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Some Alternatives for Improving The U. S. Railroad System†

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THIS PAPER describes a model developed to predict the sensitivity of railroad financial performance to various non-structural strategies for improving rail operation. The model is designed to analyze any rail system, ranging in size from a single railroad to the national rail network. As an illustrative example, the model is applied to the "national" rail system.

It is concluded that very substantial benefits can be derived through improvements in operations, labor agreements, and marketing. While the model does not prescribe a mechanism for achieving these improvements, it describes the scale of potential benefits and determines the implications of different policies.

* * *

The railroads, even with their declining market share, still carry 37% of the ton-miles transported and remain the single largest carrier of freight in the country. Furthermore, railroads appear more attractive as energy and environmental concerns gain in importance. Not only are railroads more energy efficient than motor carriers, but they move the bulk of the coal transported in the U.S. As the nation moves toward a greater dependence on coal, the need for a healthy rail industry becomes even more important. All things considered, despite continuing financial problems, the railroad industry could benefit from substantial traffic growth over the next decade.

However, the potential for traffic growth cannot be achieved unless the industry's financial position can be strengthened. Only with improved financial viability can the railroads afford the investment in equipment and facilities necessary to maintain and improve service levels as traffic volumes grow.

What can be done to help restore the economic viability of the rail system? One thing is clear—there is no single answer. Simultaneous progress in many areas will be necessary. Mergers and consolidations can help reduce overhead expense and eliminate redundant facilities or operations. Corporate restructuring, including possibilities such as separation of ownership from operation of rights-of-way and expansion of the railbox concept, may enhance the profitability or the financial capability of the industry.

Yet the greatest potential may involve the ways in which railroad companies are internally organized and operated. At this level, there are many "non-structural" strategies, so called because they do not explicitly require either physical or corporate restructuring of the industry, which could improve financial viability. The most important include:

- improving the effectiveness of all aspects of railroad operating policy, particularly as it relates to marketing strategy
- increasing labor productivity through negotiation of agreements that promote efficiency and ensure higher quality service
- enhancing railroad information systems to promote more effective management control over operations and marketing
- identifying and making those investments which have the greatest potential for improving the financial situation

These strategies are the key elements in railroad management. They also reflect the potential for "self-help" within the industry. The key questions which must be addressed as the industry strives to reach its goals are:

- What strategies for improvement exist within the railroad industry?
- What needs to be done to implement these strategies?
- How can the government assist the railroad industry in pursuing these strategies?
- What are the important constraints and how can they be reduced or eliminated?

However, the basic question is: **can significant financial improvement in the railroad industry be achieved by non-structural means (i.e., without extensive physical or corporate restructuring)?**

This paper addresses that question by presenting the methodology and results of a recent study. This study included

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†This research was conducted by Multisystems, Inc. under contract to the Federal Railroad Administration.

the development of a **Railroad System Performance Model** designed specifically to help in understanding the magnitude of improvements possible through non-structural means.

The purpose of this screening model was to facilitate the identification and quantification of major opportunities for improvement in the railroad industry. This required a relatively macroscopic analytic approach, and the results obtained were therefore not expected to be highly precise. However, the model was designed to predict the incremental impacts of various changes in the rail system. Consequently, it is appropriate to use it to predict the changes in system performance due to (for example) improvements in car utilization; its usefulness as an absolute prediction tool (e.g., for determining what NROI will be in absolute precise terms under certain assumptions) is limited.

Although the model does not prescribe mechanisms for achieving operational improvements, it seems that some such improvements are feasible. Advances in computer technology and software are giving the railroads better mechanisms to control car flows.[1] Better costing systems and rail organizational structures which are more attuned to the marketplace are being developed. While changes in the physical plant may well be required to achieve some of the components discussed earlier and constitutional barriers may prevent or slow others, there are some possibilities for progress through "soft" changes in the industry.

There is substantial potential for improving rail financial performance. While this paper does not address the issue of overcoming the constraints involved, it is useful in understanding the magnitude of the potential benefits.

MODEL DESCRIPTION

Given reasonable assumptions about the likely changes in operating parameters that would result from a particular strategy for improving rail performance, the model estimates the impacts on cost, revenue, service, and car utilization. It is important to understand at the outset that the model is not intended for the novice user. As the reader will see, some sophistication is needed to provide reasonable input to the model and to interpret the results. For example, some sense of the relation between congestion and system performance, classification policies and travel performance, and car routings and load/empty ratios is needed to make good use of the model.

The flow chart in Figure 1 depicts the model's operation. It requires as input the level of demand (in tons carried) and calculates the resulting required system supply characteristics. These characteristics are then compared with input system capacity constraints (computed from the size of the car and locomotive fleets, yard capacity, and time necessary for the distribution of empty cars). If required capacity exceeds available capacity, demand is reduced and the process is repeated until an equilibrium is reached. The supply characteristics are then converted to costs and the demand level to revenue. From these, standard financial measures, such as net railway operating income (NROI) and return on investment (ROI), are determined.[2]

The model is not confined to any distinct system or time frame. It is easily calibrated to an individual railroad or to an entire network of railroads. Furthermore, the user can manipulate the input variables to represent almost any change in the levels of demand, capacity, and operating efficiency.

RAILROAD SYSTEM PERFORMANCE MODEL FLOW CHART

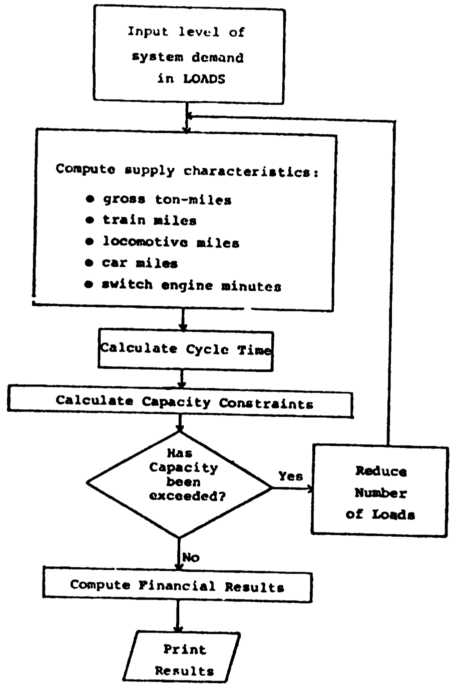

FIGURE 1

INPUT REQUIREMENTS

The model requires a large number of inputs (44 in the fully specified case), covering four areas of system operation: operating constraints; supply characteristics; system parameters; and financial measures (see Table 1). Some of the inputs are very straightforward and can be found directly in available ICC data. Other inputs require substantial judgment on the part of the user. While these judgments may at times be somewhat arbitrary (such as the "ideal" number of days which should be assigned to empty car distribution), this is not viewed as a critical problem in model use, since it is the changes in system performance predicted by a series of runs which are important, rather than the absolute value predicted by a single run. Thus, "reasonable" values will generally provide proper **benchmarks** against which to measure changes in performance.

Operating constraints include the level of demand, the car and locomotive fleet available to meet that demand, the car-time required by the shipper, and the system's classification capacity.[3]

Supply characteristics describe system operations. They are average values for the railroad(s) under consideration and are easily altered to represent changes in operating conditions. They include train speed, average tonnage per load, the number of miles and classifications per load, the number of empty car-miles associated with each load, the locomotives per train, and the average number of trains departing from a yard in one

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LIST OF INPUTS

OPERATING CONSTRAINTS

Level of demand (in tons)
Car and locomotive fleet size
Customer time/handling
Customer handlings/load
Annual classification capacity

SUPPLY CHARACTERISTICS

Train speed
Average tons/load
Miles/load
Classifications/load
Miles/locomotive-day
Empty miles/loaded miles
Locomotives/train
Outbound block frequency
Tare weight

SYSTEM PARAMETERS

Optimal and maximum tons/locomotive
Optimal and minimum SEM/classification*
Optimal idle car-time/load
Maximum loads lost due to lack of idle car-time
Minimum yard process time
Maximum classification delay
Maximum outbound delay

Four factors used to define relationship between:
- SEM/classification and Congestion
- Idle car-time/load and Loads lost
- Classification delay and SEM/classification
- Outbound delay and Available locomotive power

FINANCIAL MEASURES

Cost/move
Cost/car-mile
Cost/gross ton-mile
Cost/train-mile
Cost/locomotive-mile
Cost/SEM
Cost/ton

Fixed operating cost
Miscellaneous capital costs
Investment/car and locomotive
Resale value/car and locomotive
Interest cost/car and locomotive
Net investment base
Average revenue/load

*SEM = switch engine minute

TABLE 1

day. These inputs can be used to reflect different load types. For example, the locomotives/train can show a particular mix of local, manifest, piggyback, unit coal, and other classes of freight trains.

System parameters define optimal levels and reasonable ranges of operations. These numbers are used to determine the level of service under various operating conditions (as will be explained later).

The optimal locomotive utilization (tons/locomotive) represents that point below which the locomotives are underutilized and above which congestion will occur owing to the high power demand placed on the locomotives. A maximum is estimated based on the physical tonnage capacity the average locomotive can handle while travelling at a reasonable speed.

The optimal switch engine minutes (SEM)/classification is an estimate of the SEM required when there is no congestion. At most yards, when traffic volume increases much beyond the average, the actual SEM/switch decreases. This is often a symptom of deteriorating performance as the yard approaches capacity. When each crew is busy continuously, SEM/switch is low, but the yard has no capacity to handle peak loads and cars are therefore delayed.[4] A physical minimum is estimated based on the time required when the yard crew is working at high speed under greatest congestion.

The optimal free car time/load is the empty, non-transit time, presumably to be used for cleaning, servicing, and distribution (idle time), below which empty cars can not be distributed efficiently and above which the car fleet is under-utilized. If the free car time decreases below the optimal level, the system cannot handle as many loads and thus traffic is lost.

MODEL THEORY

The system parameters described above specify equations used to calculate the cycle time (yard time + line time + customer time):

Yard time = (Time/Yard × (# Yards/Trip)

Line Time = (Empty + Loaded Miles) ÷ (Average Speed)

Customer Time = 2 × (Average Customer Time)

Because the bulk of the car cycle time is consumed in yards, the "yard time" is modelled in greater detail:

Time/Yard = Minimum Processing Time
+ Average Processing Delay
+ Average Wait for Outbound Train
+ Average Outbound Delay

The equations used to model the two kinds of yard delay cause delays to increase when yard or power capacity constraints are reached.[5]

A classification delay is calculated using the curves shown in Figure 2. The top shows how the SEM/classification decrease as yards become more congested. The second uses the results of that calculation to determine the average classification delay. When volumes are low, delays are small but crews will often be idle. When volumes are high, delays increase and crews are fully occupied trying to catch up.

An outbound delay is found using the relationships shown in Figure 3. With low tonnage volumes, the gross tons/outbound train should be well within capacity constraints. Units will be stored to keep GTM/locomotive mile at the desired level and the average outbound delay will be small. As volume increases, however, more trains operate at full tonnage and outbound delays will therefore increase.

The remaining portions of yard time are a minimum processing time of about 3 hours and a wait time estimated as half of the average interval between appropriate trains as calculated from the outbound block frequency. When all of the above numbers have been determined, the model sums them to obtain yard time, then adds that number to line time and customer handling time to find the average system cycle time.

Having determined the gross level of system operation and the cycle time, the model proceeds to calculate four capacity constraints from the car supply, the locomotive supply, the yard classification capacity, and the need for free car-time. Each of these constraints yields a maximum number of loads that the system can handle. If the number of loads calculated at the beginning of the model exceeds any of the constraints, it is reduced by half of the difference and the model loops back to recalculate cycle time and system parameters. This loop is continued until less than 0.1% of the loads are lost.

If none of the capacity constraints are binding, the measures of the level of system operation are multiplied by their (input) unit costs to obtain the variable operating cost. This figure is added to the fixed operating cost to obtain the total operating expense, which when subtracted from total operating revenue

AS VOLUME APPROACHES LIMITS OF YARD CAPACITY, SEM/SWITCH IMPROVES BUT CLASSIFICATION DELAYS INCREASE

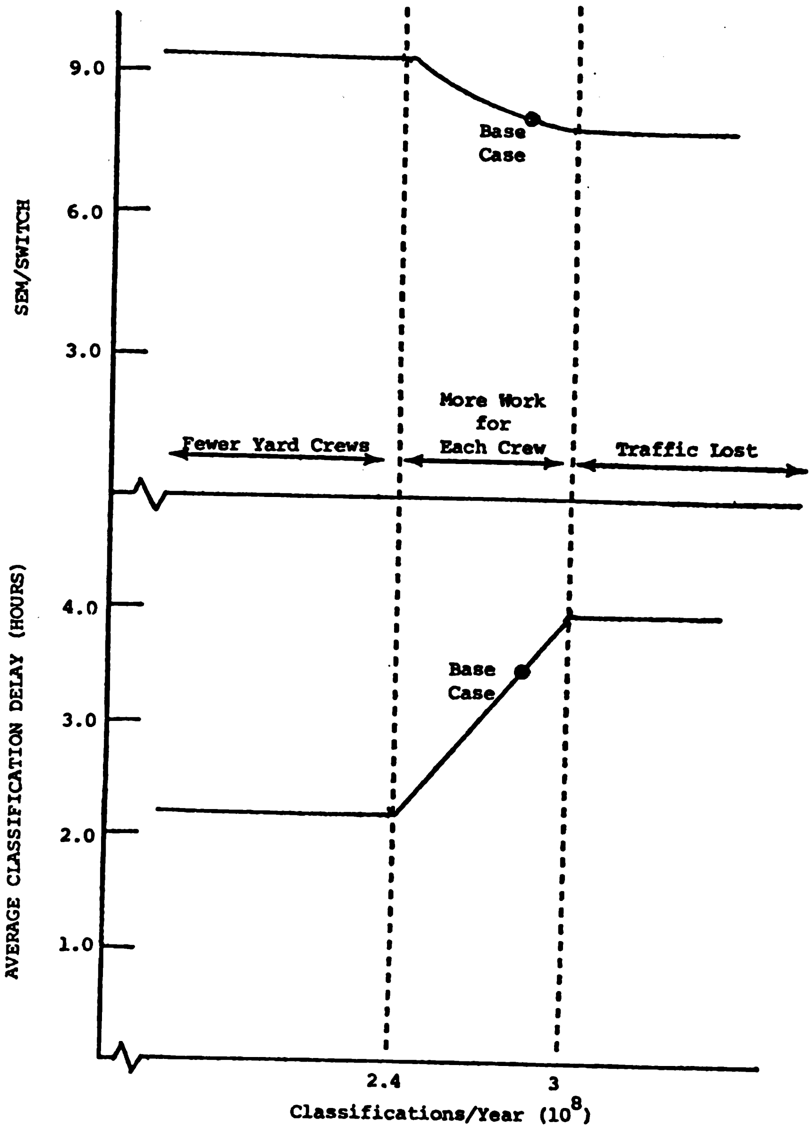

FIGURE 2

(found from the input revenue/load), yields the net railway operating income.

Finally, all results are printed on one page of output, a sample of which is shown in Figure 4.

CASE STUDY— THE "NATIONAL" CASE[6]

As an example of its application, the model was used to investigate the stra-

AS VOLUME APPROACHES LIMITS OF LOCOMOTIVE FLEET, DELAYS INCREASE DRAMATICALLY AT CLASSIFICATION YARDS

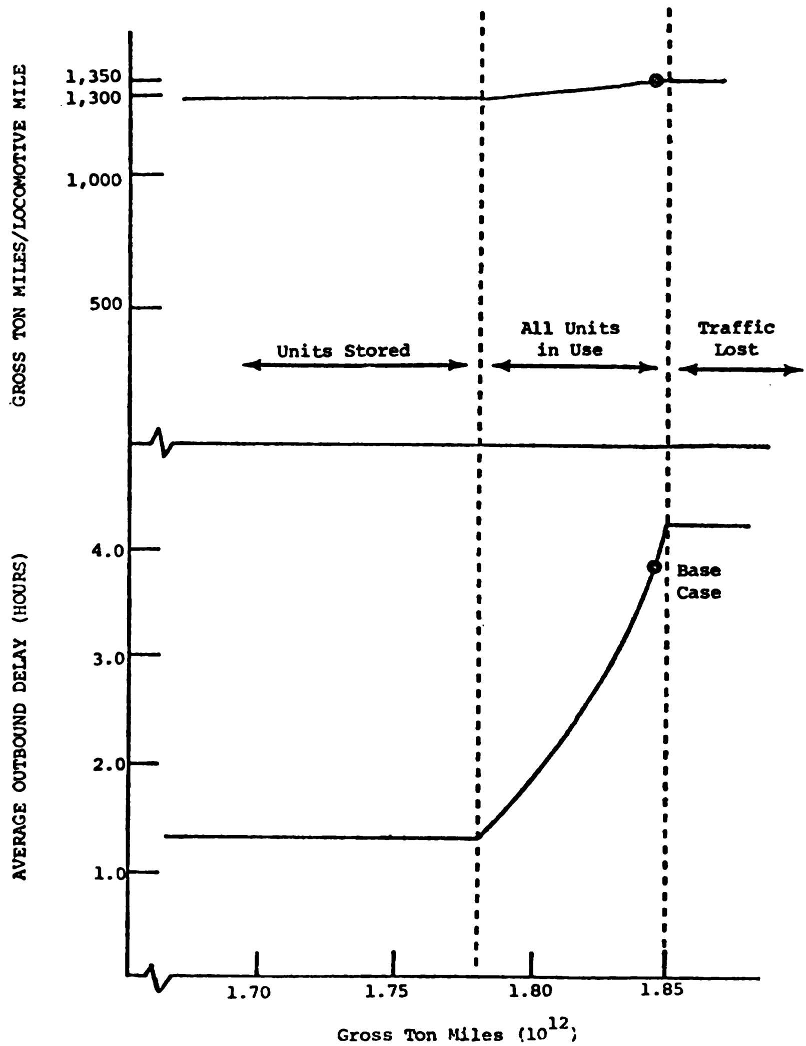

FIGURE 3

tegies for improving railroad performance listed in the first column of Table 2. The remainder of the table shows the ways in which the parameters were varied in the "National" case study (base year 1973). Each parameter was varied over the range indicated to allow the analyst to compare the relative impacts of specific strategies.

The strategies shown in Table 3 (selected from a larger set of runs) are considered to be reasonable targets, and it is certainly possible to state that several strategies appear to have a substantial effect on financial performance.

Return on investment is perhaps the best single measure of performance, because it accounts for changes in the investment base as well as in net railway operating income. The estimate of cycle time is important as an indication of service levels. Train length is included

SAMPLE OUTPUT
(RAILROAD SYSTEM PERFORMANCE MODEL)

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                 RAILROAD SYSTEM PERFORMANCE AND FINANCIAL MODEL

THIS RUN IS THE NATIONAL BASE RUN 1973
   RUN  1

           UNIT COSTS                    PARAMETERS                        SUBTOTAL COSTS

 COST/LOAD              28.7700     LOADS            27339264.0          786550656.0
 COST/CAR-MILE           0.0214     CAR-MILES     31261933560.0          667442304.0
 COST/GTM                0.0003     GTM         1847913086976.0          517415680.0
 COST/TRAIN-MILE         3.5200     TRAIN-MILES     476425344.0         1677017216.0
 COST/LOCO-MILE          0.7295     LOCO-MILES     1373057792.0         1001618240.0
 COST/SW.ENG.MIN.        0.4172     SW.ENG.MINS.   2355199232.0          982636224.0
 COST/TON                2.7904     TONS           1532201728.0         4275517184.0

         FINANCIAL RESULTS

    REVENUE                       14384563564.0
    OPERATING COST                 9908197376.0
    FIXED OPERATING COST           3440000000.0
    NET RAILWAY OPERATING INC.     1036356608.0
    NET INVESTMENT                28978053120.0
    RETURN ON INVESTMENT                 3.5763
    NET INCOME                      600192576.0
    AVG.REVENUE/LOAD                   526.1500
    AVG.COST/LOAD                      362.4164

                            PERFORMANCE RESULTS

    TARE      PCT.LOST    CYCLE TIME(DAYS)   CUSTOMER TIME    LINE TIME    YARD TIME    FREE CAR TIME(DAYS)
    26.79       2.498           19.06              8.00          2.41         8.65            2.50

    MIN.PROC.TIME(HRS)    CLASS.DELAY(HRS)    O.B.DELAY(HRS)    CLASSIF./LOAD    FREQUENCY    MAX. CLASSIF./YEAR
          3.0                  3.49                3.07              6.00            1.25         300000000.0

        CARS         LOCOS          TONS/LOCO          AVG. TRAINSPEED(MPH)          AVG. TRAIN LENGTH(CARS)
     1615000.0      19100.0          1345.84                  19.80                           65.6

 NET TONS/LOAD    LOCOS/TRAIN    DES.FREE CAR DAYS/LOAD    MAX.GROSS TONS/LOCO       MIN.SWITCH ENG.MINS./SW.
     56.04            2.88                 2.47                  1350.00                       8.00

    LOCO-MILES/DAY        MILES/LOAD        EMPTY-MI/LOADED-MI        SWITCH ENG. MINS./SW.      CLASSIFICATIONS
       196.95               659.45                0.734                       8.200                284837696.0
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FIGURE 4

TABLE 2

VARIATIONS IN MODEL PARAMETERS

Strategy	Base Case	Cases Studied	Range
Varying empty car distribution	6.4 empty car-miles/ loaded car-miles	6	0.59 - 0.77
Varying number of classifications/ load	6.0 classifications/load	5	4.5 - 6.5
Reducing crew costs;	$3.53/-rail-mile		$2.65 - $3.53
varying frequency;	1.25 outbound trains/day	7	1.19 - 1.69
varying locomotives/train	2.90 locomotives/train		2.15 - 3.05
Improving routing decisions	660 miles/load	6	593 - 692
Varying yard efficencies	8.2 switch engine minutes/ switch	7	7.0 - 9.4
Varying customer time/handling	4.0 days/handling	7	3.0 - 4.5
Varying line speed	19.8 miles/hour	8	16.2 - 24.6

TABLE 3

OPERATING STRATEGIES FOR IMPROVING RAIL PERFORMANCE: ESTIMATES OF NATIONAL IMPACTS

Strategy	NROI ($)	ROI (%)	Cycle Time (Days)	Cars/ Train
Base Case	1,036	3.6	21.6	66
Empty car distribution (ratio of empty car-miles to loaded car-miles reduced by 20%)	+ 384 (+ 37%)	5.0	20.8	63
Classifications/load (reduced by 1 per load)	+ 284 (+ 27%)	4.7	20.2	66
Labor agreements (25% lower crew costs; 20% higher frequency)	+ 324 (+ 31%)	4.6	21.0	56
Routing (5% shorter)	+ 324 (+ 31%)	4.5	21.6	66
Yard efficiency (15% improvement)	+ 274 (+ 27%)	4.3	21.7	66
Customer detention time (1 day reduction in customer time/handling)	+ 124 (+ 12%)	4.2	19.7	66
Line speed (25% faster)	+ 124 (+ 12%)	3.9	21.2	66
All of the above	+2,224 (+ 215%)	13.3	15.7	59

in this table only to indicate which strategies involve changes in line operating policy.

In considering these results, the reader should recognize that the usefulness of this analysis lies in comparing each run to the base case. For example, a particular prediction of NROI by the model is not appropriate. However, a comparison of NROI in a particular run to that in the base case is valid and hopefully useful in rail policy formulation.

The remainder of this paper discusses the most effective of the strategies, presenting the modelling methodology and the performance and financial results.

Better Empty Car Distribution: The average empty car movement is fully 75% as long as the average loaded car movement,[7] a dismal figure, especially when the equivalent value for motor carriers is in the 5 to 10 percent range.[8] In most assigned fleets, the empty return is 100%. Since empty car movements are nearly as expensive as loaded movements and put almost as much strain on yard and terminal operations, the incentive to improve empty car distribution is great. In fact, the industry has historically devoted a great deal of attention to this topic and continues to do so through the Freight Car Utilization Research/Demonstration Program.

The effectiveness of car distribution was reflected by the model in the ratio of empty-to-loaded car-miles. In the test run, this was reduced by 20% (from 0.73 to 0.59), resulting in a 37% increase in NROI and a 39% increase in ROI. The financial improvements result from an 8% reduction in total car-miles, a 4% reduction in GTM, train-miles, and locomotive-miles, and an 8% reduction in SEM and classifications. Train length drops slightly, although train tonnage remains constant (with a higher proportion of loaded cars).

Fewer Classifications: Many railroads feel that the key to improving railroad service levels lies in reducing the number of times that cars are handled. The industry has attempted to do this using run-through trains, unit trains, coordination at interchanges, operations planning, yard consolidation, and piggyback operations. These strategies can be very effective in improving trip times and reliability.

A reduction in the number of classifications from 6 to 5 for loaded trips and from 4.4 to 3.7 for empty trips resulted in a 22% increase in NROI and a 30% increase in return on investment. In addition, the cycle time was reduced by 1.4 days showing an improvement in the level of service.

New Labor Agreements: As the cost of road and yard crews increases, railroad management must investigate the provision of a better service using the existing labor force more effectively. The goals of labor negotiations should move toward an enhanced capacity to attract traffic, improved car utilization, and better working conditions—goals that both labor and management can accept. It should be possible to negotiate agreements that maintain employment levels and annual compensation as effectively as the current agreements, but that do not so severely constrain operating flexibility.

One possibility is to run shorter trains requiring fewer workers on a more frequent basis. This would allow the level of employment to remain constant while improving the quality of service. The model was used to evaluate this strategy by inputting a 25% decrease in train-mile costs accompanied by an increase in train length. Specifically, the cost per 100 train miles was reduced from $353 (roughly wages plus fringe benefits for a four-man crew) to $265. This could represent a shift to three-man crews, a basis of pay emphasizing time more than mileage, a realignment of crew districts, or a combination of these and other changes.

The financial results of this run (a 31% increase in NROI and a 28% increase in return on investment) should be interpreted only as an indication of the potential importance of changes in labor agreements. The actual results of a new agreement would be highly sensitive to the specific changes in work rules, pay scales, and basis of pay.

Multiple Strategies: Conceivably, substantial progress in all of the previously mentioned areas could be made over the next ten years. To show what this would do to financial performance, the model was run with all inputs set equal to the attractive values used in the individual strategies. In addition, traffic volume was increased by 20%.

The operating improvements translate directly into significant cost reductions and financial improvements. NROI increases by 180% or just over $2 billion. Return on investment rises to 13%, more than triple the base case performance.

CONCLUSIONS:

The results of this analysis suggest important financial benefits, but careful interpretation is required. Most notably, the analysis did not consider the investment or expense that might be needed to achieve such operating improvements. Although there is no single strategy that will solve all of the rail industry's financial problems, together these strategies can go a long way toward restoring the rail industry's financial health. Significant across-the-board improvements in areas such as operations, labor, customer relations, and marketing, if they can be achieved, could increase NROI by 1.5 to $3 billion and ROI to above 13% on a national scale.

This is not to say that it would be easy to achieve such benefits. Quite the contrary is true. There are formidable institutional, organizational, and regulatory barriers to these improvements. However, it does suggest that substantial financial benefits are available within the rail community through strategies less complex than a major restructuring of the industry.

FOOTNOTES

1 Wyckoff, Daryl and David H. Maister, **The Owner Operator: Independent Trucking**, Lexington, Massachusetts: Lexington Books, 1975.

2 It should be noted that the model treats taxes primarily as a fixed operating cost. This avoids the complexities associated with estimating federal income taxes by maintaining such taxes at roughly the level observed in the base period. The model also maintains payroll taxes at roughly the base level, which is reasonable so long as employment does not change markedly. Although the model may either overestimate or underestimate tax liability in particular situations, this approach was felt to be the most consistent.

3 This last constraint is an estimate based on observation of the system. The classifications occurring over a given time period are determined from a knowledge of the number of loads carried and an estimate of the classifications per load. If the system is congested, the classification capacity is assumed to be only slightly higher than that found for the specified time period.

4 Task Force on Reliability Studies, **Freight Car Utilization and Railroad Reliability: Case Studies**, Association of American Railroads, Report R-283, 1977, Chapter 16 "Southern Pacific Case Study: Controlled Terminal Performance."

5 It is assumed that the U.S. rail system was operating at close to capacity during the base year, 1973.

6 Space does not permit a wider range of application to be presented. However, the model has been applied to various regional studies and to several individual railroads.

7 AAR, "Operating and Traffic Statistics," 1976.

8 Daryl Wyckoff and David H. Maister, **The Owner Operator: Independent Trucking**, Lexington Books, Lexington, Massachusetts, 1975.