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Maintenance Study of Rail Track Structure for Temporary Track at Electrified Double Track Project (EDTP) Gemas-JB

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Abstract: Due to some sections of the new double track alignment overlap or are extremely close to current operating KTMB track and need infra building to acquire ownership of such sections, required construction operations must be progressed accordingly. Even though these are temporary tracks, the quality must be maintained at the greatest level, as this includes the passengers' safety as well as the running train itself. The track maintenance team is responsible for keeping the track in proper working order for the operating train. And, using the data acquired, the researcher extracts and filters the data so that the track quality value may be provided in the best way possible, and the track can be effectively monitored. The results of the track monitoring model were given, and a discussion about track quality was held resulting in using this track monitoring methodology, the maintenance staff will always receive an early warning about the track conditions for each week that the survey data is gathered, which can be addressed quickly and maintain the track in safe condition for the track and the running track. By the completion of this research, all involved will have gained more knowledge and will be able to enhance site implementation for future projects.

Keywords: Track Quality, Track Maintenance, Temporary Track

1. Introduction

The Gemas–Johor Bahru Electrified Double-Tracking Project (GJBEDTP) is a project to build a double-track electric rail line connecting the towns of Gemas in Negeri Sembilan and Johor Bahru in Johor. It is the third phase of the Malaysian Ministry of Transport's electrified double-tracking project (EDTP), which would provide a continuous double-track line across Malaysia from Padang Besar near the Thai border to Johor Bahru, near Singapore.

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The service life of rails depends especially on the operational loads and speeds on the railway lines, as well as on the rail maintenance policy. There are multiple aspects of rail maintenance optimization. The following article considers optimization of rail maintenance activities relating to rail head surface condition in order to reduce corrective work on track geometry, as well as to minimize the overall costs for track maintenance.

Owing to some sections of new double track alignment are overlapping or very close to existing operational KTMB track and need of infra construction to take possession portions of such sections, during which required construction activities need to be progressed accordingly. Thus, provision of temporary track as a diversion routes are required to uphold the services of rail trains will not be interrupted. Installation of Temporary Track Diversion (TTD) for train operation uses until completion of new track for GJBEDTP. The problem is there is no specific track model monitoring for temporary track.

In this project, the use of track geometry data has been reviewed and the track quality of the temporary track has been analyzing weekly and a model for monitoring and analyse of operation and maintenance performance of rail track structure for temporary track is developed. The model includes various methods for analysis of operation and maintenance data. The work aims to facilitate improvement and optimisation of decision-making in railway.

2. TQI and Various Method of Evaluate Track Quality

2.1.1 UK SD Index which stated that the larger the SD Index, the worse the track segment is in some aspect represented with the quality parameter

$$\sigma_i = \sqrt{\sum_{j=1}^{n} \left({x_{ij}}^2 - {\overline{x_i}}^2 \right)}$$

$$\overline{x_i} = \sum_{j=1}^{n} \frac{x_{ij}}{n},$$

2.1.2 Netherlands Q Index which converts the SD index into a more universal form across different classes of tracks. The larger the Q index, the better the track quality of a 200m long track segment.

$$N = 10 * 0.675^{\sigma_i/{\sigma_i}^{80}}$$

2.1.3 USA Track Roughness Index which proposed in 1998 by America Amtrack. The average of squared measurement values for quality parameter over a track segment

$$\mathrm{TRI_i} = \sum_{j=1}^{n} \frac{(x_{ij})^2}{n}$$

2.1.4 FRA Track Geometry Index uses the measurement value space curve length for a quality parameter over a track segment to quantify the quality of the track segment

$$\mathrm{TGI_i} = \left(\frac{L_i}{L_0} - 1\right) * 10^6$$

$$L_i = \sum_{j=1}^{n-1} \sqrt{(x_{i(j+1)} - x_{ij})^2 + (y_{i(j+1)} - y_j)^2}$$

2.1.5 Austrian track geometry index uses 5 parameter track defectiveness calculation for data obtained from geometry recording cars.

$$W = \frac{\sum L_i}{L}$$

2.1.6 Canadian track geometry index stated that the larger the track quality index, the better the quality of the track segment by using the formula;

$$TQI_i = 1000 - C * \sigma_i^2$$

2.1.7 Chinese track quality index - the larger the value of TQI, the worse the track segment in overall track quality

$$TQI = \sum_{j=1}^{7} \sigma_i$$

$$\sigma_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(x_{ij}^2 - \bar{x}_i^2\right)}$$

$$\bar{x}_i = \sum_{j=1}^{n} \frac{x_{ij}}{n}$$

2.2 Methodology

Data will be gathered through a review of the literature and historical railway operation and maintenance data, with an emphasis on the EDTP Gemas-JB Track Work Section 5 line from Kulai to Kempas line.The track geometry was collected manually weekly by the track maintenance team. All the data collected been transferred to the Excel and by using the model proposed, track quality of the track structure for the temporary track will be known and can be used to get an early warning if maintenance need. This resulting on cut cost and provide safety for both track and train itself.

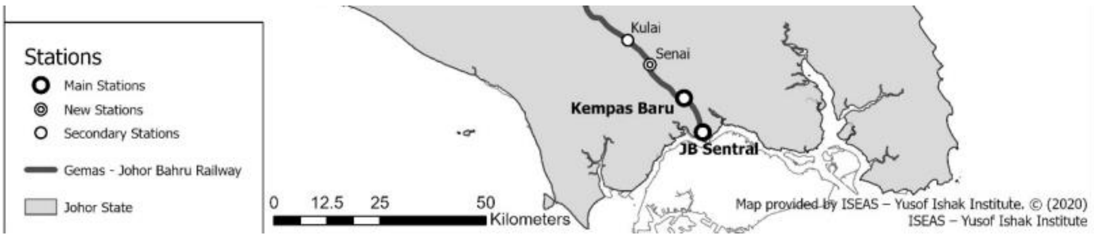

Figure 1: EDTP route from Kulai to JB Sentral line

Track quality monitoring can be done with several methods, such as by foot patrolling, trolleys and locomotives. Track geometry is a good indicator of general track condition. The parameters that should be measured are surface, track gauge, twist, profile and alignment. Track recording also can be done by 2 methods:

i. Manual gauge - the track geometry record was taken by Track Monitoring Team (TMT).

ii. KRAB 84.09 - the running machine on track will be collected the existing track geometry. The raw data will be collected and transfer to PC to generate data, so that rectification work can be done.

Figure 2: Manual Gauge activity and Running KRAB 84.09 activity

Track Recording Parameter

i. Surface (unevenness) of rail (also known as profile) - surface or longitudinal unevenness of rail is measured as a deviation in the vertical plane.
ii. Twist - measured as a change in the cross level of track under the running loaded axles.
iii. Wide gauge - the primary element used for gauge measurement consist of 3 non-contact laser measuring system which will be fitted on all 3 boogies
iv. Super elevation / cross level - angle between the machine's floor and a loaded running axle
v. Alignment - measured over a base of 10m and consist of non-optical laser measuring system, fitted on all 3 boogies
vi. Rail head wear and rail inclination

2.3 Track and Overhead Line Recording Car EM120

The track and overhead line recording car is a heavy recording and inspection vehicle that combines the measuring functions of track and overhead line measurements utilising three two-axle boogies that support the recording cabin and the third bogie that is positioned under the driving cabin.

The TORC, which can travel at speeds of up to 120km/hr, measures and electronically records and analyses any problems in the trak and overhead line geometry. Its helical coil spring suspension and hydraulic shock absorbers offer an optimum damping system, allowing the car to record track geometry at speeds of up to 120km/h. The TORC can navigate curves with a radius of 100m or greater.

Optical gauge measuring sensors are positioned between the bogies' axles, where they are permanently attached to the measuring frames that are supported on the axle bearing boxes of the bogies. They are positioned such that they do not interfere with the clearance gauge under any circumstances.Track parameter recorded by EM120 (TORC) gives continuous record of following track and rail parameters.

i. Surface (unevenness) of the left rail
ii. Surface (unevenness) of the right rail
iii. Twist
iv. Gauge
v. Superelevation/Cross Level
vi. Aligment of the left rail
vii. Alignment of right rail

EM120 TORC is also capable of measuring the following parameters:

- Horizontal and Vertical Rail Head Wear of both rails
- Rail inclination of both rails

3. Results and Discussion

Site observation was conducted from CH738000 until CH741210 for KTMB temporary track from October 2021 to January 2022. The track geometry obtained were manually taken by the Track

Maintenance Team. The main purpose of such observation is to obtain information regarding the track geometry on real site. Then all the data would be transferred to the Excel for filtering the unused data purpose.

3.1 Results

Table 1: Standard Deviation (SD) values (KTMB, P.Way Manual, 2016)

Item	Parameter Name	SD for newly laid track	SD for maintenance
1	Cross Level	3	4
2	Twist	2.6	5.25
3	Gauge	2	6
4	Alignment	4	5

By using formula below, which is the UK SD Index, the calculated standard deviation for each track parameters can be calculate and the result are as shown in Table 2. UK SD Index stated that the larger the SD index, the worse the track segment which by this represent the quality of the track parameter.

$$SD_i = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(x_{ij}{}^2 - \overline{x_i}^2\right)}$$

$$\overline{x_i} = \sum_{j=1}^{n}\frac{x_{ij}}{n},$$

Where, SD_i is Standard Deviation for each parameter, x_{ij} is measurement value of parameter, $\overline{x_i}$ is mean value of the measurement parameter and n is number of sampling of the parameter.

Table 2: Calculated Standard Deviation (SD) values for each parameters

Item	Parameter Name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7
1	Cross Level	9.5122	10.2256	8.8810	7.6220	8.6220	8.8659	8.6220
2	Twist	0.0405	0.0317	0.0273	0.03312	0.03854	0.03854	0.03854
3	Gauge	1.1707	1.7378	1.7104	0.9756	1.0610	1.0976	0.8902
4	Alignment	13.7857	7.1220	4.7317	5.0244	6.8659	8.8658	13.6951

From the standard deviation values, the index for each parameter can be calculated using the index formula.

$$X_i = \frac{SD_{mea} - SD_n}{SD_{maint} - SD_n}$$

$$I_i = 100e^{-x}$$

Which I_i is index for each parameter, SD_{mea} is measured standard deviation for each parameter, SD_n is standard deviation for newly laid track and SD_{maint} is standard deviation for maintenance. If the measured standard deviation equal to the standard deviation of the newly laid track, the formula will become

$$I_i = 100e^{-0}$$

$$I_i = 100 \text{ as } e^{-0}=1$$

From this, can said that the lower the calculated index value, the bad the track quality. But if the measured standard deviation equal to the standard deviation of the maintenance, the formula will become

$$I_i = 100e^{-1}$$

$$I_i = 36.7879$$

This indicates that the index values of each parameters should be in range of 36.7879 until 100 for the track keep in safe. Finally, with all the calculated data, a track quality index can be obtained for each day the data collected. The final result as in Table 4.3 by using the formula

$$TQI = \frac{2CL + T + G + 6A}{n}$$

Which TQI is Track Quality Indices, CL is Cross Level Index, T is Twist Index, G is Gauge Index, A is Alignment Index, n is number of meter sampling.

Table 3: Standard Deviation (SD) and TQI value

Item	Parameter Name	Index 1	Index 2	Index 3	Index 4
1	Cross Level	0.148521	0.072772	0.279199	0.983311
2	Twist	262.701731	263.575587	264.013536	263.434339
3	Gauge	123.038238	106.774612	107.508529	129.188191
4	Alignment	0.005625	4.406894	48.109044	35.901181
5	TQI Value	38.607076	39.693710	66.073472	60.999623

Item	Parameter Name	Index 5	Index 6	Index 7
1	Cross Level	0.361740	0.283447	0.3617399
2	Twist	262.896092	262.896092	262.896092
3	Gauge	126.459258	125.307434	131.976013
4	Alignment	5.693187	0.770566	0.006158
5	TQI Value	42.423795	39.3393816	39.563253

Table 4: TQI Classification for maintenance

Item	TQI Value	Maintenance requirement
1	TQI > 80	No maintenance required
2	50 < TQI < 80	Need basic maintenance
3	36 < TQI < 50	Planned maintenance

4	TQI < 36	Urgent maintenance

Table above shown the Track Quality Indices classifications for maintenance purpose. The lower the TQI, the worst the track quality of the segment. As can see, all the values of calculated TQI in the range of 36 until 100. This show that the data collected can be used for this research.

3.2 Discussions

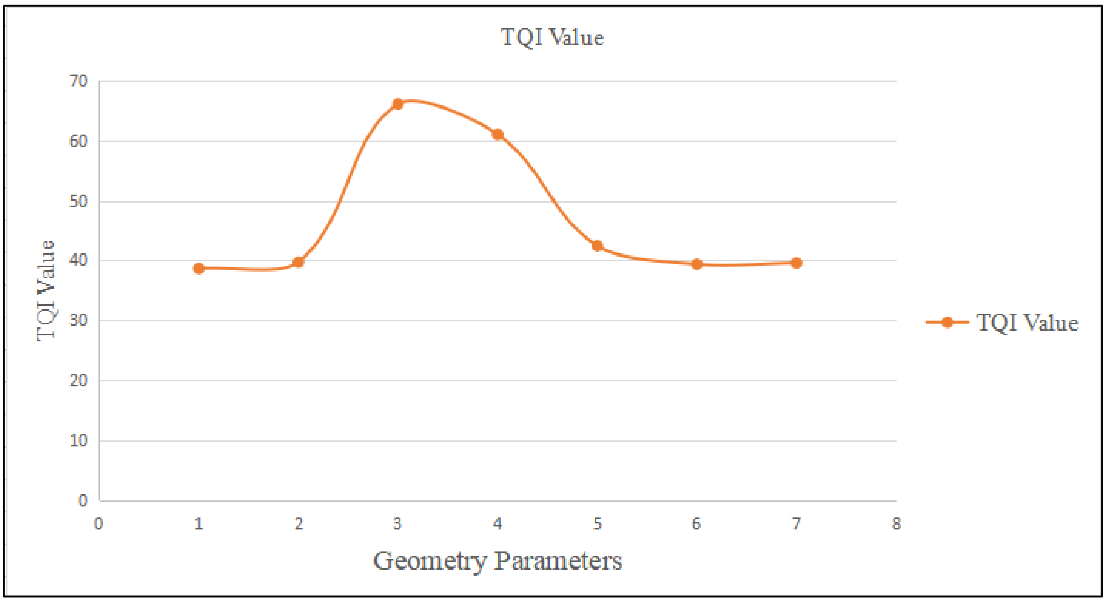

Figure 3: Graph TQI Values against Geometry Parameters

The first and second TQI values in the graph above were meant to be planned for maintenance. However, the Maintenance Team discovered irregularities in the track earlier while collecting survey data and rectified them manually, resulting in the third and fourth TQI values being in the classification where only minimal maintenance such as tamping manually was required. However, after a few weeks, the TQI values consistently fall into the maintenance class.

Even though this is a temporary track, the quality of the track must be maintained to ensure the safety of passengers and the operating train. This TQI model is essential in keeping and monitoring the running track in safe conditions, as well as providing early notice to the maintenance staff. However, this track monitoring model is limited to a track length of 200 m and just four parameters: cross level, calculated twist, gauge variation, and lateral alignment.

3.3 Manual TQI and TORC TQI

The main purpose of the manual TQI is to give an early warning to the track maintenance team about the rail track structure. Therefore, the data collected not as much as the TORC can recorded. TORC is used to measure the geometry of railway track line. From the result of geometry measurement by track recording car, geometry tolerance value is given to decide the follow up of measurement, whether it needs to do track speed reduction, immediate maintenance or railway track line rehabilitation. Currently, TORC used by this project is EM120.

However, this TORC will be used when it is commissioning of the track and once in a while. So by using manual TQI, the track maintenance team can be prepared or rectified the minor tolerance to keep the track in the best way. With the weekly data collection from the team, this model of track monitoring ca n be presented as an early warning to the team about the track structure.

4. Conclusion

From this study, track monitoring models from different countries using different gauges has been reviewed as there are many methods on evaluating the track conditions using different parameters. From the results and discussion obtained for this research, the conclusions are as below.

From this research, people will acknowledge and understand the differences of the track structure for conventional and electrified track in a better way. In addition, engineer that involve in Railway Project manage to differentiate parameters that been used in maintenance track. By using this track monitoring model, the maintenance team will always get an early warning about the track conditions for every weeks they recorded the survey data and can be rectified immediately and keep the track in safe condition for the track and the running track. By the end of this research, people that involve will gain more knowledge and able to improve for better site implementation for future project.

The author acknowledged that the four primary parameters data are required to provide track quality values since they are linked in track deterioration. However, the models can only cover a 200m segment length, and the author suggests that a new track quality index be developed that takes into account track structural parameters such as rail pad stiffness, rail type, fastening condition, sleeper condition, and ballast condition, as well as traffic parameters

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