An Overview of Mn/DOT's Pavement Condition Rating Procedures and Indices

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Equipment

Mn/DOT currently collects pavement condition data using a Pathway Services, Inc. Digital Inspection Vehicle (DIV) as shown in Figure 1. There are three lasers mounted across the front bumper, one in each wheel path and one in the center (Figure 2). In addition, there are two lasers used for rut measurements mounted at the rear of the vehicle (Figure 3). There are also four digital cameras mounted on top of the van (Figure 4). The lasers measure the pavement's longitudinal profile, used to calculate roughness. They take a measurement approximately every 1/8-inch as the van travels down the roadway at highway speed. The cameras are used to capture the pavement distress (cracking, patching, etc.), right-of-way images, and help assess the overall condition of the shoulders.

Figure 1. Mn/DOT's Pathway Services, Inc. Digital Inspection Vehicle (DIV)

Each year, approximately one-fourth of the CSAH system (6,500 miles) will be tested in both directions with the DIV. Digital images, pavement roughness and pavement distress are collected. This data can be used in a pavement management system to compare the performance of different roadways, pavement designs and for project planning and programming.

Figure 2. Close-up of lasers used to measure roughness & faulting.

Figure 3. Close-up of Rut Measurement Lasers.

Figure 4. Close-up of cameras used to record pavement distress.

Pavement Condition Indices

Mn/DOT uses three indices to report and quantify pavement condition. One index represents pavement roughness, one represents pavement distress, and one the overall condition of the pavement. These indices, listed in Table 1, are used to quantify the present condition of the pavement and predict future condition, both of which are needed for project planning and programming. For each index, a higher value means better pavement condition. The indices are reported to the tenths place.

Table 1. Mn/DOT Pavement Condition Indices

Index Name	Pavement Attribute Measured by Index	Rating Scale
Ride Quality Index (RQI)	Pavement Roughness	0.0 - 5.0
Surface Rating (SR)	Pavement Distress	0.0 - 4.0
Pavement Quality Index (PQI)	Overall Pavement Quality	0.0 - 4.5

The PQI is calculated from the RQI and SR as follows:

$$PQI = \sqrt{(RQI)(SR)}$$

Condition Rating samples are taken and reported at the following locations:

- Where there is a change in surface type (bituminous or concrete).
- Where there is a change in the number of lanes.
- At each Mile.
- All other points determined by the County. Examples are changes in surface age, base type, traffic volume and research sections.

Pavement Roughness

Pavement roughness, or ride quality, is quantified by the "serviceability-performance" concept developed at the AASHO Road Test in 1957. The serviceability of a pavement is expressed in terms of the Present Serviceability Rating, or PSR. The PSR is a reflection of the "seat-of-the-pants" feeling the average citizen gets as he or she travels down the roadway. Mn/DOT recently began referring to the PSR as the Ride Quality Index (RQI) to make it easier to understand what the index measures.

The first step in determining the RQI is to calculate the International Roughness Index, or IRI, from the pavement profile measured by the front lasers on the van. This international standard simulates a standard vehicle traveling down the roadway and is equal to the total anticipated vertical movement of this vehicle accumulated over the length of the section. The IRI is reported in units of meters/kilometer (vertical inches of movement per kilometer traveled). If a pavement were perfectly smooth, the IRI would be zero (i.e. no vertical movement of the vehicle). In the real world, however, roughness in the form of dips and bumps exist and vertical movement of vehicles occurs. As a result, the IRI is always greater than zero. The higher the IRI is, the rougher the roadway.

Many states use the IRI as their sole measure of roughness. However, in Minnesota the IRI is converted to RQI so that our customer's opinions can be taken into account. Without this step, there would be no basis for determining what IRI level people feel is unacceptable. We use the laser readings in the left wheel-path of the van to calculate the IRI. It is felt that since the left wheel-path is where the driver sits it correlates better to what he or she feels.

To convert IRI to RQI, a correlation needs to be developed. This is done using a rating panel. A rating panel involves driving people over sections of pavement and getting their opinion as to how well it rides. When last done in 1997, 32 citizens were asked to rate over 120 test sections. The sections included all pavement types, a wide variety of roughness conditions and were 0.25 miles long. Panelists were instructed to disregard grade, alignment, pavement surface condition, right-of-way, shoulders, ditch conditions and all other factors not directly related to the ride of the pavement.

Each rater assigned a numerical value between zero and five to each segment based on the following scale:

Table 2. RQI Categories and Ranges

Numerical Rating	Verbal Rating
4.1 - 5.0	Very Good
3.1 - 4.0	Good
2.1 - 3.0	Fair
1.1 - 2.0	Poor
0.0 - 1.0	Very Poor

The raters ask themselves, “How would I like to ride on a road just like this section all day long?” First they decide what qualitative rating to give the ride, ranging from Very Good to Very Poor. They then refine the corresponding numerical range by rating to one-tenth of a point. For example, a roadway considered Good and approaching Very Good might be given a rating of 3.8 or 3.9.

Panelists are first driven over a practice course to allow them to become acquainted with the system. As they practice rating the segments they are told afterwards what experienced raters had rated the same segment, thus they get a feel for what a pavement with a RQI of 3.0, 2.4, 4.0, etc. feels like.

The results of all the ratings for each test section are compiled, a mean and standard deviation are calculated and then a search for outliers is made and if necessary, an adjusted mean is calculated. The mean or adjusted mean for each section is the panel’s RQI for that section.

Using regression analysis, the panel’s RQI is correlated to the measured IRI. Separate curves are established for bituminous and concrete pavements. As a result of this correlation, the ride measured by the lasers can be used to estimate how a panel of citizens would rate the pavement. The correlation is valid as long as the public’s perception of smooth and rough roads does not change appreciably.

The current equations for converting from IRI to RQI are shown below:

Bituminous Pavements:

$RQI = 5.697 - (2.104)(\sqrt{IRI})$, IRI = International Roughness Index, in m/km

Concrete Pavements:

$RQI = 6.634 - (2.813)(\sqrt{IRI})$, IRI = International Roughness Index, in m/km

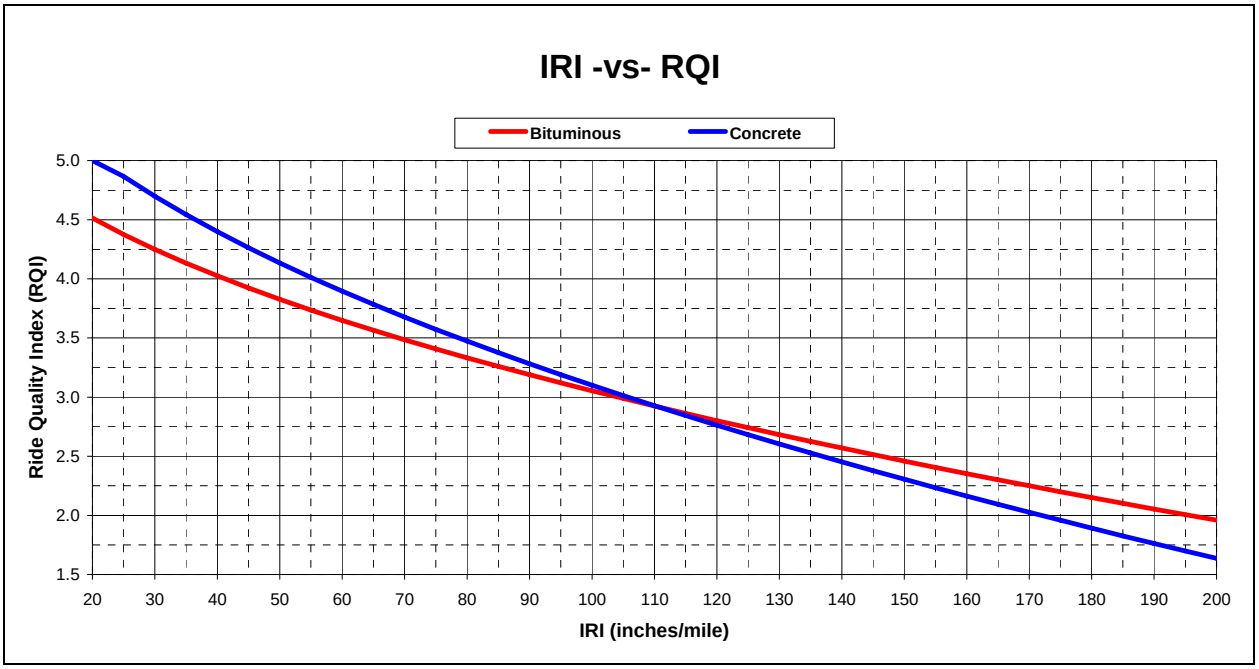

Figure 5. Graph for converting IRI to RQI (based on the 1997 rating panel)

Pavement Distress

Pavement distresses are those defects visible on the pavement surface. They are symptoms, indicating some problem or phenomenon of pavement deterioration such as cracks, patches and ruts. The type and severity of distress a pavement has can provide great insight into what it's future maintenance and/or rehabilitation needs will be.

Mn/DOT uses the Surface Rating, or SR, to quantify pavement distress. The SR was formerly based on the type and amount of distress measured by two raters driving along the shoulder of the road at 5 – 10 mph. Currently, the task is done by technicians using computer workstations, as shown in Figure 6, in the Pavement Management Unit of the Office of Materials located in Maplewood, MN.

The workstations allow the operators to view and analyze the digital images captured by the van. The van captures four images that are shown on four monitors simultaneously. There is a front, side and two down views which help the operator determine the type and severity of each defect. On divided roads, each direction is treated as a separate road and rated separately. This is necessary because the type, age and rehabilitation history may vary from one side of a divided road to another causing a difference in pavement performance. The software assists in the calculation of the quantity of distress.

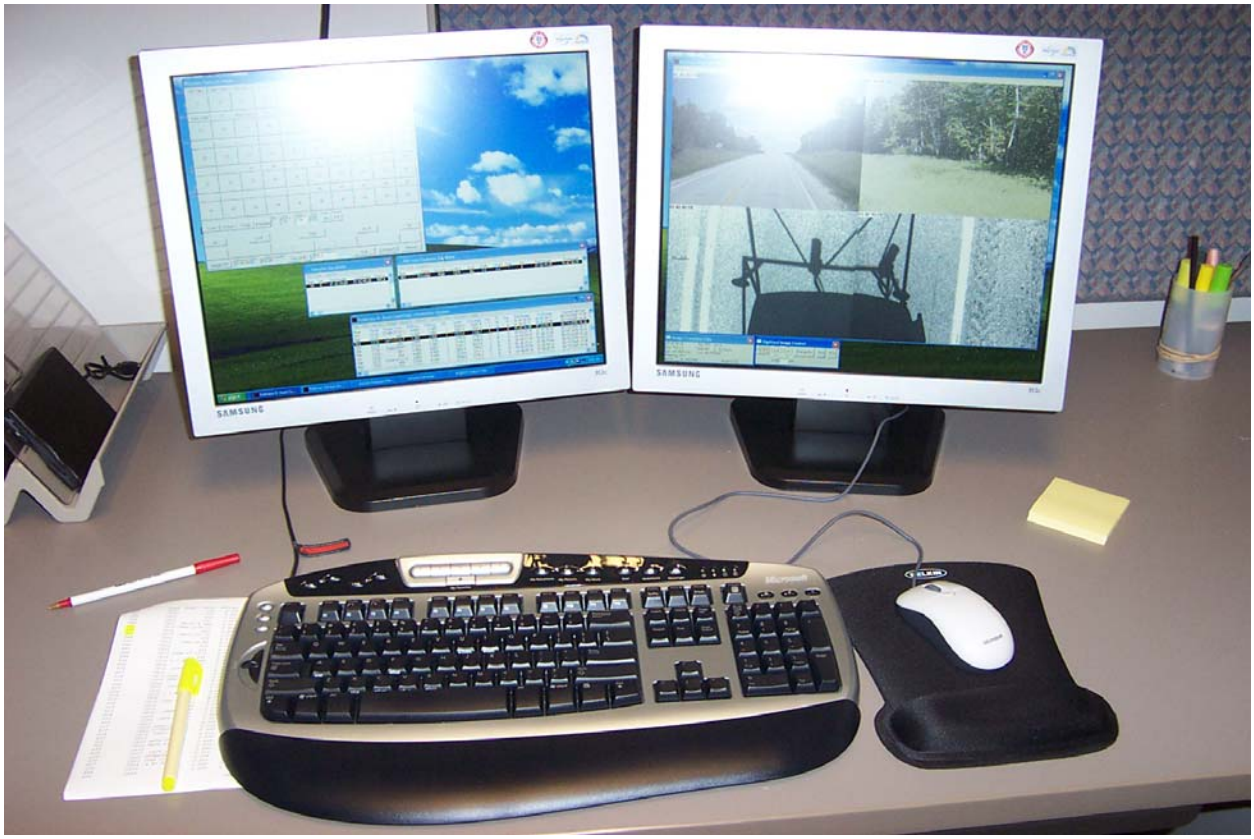

Figure 6. Digital Image Workstation

The benefits of this system include:

- The entire system is rated by only two people; resulting in better consistency.
- The ratings are done in the comfort and safety of the office.
- There is a record of the pavement condition allowing users to review sections of pavement for historical purposes and/or errors.

The one disadvantage is that because the video only provides a 2-dimensional view, some distress types are more difficult to see when viewing the images as compared to physically being able to look at the road. This is especially true in the case of raveling and weathering.

The defects monitored by Mn/DOT and included in the calculation of SR are shown in Table 3.

Table 3. Pavement Distress Types Used to Determine the Surface Rating (SR)

Bituminous Surfaced Pavement	Jointed Concrete Pavement	Continuously Reinforced Concrete Pavement (CRCP)
Transverse Cracking	**Transverse Joint Spalling**	**Patch Deterioration**
Low Severity	*Low Severity*	**Localized Distress**
Medium Severity	*High Severity*	**D-Cracking**
High Severity	**Longitudinal Joint Spalling**	**Transverse Cracking**
Longitudinal Cracking	*Low Severity*	
Low Severity	*High Severity*	
Medium Severity	**Faulted Joints**	
High Severity	**Cracked Panels**	
Longitudinal Joint Distress	**Broken Panels**	
Low Severity	**Faulted Panels**	
Medium Severity	**Overlaid Panels**	
High Severity	**Patched Panels**	
Multiple Cracking	**D-Cracked Panels**	
Alligator Cracking		
Rutting		
Raveling & Weathering		
Patching		

Because of the time involved determining the SR, Mn/DOT does not conduct continuous distress surveys. Instead, the first 500-feet of each mile and section is rated (10% sample). On undivided roadways, only the outside lane in the increasing direction (north or east) is rated when the SR is measured. On divided routes, the outside lane in both directions is rated.

The percentage of each distress in the 500-foot sample is determined and multiplied by a weighting factor to give a weighted percentage. The weighting factors are higher for higher severity levels of the same distress and higher for distress types that indicate more serious problems exist in the roadway such as alligator cracking and broken panels.

Once all of the weighted percentages are calculated, they are summed to give the Total Weighted Distress or TWD. The SR is calculated from the TWD using the following equation or by using Figure 7.

$$SR = e^{(1.386-(0.045)(TWD))}$$

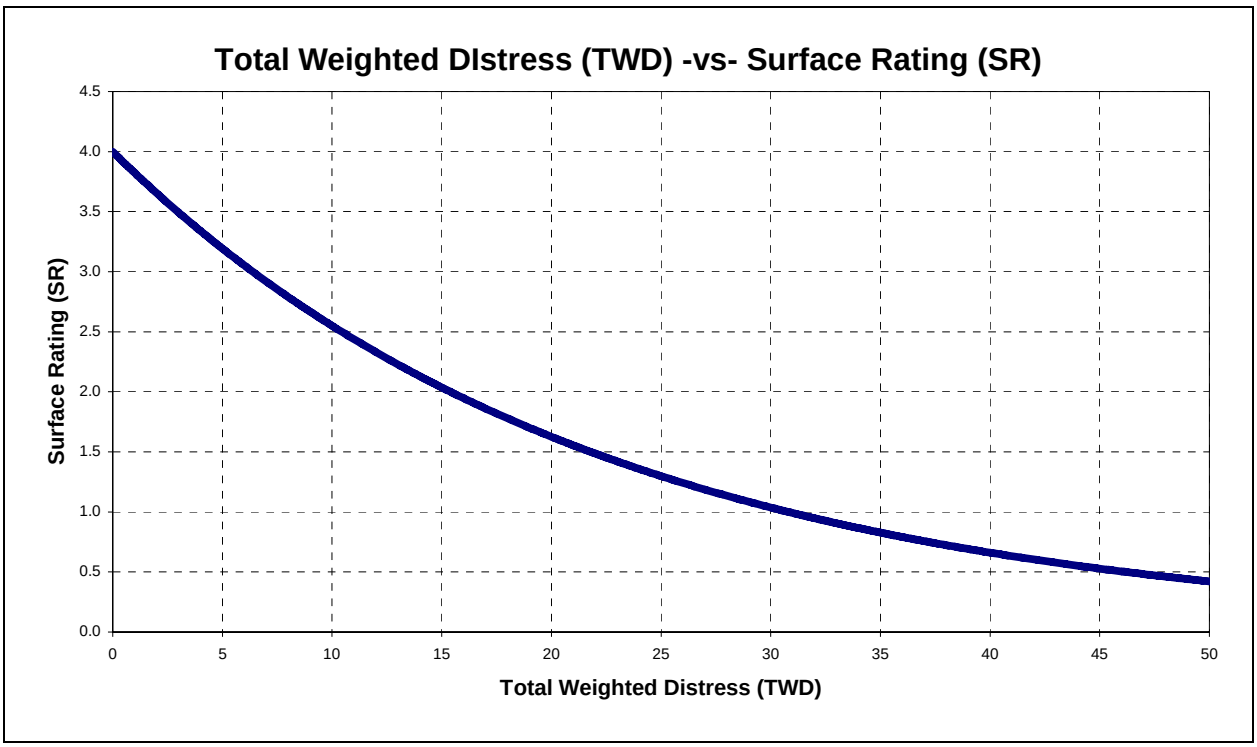

Figure 7. Chart for Converting TWD to SR.

Details of how to conduct a condition survey and calculate the SR are contained in the "Mn/DOT Distress Identification Manual," available from the Pavement Management Office website:

http://www.mrr.dot.state.mn.us/pavement/PvmtMgmt/pavemgmt.asp

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