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Tie Degradation Model Implemented for Maintenance Planning on Heavy Haul Lines

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SUMMARY

In 2006, the Transportation Technology Center, Inc. (TTCI) conducted a case study of wood tie life prediction under heavy axle load operation, and together with the Union Pacific, integrated a tie degradation model into its track maintenance planning program. This model was implemented to help the railroad allocate tie capital budget across its network, and determine short- and long-term tie replacement strategies at both subdivision and regional levels to minimize the impact of heavy axle load operation and to extend the life of wood ties.

The case study showed that heavy axle load operation has a great effect on average tie life and tie replacement costs. Other operational, track and environmental conditions, such as train operating speed, curvature, superelevation, rail type, plate size, track foundation (track modulus), and decay potential, can all affect how long wood ties can last, and are therefore critical variables that should be considered in planning wood tie replacement.

With wood ties making up over 90 percent of North American railroad networks as well as growing traffic levels and tonnage, maintaining effective and economic tie replacement cycles is a huge planning and logistical effort. Implementation of a science-based tie degradation model provides an effective means of managing this process.

The tie degradation model is one of the track component degradation models in the Railway Track Life-Cycle Model (RTLTM). RTLTM is a software package for track component degradation prediction, maintenance planning, and cost analysis developed by TTCI under the Association of American Railroads' Strategic Research Initiatives Program. RTLTM includes a number of degradation models to predict rail wear, wheel wear, rail defect growth rate, rolling contact fatigue growth, wood tie degradation, turnout degradation, ballast degradation, and track roughness growth for given track, traffic, environment, and maintenance policies.

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INTRODUCTION

With wood ties making up over 90 percent of North American railroad networks, maintaining effective and economic tie replacement cycles is a huge planning and logistical effort under growing traffic levels and tonnage. To provide an effective means of managing this process, TTCI and Union Pacific (UP) worked together in 2006 to determine the effects of heavy axle load operation on tie maintenance and replacement strategies, using a tie degradation model.

The tie degradation model is one of the track component degradation models in RTL¹. RTL is a software package for track component degradation prediction, maintenance planning, and cost analysis developed under the Association of American Railroads’ Strategic Research Initiatives Program. RTL includes a number of models to predict rail wear, wheel wear, rail defect growth rate, rolling contact fatigue growth, wood tie degradation, turnout degradation, ballast degradation, and track roughness growth for given track, traffic, environment, and maintenance policies.

WOOD TIE DEGRADATION MODEL

The wood tie degradation model predicts deterioration of wood ties with conventional base plates and spikes. These ties are assumed to fail in one or more of the following three modes:

- Plate cutting: tie plate digs into the surface of the tie
- Spike kill: one or more spikes become loose, and it is no longer possible to hold the rail in place
- Rot: fungal decay of the timber causes the tie to lose its strength

For a given set of operating conditions, the tie model calculates the number of tie failures (proportion of failed ties for each of these three modes) each year. Figure 1 shows an example of the model output.

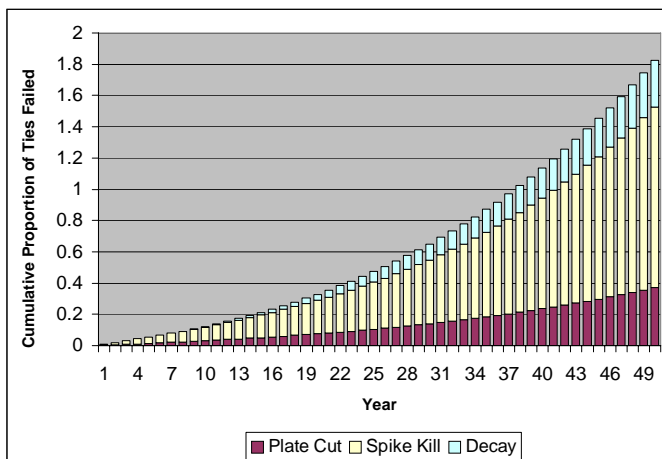


Figure 1. Example of Tie Model Output

The tie model also calculates average tie life, which is the average of tie lives weighted by the number of failed ties in each year for a 50-year period.

In the tie model, plate cutting damage is calculated as a function of the maximum vertical stress on the tie caused by the plate and the maximum vertical deflection of the tie. Spike kill damage is calculated as a function of the maximum lateral stress caused by the spike on the tie, where tie failure due to decay is mainly a function of the geographic location of the track and the wood specie used.

The following is a list of variables (inputs) considered in the tie degradation model:

- Rail weight
- Number of spikes per plate, spike size, and plate size
- Tie spacing, tie age, and tie type (soft or hard wood)
- Curvature, gage, and superelevation
- Track modulus
- Axle loads and their corresponding tonnage accumulations every year
- Train operating speeds (different track segments can have different speeds)

For the prediction of each failure mode, the model has several coefficients that can be adjusted to calibrate the model using available service failure data. In other words, if service failure data for each failure mode is available from past maintenance history, these coefficients can be adjusted to make the model more accurate for a specific track, environment, and traffic condition.

TIE ALLOCATION PROGRAM FOR BROAD NETWORK

The first application of the RTL in this study was to conduct a scientific analysis to quantify how the average tie life is related to axle load and tonnage, expressed in million gross tons (MGT) for different regions and route classes.

Table 1 lists the input values used in this study, representing a broad railroad network. Column 1 in Table 1 shows the approximate curve composition in this broad network, while Column 2 gives the data for the average track. Column 3 shows an average train for the network. Based on these input values, modeling of average tie life was done for various MGT levels and different decay zones.

Figure 2 shows the modeling results. As illustrated, both MGT and decay potential have a significant effect on average tie life.

Table 1. Input Values for Tie Allocation Analysis

Network	Track	Train
67.5 % tangent	Rail = 136 pounds (lb) per yard	3 x 400-kip locomotives
15 % 2-degree curve, 1-inch elevation	No. of spikes per plate = 4	31 x 63-kip cars
10% 4-degree curve, 2-inch elevation	Spike (length x width) = 6 x 0.5 inch (in.)	32 x 263-kip cars
5% 6-degree curve, 3-inch elevation	Plate size = 8 x 14 inches	17 x 286-kip cars
2.5% 8-degree curve, 4-inch elevation	Tie spacing = 19.5 inches	Speed = 40 miles per hour
	Tie type = hard wood	
	Track modulus = 2,500 lbs per square inch	

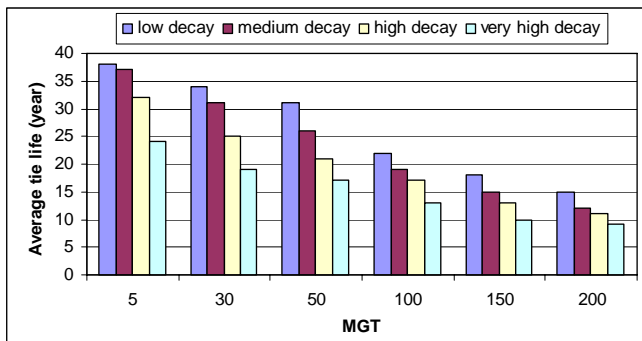


Figure 2. Average Tie Life Predicted for a Broad Network as a Function of MGT and Decay Potential

Modeling was also done for four different regions (central, south, north, and west) as well as for four different route classes (critical, premium, major, and others). For each of these specific networks, by region or route class, different input data from those listed in Table 1 were chosen by the railroad. Figure 3 is a summary of average tie life results predicted for the four regions as well as for the four route classes.

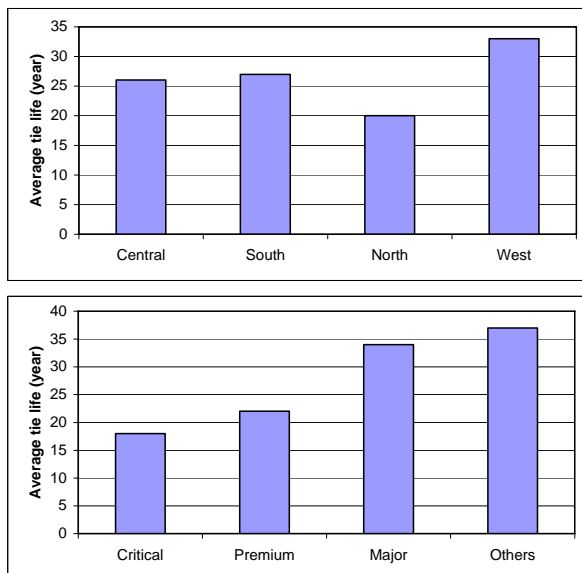


Figure 3. Average Tie Life Predicted for Specific Networks

Using the major route class as the baseline, a parametric study was conducted to show the effect of various input parameters. For example, Figure 4 shows the effect on average tie life of operating speed, track curvature, rail size, plate size, and track modulus. Obviously, higher operating speed generally leads to higher dynamic wheel loads, which would reduce tie life. Higher curvature also corresponds to higher wheel loads, leading to shorter tie life. On the other hand, increased rail size or increased plate size can help increase tie life. Track foundation support as characterized by track modulus also has a significant effect on tie life. For example, ties used on a stronger track foundation with track modulus of 3,000 lb/in/in can last longer than ties on a weaker track foundation (2,000 lb/in/in).

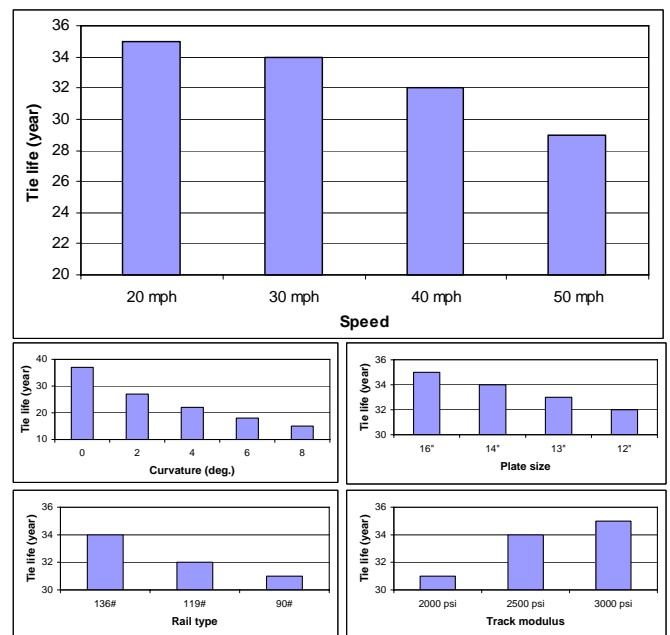


Figure 4. Effects of Input Parameters on Tie Life

TIE REPLACEMENT STRATEGIES FOR SUBDIVISIONS

UP keeps a detailed database (mile over mile) of tie condition for each subdivision and track across the railroad. One of the major objectives of implementing RTLM was to determine tie replacement strategies at the subdivision level.

From this database, the bad tie levels are determined and potential tie renewal locations are identified based on field tie inspections, route classifications, traffic levels, and other criteria. The RTLM tie model is then used to project the tie program over a 10- and 20-year horizon to determine spending levels and future year priorities. In addition, the model helps engineering managers understand the impact of various tie cycle and replacement approaches. In addition, RTLM was modified to look at existing tie conditions and the effects of system gang tie replacement efficiencies (number of ties replaced each mile that still

have useful life) so that the minimum tie replacement numbers are accurate in future years.

The tie model helps engineering managers determine the impact of various tie replacement strategies. For example, one approach on noncritical routes is to identify and replace only the minimum number of ties required to keep the route at a safe operating standard. The model is used to help identify yearly replacement requirements on these routes so that smaller local gangs can complete the work and system gangs can focus on critical routes.

The RTLM tie model is exercised once each week to ensure that all changes in condition and program work are accounted for in the model. Field managers (road masters) and directors of track maintenance have direct access to the information from the Track Maintenance Planner. Figure 5 shows the Track Maintenance Planner. From this planner, they can easily monitor tie condition across their territories and drill down to specific track/mile locations if required. They can also overlay other information, such as gage exceptions from the geometry car, to get a complete picture of conditions.

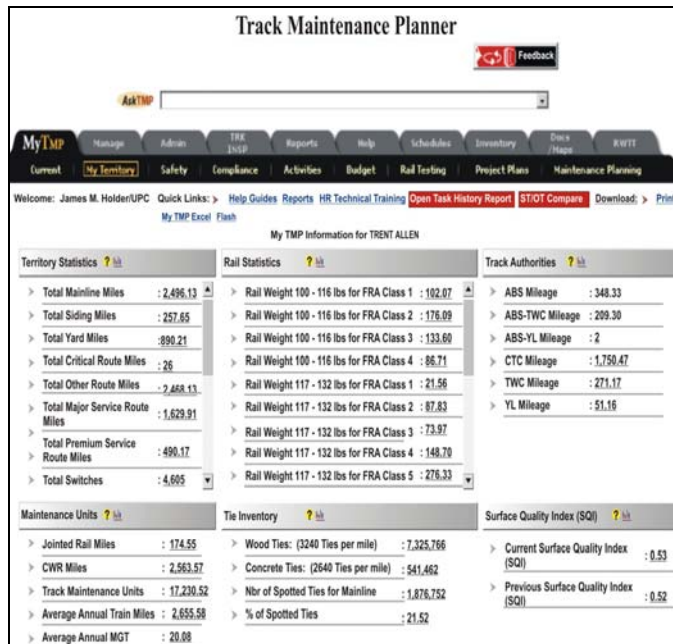


Figure 5. UP's Track Maintenance Planner

Figures 6 and 7 show examples of RTLM results incorporated as part of the Track Maintenance Planner. Figure 6 shows track and traffic conditions, tie lives, and numbers of ties that need to be replaced in 10 and 20 years as predicted from RTLM at the subdivision level. Figure 7 shows detailed tie conditions and ties that need to be replaced at the regional level.

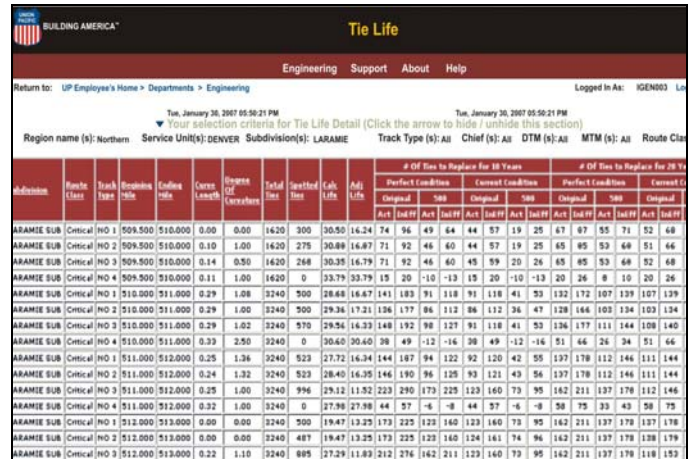


Figure 6. Tie Program View at Subdivision Level

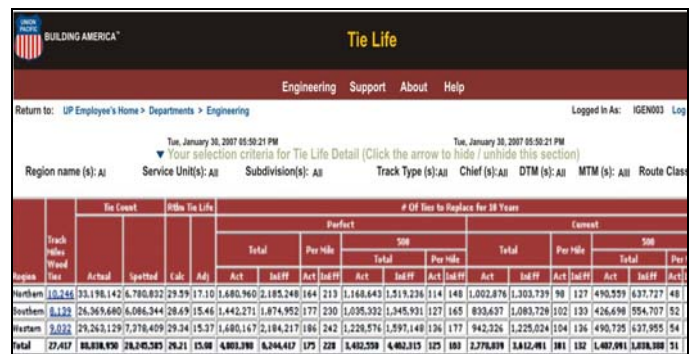


Figure 7. Tie Program View at Regional Level

NEXT STEP

The RTLM provides a critical tool to support railroads' long-term tie planning and daily track maintenance processes. TTCI will continue to improve the model and integrate other factors and logic including concrete and composite ties. Future improvements will also be made by railroads to provide the supporting information that drives the model including mile-over-mile track modules and detailed traffic history.

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REFERENCE

1. Li, Dingqing, John Tunna, and Corey Pasta. July 2003. "Railway Track Life-cycle Model, Version 1.0." *Technology Digest* TD-03-016. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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