U.S. Department
Of Transportation

Federal Railroad Administration

Research Results

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Development of Objective Track Quality Indices

SUMMARY

The Federal Railroad Administration (FRA) Office of Research and Development initiated a research project to develop a set of objective track quality indices (TQI) from track geometry data to assess track conditions in supplementary to the existing Federal Track Safety Standards. Through its Research and Development programs on the high-speed research car (T-16) and the Automated Track Inspection Program (ATIP), a large amount of track geometry data was collected between 2000 and 2002. The data portrayed a comprehensive picture of condition of the nation's rail network.

The basic concept is the use space curve length to represent track quality. Space curves are generated by track geometry measurement systems on a foot-by-foot basis. As illustrated in Figure 1, for a specified track segment length, the rougher the track surface, the longer the space curve will be when stretched into a straight line. A large number of track geometry surveys were processed and analyzed. The results show that the new FRA TQIs can quantitatively describe the relative condition of track surface geometries. Furthermore, the new TQIs are found to correlate well with the FTSS (Federal Track Safety Standards) for each track class. TQI results for different track classes were fitted to popular distributions. Satisfactory results are achieved.

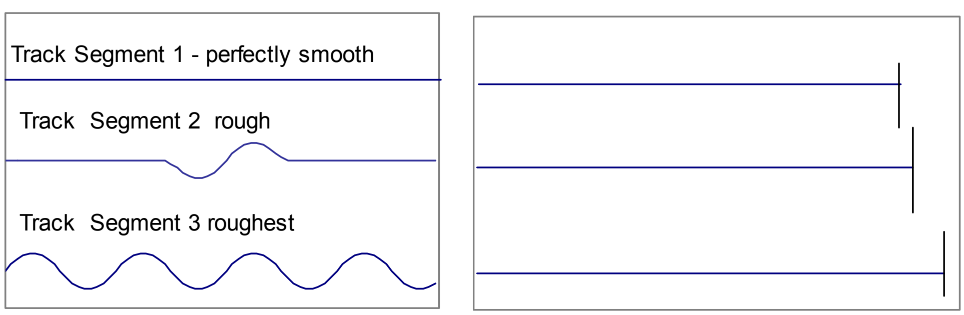

Figure 1. FRA Length-Base TQI Approach

BACKGROUND

A main goal of the project is to use the new TQIs to quantitatively assess track quality in relation to the Federal Track Safety Standards (FTSS). The newly developed TQIs should also be of wider benefit to the general railroad industry. The preferred track quality indices should be a set of non-biased and quantitative indicators that can be applied to measurements that are made by existing FRA track geometry systems, which are similar to those widely used by the railroad industry.

The work started with a review of existing TQI methods used by the railroad industry. Analysis of a small data set confirmed that the newly proposed FRA method was most promising. Full-scale data processing and analyses followed. Over 800 track geometry surveys from the FRA T-2000 track geometry inspection vehicle between 2000 and 2002, covering more than one third of the nation's rail network, were included in the analysis.

Preliminary TQI reference value ranges have been established for all track classes and different track features. These value ranges will be further refined after further analysis of integrity of the geometry data. A real time map display of TQIs has been implemented on FRA's research vehicle T-16. A real time TQI strip chart display will also be available in near future.

TQI RESULTS

Using the FRA TQI methodology as illustrated in Figure 1, TQIs were computed over nominal 528 ft (one tenth of a mile) track segments. The length of space curve was estimated as the sum of the straight distances between two consecutive data points, as show in equation (1).

$$L_S = \sum_{i=1}^{n} \sqrt{\Delta y_i^2 + \Delta x_i^2} \qquad (1)$$

where
L_s = traced length of space curve;
Δx = sampling spacing; and
Δy = difference of two consecutive measurements.

A set of track quality indices, each for profile, alignment, cross level and gage, are computed using equation (2).

$$TQI = \left(\frac{L_s}{L_o} - 1 \right) \times 10^6 \qquad (2)$$

Where L_o = the theoretical length of a track segment.

More than 100,000 track segments were extracted from the selected track geometry surveys. Each segment was evaluated against the FTSS to determine its actual class. The TQIs were calculated for each track segment. The TQI results were grouped by actual class (also referred as class met). Figure 2 shows the mean TQI values for tangent tracks. For profile and alignment the left and right indices were combined as one index. It is clear that track segment meeting higher track classes have low TQI values and thus higher track quality.

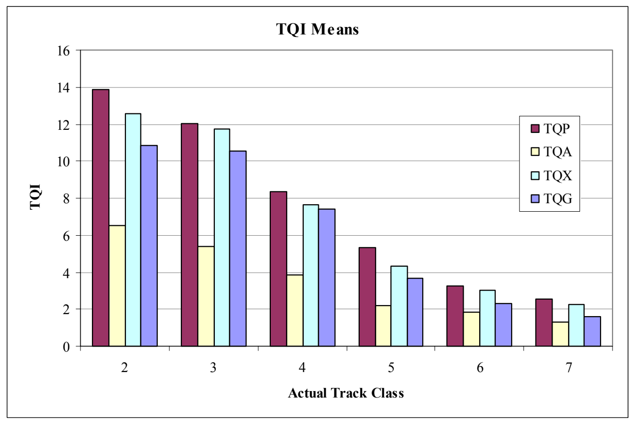

Figure 2. TQI Mean for Classes 2 to 7

Different track features, such as curves, spirals, crossings, switches, bridges and tunnels, demonstrated different track qualities. Figure 3 show a comparison of alignment quality index of difference track features and track classes.

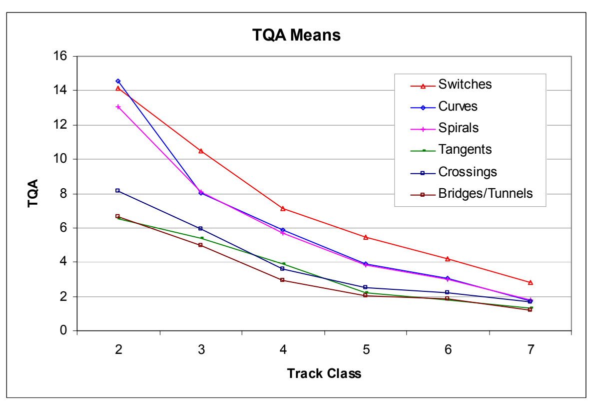

Figure 3. TQA Mean of Difference Track Features and Classes

Bridges and tunnels displayed the best quality with switches displaying the worst quality. Other TQI parameters confirmed the same trend. This seems to comply with common observations.

Histograms of the TQI results for different track classes suggest that TQIs follow certain distribution functions. Efforts were made to fit TQI results into popular distributions. The results show that either Weibull or Gamma distribution can summarize the TQI results with very high confidence. Figure 4 shows the fitted Weibull and Gamma distribution curves for class 3 TQP. The correlation coefficient between the fitted Weibull and actual TQP cumulative distribution curves is 0.9993.

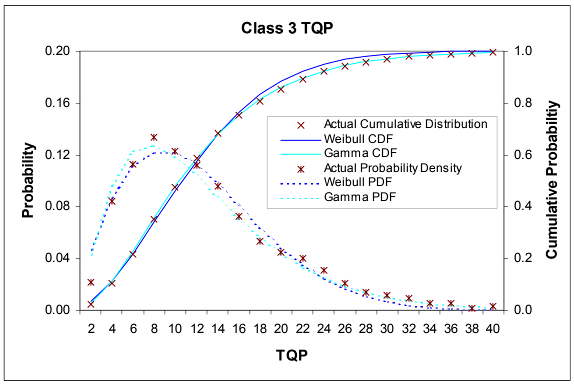

Figure 4. Class 3 TQP Distribution

The FRA TQIs are applied to one particular railroad in Northern America. Figure 5 show shows alignment TQIs of 1000 track segments, i.e. 100 miles of track. The two surveys were conducted over the same track in 2002 and 2004. The computed TQIs for the two surveys are plotted on the same chart and superimposed with national 95th and 5th percentiles values. Posted track class is also plotted along with TQI data. Figure 5 clearly depicts that 2004 survey shows better alignment quality than 2002 survey. The 2002 survey has alignment quality indices above or around the national 95th percentile level while 2004 survey indicate the alignment is at or better than the national average. This finding has been confirmed by the concerning railroad that has invested substantial funds in improving the track in question.

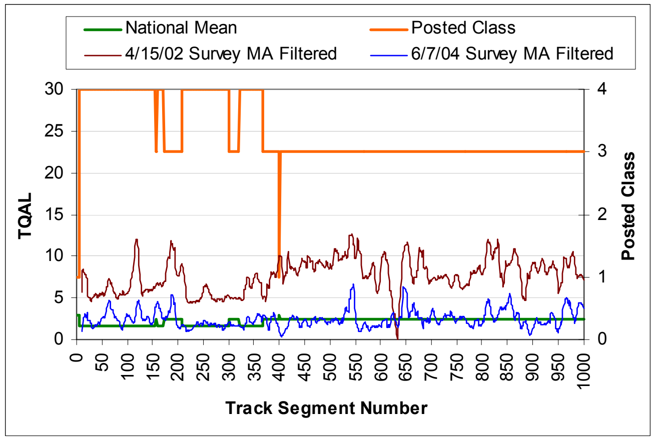

Figure 5. TQIs Applied to a Major Railroad

The TQIs are implemented on FRA's research vehicle T-16 as a real-time map and strip chart application. Figure 6 shows a snap shot of the map application. Figure 7 illustrates the TQI strip chart interface. The map continuously displays TQI values along the track being inspected by T-16. TQIs values are differentiated by the line thickness. When zoomed to a certain scale, detailed information concerning each track segment can be viewed. The strip chart interface provides a linear display of more detailed track quality indices. All TQI parameters can be displayed at the same time as individual channels. Additional information about vehicle speed, track class and milepost can also be shown on the screen. The national 95th and 5th percentile values for the posted class are superimposed on each TQI channel. The user can scale and zoom the display as well as change display colors real time.

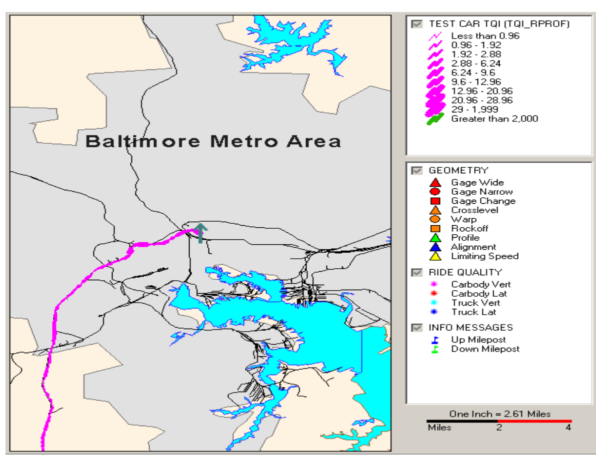

Figure 6. TQI Map Display on FRA T-16

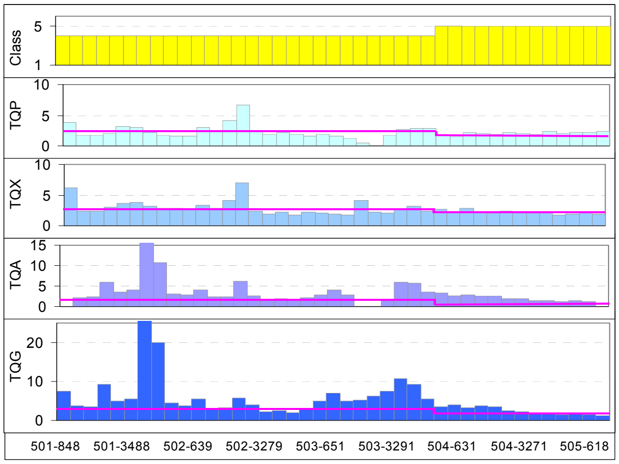

Figure 7. TQI Strip Chart Display

CONCLUSION

A set of objective TQIs have been developed based on the analysis of extensive survey data collected by the FRA's track inspection vehicle T-2000. The results show a clear inverse trend of TQIs with track classes, i.e. higher classes have lower TQI values. The trend exists even when actual class is determined by only one of the track geometry parameters. This clearly indicates some correlation between all TQI parameters.

TQI ranges are developed for track classes 2 to 7. However, it is considered that the values for classes 3 to 5 are most reliable because the track used for the analysis are posted classes 3, 4 and 5 track. Class 2 TQIs may present better than actual range because many class 2 track segments involved in the analysis are dropped from posted classes 3 to 5. There is little difference between TQI ranges for classes 7 to 9 track. The reason is that track safety standards for these classes do not vary significantly. Track segments meeting one of these classes should not be much worse than the other two track classes.

The TQIs developed were found to be able to quantitatively evaluate track quality and relate track quality to the Federal Track Safety Standards. These TQIs may be used to further evaluate vehicle and track interaction by incorporating vehicle characteristics. They may also be used as a tool to evaluate the effectiveness of track maintenance activities.

REFERENCES

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