Branchline Rail Replacement Strategies

D. E. STAPLIN AND T. R. WELLS

To increase profitability, railroads need to improve their capital budgeting processes, which include capitalized maintenance projects such as rail that have traditionally been based on historical funding levels. The Association of American Railroads, through its Track Maintenance Research Committee, has developed a model for financial analysis of rail replacement projects, the Rail Performance Model. Use of this model has been demonstrated for mainline cases. In this paper its use to analyze branchline relays, including the transfer of used rail from one location to another, is described.

The pace of change in the rail industry has accelerated just as it has in many other traditional U.S. businesses. A trip down the Monongahela and Ohio River valleys past the silent steel mills brings one to grips with the enormity of what has happened and continues to happen to the U.S. economy.

The rail industry is struggling to cope with the changes to its traditional customers and attempting to learn to be more competitive in a deregulated environment in other markets. An earlier trend to large mergers, such as the CSX Corporation, has now been followed by downsizing. Regional and shortline railroads have sprung up from branchlines spun off by large carriers.

As always, the industry is concerned about its rate of return. CSX, for example, experienced an average return on invested capital of approximately 6.5 percent from 1982 through 1986. Return on shareholder equity averaged 9 percent, exclusive of special charges (*1*). In a regulated environment blame for a low rate of return was usually laid at the doorstep of the rule-making agencies. Under deregulation it is no longer possible to stand pat and point a finger. Therefore, it is doubtful if a "business-as-usual" atmosphere would now exist even if the domestic steel industry was still experiencing 100 million ton-years or Detroit was making 10 million automobiles.

Under depreciation-accounting guidelines adopted by the regulatory agencies in the early eighties, large-scale maintenance-of-way programs such as rail relays, crosstie replacement, and surfacing were freed from having an immediate impact on earnings. But the change from operating to capital expense was soon followed by the realization that steel and wood products could not be purchased with "earnings." Cash was and is still the preferred medium of exchange, and the increasingly competitive atmosphere has made cash scarce. There is a tendency today to view large capital replacement programs in the same light as capital additions and betterments.

Meanwhile, out on the line-of-road chief engineers, division engineers, and roadmasters can now see the need for track improvement projects just as clearly today as they could in the past regardless of what name the accountant attaches to the dollars or what competitive conditions are like. What is needed is a medium by which both the maintenance engineers and the financial officers can feel comfortable about the allocation of maintenance funds.

Fortunately, in the late seventies a largely volunteer group under the auspices of the Association of American Railroads (AAR) began to prepare for the day when maintenance dollars would come under the same scrutiny as funds for a new yard. The Track Maintenance Research Committee, as it has come to be known, has developed an economic model for rail replacement known as the Rail Performance Model (RPM) (*2*). Although largely developed for heavy tonnage mainline situations, the RPM can be and has been modified for branchline use. This discussion will concern the use of the economic framework of RPM for making decisions on branchline rail replacement, giving an explanation of how the inputs to the economic and engineering framework of RPM can be developed for the branchline case.

Branchlines are a source of great interest for three reasons:

1. Large-scale upgrading programs have greatly eliminated jointed rail from heavy-tonnage, high-speed mainlines. CSX and other major railroads generally lay more than 80 percent of such routes with continuous welded rail (CWR). The replacement of jointed rail on these lines is nearly complete. This removes a potential source of secondhand rail for branchlines.
2. Concentration of joint elimination programs on mainlines has resulted in postponement of programs for branchlines. Unfortunately, restricted budgets now often do not permit a large-scale assault on these lines similar to that mounted on the mainlines in the seventies and early eighties.
3. The regional and shortline carriers often consist only of what would be considered branchlines by the large carriers.

RAIL REPLACEMENT PROCESS

At the risk of putting the cart before the horse, it seems prudent to examine the way in which rail is replaced before examining why. Some of the methods described here are used by all railroads regardless of size. Rail replacement programs

D. E. Staplin, CSX Rail Transport, P.O. Box 45052, Jacksonville, Fla. 32232-5052. T. R. Wells, CSX Rail Transport, 500 Water Street, Jacksonville, Fla. 32202.

can be divided into a source-and-use classification much like a crash-flow analysis.

Source

There are four main sources of rail. The most obvious is new rail purchased from steel companies. A second source would be used or secondhand rail purchased in the marketplace. Although this is perhaps not an important source for large railroads, it may well be the only source for a shortline. A third source is secondhand rail made available from track retirements. Finally, secondhand rail can frequently be reclaimed from a use site. Sometimes this rail can be used as is and other times it must be processed. This could include cropping out damaged ends or an internal flaw. Some railroads straighten rail that has been bent in service due to poor support or other surface breakdowns. Although inventory could be considered a source, it is always derived from one of the other four.

Use

Large replacement programs constitute the main use of rail. Both new and secondhand rail are installed out-of-face over a significant distance, generally more than 5 or 6 mi for a large railroad. Often these relays reach 40 mi in length. Such programs use large mechanized gangs and since about 1960, most of the rail laid in this manner has been continuously welded.

A second form of replacement is the patch program, used when local conditions dictate a smaller quantity but at least several rail lengths. Typical examples include replacement due to curve wear, corrugations, an epidemic of engine burns (which occur frequently where trains must stop to pick up and set off and are also common near the entrances and exits of passing sidings), and replacement of joints left in a track from wreck panels. The normal unit of such programs would be one or more ribbons of CWR (1,400+ ft), although some roads use jointed rail on higher-degree curves to allay fears of buckled track and for ease of transposing. This type of program is also seen occasionally for replacing rail on bridges. Rail utilized may be secondhand, new standard, or new premium.

A third major use of rail is for spot replacement, one rail or less at a time. The reasons for this are usually compelling, because such spot work is very labor intensive. The main reasons include fatigue cracks (or breaks), chipped or battered ends in joints, bent rails, and engine burns. In CWR territory, field welding of the replacement is common. In cold regions joint bars must sometimes be applied first until weather conditions moderate and the weld or welds can be made without fear of adverse thermal stress patterns.

A fourth major use of rail is for new trackage, often in yard or industry locations, for which secondhand rail is used.

Finally, there is a catch-all miscellaneous category. Wreck panels, road crossing programs, and switch material all require rail, as do bonded insulated joints.

As a final consequence, the rail replacement process will generate scrap. Unless inventories are built up or depleted, the amount of scrap generated from relays (measured in lineal units) must equal the new and secondhand purchased rail plus the rail utilized from retirements.

Case Study

Before its consolidation into a single CSX road, the Seaboard System Railroad sources and uses for a typical year were as shown in Table 1.

It may be noted that 394 mi of source rail produces total use of 731 mi, which appears to be unbalanced. The reason for this is that rail reclaimed from the relay of the source material (394 mi less 24 mi of construction rail) cascades into other relays, a process that will be discussed next. In reality cascading creates an internal source that accounts for another 337 mi of rail.

CASCADING OF RAIL

Branchlines are often the recipients of rail relay through a process called cascading, which is the removal of rail and its relay to an area of lesser use. From the standpoint of the RPM, this cascading often occurs before the point of optimum life, when only a single stage of use is considered.

History

Almost from the start, railroads have been made up of lines with widely varying service demands. Annual tonnage, axle loading, speed, track geometry (curvature), and service class (passenger, bulk, merchandise, etc.) varied widely. Often lines having higher annual tonnages were also operated at higher speeds. Although the reduction of intercity passenger trains on most routes has reduced the concern for speed somewhat, freight axle loads have pushed higher. Some hint at the diversity of line characteristics today can be seen in Figure 1, which shows CSX track and traffic conditions for 1986 as reported in the Annual Report to the Interstate Commerce

TABLE 1 SEABOARD SYSTEM RAILROAD: SOURCES AND USES OF RAIL

Source of Rail		Use of Rail (program type) (mi)					
Type	Miles	Large Relays	Curve and Miscellaneous Patch	Single Replacements	Construction	Switch and Other	Wreck Panels
New	224	205	10		4	5	
New premium	80	30	40			10	
Secondhand purchase	40	40					
Retirements	50	30			20		
Secondhand	NA	210	70	30	10	10	7
Total	394	515	120	30	34	25	7

SOURCE: CSX Internal Records.

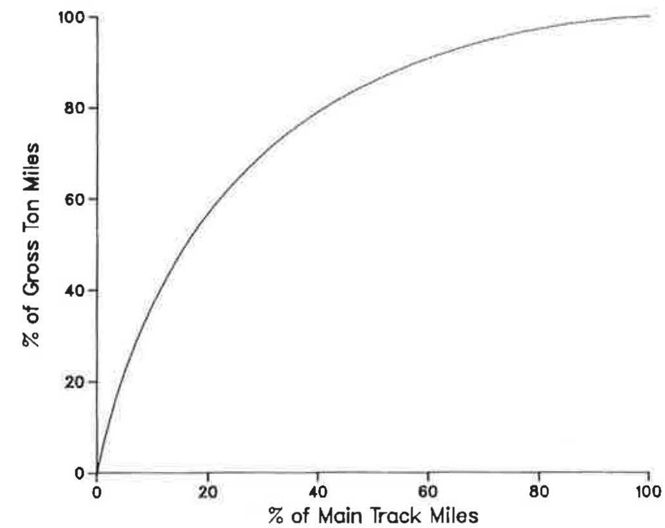

FIGURE 1 CSX track and traffic distribution.

Commission (*3*). Just focusing on annual tonnage as a factor, 66 percent of all gross ton-miles is carried on only 27 percent of the track and 95 percent of all gross ton-miles is carried on 58 percent of the main tracks.

Improvements in Rail Design

As service requirements increased, rail was improved. Design improvements first concentrated on heavier, stiffer sections to improve ride quality. Improved cross-section design reduced local stresses such as those at the head web fillet junction. Longer rolled lengths produced fewer joints. Better drilling patterns and continuous welding improved the joint area itself.

Better steel also contributed to rail endurance. Higher yield strengths, improved hydrogen elimination, and cleaner grain structure are significant examples.

Natural Process

The tendency of service demands to be concentrated and the steady introduction of improved rails made cascading a natural process. The introduction of control-cooled rail, for example, was a very important factor in increasing the margin of safety for high-speed passenger traffic. Today railway maintenance officers would cringe at the thought of running 100 mph on jointed 100-lb non-control-cooled rail. Earlier maintenance engineers reaped the benefit of using the displaced 100-lb rail for branchlines laid with 60- and 70-lb rail.

Cascading Today

Improvements in rail technology have vastly increased reliability of rail. Installation of CWR on lines with heavy traffic has improved reliability and safety. Still, cascading remains a valid process for several reasons.

First, as Figure 1 indicates, there is still a variety of lines to be maintained. Even the downsizing trends will not eliminate this variety, especially when yard mileage is considered. Considering the tendency of shortlines to be formed when medium- and low-density lines are spun off, there may exist in the future a market for large railways to buy new rail and sell the released secondhand rail to their smaller partners.

A second reason for cascading is that rail manufacturing technology is still improving. Medium- and high-strength rails, continuous casting, and longer lengths have all become widely available in the last 10 years.

Maintenance officers are also becoming better informed for decision making. It is now known that the Weibull distribution can be used to model the occurrence of fatigue defects in rail (*4*). The increase in rates of failure causes the maintenance cost to escalate. Maintenance costs related to wear and joint conditions also worsen with time and use. Cost control, then, can be a very important reason for cascading rail. Figure 2 shows an example of reducing annual rail defects (and therefore costs) by cascading. As noted in the preceding section, earlier engineers did not upgrade the railroads totally. CSX, a composite of at least six major railroads, still has nearly 50 percent of its total trackage laid with jointed rail. Moreover, as shown in Figure 3, there is still much lightweight rail in the mainlines and branchlines. Inclusion of sidings and yards would make the percentage of lightweight rail much higher.

GENERAL ECONOMIC FRAMEWORK

At CSX, the Engineering Department staff was challenged to prove that removing welded rail and relaying it on a branchline was cheaper than simply waiting and buying new rail for that line. The RPM was used for this analysis. Cascading, it was reasoned, was economical if the present value of moving the welded rail (and associated future maintenance cost) was less than the total optimum (lowest) life-cycle costs for both the new and secondhand relay sites. These optimums for the sites assumed buying new rail and running it until scrap value was reached. To perform this analysis, specific candidate sites must be identified along with their history (tonnage and defects) and all related maintenance costs.

The general economic concept is shown in Figure 4. Premature replacement in the new rail territory will result in a higher

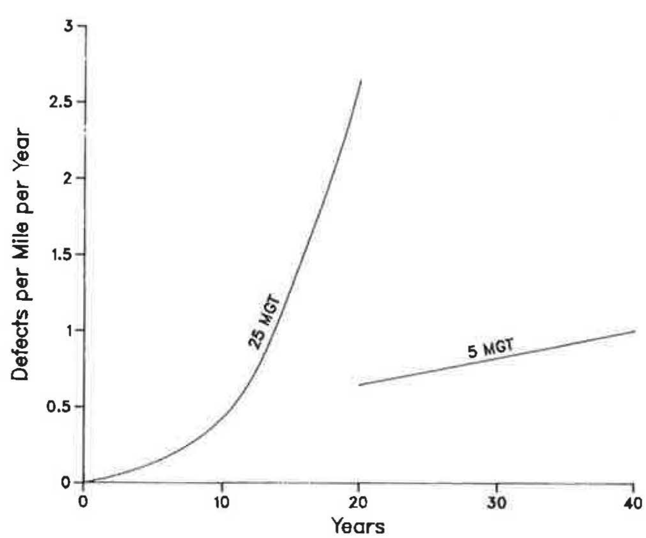

FIGURE 2 Rail cascade impact on yearly defects.

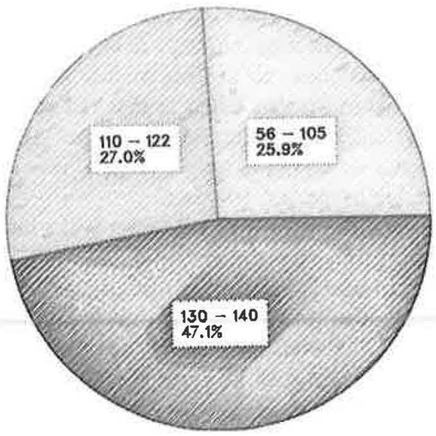

FIGURE 3 CSX transportation: weights of rail in main and branch track (rail weight in pounds per yard).

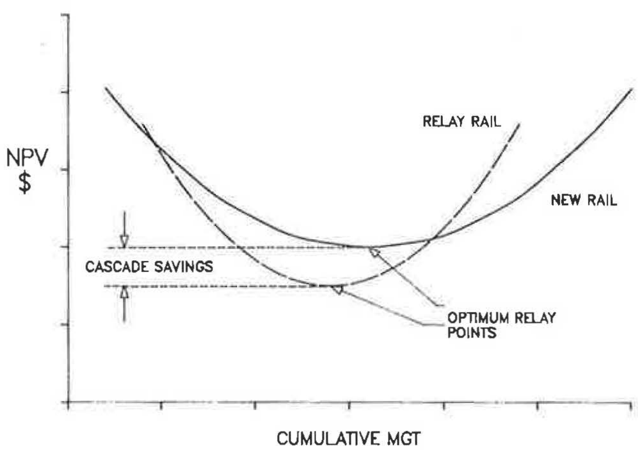

FIGURE 4 Economics of rail cascading.

net present value of costs compared with the optimum relay point. The optimum net present value can be maintained, however, if the railroad receives more than scrap value for the released rail. This seems plausible because the rail is still usable. Even though secondhand rail would cost more to maintain than new rail if both were laid at the same time, the secondhand rail site may receive the benefits of being rid of the existing, troublesome rail sooner or at a lower total cost. It is these benefits that offset the increased costs of maintenance. There may even be specialized cases in which the cascading process eliminates a costly maintenance problem in new rail territory. On CSX, for example, rail welded years ago by the oxyacetylene method is experiencing high rates of weld fatigue. By cascading this rail (rewelding in the process) it is often possible to kill two birds with one stone, so to speak.

PRACTICAL EXAMPLES OF CASCADING

With the diversity of line characteristics and rail conditions on even a medium-sized road, the possible combinations for cascading are seemingly infinite. There are three general cases that draw in many of the site-specific possibilities.

Main to Branch

The most common example is that which has already been discussed—new rail laid on lines of heaviest use, which releases rail for branchlines experiencing high maintenance costs. Table 2 gives a relative idea of the financial stakes involved, using CSX as a hypothetical example. The reason a higher average life might be expected if rail is cascaded may be clearer after the next example.

Tangent to Curve

Often patch rail must be installed where a local condition such as curvature causes more rapid deterioration than that in adjoining rail. On high-tonnage lines this situation may warrant use of a premium rail. On medium- and lower-tonnage lines another alternative exists. Were new rail to be laid at such locations, say a curve, premium grades could not be justified. Suppose that the hypothetical life of new standard rail in this branch curve regime is 300 million gross tons (MGT) before scrapping. It may be possible to take rail from a mainline with 350 MGT and get another 250 MGT on the curve for a total life of 600 MGT. If side (high rail) or vertical (low rail) head wear is the condemning factor, such an example is entirely feasible. Thus the possibility of life extension through cascading is significant.

Transposing rail is a special subcase on which there are many opinions but little hard data. The authors encourage future work in that area.

Branch and Curve to Industry and Yard Tracks

All maintenance officers have had the experience of being on inspection and finding rail recently laid in track that is only marginally better than scrap. The classic reply to the inquiry that this generates is, "You should have seen what was here before!" Often this reply makes perfect sense. CSX in the past 5 years has averaged approximately 150 track-mi of curve patch annually. Premium rail and better lubrication may

TABLE 2 CSX HYPOTHETICAL NEW RAIL REQUIREMENTS

Case	Total Traffic (million gross mi)	Avg Total Life of New Rail (MGT)	New Rail Required Annually (track-mi)	Cost of New Rail Purchases at $400/Ton ($ millions)
Lay only new rail	291,984	500	584	50.2
Cascade	291,984	700	417	35.8
Difference		200	167	14.4

reduce this in the future, but it is not yet possible to estimate the net requirement. It is clear that significant mileage will still be involved and that disposal of this rail will also be necessary.

The normal case is that the released material is welded, of a heavy section, and contains one or more of the following defects: side wear, flattened head (vertical wear), plastic flow, and corrugation or other surface defects. If only mainline and branchline use is considered, this rail would be scrapped.

Consider Figure 3 and the 25 percent of the railroad still laid with lightweight rail or those miles and miles of yard track. This track needs relief from terrible joint conditions and girder strength to support relatively slow-moving loads. Consider the 56-lb rail that is laid in an elevator track to support 100-ton covered grain hoppers. Rail that is scrap for mainline replacement purposes is traded for rail that is scrap for another purpose. The relief that this "near-scrap" rail gives in some deplorable back track will cause a roadmaster to drag a released ribbon for miles. Truly, this is a case of the frog turning into a prince.

VALUE OF RAIL

Rail installation is one railroad activity in which the ratio of material value to labor costs is high. In an economic or budget analysis the price of the rail and associated fasteners needs to be given careful consideration. Rail that is purchased has a well-defined value, but as has been shown (Table 1), it may account for less than 50 percent of rail actually used. Is the rest automatically free? Rail already on the property is an asset and therefore must have some sort of value. To overcome this problem most railroads have an internal or "book" value for secondhand rail. Often it is based on an accounting convenience, which bears only a coincidental resemblance to economic values. To make sound economic decisions on branchline relays, realistic values must be established.

Economic Value as Determined by RPM

With the RPM, it is possible to estimate the value of existing rail being replaced by new rail. The analysis is based on traffic

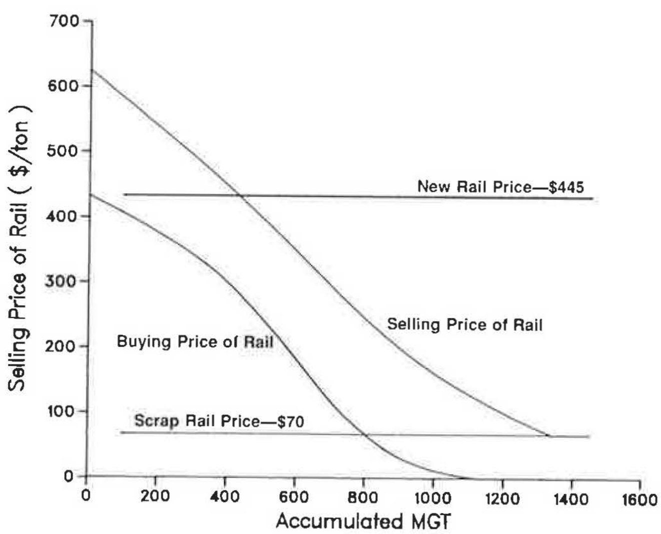

FIGURE 5 Minimum selling price needed to replace existing rail.

characteristics of the particular site and the fatigue history of the present rail. Figure 5 shows the concept of a "selling" value for rail in track (*5*). It is the minimum price that the owner would have to receive to be able to purchase and install new rail in replacement for the existing rail. The basis for the comparison is running the existing rail to scrap value. As the tonnage accumulates and the condition of the existing rail worsens (maintenance costs go up), the owner would have to receive less and less to persuade him to replace the rail because he is getting closer to the point when he will have to do so anyway.

This concept is extremely useful if a railroad is considering selling secondhand rail. It could prove especially beneficial for setting prices if the sale of rail to shortlines is considered. It is also useful in analyzing cascade opportunities, as will be seen in a later section.

Another curve produced by the RPM is termed the "buy" value curve. This curve shows the price the railroad could afford to pay for rail of comparable quality for use at that specific location (*5*). If a railroad is buying rail of a known defect and tonnage history for a specific use, it has a powerful tool to ensure value in its purchase.

Market Value of Rail

The existing market for new rail is relatively well defined and understood. The market for secondhand rail is relatively small and not well defined or understood. Moreover, recent abandonments due to consolidation and downsizing have changed that market.

Secondhand rail suitable for use in main tracks carrying any appreciable traffic is very scarce and commands a high price, usually between 60 and 70 percent of new. Because railroads usually find this sort of rail valuable for internal use, they rarely sell it. Normally it becomes available from a large abandonment where it cannot be immediately used and the time value of money to carry the inventory cannot be justified. Another source is through liquidation proceedings such as the Rock Island bankruptcy. The price is quoted "as is," which usually means with bolt holes. The price to the site at which the rail will be used must include any processing, such as cropping. Thus, if 132-lb rail is purchased for $275/ton, cropping costs $5/rail, and scrap sells for $80/ton, the net price of rail ready for welding is almost $300/ton, exclusive of freight.

Lighter weights of secondhand rail naturally command a lower price. Often this is in the range of 30 to 40 percent of new on a per-ton basis. Several years ago, 100-lb rail was scarce and brought a relatively high price for construction of yard and industrial facilities. Sections of 90- and 85-lb weights were more commonly available and therefore less valuable. With downsizing, 100-lb material is now commonly available and lighter weights probably do not bring a large premium over scrap. CSX will no longer weld rail under 100 lb/yard.

If relay rail is purchased to be used as jointed rail, care needs to be exercised over the drillings to ensure compatibility with existing rail. Purchasers can expect to pay a premium for drillings that are not common if they must obtain them to match their own.

Alternative Uses

There are classes of relay rail that do not fit easily into either of the previous uses. Earlier in this discussion, it was indicated that CSX is often happy to install worn, heavy weights of rail in sidings and yards. From the perspective of the RPM, this rail is not fit to install in a main or branch track and therefore has a value near scrap. From a market standpoint, who would be willing to buy this rail? A major railway would usually have this class of rail available on its own property. A contractor would not pay the same price per ton (and therefore a higher price per foot of track) for 100-lb rail when the lighter rail is perfectly adequate for a siding. Yet, if the railroad is willing to use the rail, how can it be claimed to have only scrap value?

There is another approach that considers the railway's alternatives. First, the railroad will never accept lower than scrap value, so that price becomes the floor. Although the worn heavier weights cannot be sold at sidetrack prices (per ton), the railroad might be able to sell them at the same price per foot. Then the buyer could afford to buy the heavier rail because there would be no price premium. If the railroad has lighter weights of rail in its stock that could have been used wherever the worn heavy rail was installed, an opportunity cost is assessed for the weight differential when this lighterweight rail is scrapped. More cash could be generated by scrapping the heavier rail. An example of such a calculation is as follows:

Given that the market price of 100-lb relay rail is \$160/ton and the market price of scrap rail is \$80/ton,

Calculate

1. Value of 132-lb siding rail if railroad has no surplus of siding-grade rail:

Price = \$160/ton × (100/132)
= \$121/ton

2. Value of 132-lb siding rail if railroad has surplus siding-grade rail:

Price = \$121/ton + \$80/ton × [(132 − 100)/(132)]
= \$140/ton

Under a surplus condition, the value of the 132-lb siding rail could be as high as \$140/ton or 75 percent above scrap. If a railroad needed siding-class rail of all weights, the value of the 132-lb rail of that class would drop to \$121/ton or 51 percent over scrap. Two cautions must be exercised in connection with these values. By laying heavier weights of rail in sidings, the railroad may have to spend more cash for fittings. Frequently, surplus tieplates are readily available for 100-lb rail but not for 132-lb rail. Buying new tieplates at \$4.50 each would add an additional \$90 to \$102/ton to the cost of installing the 132-lb siding rail. A second caution has to do with the buying and selling prices of rail. A railroad can earn market values for its secondhand rail if it sells directly to the end user. Often the railroad sells this rail to a broker, who must earn a profit. If the market value of 100-lb rail is \$160/ton, the carrier may realize only \$120 to \$130/ton by selling to a broker. Inventory carrying costs must also be considered whenever the rail is held, whether by a carrier or a dealer.

Summary

The three methods of valuing rail mentioned can be used to solve particular problems. There may also be cases in which rail value can be determined by using more than one method. Good economics dictates that the highest alternative price should set the value.

Traditional methods of grading and valuing rail have included measuring head and side wear, plastic flow, and examination of surface condition. The methods outlined here would be satisfactory for estimating purposes, but inspections should be included before buying or selling actually occurs. The best decisions can be made with sound inspection and when the history of the rail and future use are both known. Because the market for secondhand rail is relatively small, it is also suggested that relay economics be tested by using a range of values. The chances of estimating the value with precision are low because of potential price variability if there is no firm quote on the table.

CASCADE ANALYSIS WITH THE RPM

The RPM calculates optimum rail life by using expected future maintenance, relay, and other pertinent costs and treating them with the accepted financial analysis tool of net present value (NPV). This method is used by analysts to incorporate time factors into an economic analysis. The NPV method will be reviewed briefly as a beginning of the concepts underlying the RPM and cascade analysis.

Net Present Value in the RPM

In the NPV concept, cash in hand today is valued more than cash in hand at a future time. As an example, if \$1,000 were put in a savings account today and earned 5 percent per year, next year there would be \$1,050 in the account. In the following year, there would be approximately \$1,103 in the account. Reversing the logic a bit, if it were desired to have \$1,100 in 2 years, approximately \$1,000 would need to be deposited today. The RPM uses this logic of discounting future expenditures to today's cash equivalent in testing rail relay strategies. This enables comparisons to be made between alternatives on an "apples for apples" basis.

The RPM estimates the necessary cash maintenance requirements for rail into the future. It then calculates what it would take to finance that maintenance by putting a fixed sum of money in a high-yield account. High yield refers to what a company feels it needs to earn on capital investments before they are made. These investments, usually internal to the company, have earnings that are above what is traditionally seen in savings accounts, certificates of deposit, and bonds. For example, today the individual investor can buy various financial instruments in the established market with earnings of 5 to 10 percent per year. Many companies feel that a project is not worth investing in unless it returns 15 percent. If a company is cash poor, it may raise that threshold as a means of determining its spending priorities. A company's threshold is

typically higher than market investments because of the higher likelihood that the benefits from an expenditure will not be realized.

Early versions of the RPM keyed on the rate of defect formation as the means to estimate future rail maintenance costs. As further research quantified other maintenance problems, and therefore maintenance expenditures, they were incorporated into the model. The prediction of defects shows that they can be expected to grow in number as the rail gets older, meaning that annual maintenance expenses also grow. Maintenance expense that grows as an item gets older is a common occurrence but predicting the type of growth requires research.

Rail defect formation was first used in the RPM to predict future maintenance costs because maintenance-of-way engineers began asking at what point it is more economical to replace rail than to fix defective and broken rail. Many believed that defect formation may be an explosive situation, resulting in defect occurrences over a period of a year or two followed by dramatic growth to unacceptable levels. Analysis of defect trends now shows that over a long period, defect occurrences do grow, but rarely in an explosive manner. From year to year, there may be wide variances in defect occurrences; an upswing in occurrence may make it appear as if the defect growth were explosive. Figure 6 shows the number of defect occurrences on a branchline for which a cascade analysis was performed.

Because defect occurrences may take a random pattern from year to year, trend lines over several years are needed. Overlaid on Figure 6 is an example trend line from which costs associated with the defect occurrences can be assigned in each year, representing the expected maintenance costs. Over the years, the maintenance costs increase as the defect occurrences increase. There is an optimal year when an out-of-face rail relay is more economical than continued increased maintenance costs. The RPM tests for the year in which the optimum occurs, which is the year with the lowest NPV.

The NPV that will be referred to in the upcoming text includes all predicted future rail maintenance costs plus the costs of rail relay, adjusted for time. The time adjustment is the discounting process described previously in which future costs are reduced by the annual discount rate for each year into the future in which they will occur. Rail relay costs are estimated on the basis of the cost of rail; other track material (OTM); labor associated with installation, including fringes; other overhead; and project costs, such as rail welding and transportation. Rail maintenance costs hinge primarily on costs of defects, although other costs, including tie and surfacing costs and rail wear, have been experimented with in various versions of the RPM. The RPM also includes tax effects in the calculations. Although no details will be given here, in past years the tax effects reduced the theoretical cost to do maintenance and relay rail by approximately 50 percent. This is mentioned because NPV values may be quoted that will be significantly below the cash outlay to relay rail.

RPM for Cascade Analysis

Cascade analysis was initiated at CSX when the economy of rail relay on secondary lines was in question. Quite an expenditure is made to move rail from one site to another in order to minimize new rail purchases. Several questions were asked—for example, does a secondary line ever justify a rail relay, and if it does, is it truly economical to cascade instead of buying new rail? Earlier the RPM had been used to develop rail section standards and guidelines for premium rail use at CSX. Benefits of rail replacement extend many years into the future. On the lighter-density lines, heavy modern sections, if laid new, could be expected to last 50 years or more. Some results of the RPM suggest that in certain branchline situations, a low-maintenance CWR may never need a relay after installation; instead, ongoing maintenance after a relay is the most economical.

However, branchlines are rarely endowed with heavy, good-quality rail that can be expected to last forever. Instead, many have lightweight rail with poor joint conditions and other maintenance problems. Use of the RPM allows an evaluation as to when a rail replacement would be the most economical from an investment point of view.

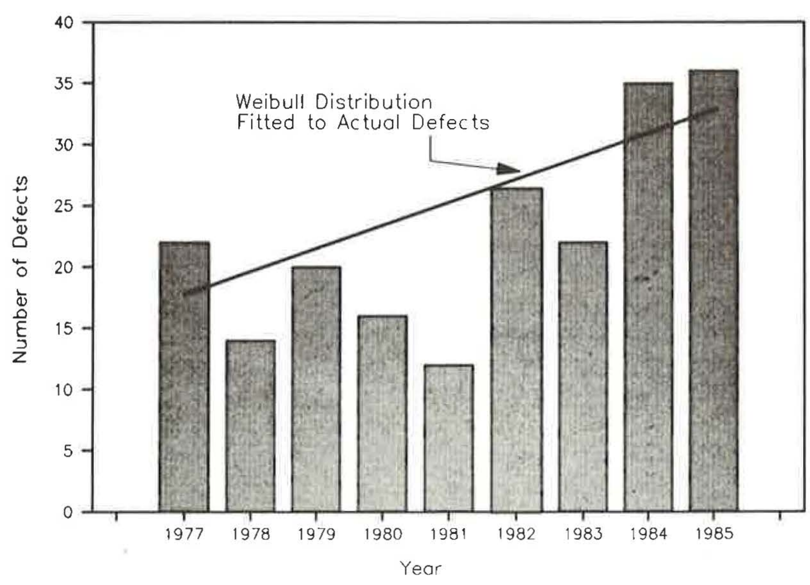

FIGURE 6 Rail defect trending.

The RPM was developed by looking at rail replacement on high-density mainlines, typically with 20 MGT of traffic annually. Despite this intent in its development, the model can be used for lighter-density lines, and various versions have been made to handle branch- or light-density lines. To properly evaluate a lighter-density line, a longer time horizon to estimate the life of the replacement rail is needed than for heavy-density lines.

The typical reason for branchline relay is jointed rail burdening the line with much more track maintenance costs than welded rail. On lines with poor rail, more attention to maintaining joints, such as tightening bolts and replacing bars; decreased tie life in the joint areas; potentially more surfacing costs; and potentially shorter surfacing cycles result in higher maintenance costs. The RPM in the various analyses shows that the higher maintenance costs associated with jointed rail shorten the economic life of that rail.

Because rail has a long life, the time effects on expenditures for maintenance have a very dramatic impact on the value rail has for a particular site. In a heavy-density line with a high level of defect occurrences, the value of rail could be as low as that of scrap. But by transferring that rail to a site that has a fraction of the traffic of a heavy-density line, defect occurrences can also be expected to lessen. Defect occurrences are expected to go down on an annual basis because they occur as a direct result of use. If a branchline is close to justifying new rail, it most likely can afford to pay a reduced price for secondhand rail that can cut out most of the maintenance costs of the existing rail.

To perform the cascade analysis with the RPM, two track sites need to be chosen that will be rail relay candidates in the next couple of years. One site should be a new rail site, where the service requirements call for the best materials. The other site should be a branchline site, in which it seems logical to use secondhand materials.

At CSX, a special version of the RPM was developed to analyze cascade economics. In that version, an economic analysis is done first on the heavy-density line that is used as the new rail site. The model is run assuming that the rail in track will stay there until it is considered scrap for that site. This is a key assumption for valuing the rail during the years before it is considered scrap.

Choice of Cascade Sites

As discussed earlier, the further into the future that money is needed, the less money today that has to be saved to cover the future expense. For rail, the cost to relay is a large component of the total cost and one that occurs all at once. If the rail relay cost occurs over the next couple of years, it will be the major component of the NPV; the other major component is the annual maintenance cost. On the other hand, if the best time to relay rail is decades in the future, the NPV component for the relay will be relatively small.

This means that when the NPVs for various sites are considered, those sites with relays in the current or next few years will have the largest NPVs, whereas the sites with relays deferred for several years will have lower NPVs. Taking that analogy a little further, when one site is analyzed, the NPV the year after the relay will be the lowest, because the rail relay is a past expenditure, which is not included in future costs. On the other hand, in the year of relay, the NPV will be the highest, because cash is needed immediately to fund the project.

When evaluating a site in which new rail is being considered, the larger railroads will hope to use the released rail on lighter-density lines, or possibly to sell the rail. The question then arises as to the value that the rail needs to make it worth removing before it is scrap. This value of rail can either be its sale price or its internal value for cascade purposes.

The RPM was used to produce various sale prices of rail in the years preceding the optimal year of relay, when the rail is considered scrap. The analysis consists of calculating the NPV to relay the rail this year (no consideration for the optimal time for relay) and that for rail relay in the optimal year. If the optimal year is in the future, the NPV to relay in the current year must be lowered to match the NPV of the optimal year, or there will be an economic loss. To do this, it is assumed that the rail is worth more than scrap and that the extra value above scrap will be treated as a credit against the relay, lowering the NPV. A calculation is made to determine how much extra value the rail has to contain to equal the optimal NPV. This procedure then assumes that because the NPV for relay this year and the optimal year are the same, the railroad is indifferent to relay timing.

The extra value calculated to bring an NPV down to the optimal NPV is prorated over the tons of rail that would be removed from track. This proration is added to the scrap value of the rail to arrive at a price per ton that the railroad needs to realize to make the relay worthwhile. Figure 5 shows the selling price, which is the value the railroad needs to get for rail, at the various points during the rail life.

Because installation costs are included in the rail relay analysis, the railroad will have to get more money for recently replaced rail than the price of the material alone. This reflects the cost of undoing work recently completed. Obviously, during the period of time that the railroad would need to sell the rail for more than the cost of new rail, there is no reason to expect that rail to be relayed for cascading. Once the selling price of the rail becomes less than the cost of new rail, the rail can be considered available for cascade. As a practical matter, most railroads probably would not consider rail available for relay until its selling price was significantly less than the value of new rail.

It must be kept in mind that the value of rail at one site can be different than the value of identical rail at another site. The purpose of cascading is to reduce total costs of relay and maintenance. The special CSX version of the RPM used in the cascade analysis can produce a table of rail selling prices from the new rail site and read them into an analysis for a branchline. This was done for one example to see whether there are economies of cascading. The result showed a considerable drop in NPV for rail maintenance of the two sites together when rail was cascaded from one site to another site. The alternative tested was new rail at both sites.

Example of Cascade Analysis

The RPM used actual data from both sites to estimate the expected maintenance costs in the future. The new rail site was

a high-speed line carrying several passenger and piggyback trains a day, plus a medium to heavy volume of other traffic, for a total of 43 MGT per year. The track consisted of relatively old welded rail with over 600 MGT of traffic on it. Its defect rate was still low—less than one defect per mile per year—with little evidence that the rate would suddenly grow. This site was considered for relay with the idea of producing good quality relay rail and with a concern over future problems with oxyacetylene welds. Otherwise, relay of the line would not have made good sense economically.

The branchline considered handled about 12 MGT a year of traffic; a good portion of that was unit coal trains. This line had 100-lb jointed control-cooled rail. The defect rate was rising on the line, and tie and surfacing work were on short cycles because of joint conditions. Maintenance levels on the line were relatively high and were expected to continue to grow.

On the branchline, the RPM was used to see whether the site could support a rail relay. The analysis showed that a new rail relay program would be justified in about 5 years. This analysis confirmed that expected maintenance costs were too high to expect to maintain the line without rail replacement. The NPV of relaying the branchline was noted, and a second analysis feeding the used rail characteristics from the new rail site was used. In this analysis, it was assumed that the year the rail was removed from the new rail line would be the year that it was laid in the light-density line. This means that the cost to the branchline to buy the rail would to down each year that it waited to buy it, because the rail's selling price would fall every year on the new rail site.

When this analysis was done, the optimal time for relay was still about 5 years into the future, but the NPV of this strategy was noticeably below that of the first strategy, as shown in Figure 7. Although it may be surprising that the time of the relay was coincidentally in the same year instead of earlier, it must be remembered that over time the selling price of the relay rail is going down faster than the rise in maintenance costs on the branchline. There does come a point when the rise in maintenance costs exceeds the drop in price of the rail, which is the point at which the cascade should be performed.

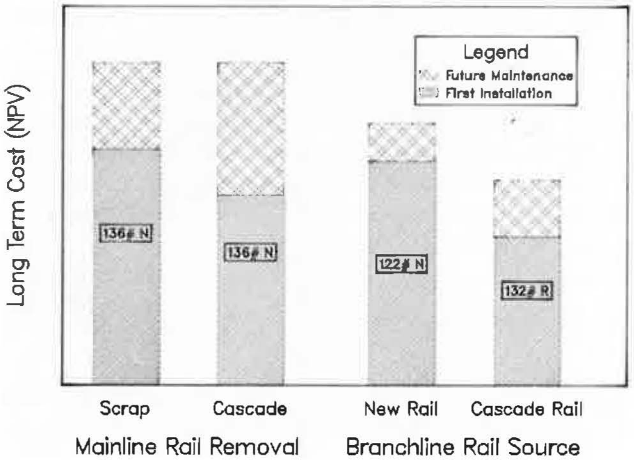

FIGURE 7 Rail cascade cost example.

Timing

To further demonstrate that cascading can be beneficial, more work was done with the CSX version of the RPM to see what value should be placed on relay rail available for branchline use. Because the relay rail gets more use at its original site, its value on the branch site falls. The "buy" line in Figure 8 illustrates this concept. During the years in which the selling price exceeds the buying price, cascading relay rail to the branchline site would not be economical. In this example, after 500 MGT, there does come a point when the branchline buying price and the new-rail selling price are equal. Then for the following several years, a gap develops, because the branchline buying price exceeds the new-rail selling price. Eventually, the rail can be expected to require so much maintenance, even on the branchline, that it will be considered scrap, at which point it does not pay to cascade it. Figure 8 shows this point being reached at about 1,500 MGT.

Theoretically, the most beneficial time for the railroad to cascade is when the difference between the branch site's buying price and the new-rail site's selling price is the maximum. In Figure 8 the maximum buy-sell differential appears to be between 1,000 and 1,200 MGT. A precise mathematical solution is possible but has not yet been incorporated into the model.

An explanation is in order for why rail can have a higher value for a branchline than a higher-density mainline. The NPV calculation by the RPM includes both maintenance and relay costs. Because a time discount is made for a future cost, transferring rail with relatively high maintenance to a light-density line will lower the use-related annual maintenance costs substantially. For example, if rail is transferred from a 25-MGT line to a 5-MGT line (i.e., the traffic falls 80 percent), as shown in Figure 2, the annual maintenance levels are expected to decrease 80 percent. Likewise, the future increase in maintenance costs related to use on the branchline will be expected to be 20 percent of the high-density line costs. With these assumptions, the rail-related maintenance costs expected in one year on the high-density line would now be spread over 5 years on the branchline. The NPV of the costs spread over 5 years is significantly less than if they occurred in the current year. As a result the maintenance component of the RPM NPV substantially drops. When the maintenance component of NPV falls, the value of the rail for use on the branchline rises.

Other Considerations

The preceding discussion describing cost impacts of cascading reveals that there are significant economies. A major assumption underlying this analysis is that the branchline receiving cascaded rail is expected to be operated for many years into the future. In the railroad environment today where many are downsizing, the possibility of divestiture of a branchline may preclude it from having a rail relay performed. Because newly formed carriers enjoy reduced unit labor costs, improved labor productivity, or government-sponsored funds, or all three, it may be more efficient to have them perform the work. If the Class I railroad did the work before the sale, the selling price added to the property might not recoup the expenditure.

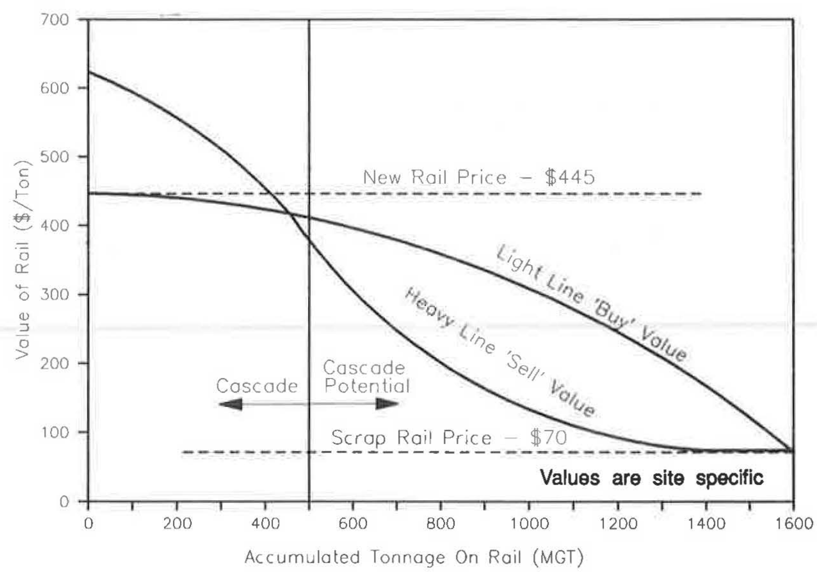

FIGURE 8 Rail cascade values from heavy to light tonnage lines.

RPM ON BRANCHLINE CASES

Analysts looking at the economics of branchline relays may lack hard data on the source of the rail to be used. In the case of a shortline, the rail may have been purchased from another railroad or supplier. It may have been part of the inventory when the property was purchased. In these cases, cascade analysis is not relevant and the RPM can be used to evaluate the potential relay site directly. The analyst will often be without hard data for some key inputs, but this does not mean that all is lost.

Areas of High Sensitivity in RPM

Fortunately there is help available for the analyst by using the RPM (*6*). Table 3 gives input parameters with their corresponding degrees of sensitivity. The degree of sensitivity is a measure of the impact on the output (results) of a change in a particular input.

Branchlines represent an interesting challenge for choosing a discount rate. The default value in RPM is established near the industrywide cost of capital. Applying this to projects of low to average risk in the rail industry, such as new rail relays, is acceptable. Applying it to branchlines may be dangerous unless other provisions for risk are made. Relays on mainlines have little risk because the commodities carried are diverse. On branchlines, the cargo may be limited to only a few customers or a few commodities. There is a much greater chance of a radical change that could render the anticipated benefits of the rail replacement useless. Financial experts should be consulted, but a one- or two-point increase in the discount rate would be acceptable if no other information is available.

An alternative approach to hiking the discount rate would be to use high and low estimates for traffic or benefit levels so that the results of a major change could be anticipated. As mentioned elsewhere, the same approach to estimating the fatigue history of the rail should be taken where hard data are not available.

Not shown in Table 3 but discussed in a previous section is the input price of rail. The methods outlined provide a framework for estimating the value of rail that yields a wide variation in prices depending on the rail quality and intended use. First cost has significant impact in a discounted cash flow, and therefore input rail values are also highly sensitive.

If rail to be used for relay has a known defect and tonnage history, the Weibull parameters can be determined for use in the RPM either through graphic plotting or use of a computer model such as WIBPAC (*7*). If the history is not known, then several options are open:

1. Expert opinion: If the analyst is familiar with Weibull parameters from rail defect data, a reasonable range of values may be estimated based on the type of rail, age, wheel load history (if available), and wear. Weibull slopes typically range between 2.0 and 4.0, with the average slightly above 3. The characteristic life ranges from 500 MGT to over 3,000 MGT, with an average near 1,500 MGT. In general, the more inferior the design and chemistry, the higher the slope and the lower the characteristic life. Inferior track support conditions would also result in higher slopes and lower characteristic lives. A "best case–worst case" approach should be considered.

TABLE 3 RPM PARAMETER SENSITIVITY

Category	Parameter	Relative Sensitivity
Economic	Discount rate	High
	Derailment cost	Medium
	Depreciation method	Medium
	Defect repair cost	Low
	Gang costs	Low
Engineering	Weibull slope	High
	Characteristic life	Medium
	Inspection reliability	Medium
Traffic	Tonnage rate	Medium
	Previous tonnage	Medium

2. Use of similar type rail where data are available would certainly provide an estimating vehicle; care would have to be taken to ensure that any differences in past use were considered. Again, a range of values should be used.

3. If only recent tonnage and defect histories are available, a regression on the defect rate per million gross tons could be attempted. Making better predictions in this case is a current priority of the Rail Working Group of AAR's Track Maintenance Research Committee.

4. The Rail Working Group, in conjunction with a research team from George Washington University, has developed a Bayesian model that will predict future defect probabilities if some recent tonnage history and defect information are known. An alternative model has also been developed by the Santa Fe Railroad.

Defect records should be examined closely to determine whether it is appropriate to include all data in an analysis. If rail with a history of weld failures were to be rewelded and laid in a branchline, the weld failure history should be excluded from future projections. If rail with a history of joint failures is cropped, welded, and relayed, future projections should not be made with historical joint failure data.

A second problem arises in making defect projections on lines with very high failure rates. The Weibull distribution assumes that a rail can fail only once (no multiple defects) and that it is removed from the population upon failure. Inspection and detection of cracked or broken rails lead to the introduction of replacement rails. Often no history of these rails is known. In time, these rails may also fail, but to lump their statistics with those of the original rail is technically incorrect. The RPM assumes that replacement rails have a use history similar to that of the original rail. In a main track, this may be a valid assumption because there is usually a conscientious attempt to match wear patterns. On branch tracks, especially lower-tonnage ones, this assumption is tenuous at best. The failure history must be closely scrutinized. Perhaps a regression would give a better explanation of future trends than a Weibull plot, especially if there has been a high failure rate for an extended period of time.

Other Areas of Concern

The RPM contains a matrix of cost savings for replacing joints with CWR. The pretax savings for branchlines discounted at 6 percent are approximately $14,000 for 1 track-mi. Moreover, the timing of these savings is spread evenly over the future years. This matrix was designed as an average case, which may well understate the condition of some deteriorated branchline rail.

Not only the rail can cause maintenance headaches, but the other fittings as well. Many lighter weights of rail have joint bars that are obsolete in design. Skirted bars with spike notches cut out are especially famous for quarter cracks. If the spike holes have been used, poor anchorage will often result in severe cocking of and damage to the joint ties. If the rail does run and these spike holes are not used, the bars often hit spikes of an adjacent tie with similar results.

With poor anchorage, there is increasing risk of pull-aparts, broken center bars, and chipped rail ends. The joints themselves are often mechanically worn, making it impossible to keep them tight. The surface deteriorates as a result of poor joint conditions.

Tieplates are often of the small, single-shoulder variety that have inadequate bearing area. This type of tieplate tends to rotate, causing an irregular gauge. Small plates have also been known to curl up under heavy axle loads, which accelerates tie deterioration.

Unless rail support is reasonably well maintained, lightweight sections are prone to becoming surface bent, including in the lateral direction. Often this accentuates rock and roll, not to mention gauge problems.

The deterioration mechanisms described here result in track that will not dependably support regular use, especially where heavily loaded equipment is involved.

In the long term, maintaining such a line would likely result in escalating costs. There may even be cases where repair material is no longer available from internal stocks and must be purchased. Maintenance savings from 10 to 50 percent higher than those calculated by the RPM are possible on branch and industry track with extremely poor rail. It is even possible that derailments other than those due to broken rails will be saved by relay. A future modification of the RPM will permit the user to identify site-specific problems. Currently it is recommended that the analyst consider those items not included in the model in a separate analysis.

Derailment costs are shown (Table 3) to be of medium sensitivity. They are based on experience with averages. Although average costs are used in the model, the deviation from average is considerable, and railway management tends to be averse to risk as a result. The concern over expensive mainline accidents raises the sensitivity of this variable for those territories. On branchlines, incidents tend to be much less costly and the analysis therefore is less sensitive. Site-specific traffic should be considered for relay analyses, however, because there are branchlines that carry high volumes of chemicals and other potentially dangerous commodities. On very light tonnage lines, the number of derailments may be a more important factor than average expense. In that case the default value for the probability of a derailment given a rail failure may need to be changed.

The RPM does not include any savings for transportation. Under normal conditions, work rules do not permit running-time reductions to be turned into hard dollar savings. The branchline (or shortline) case may be an exception. Raising speeds from 10 or 25 mph to 25 or 40 mph may well result in productivity gains if local schedules can be rearranged. For example, a 10-mi branchline will take more than 2 hr to serve at FRA Class 1. Improving the running speed to 25 mph would cut the service time in half because of over-the-road movement. Reliability of service could be important to any carrier.

User's Guide to RPM

As noted earlier, the prospective analyst can obtain the RPM User's Manual (*6*). By so doing, inputs to RPM can be researched ahead of time. Some of the inputs assume that welded rail will be installed, but jointed rail can also be handled. A shortline is likely to be in a better position to

estimate costs than a large carrier. Current default values are more pertinent to large railroads.

CONCLUSION

The RPM provides the basic economic framework for evaluating branchline rail relays. Although special programming improves the productivity of these analyses, the standard version available from the AAR Research and Test Department is entirely adequate for the job.

The RPM can handle branchline analysis as part of a cascade program or as a stand-alone. Rail values must be carefully thought out in the stand-alone case.

For railroads with the proper variation in line use, cascading has been demonstrated to provide substantial benefits compared with a strategy of relaying only new rail. This finding affirms what maintenance engineers have believed and practiced for years. The model goes on, however, to provide a means of ranking expenditures and making more nearly optimal relay decisions.

Several input items to the RPM need careful consideration because of their sensitivity. One of these is the price or value of rail, especially relay rail. The RPM is capable of valuing rail if adequate history of use is available. Market value and alternative use provide other avenues if insufficient history exists.

Interest (discount) rates or traffic type and volume, or both, need to be considered as a package because of potential large variations in actual benefits from those projected within the RPM framework. Higher discount rates can be used to reduce uncertainty. Using input ranges instead of single values for sensitive variables will also accomplish the task.

Finally, branchline relays may involve benefits above and beyond those calculated directly by the RPM. Lines that have suffered from extremely poor rail conditions are likely to show benefits exceeding those predicted by using default values in the model.

It is apparent from working with the RPM that those railroads with efficient records of traffic, rail defect data, and maintenance costs will find themselves in an enhanced position to take advantage of its capabilities. In an increasingly competitive environment, those firms with the best decision-making apparatus will be the survivors.

REFERENCES

1. *CSX Corporation 1986 Annual Report and Form 10K.* CSX Corporation, Richmond, Va., 1987, pp. 4, 17.
2. T. R. Wells and T. A. Gudiness. *Rail Performance Model: Technical Background and Preliminary Results.* Report R-474. Association of American Railroads, Chicago, 1981, pp. 1–8.
3. *Annual Report to the Interstate Commerce Commission for 1986.* CSX Corporation, Jacksonville, Fla., March 1987, pp. 72–72A, 85, 90, 98.
4. P. M. Besuner, D. H. Stone, K. W. Schoeneberg, and M. A. De Herrera. Probability Analysis of Rail Defect Data. Presented at Heavy Haul Railways Conference, Perth, Western Australia, 1978.
5. T. R. Wells. Rail Performance Model: Evaluating Rail. Presented at the 1983 Annual Conference of the American Railway Engineering Association, Chicago, March 1983.
6. D. D. Davis. *Rail Performance Model—User's Manual.* Report R-654. Association of American Railroads, Chicago, 1987, p. 76.
7. R. A. Armstrong. *User's Guide to the Program: WIBPAC for the Analysis of Rail Failure Data.* Report R-513. Association of American Railroads, Chicago, 1982, pp. 1–3.