specific rail services is described. This methodology allows the estimation of track maintenance costs to support engineering planning and equipment selection as well as marketing activities. This methodology can be implemented with the aid of a computer program, TMCOST, which allows the voluminous calculations to be performed without undue effort. The data requirements are significantly greater than those of the traditional accounting-based rail maintenance costing procedures, but the cost estimates are route- and service-specific rather than system averages.

The current deterioration models used in TMCOST are sufficiently accurate to support the planning and marketing functions. Work continues to develop even more accurate models for rail, tie, and ballast performance, especially in high-density territory. As the railroads develop more detailed computer data bases to support operations and maintenance, the ability to calibrate and utilize these models will increase. This methodology provides the basis for utilizing this additional information to produce more accurate cost information for managerial purposes.

REFERENCES

1. T.R. Wells and T.A. Gudiness. Rail Performance Model: Technical Background and Preliminary Results. AAR Research Report R-474. Association of American Railroads, Washington, D.C., May 1981.
2. M.D. Roney et al. Road Maintenance Cost Model, Phase I: Rail Wear Modelling. CIGGT Report 78-2. Canadian Institute of Guided Ground Transport, Kingston, Ontario, Canada, May 1978.
3. R.K. Steele and R.P. Reiff. Rail: Its Behavior and Relationship to Total System Wear. In Proceedings, Second International Heavy Haul Railway Conference, Colorado Springs, Colo., Sept. 1982.
4. A.M. Zarembski and R.A. Abbott. User's Manual for Rail Fatigue Life Program. AAR Research Report R-336. Association of American Railroads, Washington, D.C., Jan. 1980.
5. E.R. McIlveen et al. Rail Wear Cost Model User's Manual. CIGGT Report 81-19. Canadian Institute of Guided Ground Transport, Kingston, Ontario, Canada, April 1982.

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

Track Maintenance Policy and Planning

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ABSTRACT

Track maintenance planning within the railroad industry is described. The efforts of the Association of American Railroads to develop maintenance planning models to assist in such planning are reviewed and the problems involved in railroad bridge maintenance and replacement are discussed.

In defining the maintenance policy of a railroad, all major railroads, as well as other private industry companies, have the policy to maintain their railroad and property to the standards necessary to move the traffic designated at a volume and speed necessary for their company to earn a reasonable profit. They must accomplish this goal within certain monetary constraints established by their management. The cost of maintaining the property and trackage is a big portion of the cost associated with the profit.

To accomplish the policy described, the maintenance manager must plan the expenditures involved with accomplishing the satisfactory maintenance of his trackage and property.

Planning, as defined by the dictionary, is a scheme for making, doing, or arranging something; project, schedule, etc. A railroad maintenance officer has defined maintenance management as the planning of all maintenance operations to economically maintain the facilities of the railroad at the most economical level possible to satisfactorily meet the needs demanded by management. To accomplish this level of planning, the manager must project maintenance needs far enough in advance to coordinate funding, personnel, equipment, materials, designs, and operations by using the most up-to-date predictive technology available.

Today's railway maintenance engineering can be divided into three operations:

1. Planning,
2. Execution of the plan, and
3. Maintenance of the completed plan.

Note that in every operation, the plan devised is the key to each of the other operations. There is no

function in today's railroading that does not involve planning. It is in every function of every maintenance-of-way and engineering department operation from the lowest level of supervision to top management.

Although the tendency is to think of planning in terms of major renewal programs such as rail, ties, surfacing, and ballast, because of their major effect on costs, planning occurs at all levels of operation and supervision. Planning at all levels must continue to improve. The best-laid plans cannot be accomplished without the proper detailed planning right down to the last spike to be driven.

In terms of the major expense items in today's railroading, the following are considered major items because they account for approximately 30 percent of a railroad's capital and operating expenses:

1. Rail renewals,
2. Tie renewals,
3. Surfacing operations,
4. Ballast and subgrade maintenance, and
5. Bridge and building maintenance.

All of the foregoing maintenance functions can and must be planned. They must be planned to ensure

1. Expenditures to match the property's needs,
2. Current technology of materials so that there is efficient expenditure of funds,
3. Maximum safety of personnel and operations,
4. Maximum use of the minimum number of machines and personnel,
5. Service to all departments according to their needs by maintenance planning operations, and
6. Coordination of train operations to allow efficient operations.

All maintenance-of-way and engineering planning must be

1. Both short- and long-term;
2. Made by using the most current technology available;
3. Originated at the basic maintenance supervisional level;
4. Detailed in design, materials, and operations for field execution; and
5. Controlled by a centralized manager.

To accomplish the planning of these renewals and to be able to satisfy the economic requirements, certain basic history and engineering facts must be known. The following are considered necessary to efficiently and effectively plan today's maintenance:

1. A complete and properly designed data base of the property,
2. Acceptable safety and material life limits on the various portions of the property,
3. Inspection frequencies and methods as a source for planning, and
4. Computer systems to use the data base, limits, and inspections to predict planning needs.

I once heard an old timer say, "We have been railroading for 100 years and we still don't know how to do it." Well, I agree with him, although as an engineer, I would like to state that the environment has continually changed during that 100 years. In fact, the environment has changed at a rate that is difficult to stay ahead of. But those who are responsible for the maintenance of the railways must stay ahead. Railroad managers must continue to contribute to the effort in developing new materials, methods, theories, and maintenance approaches in order to stay ahead of the deterioration of their properties.

One critically important additive to all planning operations is supervision. A railroad, as in all engineering fields, must continue to develop quality supervisors. The tendency is to think that good, knowledgeable supervision just happens, that supervisors will naturally develop from normal operations. However, considerable effort and planning are involved in the continuing development of good engineering supervision, which is one of the most important items in a manager's ability to fulfill his company's policy of track maintenance.

DATA BASE

The computerization of a data base for all maintenance and engineering functions and operations of the property is and must be a necessity. Almost all railroads have engineering records, statistics, historic maintenance operations, and other records on paper. Although these were and are important for a permanent record, they are cumbersome to use in planning efficient maintenance operations. There tends to be too much opportunity for error and too much input tied to the old timers' knowledge of the facility and maintenance functions of the past.

The computerization of a railroad's records is an expensive undertaking. It takes computer hardware, many man-hours of accumulation and input, and constant updating to keep the records current.

The data base must be planned. This is a most important point that is often overlooked. In many cases, because the department developing the data base is not the department using it, it is inadequate as a usable information source. And because communications are not a strong point of railway departments, all data are not included for proper functioning of the operating of maintenance planning models. Of course, another reason for not developing an adequate data base is simply that the information is not available. Thus alternative methods must be developed such as using other railroad statistics or just choosing an estimated limit for the missing function or data.

What should be in a data base? Committee 32 of the American Railway Engineering Association (AREA) is working on recommendations for various data bases. The Track Maintenance Research Committee of the Association of American Railroads (AAR) has developed and is continuing to develop recommendations for data bases for planning maintenance operations for rail, ties, and ballast and subgrade. These are available to all as a basis for each railroad to begin its data base development.

Railway managers must make the commitment to develop a data base for their railway at whatever cost if they are going to efficiently plan their maintenance operations for the future.

Rail

Rail is the most expensive maintenance renewal operation, and it is one of the most important basic necessities in the operation of railroads. There is no more efficient manner of moving tonnage than the steel wheel on a steel rail. The planning of rail renewals becomes increasingly difficult as loads get heavier and are moved faster over varying conditions to match the speed of the competition. The replacement of rail must still be predicted in planning operations for efficiency and safety of operations within acceptable limits.

All maintenance officers realize at about what

rate their rail deteriorates. They know the statistics of their rail such as age, metallurgy, tonnage, defect rates, and joint conditions. From these they develop a rail renewal plan. But is this plan the most economical for their railroad? Is it developed based on proper priority ranking of rail renewal projects? Is it developed with the needed skill of economical cascading of rail? Is the renewal of curves planned? I think not. A more organized, more technologically correct approach to rail renewal planning and cascading must be developed.

The AAR Track Maintenance Research Committee has a working group on rail planning that is developing just such a model, and it will be made available to all railroads in the near future. The committee consists of a mixture of research and technical personnel, railway-knowledgeable technical staff, consultants from several fields of specialty, and track maintenance operating officers. This committee is headed by Dave Staplelin, Planning Officer for the Seaboard Systems, who is a most capable engineer in rail technology, computerization, and planning. I am sure that there are some railroads developing their own planning models. Nevertheless, let me briefly describe what the committee has accomplished.

The working group has developed and published in the October 1984 AREA Bulletin an empirical rail wear model that has the ability to predict the life of tangent and curve rail. The model predicts this life in million gross tons (MGT). The model requires the input by the railroad of the following information:

1. Allowable cross-sectional area loss of rail head on tangents and curves,
2. Annual traffic density,
3. Degree of curvature,
4. Grade, and
5. Static wheel loads (in kips).

A model such as this, with some adjustments in its input variables to make it meet a railroad's particular conditions, could be used to develop a rail renewal long-range planning forecast. Short-range programs may be developed from revisions of the long-range ones by analysis of current rail defects, joint conditions, predicted traffic changes, and needs for cascading.

Thus any railway would have the ability to plan its rail renewals by using the most current technological means available. Of course, as the technology of improved metallurgy, lubrication, profile grinding, and so forth becomes more defined in terms of the effect on rail life, the model will be adjusted to take these material life changes into account.

The working group is developing a rail cascading model as well, thus making the model usable on secondary trackage and not just main-line renewals.

The economic justification of rail renewals is an approach that the committee has added to the normal rail renewal theories. The economist of the AAR, led by Mike Hargrove and Tom Gudiness, has given very valuable assistance in this endeavor. Many costs associated with rail left in the track beyond its economical life were considered, some of which are

1. Cost of changing a defective rail, including labor, materials, traffic delays, slow orders, and support equipment;
2. Cost of derailment liability;
3. Cost of additional surfacing;
4. Cost of tie life;
5. Cost of investment; and
6. Tax considerations.

Ties

Most railroads use field personnel to spot check or mark their railroad for tie renewals for the current or upcoming year's programs. Whether they use a system tie inspector or local supervision, they still must rely on each individual's ability to predict the life of the tie and estimate when it should be removed.

Thus there is no efficient or economical means of predicting or planning tie renewals. Field inspection is the only method known to be effective and is used by most railroads. In tie-renewal planning, it is of short-range use only.

The only long-range planning method for tie renewals is to use past renewal history. With the ever-changing rail conditions--the increasing wheel loads and tonnage, the method and frequency of surfacing, the condition of drainage, and the changing climatic conditions over the 20- to 50-year life of the existing ties--the prediction of tie renewals using the history of past renewals is unreliable.

Some railroads have tie-renewal prediction models of one type or another. Some are effective and some are not. Some have models but just do not use them because the field maintenance officer does not believe in their ability to effectively predict renewals. None are really reliable because of the many variables affecting the life of a tie. Even the tie itself is not made of a very predictable material. Not only is it made of various types of wood, it is treated with varying amounts of chemicals and methods. It is even made in varying sizes and carries the wheel load on various sizes of tie plates.

Thus the art of predicting renewal of crossties is most difficult. Yet if the maintenance engineer is to properly plan his tie renewals, he must have a means to predict them.

The AAR Track Maintenance Research Committee has a working group on tie planning chaired by Mike Roney, Manager of Engineering Systems for Canadian Pacific Limited. The group consists of AAR technical staff, railway maintenance officers, technical researchers, and various consultants. They are developing a model that will be able to predict tie-renewal life in terms that can be used by the maintenance officer in his tie-renewal planning.

In their study of the life of a tie, the group has investigated the different conditions that can affect that life. Many conditions were considered and through many discussions they limited the number to be considered in the model because many conditions thought to affect tie life were not qualifiable or not important. The group narrowed these conditions affecting tie life to

1. Foundation and support,
2. Precipitation,
3. Temperature (growth of bacteria and freeze-thaw cycle),
4. Operating speeds,
5. Wheel load spectra,
6. Ballast materials, and
7. Alignment.

Although the group has not at this time developed a working model, one is rapidly forming. They have developed a statistical tie-life model, a variation of the Forrest product tie failure distribution curve. They are now field testing this model with various railroad renewal statistics and actual personal field observations.

The model functions on an IBM Personal Computer (PC). The spreadsheet-type program is used. Much of the model's algorithm is included in AAR Report

R-515, Tie Failure Rate Analysis and Prediction Techniques (1). Inputs to this model include the number of ties inserted by year and the expected life of each group. Each group is then tested on the modified Forrest product curve to determine the number of ties that have failed since the last tie renewal. Up to 19 sets of yearly renewal statistics can be included.

The failed-tie count is projected into the future years. The model assumes a tie renewal of all predicted failed ties. Because the model can be run year by year, a predicted tie-renewal count is available. The tie cluster model uses these counts to estimate, by years, the number of clusters and then yields a prediction for that year of tie-renewal planning. The model provides a good working framework for the group but considerable work must be done in verifying the inputs to make it a usable predictor of tie-planning renewal.

The group has also developed a tie sampling scheme that would aid a railroad in long-range planning without actually having to count 100 percent of the ties in a given segment. It is basically a statistically random sampling of 50 tie clusters, varying in numbers to the length of the renewal segment. Thus it is able to reasonably and accurately predict gross required renewals over a segment of track.

The group has also investigated such areas affecting tie life and renewal predictions as

1. Clustering effect on other maintenance costs such as surfacing cycles, tie renewals, rail life, slow orders, fuel costs, and others;
2. Cost of the failed tie;
3. Cause of tie failure from one railway to another;
4. Effects of mechanical wear, axle loading, and curvature; and
5. Effects of a good adjacent tie.

Ballast and Subgrade

The riding surface of the track is the end result of all wheel-supporting materials such as rail, ties, and ballast and subgrade. Although most effort in the past has been centered on rail and ties, both in research and development and renewal techniques, ballast and subgrade must be recognized for their importance. Not only will there not be an operable track surface without good ballast and subgrade support, considerable life in both rail and ties will be lost. Therefore the maintenance of the ballast and subgrade to provide a serviceable track surface at an economical cost must also be planned.

Track surfacing of the ballast is the current method of maintaining track surface. Surfacing of the track is a necessary maintenance function but at the same time it is detrimental to the ballast and ties because of the crushing action of the modern tamper. The necessity to buy and maintain a good quality ballast that is capable and free to drain is even more important than in the past. With ballast in better condition, surfacing cycles are reduced.

The subgrade is also a most important track support material. Most do not consider subgrade a maintenance planning item until surface trouble shows the need for some kind of action. Subgrade problems can be predicted, thus allowing a planned maintenance operation.

Some research has been done by a few railways and university researchers in ballast and subgrade maintenance in the fields of ballast gradation studies and variances causing problems in subgrade soil support condition, ballast type, and so forth. Drainage improvements and undercutting-cleaning or straight renewals are the only maintenance operations now used to correct ballast problems.

Subgrade research and investigations have been conducted in the past by soil testing through boring and excavation techniques with the only maintenance operation being cement grouting, lime stabilization, use of fabrics, and various other temporary repairs. Even these are only used as a trouble-spot operation and only after prolonged problems with the track surface.

Several railroads and universities as well as the AAR have conducted ballast and subgrade research tests in the United States. All vary in their approach. Once again, because a particular railway or geographical area experiences specific problems, the research tends to center on solving that problem. Therefore a solution is not reached that could be used for maintenance planning of ballast and subgrade on all railroads.

The AAR Track Maintenance Research Committee has a ballast and subgrade working group chaired by Bob Ahlf, Chief Operations Planning Officer of the Illinois Central Gulf Railroad. The working group is developing a maintenance planning model for ballast and subgrade maintenance. In their investigations to date they have been trying to understand how to predict the amount of differential settlement for a given segment of track and therefore the required ballast or subgrade maintenance for a given MGT of traffic. To do so, such contributing factors as ballast and subgrade conditions, climatic variances and extremes, varying loading patterns, and other conditions affecting the ballast and subgrade must be understood, defined, and quantified.

The working group is considering many research projects and is wrestling with many difficulties to master the problems. Some of these difficulties are as follows:

1. Variability: To intelligently design a predictable structure, one must know the average strength of its material. Most track operated over today was placed before soil mechanics became the science that it is today. Ballast, although measurable in gradation, strength, and ability to resist climatic conditions, is almost unpredictable, because few railroads use a homogeneous type of ballast throughout their trackage. Each railroad has changed types, gradation, and cleaning policies in its ballast history, and few records are kept of those changes.
2. Accessibility: Because the ballast below the tie and the subgrade are hidden from view, the nature of their problems is not easily assessed. Testing and prediction of corrective actions are doubly difficult. In fact, it is often difficult to distinguish between a subgrade and a ballast failure solely by observation.
3. Ballast performance: When ballast fails to perform adequately, the ballast specification is often blamed. The real problem may be that the ballast has simply worn out and should be cleaned or, if necessary, replaced like a tie or a rail. However, predicting this maintenance operation or replacement is very subjective. One means could be to determine the time or amount of traffic tonnage at which the ballast must be cleaned or replaced. This can or could be tied to other maintenance functions such as tie renewals.
4. Ballast-subgrade interaction: When ballast and subgrade are finally defined and quantifiable in terms predictable enough to use in a maintenance planning model, the interaction between the two support materials must be defined. This interaction must be understood to the extent that its effect on

the ability of both materials to perform as predicted is also definable.

5. Ballast and subgrade monitoring and testing; Many means of monitoring and testing these materials are being investigated, such as

a. Gradation,
b. Sampling and identification of the subgrade soils,
c. Absorption values,
d. Effectiveness of tamping,
e. Soil expansion,
f. Track quality, and
g. Subgrade moisture.

It is apparent that the working group has many irons in the fire. An excellent group has been assembled composed of AAR research personnel, university professors and their research staff, soils and ballast research specialists, railroad technical officers, and operating management.

It is expected that this group will develop a ballast and subgrade maintenance planning model that will be able to predict maintenance needs. These predictions will be for both short- and long-term needs and priorities. The model will operate with inputs from the geometry car data, ballast and subgrade random testing, historic data of maintenance cycles, and the ballast and subgrade data base. Ballast and subgrade maintenance planning can be predicted and managed much the same as that for rail and ties.

BRIDGES

Bridges involve another maintenance facility that is extremely important to the operation of railroad traffic but that falls into the category "out of sight, out of mind." The maintenance of bridges and structures is apparently not planned beyond a year or two ahead.

The reason for this short-range planning is that the maintenance or replacement programs are based on field inspection only. Most of these inspections are made annually. At the time of the inspection the subjective opinion of the inspector determines what maintenance is to be accomplished and when it is necessary to do that maintenance. The inspector has little assistance other than his visual observation and personal experience with the structure to use in making his decisions.

Long-range maintenance programs can and are developed to satisfy upper management's demands for such a prediction but are based purely on the age of the structures. This prediction, geared to the desire for a stable maintenance force and equipment inventory, is the controlling factor in these long-range programs. Because many railroads were constructed in segments with time frames of 10 or so years, the predicted renewals tend to come in large quantities. Thus many leveling-out processes to delay renewals have been developed in recent years. But the actual planning of the renewals still comes from the field inspection.

There are several problems in the long-range planning of bridge and structure maintenance or renewal. Some of them are

1. An unknown history of loading cycles,
2. The difficulty in prediction of loss of section from corrosion or wear because of its lack of visibility,
3. The rather long life of a bridge or structure versus ties and so forth, and
4. The gross number of these structures to be renewed.

There are some advantages to bridge maintenance prediction over other track maintenance material. Some of them are as follows:

1. The materials have had a known strength and design specification for approximately 100 years,
2. Excellent historic inspection records are available,
3. Excellent maintenance records are available, and
4. The foundations of the bridge structures involve few maintenance problems because excellent historic records are available, problems are easily definable, and the foundations have probably been repaired.

Canadian National and Burlington Northern have made some efforts toward bridge repair and replacement predictions. It appears that some problems exist with predicting the loss of section of the steel structures.

Because most timber fails from decay rather than crushing, most railroads have begun installing concrete or steel piling with concrete stringers and caps. This will help in the prediction of the individual unit's life because concrete is a much more predictable material than wood. The originally designed concrete now has had to be revised to prestressed concrete members to resist the moisture penetration found in standard concrete members.

One of the other problems with bridge renewal prediction is the fact that gross tonnage on the bridge has little to do with bridge deterioration. Decay, climatic conditions, quality and deteriorating rates of materials, and the structural design are the contributing factors for most renewals.

Thus little long-range planning is done with the confidence that it will be accomplished. Although a considerable portion of the maintenance dollar is spent on these structures, problems must be found before repair can be planned. It would appear that a better, more sophisticated means should be developed to assist the maintenance engineer in predicting his bridge and structure maintenance and renewals.

SUMMARY

There has been a start in track maintenance planning within the industry. Through the AAR's efforts to support a unified effort among the many technical and practical experts to develop maintenance planning models, considerable progress has been made.

Although there are still many maintenance officers of railroads who do not believe that they need such a tool, they soon become believers once they see what such a predicting model can do for them. There is still a lot of work to do before the models are usable. The working groups need the cooperation of all railroads in technical personnel, information on maintenance operations on their properties, and support through the AAR. All will be recipients of the end product: a tool to assist all railroad managers in predicting their track maintenance needs in both short- and long-range planning using their own wear and specification limits, known track conditions, and tonnage-wheel loadings--a universal model that can be tailored to match each railroad's specific needs.

REFERENCE

1. T.R. Wells. Tie Failure Rate Analysis and Prediction Techniques. AAR Report R-515. Association of American Railroads, Washington, D.C., Oct. 1982.

Publication of this paper sponsored by Committee on Railway Maintenance.