their early stages of development. Although camber and drainage ratings were recorded to complete the inspection survey, no regression relationships were determined between PCR and the two variables. Rating of gravel looseness, drainage, and camber should be included in the inspection survey, however, to decide side ditching, grading, or major improvement needs based on PCR.

Comparison of Panel Ratings

To compare the ratings of the Purdue University panel and county officials in Bartholomew and Huntington Counties, one-way analysis of variance tests were conducted on the data. Using the SPSS computer packages, homogeneity of variance tests were conducted by applying the Cochran C and Bartlett-Box tests, as well as a range test using the least-squares difference (LSD) procedure *(12, 14)*. The LSD procedure is equivalent to a standard *t*-test because only two means were tested. The results of the analysis for the two counties are given in Tables 3 and 4.

In both cases, the mean of the ratings by the county panel was lower than the mean of the ratings by the Purdue panel. The analysis of variance test showed that the difference between groups was significant in both cases at an α-level of 0.05. The homogeneity of variance tests and the range test also confirmed that apart from average rater speeds for Huntington County, where the differences in variance were statistically significant, all the other variances depicted in the tables can be assumed to differ little, and, hence, the means could be compared. The results of the analysis of the means show that officials in both counties rated unpaved roads with lower PCR (in better condition) than did the Purdue panel. The difference between groups may also be confounded by the differences in the vehicles used for the ratings. County officials used pickup trucks normally used for county highway duties, whereas the Purdue panel used Chevrolet Citation automobiles. The test conditions were considered realistic, however, because the county officials would rate roads under normal working conditions while driving pickup trucks. Relationships obtained using the Purdue University panel may be made applicable to county raters by applying a reduction factor of about 1.

APPLYING THE RATING SCHEME IN ROAD SURFACE MANAGEMENT

Using the relationships determined in this paper, Table 5 was prepared to serve as a preliminary guide in road surface management decisions for selected Indiana counties *(10, 15)*. The simplified decision basis can be easily applied by a typical county, and a PCR or PSR rating scheme can be used.

CONCLUSIONS

Regression relationships were determined between PCR and roughness with R^2 values of 0.822 and 0.533. This confirms that on gravel roads, PCR and roughness are acceptable criteria for representing road condition, and relations exist between PCR and roughness number. Because roughness is an accepted criterion for determining unpaved road condition, PCR (or PSR) may be substituted in the absence of suitable equipment. PCR will enable the ranking of roads by condition, but additional assessment of surface distresses and drainage will be required to enable the improvement required to be accurately determined. Although a logical relationship was found between PCR and average rater speed, additional research using a wider range of road condition is required to confirm the potential use of speed as a rating criterion.

Corrugation and potholes are related to PCR and can be assessed visually. A distress rating and the percentage of the road surface it covers are two measures determined for the preceding distresses to estimate a new rating.

The PCR values used ranged from 0 to 5 with higher values for rougher roads. PCR predictions using equations presented in this paper were determined by the five-member study panel from Purdue. In general, the Purdue panel was found to rate the roads to be in poorer condition than did county officials. Because most of the relationships derived in this paper used the

TABLE 3 COMPARISON OF MEANS OF RATINGS AND AVERAGE SPEEDS OF PURDUE PANEL AND OFFICIALS OF BARTHOLOMEW COUNTY

Statistic	Purdue Panel		County Officials	
	Rating	Average Speed (mph)	Rating	Average Speed (mph)
Number of Sections	50	39	20	20
Mean	2.83	30.64	1.65	34.58
Standard Dev.	0.55	4.26	0.75	4.32
Standard Error	0.08	0.68	0.17	0.97
Range of Values	2-4	21.2-38.3	1-3	22.8-40.
95% Confidence Interval (Means)	2.26 - 2.59	29.3 - 32.0	1.3 - 2.	22.8 - 40.

Homogeneity of Variance and Means Comparison Tests

Test	Rating		Average Speed	
	Test Value	Probability	Test Value	Probability
Cochran C	0.648	.80	.508	.934
Bartlett-Box	2.688	.101	.006	.938
Difference between Means	1.18	-	3.94	-
LSD Range Statistic	.085	-	.648	-

TABLE 4 COMPARISON OF MEANS OF RATINGS AND AVERAGE SPEEDS OF PURDUE PANEL AND OFFICIALS OF HUNTINGTON COUNTY

Statistic	Purdue Panel		County Officials	
	Rating	Average Speed (mph)	Rating	Average Speed (mph)
Number of Sections	95	74	57	55
Mean	2.5	33.49	1.4	41.
Standard Dev.	0.68	2.35	0.53	5.74
Standard Error	0.07	0.273	0.07	0.774
Range of Values	1-4	29.2-43.2	1-3	31.-61.
95% Confidence Interval (Means)	2.36 - 2.64	32.9 - 34.0	1.26 - 1.54	39.5 - 42.6

Homogeneity of Variance and Means Comparison Tests

Test	Panel Rating		Average Speed	
	Test Value	Probability	Test Value	Probability
Cochran C	0.622	.032	.857	.000
Bartlett-Box	4.138	.042	47.55	.000
Difference between Means	1.10	-	7.55	-
LSD Range Statistic	.05	-	1.49	-

TABLE 5 SUGGESTED MAINTENANCE STRATEGIES FOR VARIOUS ROAD CONDITIONS

PCR	Equivalent PSR	Average Speed (mph)	Roughness (counts/mi)	Maintenance Options
1.5	3.5	>40	< 1000	No Maintenance
2.0	3.0	>40	1000 - 1500	Light Grading & Local Repairs
2.5	2.5	36-40	2000 - 3100	Grading & Local Repairs
3.0	2.0	28-35	2900 - 3000	Heavy Grading
3.5	1.5	24-27	3700 - 4000	Rehabilitation * Check Condition for Deep Ruts, Gravel Loss & Other Failure Types
4.0	1.0	<24	4600 - 5000	

* NOTE: A detailed condition survey will be required to determine the extent of rehabilition required

Purdue panel ratings, a reduction in PCR by a factor of about 1 is required to conform to typical county panel ratings. On the other hand, the low R^2 values obtained by using the county panel data showed the influence of the smaller panel size and the potential variability in the ratings. With experience in applying the rating scheme in five counties, the Purdue panel was likely to conform more closely to the specified rating criteria.

For most local highway agencies, subjective rating schemes are still practical for road condition assessment and screening. Relationships can be determined between the PCR and measured roughness number for each local area. However, it is important to provide a longer training period and to ensure consistency within the same group of raters even though slight differences may occur in some individual ratings. For Indiana counties, preliminary decision guidelines were suggested for road surface management.

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