TECHNOLOGY DIGEST

TD-03-016
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Railway Track Life-Cycle Model Version 1.0

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Summary

Transportation Technology Center, Inc. (TTCI) has recently completed the development of the first version of an integrated track component degradation and cost analysis program. The program is known as RTLM™ — Railway Track Life-Cycle Model.

This program was developed to predict rail wear rate, rail defect growth rate, wood tie degradation, turnout degradation, ballast degradation, and track roughness growth. Inputs to RTLM are details of track components, traffic conditions, maintenance policies, unit costs, and interest rates.

RTLM is an Internet web-based program, which users can access with account names and passwords. In RTLM, track component degradation and economic analyses are performed automatically for a track system that may consist of many segments with different track conditions and traffic components. Analysis results are given for individual track segments, as well as for the entire track based on weighted averages of all individual segments.

The program allows users to build track with different rail, tie, fastener, and ballast types, and to build train service of mixed vehicles with different payloads. Users also have the option of using or modifying track and traffic components from the RTLM library.

Suggested Distribution:

- ☐ Safety
- ☐ Maintenance-of-Way
- ☐ Track Maintenance
- ☐ Planning & Analysis

INTRODUCTION AND BACKGROUND

Under the Association of American Railroads' (AAR) Technical Support Research Program, the development of the Railway Track Life-cycle Model (RTLM™), an integrated software package for track and vehicle component degradation analysis, maintenance planning, and cost analysis, was designed so that the latest AAR research results could be incorporated under a common platform for enhancing existing models and developing new models.

TTCI has recently completed the development of Version 1.0 of the program. Five track component degradation models are integrated into the program to predict rail wear rate, rail defect rate, wood tie degradation, turnout life, ballast degradation, and track roughness growth. Maintenance costs are calculated based on degradation rates, maintenance policies, replacement costs, and interest rates.

Improving on a previous TTCI analysis program,[*] RTLM 1.0 has the capacity for (1) upgrading obsolete degradation calculations, (2) allowing dynamic (automated) segmentation across all track parameters for a "non-homogeneous" track, which may include many track and traffic components, (3) separating the database from the degradation and cost calculations so that the database can be upgraded or even replaced in the future; and (4) allowing multiple users to have access to a centralized RTLM server and to carry out analyses via Internet.

PROGRAM DEVELOPMENT

RTLM Structure

RTLM was designed to meet the following criteria:

- Extensible framework so that new track and vehicle degradation models and new test results can be used to enhance and expand the program
- Single program that can house all available degradation and economics models
- Single-user interface for multiple analysis tasks
- Management of track and traffic information for any scale of interest

To meet these criteria, the program has been developed with the structure illustrated in Figure 1. As shown, it consists of three major elements: the degradation and economics calculation engine, the infrastructure and traffic database, and the graphical user interface.

The database for RTLM includes a library of track component and train service files. Nevertheless, RTLM also allows users to build a route from track components, such as rail, tie, and ballast, and traffic components, such as car weight, payload, number of cars, number of trips, and speed.

To run RTLM, users need only an Internet connection with a user name and password, with no responsibility for software installation and future upgrades.

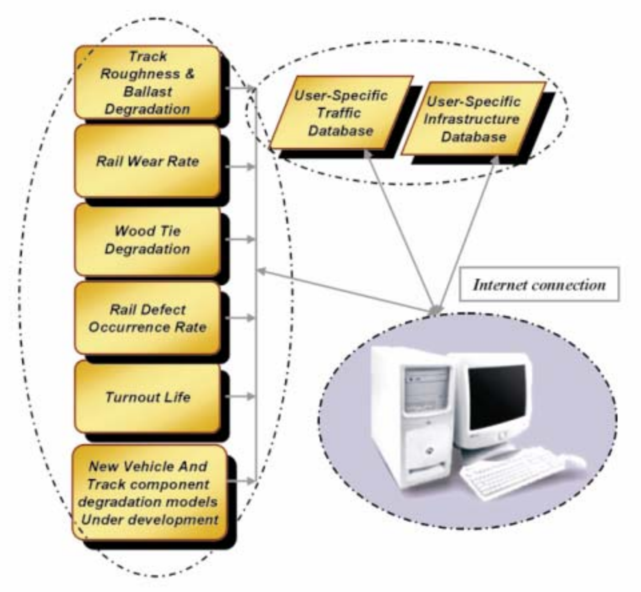

Figure 1. RTLM Structure

Degradation Calculation

In RTLM, degradation calculations are based on the mechanistic models derived from theoretical or experimental results. For example,

- Track roughness is calculated from cumulative permanent deformation of ballast, subballast, and subgrade layers under repeated axle loads.
- Ballast life is calculated based on ballast fouling from breakdown due to traffic and tamping, and from other sources such as subgrade mud pumping.
- Wood tie degradation is calculated in terms of plate cut and spike kill damage due to traffic, and decay due to weather.
- Rail wear rate is calculated from wear index (the product of wheel/rail tangential forces and creepage).
- Rail defect rate is derived from metal fatigue equations and Weibull distribution

Each degradation model has coefficients that allow for calibration against field test results.

Table 1 lists some of the major track and traffic variables considered in the five track component degradation models in RTLM 1.0.

Table 1. Major Input Variables

Component	Input Variables
Traffic	Axle loads, # of cars, # of trips, speed
Track	Length, curvature, lubrication, modulus
Rail	Hardness, weight, length, profile
Tie	Type, tie spacing, age
Ballast	Grade, thickness, fouling condition
Subgrade	Soil type, soil strength
Turnout	Split of traffic
Other	Maintenance policies

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[*] TRACS™ (Total Right-of-way Analysis and Costing System)

Economics Calculation

In RTLM, maintenance cost is calculated as EUAC (equivalent uniform annual cost), based on:

- Degradation rate
- Unit cost for maintenance or replacement, which can be entered directly, or calculated from labor rates, machine rates, materials and transportation
- Interest rate and planning horizon

Dynamic Track Segmentation

One feature of RTLM 1.0 is that it allows automated execution of degradation and cost calculations for a given track, which may include many track and traffic segments. Figure 2 shows a sample railroad network that RTLM can interpret. As illustrated, the network consists of four lines. Line 4 includes two tracks. Track 1, in this example, includes one turnout, three ballast segments, two tie segments, and two rail segments. With RTLM 1.0, calculations of degradation and cost for each individual segment as well as the weighted average for the entire track can be executed dynamically (automatically).

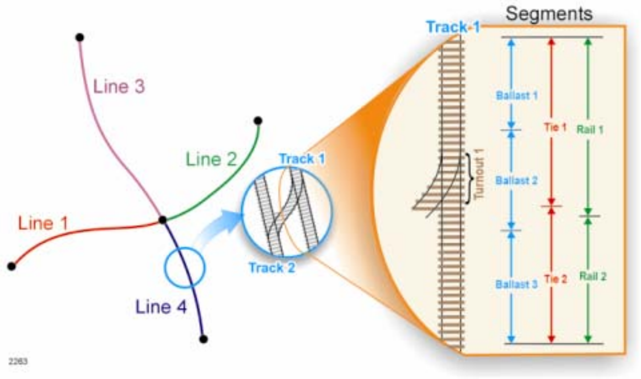

Figure 2. Line-Track-Segment in RTLM

EXAMPLE MODELING RESULTS

Under RTLM 1.0, users can select any number of track component degradation modes for analysis including rail wear rate (low and high rails) and rail wear life, rail defect rate and rail fatigue life, track roughness growth, remaining ballast life, spike kill, plate cut, decayed ties and average tie life, and turnout component life. In the following sections, examples are given to illustrate how each individual model can be used for degradation and cost analysis.

Ballast Model Example

Figure 3 shows an example of track roughness and ballast degradation analysis for 10,000 feet of track. The inputs include an annual tonnage of 52 MGT, wood tie track with good subgrade, and tamping requirement when track roughness exceeds 0.35 inch.

As shown, the first tamping operation is required at the 8th year, and the second one is required at the 12th year when the remaining ballast life is almost zero (i.e., completely fouled). At this time, ballast cleaning is also required. As a result of improved ballast quality, the next tamping is not required until 9 years later.

Based on the results of track roughness and required tamping operation, the EUAC for ballast tamping operations for this section of track is $1200, assuming nominal labor rates, machine, and material costs.

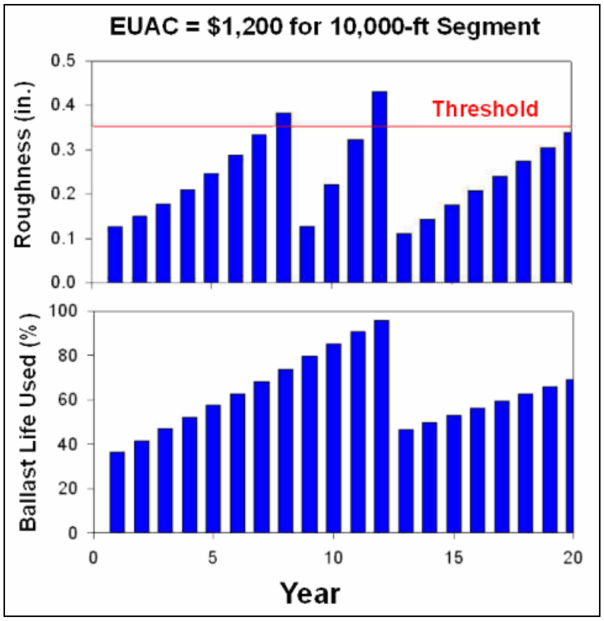

Figure 3. Track Roughness and Ballast Life

Tie Model Example

Figure 4 shows an example of tie degradation modeling results for 1 mile of tangent track (hard wood, annual traffic 30 MGT, 33-ton axle load). The results are cumulative plate cuts, spike kills, and decayed ties. Figure 5 shows the sensitivity of average tie life to curvature and decay potential. Obviously, higher curvature or higher decay potential causes a shorter life span for wood ties.

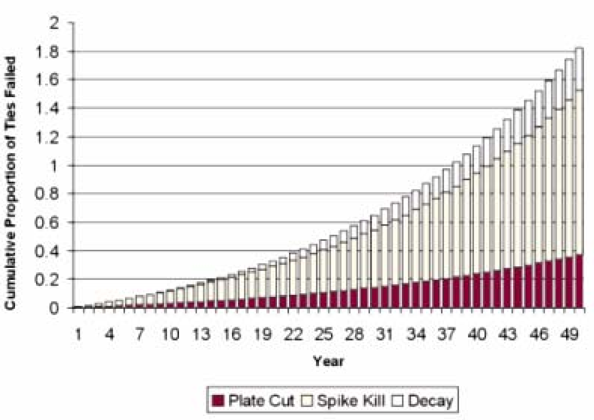

Figure 4. Example Tie Degradation Results

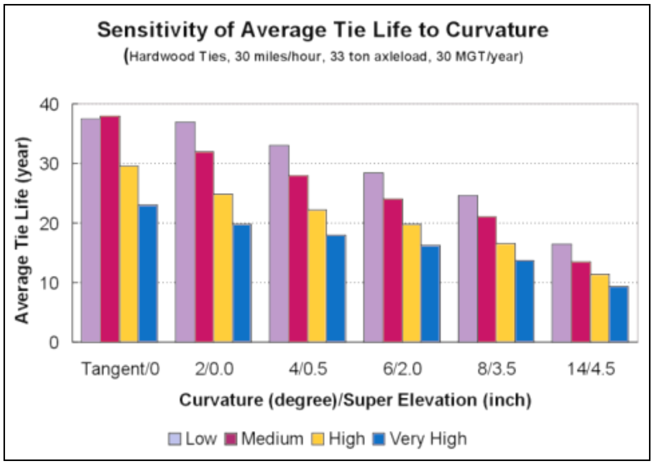

Figure 5. Tie Model Sensitivity Analysis

Rail Defect Model Example

Figure 6 shows an example of calculated rail defect growth rate for the following track and traffic conditions:

136 lb/yard rail with 270 BHN, worn rail profile with a wear rate 0.8 mm/MGT, and 30 MGT/year traffic with 33-ton axle load. If a tolerant defect rate is assumed to be 1/mile/year, the average rail defect life would be 8 years or 240 MGT for this example.

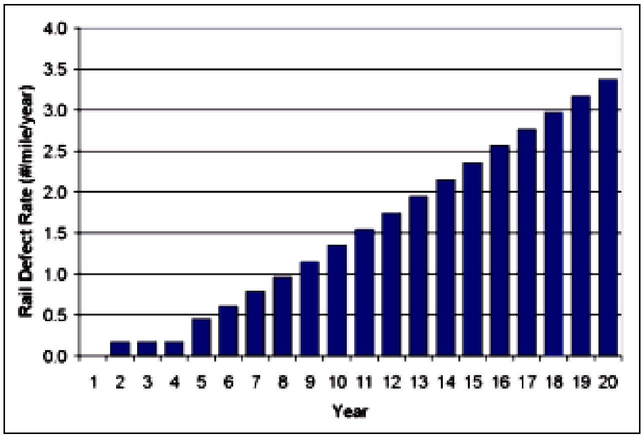

Figure 6. Rail Defect Model Example

Rail Wear Model Example

Figure 7a shows an example of calculated wear rates for 360 BHN rail in track with several curvatures under a 100 MGT/year condition. Other conditions include medium lubrication and cars equipped with standard three-piece trucks. As shown, higher curvature leads to higher wear rate, and the high rail experiences more wear than the low rail. For comparison, the wear-rate test result obtained for this rail type in a 5-degree curve at FAST is also included in Figure 7a.

Figure 7b shows the maintenance costs (EUAC) based on the results in Figure 7a, assuming a unit cost of rail replacement of $1,900 and 1.5 in^2 wear limit.

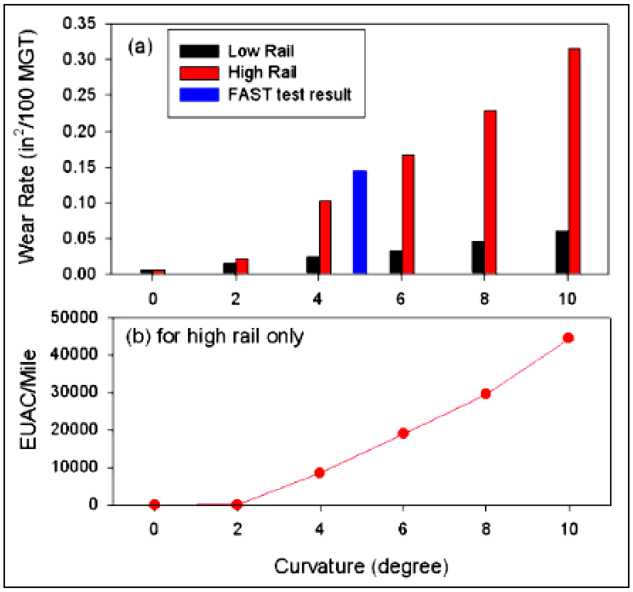

Figure 7. Rail Wear Model Example

FUTURE WORK

In 2003, new degradation models will be developed and added to RTLM, including calculations for wheel wear, rail rolling contact fatigue and gage strength degradation. In addition, the existing degradation models will be enhanced using new degradation experiment results obtained from the tests conducted at the Transportation Technology Center and in revenue service.

Acknowledgements

Bob Besaha, Steve Clark, Huimin Wu, Tom Guins and David Davis have contributed to the development of RTLM 1.0.