

STATE OF FLORIDA



EVALUATING THE RIDE NUMBER AS A PAVEMENT MANAGEMENT ROUGHNESS INDEX

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PAVEMENT MANAGEMENT ROUGHNESS INDEX**

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EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) has recently converted all of its five road profilers from ultrasonic to laser. These profilers are normally used to collect roughness measurements which are converted to ride ratings. The ride ratings are entered in the FDOT pavement management system which is used to select sections in need of rehabilitation. In this study, the ride number as developed in NCHRP study 1-23 was evaluated to determine if it can be used instead of the correlation procedure currently used to convert ultrasonic IRI values to PSIs. Roughness measurements were obtained with both ultrasonic and laser profilers on representative pavements sections in three counties in the state of Florida. These measurements were beneficial in concluding that the currently followed FDOT procedure for determining ride rating can be replaced by the rate 4 ride number. There were some additional interesting conclusions which are fully documented in this paper.

INTRODUCTION

Pavement roughness has long been recognized as a primary indicator of pavement performance. Therefore, highway agencies monitor the roughness of their pavements at regular intervals. The Florida Department of Transportation (FDOT) collects roughness measurements on about 18,000 Miles (29,000 Kilometers) annually. Since 1991, Florida DOT has been using five ultrasonic road profilers to collect the necessary roughness data on all pavement sections. The collected data is normally used as part of the FDOT pavement management system. Once the data is collected, the International Roughness Index (IRI) is normally calculated for every section in the network [1]. A linear regression equation is then used to convert the IRI values from the ultrasonic profilers to ride ratings (0 to 100 scale) [2]. The regression equation was developed from a comparison between IRI and Present Serviceability Index (PSI) values obtained from the CHLOE profilometer. The use of the CHLOE profilometer for measuring ride was developed as a national standard at the AASHTO Road Test in the early 1960's.

Since the pavement condition survey was developed for pavement management purposes in 1973, Florida's ride monitoring equipment has been correlated to PSI attributed to ride only from the CHLOE profilometer. PSI values are on a 0 to 5 scale. Ride rating values used with the pavement condition survey are calculated by multiplying PSI by twenty to make the scale from 0 to 100. The correlations have allowed FDOT to preserve its historical ride data despite of using three different types of equipment to monitor ride since 1973. In 1998, FDOT converted all of its ultrasonic road profilers to laser. The use of the laser profilers will enhance the accuracy of

measuring ride. This paper evaluates two different methods for processing roughness data collected with laser profilers. These two methods are described in the next section.

BACKGROUND

The International Roughness Index (IRI) has been utilized by various state DOTs to reflect pavement roughness. These roughness measurements are normally used to make pavement rehabilitation decisions. A comprehensive study was performed by FDOT in 1992 to convert the IRIs from ultrasonic road profilers to PSIs. The following correlation equation resulted from that study [2]:

$$\text{PSI} = 4.9879 - .0078 * \text{IRI} \quad (1)$$

Where:

PSI: Present Serviceability Index.

IRI: International Roughness Index.

The PSI numbers generated from the equation 1 are normally multiplied by 20 to generate ride ratings on a scale of 0-100. Those ride ratings in addition to other performance indices are utilized by FDOT to determine when to rehabilitate pavement sections. The conversion of all FDOT road profilers from ultrasonic to laser provided the opportunity to compare the above technique with using ride numbers as proposed by ASTM. Ride Number (RN) is a mathematical processing of longitudinal profile measurements to produce an estimate of subjective ride quality.

The ride number is based on an algorithm developed in National Cooperative Highway Research Project (NCHRP) 1-23. The standard is presently being balloted for ASTM standard E 1489.

Ride number is a computer vehicle simulation model on a 0 to 5 scale which closely relate to Present Serviceability Index (PSI). The ride number should eliminate the need for future correlations of various roughness equipment to PSI.

DESIGN OF EXPERIMENT

Recently, the FDOT laser and ultrasonic road profilers were used to collect roughness data on all pavement sections in Alachua, Clay, and Marion Counties. Three hundred and forty-five sections were tested. The rated sections varied in length and exhibited a wide range of roughness values typical of those found in Florida. The total length of sections tested was about 930 Miles (1500 Kilometers). The laser profiler collected the data at rates 2 and 4. These rates reflect the distances at which the laser profiler averages the collected data. Laser sensors fire at 32,000 per second and average the data every six inches at rate 2 and every foot at rate 4.

The ultrasonic road profilers collected data at the normal speed of 55 miles per hour which resulted in about one measurement per foot. The collected data on all test sections was analyzed to produce the following:

- a. IRIs from laser and ultrasonic road profilers.
- b. The IRIs from the ultrasonic sensors were processed through equation (1) to convert them to PSIs. The resulting values were multiplied by 20 to obtain ride ratings on a scale from 0 to 100.

- c. IRI values from the laser road profiler were also processed through equation (1) and then multiplied by 20 to produce ride ratings.
- d. Pavement profile measurements with the laser profiler at rate 2 were used to calculate the rate 2 ride numbers. These ride numbers were multiplied by 20 to convert them to a scale from 0 to 100.
- e. Pavement profile measurements with the laser profiler at rate 4 were also used to calculate the rate 4 ride numbers. These ride numbers were multiplied by 20 to convert them to a scale from 0 to 100.

DATA ANALYSIS

All the calculated indices were summarized in a computerized database and then analyzed statistically. The aim of the analysis was first to compare IRI values from laser and ultrasonic sensors. The other objective was to determine if ride numbers can be used instead of equation (1) to reflect the conditions of pavement sections in the state of Florida. The following sections summarize the findings from the analysis performed.

Descriptive Statistics

The first step in the statistical analysis consisted of obtaining some descriptive statistics on the various indices calculated in this study. Table 1 summarizes these indices. It is clear from Table 1 that the average values of IRI measurements from the ultrasonic profilers were

significantly higher than those obtained with the laser profiler. Ride ratings from the ultrasonic sensors were less than those obtained from the laser sensors due to the differences in IRI values.

Ride numbers at rate 2 times 20 were significantly less than those values obtained at rate 4. Both rates 2 and 4 generated indices less than the ride ratings from the ultrasonic profilers which are currently used by FDOT.

International Roughness Index Comparison

Figure 1 shows a graphical comparison between IRI values acquired with the ultrasonic and laser profilers. It is clear from Figure 1 that most of the points fell below the equality line indicating that the laser profiler produces IRI values less than those produced with the ultrasonic profilers. The following model was developed to compare the IRI values from both systems:

$$IRI_{\text{laser}} = -4.41 + 0.8 * IRI_{\text{ultrasonic}} \quad (2)$$

Where:

IRI_{laser} : International Roughness Index from laser profiler.

$IRI_{\text{ultrasonic}}$: International Roughness Index from ultrasonic profiler.

The correlation coefficient r^2 for the above model was 0.79 with a slope of 0.81 (39 degrees).

Ride Ratings Comparison

Figure 2 shows a graphic illustration of the comparison between ride rating values

acquired with both the ultrasonic profilers and the laser profiler. In this case, most of the points were above the line indicating that the laser measurements are smoother than the ultrasonic measurements. The following model was developed to compare ride ratings from ultrasonic and laser profilers:

$$RR_{\text{laser}} = 20 + 0.81 * RR_{\text{ultrasonic}} \quad (3)$$

Where:

RR_{laser} : Ride rating from laser profilers.

$RR_{\text{ultrasonic}}$: Ride rating from ultrasonic profilers.

The correlation coefficient r^2 of the above model is 0.79 and the slope is 0.81 (39 degrees). As described earlier, both ride ratings from laser and ultrasonic profilers were obtained from Equation 1 after multiplying by 20. Note from Figure 2 and the above equation that the ride rating values collected using the laser sensors are higher (smoother) than those collected with the ultrasonic sensors.

Figure 3 shows that 99.9 percent of the ride rating values acquired with the laser profiler were within plus or minus 10 points of those collected using the ultrasonic profilers. Figure 3 also shows that 37.4 percent of the ride rating values increased by 10 points while only 0.03 percent decreased by 10 points.

The single factor Analysis of Variance (ANOVA) was performed on the data. As shown in Table 2, the calculated F value of 49.5 was significantly higher than the critical value which

indicates that the ride numbers produced in this analysis from the laser and ultrasonic profilers are statistically different.

Ride Number Rate 4 Versus FDOT's Ride Rating

Figure 4 compares ride ratings from the ultrasonic profilers to those from the laser profiler at a rate 4 (averaged every foot). In this case, more points fell below the line resulting in laser ride ratings slightly less than the ultrasonic ride ratings. The following model was developed to correlate the two ride ratings:

$$20 * RN4_{\text{laser}} = 6.6 + 0.9 * RR_{\text{ultrasonic}} \quad (4)$$

Where:

$RN4_{\text{laser}}$: Ride number from laser profilers at rate 4.

$RR_{\text{ultrasonic}}$: Ride rating from ultrasonic profilers.

The correlation coefficient r^2 of the above model is 0.64 and the slope is 0.90 (42 degrees). Figure 5 shows that 99.4 percent of the ride rating values acquired with the laser profiler (Rate 4) were within plus or minus 10 ride rating points of those collected with the ultrasonic profilers. Figure 5 also shows that 25.6 percent of the ride rating values increased by 10 points while 21.4 percent decreased by ten points.

The single factor Analysis of Variance (ANOVA) was performed on the rate 4 ride rating. As shown in Table 2, the calculated F value was 5.5 while the critical F value was 3.9 which

indicates that the laser and ultrasonic sensors are producing slightly different ride ratings at $\alpha = 0.05$. The two systems produce statistically equal numbers at $\alpha = 0.02$.

Ride Number Rate 2 Versus FDOT's Ride Rating

Figure 6 provides a graphic representation comparing ride rating from the ultrasonic profilers to ride numbers from the laser profiler at a rate 2 (averaged every six inches). The following regression model was developed to correlate these two ratings:

$$20 * RN2_{\text{laser}} = -4.6 + 0.97 * RR_{\text{ultrasonic}} \quad (5)$$

Where:

$RN2_{\text{laser}}$: Ride number from laser profilers at rate 2.

$RR_{\text{ultrasonic}}$: Ride rating from ultrasonic profilers.

The correlation coefficient r^2 for the above model is 0.59 with a slope of 0.97(42 degrees). Note from Figure 6 that the laser profiler resulted in lower ride rating values than the ultrasonic profilers. Figure 7 shows that 91.7 percent of the ride rating values acquired with the laser profiler (rate 2) were within plus or minus 10 points of those collected with the ultrasonic profilers. Figure 7 also shows that 3.0 percent of the ride rating values increased by 10 points while 43.5 percent decreased by ten points.

The single factor Analysis of Variance (ANOVA) was also performed in this case. It is

clear from Table 2 that the calculated F value of 94.07 is significantly higher than the critical value of 3.9 which indicates that at rate 2, the ultrasonic and laser profilers are producing statistically different numbers.

Ride Numbers Rate 2 Versus Rate 4

The ride numbers obtained at rates 2 and 4 were also compared statistically. The single factorial ANOVA resulted in a calculated F value of 50.7 which is higher than the critical value of 3.9 indicating that the two are statistically different. The following regression model was developed to correlate the ride numbers at rate 2 and 4:

$$RN2_{\text{laser}} = -.37 + 1.03 * RN4_{\text{laser}} \quad (6)$$

Where:

$RN2_{\text{laser}}$: Ride number from laser profilers at rate 2.

$RN4_{\text{laser}}$: Ride number from laser profilers at rate 4.

The r square for the above model was .84 indicating a good fit.

CONCLUSIONS

The recent conversion of FDOT road profilers from ultrasonic to laser presented interesting questions related to preserving the consistency of ride data collected by various systems. This study aimed at evaluating various roughness indices obtained by laser and ultrasonic road

profilers. The following conclusions were drawn based on the testing and analysis performed:

- 1) The laser profiler does produce IRI values lower than those produced with the ultrasonic profilers. Therefore, agencies in the process of converting their road profilers from ultrasonic to laser should be aware that data from the two systems must be correlated prior to performing any comparisons.
- 2) If equation 1 was used to convert laser IRI values to ride ratings, it will result in smoother ratings for about thirty to forty percent of the Florida's State Highway System. The ANOVA analysis indicated that the ultrasonic and laser ride ratings are statistically different.
- 3) Ride numbers at rate 4 multiplied by 20 to produce ride ratings resulted in a linear relationship with the ultrasonic ride ratings. This relationship has a favorable 42 degree slope. In addition, the Analysis of Variance indicated that these values are statistically equal to the ride ratings currently obtained from the ultrasonic profilers.
- 4) Ride numbers at rate 2 multiplied by 20 to produce ride ratings did not correlate as favorably to existing ultrasonic ride rating values. The Analysis of Variance indicated that the ride ratings produced from the laser profilers at rate 2 are significantly different from those obtained from the ultrasonic profilers.
- 5) Ride numbers obtained at different rates are statistically different. In this study, rates 2 and 4 were found to be significantly different despite of the fact that the same laser road profiler was used to collect all data.

ACKNOWLEDGMENT

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REFERENCES

1. World Bank Technical Paper Number 45, "The International Road Roughness Experiment Establishing Correlation and a Calibration Standard for Measurements", Sayers, M.; Gillespie, T.; and Queiroz, C., 1986.
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3. Janoff, M. S.; Nick, J. B.; and Davit, P. S.; "Pavement Smoothness and Rideability", NCHRP Report 275, 1985.

Table 1. Descriptive Statistics of Various Indices Used.

INDEX	PROFILER	MEAN	MINIMUM	MAXIMUM	RANGE
IRI	Laser	82	37	427	390
IRI	Ultrasonic	107	43	462	419
Ride Rating	Laser	87	33	94	61
Ride Rating	Ultrasonic	83	27	93	66
Ride Number Rate 4 * 20	Laser	82	35	92	57
Ride Number Rate 2 * 20	Laser	77	27	89	62

Table 2. Results from The ANOVA Analysis.

FACTORS COMPARED		F_{CRIT}	F	RESULTS
IRI _{laser}	IRI _{ultrasonic}	3.9	50	DIFFERENT
RR _{laser}	RR _{ultrasonic}	3.9	49.5	DIFFERENT
RN4 * 20	RR _{ultrasonic}	3.9	5.5	DIFFERENT
RN2 * 20	RR _{ultrasonic}	3.9	94	DIFFERENT

NOTES: RN4: Ride Number at rate 4.
 RN2: Ride Number at rate 2.

Figure 1. IRI's from Laser and Ultrasonic Road Profilers.

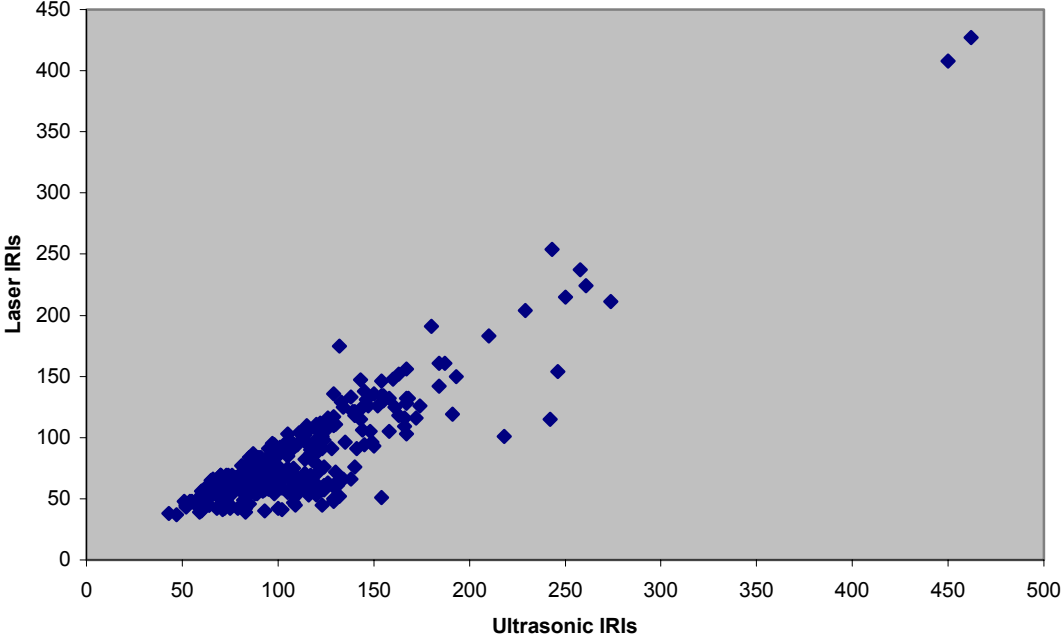


Figure 2. Ride Ratings from Laser and Ultrasonic Road Profilers.

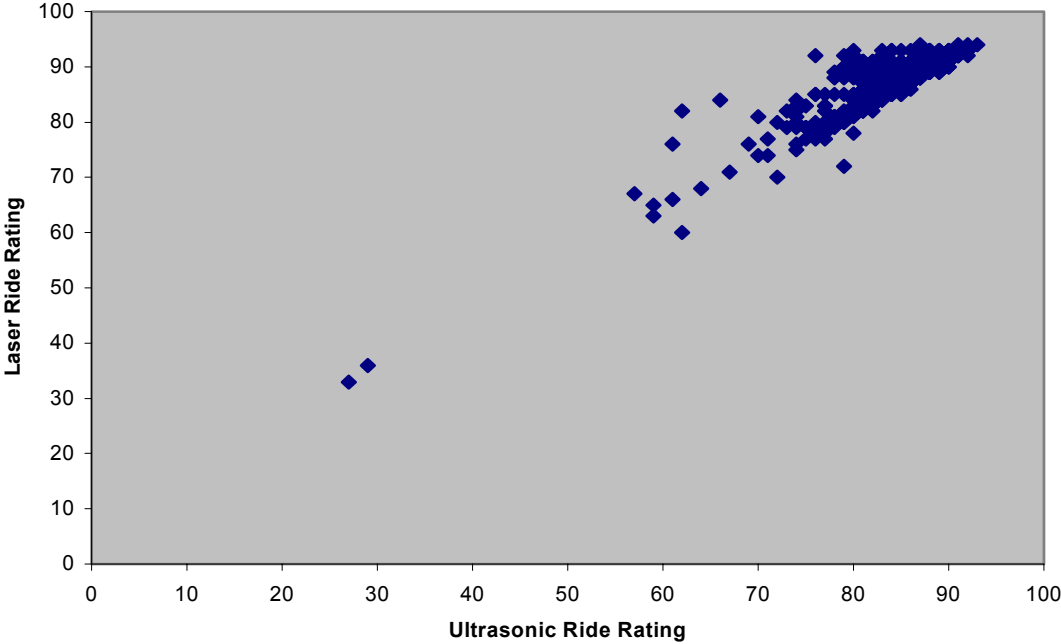


Figure 3. Effect of Replacing Current Ultrasonic Ride Ratings with The Laser Ride Ratings.

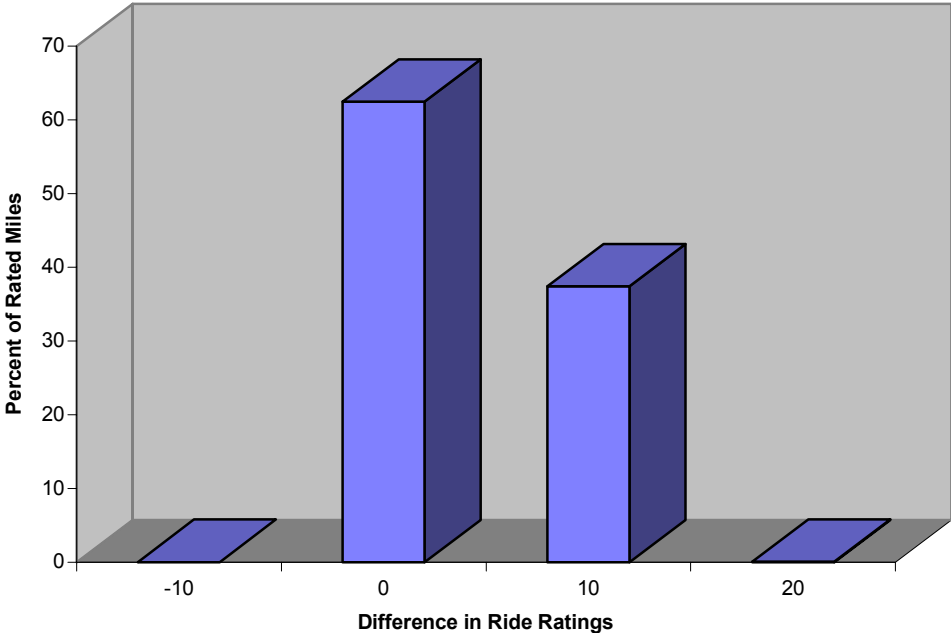


Figure 4. Ultrasonic Ride Ratings Versus Laser Rate 4 Ride Numbers * 20

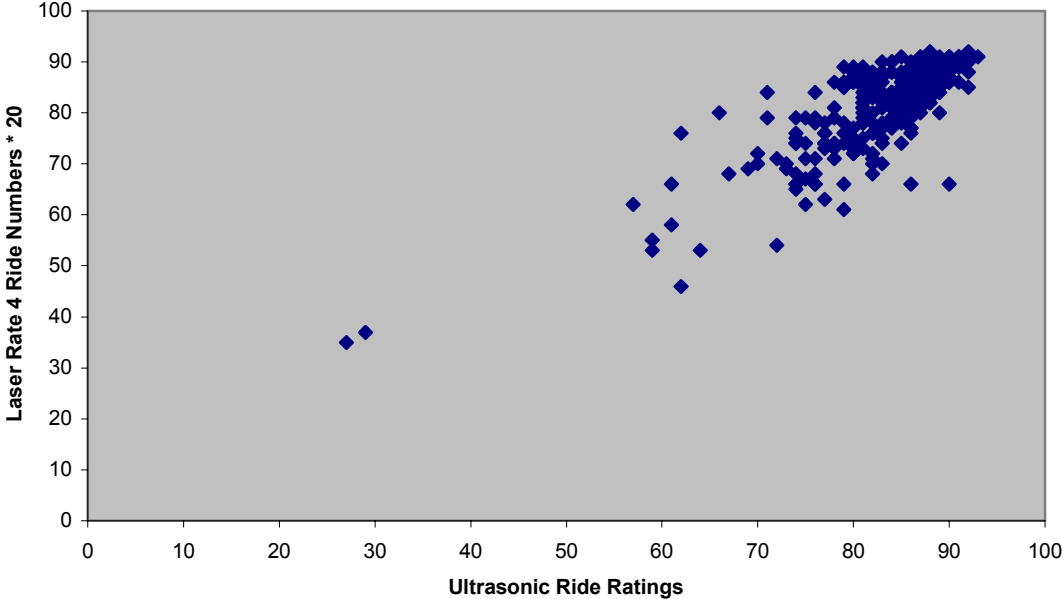


Figure 5. Effect of Replacing Current Ultrasonic Ride Ratings with The Laser Rate 4 Ride Numbers * 20

