# Predictive Maintenance Management of Rail Track

R B FAIZ , S.SINGH
Department of Computer Science,
Loughborough University, Leicestershire, LE11 3TU
GREAT BRITAIN
R.Faiz @lboro.ac.uk, S.Singh@lboro.ac.uk

*ABSTRACT*

Track defects are deviation of actual from theoretical values of the tracks geometrical characteristics. Track defects are macroscopic and geometric in nature and are exclusively the consequence of train traffic [5]

Rail track maintenance has been typically based on use of reactive maintenance. In that case discrete exeecedence of all measurements are compared against a pre-set threshold such that if they exceed the threshold then reactive maintenance is required to be done. This is particularly so in cases when current practices rely on conservative, engineering, decision. Besides it will not inform staff regarding defects in rail track which can subsequently helps in predictive maintenance.

This paper focuses on linear regression analysis of track geometry parameters which leads to significant rail track maintenance productivity gains. The overall aim of the paper is to apply preventive maintenance management to evaluate and prioritise condition monitoring effort across network rail. Such research will result in effective and efficient maintenance management resulting in low operating cost better train transit times for rail industry [2].

*KEY WORDS:* Predictive Maintenance Management, Rail Track, Track Geometry, CURV, Cant Def, Cross Level, Dipped Left.

## 1. Introduction

One of the most important railway engineering tasks is effective and robust condition monitoring, as track degradation problems can have serious affect on the safety of train operations. In order to determine an effective condition monitoring strategy it is necessary to analyze track geometry parameters.

Maintenance can be either corrective: fixing on failure or it can be preventive: predicting failures before they happen. It is often very difficult to predict all maintenance and thus in reactive maintenance, expert judgments are made on the basis of imperfect information and previous experiences with a relatively short-term view of the future impacts on future maintenance.

In contrast to reactive maintenance predictive maintenance avoids excessive cost normally incurred by corrective maintenance. Besides it helps preventing defective track components and ensures that they carry out their intended functions throughout their service life. [3]

There are two key approaches to preventive maintenance. One is Time Directed maintenance in which time directed tasks are performed to prevent defects. Other type of maintenance is Condition-Based Maintenance which is also known as on-condition maintenance or condition-directed maintenance or predictive maintenance. It is designed to detect the start of a failure in conditions where either failure prevention is not feasible or how it can be achieved is not yet known. Condition maintenance is based on periodic inspection of rail track parameters thus helping in determining the true condition of rail track in time.

In rail industry, there is a widespread belief that corrective maintenance is always less economical than preventive maintenance [4]. As a result, time-directed maintenance becomes the norm of preventive maintenance action, motivating the indiscriminate use of overhaul or preventive replacement procedures. This approach to preventive maintenance, firstly, wastes a lot of resources in doing unnecessary tasks which will not reduce defects in rail track and secondly it is potentially risky [4].

## 2. Track Geometry

Track geometry is the study and analysis of the spatial position of rail track. X-axis defines the distance along the track towards the direction of the travel. Y defines the axis parallel to the running surface and Z defines the axis perpendicular to the running track

Track geometry has ballasts, sleepers, rail, and clips etc. Now track geometry can deteriorate because of frequent passage of heavy traffic, climate changes (weather), variations in soil conditions and geotechnical movements. Each track is composed of two types of structures:

The interaction between track components under a moving wheel load causes a large impact load, which increases with increasing track irregularity and train speed. This is because impact load increases with an increase in the size of the gap underneath the sleepers. The impact load increases the stresses on the ballast which, as a result, increases ballast settlement and ultimately results in a larger gap underneath the sleepers. Thus, degradation of track geometry tends to get faster. One the most effective way of restoring a track which has lost his geometry is by tamping. However, this may also result in ballast break downs.

**Reasons for Rail track Deterioration:** Common effects of trains on rail track which result in more frequent rail track deterioration thus resulting in maintenance of track are:

1. The number of trains passing through as higher the number higher the rate of rail track deterioration would be.
2. A track may be subjected to heavy trains instead of light ones.
3. Speed has an important influence on track deterioration as high speed tilt trains are worse than average speed trains.
4. Better rail profile (stronger steels) gives less deterioration than rail profiles (weaker steels).
5. Track laid on blast deteriorates faster than slab track.
6. Stability of the track is dependent on type of soil it is laid on.
7. Thicker and cleaner ballast layer is better than thinner and dirtier blast layer.
8. Rate of deterioration of curved track is faster than tangent track.
9. Track deterioration can also be prevented by better drainage.

### 2.1. Track geometry parameters

Track geometry is fundamental for the safe passage of vehicles. Failing to be so, in which case, may result in disastrous consequences.

Rail defects are the most critical defects that affect the safety of train operations. Rest of the defects which are non critical are may occur in the rail but do not affect the structural integrity of the rail or the safety of the trains operating over the defect.

Degradation in track geometry due to frequent passage of heavy rail traffic, effects of Climate changes Like for instance flooding, extreme cold etc, variations in soil conditions and Geotechnical movements will cause the track to move away from the design geometry in both the vertical and horizontal planes and this deterioration away from the design can cause discomfort for passengers and eventually become unsafe for the passage of trains. To ensure the track can be repaired in good time, the deterioration must be detected and the worst areas prioritised so that engineers can maintain the track based on an urgency basis.

**DIPPEDLEFT:** Fish plate is a joint that is used to join two rails together longitudinally. These longitudinal rails may be joined together by a fish plate. When the joint wears out it dips on inner sides as shown in the diagram 14. It can happen on either rail left (dipped left) or right (dipped right**)**. Series of dips at regular intervals in one or both rails of track can also cause derailment.

**CURV:** A track can be either of three types: tangents, curves, and spirals. A tangent track refers to straight track (As shown in Figure 8) and a curve track refers to a track with measurable curvature (As shown in Figure 8).

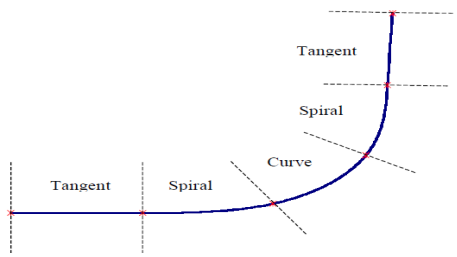


Figure 1 [3]

Track curves are typically identified by degrees. As explained in Figure 9, a one-degree curve is defined as a curved section of the track with a radius such that a 100-ft cord corresponds to a one-degree arc

The term spiral track refers to the section of the track that acts as a smooth transition between tangents and curves (As shown in Figure 8).

So curvature (CURV) is the spatial rate of turn in the horizontal plane of the track. It can be measured by measuring the distance between centres of string to the centre of rail in a curve or it can even be calculated by radius formula.

**CANTDEF:** As most trains cannot lean (or tilt) into curves to counteract the centrifugal (G) force, the track is canted (one rail raised above the other) into the curve so that the forces are at equilibrium at the maximum line speed. This parameter calculates whether the cant is sufficient to ensure the comfort of passengers and safety of freight.
The difference between levels of two rails in a curve is called as track cant (which is same as super elevation) and is arranged to compensate lateral part of acceleration. A cant angle arises where cant is rearranged. Maximum value of cant is set with respect to stationary conditions and slowly running trains so as to avoid passenger discomfort at stand still or low speed and risk of derailment of freight trains. It is than desirable to have cant deficiency some amount of uncompensated lateral acceleration remains in the track plane. So in other words cant deficiency is the difference between equilibrium cant and the actual cant. [17]

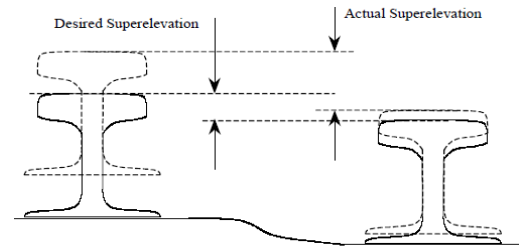


Figure 2 [3]

Cross Level: Cross Level is the difference in elevation between the top surfaces of the two rails measured at right angles to the track as explained in figure 12. On curves cross level is often referred to as ‘cant’ or ‘super elevation’. On curves the track will have a designed cross level to counteract the g forces involved in a train changing direction at speed.

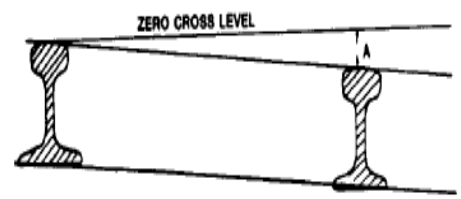


Figure 3

So the cross level, not to be confused with the super elevation, is the amount of vertical deviation between the left and right rail from their intended distance or it is the intended increase in elevation of the outer rail above the inner rail in curve. The intended distance refers to the amount of super elevation. For instance, if the super elevation is zero, then any difference between the elevation of the left and right rail is the cross level.

If the super elevation, however, is a positive, for example, then the cross level is the deviation from this super elevation. A positive cross level refers to the case when the left rail is above the right rail, and a negative cross level refers to an instance when the left rail is below the right rail. [26]

Super elevation is the amount of elevation that the outer rail in a curve is raised above in comparison to the inner rail. This is being done to compensate centrifugal forces that the vehicle will experience when travelling through a curve for that reason the outer rail may be raised, or super-elevated so as to tip the train inward. Now super elevation can either be positive super elevation: when the left rail is raised above the

right rail or a negative super elevation when the right rail is raised above the left rail.

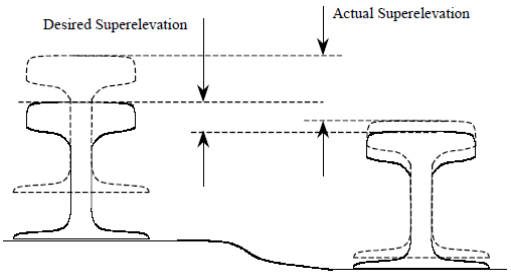


Figure 4 [3]

# 3. Experimental Design

The current research paper focuses on how well linear variables can be predicted from rest of variables in same file using regression model. The conclusions drawn from the research are specific to rail data analysed and can not be generalized for all rail tracks

Altogether we had 4 base files of track geometry data. There were four base files, of different dates, for same patch that were analysed. All four base files were aligned based on engineers line reference (ELR), Track ID, Miles and Yards and make all data files ready for analysis.

In terms of data analysis track geometry had number of statistical values of variables, in itself explaining in great detail of what they are. Among all the variables dipped left, cross level, cant deficiency and curvature were linearly distributed.

Linear Regression estimates the coefficients of the linear equation, involving one or more independent variables that best predict the value of the dependent variable. For each value of the independent variable, the distribution of the dependent variable must be normal. The variance of the distribution of the dependent variable should be constant for all values of the independent variable. The relationship between the dependent variable and each independent variable should be linear, and all observations should be independent

All four linear variables in each of four base files are predicted from all other variables in same file.

All values in the table i.e. dependent variables, constants, Adjusted R square, standard estimate error have their mean as first value in the table and standard deviation as second value. Standard deviation is calculated so as to see how well mean values represent population, the less they deviate the better the mean represents the population

In regression table Adjusted R squared (attempts to correct R squared to more closely reflect the goodness of fit of the model in the population) helps you to determine which model is best or how well dependent variable can be well predicted by the independent variables. In regression, the R square coefficient of determination is a statistical measure of how well the regression line approximates the real data points. Higher the value of R squared the better the model is. An R square of 1.0 indicates that the regression line perfectly fits the data. Hence R square is a statistic that will give some information about the goodness of fit of a model. Where as, standard estimate error is the standard deviation of sample mean. It is a measure of how representative a sample is likely to be of the population. A small standard error (relative to sample mean) indicates that most sample means are similar to the population mean and so our sample is highly likely to be a true representative of population.

## 3.1 Dipped Left

Fish plate is a joint that is used to join two rails together longitudinally. These longitudinal rails may be joined together by a fish plate. When the joint wears out it dips on inner sides as shown in the diagram 14. It can happen on either rail left (dipped left) or right (dipped right**)**. Series of dips at regular intervals in one or both rails of track can also cause derailment.

The highest mean value amongst all independent variable was cantdef or cant deficiency (3.36) which means that if cantdef goes up by one mm then dipped left will go up (because of positive relationship between them) by 3.36 mm. Where as, few lowest mean values were of TOPRS, ALIGML, ALIGMS, TWIST 1 and TWIST 2 was -0.00. Mean of R square value is 0.13 which means that this dependent variable can be predicted with less confidence by the independent variables. Mean of standard estimated error is 0.88, which is measured in comparison to sample mean, shows that the sample may be or may not be a good representation of population. The standard deviation of standard estimate error is 0.16 which shows that mean of standard error is good representation of population.

Regression Table 1

| In Dependent Variables | Mean and Standard Deviation of Dependent Variables | | | |
|---|---|---|---|---|
| | DIPPED _LEFT | CANT _DEF | CROSS_ LEVEL | CURV |
| DIPPED LEFT | | .00<br>.00 | -.21<br>.56 | -.01<br>.00 |
| DIPPED RIGHT | .28<br>.07 | -.01<br>.00 | -.02<br>.024 | .06<br>.00 |
| CANTDEF | .00<br>.00 | | -.45<br>.01 | 3.3<br>.13 |
| GAUGE | -.00<br>.00 | -.09<br>.00 | .07<br>.94 | .38<br>.01 |
| CROSS LEVEL | .00<br>.00 | -.52<br>.047 | | 3.05<br>.085 |
| CURV | -.00<br>.00 | .206<br>.015 | .28<br>.01 | |
| TOPLS | .01<br>.01 | .00<br>.00 | .07<br>.24 | .00<br>.00 |
| TOPRS | -.00<br>.01 | .00<br>.00 | -.05<br>.22 | -.00<br>.00 |
| TOPML | -.00<br>.00 | .00<br>.00 | -.00<br>.00 | .00<br>.01 |
| ALIGML | .00<br>.00 | .00<br>.00 | -.02<br>.20 | -.02<br>.06 |
| ALIGMS | -.00<br>.01 | -.00<br>.00 | -.12<br>.40 | -.08<br>.19 |
| TWIST2 | .00<br>.00 | .00<br>.00 | .10<br>.16 | -.01<br>.00 |
| TWIST 1 | .00<br>.01 | .00<br>.00 | -.18<br>.04 | .00<br>.00 |
| **Constant** | .04<br>.01 | -34.6<br>9.51 | 1.78<br>4.03 | 6.62<br>1.87 |
| **Adjusted R Square** | .13<br>.15 | .86<br>.02 | .73<br>.45 | .97<br>.00 |
| **Standard Estimated Error** | .88<br>.16 | 8.6<br>.61 | 12.53<br>12.30 | 2.15<br>.045 |

### 3.2 Cant_Def

As most trains can not lean (or tilt) into curves to counteract the centrifugal (G) force, the track is canted (one rail raised above the other) into the curve so that the forces are at equilibrium at the maximum line speed. The difference between levels of two rails in a curve is called as track cant (which is same as super elevation) and is arranged to compensate lateral part of acceleration.

The highest mean value amongst all independent variable was curvature (0.20) which means that if curvature goes up by one mm then cant_def will go up (because of positive relationship between them) by 0.20 mm. Where as, among all independent variables TOPRS, TOPLS, TOPML, ALIGML, ALIGMS, TWIST 1 and TWIST 2 had -0.00 values. . Mean of R square value is 0.86 which means that this dependent variable can be well predicted by the independent variables. Where as mean of standard estimated error is 8.6, which is measured in comparison to sample mean, shows that the sample is not a good representation of population. The standard deviation of standard estimate error is 0.61 which shows that mean of standard error is good representation of population.

### 3.3 Cross Level

Cross Level is the difference in elevation between the top surfaces of the two rails measured at right angles to the track.

The highest mean value amongst all independent variable was cant_def (-0.80) which means that if cant_def goes up by one mm then cross level will go down (because of negative relationship between them) by 0.80 mm. Where as, among all independent variables Dipped Left, Dipped right, TOPRS, TOPLS, TOPML, ALIGML, ALIGMS, TWIST 1 and TWIST 2 had 0.00 values. Mean of R square value is 0.73 which means that this dependent variable can be well predicted by the independent variables. Where as mean of standard estimated error is 12.53, which is measured in comparison to sample mean, shows that the sample is not a good representation of population.

Because of the fact that standard deviation of standard estimate error is very high, 12.30, so the mean of standard error is not a good representation of population.

### 3.4 CURV

Curvature (CURV) is the spatial rate of turn in the horizontal plane of track. The highest mean value amongst all independent variable was cant_def (3.3) which means that if cant_def goes up by one mm then curvature will go up (because of positive relationship between them) by 0.80 mm. Where as, among all independent variables TOPRS, TOPLS, TOPML, TWIST 1 had 0.00 values and TWIST 2 had -0.01 values. Mean of R square value is 0.97 which means that this dependent variable can be well predicted by the independent variables. Where as mean of standard estimated error is 2.1, which is measured in comparison to sample mean, shows that the sample is not a good representation of population. The standard deviation of standard estimate error is 0.04 which shows that mean of standard error is a good representation of population.

## 3. Conclusion

Preventive maintenance management can be used to determine defects in rail track and prevent them happening in future. Such system can also help in identifying trends for effective and efficient preventive maintenance management. Unfortunately the pressure on rail road to reduce operating costs usually result in cutting or eliminating investment in research because it often does not generate a short term return on investment.

This paper focuses on linear regression analysis of track geometry parameters which leads to significant rail track maintenance productivity gains. The conclusions drawn from the research are specific to rail data analysed and can not be generalized for all rail tracks.

The aim of research paper is to apply preventive maintenance management to evaluate and prioritise condition monitoring effort across network rail. Such research will result in effective and efficient maintenance management resulting in benefits like low operating cost, better train transit times for rail industry [2].

## *4. REFERENCES*

[1] Leedham, R.C.; Nelson, S, “Wheel /rail profile studies”, Railroad Conference, Proceedings of the 1995 IEEE/ASME Joint, Page(s):159 – 162

[2] L. Ferreira.. and Murray, M, “Modelling Rail Track Deterioration and Maintenance: Current Practices and Future Needs”, 1997.

[3] Darris L. White, “Statistical Characterization of Vehicle and Track Interaction Using Rail Vehicle Response and Track Geometry Measurements”, Thesis submitted to the Faculty of Virginia Polytechnic Institute and State University, July 29, 1998

[4] J. woodhouse, “Asset management decision making”, June 2001.

[5] Alfelor R.M., Mc Neil S., (1994), ‘ Heuristic Algorithms for aggregating rail surface defect data’, ASCE, Journal of Transport Engineering, Vol. 120, No. 2.