tion in Pavement Structures: User's Manual. FHWA, Rept. FHWA-IP-80-2, Vols. 1 and 2, Oct. 1979.
2. State of the Art: Lime Stabilization. TRB, Transportation Research Circular 180, 1976.
3. Lime-Fly Ash Stabilized Bases and Subbases. NCHRP, Synthesis of Highway Practice 37, 1976.
4. Fly Ash--A Highway Construction Material. Implementation Package 76-16, FHWA, May 1976.
5. Soil Stabilization with Portland Cement. HRB, Bull. 292, 1961.
6. Soil-Cement Laboratory Handbook. Portland Cement Assn., Skokie, IL, Publ. EB0525, 1971.
7. Soil-Cement Construction Handbook. Portland Cement Assn., Skokie, IL, Publ. EB0035, 1979.
8. Soil-Cement Inspector's Manual. Portland Cement Assn., Skokie, IL, Publ. PA0505, n.d.
9. Basic Asphalt Emulsion Manual. Asphalt Institute, College Park, MD, MS-19, March 1977.
10. Asphalt Cold-Mix Manual. Asphalt Institute, College Park, MD, MS-14, Feb. 1977.
11. Mix Design Methods for Liquid Asphalt Mixtures. Asphalt Institute, College Park, MD, MISC-74-2, Feb. 1974.
12. J.A. Newby. In-Depth View of Geotextile Subgrade Stabilization. Railway Track and Structures, June 1980.
13. M.R. Thompson and L. Raad. Fabric Utilization in Transportation Support Systems (Low Deformation Criteria). Civil Engineering Studies, Transportation Engineering Series 26, Univ. of Illinois at Urbana-Champaign, Dec. 1979.
14. J.M. Waters. Discussion of Paper 7468. Proc., Institution of Civil Engineers, Part 2, Vol. 53, Dec. 1972.
15. D.H. Coombes. Discussion of Paper 7468, Proc., Institution of Civil Engineers, Part 2, Vol. 53, Dec. 1972.
16. A.C. Benkleman. Structural Deterioration of Test Pavements: Flexible. HRB, Special Rept. 73, 1962, pp. 173-185.
17. E.J. Barenberg. A Shear-Layer Concept for Flexible Pavements. Presented at the 47th Annual Meeting, HRB, 1968.
18. L. Raad and M.R. Thompson. Discussion of paper, Study of Analytical Models for Track Support Systems, by C.W. Adegoke, C.S. Chang, and E.T. Selig. TRB, Transportation Research Record 733, 1979, pp. 19-29.
19. W.W. Hay. Track Structures for Heavy Wheel Loads. Tech. Proc., 12th Annual Railroad Engineering Conference, Federal Railroad Administration, U.S. Department of Transportation, Rept. FRA-ORD-76-243, 1976.
20. J.R. Lundgren, G.C. Martin, and W.W. Hay. A Simulation Model of Ballast Support and the Modulus of Track Elasticity. Civil Engineering Studies, Transportation Engineering Series 4, Univ. of Illinois at Urbana-Champaign, Sept. 1970.
21. Construction and Maintenance Operations. Proc., American Railway Engineering Assn., Bull. 645, Vol. 75, Nov.-Dec. 1973.
22. R.M. Knutson and M.R. Thompson. Resilient Response of Railway Ballast. TRB, Transportation Research Record 651, 1977, pp. 31-39.
23. R.M. Knutson and M.R. Thompson. Permanent-Deformation Behavior of Railway Ballast. TRB, Transportation Research Record 694, 1978, pp. 47-53.
24. M.R. Thompson, W.W. Hay, and S.D. Tayabji. Summary Report--Ballast and Foundation Materials Research Program. Federal Railroad Administration, U.S. Department of Transportation, Rept. FRA/ORD-78/10, June 1978.
25. M.R. Thompson. Soil-Lime Mixtures for Construction of Low-Volume Roads. TRB, Special Rept. 160, 1975, pp. 149-165.
26. L. Raad, C.L. Monismith, and J.K. Mitchell. Crack Propagation in Soil-Cement Bases Subjected to Repeated Wheel Loads. TRB, Transportation Research Record 690, 1978, pp. 1-5.
27. M.R. Thompson and J.L. Figueroa. Mechanistic Thickness-Design Procedure for Soil-Lime Layers. TRB, Transportation Research Record 754, 1980, pp. 32-36.

Publication of this paper sponsored by Committee on Track Structure System Design.

Better Track at Lower Cost: Advantages, Benefits, and Limitations of Track Renewal

G. RICHARD CATALDI

A discussion of the track-renewal method of railroad track maintenance is presented that emphasizes the operational advantages, economic benefits, and limitations of the method in comparison with the selective-maintenance method. Track renewal is the predominant maintenance method in Europe and is currently spreading to other parts of the world. The method consists of using a highly mechanized on-track system to completely rebuild the track in one continuous pass. Therefore, the track needs little work until the next rebuilding. In contrast, under selective maintenance (still the predominant method in North America), track structure components are replaced individually as they fail or wear out. There is growing interest in track renewal in North America, and this paper is based on research studies of track renewal sponsored by the Federal Railroad Administration and performed by Unified Industries Incorporated (UII). Those studies resulted in the development of a detailed framework for conducting a comparative economic analysis of track renewal versus selective maintenance within a North American context. The framework was subsequently used by UII in a sample analysis of 14 specific track-maintenance scenarios designed to reflect a range of track conditions. From the results of the sample analysis (reported in this paper), UII concluded that track renewal offers the potential of significant operational advantages, which include a completely rebuilt track structure, a major reduction in the track occupancy time needed for track maintenance, and a smaller workforce. In addition, it offers the prospect of major cost savings. On a long-term (life-cycle) basis, track renewal can generate a savings of $15 000-$30 000-plus/track mile under certain conditions. Furthermore, in a limited number of cases, there may also be a first-year track-renewal savings, despite the heavy investment needed in new ties. The limitations of track renewal include the need for major financial, planning, and management commitments and the inevitable risks associated with the introduction of a new method of maintenance in North America. A discussion of research areas for further study and a short summary that emphasizes the potential of track renewal to produce better track at lower cost are given in conclusion.

One of the principal conclusions of the Railroad Research Study (1) conducted by the Transportation Research Board (TRB) in the mid-1970s was that "with some modification and good maintenance, present track design is adequate not only for the present but also for the foreseeable future."

Good maintenance, however, is very expensive. Although some railroads are able to afford good maintenance, there are others that, because of the economic difficulties that beset the industry, are forced to settle for performing only limited maintenance and deferring the rest.

Taken together, the cumulative effects of maintenance deferral plus the impact of inflation, the increasing use of heavy unit trains, and the prospect of overall growth in railroad freight traffic because of both deregulation and national energy considerations indicate that both the need and the outlays for good track maintenance are in the process of rising sharply.

Given this trend, any prospect of increasing the cost-effectiveness of track maintenance should be of considerable interest to the railroad industry. One such prospect exists in the form of so-called track renewal, a method of track maintenance that has long been widely used in Europe. Before this method is examined, though, it is useful to look briefly at the maintenance method that still prevails in North America.

SELECTIVE MAINTENANCE

The selective method of track maintenance is traditional in the United States, Canada, and Mexico. Under selective maintenance, the rails, ties, and other track structure components are replaced on an individual basis as they fail or wear out. Allowing for government track and safety regulations, each railroad makes its own decision as to when each component is actually replaced.

Originally, selective maintenance was performed by section gangs; each gang did most work manually and was responsible for all track inspection and maintenance on a short length or section of the railroad. Since about 1950, most track-maintenance work has been performed by specialized mechanized gangs that cover long stretches of track. These include rail, tie, and surfacing gangs. Mechanized gangs customarily operate independently of one another because of their different production rates and the variations in service life of the track components. Consequently, each gang is usually a self-contained unit and has to include the tampers and other equipment necessary to leave the track passable behind them.

TRACK RENEWAL

Track renewal (also referred to as out-of-face renewal) consists of completely rebuilding the track structure in a single continuous process that involves renewing and leveling/aligning all the track structure components in a given section of track in a scheduled period of time, during which the track is closed to traffic. Following the initial rebuilding process, such a track section is customarily given only light section-gang or basic maintenance for perhaps 15 or 25 years or more (the length of the period depends on track structure, traffic, and environmental conditions) until it is again rebuilt under the track-renewal method.

The track-renewal method is a highly mechanized procedure that can be used both for wood-to-wood tie renewal and for wood-to-concrete tie conversion. It involves the application of large integrated track-renewal systems (TRSs). A typical TRS is designed around a specialized track-renewal machine (TRM) or pair of such machines that moves along the track and picks up the old rails and ties and installs new rails and ties in a single continuous process. The TRM is supported by other types of conventional track-maintenance equipment that perform such tasks as removing or inserting fasteners, cleaning the ballast, and aligning and tamping the track.

Progress in North America

In recent years, spurred largely by the successful European experience, the North American railroad community has become interested in the potential advantages of track renewal as an alternative to selective maintenance. As noted in TRB's Railroad Research Study (1), although the cost-effectiveness of selective maintenance has been improved over the years, there is now "growing concern that this approach may be reaching the limit of its potential efficiency. The alternative philosophy is one of complete rebuilding of the entire track system."

The railroad community's initial interest, however, has been largely in the specialized application of track renewal as an effective method for the rapid rehabilitation of main-line track based on wood-to-concrete tie conversion. At present, the National Railroad Passenger Corporation (Amtrak) is using a TRM for this purpose in the heavily traveled Northeast Corridor and Canadian National Railways (CN Rail) is using a TRM to install concrete ties on high-tonnage main-line curves and connecting tangents. Both Amtrak and CN Rail have reported that their TRM-based conversion programs are successful. In addition (although I do not know the results of the program), National Railways of Mexico has three TRMs for concrete-tie installation.

However, for the North American railroad community as a whole, the principal attraction of track renewal is that, as an alternative to the selective method for maintaining wood-tie trackage, it offers such potential benefits as significant long-term maintenance cost savings and a major reduction in the amount of track-occupancy time required for maintenance activities.

Given that there has been no firsthand experience in North America with such application of the track-renewal method and also that the economics of European track renewal are not readily transferable, the exploration of these potential benefits has had to be based on the application of specialized research techniques.

In 1978, the Office of Research and Development of the Federal Railroad Administration (FRA) initiated a track-renewal research program to determine the costs and benefits of track renewal and to disseminate the findings to the railroad community. The first phase of the program, conducted by FRA contractor Unified Industries Incorporated (UII), included preparation of a survey report on track renewal (2) and a companion report on the associated topic of wood-tie reuse (3), both of which drew in part on the pioneering work in track renewal done by David R. Burns at the Illinois Central Gulf Railroad Company (4).

During the second phase of the FRA program, undertaken in coordination with the Association of American Railroads' Committee on Track Maintenance Research and the American Railway Engineering Association's Committee 22, UII developed a detailed framework for conducting a comparative economic analysis of the track-renewal method versus the selective-maintenance method. This framework is intended to serve as a planning and decision-making tool. It is organized so that the reader can examine and modify the built-in assumptions and thereby apply the framework to specific situations.

In addition, UII undertook a sample analysis by using the framework to compare the results of applying both the track-renewal and selective-maintenance methods to 14 specific track-maintenance scenarios, each of which represents a particular set of assumptions concerning average tie life, average rail life, and other significant variables.

The results of the sample analysis together with the framework itself are included in the FRA report entitled Track Renewal System and Wood Tie Reuse Analysis (5). This paper is based almost entirely on the results of the sample analysis and other information contained in the FRA report.

Advantages and Benefits

UII concluded that, under certain circumstances, North American railroads could derive significant operational advantages and economic benefits from using track renewal in lieu of selective maintenance.

This conclusion assumes the use of only existing track-maintenance equipment. The TRM itself is the Canron P-811 (the type of TRM currently being used by both Amtrak and CN Rail). All the remaining equipment in the TRS is assumed to be conventional track maintenance machines used by North American railroads.

Operational Advantages

The seven principal operational advantages of track renewal are as follows:

1. A single pass of a TRS completely rebuilds the track. Although the TRM designs currently in use vary considerably in their method of operation, a standard TRM (such as the P-811) combined with appropriate support equipment replaces both rails and all the ties; cleans, sleds, or plows and replenishes the ballast; and finishes by putting the track in correct alignment and surface. In addition, a P-811-based TRS completely rebuilding the track moves along the track at much the same speed as does a mechanized tie gang that replaces 25 percent of the ties. After the track has been completely rebuilt, the only maintenance likely to be required before the next rebuilding is resurfacing, some strategic tie replacements, and possibly some rail maintenance. Depending on rail and tie life under the traffic and physical conditions present, the time between rebuildings can be as long as 20 or 30 years; this time span may be even longer on very light-density lines.
2. Not only can a TRS rebuild track but it can also simultaneously alter the design of the track itself. For example, Amtrak and CN Rail are using TRSs primarily for the purpose of converting from wood to concrete crossties. In one pass, each of these TRSs effects tie conversion, changes the tie spacing, and installs positive fasteners, as well as performs all the standard TRS functions. In addition, Amtrak is also using its TRS to do some track realignment. Other track design changes possible by using the TRS include complete grade changes and other types of radical track realignment, subgrade-structure rebuilding, and engineering-fabric installation.
3. Track renewal can greatly reduce the long-term need for track maintenance and thereby cut down on the amount of time that a track is closed to revenue service. The actual long-term savings in track occupancy time is likely to vary with the amount of maintenance required between renewals, which is affected by local conditions. UII's report estimated the long-term track occupancy time requirements for track renewal to be about 60 percent less than those for selective maintenance.
4. Track renewal requires a smaller workforce than does selective maintenance. UII examined the first-year differential between the two methods. If those operations that are exactly the same under both methods are excluded (setting new rail alongside the track, for example), UII calculated the workforce requirements to be 219 person days per mile for selective maintenance (change rails, change 25 percent of the ties, undercut and clean the ballast, and surface and line) and 97 person days per mile for track renewal (100 percent tie change, etc.).
5. There is also a significant labor cost differential in favor of track renewal for the track life cycle beyond the first year because fewer maintenance operations will be required. The economic gains associated with having a smaller workforce may be partially offset by the fact that the TRS supervisors and machine operators would require more training and therefore command higher wages. On the other hand, a better-trained and higher-paid workforce should have lower absentee and turnover rates than those currently experienced by railroad maintenance-of-way forces.
6. Under the TRS, safe and productive maintenance operations can be performed at any time of the day or night as well as during bad (although not severe) weather. CN Rail's P-811-based TRS, for example, regularly operates at night, when train traffic is lightest. Some European TRMs are equipped with enclosed work stations for the operators, which makes it possible to continue safe operations, although at a reduced speed, during periods of bad weather; similar enclosures could be provided for North American TRMs.
7. Given the generally hazardous nature of working on track, use of the track-renewal method means far fewer person hours of exposure to danger, principally because of the smaller workforce and reduced track occupancy time for maintenance.

In addition to the above, there are several potential operational advantages that may be possible with track renewal. One is that completely renewed track has a better overall average track structure than does selectively maintained track. A better track structure, in turn, could provide a railroad with several important side benefits for its operating department. It is appropriate to suggest (rather than claim) that these could include fewer train derailments, reduced lading damage, reduced freight-car truck and wheel wear, and reduced locomotive fuel consumption.

To summarize, track renewal offers several operational advantages that, although not all readily translatable into economic benefits, together tend to improve both track-maintenance activities and the overall movement of trains. These advantages are likely to be most attractive to railroads that (a) have high-density main lines in need of heavy maintenance and/or rehabilitation, (b) cannot afford extended or frequent interruptions of revenue service, and (c) are striving to develop more cost-effective maintenance procedures.

Economic Benefits

A North American railroad manager contemplating adoption of track renewal has to be able to at least estimate the likely costs and benefits associated with the changeover from selective maintenance. Because North American railroads differ considerably in their operating and maintenance policies and practices and also because track renewal is not yet well established in North America, it simply is not practical to develop a simple, universal formula for determining the economic feasibility of the change-over. As an alternative approach, UII has developed a detailed economic framework that enables the railroad manager to follow certain steps that lead eventually to a quantitative comparison of track renewal versus selective maintenance. The railroad manager (or any other interested party) can use this framework, modifying it as necessary, to explore the economic feasibility of track renewal within the context of a specific real-world situation.

To test the framework and provide a range of examples for analyzing the potential value of the track-renewal method, UII formulated 14 specific hypothetical situations designed to reflect a variety of real-world circumstances.

These situations, presented in the form of track-maintenance scenarios, are summarized in Table 1. The variables built into the scenarios include tie-replacement requirements, average tie life, average rail life, rail change schedule, track-renewal life cycle; and ballast-maintenance schedule. Twelve of the scenarios are for wood-tie tracks; the remaining two (scenarios 13 and 14) are for wood-to-concrete tie conversion.

The economic framework was then applied to these 14 scenarios, which resulted in some preliminary estimates of the benefits of track renewal. These are presented in Table 2 in the form of net cost savings per track mile--the net differences between track-renewal and selective-maintenance costs per track mile. These estimates are all based on 1980 material, labor, equipment, and fuel costs; long-term costs are given in 1980 dollars. (Although not broken down in the table, the costs include equipment depreciation or lease costs, equipment maintenance, labor, materials, and the cost of transporting ties.)

As is evident in Table 2, material credit constitutes a key element in considering the benefits of track renewal. Material credit is the net value of used track components after they have been removed from track; transported to a sorting, reclamation, or salvage facility; and either made ready for reuse or sold. In UII's study, only wood ties were considered in calculating material credit, since there was no significant difference between track renewal and selective maintenance for rail and other used track components. UII developed a formula for deriving the material credit for wood ties removed from track based on their remaining in-track service life or disposal value. This formula indicates that the higher the proportion of reusable ties to scrap ties, the greater the material credit.

Track-renewal cost savings can be maximized by applying material credit, since material credit is essentially realized in the first year when it can

Table 1. Track-maintenance scenarios.

		Selective-Maintenance Method		Track-Renewal Method								
					Cumulative Defective-Tie Level (years)					Ballast Maintenance		
Scenario	Tie Replacement in Year 1 (%)	Avg Tie Life (years)	Tie-Gang Cycle (years)	Avg Tie Life (years)	25%	50%	Next Renewal (years)	Avg Rail Life (years)	First Rail Change (years)	Undercut and Clean	Raise Only	Surfacing Cycle (years)
1	25	36	9	36	29	34	35	35	1	X		9
2	25	36	9	36	29	34	35	35	1		X	9
3	25	36	9	45	36	42	36	35	1	X		9
4	25	25	6	25	20	24	25	24	1	X		6
5	25	25	6	30	24	28	25	24	1	X		6
6	50	25	6	30	24	28	25	24	1	X		6
7	25	19	5	19	15	18	16	17	1	X		5
8	25	19	5	22	17	21	18	17	1	X		5
9	25	30	7-8	30	24	29	24	21	1	X		7-8
10	25	30	7-8	30	24	29	22	21	1	X		7-8
11	25	30	7-8	30	24	29	24	21	10	X		7-8
12	25	25	6	25	20	24	20	10	1	X		6
13[a]	25	25	6	50[b]	40	-	41	24	1	X		6
14[a]	25	19	5	50[b]	40	-	41	17	1	X		5

[a]Conversion from wood to concrete ties. [b]Average tie life given is for concrete ties.

Table 2. Long-term cost analysis summary.

	Economic Life for Comparison	Costs per Mile ($)		Track-Renewal Savings per Mile ($)		Internal Rate of Return on Track Investment (%)	
Scenario	(years)	Selective Maintenance	Track Renewal	Without Material Credit	With Material Credit	Without Material Credit	With Material Credit
1	34	221 900	225 800	-3 900[a]	18 700	7.3	-[b]
2	34	205 900	213 400	-7 500[a]	15 100	5.9	25.4
3	36	221 900	220 200	1 700	24 300	9.9	-[b]
4	24	224 900	225 100	-200[a]	17 700	8.5	31.2
5	24	224 900	216 800	8 100	26 000	12.1	31.8
6	24	229 500	216 800	12 700	26 800	33.2	-[b]
7	15	218 000	216 400	1 600	17 200	9.6	29.3
8	17	228 000	217 000	11 000	27 000	13.5	31.0
9	23	278 300	280 400	-2 100[a]	18 400	8.2	35.2
10	21	218 800	220 200	-1 400[a]	19 100	8.5	35.2
11	23	164 800	182 700	-17 900[a]	2 600	3.3	10.4
12	19	314 800	314 700	100	18 000	9.4	30.4
13	40	295 600	296 200	-600[a]	17 300	9.3	12.6
14	40	367 200	353 700	13 500	29 500	11.0	14.1

[a]Indicates loss of cost savings by using track renewal.
[b]Rate of return not calculated because of no extra cost in the first year (the rate of return is based on the differential cost incurred in the first year).

help offset the material cost of replacing 100 percent of the ties in the track. With material credit, all 14 scenarios in Table 2 provide long-term savings. All but one of them can generate a long-term cost savings of \$15 000-\$30 000+/track mile over selective maintenance. The exception, scenario 11 (rail change not coincident with first-year track renewal), still provides a cost savings, although it is only about \$2600/track mile.

Without material credit, the cost savings derived from track renewal is reduced by \$14 100-\$22 600/track mile/scenario, thereby eliminating the cost savings in seven scenarios (as indicated by the parentheses) and lessening it in the others. Even so, four scenarios still have a long-term cost savings of \$8100-\$13 500/track mile (and that assumes that all the old ties are simply thrown away).

Both wood and concrete tie installations are economically advantageous on a long-term basis if installed by the track-renewal method. With material credit realized, the wood-tie scenarios (except scenario 11) have long-term savings of \$15 000-\$27 000/track mile and internal rates of return of at least 25.4 percent (Table 2). Although concrete-tie installations are projected to have large long-term savings, the payback period is much longer, which results in lower internal rates of return (12.6 and 14.1 percent in scenarios 13 and 14).

In examining the economic benefits of track renewal, it is essential to consider first-year costs as well as long-term costs, since first-year costs are generally higher for track renewal than they are for selective maintenance, principally because of the additional expense of materials. As shown in Table 3, the added cost for track renewal can be as high as \$30 800/track mile when concrete ties are installed (scenario 14). The added cost per track mile is \$2100-\$6600 in eight of the scenarios and zero in two scenarios; in scenario 6, track renewal is actually \$9900 cheaper than selective maintenance in the first year.

Given the magnitude of first-year costs, a railroad manager needs to examine both the options and financial resources carefully when contemplating track renewal. First-year break-even analysis is a useful management tool. As shown in Figure 1, track renewal of wood-tie track can be economically feasible in the first year if tie and rail renewal coincide, if material credit is taken for the used ties, and if more than 32 percent of the ties in the track need to be replaced. When no material credit is taken, the break-even point is approximately 56 percent tie replacement.

Figure 2 presents a comparable break-even analysis for wood-to-concrete tie conversion. Such conversion will be cheaper in the first year if more than 75 percent of the ties need to be replaced and if material credit is taken. Without material credit, that figure climbs to about 90 percent.

In addition to examining the overall economic benefits associated with using a TRS, UII identified one specific track-maintenance operation that is likely to be more cost-effective when performed by the TRS than when done separately. That operation is ballast undercutting and cleaning. With conventional ballast undercutting and cleaning, loose spikes and ties fall away when the rails are raised; this adds to the labor costs (for lifting or removing the ties) and slows down the operation. However, when a TRS ballast cleaner follows immediately behind the TRM and spikers, all the ties are new and freshly spiked and therefore stay with the rails when they are raised. The lower labor requirement and higher production rate result in about 28 percent lower costs for ballast undercutting and cleaning when it is included in the TRS operation.

Table 3. First-year cost analysis summary.

	Costs per Track Mile (\$)			
Scenario	Selective Maintenance	Track Renewal	Track Renewal Minus Material Credit	Net Track Renewal
1	189 300	211 900	189 300	0
2	178 200	204 300	181 700	3 500
3	189 300	211 900	189 300	0
4	189 300	211 900	194 000	4 700
5	189 300	211 900	194 000	4 700
6	207 700	211 900	197 800	-9 900[a]
7	189 300	211 900	195 900	6 600
8	189 300	211 900	195 900	6 600
9	189 300	211 900	191 400	2 100
10	189 300	211 900	191 400	2 100
11	31 300	69 800	49 300	18 000
12	189 300	211 900	194 000	4 700
13	189 300	236 100	218 200	28 900
14	189 300	236 100	220 100	30 800

[a]Cost cheaper than in first year.

Figure 1. First-year break-even analysis: track renewal versus selective maintenance (wood-tie track).

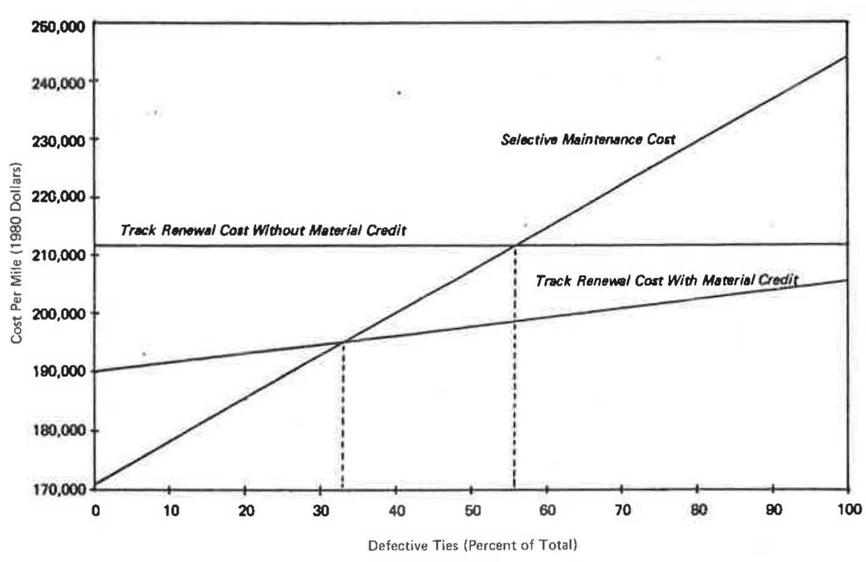
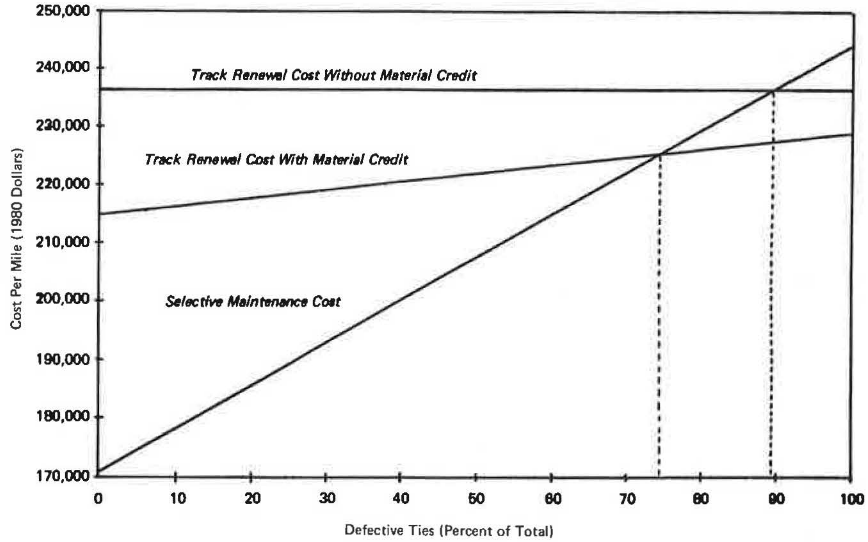


Figure 2. First-year break-even analysis: track renewal wood-to-concrete tie conversion versus selective maintenance of wood ties.



Other Potential Advantages and Benefits

Reflecting current interest in North America and prevailing use in Europe, UII's research study focused on the track-renewal method as a means of long-term track maintenance. However, it is evident that TRMs are also suitable for performing certain other specialized functions. Some TRMs are designed specifically for one such function, whereas others can perform several functions. Taken together, the 10-20 types of TRMs currently available can build new track, remove abandoned track, change one or more track design characteristics (alignment, for example), and upgrade track (change rail weight, tie type and size, fastener type, ballast type, etc.). It may also be possible to use track renewal to improve the subgrade structure, particularly by inserting engineering fabrics beneath the ballast.

One specialized track-renewal application that may warrant consideration during the 1980s, especially if there is a resurgence of railroad freight traffic, is the rehabilitation or upgrading of deteriorated tracks, particularly branch lines. Track renewal offers a method of rebuilding the track that is both rapid and cost-effective.

UII's track-renewal research study assumed that all TRMs to be used in North America would be owned and operated by the user railroad. This assumption has been built into the economic framework and into all 14 scenarios. Nevertheless, it is useful to consider ownership alternatives.

Track renewal would appear to lend itself readily to contractor ownership and operation. Contractors already perform all track-maintenance functions for many short lines and should be able to serve a track-renewal market. In addition, it is possible that they could perform regular track-renewal maintenance for class I railroads if the economics were beneficial to both the railroad and the contractor and if railroad labor agreements would allow such outside work.

Another ownership alternative would be for a TRM to be owned wholly by a nonrailroad entity or jointly by a consortium of railroad and nonrailroad entities and for the machine to be leased to individual railroads on an as-needed basis. This approach would enable railroads that had limited track-renewal requirements to benefit from application of the track-renewal method.

Limitations

The principal limitation or disadvantage associated with track renewal is the element of uncertainty attached to a large-scale commitment based on a new method of track maintenance that has yet to be fully established in North America. It appears likely that detailed cost-benefit analysis, selective-risk analysis, and prudent decision making can reduce this uncertainty but they cannot eliminate it; after all, the track-renewal life cycle is 25 years or more.

Certain operational factors must also be taken into consideration. For example, the track-renewal method combines the two largest and most complex track-maintenance elements now in use (tie and rail gangs) plus two other mechanized gangs (ballast undercutting and cleaning and surfacing and lining), which creates a far more complex operation for planning, supervision, and logistics. To use a TRS effectively, therefore, the railroad must be willing and able to make all the necessary management and organizational as well as financial commitments to a track-renewal decision.

Track renewal is most attractive economically when it combines certain maintenance operations (tie and rail replacement, ballast cleaning or replacement, wood-tie reuse and/or disposal, etc.) under certain conditions (for example, when 25 percent or more of the ties in the track need replacing). Consequently, it is essential that any prospective North American user of track renewal recognize that the method does not necessarily have universal application and that detailed evaluation, analysis, planning, and corporate commitment are prerequisites for successful track-renewal programs.

AREAS FOR FURTHER STUDY

North American railroads have had little direct experience with track renewal and even that has been limited to wood-to-concrete tie conversion. Consequently, they are likely to find it difficult to determine reliably the full range of the pros and cons of a changeover to track renewal, especially in localities that use wood-tie track. As a result of its study of track renewal, UII identified several areas for further study that could contribute to both a more-useful economic framework and a more-effective and reliable assessment of the track-renewal option. The eight principal areas are as follows:

1. Service life of wood ties installed by track-renewal method: Possibly the uniformity of the renewed track structure could extend the in-track life of wood ties compared with the selectively maintained track. As shown in the UII study, a 20 percent increase in average tie life (an assumption in scenarios 3 and 5) could reduce long-term track-renewal cost savings by as much as $6000-$9000/track mile. A research study could examine this issue, state the conditional factors, quantify the increase in service life, and also determine the likely pattern of individual tie failures in renewed track over the track's life cycle.

2. Remaining service life of reusable wood ties: What are the best methods of handling and processing used wood ties to maximize their life when reinstalled in track? Research on this issue, in addition to helping to refine UII's material-credit formula, also could provide useful information for the cost-conscious railroad industry.

3. Profitable disposal of used wood ties for landscaping and other nontrack uses: UII's study assumed a flat rate value of $2/tie. Research could lead to alternative values for the framework and the identification of marketing possibilities for the railroads.

4. Interim selective-maintenance requirements during track-renewal cycle: Certain assumptions were made in UII's study that should be reexamined to permit a more-precise determination of overall long-term track-renewal costs.

5. Quantification of costs and benefits to be derived from certain factors identified in UII's study that could have a significant impact on any decision to change over to track renewal: These factors, all of which assume an advantage of track renewal over selective maintenance, include (a) the value of reduced track occupancy time needed for track maintenance, (b) the value of reduced energy consumption, and (c) the value of reduced equipment and lading damage. The determination of these values could play an important role in any decision to adopt track renewal.

6. Design, performance, and safety specifications for TRMs in North America: Existing TRM designs have been created for track-renewal operations outside North America, and the few North American machines are all modified European machines. An industry-wide survey could lead to the eventual development of wholly North American TRMs and provide realistic TRM performance options for use in UII's economic framework (currently based solely on the assumed use of a particular TRM, the Canron P-811).

7. Economic impact of TRM ownership options and specialized applications.

8. Testing of economic framework: Given the hypothetical nature of the economic framework developed in the study, the framework should be tested by one or several railroads. The results should be used to strengthen the framework's value as a research tool and should be shared with the railroad community.

SUMMARY

Under certain circumstances, the track-renewal method offers significant operational advantages and long-term cost savings in track maintenance over the selective-maintenance method. It appears likely that at least some North American railroads could benefit from adopting the track-renewal method.

There is need for further study to expand knowledge of the track-renewal methods, improve the forecasting of associated costs and benefits, and provide potential users with more and better information for planning. To these ends, the methodology of UII's economic framework should be tested in a real-world situation and the results disseminated to the North American railroad community.

With continued research and information exchange, track renewal eventually may help provide North America with better track at lower cost.

ACKNOWLEDGMENT

This paper is based on research performed by UII for the Office of Research and Development of FRA. Railroad companies and railroad equipment manufacturers are identified here solely because such identification is essential to the purpose of the paper.

For assistance in preparing this paper, I extend my thanks to FRA research manager Claire L. Orth; to my UII colleagues Paul Elliott, David N. Elkaim, and Virginia O. Clem; and to UII consultant David R. Burns.

REFERENCES

1. Rail Transport Research Needs. TRB, Special Rept. 174, 1977.
2. G.R. Cataldi, D.N. Elkaim, and K.W. Larsen. Track Renewal Systems: A Survey Report. Unified Industries Incorporated, Springfield, VA; Federal Railroad Administration, Rept. FRA/ORD-79/43, 1979. NTIS: PB 300866.
3. G.R. Cataldi, D.N. Elkaim, K.W. Larsen, and P. Elliott. Wood Tie Reuse: A Survey Report. Unified Industries Incorporated, Springfield, VA; Federal Railroad Administration, Rept. FRA/ORD-79/44, 1979. NTIS: PB 114044.
4. D.R. Burns. The Economics of 24-Year Cycle Track Maintenance Using High Speed Track Renewal Trains. Illinois Central Gulf Railroad Co., Chicago, 1976.
5. G.R. Cataldi and D.N. Elkaim. Track Renewal System and Wood Tie Reuse Analysis. Unified Industries Incorporated, Springfield, VA; Federal Railroad Administration, Rept. FRA/ORD-80/63, 1980. NTIS: PB 81 125510.

Publication of this paper sponsored by Committee on Track Structure System Design.