

# TRACK GEOMETRY INSPECTION REPORT EXPLANATION

An Automated Track Inspection Program (ATIP) Track Geometry Inspection Report (TGIR) is generated for each ATIP survey. The TGIR summarizes the data collected and can be used in conjunction with the strip chart. The TGIR is generated electronically onboard the car and hard copies are distributed as follows:

- One (1) copy is provided to onboard railroad representative, as requested
- One (1) copy is provided to onboard FRA Inspector, as requested
- One (1) copy is archived for FRA management

Following ATIP Compliance survey operations, electronic copies of TGIRs are distributed via email, to a list of recipients designated by FRA and railroad management.

The TGIR may consist of up to ten parts;

- Cover
- Notes
- Exception List
- Curve Analysis
- Exception Summary
- Track Quality Index (TQI)
- GRMS Exception List (if equipped)
- Class+1 (C+1) Exception List
- C+1 Exception Summary
- Alignment 62 Mid-Chord Ordinate (MCO) Stations

Track measurement sample frequency is once per foot.

An exception is reported when track geometry values exceed the prescribed limit, plus 0.10-inches of grace, for two (2) or more consecutive samples (minimum length of 1- foot).

Exceptions are not reported for profile and alignment using 31 and 62 MCO when ATIP car speed is less than five (5) miles per hour.

## REGULATORY INFORMATION

Regulatory information for minimum track geometry safety limits in accordance with the FRA Track Safety Standards (TSS) can be found on the web at:

[https://www.ecfr.gov/cgi-bin/text-idx?SID=0d4f018b4eac4872f4cec827561c657c&mc=true&tpl=/ecfrbrowse/Title49/49cfrv4\\_02.tpl#0](https://www.ecfr.gov/cgi-bin/text-idx?SID=0d4f018b4eac4872f4cec827561c657c&mc=true&tpl=/ecfrbrowse/Title49/49cfrv4_02.tpl#0)

Railroad authorized train speed determines the Class of Track, which categorizes the minimum or maximum track geometry requirements.

## SECTION 1 – COVER PAGE

The *Cover Page* contains the report title, ATIP car designation, survey number, railroad, milepost limits, survey geography, contractor information, and certificate of accreditation. The ATIP contractor Survey Director's name is also printed on the cover page, adjacent to a signature line.

When a TGIR is generated in hard copy and distributed onboard ATIP survey cars, it is signed by the contractor Survey Director. This signature indicates that the data contained in that report is considered to be accurate and complete and collected in accordance with approved procedures and guidelines.

Any portion of the information which does not conform to the requirements of the ATIP Quality Program will be denoted, in writing, on the cover page.

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## SECTION 2 – NOTES PAGE

Information is provided about the purpose of the TGIR and the distribution of TGIRS onboard ATIP survey cars. There is also an explanation of survey data cut-off speeds, system limitations, and a hyperlink to the FRA website for further explanation of the contents of the TGIR.

## SECTION 3 – EXCEPTION LIST SECTION

This section of the TGIR lists the location and amplitude of each detected exception which exceeds the FTSS. The header of this section consists of report title identification text, milepost and geographic information, processing ID number, and survey date.

The column headings indicate specific exception information. From left to right, the headings identify the railroad milepost (*MP*) and distance (*FT*) from the milepost where the exception parameter's peak value is located, except as described below.

Exception location reporting is handled in two manners in ATIP operations, depending upon the mode of survey operations: Manned or Unmanned.

For manned operations, location of the exceptions will be identified by the number of feet beyond the last milepost entered into the data stream by human input. For unmanned operations exception reporting is handled by calculating the exception's location between two known milepost locations. Figure 1 depicts this difference between the two modes for reporting exception location on the track. Milepost locations are determined using historical manually-collected mileposts or railroad provided milepost GPS data.

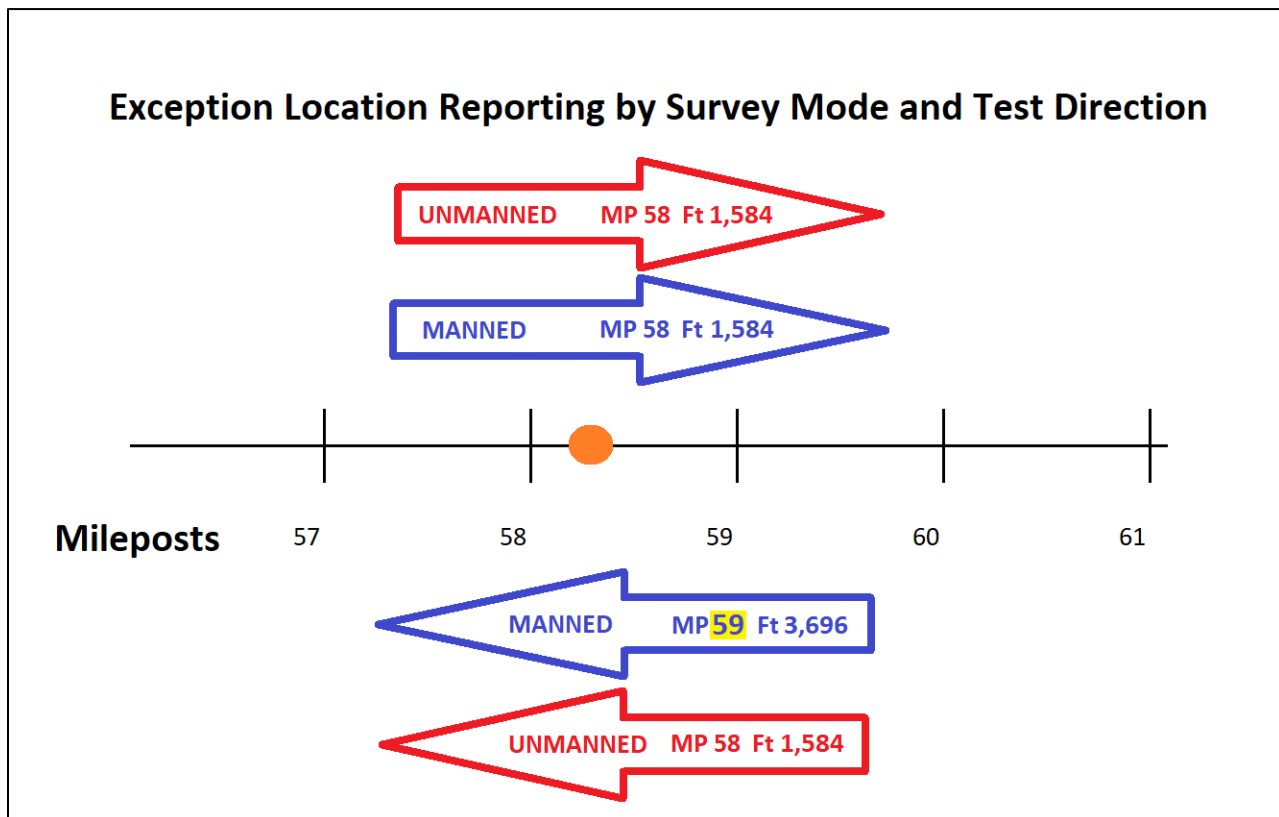


Figure 1. ATIP Exception Location Convention

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Manned ATIP cars count the number of feet from the last entered milepost. Reading from the TGIR, if the mileposts are *increasing* (e.g., 57, 58, 59), the footage from a milepost is added, *i.e.*, an exception located at milepost 58+1,584 would be interpreted as 1,584-feet from milepost 58 (decimal milepost 58.30). If the mileposts are *decreasing* (e.g., 60, 59, 58), the footage from a milepost is subtracted, *i.e.*, an exception located at milepost 59+3,696 feet (specifically between milepost 59 and milepost 58), would be interpreted as 3,696-feet from milepost 59 or 0.7 mile towards milepost 58. If there are exactly 5,280 feet in the mile, (in many cases there are not), this can be interpreted as milepost 58+1,584 feet (decimal milepost 9.3).

Most exception locations are identified in the TGIR by the location where the peak measurement value can be found. However, some exception types (Warp62, Twist31, Rockoff Hazard, etc.) are reported by the last location (end) of the exception deviation, referenced in the direction which the survey car traveled during the test.

The *Seq#* column provides the sequential ID # of the exception as detected by the geometry car and a helpful means to reference exceptions.

The *Parameter* column identifies a variety of events as well as exceptions, e.g., Posted Class (of track) changes, Posted Speed, Track Number changes, State Lines, and track exceptions being reported in reference to the survey train direction. Exceptions indicated with an '\*' are advisory and serve to emphasize a potential safety condition. Bold parameter text indicates an exception to TSS or an advisory. Exception parameter reporting convention is explained below.

\* Federal Track Safety Standard Advisory

Alinement exceptions reported in turnout paths are considered Federal Track Safety Standard Advisory but are not denoted with \*.

+ Maximum curve speed is limited at qualified cant deficiency. However, actual cant deficiency does not exceed grace allowed under 49CFR 213.57(b)(allows 1"), and 49CFR 213.329(b)(allows ½").

Rail Cant Exception denoted with (RSA) indicates possible Rail Seat Abrasion.

The *Value* column contains the maximum exception value measured by the geometry system. Geometry exception values are reported by the peak measurement of the deviation. All Exception Parameter values are reported in inches, except for the following:

Limiting Speed (Vmax) expressed in: MPH.

Ride Quality exceptions; Carbody Lateral, Carbody Vertical, Truck Lateral expressed in: g (gravitational acceleration)

Rail Cant; Left (L) and Right (R), NEG[ative] and POS[itive] expressed in: angular degrees (°)

For Rail Cant exceptions: Negative (-) values indicate an outward shift in the rail angle, and

Positive (+) values indicate an inward shift in the rail angle. Rail Cant exceptions have a minimum length of 15 feet. Rail Cant advisories begin at +4.4 POS and at -1.6 NEG degrees.

Rail Impact Values are unit-less; indicating a location with a large vertical axle acceleration.

For Alinement exceptions: Negative (-) values indicate rail shifting to the right and Positive (+) values indicate rail shifting to the left, referencing direction of ATIP car travel during testing.

The *Length* column lists the length that the exception extends, after exceeding the threshold plus the grace, and until track measurements return below the threshold.

The *Speed* column indicates the speed of the survey car at the location where the exception was detected. In the case of Limit Speed exceptions, the average speed of the survey car through the body of the curve is reported.

The *TSC* (T = tangent, S = spiral, C = curve body) column heading provides further information for each detected exception, by specifying the type of track on which the exception occurred.

*LC* (Limiting Class) and *PC* (Posted Class) columns indicate the Limiting Class of Track and the Posted Class of

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Track, respectively. These fields are not applicable for Limited Speed, Ride Quality [in classes 1-5], and Rail Cant. Track that is posted as “Excepted Class Track” by the railroad will be tested as Class 1 Track. In the case of excepted class track, the railroad is not required to repair the exceptions to Class 1 standards noted in the TGIR if the exceptions indicated are permitted by the entirety of the excepted track regulations.

The *Track* column identifies the track number the ATIP car surveyed. For the purpose of ATIP surveys, the TGIR designates tracks 1-4 as standard notations for multiple controlled track configurations. A single main track is designated as five (5) where single track exists. A controlled siding is designated six (6) and track seven (7) notations represent all ‘other than main’, and non-controlled tracks.

The onboard GPS system ‘tags’ all parameters with a *Latitude* and *Longitude* coordinate. Track geometry exceptions may be located for re-inspections by using a combination of the TGIR, GPS data downloaded into a handheld GPS device, the paper printout of foot-by-foot plot if applicable and/or special software program such as *GeoEdit8*.

### SECTION 4 – CURVE ANALYSIS SECTION

Below the section and page header information, an explanation of sign convention for Elevation and Curvature is provided. In the table, curvature and elevation values will show a minus sign (-) preceding the degree/minutes or inches, indicating curvature to the left with right rail high or elevated. Conversely, a positive value (+ sign omitted) indicates curvature to the right and left rail high or elevated.

The Curve Analysis Section table reports; the curve location, average curvature and elevation values, limiting speed information using three (3) inches of unbalance, including a section that lists limiting speed values from three (3) through nine (9) inches of cant deficiency. ATIP uses this standard convention; the Primary Unbalance value is three inches of unbalance where timetable speeds are provided exclusively for freight trains, and four inches of unbalance (as a secondary input) where passenger train speeds are also provided.

The following formula contained in 490 CFR Part 213 Section 57 is helpful in solving unbalance for track that is class 1-5:

$$V_{\max} = \sqrt{\frac{E_a + E_u}{0.0007D}}$$

Where—

$V_{\max}$  = Maximum allowable posted timetable operating speed (m.p.h.).  $E_a$  = Actual elevation of the outside rail (inches).<sup>1</sup>

$E_u$  = Qualified cant deficiency <sup>2</sup> (inches) of the vehicle type.  $D$  = Degree of curvature (degrees).<sup>3</sup>

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<sup>1</sup> Actual elevation,  $E_a$ , for each 155-foot track segment in the body of the curve is determined by averaging the elevation for 11 points through the segment at 15.5-foot spacing. If the curve length is less than 155 feet, the points are averaged through the full length of the body of the curve.

<sup>2</sup> If the actual elevation,  $E_a$ , and degree of curvature,  $D$ , change as a result of track degradation, then the actual cant deficiency for the maximum allowable posted timetable operating speed,  $V_{\max}$ , may be greater than the qualified cant deficiency,  $E_u$ . This actual cant deficiency for each curve may not exceed the qualified cant deficiency,  $E_u$ , plus 1 inch.

<sup>3</sup> Degree of curvature,  $D$ , is determined by averaging the degree of curvature over the same track segment as the elevation.

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Referencing left to right, the *Track* column indicates the ATIP track designation for the track where the curve is located. The beginning and ending points of a curve are listed by the *Starting* and *Ending* columns and include the respective milepost (MP) number and the distance in feet (FT). *Length* is the calculated overall length of the full-

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body of the curve including the spirals. *Spd* (speed) is the average speed of the geometry car through the curve.

*Average* values of *Curve* (degrees/minutes, e.g., 3/7 means 3 degrees and 7 minutes of curvature) and *Elev* (elevation) give the average of all points measured in the body of the curve (point-of-curve to point-of-spiral).

The *Speed* column is divided into *Post* (posted speed) and *Lmt* (Limiting Speed) values in miles-per-hour. Posted speed is provided to FRA by the track owner and entered into the *TGMS* onboard ATIP cars. The Limiting Speed indicates the maximum allowable speed ( $V_{max}$ ) information for each curve in accordance with §213.57(b) using the 3-inch or 4-inch underbalance setting.

The *Limiting Point* heading specifies the milepost and feet from the milepost for the peak deviation from uniformity which results in the limiting speed condition. The column headings *Curve* (curvature) and *Elev* (elevation) provide the actual curvature and elevation used to compute the limiting speed. The column *Total FT/Grp* (feet/group) offers the total number of feet where the computed speed is lower than the posted speed and also lists the number of groups of points that are lower than the posted speed in the curve. For a compound curves, each portion of a curve body is provided as a separate record in the table.

The column heading *Limiting Speed at* lists the calculated maximum allowable speed ( $V_{max}$ ) for the curve on that output line using each of the following unbalance increments (at times referred to as cant deficiencies) 3 through 9 inches. The value shown indicates the speed in miles-per-hour for each cant deficiency. Values in this section which are bold indicate the geometry car's Primary Unbalance setting for the survey.

### SECTION 5 – EXCEPTION SUMMARY SECTION

This section summarizes track geometry exceptions which were detected during the survey. From left to right, the column headings provide for specific summary information.

The *MP* (milepost) heading indicates the starting milepost number for each entry line. The *FT* (feet) column indicates total feet counted until the next milepost was entered. Each exception column lists the exception description. Listed under each exception are the headings *Tot EXC*, *Exc FT* and *2 Cl Drop* (total exception, exception feet, and two class drop). The *TOT Exc* column lists the total number of exceptions, which were detected during each mile. The *Exc FT* column lists the total combined length in feet of the exceptions detected. The *2 Cl Drop* column indicates serious safety noncompliance where track conditions exist that require two or more reduction in track class to be compliant with TSS.

*Lmt Spd Tot EXC* column is provided for indication of segments of track which include one or more Limited Speed exceptions.

The *Lim Cls* and *Pst Cls* (limiting class and posted class) heading provides the lowest computed track class for the combined exceptions. If there is more than one Class of Track in a given mile, a separate entry for each class change will occur. The last column *Trk* (Track) provides the track number notation.

These fields are totaled on the final page of the Exception Summary Section.

The last entry shows the total miles surveyed, the exceptions per 100 miles rate for the selected survey, a 3-year national average of all railroads surveyed by ATIP, and total miles and percentage of concrete crossties (if applicable).

### SECTION 6 – TRACK QUALITY INDEX INFORMATION SECTION

Onboard ATIP cars, a TQI summary report is generated as part of the Track Geometry Inspection Report. The summary report provides a survey overview of track quality 'roughness'. The report contains a bar chart (**Figure 2**) which has the similar format to the real-time TQI stripchart. The chart is segmented into 50-mile sections per

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page. There are 5 data channels displayed vertically. From top to bottom, it shows: posted track class represented as a red line, crosslevel, profile quality index, averaged for both left and right profile, alignment, averaged for both left and right alignment, and gage quality index. Similar to the onboard TQI stripchart display, the national average (red) lines are plotted along each geometry channel.

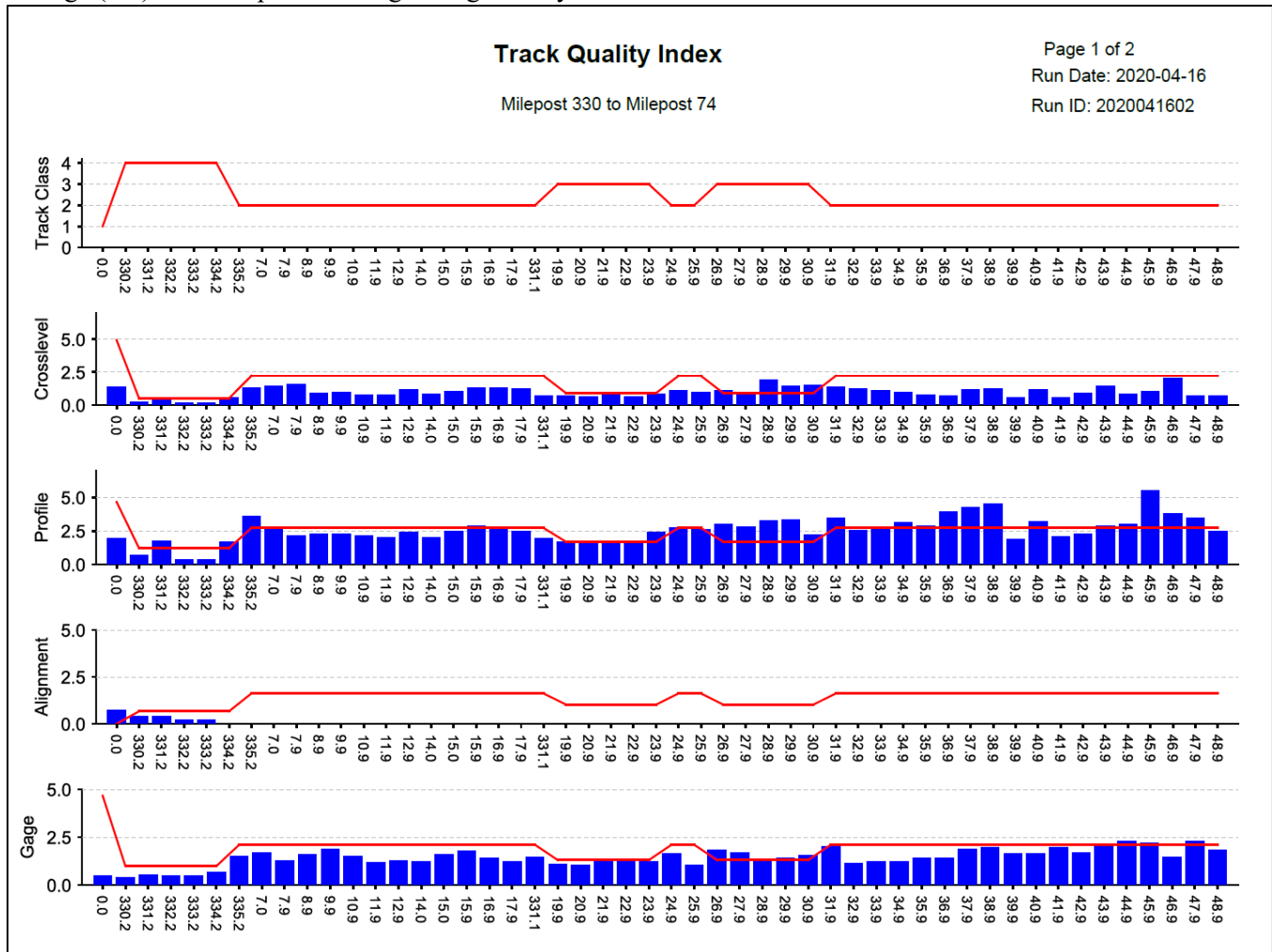


Figure 2. TQI Summary Chart

Figure 2 illustrates a TQI summary chart of milepost locations where track quality is better or poorer than the national average, i.e., the bars are lower or higher than the national average lines, respectively. Milepost segments significantly higher than the national average means the track structure is probably failing and reinspection is warranted.

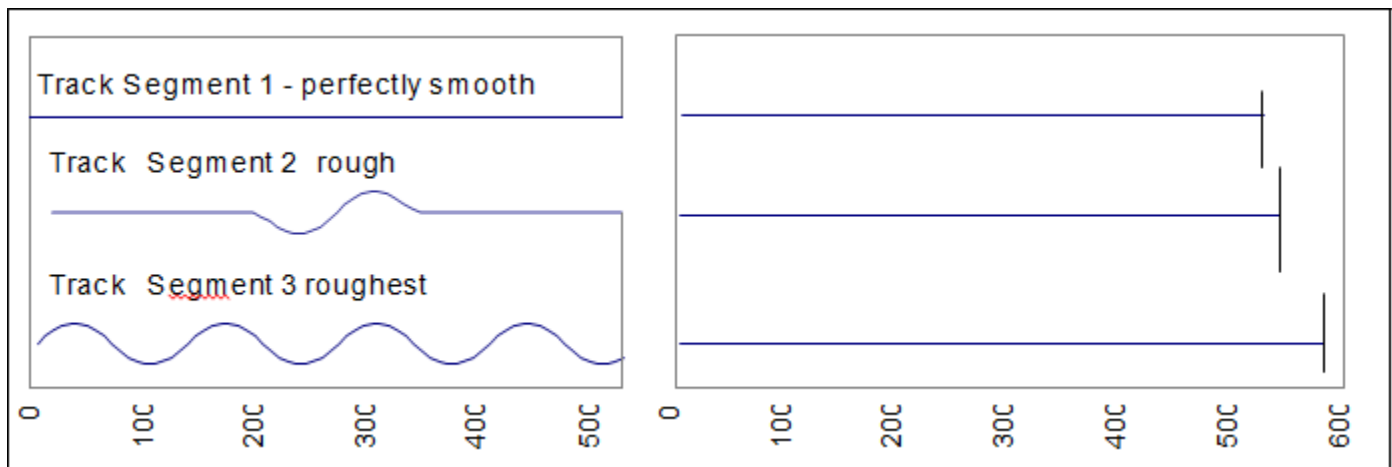
TQI is a dimensionless track quality indicator. Alternate TQI methods may have intrinsic worth. However, they lack rating track by its classification, as determined by the FTSS. FRA developed a TQI method and through its Automated Track Inspection Program, has collected an enormous amount of track geometry data. The geometry data represents a comprehensive picture of track quality nationwide. This offers FRA the capacity to derive objective track quality indices from a large volume of data and relate the TQI to the FRA TSS. The comprehensive track geometry data collected by ATIP geometry cars are screened and analyzed to derive a set of TQIs. On a segment-by-segment basis, once a segment is determined to meet a certain track class, for example Class 4, the TQI values will rate the segment as a “good,” “average,” or “poor” Class 4 track segment.

The basis of FRA TQI calculation is to compute or “trace” the length of space curves and unedited data plots. To calculate the space curve length for a fixed 528-foot track segment length, the space curve length between any two data points is approximated as the straight distance between these two points. Instead of calculating TQIs from standard deviations of track geometry parameters FRA TQIs compute the length of ‘space curves’, which are

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generated by track geometry measurement systems at one-foot intervals. When track geometry signals are viewed as a space curve, the data reveals that lower-class track has rougher signals. If track segments of fixed distance along the track were to be flattened or smoothed out to perfection, the rougher segments will be more elongated than the smoother ones. Thus, the actual length of a segment along its space curves would serve as an appropriate indication of its roughness and hence its overall quality.

The space curves resemble two-dimensional plots with x-axis being the distance along the track and y-axis being the deviation of the track geometry parameter from a reference plane. As depicted in **Figure 3**, a perfectly smooth track would have the space curve overlapping on the x-axis, and therefore the length of the space curve would be equal to the distance along the track. Any less than perfect space curves, e.g. segments 2 and 3 when stretched, would have a length longer than the distance along the track. It is the difference between the space curve and the horizontal distance of the track that determines the quality of the track.



**Figure 3. Space Curve Length of Track Segment with Different Track Roughness**

Various methods are used to compute TQIs from track geometry measurements and hence, there are different TQIs in the railroad industry. The existing methods could be adopted for computing TQIs. However, FRA method is better suited for segment-by-segment analysis.

A set of objective TQIs has been developed based on the analysis of extensive survey data collected by FRA's ATIP fleet. The results clearly show an 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 finding clearly indicates some correlation between all TQI parameters. TQI ranges are developed for track Classes 2 through 7. The TQIs developed were found to be able to quantitatively evaluate track quality and relate track quality to the FTSS. These TQIs may be used to further evaluate vehicle and track interaction by incorporating vehicle characteristics. They may also be used to study track geometry deterioration trends and rates.

### SECTION 7 – GAGE RESTRAINT MEASUREMENT SYSTEM (GRMS) EXCEPTION LIST SECTION

This section provides tabular results of the GRMS system exception types for survey cars that are equipped with that technology. Similar to the Exception List sections of the report, each exception is identified by *MP* and *FT* (feet past the milepost) location, a *Parameter* name, peak *Value*, *Length*, and GPS *Latitude* and *Longitude*. Additionally, the values reported by the *UGage* (Unloaded Gage), *LGage* (Loaded Gage) values, and the *PLG* (Projected Loaded Gage) and *GW* (Gage Widening Projection) values at those locations.

Summary information is provided on the last page of this section, and totals groups of exception types by total feet and number of exception locations.

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The GRMS systems can only be utilized when the geometry car consist travels in the forward orientation.

### **SECTION 8 – CLASS +1 EXCEPTION LIST SECTION**

In 2013, ATIP added two new sections to the TGIR: The Class +1 Exception List and Class +1 Exception Summary sections. These two additional sections of the TGIR are provided for information only, as a courtesy to the railroad owner.

The Class +1 Exception List Section identifies exceptions to the FTSS which would exist on a territory if the posted track class was increased by one during the ATIP test. During ATIP compliance surveys, the current timetables and track warrants dictate the established posted track class for testing under 49 CFR Part 213 Subpart C. As the ATIP survey car tests across a territory, the posted class for the compliance survey is adjusted up or down per the current railroad published speeds, providing a real-time list of exceptions to FTSS to maintain current posted track class and track speeds.

For territories where an increase in posted track class is being considered, or where temporary speed restrictions are in place, information in this section of the TGIR may be of value to the railroad company. The format of this section of the TGIR is the same as that of Section 3-- Exception List Section. This section includes the original actual posted track class FTSS exceptions, as well as the “Class +1” exceptions.

### **SECTION 9 – CLASS +1 EXCEPTION SUMMARY SECTION**

This section of the TGIR serves to summarize the exception information in Section 8 --Class +1 Exception List Section. The format for this section of the TGIR is the same as for Section 5 – Exception Summary Section. In this Class +1 Exception Summary the results of the Class +1 testing are summarized in a tabular format. This summary includes the original actual posted track class FTSS exceptions, as well as the “Class +1” exceptions.

### **SECTION 10 – ALIGNMENT 62 MID-CHORD ORDINATE (MCO) STATIONS SECTION**

This section breaks out the individual track geometry measurements for Alignment 62 Exceptions for nine (9) stations centered on the exception, with 15.5-foot spacing. The individual Align 62 exceptions are provided as headers for a table of relative geometry measurements. This table lists the measurements that can be found during field verification or re-inspection of the Align 62 exceptions, in the parameters of *Align62*, *MCO*, *Curve* (Curvature), *Xlevel* (Crosslevel), and *Gage*.