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TRANSPORTATION RESEARCH FORUM

The Relationship Between Railroad Work Rules and Operating Plans

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I. A THEORETICAL STRUCTURE

The Road/Yard Trade-Off and The Work Rule Impact

IN THE OPERATION of a railroad there is a fundamental trade-off between road and yard costs. A policy of running long trains consisting of many blocks decreases road costs by reducing total train mileage at the expense of the increased yard cost of additional intermediate switching. Conversely, a policy of running short trains consisting of a few blocks decreases yard costs by reducing intermediate switching, at the expense of the increased road cost of additional train mileage.

Work rules impact the choice of an operating policy or plan by their effect on road and yard cost structures. Work rules which raise road costs relative to yard costs dictate a more yard intensive, longer train operation. Work rules which lower road costs relative to yard costs call for a more road intensive, shorter train operation.

Breakdown of Costs

Exactly what costs are involved? In this analysis we are concerned with variable operating costs only, since we wish to observe the short run impact of a change in work rules on the choice of an operating plan, with the fixed plant held constant.

Road variable operating costs (C_R) can be broken down into:

1. Road crew cost (C_{RC})
2. Road car hour cost (C_{RH})
3. Road locomotive cost (C_{RL})
4. Road fuel cost (C_{RF})

Thus:

$$C_R = C_{RC} + C_{RH} + C_{RL} + C_{RF}$$

Yard variable operating costs (C_Y) can be broken down into:

1. Direct yard switching cost (C_{YS})
2. Yard car hour cost (C_{YH})

Thus:

$$C_Y = C_{YS} + C_{YH}$$

Note that yard costs have been broken down less microscopically than road costs. Clearly, C_{YS} could have been further dissected into yard crew, locomotive and fuel costs. Such detail on the yard side is not necessary for this analysis since the work rule to be varied is road crew consist; yard crew work rules are not altered.

In considering the impact of a work rule alteration in concert with a shift in operating plans, the change in total cost (C_T) is calculated as follows:

$$\triangle C_T = \triangle C_R + \triangle C_Y$$

$$\triangle C_T = \triangle C_{RC} + \triangle C_{RH} + \triangle C_{RL} + \triangle C_{RF} + \triangle C_{YS} + \triangle C_{YH}$$

Assuming the availability of a range of locomotive horsepower and no change in line haul speed, $\triangle C_{RL}$ and $\triangle C_{RF}$ will be approximately zero for a given ton-mileage of traffic. Assuming no change in line haul time, $\triangle C_{RH}$ also goes to zero. Thus, the difference equation reduces to:

$$\triangle C_T = \triangle C_{RC} + \triangle C_{YS} + \triangle C_{YH} \,^*$$

Up to this point we have been talking only about costs. Where does service fit in? Obviously, the quality of service is important because it plays a major role in determining the demand of shippers, which in turn determines the quantity and type of traffic hauled. Service can be incorporated into the analysis as a premium car hour cost added to the basic car hour cost. Thus, cars carrying traffic or empties assigned to carry traffic for which shippers demand a

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*In the unabridged version of this paper, this general equation is developed in more detail on a hypothetical four yard network.

higher level of service would bear higher total car hour costs.

II. BOSTON AND MAINE CASE STUDY

Application of the Theory to the Boston and Maine Railroad

As a practical example, the theory has been applied to the Boston and Maine Railroad (B&M). The particular work rule change investigated is a change in crew consist.

Those portions of the B&M network and traffic flows examined in this analysis are depicted in Exhibit 1. The network studied is a simple one, making it suitable for the development of straightforward examples. In spite of the network's simplicity, it contains an element crucial to our study — a node at which intermediate switching is done, switching which could be eliminated by the addition of new through trains. Thus there is a basis for a trade-off of road and yard costs, subject to the impact of work rules, in the selection of an operating plan.

The major intermediate switching point on the B&M is East Deerfield Yard. At East Deerfield, cars are switched between northbound/southbound trains and eastbound/westbound trains. Average daily volumes of this northeast, northwest, southeast and southwest traffic switched at East Deerfield, along with the cars hours incurred, were derived from train make-up reports covering the period from No-

PORTION OF B&M NETWORK AND TRAFFIC FLOWS EXAMINED IN THIS ANALYSIS

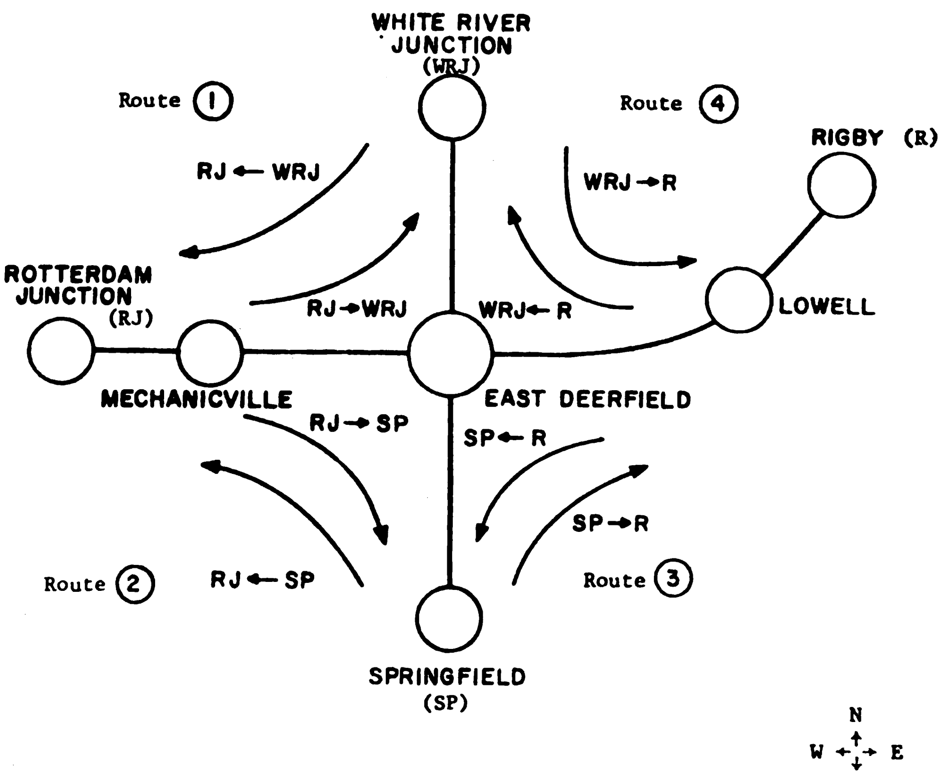

EXHIBIT 1

In this abridged report, only results for Route 1, Rotterdam Junction to White River Junction, have been presented. The other routes exhibited similar behavior, so Route 1 can be taken as being representative.

TRAFFIC SWITCHED AND ASSOCIATED YARD COSTS AT EAST DEERFIELD (ROUTE 1 ONLY)

Rt. No.	Cars From	Switched Into	Cars/ Day	Car Hrs./ Day	Hrs./ Car Swtchd	Cost Per Day: Direct Switch[1]	Cost Per Day: Car Hr[2]	Cost Per Day: Total Yard	Cost Per Day	Total Yard Cost/Car Switched
1	eastbound trains	northbound trains	24	940	39	$54	$400	$450	$760	$19
	southbound trains	westbound trains	23	610	27	52	260	310		13

EXHIBIT 2

1 Direct switching costs figured at $2.25 per car switched.
2 Car hour costs figured at $.42 per car hour.

vember 1 through November 15, 1977. These statistics form the traffic data base for the analysis. Statistics for Route 1 are presented in Exhibit 2.

The Road Intensive Alternative

As an alternative to the intermediate switching at East Deerfield, the operation of four new round trip through trains is considered:

1. Rotterdam Junction to White River Junction, and back
2. Springfield to Rotterdam Junction, and back
3. Springfield to Rigby (Portland), and back
4. White River Junction to Rigby, and back

For each of these proposed trains, the extra road cost of its addition is traded off against the yard cost of intermediate switching in its absence. The road/yard trade-off is conducted for various road crew sizes (4, 3, 2 and 1-man crews) to determine the crew consist at which each new train becomes economically justified for existing traffic flows. Similarly, the critical volumes at which the new trains become justified are derived for various crew consists. (Note that crew consists in the case study are varied on the proposed new trains only.) Finally, a series of sensitivity analyses are performed.

Cost Structure

Road and yard costs were structured according to the theory's most general form. Thus, the change in yard costs ($\triangle C_Y$) effected by the addition of through trains was determined as follows:

$$\triangle C_Y = \triangle C_{YS} + \triangle C_{YH}$$

The change in direct yard switching cost ($\triangle C_{YS}$) was calculated by multiplying the unit switching cost (c_s) by the change in the volume of cars switched ($\triangle V_s$). The change in yard car hour cost ($\triangle C_{YH}$) was derived from the train make-up reports which list the number of hours each car spends in the yard. The total of yard car hours was multiplied by the unit car hour cost (h) to arrive at $\triangle C_{YH}$.

The unit switching cost (c_s) used in the analysis is $2.25 per car, the block switching cost based on a block switching rate of 40 cars per hour and a yard variable operating cost (per switch engine with 4-man crew) of $90 per hour.[1]

The unit car hour cost (h) used is $.42 per car hour ($10 per car day) based on the replacement cost of the average freight car (equivalent to per diem on an average new car).[2] Both unit car hour cost and unit switching cost are implicitly varied in the sensitivity analyses.

The changes in road cost ($\triangle C_R$) incurred by the addition of through trains were calculated for 4, 3, 2 and 1-man crews using actual mileages and estimated running times for the proposed through trains. These mileages and times were multiplied by the standard mileage and daily wage rates. Arbitraries were dealt with by adding 10% to the calculated wages, a percentage borne out by B&M data on existing runs. Benefits were dealt with similarly by adding 30% to wages.

Results: Relationship Between Road Crew Consist and Choice of Operating Plan

Results of the analysis for Route 1 are presented in Exhibits 2, 3, 4 and 5. The exhibits are described in detail below.

Exhibit 2 presents yard costs for Route 1 traffic volumes switched at

East Deerfield. On route 1 an average of 24 cars per day are switched from eastbound trains out of Rotterdam Junction (or Mechanicville) to northbound trains out of East Deerfield. This Rotterdam Junction to White River Junction traffic incurs 940 car hours per day at East Deerfield; a yard time per car of 39 hours. At a direct switching cost of $2.25 per car switched and a car hour cost of $.42 per car hour, the traffic incurs $54 of direct switching cost and $400 of car hour cost per day for a total yard cost of $450 per day ($19 per car). Adding this total yard cost to the total yard cost per day of $310 incurred by traffic flowing in the opposite direction (White River Junction to Rotterdam Junction) yields a $760 total round trip yard cost per day incurred on route 1. This total round trip yard cost is the $-\triangle C_Y$ which will be compared to $\triangle C_R$ in the trade-off of road and yard costs.

The road/yard trade-off for route 1 is presented in Exhibit 3 using the total yard costs developed in Exhibit 1 and road crew costs derived from the standard daily and mileage rates applied to the route. The trade-off is performed by setting $\triangle C_T = 0$:

$$\triangle C_T = \triangle C_R + \triangle C_Y = 0$$

Thus, for any road crew consist $-\triangle C_Y \geqslant \triangle C_R$ means that the proposed additional through train should be operated, while $-\triangle C_Y < \triangle C_R$ means that the proposed additional through train should not be operated. In Exhibit 3, the largest road crew consist for which the additional through train will be operated (critical crew consist, K_R*) according to the $\triangle C_Y$, $\triangle C_R$ criteria is indicated by underscoring. Thus for route 1, a 2-man road crew is the largest crew consist for which the additional through train will be operated. Therefore, a reduction in road crew consist from 4-man to 2-man crews causes a shift to a more road intensive operating plan.

A sensitivity analysis of the road/yard trade-off for a ±20% variation in total yard cost is also presented in Exhibit 3. The largest road crew consist for which the proposed train is operated (K_R*) is again indicated by underscoring. For route 1, a decrease in total yard cost by 20% reduces the critical road crew consist to 1-man crews. Conversely, a 20% increase in total yard cost raises K_R* to 3-man crews.

What does the variation in total yard cost represent? Total yard cost is a function of traffic volume (V), direct switching cost per car (c_s), unit cost per car hour (h) and hours in yard per car (t):

$$C_Y = (c_s + ht)V$$

Thus, a variation in total yard cost could represent a variation in:

1. Traffic volume (V)
2. Direct switching cost per car (c_s)
3. Unit cost per car hour (h)
4. Hours in yard per car (t)

For example, a 20% increase in total yard cost on route 1 from $760 per day to $910 per day could be caused by:

1. A 20% increase in traffic volume

THE ROAD/YARD TRADE-OFF FOR ROUTE 1, ROTTERDAM JUNCTION TO WHITE RIVER JUNCTION, ROUND TRIP (386 MILES)

	Yard Costs Eliminated by Addition of Through Train ($-\Delta C_Y$)	Cost of Additional Through Train (ΔC_R) 4-man crews	3-man crews	2-man crews	1-man crews
Observed Yard Costs	$760	$1120	$ 870	<u>$ 620</u>	$ 340
Observed Yard Costs -20%	610	1120	870	620	<u>340</u>
Observed Yard Costs +20%	910	1120	<u>870</u>	620	340

EXHIBIT 3

Note. Underscoring indicates largest road crew consist for which additional through train will be operated ($-\triangle C_Y \geqslant \triangle C_R$).

(V) to 29 cars per day from Rotterdam Junction to White River Junction, and 28 cars per day from White River Junction to Rotterdam Junction.

2. A 140% increase in the direct switching cost per car (c_s) to $5.40 per car switched.
3. A 22% increase in the unit cost per car hour (h) to $.51

   or

   a consideration of the impact of service or contribution to net revenue which results in a 22% increase in the unit cost per car hour to $.51.
4. A 24% increase in the hours in yard per car (t) to 48 hours per car from Rotterdam Junction to White River Junction, and 33 hours per car from White River Junction to Rotterdam Junction.

Exhibit 4 presents the critical volumes at which the proposed route 1 through train will be operated. The critical volumes are derived as follows:

$\triangle C_R$ is constant with respect to V

$$\triangle C_Y = (c_s + ht)V$$

Assume $c_s + ht$ is constant for any given run

$$\therefore \triangle C_Y = kV$$

$$\frac{\triangle C_Y}{V} = k = \text{constant unit yard cost}$$

$$-\triangle C_Y = \triangle C_R \text{ at } V^*$$

$$\therefore -V^*(c_s + ht) = \triangle C_R$$

$$-V^*k = \triangle C_R$$

$$V^* = \frac{\triangle C_R}{-k}$$

where: k is the constant

$$\text{unit yard cost} = \frac{\triangle C_Y}{V}$$

Thus, for route 1, Exhibit 4 conveys the information detailed below.

On the northeast run from Rotterdam Junction to White River Junction, with an observed total yard cost per car of $19, the critical volumes are 35, 27, 20 and 11 cars per day for road crew consists of 4, 3, 2 and 1-man crews, respectively. Similarly, the southwest route 1 run from White River Junction to Rotterdam Junction, with an observed total yard cost per car of $13, has critical volumes of 34, 26, 19 and 10 cars per day for road crew consists of 4-, 3-, 2-, and 1-man crews, respectively.

Thus on route 1, the critical volumes, for 2-man crews, of 20 cars per day from Rotterdam Junction (RJ) to White River Junction (WRJ) and 19 cars per day from WRJ to RJ are exceeded by the observed traffic volume of 24 cars per day from RJ to WRJ, and 23 cars per day from WRJ to RJ. The critical volumes for 1-man crews are also ex-

CRITICAL VOLUME (V*) FOR VARIOUS ROAD CREW CONSISTS

	Rt. No.	Run	Total Yard Cost/Car	Road Crew Consist: 4-man	3-man	2-man	1-man	Traffic Volume: Observed -20%	Observed	Observed +20%
			Observed							
	1	Rotterdam Jct. to White River Jct.	$19	35	27	20	11	19	24	29
		White River Jct. to Rotterdam Jct.	13	34	26	19	10	18	23	28
← Sensitivity Analysis →			Observed-20%							
	1	Rotterdam Jct. to White River Jct.	$15	44	34	25	14	19	24	29
		White River Jct. to Rotterdam Jct.	10	43	33	24	13	18	23	28
			Observed+20%							
	1	Rotterdam Jct. to White River Jct.	$23	29	23	17	9	19	24	29
		White River Jct. to Rotterdam Jct.	16	28	22	16	8	18	23	28

↑ Critical Volumes ↑

EXHIBIT 4

ceeded by the observed traffic volumes. Thus, for 2-man and 1-man crews the additional through train should be operated. For 3-man-crews, the critical volumes of 27 cars per day RJ to WRJ, and 26 cars per day WRJ to RJ, are above the observed traffic volumes, as are the critical volumes for 4-man crews (35 RJ to WRJ, 24 WRJ to RJ). Thus, for 3-man or 4-man crews, the additional through train should not be operated.

Increasing the traffic volumes on route 1 by 20% (29 RJ to WRJ, 28 WRJ to RJ) raises them above the critical volumes for 3-man crews. Conversely, a 20% reduction in traffic volumes on route 1 (19 RJ to WRJ, 18 WRJ to RJ) reduces them below the critical volumes for 2-man crews.

Exhibit 4 also presents a sensitivity analysis of critical volume with respect to a ± 20% variation in the total yard cost per car. The new critical volumes were calculated as before:

$$V^* = \frac{\Delta C_R}{-k}$$

where k is constant unit yard cost.

Thus, a 20% decrease in total yard cost per car (unit yard cost) results in 25% increase in critical volume. A 20% increase in total yard cost per car results in a 17% decrease in critical volume. The impact on route 1 of a 20% decrease in total yard cost per car is to shift the critical road crew consist (K_R^*) down to 1-man crews for the observed traffic volumes of 24 cars per day from RJ to WRJ and 23 cars per day from WRJ to RJ. For increased traffic volumes (29 RJ to WRJ, 28 WRJ to RJ), K_R^* goes up to 3-man crews. A critical road crew consist matrix detailing the effects of traffic volume and yard cost per car for route 1 is presented in Exhibit 5. Note that opposing changes in traffic volume and yard cost per car tend to cancel one another.

III. CONCLUSIONS AND RECOMMENDATIONS

Specific Conclusions: Road Crew Consist and Through Train Operation

As crew consist is decreased, the cost of a train also decreases. Given traffic volume, unit switching cost, unit car hour cost, and time in yard per car, there is a critical crew consist (K_R^*) at which the cost of a train drops below the yard cost incurred in its absence. At that point, the operation of the train becomes economically desirable.

Similarly, given road crew consist, unit switching cost, unit car hour cost, and time in yard per car, there is a critical traffic volume (V^*) at which the addition of a new through train becomes desirable. As road crew consists decreases, the critical volume also decreases.

Increases in total yard cost per car, independent of the choice of operating plan (due to increase in unit switching cost (c_s), unit car hour cost (h), or time in yard per car (t), where $C_Y = [c_s + ht]V$) decrease the critical volume and increase the critical road crew consist, by increasing the yard savings made possible by the addition of a new through train.

Employment is not necessarily decreased by a cut in crew consist. For a system-wide reduction in crew consist, the operating plan change of adding new through trains may compensate, or more than compensate for the reduced crew consist. The result is maintained or increased employment. For reduced crew consist on added trains only, which

CRITICAL ROAD CREW CONSIST (K_R^*)

Rt. No.	Total Yard Cost Per Car	TRAFFIC VOLUME		
		Observed -20%	Observed	Observed +20%
1	Observed -20%	1	1	2
	Observed	1	2	3
	Observed +20%	2	3	4

EXHIBIT 5

would not be run without the reduction, employment can only increase. In any case, it is assumed that there is no reduction in yard employment stemming from the decrease in the volume of cars switched; the switch engine and crew time made available being used to improve yard performance.

Though employment may increase as a result of decreased road crew consist, there will be a change in the ratio of different crafts employed, with more engineers relative to trainmen being employed. Because of the institutional split between the Brotherhood of Locomotive Engineers (BLE, representing engineers) and the United Transportation Union (UTU, representing trainmen), and the separate lines of progression for engineers and trainmen, this change in employment ratios may cause problems.

Just as reduced crew consist need not mean reduced employment, increased crew consist need not mean increased employment. A high road crew consist, according to this analysis, reduces the number of trains, which can result in a net decrease in employment.

The consideration of car hour costs is crucial to the analysis. The direct cost of switching represents only 10 to 20% of total yard cost per car (see Exhibit 2), the remaining 80 to 90% are car hour costs. If car hour costs were ignored, the route 1 through train would not be run, even with a 1-man crew. Indeed, the failure to include car hour costs in the operating budgets of those charged with making operating plan decisions, or the underestimation of such costs, results in excessively yard intensive, long train operations.

General Conclusions: Work Rules And Operating Plans

There exists a relationship between railroad work rules and operating plans. A change in work rules alters the balance of road versus yard costs. This produces economic pressure for a change in operating plans.

Work rules which raise road costs relative to yard costs result in a more yard intensive operating plan (longer trains, fewer through trains, more intermediate switching). Work rules which lower road costs relative to yard costs result in a more road intensive operating plan (shorter trains, more through trains, less intermediate switching.) In either case, a proper perception of the work rule impact rests on the crucial inclusion of car hour costs in the analysis. Failure to consider car hour costs results in an excessively yard intensive, long train solution.

Just as work rules affect the operating plan, the choice of operating plan affects the work rules. For example, an operating plan of minimizing road train mileage, pursued as a general management policy over several years, will result in labor resistance to decreases in road crew consist, since crew consist becomes labor's only perceived control over declining employment. Ironically, this resistance to decreased crew consist maintains economic pressure on management to continue in its policy of train mileage minimization. The result is a deadlock, with ever decreasing employment and level of service. Through a clear understanding of the relationship between work rules and operating plans, and the initiative of either labor or management (preferably both) to change the rules and plans in concert, such deadlocks can be broken.

Recommendations

As a preliminary step, railroad managements should include car hour cost in the operating budgets of those charged with making operating plan decisions. Failure to do so will cause misperception of the impact of various work rules and an excessively yard intensive (long train) operation will result.

Following this preliminary step, both railroad management and labor should develop an understanding of:

1. The trade-off between road and yard cost
2. How the choice of operating plan depends on that trade-off
3. How a change in work rules alters the road versus yard cost structure, thereby necessitating a change in operating plans
4. How the choice of operating plan encourages the development of a particular set of work rules.

It is then the responsibility of railroad management to perform the necessary trade-off of road versus yard costs for various work rule/operating plan combinations. Using the results of such analyses, assuming both labor and management understand the work rule/operating plan relationship, it should be possible to reach an agreement on work rule/operating plan reform. Chances of reaching an agreement should be enhanced by the fact that work rule reform, when coupled to a shift in operating plans, need not necessarily result in decreased employment. (Chances of reaching an agreement would be further enhanced if the UTU and BLE could work out some institutional means of dealing with changes in the employment ratios among different crafts. For ex-

ample, a training program could be established to teach trainmen to serve as engineers.)

There are a variety of approaches to reaching an agreement on work rule/operating plan reform. For example:

- Specific work rule/operating plan packages can be put together
- General work rule/operating plan principles can be established
- A general employment guarantee can be offered in exchange for work rule reform, with choice of the operating plan left to management

No one of these approaches is necessarily the best for all railroads. It is up to the individual railroad managements and their labor counterparts to develop the approach which suits them best. But whatever approach is chosen, the key to the problem lies in an understanding of the relationship between work rules and operating plans.

FOOTNOTES

1 From conversations with railroad officials and AAR staff.

2 From AAR Car Hire Rate Table, for a car less than six years old costing $25,000 to $30,000 when new.

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