Tie Planning Tools for the Track Inspector

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Paper Submitted to:
AREMA 1999 Track & Structures Annual Conference

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Abstract

With the current trend of increased traffic and axle loads, decreased maintenance budgets, and increased spending on crossties, it has become increasingly important to optimize track component maintenance. This includes longer life components, better identification of failed components, and higher production inspection and maintenance activities. This paper focuses on one aspect of this need, the inspection and maintenance planning improvements for crossties.

The status quo for crosstie inspection is to use the calibrated eye of the tie inspector to identify those ties that need replacement. This results in a requirement that the inspectors be trained to consistently identify bad ties based on their condition and the reason for replacement. An advancement made in crosstie evaluation is the lateral track strength inspection vehicles, which provide a continuous measure of the track's ability to withstand lateral forces. Traditional methods of counting bad ties in a mile do not provide for analysis of the distribution of tie condition within a stretch of track. A recent innovation in data acquisition, *TieInspect*™, allows for a complete analysis of the tie condition and distribution, as well as the development of a database of historic tie condition.

To aid in planning for tie requirements, a tie forecasting system is available *TieLife*™, which predicts future crosstie requirements on a macro basis, given historic tie installations.

It is tools of this nature that allow the inspector and planner to make the most appropriate decisions of when and where to replace crossties.

Key Words: crosstie, inspection, track-strength, planning, forecasting.

Introduction

Crosstie replacement continues to be one of the largest areas of expenditures in maintenance-of-way, with some railroads progressively spending more on ties and less on rail [1]. With increased axle loads and costs, and decreased track time, it has become increasingly important to optimize maintenance-of-way expenditures in general and the costs in particular. This optimization takes the form of extended component life, accurate identification of components to be replaced, and increased productivity of maintenance operations.

An analysis of the recent installations of crossties has shown that the number of crossties being installed has been decreasing at an average rate of 3% per year from 1996 to 1998 [2,3]. Projections for tie installations for 1999 showed an alarming decrease in ties installed of 14% for many of the Class I roads [1]. This is particular disconcerting considering an industry projection showed that a 4% increase from 1998 to 1999 was required to keep pace with projected tie failures [2]. An analysis of this nature illustrates the importance of choosing only those ties that have failed, or will fail soon, for replacement.

Considering crossties, it is the track or tie inspector's job to properly identify when and where ties require replacement. Without the luxury of an accurate total tie condition measurement system, the inspector is left with his experience and trained eye. The inspector's assessments can be supplemented with lateral track strength information, which provides data on only one of the crosstie's functions.

The information traditionally collected by the tie inspector is bad tie counts and cluster ties per mile. This information is used, along with other track, traffic, and maintenance planning information to identify where and how many ties should be installed. A new series of tools is available to assist the tie inspector and planner in making more accurate and optimal decisions concerning crosstie replacement. The first is *TieInspect*™, which provides the tie inspector with an easy to use tool for recording, storing and analyzing tie condition information, and the second is the Railway Tie Association's *TieLife*™, which evaluates historic tie installation information for forecasting future tie requirements on a macro basis.

The following paper considers the function of the crosstie, and investigates the latest technology available for assisting the tie inspector and maintenance planner in determining where and when to install crossties.

Function of the Crosstie

The primary function of the crosstie is three-fold as follows [4]:

1. Withstand lateral loading such that the two lines of the rails are transversely secured and held to correct gage.
2. Withstand vertical loading (axle load) such that the weight of passing vehicles is borne and transmitted to the ballast with a diminished unit pressure.
3. Withstand lateral, longitudinal, and vertical movement via tie/ballast interaction.

Given the above function of crossties, and according to the Federal Railroad Administration – Office of Safety Track Safety Standards, Part §213.109 (b) [5], defective cross-ties are categorized as those ties that will not:

i. Hold gauge within the prescribed limits

ii. Maintain surface within the prescribed limits.

iii. Maintain alignment within the prescribed limits.

Again, according to the FRA 213 §213.109 (c), the following factors should be considered in determining if a tie is defective.

(1) Broken through;

(2) Split or otherwise impaired to the extent the crossties will allow the ballast to work through, or will not hold spikes or rail fasteners;

(3) So deteriorated that the tie plate or base of rail can move laterally more than ½ inch relative to the crosstie; or

(4) Cut by the tie plate through more than 40 percent of ties' thickness.

In addition, each 39-foot segment of track shall have the minimum number and type of crossties as indicated below in Table 1.

Table 1. Minimum number of timber ties required in 39 feet.

Class of track	Tangent track and curves (2 degrees	Turnouts and curved track over 2 degrees
Class 1 track	5	6
Class 2 track	8	9
Class 3 track	8	10
Class 4 and 5 track	12	14
Class 6 track	14	14
Class 7, 8, and 9 track	18	18

In addition to "defective" or "non-defective" decisions for individual ties and "safe" or "unsafe" decisions for combinations of defective ties, there are other reasons for making inspections of the condition of ties in track with respect to their overall function. Inspections are required to properly plan tie renewal programs. These inspections can take place at various stages of planning. A count of defective ties may be taken for comparative purposes in order to determine which sections of track will be scheduled for a tie renewal program. If this is the purpose of the tie inspection, it is important to be sure that the definition of ties to be replaced is uniform throughout the entire inspection.

In another situation, a decision may already have been made that ties will be renewed in a certain stretch of track. The inspector may be given the assignment of determining the number of new ties required. Before this is done, the inspector should find out what policy is to be followed. Perhaps in some important tracks, it may be desired to replace all defective ties. In other tracks, only a percentage of defective ties are to be replaced. The determination of whether a tie is defective may be based on the FRA § 213.109 definitions. Alternatively, some specific condition, perhaps plate cutting, may be graded more severely. The goal may be to replace enough ties to insure compliance with FRA standards for a certain period of time. Whatever practice is desired will only be followed to the extent that the inspector understands it.

The inspector may be requested to mark ties for renewal in accordance with the number of new ties that have already been unloaded for insertion. It is necessary to determine the number of new ties available within relatively short segments. Then the ties with the most serious defects are marked within each segment, to the limit of new tie availability.

Ties may also be inspected during the investigation of another problem, such as gauge widening -or irregular track surface. If it is determined that the ties are contributing to the problem, it will probably be necessary to identify the ties to be replaced, in order to correct the condition.

Tie Failure Mechanisms and Replacement Criteria

The failure of wood ties may be categorized into three different mechanisms: Mechanical Wear, Environmental Conditions, and Damage.

1. Mechanical Wear: Failed ties in this category include: Plate cut tie, spike killed tie, worn tie, anchor cut tie.

   - *Plate Cut*: Movement of the tie plate, laterally due to gauge spreading forces or longitudinally due to train braking/accelerating or thermal expansion/contraction of the rail, can lead to plate cut ties. A plat cut tie is shown in Figure 1.

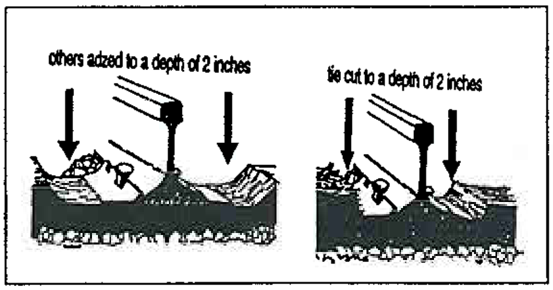


Figure 1. Plate Cut Tie.

   - *Spike Killed*: Spikes that no longer have the capability to hold the tie plate from moving laterally or prevent the rail base from lifting, indicate the presents of a spike killed tie. Constant lateral and longitudinal forces that elongate or widen the spike hole, or spikes that have been removed and replaced several times (as in the case of high frequency of rail change out or spike lining of track) may contribute to spike kill. In addition, ties may split if the holes are plugged too many times, and this situation may also be labeled as spike kill. A spike killed tie is shown in Figure 2.

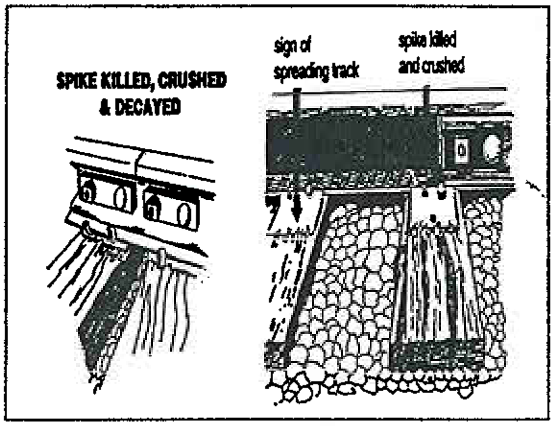


Figure 2. Spike Killed Tie.

- *Worn*: Tie movements in the ballast section, either laterally or longitudinally, can cause the tie to become rounded resulting in poor surface, line and the inability to hold spikes. This tie condition will be classified as worn.
- *Anchor Cut*: High longitudinal rail forces will cause the rail anchor to push against the tie to transmit the forces through the tie into the ballast. This action can cause the rail anchor to wear away the side of the tie until the anchor rests against the tie plate. This is an anchor cut tie, and if allowed to stay in track will lead to spike kill and plate cutting.

2. Environmental Conditions: Failed ties in this category include: split tie, split tie end, decayed tie, crushed rail seat, warped.

- *Split*: Over time, ties subjected to wet/dry cycles, or freeze thaw cycles can develop splits that can migrate from one end of the tie to the other. Splits can also be the result of improper drying of the green wood before treating. In either case, once the split starts, it will generally progress, and widen with time. The introduction of rain, ice and ballast into the split will wedge the opening further apart until the tie can no longer support the load or hold the spikes. A tie that is split end to end is shown in Figure 3.

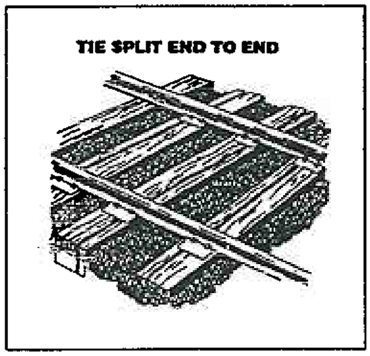


Figure 3. Split Tie.

- *Split Tie End*: The split tie end may be the result of all of the above noted causes or in addition, could be the result of excessive tie plugging or rail seat crushing. A split tie end is only a problem if the split migrates to, or emanates from the spike hole. If it affects the spike holding capability of the tie, the tie should be removed.

- *Decayed*: Exposed wood fibers caused by a tie split or a puncture of the tie coating from mishandling or damage, can be attacked by air-borne fungal spores. The spores begin to grow in the moist wood fibers and the roots of the fungus will break down the wood fibers into pulp. Eventually the tie can no longer hold spikes, gauge or surface. A decayed tie is shown in Figure 4.

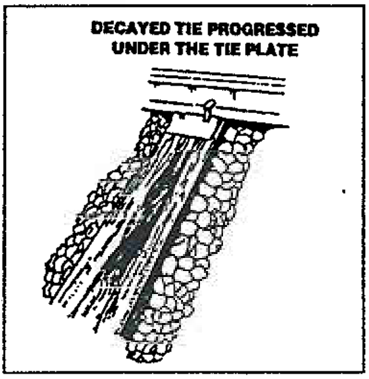


Figure 4. Decayed Tie.

- *Crushed Rail Seat*: Crushing of the rail seat can be caused by any combination of decay, break down of the wood fibers by iron oxide, and rail seat loading. When this condition progresses to the point where the tie can no longer support the load or hold a spike, it must be removed.
- *Warped*: Improper drying of the green tie prior to treatment, especially hardwood ties, may result in the tie twisting like a corkscrew from end to end. This can happen in the track or on route from the treatment plant. If this occurs enroute, the tie must be adzed on the rail seats before installation that will expose the wood fiber. If

it occurs in track, the tie could crack or split, or cause surface or line defects in the track.

3. Damage: Failed ties in this category include: broken tie, burned tie, damaged tie.

- *Broken*: Center binding or end bearing ties can crack or break under load causing the tie to lose its ability to hold line, surface or gauge. An example of a broken tie is shown in Figure 5.

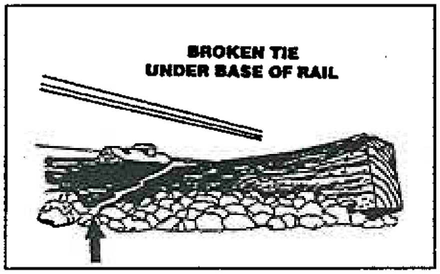


Figure 5. Broken Tie.

- *Burned*: Ties can be ignited (especially in the heat of summer when the creosote coating becomes volatile) by a spark from a brake shoe, a lit fusee, a grass fire or in many cases, hot metal from rail grinding operations. If the burn is deep enough it can impact the integrity of the tie and replacement is required. A burnt tie is shown in Figure 6.

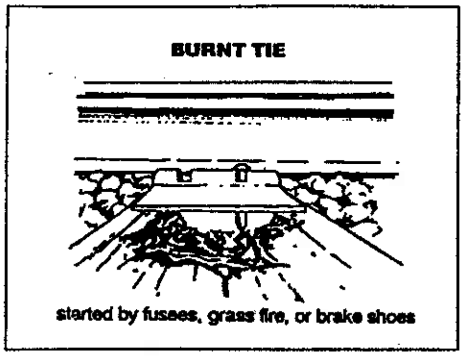


Figure 6. Burnt Tie.

- *Damaged*: A tie that is damaged by a derailed wheel, dragging equipment, fire or some other deleterious means to a depth of 2 inches or more should be replaced.

Tie Maintenance Philosophy

Although differences in operational organizations and physical conditions on the various railroads make it impractical to formulate a procedure that is applicable everywhere, no phase of track maintenance is more important than the selection of the ties to be renewed in a given year. Improper tie renewals over a period of years are sure to be costly, and may prove to be disastrous, whether the replacements are too few or too many.

The total number of ties required to maintain satisfactory track in one year is rarely the same as the number renewed during the previous year or the average renewals over any period. Therefore, careful inspection of the ties in track will provide more dependable information than any assumptions based on statistics.

Whatever method is used in the inspection and selection of the ties to be renewed, the procedure should be so planned as to provide a record of the system requirements as distinguished from those of a section or division. Training and experience for those making inspections of ties in track are necessary to assure uniformity in their procedure and consistency in their conclusions.

Each tie to be removed is generally identified by a mark on the tie or on the rail above it. Absolute adherence to this marking is required in some instances. More often the foremen is allowed to leave some marked ties and to remove some unmarked ties. Ordinarily, only those ties that are useless should be removed; but when track is given a general out-of-face overhauling, all ties, which appear to be nearing the end of their service life, may be removed.

Records of inspections of the condition of ties in track, detailed as to location by telegraph poles or other short stretches having easily recognized landmarks, aid in the unloading of ties and thus avoid expensive extra handling.

Ties still serviceable enough for economical reuse become available when lines are abandoned and tracks are taken up; when the renewal of all ties in tunnels, in road crossings, or at station platforms releases them; and when ties under heavy traffic have to be removed because their service in such track is no longer satisfactory.

While the reclamation or salvage of ties is sound in principle and highly desirable, it can easily be overdone. To guard against any tendency toward false economy resulting from loyalty to reclamation as such, all costs must be considered. Complete records of all expenses connected with picking up, stacking, preparing, and shipping ties for reuse should be kept for comparison with the prices of other materials for a given purpose, together with the respective costs of installation. Expenditures for handling and hauling may confine their reuse to locations close to where they are removed from track.

The most economical use of ties is to leave them in their original locations until they are so decayed or mechanically worn that they cannot serve their purposes any longer. However, in connection with general track reconditioning, it is usually economical to replace ties beneath the end of their serviceability, in order that the track need not be disturbed again for several years. This procedure is desirable in heavy traffic, high-speed lines where spot tie renewals are expensive and the disturbance of refined track surface is especially inadvisable.

Tie Inspection and Planning Tools

Several efforts have been made in the past to develop an automated tie inspection system that provides an objective measure of the tie's condition. These efforts have proven to be less successful than desired and many are still under development. However, there are several tools available to railway inspection and maintenance planning personnel to aid in a better understanding of tie degradation and future crosstie requirements.

Lateral Track Strength Measurement Systems

The first of the class of tools that aid the tie inspector is the lateral track strength measurement system. The lateral track strength measurement system can be used to locate clusters of ties not suitable in the lateral direction. There are currently two forms of lateral track strength vehicles commercially available for sale or contract, which are distinguished by their level of loading and mode of propulsion.

The first of these lateral track strength system is the Gage Restraint Measurement System (GRMS) provided jointly by Plasser and ENSCO, Inc. This system is a self-propelled rail-bound vehicle that operates in the upper load regime with vertical and lateral operating loads of 19 and 14 kips respectively [6]. This vehicle is pictured below in Figure 7.

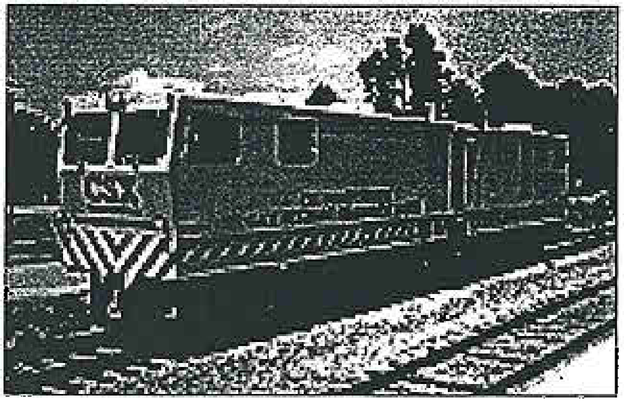


Figure 7. GRMS Vehicle. [6]

This system tests track strength at speeds up to 35 mph [6] using a split-axle to apply a defined lateral force. The change in gage under load is measured and is extrapolated to a 24 kip lateral load, from which exceptions are determined.

In addition to safety exceptions, tie maintenance planning can be performed on the data to result in counts of ties required by mile. A sample of this output is shown below in Figure 8.

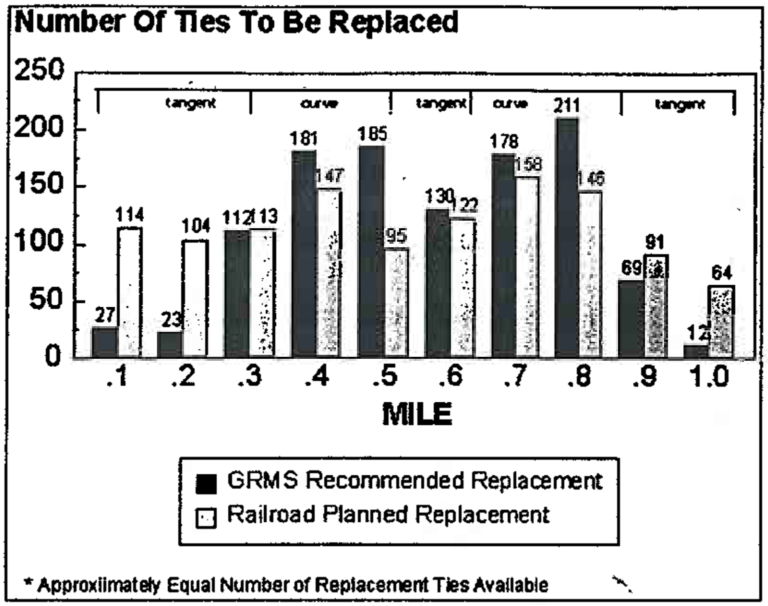


Figure 8. GRMS Planning Output. [7]

The second in the class of lateral track strength vehicles is the hi-rail spread axle vehicle, which operates in a lower load regime than the GRMS. The TrackSTAR system is produced by the Holland Co. and applies vertical and lateral loads in the range 15 and 12 kips respectively. Again, extrapolation of the measured data under load is performed to determine exceptions of actual cars. Figure 9 shows the TrackSTAR vehicle from Holland Co.

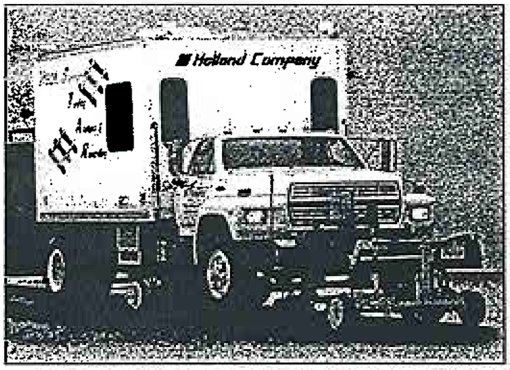


Figure 9. TrackSTAR Vehicle.

The advantage of this system is that it is a hi-rail vehicle and can be easily moved from one test location to another.

This system also provides planning software in the form of exception reports, mile-by-mile tie requirements, cluster breaking tie requirements, and a host of other statistics. An example of the type of output available from the TrackSTAR is shown in Figure 10.

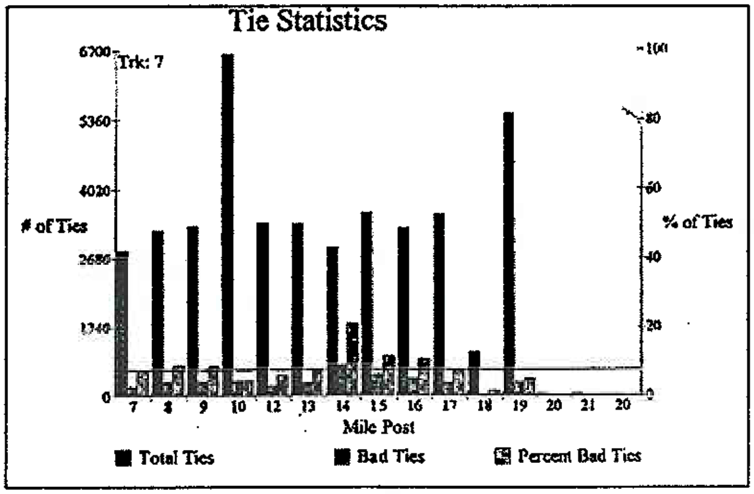


Figure 10. TrackSTAR Planning Output.

The lateral track strength vehicles are limited to testing groups of ties in the lateral plane only and very effectively find weak spots in track where the tie/fastener is unacceptable in the lateral plane only. Therefore, walking tie inspections are still very important.

Hand-Held Inspection Tools

While the lateral track strength vehicles provide invaluable information for the condition of ties in the lateral direction, they do not provide information for the vertical and longitudinal modes of failure. Therefore, railroads today continue to use the tie inspector to count and/or mark defective ties according to the conditions noted above along with the lateral track-strength information.

The traditional tie inspector performs tie counts on a per mile basis. This may be achieved by walking the whole mile and counting bad ties, or inspecting part of the mile and prorating the bad tie count for that portion. Depending on the type of count being performed, spot renewal or out-of-face renewal, the calibrated eye of the inspector will mark ties that fall into maintenance activity. This value for the mile is usually recorded and decisions made based on this value. A subsequent marking activity is then carried out based on the number of ties allocated to a mile to identify/mark those ties to be replaced in the upcoming maintenance activity.

While this method has been effective to date, it does not allow for determining and analyzing the distribution of tie condition within the mile. A second class of tools to aid the tie inspector in this regard was recently developed by Zeta-Tech Associates. This new inspection system is an innovative hand-held tie inspection tool called *TieInspect*™. *TieInspect*™ is a comprehensive computerized crosstie inspection system designed to accurately and efficiently collect tie condition data based on a tie inspector's assessment of condition. This revolutionary unit aids the tie inspector by providing an easy to use mechanism that allows for the complete collection and storage of valuable tie condition data. Tie condition data can be stored for each and every tie inspected, providing a complete database of historical and current tie condition. In addition, offline analysis software is provided for viewing and analyzing the collected data.

The system is outfitted with a handgrip input device, which is connected to a palmtop computer via an RS-232 interface. The palmtop computer is conveniently held in a belt pouch, which also contains a rechargeable battery good for hours of continued inspection. All inspection data is stored on the palmtop and can be downloaded to a desktop PC for analysis and reporting. All acquisition and offline analysis software is provided with the system. The *TieInspect*™ hardware system is shown below in Figure 11.

Figure 11. ***TieInspect*™ System.**

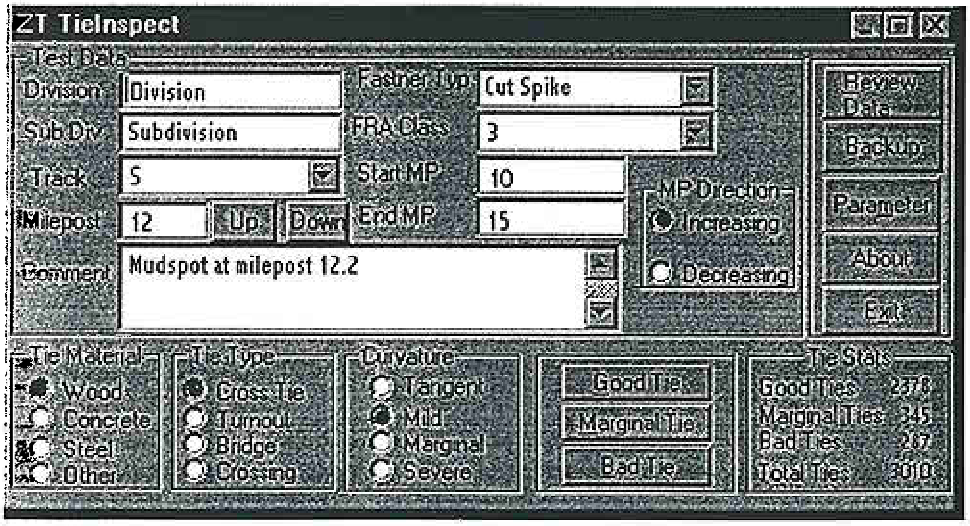
The general features of the system provide the tie inspector with an easy to use, digital tie inspection and recording device. The palmtop computer records the tie inspectors inputs from the handgrip. In addition, the inspector has the ability to fill in certain fields within the software on the palmtop including, division, subdivision, inspection direction, fasteners, comment, and others. The inspector can quickly evaluate how many good, marginal, bad, and total ties were counted for any given milepost while in the field. A complete record of all inputs is kept on the palmtop until downloaded to the host software.

The system provides two primary modes of inspection capability, a detailed identification of the condition of every tie, and a bad tie only count by milepost. The inspector can choose which configuration to use based on their individual requirements. For the detailed tie inspection, every tie is graded as good, marginal or bad. The handgrip provides input buttons for each of these conditions. Pressing the good tie button will store a good tie record in the system. Each tie is graded by the inspector and the appropriate button clicked. For the bad ties only inspection mode, the bad tie button is clicked for each bad tie encountered. In addition, whenever a tie cluster is located (as defined by the inspector), the tie cluster button is clicked.

The *TieInspect*™ host software provides the user with the ability to upload the inspection information and creates a historical database of the inspection data. This data can then be viewed for several miles in both a summary and detailed format, showing the distribution and counts of good, marginal, and bad ties. In addition, bad tie clusters and FRA defects are listed by location to aid in maintenance planning.

The host analysis software allows the user to specify any track location within the database (a contiguous range) and view the summary inspection results (good, marginal, bad, and total tie counts), as well as the detailed distribution of ties for any given mile for a historically defined time frame. The detailed distribution is analyzed to provide the user with number of tie clusters, defined as continuous counts of 2 to 10 (or more) bad ties in a row. This provides the analyst with the ability to estimate how many ties are required to breakup tie clusters and insure safety. In addition, the host software has an FRA analysis package, which provides the user with a graphical and tabular representation of FRA defects as defined by track class. A moving window analysis allows the user to define the number of ties required to eliminate FRA defined defects.

The palmtop software is the control system that allows the user to input, collect, and store tie condition data in an easy and intuitive manner. The palmtop computer uses the Windows CE operating system and is compatible with Windows 95/98/NT. The software allows the user to input information using intuitive controls such as drop-down list boxes, radio buttons, and input text boxes. The main access screen (See Figure 12 below) provides the user with feedback of the current state of the primary input variables. These variables can be changed as necessary during inspection by removing the palmtop from the case and initiating changes. In addition, the current tie status (wood, crosstie, curvature) and tie counts (good, marginal, bad) for the milepost being inspected are available to the user when viewing the palmtop screen. It is this screen that is used when the inspector wishes to enter a comment at any time during the inspection.


ZT TieInspect

Test Data
Division: Division
Sub Div: Subdivision
Track: 5
Milepost: 12
Comment: Mudspot at milepost 12.2
Fastner Typ: Cut Spike
FRA Class: 3
Start MP: 10
End MP: 15

MP Direction
● Increasing
○ Decreasing

Tie Material
● Wood
○ Concrete
○ Steel
○ Other

Tie Type
● Cross Tie
○ Turnout
○ Bridge
○ Crossing

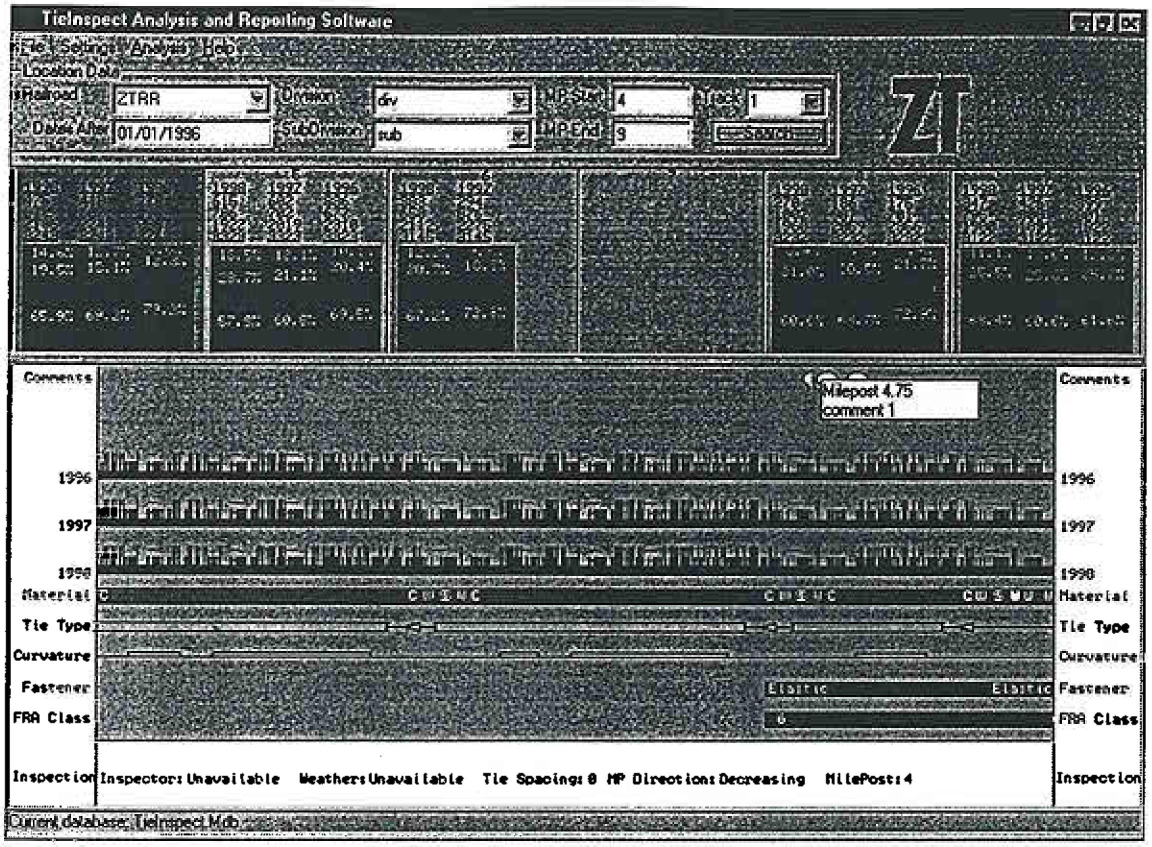
Curvature
○ Tangent
● Mild
○ Marginal
○ Severe

Tie Stats
Good Ties 2378
Marginal Ties 345
Bad Ties 287
Total Ties 3010

Figure 12. Palmtop Main Screen.

The offline analysis software allows the user to upload the inspection data into a comprehensive database for later retrieval, viewing and analysis. Utilities are provided for uploading the *TieInspect*™ field collected data files. These utilities parse the incoming data and create a database (Microsoft Access compatible) for use with the analysis and reporting features.

The user can select the boundaries of a segment of track and a bar chart will show the summary data for each milepost in that segment for each date an inspection occurred. The summary data includes the tie count and percentage of ties in each condition category. By clicking on a milepost, a detailed graphical representation (See Figure 13) of the tie inspection data appears for each date of inspection. This intuitively identifies to the user the location of bad tie clusters, as well as all of the other information collected during inspection. The locations of curvature, track class, and tie type and material are shown as well as the general inspection parameters entered by the user. In addition, any comments entered appear as "balloons" at the milepost where they were entered. The actual comment can be viewed by moving the mouse over top of the icon. Lists of clusters and FRA defects are also identified.



Railroad: ZTRR
Dates After: 01/01/1996
Division: div
SubDivision: sub
MP Start: 4
MP End: 9
Track: 1

Milepost 4.75
comment 1

Inspector: Unavailable Weather: Unavailable Tie Spacing: 0 MP Direction: Decreasing MilePost: 4

Current database: TieInspect.Mdb

Figure 13. Detailed Tie Condition Output.

The database and analysis results generated by the inspection provide an immediate means for making better decisions on when and where to replace crossties. This information provides an ongoing "map" of the condition of the ties in track. This will allow for predicting longer-term maintenance needs as well as provide for a better understanding of crosstie deterioration [8].

Maintenance Planning Software

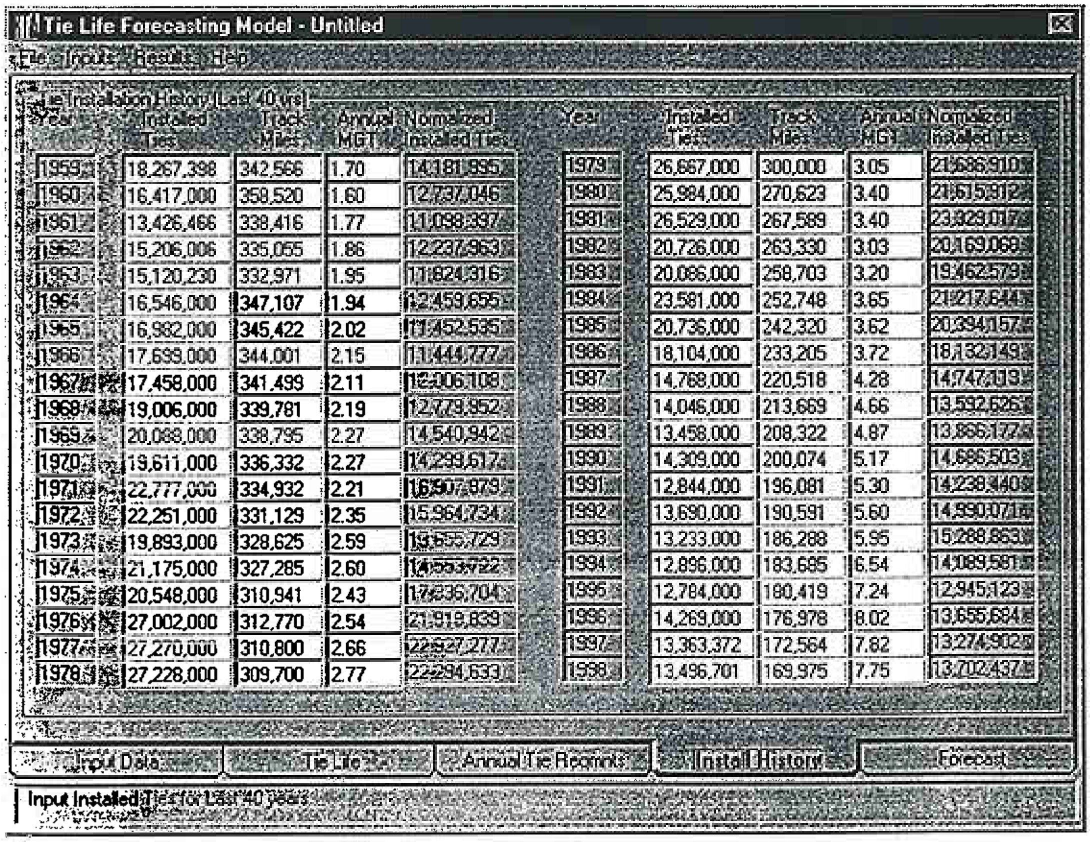
The third class of tools for aiding the tie planner is tie planning software. This software is in addition to the software available from both of the commercial lateral track strength vehicles. These tools do not just provide exceptions and statistics; rather they are forecasting tools that can be used to determine future crosstie requirements.

One such planning tool for determining future crosstie requirements is the

Railway Tie Association's (RTA) *TieLife*™. This system uses historic tie installations, miles of track operated, and annual tonnage to determine the number of cross ties required for a twenty-year time horizon [9].

The system evaluates a segment of (or entire) railroad based on a matrix of trackage, defined by curvature and annual tonnage category. Based on an average tie life for each of the categories in the curvature/tonnage matrix and the number of track miles in that category, a steady state number of ties required for that category can be determined.

This information is used with the tie installation, trackage operated, and annual tonnage history to develop a forecast of tie requirements for the system being evaluated. Figure 14 shows the data input history for the North American freight railroads [3].



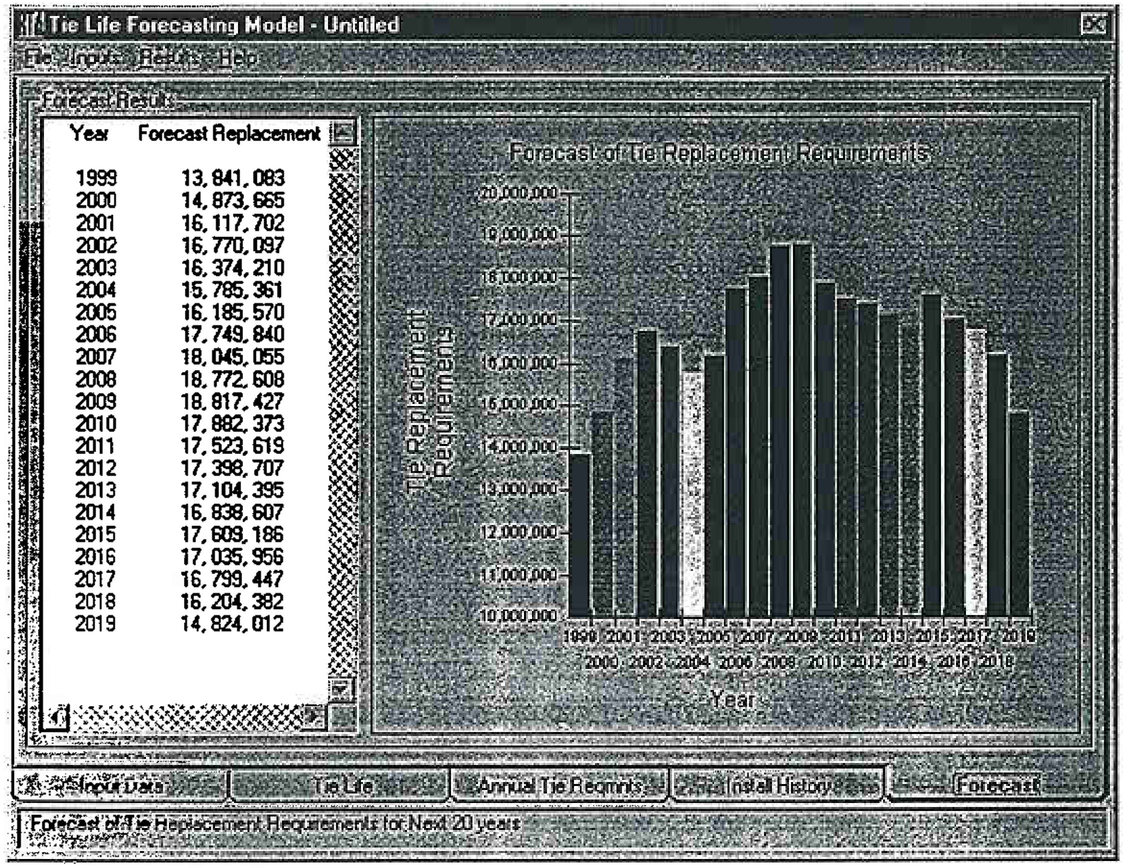
Tie Installation History (Last 40 yrs)

Year	Installed Ties	Track Miles	Annual MGT	Normalized Installed Ties	Year	Installed Ties	Track Miles	Annual MGT	Normalized Installed Ties
1959	18,267,398	342,566	1.70	14,181,895	1979	26,667,000	300,000	3.05	21,686,910
1960	16,417,000	358,520	1.60	12,737,046	1980	25,984,000	270,623	3.40	21,615,912
1961	13,426,466	338,416	1.77	11,098,397	1981	26,529,000	267,589	3.40	23,929,017
1962	15,206,006	335,055	1.86	12,237,963	1982	20,726,000	263,330	3.03	20,169,068
1963	15,120,230	332,971	1.95	11,824,316	1983	20,086,000	258,703	3.20	19,462,579
1964	16,546,000	347,107	1.94	12,459,655	1984	23,581,000	252,748	3.65	21,217,644
1965	16,982,000	345,422	2.02	11,452,535	1985	20,736,000	242,320	3.62	20,394,157
1966	17,699,000	344,001	2.15	11,444,777	1986	18,104,000	233,205	3.72	18,132,149
1967	17,458,000	341,499	2.11	12,006,108	1987	14,768,000	220,518	4.28	14,747,313
1968	19,006,000	339,781	2.19	12,779,952	1988	14,046,000	213,669	4.66	13,592,626
1969	20,088,000	338,795	2.27	14,540,942	1989	13,458,000	208,322	4.87	13,866,177
1970	19,611,000	336,332	2.27	14,299,617	1990	14,309,000	200,074	5.17	14,686,503
1971	22,777,000	334,932	2.21	16,907,979	1991	12,844,000	196,081	5.30	14,238,440
1972	22,251,000	331,129	2.35	15,964,734	1992	13,690,000	190,591	5.60	14,990,071
1973	19,893,000	328,625	2.59	13,655,729	1993	13,233,000	186,288	5.95	15,288,863
1974	21,175,000	327,285	2.60	14,553,722	1994	12,896,000	183,695	6.54	14,089,581
1975	20,548,000	310,941	2.43	17,236,704	1995	12,784,000	180,419	7.24	12,945,123
1976	27,002,000	312,770	2.54	21,919,839	1996	14,269,000	176,978	8.02	13,655,684
1977	27,270,000	310,800	2.66	22,927,277	1997	13,363,372	172,564	7.82	13,274,902
1978	27,228,000	309,700	2.77	22,294,633	1998	13,496,701	169,975	7.75	13,702,437

Input Installed Ties for Last 40 years

Figure 14. *TieLife*™ Input History.

Using the RTA's *TieLife*™ model, and the input data history for North America, a crosstie forecast can be determined for the industry. This forecast is shown in Figure 15 and shows the modest increase in tie requirements for the next couple of years with significant jumps to try and achieve a steady state tie life. Depending on the current trends of increases in traffic and decreases in trackage operated, this forecast can be modified, as additional data is obtained.



Year	Forecast Replacement
1999	13,841,083
2000	14,873,665
2001	16,117,702
2002	16,770,097
2003	16,374,210
2004	15,785,361
2005	16,185,570
2006	17,749,840
2007	18,045,055
2008	18,772,608
2009	18,817,427
2010	17,882,373
2011	17,523,619
2012	17,398,707
2013	17,104,395
2014	16,838,607
2015	17,609,186
2016	17,035,956
2017	16,799,447
2018	16,204,382
2019	14,824,012

Forecast of Tie Replacement Requirements for Next 20 years

Figure 15. *TieLife*™ Output.

Discussion

This paper showed the importance of identifying where and when crossties require replacement. This is becoming increasingly important in order to optimize maintenance expenditures due to the increased costs, axle loads, traffic, etc. along with decreased budgets. Several tools are available for aiding the tie inspector and maintenance planning personnel in making optimal decisions.

The first of these tools is the lateral track strength measurement systems that are currently available for sale and/or contract. The data from these systems is invaluable in assessing locations in track that may not be observed by a walking inspection that exhibit poor performance in the lateral direction.

The second of these tools, *TieInspect*™, aids the walking tie inspector in obtaining information that is more complete and more useful than is currently being obtained by walking inspections. Walking tie inspections are necessary and provide the basis for tie replacement programs. More accurate information obtained during the inspection, along with the offline analysis software, allow for more optimal decision making of when and where to replace ties.

The third in the line of tools available for the tie planing personnel is *TieLife*™, a maintenance planning software package available for performing a macro analysis on historic tie installations for predicting future crosstie requirements. This allows for future budgeting and smoothes the planning process.

The most valuable characteristic of these tools is that, while they each provide useful information in and of themselves, they provide a more complete result when used together. Correlating track strength data with walking inspection data (since each method overlaps failure mechanisms) allows for determining the exact locations of where to replace ties. Using this information along with the forecasting packages allows for budgeting the total number of ties required, which can then be distributed based on the individual inspection methods.

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