WIT CONFERENCES This paper is part of the Proceedings of the 15th International Conference on Railway Engineering Design and Operation (CR 2016)
www.witconferences.com

A comparative study of the TQI method and process performance index method in the quality evaluation of track fine adjustment

F. Y. Li[1], Y. D. Xu[1], H. F. Li[1,2], J. F. Shen[1], W. Y. Liu[1] & J. X. Qiu[1]
[1]Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, China
[2]Department of Transportation Engineering, Tongji Zhejiang College, China

Abstract

The track quality index method (TQI method) is widely used in the quality evaluation of track fine adjustment, while the process performance index method is a new method to evaluate the quality of track fine adjustment based on a process performance index. In this paper, the quality of the same section of track was evaluated separately with the two methods, and the similarities and differences as well as the advantages and disadvantages of the two methods are compared. The conclusions are: in the evaluation results of the general and individual statistical index of the quality of track fine adjustment, the results obtained by the two methods are basically consistent, but the new method is more clear and comprehensive; in the efficiency of track fine adjustment, the new method is more targeted than the TQI method; in terms of the convenience of analysis, the TQI method is more convenient. Comprehensively, the process performance index method is better than the TQI method.
Keywords: ballastless track, track fine adjustment, operational quality evaluation, TQI, process performance index, comparative study.

1 Introduction

Ballastless track fine adjustment is a key link in the track accuracy control, and the operational quality has important effects on the safety, ride comfort

WIT Transactions on The Built Environment, Vol 162, © 2016 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/CR160041

and comfort of running high-speed trains. For the construction technology and operational methods of fine adjustment, Wang [1], Ma [2], and Zhang and Huang [3] have been studied a lot. However, quality control, as an important part of project management [4], has not been fully studied in the evaluation of track fine adjustment quality. At present, for track dynamic irregularities management, Chinese railways document “Rules of railway track maintenance” [5] classifies it as peak management and mean management in the operation management stage, with the track quality index (TQI) to evaluate the operational quality. In recent years, more and more attention has been paid to quality management. Therefore, a new method based on the process performance index is proposed to evaluate the quality of track fine adjustment. But the comparative study of the two methods is less, therefore, in this paper, the operational quality of the same section of track was evaluated separately with the two methods, and the similarities and differences as well as the advantages and disadvantages of the two methods are compared.

2 The evaluation based on the TQI method

2.1 Track quality index

Track quality index (TQI) refers to regarding 200m sections as a unit, and the standard deviations of the seven local geometrical parameters about profile, alignment, gauge, cross-level and twist of each unit were calculated respectively. The sum of the standard deviations, which is used to evaluate the comprehensive quality of track irregularity of the unit, is the TQI [5]. At present, the evaluation of track fine adjustment quality is measured with the TQI index, and the formula is as follows:

$$TQI = \sum_{i=1}^{7} \sigma_i \tag{1}$$

$$\sigma_i = \sqrt{\frac{1}{n} \sum (x_{ij} - \overline{X}_i)^2} \tag{2}$$

$$\overline{X}_i = \frac{1}{n} \sum_{j=1}^{n} x_{ij} \tag{3}$$

where: σ_i is the standard deviation of a single geometrical parameter (unit: mm); i=1, 2, …, 7, represents the geometrical parameter, $\overline{X}_i$ is the average value of the sampling points of the parameter i (unit: mm); x_{ij} is the value of the parameter i at the sampling point j (unit: mm); and n is the number of sampling points in the unit section. The distance between two adjacent sampling points is 0.25m in Chinese railways, and the number is 800.

2.2 Evaluation criterion

According to Chinese railways document "Rules of railway track maintenance" [5], when the unit section length is 200m, and the speed is in the range of 250 (excluding) –350km/h, the management values of TQI are shown in Table 1.

Table 1: Management values of TQI (unit: mm).

Profile	Alignment	Gauge	Cross-level	Twist	TQI
0.8×2	0.7×2	0.6	0.7	0.7	5.0

2.3 Evaluation results

According to the eqns (1)–(3), unified the left and right profile and the left and right alignment into profile and alignment to calculate, after fine adjustment the results of the average value of each individual and general statistical index of each section are shown in Table 2.

Table 2: Average value of the estimated variability of each individual and general statistical index.

Section	Cross-level	Profile	Twist	Gauge	Alignment	TQI
1	0.21	0.57	0.25	0.19	0.44	2.66
2	0.19	0.52	0.24	0.23	0.40	2.51
3	0.25	0.49	0.30	0.22	0.39	2.53

3 The evaluation based on process performance index method

Process performance refers to the actual processing capacity of the process in a state of control (steady state) in a certain period of time. In order to carry out the process performance analysis and directly reflect the result of the process performance evaluation, a non-dimensional measurement and evaluation index, process performance index, was proposed and the performance is evaluated by its numerical value [6].

Process performance index reflects the degree that of the current process to meet the standards and specifications, and according to the collected data to estimate the current process performance, it can reflect the comprehensive indicators of the production process information [7, 8]. Thus, the managements enable to have a comprehensive understanding of the actual track fine adjustment ability. According to the different specifications, the process performance index is divided into the bilateral process performance index and the unilateral process performance index. For the quality evaluation of track fine adjustment, the unilateral process performance index is applied.

3.1 Calculation principle

For specifications that only have an upper limit, the calculation equation is:

$$P_{pU} = \frac{S_U - \mu}{3\sigma} \tag{4}$$

where: S_U is the upper specification; μ is the estimated mean of the process; σ is the estimated variability of the process (expressed as a standard deviation).

For specifications that only have a lower limit, the calculation equation is:

$$P_{pL} = \frac{\mu - S_L}{3\sigma} \tag{5}$$

where: S_L is the lower specification.

As shown in Figure 1, the value of the process performance index depends on the estimated mean and the estimated variability of the process. The larger the process performance index is, the higher the quality characteristics meet the requirements of the limit value, or the more samples are in the limited area, the stronger the process performance is.

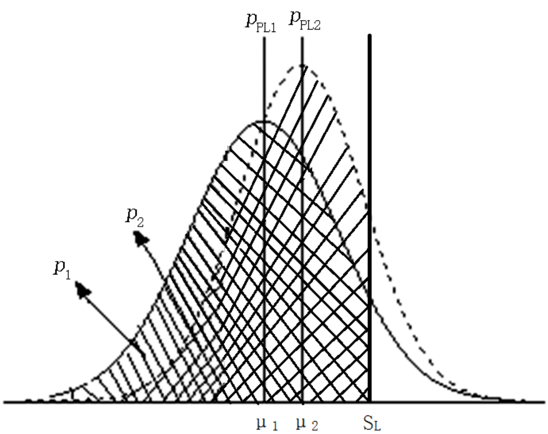

Figure 1: The upper unilateral process performance index.

3.2 Process performance index of track fine adjustment

1) The estimated mean of the track fine adjustment process μ_k:

$$\mu_k = \frac{1}{N}\sum_{j=1}^{N}\sigma_{kj} \tag{6}$$

where: σ_{kj}(k=1, 2…6) is the value of the parameter k at the sampling point j in the same section; N is the number of the unit sections.

2) The estimated variability of the track fine adjustment process σ_k:

$$\sigma_k = \sqrt{\frac{1}{N}\sum(\sigma_{kj} - \mu_k)^2} \tag{7}$$

3) The upper limit of the track fine adjustment $S_{U,k}$:

According to the statistical results of the test data of Hangzhou-Changsha, Hefei-Fuzhou and Nanjing-Anqing High-speed Railway, and the requirement of Chinese railways document "Rules of railway track maintenance" [5], we can get the upper specification limit values of estimated variability of each individual and general statistical index in different grades, as shown in Table 3.

Table 3: Upper specification limit values of estimated variability of each individual and general statistical index.

Upper specification	Cross-level	Profile	Twist	Gauge	Alignment	TQI
Class I	0.27	0.3	0.27	0.26	0.3	2.0
Class II	0.4	0.5	0.4	0.4	0.4	3.0
Class III	0.7	0.8	0.7	0.6	0.7	5.0

4) Process performance index of track fine adjustment $P_{pU,k}$:

Because the track fine adjustment is only limited to the upper specification, and there is no requirement for the limit of the lower specification, the requirements of eqn (4) can be met. Therefore, the calculation equation for the process performance index of track fine adjustment is:

$$P_{pU,k} = \frac{S_{U,k} - \mu_k}{3\sigma_k} \tag{8}$$

3.3 Evaluation criterion

Generally, for the process performance index, there is an evaluation criterion for reference as shown in Table 4.

Table 4: Evaluation criterion of P_{pU}.

Class	P_{pU}	Condition and suggestion
A	$P_{pU} \geq 1.33$	The condition is stable and the ability is good.
B	$1.33 > P_{pU} \geq 1.0$	The condition is good, but the factors of the production process have a slight variation will lead to a risk, and it should take measurements to improve the level to A.
C	$1.0 > P_{pU} \geq 0.67$	There are many defects in the manufacturing process, and must enhance its ability.
D	$0.67 > P_{pU}$	The ability is too poor, and it should be considered to redesign and manufacturing process.

3.4 Evaluation results

Through the calculation of 2.3, the track fine adjustment level of the three sections are Class II, so calculate the P_{pU} of the above test data to evaluate and class the level of the fine adjustment ability of each section. After fine adjustment, the calculation results of P_{pU} of each individual and the general statistical index of each section are shown in Table 5.

Table 5: P_{pU} of each individual and general statistical index.

Section	Cross-level	Profile	Twist	Gauge	Alignment	TQI
1	0.97	-0.29	1.2	2.15	-0.19	0.48
	C	D	B	A	D	D
2	2.6	-0.14	1.52	1.89	-0.01	1.02
	A	D	A	A	D	B
3	1.36	0.04	0.79	1.92	0.1	0.74
	A	D	C	A	D	C

4 Comparative study of the two evaluation methods

4.1 Evaluation of general statistical index

From Table 2, we can see that in the TQI method, the general levels of TQI are between 2.51 and 2.66, and are significantly less than the standard 5.0 in Table 1. However, there will appear that the general level of TQI reaches the standard, but one or two of the individual levels are out of limits, so that the results are not comprehensive enough.

From Table 5, the P_{pU} of TQI is distributed in B, C or D. For example, the P_{pU} of TQI of second section is grade B, because of the existence of profile and alignment, which are classed in D, although the other individual statistical indexes are Class A, ultimately the TQI is classed in B. So, the process performance index method can reflect to the general level of fine adjustment more comprehensively.

4.2 Evaluation of individual statistical index

From Table 2, the average value of the estimated variability of gauge and cross-level after fine adjustment are smaller than others, and the value of profile and alignment are larger, which reflect that the operational quality of fine adjustment of gauge and cross-level are more concentrated, and profile and alignment are more dispersed. But it doesn't estimate the cause of the result, which is because the general were dispersed or just because one or two poor individual statistical indexes pulled down the general level. Therefore, in the existing TQI method, the peak management can only reflect the distribution of location (μ), but can't reflect the distribution shape (σ); and the mean management can only reflect the distribution shape (σ), but can't reflect the distribution of location (μ).

From Table 5, we can see that the operational quality of fine adjustment of each individual statistical index is diverse from each other: all of the gauge attained to class A; the cross-level took second place, two of which reached class A; the twist was distributed in different classes; both of the profile and alignment were in the class D. From each individual index of each section, the operational quality of gauge and cross-level are better than twist, profile and alignment. The lower classification shows that the general distribution is closer to the limit, so there is a greater probability of exceeding the limit, that is, the distribution is more dispersed. Therefore, it can be explained that because the total distribution is comparatively dispersed, the operational quality of fine adjustment of profile and alignment is poor, which means the total operational quality remains to be improved.

Through the above analysis, it can be found that the evaluation results of each individual statistical index with the two methods are basically consistent, but the process performance index method can get more explicit evaluation result.

4.3 Efficiency of fine adjustment

Because the ballastless track has a high requirement to precision, and it needs adjustment many times when it is necessary. But because of the different standards of each individual statistical index, the different operational quality of fine adjustment, and other reasons, the evaluation based on TQI method can only get the relative size among each index, while the situation of fine adjustment of each individual statistical index is not clear, and can't directly reflect the difference between each individual value and the control standard, thus affecting the further targeted analysis, and is not conducive to the guidance of next fine adjustment.

And from Table 5, it can be seen that due to the process performance index method retained the classified evaluation results of each individual index, the corresponding P_{pU} of each individual statistical index can be calculated, so that the operational quality of each individual statistical index can be analysed and carry out the targeted analysis, and it is conducive to develop the next fine adjustment plan. Similarly, take the second section as an example, it can be obviously noticed that except for profile and alignment, the fine adjustment state of the other individual statistical index is good, so in the next fine adjustment, only the two lower classed individual statistical indexes need to be paid attention.

4.4 Convenience of analysis

Through the above calculation and analysis, it isn't too hard to see that, to carry out the analysis of process performance index method, the first step is to process data in accordance with the TQI method, so the process performance index method is based on the TQI method, and is a supplement to the TQI method, but it needs the further analysis and calculation to get the final result. Therefore, as for the convenience of the analysis, it is not as good as TQI method.

5 Conclusion

In this paper, the operational quality of the same section of track was evaluated separately with the TQI method and the process performance index method, and the similarities and differences as well as the advantages and disadvantages of the two methods are compared. The conclusions are:

1) The TQI method is not clear and comprehensive in the evaluation of general and individual statistical index of the quality of track fine adjustment, which affects the further efficiency. But the method is much simpler to process and analysis data, and the evaluation results on the general track fine adjustment quality can be got quickly and conveniently.

2) The process performance index method is more comprehensive in the evaluation of general statistical index, meanwhile, as for the calculation equation, it contained more statistical indicators and retained the analysis results of each individual statistical index, so it's conducive to carry out the further fine adjustment pointedly and improve the efficiency. But to carry out the analysis needs to use the TQI method to deal with the data, so it is not as convenient as the TQI method.

References

[1] Wang, J.H., Technologies for Measurement and Fine Adjustment of Ballastless Track. *Journal of Railway Engineering Society*, 9, pp. 31-35, 2009.
[2] Ma, M.Z., Key Technologies of Process Control of Steel Rail Fine Adjustment of High-speed Railway. *Railway Standard Design*, 58(3), pp. 21-24, 2014.
[3] Zhang X.D. & Huang S.G., Research and development of visualized management technology for construction of railway project. *Railway Computer Application*, 16(1), pp. 1-3, 2007.
[4] Chen, P., Wu, Y.H. & Jin, Y.C., Application of Game Theory in Quality Management of Engineering Project. *Journal of East China Jiaotong University*, 21(4), pp. 30-33, 2004.
[5] The Railway Ministry of People's Republic of China. *Railway Transport, 2006. No. 41. Rules of railway track maintenance*. People's Republic of China: China Railway Publishing House, Beijing, 2010.
[6] Douglas C. Montgomery, *Introduction to Statistical Quality Control (7th Edition)*, John Wiley & Sons Inc., Hoboken, 2012.
[7] Chen Y.L., Study on process capability index and process performance index. *Journal of China Jiliang University*, 16(4), pp. 305-310, 2005.
[8] Dzekevich, J.A. & Garretson, J., A Design Margin Index for MTBF and Ao. *IEEE Reliability and Maintainability Symposium*, pp. 288-291, 2007.