Identification of Short-Term Track Maintenance Priorities at CP Rail

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ABSTRACT

The organization of the engineering function at Canadian Pacific Rail (CP Rail) has been dictated largely by geography. A transcontinental system such as CP Rail's is characterized by large variation in the traffic handled and the geomorphology over which it travels. The identification of short-term track maintenance needs and their repair are by and large the exclusive purview of local roadmasters and division engineers who develop an intimate relationship with their territories. The head office engineering function is charged with the responsibility of monitoring the results of these local initiatives and of providing overall guidance on standards and practices. It has been CP Rail's experience that the best way to meet this objective is through strategic interventions into the process that point out potential problem areas while not interfering with or second-guessing the judgment of local people on which CP Rail relies so heavily. Certain of these target areas will be reported on in this paper, specifically, track upgrading, automated track inspection, rail fatigue monitoring, and computer assistance to local offices. Long-range plans are described.

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TRACK UPGRADING

A key strategy that is being followed at CP Rail is the progressive upgrading of the track plant. Stated simply, they have found that it makes sense to buy the best they can afford. The ultimate objective would be to achieve a track structure without clearly identifiable weak points, which would enable the optimal utilization of high-production gangs whose activities can be planned well in advance.

Ideally, CP Rail hopes to reach a situation in which the more expensive routine maintenance by basic forces is only required because of local breakdown of the track structure at joints, over problem subgrades, and so forth. In essence, the strategy is to provide a no-surprises track structure that will allow substitution of planned component renewals for firefighting.

The annual replacement of an average of 270 mi of jointed rail with heavier section continuous welded rail is contributing significantly to the elimination of the traditional weak spot in track. A continued program of thermite welding of rail in track combined with the use of prebonded insulated rail joints where isolation of track circuits is necessary has also contributed to reduction in short-term maintenance requirements.

CP Rail has found it economical to use 9-ft hardwood ties in curves in primary main-line territories, and in both curves and tangents between Calgary and Vancouver. In 1976, 14- and 16-in. eccentric tie plates were adopted for high tonnage location in curves of 3 degrees and above. This combination significantly contributed to prevention of plates from nose-diving, or cutting of the ties on the field side, thereby reducing the need for regauging.

In 1982, CP Rail adopted a new ballast specification that is unique in the industry in its attempt to relate measurable characteristics of potential ballast sources to expected service lives in track.

Ballast can be selected to have an abrasion number that is commensurate with traffic levels, minimizing the possibility that premature breakdown will result. The expected service life for ballast for a given source can be assessed using the correlations that have been developed (Figure 1). Ongoing research being conducted in conjunction with CN Rail and Transport Canada is attempting to develop instrumentation to detect problems of weak subgrades due to unfavorable pore-water pressures. Under the same program, guidelines are being developed for the use of geotextiles to protect weak subgrades.

A final area of weakness in track structure that has received some attention is the frog. In 1975, CP Rail introduced explosive depth hardening of railbound manganese frogs. Studies have indicated that

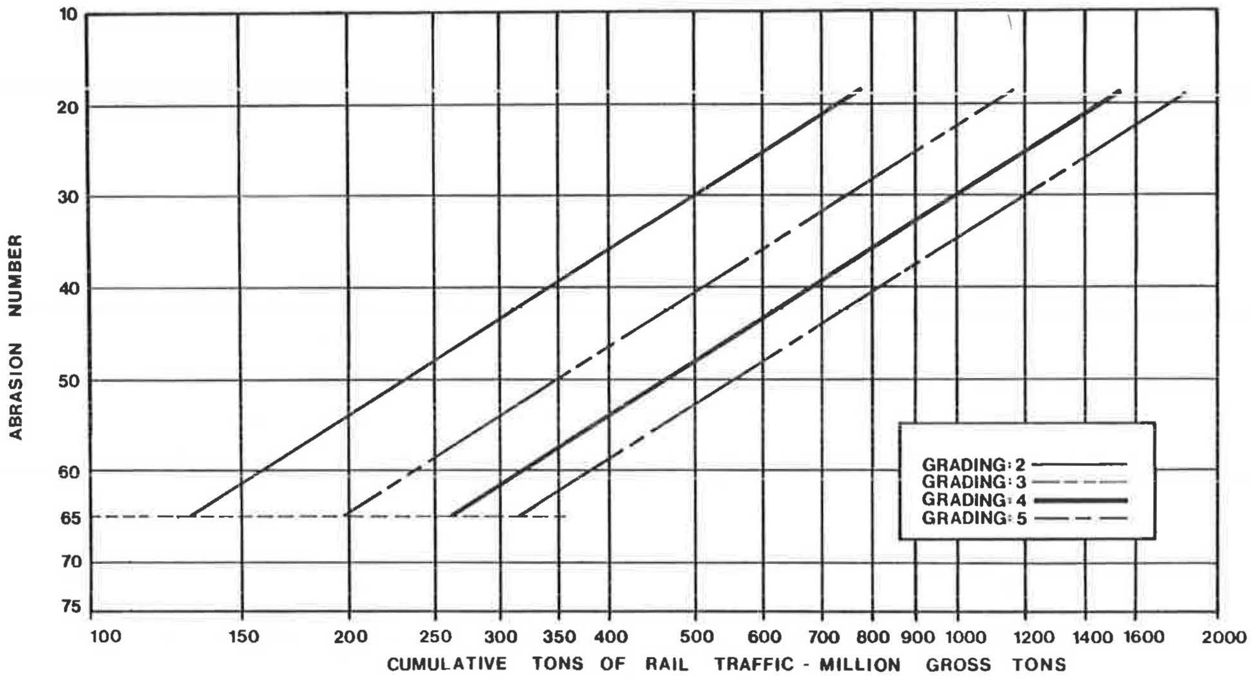

FIGURE 1 Relationship between ballast abrasion number and expected service lives.

this has increased the average life of a frog insert from 60 to 115 million gross tons. CP Rail's ultimate objective is to eliminate the frog as a weak point in the track structure. To this end, research is under way into both use of a moveable point frog and improved alloying and treatment of the Hadfield's manganese steel used in track-work castings.

TRACK GEOMETRY MEASUREMENT

In the 14 years during which CP Rail's car has been operating, the Track Geometry Car has proven to be an ideal tool for determining short-term priorities for maintenance. Its primary function is to assist the roadmaster in locating potentially hazardous conditions. At the same time, it provides valuable information for both regional and system levels. Comparison of overall deterioration trends guides decisions on when infusions of resources are required to meet standards.

Eleven defect types identified by CP Rail's track geometry car are summarized in Table 1. They are classified as either priority defects or urgent defects. Each roadmaster receives a report of the location and type of track defects found on his territory when he leaves the car. CP Rail's defect definitions have evolved progressively over time in response to their experience of what actually constitutes a track problem. For example, the cross-level defect threshold was recently increased to a minimum level of 3/4 in. over 8 ft, 3 in.

Adoption in 1984 of a new standard for rate of change of superelevation has significantly helped in combatting the derailment problem of empty tank cars. With side bearing clearance just within tolerance, a rate of change of superelevation exceeding 2 in. was found in field tests to cause significant wheel off-loading. A priority-defect classification is now printed out if rate of change of superelevation exceeds either 1 in. in 20 ft or 1 3/4 in. in 55 ft. Concurrent use of two measurement baselines for superelevation measurement, one corresponding to one-half of a rail length and the other corresponding to the wheelbase of a tank car, results in coverage of variation in geometry occurring over a wide range of wavelengths.

A unique feature of CP Rail's defect definitions is the detection of three conditions that could lead to rock-and-roll derailments. Rock-and-roll derailments occur when a periodic pattern of track errors is present at a wavelength that will excite vehicle resonance in one of its possible modes of vibration. The ability of the on-board computer to perform instant pattern recognition is a significant strength of automatic track inspection. Many times, the critical sequence of track errors has been too subtle to be recognized by the track inspector. The geometry car is able to specifically locate errors in surface, cross level, and superelevation that, when occurring at the specified distance apart, will cause unfavorable dynamics. If the resonant condition is not found with their rock-and-roll defect definitions, CP Rail can record all measurements for off-line computer analysis to test the existence of one of a variety of different patterns.

Summary of information from the geometry car is prepared graphically by computer to assist planning of work programs. The current run of the car is plotted against the run made at the same time 1 year previously for indices of surface and cross level, and for comparing total footage of wide gauge. These comparisons show the rate at which track condition is deteriorating or, alternatively, the extent of improvement achieved with a work program. Figures 2 and 3 are sample comparisons. The bold line represents the current year and the past spring is shown as a dotted line. The unit of the gauge graph is number of feet of wide gauge greater than 1/2 in. wide per 1/4 mi.

In the section between mileposts 77 and 93 in Figures 2 and 3, jointed rail was replaced with new welded rail. Both the surface graph (Figure 2) and gauge graph (Figure 3) show marked improvement in track condition. The adjacent section of track, on the other hand, has deteriorated rapidly, indicating the need to extend the program this year.

TABLE 1 Summary of Defects Detected by Track Geometry Car

EXPLANATION	PRIORITY DEFECT	URGENT
Wide gauge (Feet/No. occurences)	3/4"	1"
Surface roughness - left rail	1" to 1 1/2"	over 1 1/2"
Surface roughness - right rail	1" to 1 1/2"	over 1 1/2"
Rock & Roll - Surface Roughness	6 Surface Defects over 5/8" each	6 Surface Defects over 5/8" each but averaging 7/8"
Cross Level	Rate of change greater than 3/4" over 8'-3" or 1" over 11"	Rate of change greater than 1" over 7'-4" or 1 1/2" over 11"
Rock & Roll - Cross Level	N/A	Rate of change of 3/4" in 11" occuring 3 times in 80'
Superelevation - actual elevation	elevation of 5 1/2" to 6 1/2"	elevation over 6 1/2"
Superelevation - rate of change in 20'	1" to 1 1/2" in 20'	over 1 1/2"
Superelevation - rate of change in 55'	1 3/4" to 2"	over 2"
Rock & Roll - Superelevation	N/A	Change in elevation of 3/4" followed by a reversal of elevation of 3/4" within 62'
Alignment	20 mph:change of curvature of 6° 50 mph:change of curvature of 4° all within 62'	N/A

On the sample comparisons in Figures 2 and 3, a plot of the posted subdivision speeds versus the rated curve speeds as determined with the geometry car are provided. The posted speeds are those listed in the operating timetables. The design speeds are assessed by the car on the basis of the average measured superelevation and curvature, using a CP standard of 2 in. of unbalanced superelevation. In general terms, this gives a picture of how well speeds have been selected for the territory. It indicates the curves that are controlling subdivision speed limits and the factor of safety to be applied when assessing cross-level and gauge deviations measured in the curve. These graphs are also useful for guiding curve realignment programs to reduce rate of change of superelevation because they identify curves with both high rate of change of superelevation and excess superelevation. This enables alignments to be designed to minimize reductions in train speeds.

Track Geometry Car No. 63 has recently been upgraded to better accomplish its objective of assessing maintenance priorities. These upgrades include

- A new superelevation system
- Gradient measurement
- An all-wavelength all-speed profilometer system
- A computer upgrade to a fast HP A900 and the addition of video cameras

The video cameras trained on both wheels of the leading axle of the trailing truck are of particular interest. They visually display to the roadmaster

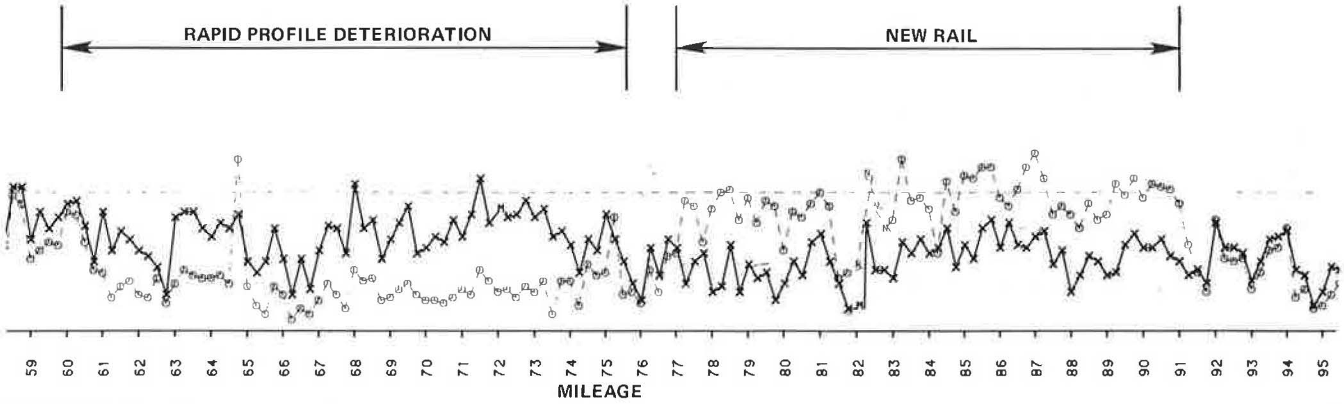

FIGURE 2 Sample comparison of year-to-year surface roughness ratings.

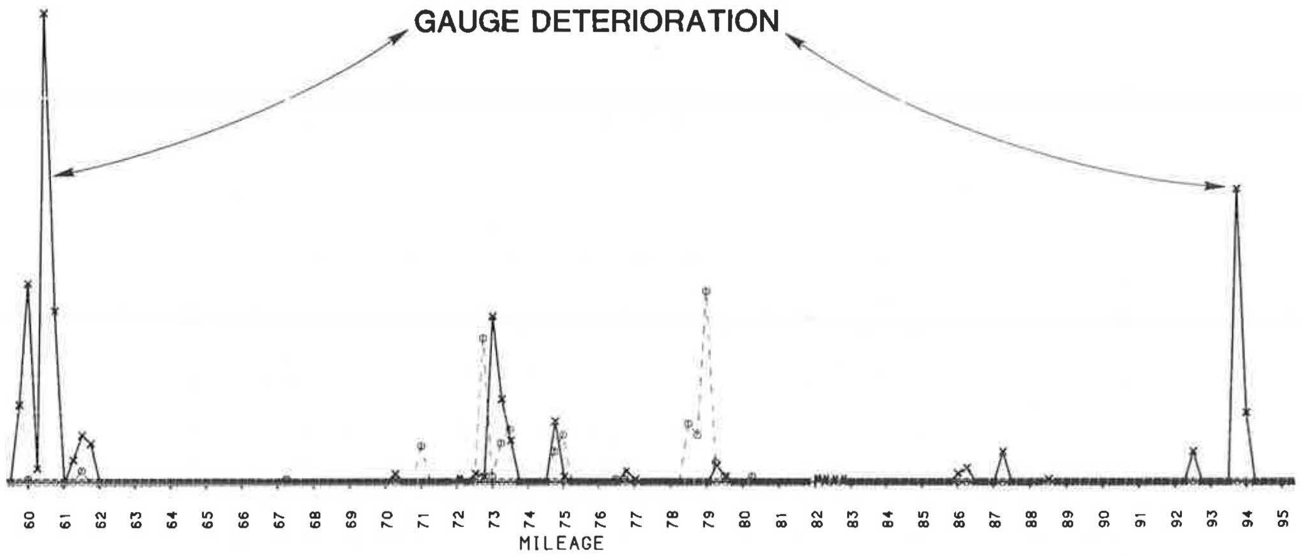

FIGURE 3 Gauge deterioration: comparison of no. of feet of wide gauge per ¼ mile.

the wheel tracking location as the car responds to unfavorable track geometry. CP Rail is particularly concerned with locations where the false flange of the wheel is able to ride on the field side of the low rails, producing heavy plastic flow and corrugations.

A second track geometry car is currently under development. This two-car consist will emphasize high reliability and high production, enabling CP Rail to increase from three to five times per year coverage of all main lines. This new car will incorporate several additional test parameters, including rail corrugation and rail wear assessment.

CP Rail has a unique requirement for durability in the construction of track geometry measurement equipment because of a policy of operating at the end of regularly scheduled freights under all weather conditions.

MONITORING RAIL FATIGUE

Monitoring of rail failures receives a high priority as both a problem locator and as a tool for assisting in long-range planning. CP Rail now has a data base containing 15 years of rail failure data, for a total of 230,000 defects. Failures can be grouped according to any combination of mile, subdivision, failure type, track classification, weld or joint area, weight of rail, manufacturer, ingot position, and curve versus tangent.

One of the reports used to locate problems is the rail failure hot list (Table 2), which ranks the 50 worst miles and 50 worst 10-mile sections by mainline versus branchline. This list is used to ensure that priorities for rail programs are properly set and that new rail is distributed over the proper mileages.

CP Rail has recently developed a program for accessing its mainframe files of rail defects, track geometry, and rail failures to analyze rail fatigue trends. This program uses the Weibull statistical analysis technique pioneered at the Association of American Railroads. Historical-defect-occurrence rates can be automatically displayed and analyzed to decide whether rails are exhibiting a mature fatigue process, as indicated by a steadily increasing rate of rail defect occurrences. Constant failure rates over time are considered less of a problem because they indicate random failures of rails that are locally overstressed. Such rails may be part of the infant-mortality segment of the rail population that fails before the general population of rails in the segment.

When it is suspected that a rail is fatiguing, the computer program is used to access the data bases for the section in question, separating tangent sections from curves. A curve-fitting routine is automatically performed to the time series progression of rail failures to test their degree of fit to an equation in the form of the Weibull distribution, which has been found to reflect the progression of fatigue failures in engineering materials. Use of this technique enables the system engineering office not only to test the existence of a mature fatigue process, but also to quantify when critical levels of failures will have been reached. Future failures can be projected to an economic renewal timing of from 3 to 6 defects per year, depending on the level of traffic.

Figure 4 shows sample rates of rail failures in four different lengths of track. An X indicates when the rail was removed. In general, rail is replaced well before its economic fatigue life because of the existence of other wear mechanisms such as gauge-face wear, shelling, and corrugation. As the rail grinding effort is increased, CP Rail expects to increase rail wear limits, leading to more cases of rail renewal due to fatigue. The challenge to extend rail life without incurring heavy penalties in spot rail replacements will put a premium on the ability to track defect trends and recognize the optimal renewal training.

COMPUTER ASSISTANCE IN PLANNING

Last year, personal computers were installed in all division engineering offices to supplement those already used in the regional offices and some of the maintenance-of-way work equipment and signal shops. Although software has been provided to assist project management, personnel management, and engineering design calculations, perhaps their greatest value is in the promotion of planning.

Initially, personal computers were installed in two pilot divisions for a 6-month period. Both divisions responded by setting up many different kinds

TABLE 2 Excerpt from Rail Failure Hot List

REGION	NUMBER	SUBDIVISION	BRANCHLINE WHICH TRACK	MP FROM	MP TO	TOTAL DEFECTS
EASTERN	2147	WALKELY LINE	SINGLE	4	5	10
EASTERN	2346	PORT BURWELL	SINGLE	5	6	6
EASTERN	2147	WALKELY LINE	SINGLE	1	2	6
PACIFIC	4151	LOMOND	SINGLE	18	19	6
ATLANTIC	1156	FREDERICTON	SINGLE	4	5	5
ATLANTIC	1142	GIBSON	SINGLE	56	57	5
PACIFIC	4154	LANGDON	SINGLE	36	37	5
PACIFIC	4151	LOMOND	SINGLE	26	27	5
PACIFIC	4151	LOMOND	SINGLE	23	24	5
EASTERN	2147	WALKELY LINE	SINGLE	5	6	4
ATLANTIC	1541	TRURO	SINGLE	1	2	4
ATLANTIC	1541	TRURO	SINGLE	2	3	4
ATLANTIC	1142	GIBSON	SINGLE	55	56	4
ATLANTIC	1142	GIBSON	SINGLE	52	53	4
PACIFIC	4531	PRINCETON 3B	SINGLE	158	159	4
PACIFIC	4245	BRETON	SINGLE	6	7	4
PACIFIC	4244	WILLINGDON	SINGLE	130	131	4
PACIFIC	4241	HOADLEY	SINGLE	3	4	4
PACIFIC	4154	LANGDON	SINGLE	57	58	4
PACIFIC	4154	LANGDON	SINGLE	53	54	4
PACIFIC	4151	LOMOND	SINGLE	30	31	4
PACIFIC	4140	ACME	SINGLE	16	17	4
PACIFIC	4140	ACME	SINGLE	5	6	4
PACIFIC	4134	EMPRESS 3B	SINGLE	67	68	4
PACIFIC	4134	EMPRESS 3B	SINGLE	9	10	4
PRAIRIE	3630	LANIGAN	SINGLE	47	48	4
EASTERN	2540	TEMISCAMING	SINGLE	2	3	3
EASTERN	2147	WALKELY LINE	SINGLE	2	3	3
EASTERN	2142	ELLWOOD	SINGLE	2	3	3
ATLANTIC	1156	FREDERICTON	SINGLE	19	20	3

of lists--including records of allocation of machines to territories, accumulated overtime, and eyebolt replacement schedules. Because it was so easy to organize their data, they were keeping more information than before, and, more importantly, they were using it in their planning. The support of personal computing at the divisions was, therefore, seen as a way to assist and promote planning.

Throughout the past year, a project management computer package was implemented at the divisions, based on CP Rail's SPEC planning methodology, which allows local offices to track each individual appropriation in terms of

- Length of critical path
- Effects of delays on project completion
- Estimated project expenditure versus budget

In short, it allows local people to visualize their project, easily make changes to their schedule, and answer questions such as "Do I have enough money in my budget to rent a bulldozer to bring me back on schedule?"

All personal computers are also connected to the mainframe computer, giving them access to CP Rail's excellent electronic mail system. This has speeded up CP Rail's communications and has been invaluable in emergency situations. The Chief Engineer is now afforded the capability to communicate instantly with any engineering office and to view the contents of

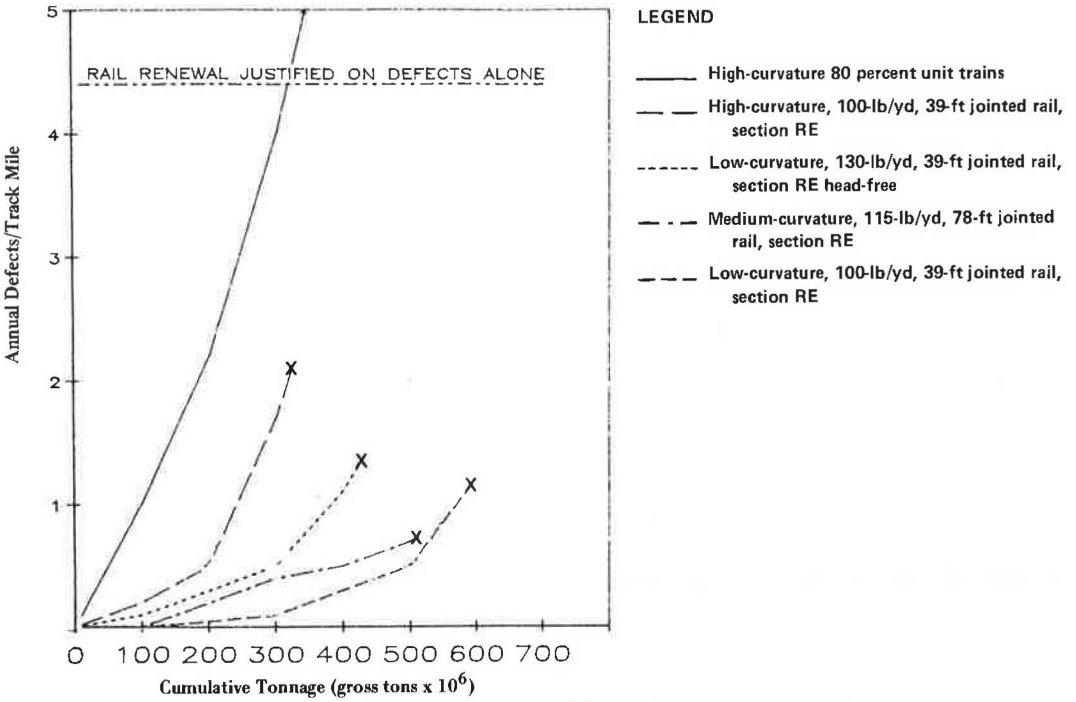

FIGURE 4 CP Rail's rail failure trends on five main line subdivisions.

his in-basket from virtually any office on the system.

The Chief Engineer's office is in the process of implementing full office automation. Files are being kept electronically and many of these will be shared among all engineering offices. For example, a file on the rehabilitation of a bridge could be accessed on the screen and memoranda posted from any office. The elimination of paper is seen as a way to free more time for planning.

LONG-RANGE PLANS

CP Rail has made a long-term commitment to implement Manufacturing Resource Planning (MRP) at the corporate level. MRP is a management philosophy that emphasizes planning and is run on integrated computer software that guides all aspects of the planning of work, through the ordering of materials and the monitoring of gang progress relative to plan. In effect, it makes 80 percent of CP Rail's current systems obsolete and replaces them with an integrated approach to planning and controlling resources used by all operating departments.

According to the plan, these strategies for improving track structure to eliminate weak links, and development of information systems to assess maintenance priorities, will enable CP Rail to make full use of a long-range integrated planning approach that will reduce firefighting to an absolute minimum.

Principles of Maintenance-of-Way Planning

E. R. TRASK

ABSTRACT

Doing track maintenance in a planned manner reduces the overall cost of a series of related activities. To obtain optimum results, the planning staff should be experienced and technically knowledgeable. Some of the more important principles to consider when making any plan are establishing the size of the permanent work force, implementing directives from regulatory bodies, establishing standards, measuring rate of plant deterioration, educating staff, communicating effectively, mechanizing gangs, using forecasting material, forecasting future travel levels, creating a plant inventory, establishing a planning period, establishing a logical sequence for replacement of components, coordinating field activities with train schedules, using theoretical degradation models, and reporting progress of work and comparing it with the plan.

After the maintenance requirements for track, roadbed, and right-of-way have been identified, and after priorities have been assigned, the maintenance-of-way activities need to be planned. Almost any good, ambitious individual could fix up a deteriorating piece of track if he was told what to fix and if he had unlimited supplies of money, labor, material, and time. Because there are limitations, planning is required; this is based on the assumption that planning is a method of obtaining maximum benefit for minimum overall cost.

To obtain this benefit, the planning must be done by people who have a feel for how all of the different parts of a track structure relate to each other and what effect a weakness in one component has on other components. Therefore, the first obvious principle of maintenance-of-way planning is as follows: have the planning group staffed with people who have had practical field experience and a basic civil engineering education, and have an ability to do basic economic analyses.

Other principles that will be explained in more detail are

- Establishing the size of the permanent work force
- Implementing directives from regulatory bodies
- Establishing standards
- Measuring plant deterioration
- Educating staff
- Communicating effectively
- Mechanizing gangs
- Using forecasting material
- Forecasting future traffic levels
- Creating a plant inventory
- Establishing a planning period
- Establishing a logical sequence for replacement of components
- Coordinating field activities with train schedules
- Using degradation models
- Reporting progress of work