IRI Analysis and Reports

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IRI Algorithm

The IRI algorithm is well-defined in “Guidelines for conducting and calibrating road roughness measurements” by Sayers et al. (1986) (note: the World Bank’s citation was incorrect with Gillespie as the lead author.)

The majority of IRI users may not be familiar with the algorithm, which may be due to its complexity and solutions. Therefore, some important aspects of IRI may not be well understood.

IRI is a mechanical model and acts like a band pass filter. The core model is the “golden” quarter-car model that was calibrated and tuned by Sayers in the 1980’s. Therefore, the model’s parameters and simulation speed were fixed.

The “**250 mm filter**” in the IRI algorithm is a moving average filter that acts like a tire-enveloping filter. This filtering needs to be applied to pavement profiles before running the IRI’s quarter care model with the following exception:

- The profile was previously low-pass filtered (anti-aliasing) or smoothed.
- The profile was collected using a mechanical device such as a walking profiler with a rigid beam between the two measurement points/wheels.

Selecting or de-selecting the “250-mm filter” would affect the IRI values. See the following example.

With 250-mm filter				Without					
Rounded to 2 digits			Rounded to 3 digits						
Start Dista	Stop Dista	Length (m	Left Elevation - IRI (m/km)	Start Dista	Stop Dista	Length (m	Left Elevation - IRI (m/km)	Diff	Diff (%)
0.00	100.00	100.00	2.028	0.00	100.00	100.00	2.049	-0.020	1.00%
100.00	200.01	100.00	1.385	100.00	200.01	100.00	1.402	-0.017	1.24%
200.01	300.01	100.00	2.838	200.01	300.01	100.00	2.873	-0.035	1.25%
300.01	400.01	100.00	3.293	300.01	400.01	100.00	3.348	-0.055	1.66%
400.01	500.01	100.00	1.353	400.01	500.01	100.00	1.373	-0.020	1.47%
500.01	600.02	100.00	0.929	500.01	600.02	100.00	0.945	-0.015	1.65%
600.02	700.02	100.00	1.118	600.02	700.02	100.00	1.134	-0.016	1.43%
700.02	800.02	100.00	0.824	700.02	800.02	100.00	0.842	-0.018	2.17%
800.02	900.03	100.00	0.994	800.02	900.03	100.00	1.015	-0.021	2.09%
900.03	1000.03	100.00	1.003	900.03	1000.03	100.00	1.016	-0.013	1.33%
1000.03	1100.03	100.00	1.222	1000.03	1100.03	100.00	1.235	-0.013	1.06%
1100.03	1200.03	100.00	1.220	1100.03	1200.03	100.00	1.238	-0.018	1.49%
1200.03	1300.04	100.00	1.228	1200.03	1300.04	100.00	1.245	-0.017	1.38%
1300.04	1400.04	100.00	1.124	1300.04	1400.04	100.00	1.144	-0.020	1.81%
1400.04	1500.04	100.00	1.363	1400.04	1500.04	100.00	1.381	-0.019	1.37%
1500.04	1600.05	100.00	1.227	1500.04	1600.05	100.00	1.246	-0.019	1.51%
1600.05	1700.05	100.00	1.326	1600.05	1700.05	100.00	1.343	-0.018	1.34%
1700.05	1800.05	100.00	1.062	1700.05	1800.05	100.00	1.077	-0.016	1.48%
1800.05	1900.05	100.00	0.895	1800.05	1900.05	100.00	0.909	-0.014	1.51%
1900.05	2000.06	100.00	0.821	1900.05	2000.06	100.00	0.837	-0.015	1.88%
2000.06	2100.06	100.00	0.882	2000.06	2100.06	100.00	0.896	-0.014	1.56%
2100.06	2200.06	100.00	0.958	2100.06	2200.06	100.00	0.976	-0.018	1.91%
2200.06	2300.07	100.00	1.741	2200.06	2300.07	100.00	1.746	-0.005	0.28%
2300.07	2400.07	100.00	2.102	2300.07	2400.07	100.00	2.120	-0.018	0.85%
2400.07	2500.07	100.00	1.434	2400.07	2500.07	100.00	1.449	-0.014	1.00%
2500.07	2600.07	100.00	1.225	2500.07	2600.07	100.00	1.245	-0.020	1.64%
2600.07	2626.18	26.11	1.212	2600.07	2626.18	26.11	1.225	-0.013	1.08%

Figure 1. Effects of the 250-mm Filtering on IRI.

There is also a “stabilization length” that not many people know about. The IRI model requires 11 m to initialize the quarter variables. See the following text and equation (3) in WTP 46.

3.4.1 Equations. The calculation of IRI is accomplished by computing four variables as functions of the measured profile. (These four variables simulate the dynamic response of a reference vehicle travelling over the measured profile.) The equations for the four variables are solved for each measured elevation point, except for the first point. The average slope over the first 11 m (0.5 sec at 80 km/h) is used for initializing the variables by assigning the following values:

$$Z_1' = Z_3' = (Y_a - Y_1) / 11 \quad (1)$$

$$Z_2' = Z_4' = 0 \quad (2)$$

$$a = 11 / dx + 1 \quad (3)$$

Figure 2. A Stabilization Length of 11 m is required for the IRI Model (Sayers et al. 1986)

Considering IRI as a response system, it would also take some lag distance to react to a surface disturbance in addition to the “stabilizing length”. Therefore, IRI will be slightly different between identical profiles if one of them has an offset (i.e., the IRI model response starts at different locations).

Then, such offset influence will dissipate after a distance, depending on the profile features and magnitudes of undulations. See the following IRI code and report examples for further details.

IRI Code

Sayers et al. (1986) included the IRI code in Basic. The “golden IRI code” that are widely used or adapted from the Fortran code in ASTM E1926 Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements. The “golden IRI-code” was corrected and validated by Chang and Karamihas for the ASTM 1926 revision in 2008 as E 1926-08. The standard was reapproved in 2021 without further changes as E 1926-08 (2021).

The correction of the “golden IRI code” in 2008 was important since there were some typos in the previous IRI-related publications and code errors. The same code (in Fortran 90 version) is used in ProVAL.

```
1150  REM  -------------------------------------  Initialize variables.
1160       INPUT "profile elevation 11 m from start:", Y(K)
1170       INPUT "X = 0. Elevation = ",Y(1)
1180       Z1(1) = (Y(K) - Y(1)) / 11
1190       Z1(2) = 0
1200       Z1(3) = Z1(1)
1210       Z1(4) = 0
1220       RS = 0
1230       IX = 1
1240       I = 0
```

Figure 3. BASIC Code for the Stabilization Length of 11 m required for the IRI Model (Sayers et. al. 1986)

```
C  Initialize simulation variables based on profile start.
      I11 = MIN(INT(11./DX + 0.5) + 1, NSAMP)
      XIN(1) = UNITSC*(PROF(I11) - PROF(1))/(DX*I11)
      XIN(2) = 0.0
      XIN(3) = XIN(1)
      XIN(4) = 0.0
```

Figure 4. FORTRAN Code for the Stabilization Length of 11 m required for the IRI Model (ASTM E1926-08)

Also, any implementation of IRI code or software needs to pass the test with the tripulse example in ASTM E1926 with the correct results of 4.36 m/km. See the following **ProVAL 4.0.63** results for both the World Bank and ASTM 1926’s tripulse examples (sample interval: 150 mm. Length: 15 m).

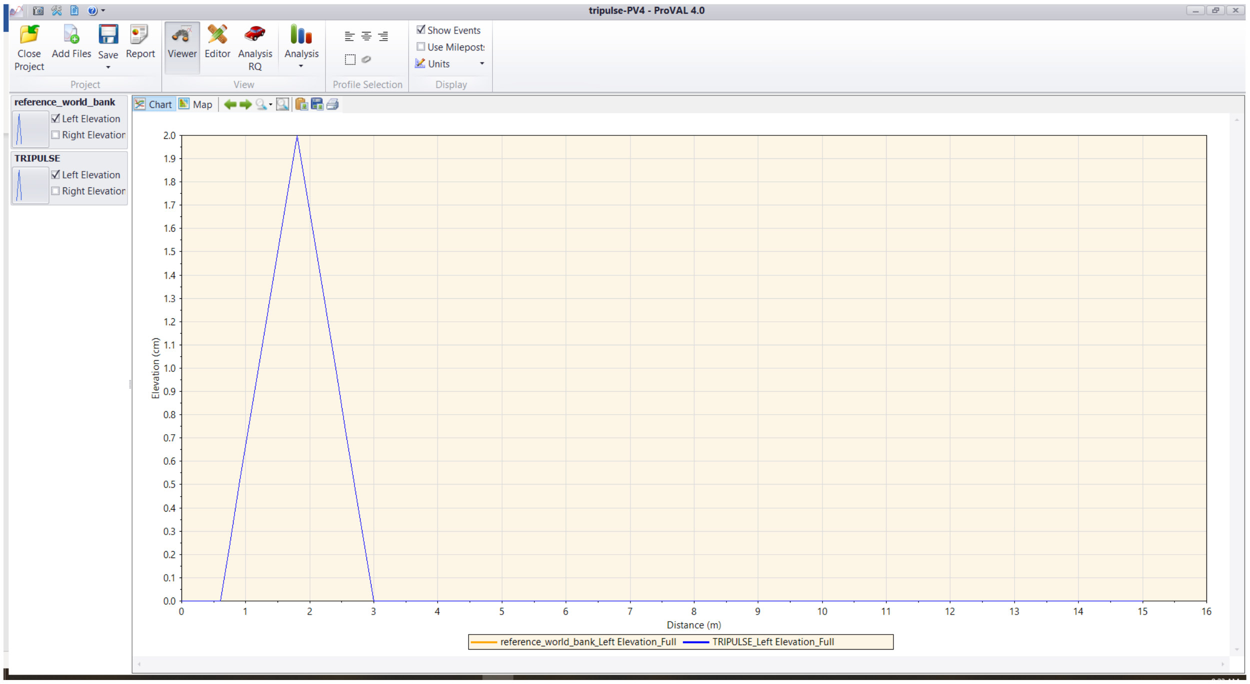


Figure 5. Tripulse example files from World Bank and ASTM.

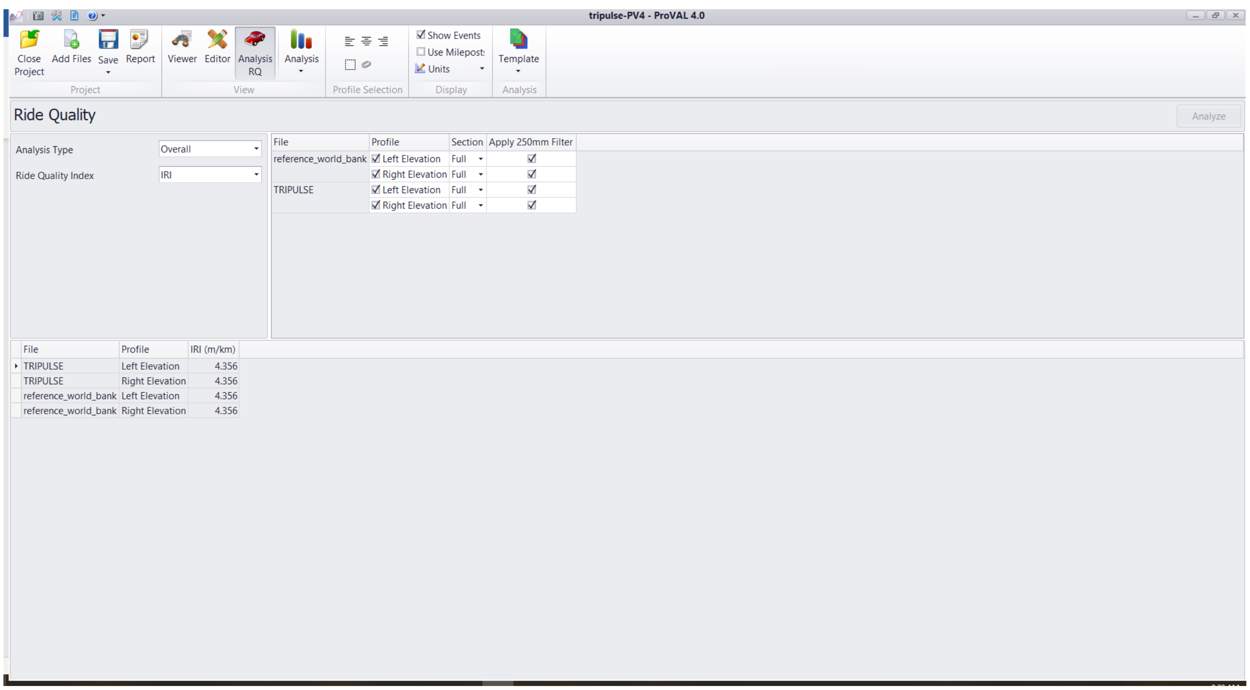


Figure 6. IRI results of the Tripulse example files from World Bank and ASTM.

IRI Reporting

The IRI reporting requires averaging with appropriate base lengths, as described in Sayers (1990). For the ride quality report, the adequate base length is 0.1 mile (528-ft). For localized roughness, the baselength is 25-ft (as in AASHTO R54) – though Sayers recommended 20-ft in Sayers (1990).

The averaging effects need to be considered when setting threshold values (Sayers, 1990). For example, 60 in./mi. for 0.1-mile ride quality full-pay and 120 in./mi. for 25-ft-moving averaged localized roughness.

The majority of ride quality reports are in the ProVAL fixed interval form. The averaging is applied within the baselength (0.1-mile) after the required processing, as detailed in Sayers (1990). However, there may be a slight issue when the profile was collected with offset start points (e.g., 10 m) and the baselength is short (e.g., 10 m instead of 100 m) due to "stabilization length" and "dissipation of disturbance" of the IRI model responding to the initial areas of the profiles.

The following examples illustrate the differences by using a modified ProVAL Workshop's Ride Quality example (03_Ride Statistics-mod.pvp).

100 m Fixed Interval Reports

The original profile was cropped out the first 100 m. Then, both profiles were compared using 100-m fixed ride quality report.

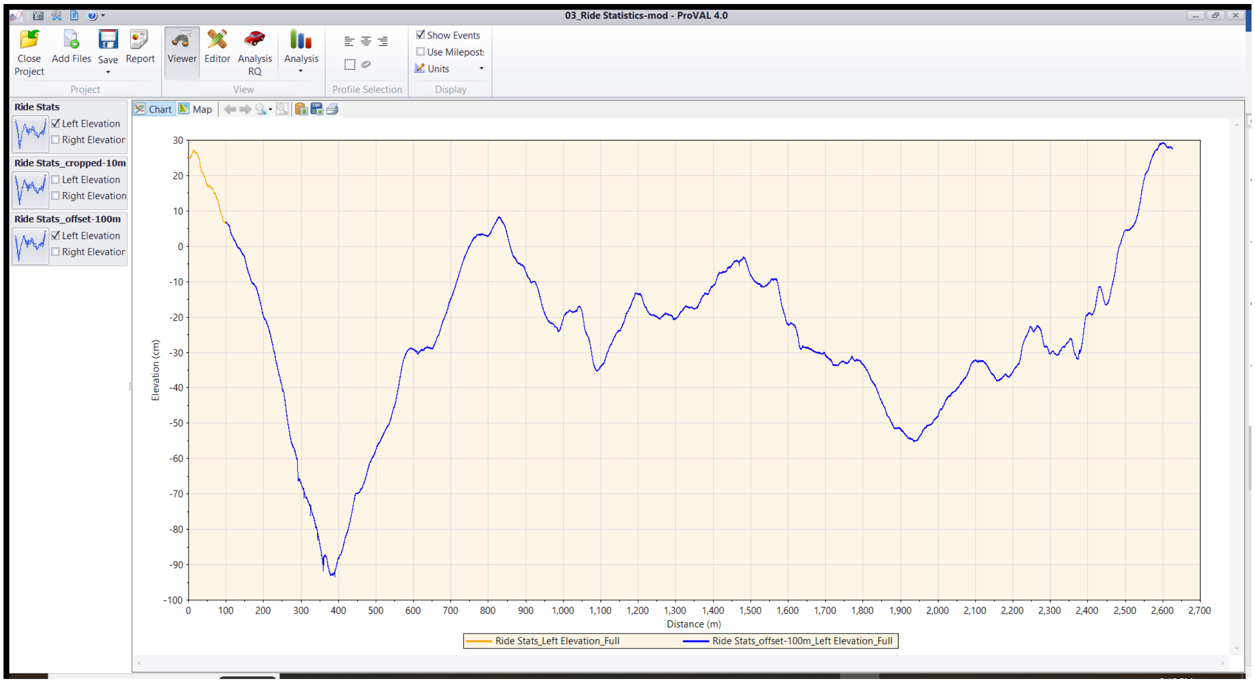
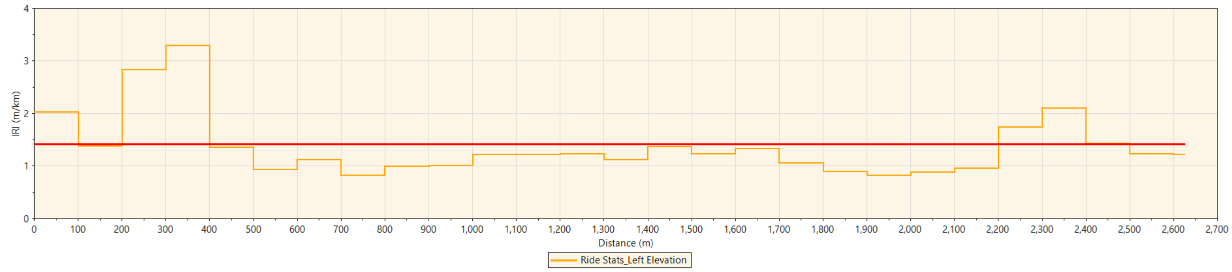


Figure 7. Original Ride Quality profile and cropped by 100-m.



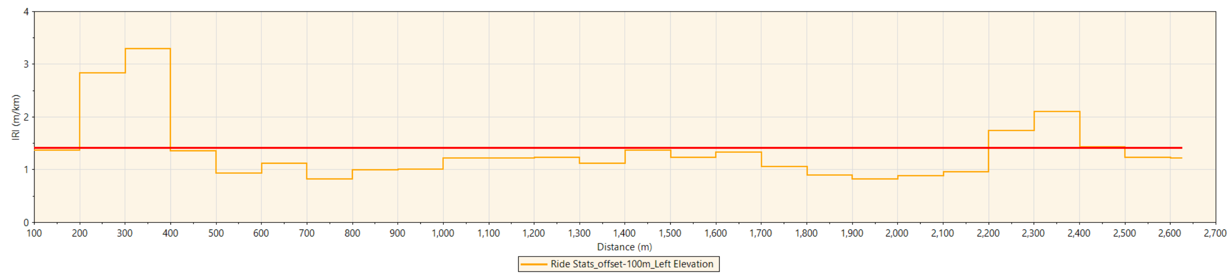


Figure 8. 100-m Fixed Interval Reports of the Original Ride Quality profile and cropped by 100-m.

Fixed Interval (100 m)									
Original				Cropped and Offset 10 m					
Start Dista	Stop Distai	Length (m)	Left Elevation - IRI (m/km)	Start Dista	Stop Distai	Length (m)	Left Elevation - IRI (m	Diff (offset)	
0.00	100.00	100.00	2.03						
100.00	200.01	100.00	1.38	100.00	200.00	100.00	1.36	0.02	the IRI stabilizing and response effect dimishes after 1X100 m segment
200.01	300.01	100.00	2.84	200.00	300.01	100.00	2.84	0.00	
300.01	400.01	100.00	3.29	300.01	400.01	100.00	3.29	0.00	
400.01	500.01	100.00	1.35	400.01	500.01	100.00	1.35	0.00	
500.01	600.02	100.00	0.93	500.01	600.01	100.00	0.93	0.00	
600.02	700.02	100.00	1.12	600.01	700.02	100.00	1.12	0.00	
700.02	800.02	100.00	0.82	700.02	800.02	100.00	0.82	0.00	
800.02	900.03	100.00	0.99	800.02	900.02	100.00	0.99	0.00	
900.03	1000.03	100.00	1.00	900.02	1000.03	100.00	1.00	0.00	
1000.03	1100.03	100.00	1.22	1000.03	1100.03	100.00	1.22	0.00	
1100.03	1200.03	100.00	1.22	1100.03	1200.03	100.00	1.22	0.00	
1200.03	1300.04	100.00	1.23	1200.03	1300.03	100.00	1.23	0.00	
1300.04	1400.04	100.00	1.12	1300.03	1400.04	100.00	1.12	0.00	
1400.04	1500.04	100.00	1.36	1400.04	1500.04	100.00	1.36	0.00	
1500.04	1600.05	100.00	1.23	1500.04	1600.04	100.00	1.23	0.00	
1600.05	1700.05	100.00	1.33	1600.04	1700.05	100.00	1.33	0.00	
1700.05	1800.05	100.00	1.06	1700.05	1800.05	100.00	1.06	0.00	
1800.05	1900.05	100.00	0.90	1800.05	1900.05	100.00	0.90	0.00	
1900.05	2000.06	100.00	0.82	1900.05	2000.05	100.00	0.82	0.00	
2000.06	2100.06	100.00	0.88	2000.05	2100.06	100.00	0.88	0.00	

Figure 9. Comparison of the 100-m Fixed Interval Reports of the Original Ride Quality profile and cropped by 100-m- the IRI stabilizing and response effect diminishes after 1X100 m segment.

10 m Fixed Interval Reports

The original profile was cropped out the first 10 m. Then, both profiles were compared using 100-m fixed ride quality report.

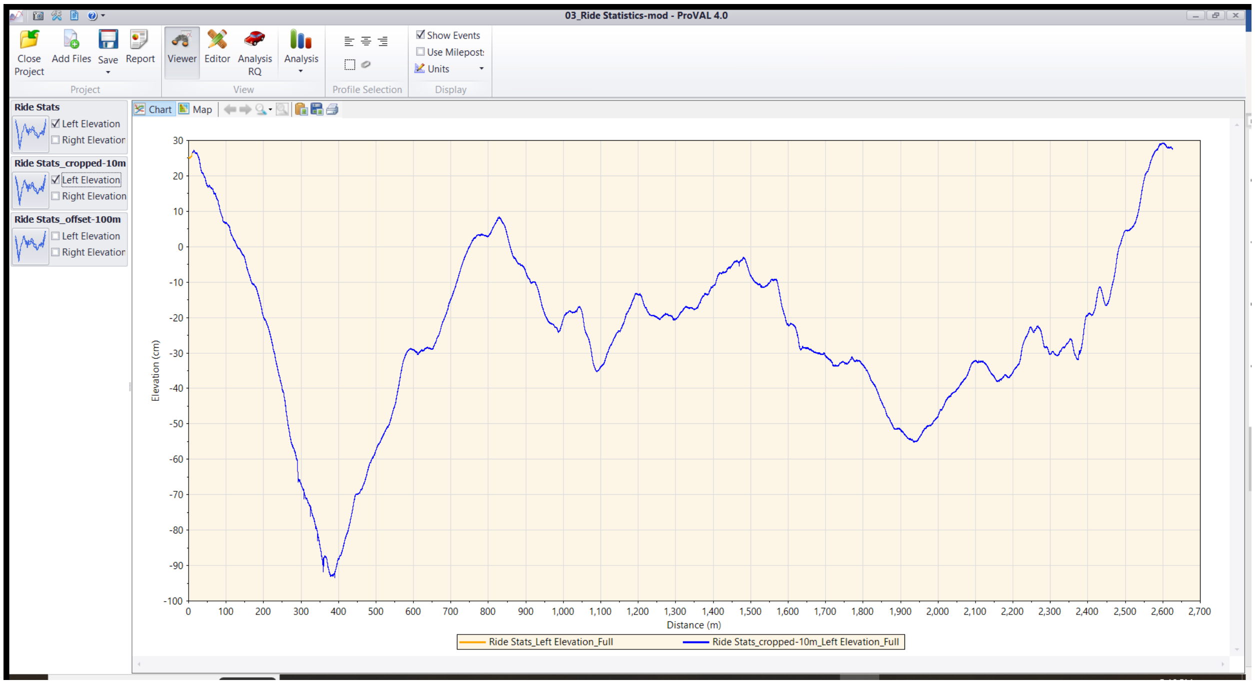


Figure 10. Original Ride Quality profile and cropped by 10-m.

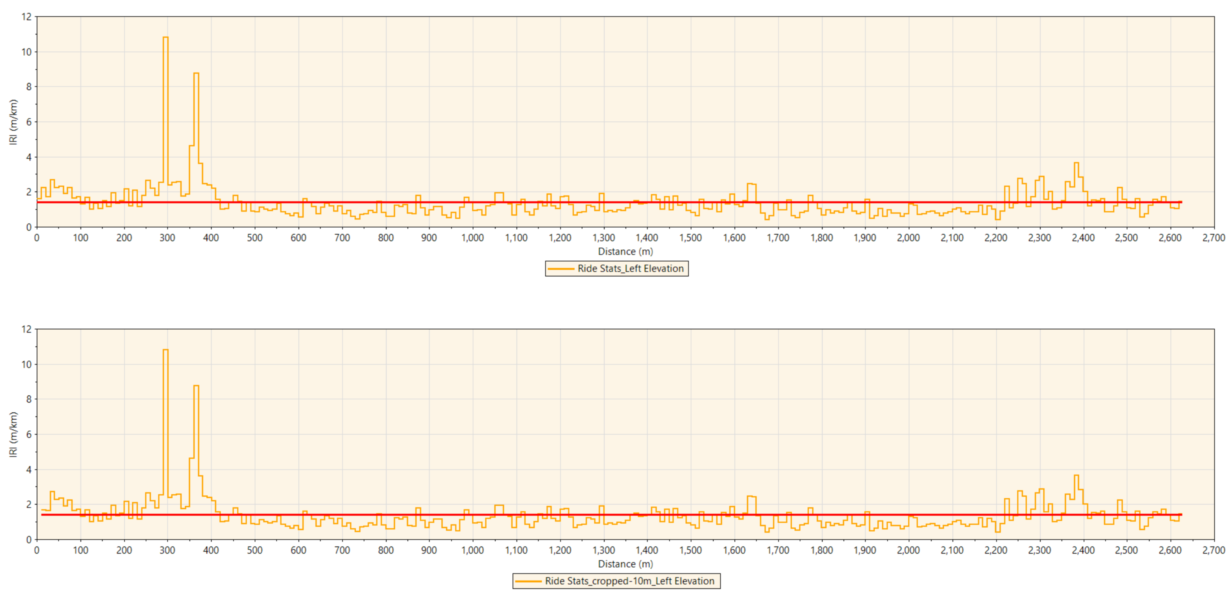


Figure 11. 10-m Fixed Interval Reports of the Original Ride Quality profile and cropped by 100-m.

Fixed Interval (10 m)										
Original					Cropped and Offset 10 m					
Start Dista	Stop Distai	Length (m)	Left Elevation - IRI (m/km)		Start Dista	Stop Distai	Length (m)	Left Elevation - IRI (m	Diff (offset)	
0.00	9.99	9.99	1.61							
9.99	19.99	9.99	2.22		10.00	19.99	9.99	1.68	0.54	
19.99	29.98	9.99	1.72		19.99	29.99	9.99	1.62	0.09	
29.98	39.97	9.99	2.69		29.99	39.98	9.99	2.70	-0.02	
39.97	49.97	9.99	2.25		39.98	49.97	9.99	2.27	-0.02	
49.97	59.96	9.99	2.33		49.97	59.97	9.99	2.34	-0.01	the IRI stabilizing and response effect dimishes after 60 m
59.96	69.96	9.99	1.90		59.97	69.96	9.99	1.90	0.00	
69.96	79.95	9.99	2.23		69.96	79.96	9.99	2.23	0.00	
79.95	89.94	9.99	1.66		79.96	89.95	9.99	1.66	0.00	
89.94	99.94	9.99	1.70		89.95	99.94	9.99	1.70	0.00	
99.94	109.93	9.99	1.31		99.94	109.94	9.99	1.31	0.00	
109.93	119.92	9.99	1.69		109.94	119.93	9.99	1.69	0.00	
119.92	129.92	9.99	1.00		119.93	129.92	9.99	1.00	0.00	
129.92	139.91	9.99	1.36		129.92	139.92	9.99	1.36	0.00	
139.91	149.90	9.99	1.05		139.92	149.91	9.99	1.05	0.00	
149.90	159.90	9.99	1.49		149.91	159.90	9.99	1.49	0.00	
159.90	169.89	9.99	1.17		159.90	169.90	9.99	1.17	0.00	
169.89	179.88	9.99	1.92		169.90	179.89	9.99	1.92	0.00	
179.88	189.88	9.99	1.35		179.89	189.88	9.99	1.35	0.00	
189.88	199.87	9.99	1.50		189.88	199.88	9.99	1.50	0.00	
199.87	209.87	9.99	2.15		199.88	209.87	9.99	2.15	0.00	
209.87	219.86	9.99	1.19		209.87	219.87	9.99	1.19	0.00	
219.86	229.85	9.99	2.07		219.87	229.86	9.99	2.07	0.00	
229.85	239.85	9.99	1.17		229.86	239.85	9.99	1.17	0.00	
239.85	249.84	9.99	1.78		239.85	249.85	9.99	1.78	0.00	

Figure 12. Comparison of the 10-m Fixed Interval Reports of the Original Ride Quality profile and cropped by 10-m- the IRI stabilizing and response effect diminishes after 60 m.

Lengths in ProVAL

ProVAL handles profile lengths very precisely and reports interval lengths by "snapping" the data points to the nearest boundary. That's why you may see 9.99 m instead of 10 m. (e.g., see Figure 12)

ProVAL 4.0 uses higher precision than ProVAL 3.61. Also, ProVAL 3.61 will no longer updated, and the support for ProVAL 3.61 may be dropped in the near future. All users need to update to ProVAL 4.0.63 or later.

Summary

- ProVAL's IRI code is the golden IRI code identical to WTP 46 and ASTM E1926-08.
- The 250-mm filter choices will affect the IRI results.
- The profiles need to start at the same locations to be fairly compared. Starting at different locations with an offset will also affect the fixed interval results within the first 60 m. Therefore, users need to use the same starting locations or use a long lead-in for at least 60 m (US specifications recommend 300 ft lead-in for approximately 91 m).
- The lengths in ProVAL are highly precise.

References

Sayers, M., Gillespie, T.; and Paterson, W. (1986); Guidelines for conducting and calibrating road roughness measurements (English). World Bank technical paper, no. WTP 46 Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/851131468160775725/Guidelines-for-conducting-and-calibrating-road-roughness-measurements

Sayers, M. (1990) Profiles of Roughness, Transportation Research Record, No. 1260, TRB Committee on Surface Properties-Vehicle Interaction (note: it is now TRB AKP50 in 2024).