

# Demonstration of the Rail Energy Cost Analysis Package: The Route Perspective (RECAP II)

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## ABSTRACT

A demonstration of the Rail Energy Cost Analysis Package: The Route Perspective (RECAP II) is presented. RECAP II is a computer model that can be used to perform engineering-economic cost analysis of specific rail movements. The program was designed in response to the need for costing tools that are adequate for analyzing changes in railroad technology. Existing costing tools, such as the Uniform Rail Costing System, assume fixed technology, and therefore cannot be used to assess the value of technological advances. The RECAP II model calculates costs by determining the resources consumed in making a specific movement. To perform this function, the model contains a Train Performance Simulator that calculates train running time and fuel consumption. With this information, and with track maintenance costs developed from a matrix of marginal costs of track maintenance, RECAP II determines the cost of running a specific consist over a specific route. Through a demonstration run detailed in the paper, RECAP II is shown to be a powerful decision-making tool. With its help, informed choices can be made among many service and technology options.

For many years, railroads have relied exclusively on accounting procedures and techniques to determine the cost of moving freight. By far the greatest source of railroad cost information in the past has been Rail Form A and its successor, the Uniform Rail Costing System (URCS). These accounting-based costing methods were developed primarily to meet the needs of regulatory cost analysis. That is, they were used to determine the variable cost of given moves in order to establish maximum legal freight rates.

## INTRODUCTION

The basic approach to accounting-based costing is to determine unit costs (e.g., cost per switch engine minute) by regressing all expenses associated with an expense category (e.g., the time-related expense of running switch engines) against the number of service units (e.g., number of switch engine minutes) associated with that expense. After the resulting fixed and variable costs were developed, costs for a specific move were calculated by determining the number of service units of each category consumed and multiplying by the variable cost rate and adding fixed costs. A thorough description of the URCS system is available in Uniform Railroad Costing: 1980 Rail Cost Survey (1).

Although such systems may be quite useful for overall pricing strategy or for regulatory analysis, they are not particularly well suited to analyzing alternative service options and alternative technologies for two major reasons. First, the unit costs developed are highly aggregate, as they must be, having been developed as averages for an entire railroad. Because of this aggregation, cost differences resulting from special or individual cases cannot be accounted for. For example, a URCS-based analysis of the cost of moving a consist over severe grades would yield the same cost as running the same consist over flat territory. A second difficulty occurs because accounting-based cost analysis as-

sumes fixed technology. For example, road-haul fuel costs are usually determined by multiplying appropriate unit costs by gross ton-miles and by locomotive unit miles. If a more efficient locomotive is used, or if cars are streamlined, the cost analysis procedure would overestimate fuel costs. Therefore, such cost analysis procedures are usually not adequate for assessing the value of technology improvements.

To better evaluate technological improvements, an engineering-based economic model is more useful. An engineering economic model uses engineering knowledge to determine the actual resources used in a specific move and then to calculate costs by determining the price and quantity of each resource. The Rail Energy Cost Analysis Package: The Route Perspective (RECAP II) is a tool that can be used to determine point-to-point rail costs based on an engineering analysis of the movement.

Before specifically discussing RECAP II, however, it is useful to make a few points about engineering economic models in general. Although such models are useful for analyzing service and technology alternatives, they are of limited use in overall pricing strategy or regulatory analysis. This is because an engineering economics analysis will generally provide a reasonable estimate of the difference in cost between two alternatives, but will usually provide only a lower bound estimate on the absolute cost of any given alternative. By modeling a specific circumstance and determining costs by evaluating resources consumed in that circumstance, engineering economics models can miss certain components of cost, such as administrative overhead and costs associated with unforeseen events (e.g., train accidents).

Given these constraints, potential applications for RECAP II can be listed. The following is a brief, but not exhaustive, list of potential uses for RECAP II:

1. Comparison of relative costs of different routes;

2. Determination of the cost and operating effects of alternative train makeup strategies;
3. Determination of the effect on all categories of the cost of reducing tare weight, increasing lading, or both;
4. Calculation of cost savings generated by reducing aerodynamic drag or reducing bearing resistance;
5. Calculation of absolute and relative cost impacts of changing crew compensation methods and costs;
6. Determination of cost and operating impacts of various refueling strategies; and
7. Calculation of cost and operating impacts of improving locomotive performance through increased traction, increased horsepower, and decreased weight.

RECAP II, then, is a powerful tool to assist railroad management in making operating and investment decisions that affect the cost of operation over specific routes.

#### PROGRAM LOGIC

RECAP II is composed of several submodels. It is primarily built around the Train Energy Model (TEM), which is an enhanced Train Performance Simulator (TPS) (2) developed by the Association of American Railroads (AAR) Technical Center in Chicago, Illinois. The full RECAP II model contains a TEM module, as well as a Driver program, a Cost model, and a matrix of data generated by the Track Maintenance Cost Model (discussed later). A flow chart for RECAP II is shown in Figure 1.

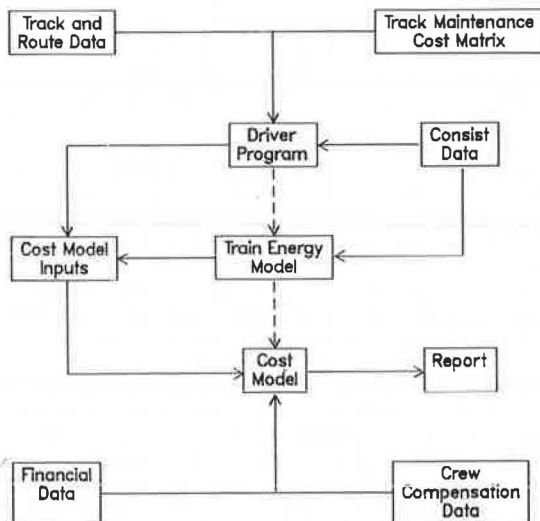


FIGURE 1 Flowchart for RECAP II.

RECAP II is written in FORTRAN and is currently designed to run on a Digital Equipment Corporation model 2060 (DEC 20) computer. Railroads that are members of the AAR may establish an account for access to the DEC-20 computer at the AAR Technical Center in Chicago, Illinois. RECAP II can then be executed remotely via modem. In the future (sometime in 1985), a version of RECAP II will be available for the IBM Personal Computer (PC). The PC version will be written in FORTRAN and BASIC.

The program begins by executing the Driver program. The Driver program reads two input files, the track and route profile file and the consist and route data file. These files contain the information

necessary to specify the train consist and the route over which it runs. The files are based on similar files used to run TPS models. After the Driver program has read the input files, the program then creates a cost analysis file to be read by the costing subroutines. The cost analysis file contains the following information:

- \* Consist general data: makeup, gross weight, net weight, cubic capacity.
- \* Locomotive data: purchase prices, availability ratios, running cost per mile.
- \* Car data: daily rate, per-mile rate.
- \* Crew data: crew change points, crew district boundaries.
- \* Track maintenance cost data: incremental track maintenance cost for each track segment.

The last data category (track maintenance cost) is determined based on input of a track maintenance cost matrix. The matrix provides the marginal track maintenance cost per gross-ton-mile based on the following characteristics: (a) type of rail; (b) gross tons per year traversing that segment; (c) type of consist (standard unit train, heavy unit train, intermodal, mixed freight, or empty); (d) grade; and (e) curvature. The costs in the matrix were determined by executing the Track Maintenance Cost Model (TMCOST). TMCOST is an AAR-enhanced version of the Canadian Institute for Guided Ground Transport Rail wear Cost Model (3). The track maintenance cost matrix provided with RECAP II is based on industry averages.

After the Driver program has produced the cost analysis file, it passes control to the TEM. The TEM is a train simulator similar to the TPS, with the exception that the TEM produces slightly more information about energy use. In modeling the train over the route, the TEM will handle the train by attempting to match the train's speed to the speed limit, as found in the track file. For trains that run substantially below the speed limit, the speed limits in the track file should be adjusted accordingly. The TEM stops the train at user-specified points for a user-specified dwell time. This feature is useful in including stops and signal delays that the user believes are representative of the average case. Like the Driver program, the TEM produces a file for input to the Cost model. This file contains the following information for a large number of points on the route:

1. Distance in feet,
2. Elapsed time since beginning of trip,
3. Cumulative fuel consumption, and
4. Current throttle notch position.

The frequency of entries in this file varies; however, it averages about one entry for every 200 to 500 ft. The user specifies the mile per hour increment that must occur to create an entry in this file. The TEM also produces a summary report on train makeup and the train's trip history. Later, the Cost model appends cost information to this report.

After the Driver program and the TEM have developed the appropriate files, control is passed to the Cost model. The Cost model determines the following costs of running the specified consist over the specified route:

1. Crew costs,
2. Locomotive ownership and running costs,
3. Car ownership and running costs,
4. Fuel cost, and
5. Track maintenance costs.

Also, the model will determine each of these costs per gross ton-mile, per net ton-mile, and per cubic foot-mile. In the case of a train running empty, the costs per net ton-mile will be set to arbitrarily large numbers.

To determine these costs, the Cost model requires additional inputs; therefore, data are read from the financial data file and the crew compensation file. With that additional information, the Cost model then has all the data it needs to calculate costs.

Crew costs are calculated by the time-distance formula used throughout the industry. The Cost model reads through the train running history as output by TEM and stops when the distance marker exceeds the distance marker for the first crew change point. At this point, the elapsed time and elapsed distance are used to calculate crew basic pay, in accordance with the following formula:

$$p = b + m*(100 - d) + b*[t - (d/12.5)]*.1875$$

where

p = basic pay,  
 b = basic daily rate,  
 m = mileage rate (or zero, if d is less than 100),  
 d = distance traveled, and  
 t = elapsed time.

To the basic pay is added a fixed arbitrary allowance to yield gross pay. Gross pay is then multiplied by 1 plus the fringe benefits rate to yield total compensation.

Locomotive ownership and running costs are calculated on the basis of locomotive data in the consist file, the elapsed time and distance calculated by the TEM, and, because locomotives are a capital asset, the information in the financial data file. Locomotive ownership costs are developed by first calculating an equivalent hourly rent on the equipment. This equivalent rent is calculated on the basis of each locomotive's purchase price and the present value of depreciation tax shelters and investment tax credits. The equivalent hourly rents are multiplied by elapsed time in hours to yield locomotive ownership costs. Locomotive running costs are determined by multiplying the running cost per mile (user input) for each locomotive by the number of miles traveled.

Car ownership costs are determined for each car by dividing the per diem rate by 24 and multiplying by the elapsed time in hours. The per diem rate input by the user should be the actual rate divided by the proportion of time that the car is in service. Car running costs are determined by multiplying each car's mileage rate by the number of miles traveled.

Fuel costs are determined in a straightforward manner. The fuel consumption calculated by the TEM is multiplied by the price per gallon specified by the user to determine fuel cost. Track maintenance cost is calculated in the Driver program, as described earlier.

#### SAMPLE ANALYSIS

As an example application for RECAP II, consider the following. A railroad operates a unit coal train in a mountainous area. Railroad officials are trying to decide whether to replace 100-ton coal cars (263,000 lb gross weight) with 112-ton coal cars (286,000 lb gross weight). They would like an estimate of the line-haul operating costs of moving the coal using each car type.

The first step in analyzing the alternatives is to prepare the data needed to execute RECAP II. The following information is needed: (a) track and route profile data, (b) consist and route data, (c) financial data, and (d) crew compensation data.

For this example, it is assumed that most of the track and route profile data are available from existing files used in executing a TPS. In addition to the data usually found in a TPS route profile deck, the following information is also required: (a) gross tons of traffic at each point, (b) crew district boundaries, (c) crew change points, (d) track type at each point, and (e) track lubrication data. For this example, it has been assumed that all the track on the route is 132 lb/yd hardened continuous welded rail, track is unlubricated, and gross tons of traffic is 30 MGT/year on each track at all points. Crew district boundaries and crew change points are given on the system schematic shown in Figure 2.

A summary of the route data available is provided in Table 1. Together with the system map in Figure 2 and the requirement to model a train from Hub A to

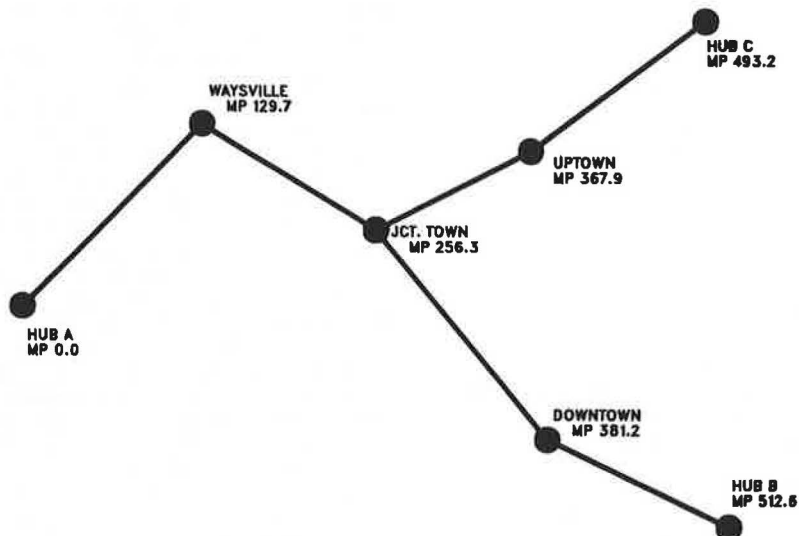


FIGURE 2 System schematic. (All stations shown represent crew district boundaries and actual crew change points for this route.)

**TABLE 1 Summary of Track and Route Profile Data**  
(File name = TRAK)

Segment No.	Begin Mile	End Mile	Begin Station	End Station	On Route
1	0.0	129.7	Hub A	Waysville	Yes
2	129.7	256.3	Waysville	Junction Town	Yes
3	256.3	367.9	Junction Town	Uptown	No
4	367.9	493.2	Uptown	Hub C	No
5	256.3	381.2	Junction Town	Downtown	Yes
6	381.2	512.6	Downtown	Hub B	Yes
7	512.6	381.2	Hub B	Downtown	No
8	381.2	256.3	Downtown	Junction Town	No
9	493.2	367.9	Hub C	Uptown	No
10	367.9	256.3	Uptown	Junction Town	No
11	256.3	129.7	Junction Town	Waysville	No
12	129.7	0.0	Waysville	Hub A	No

Hub B, a route can be selected consisting of segments 1, 2, 5, and 6.

The consist and route data file is the main driving file that the user is likely to change most often. It contains the following information: (a) general job data, (b) route segment list, (c) general train data, (d) data on locomotive units, and (e) data on cars.

A summary of the general job data is provided in Table 2. The first item is for selection of summary or detailed printed reports. Because RECAP II is only capable of summary printouts at this time, they have been selected. As indicated in Table 1, there are four route segments involved in this analysis. The track file information item indicates that the route profile deck is on disk with file name TRAK.KED. The coasting overspeed values indicate that the train may be permitted to exceed the posted limit by 10 mph or 25 percent (whichever is less) before applying brakes. The next three items are switches for certain summary printouts. All have been set to 1 to indicate a desire that they all be printed. The cost of fuel is found to be 85¢ per gallon for this railroad. The iterative velocity increment is the change in speed that will cause the simulation model to update the train movement. The setting of 1.0 mph is standard. The duplicate segment switch has been set to zero, thereby disallowing the same route segment from appearing twice in the route description.

**TABLE 2 Job Data**

Item	Value
Printout type	Summary
Number of route segments	4
Track file information	DSK: TRAK
Coasting overspeed (mph)	10
Coasting overspeed (%)	25
Throttle position summary	1
Velocity range summary	1
Energy use summary	1
Cost of fuel	85.0
Iterative velocity increment	1.0
Duplicate segment switch	0

The next set of data in the consist and route data file identifies the route segments used in this run. These data are indicated as follows:

Item	Value
Milepost at special begin point	None
Segments on route	1, 2, 5, 6
Milepost at special end point	None

The first item is a milepost at any special begin point. That is, if a trip begins in the middle of the first segment listed, this is the milepost where the trip begins. In this case, the trip begins at the beginning of the first segment, so there is no special begin point. Similarly, there is no special end point, as indicated in the last data item. The remaining data item is the list of route segments, given in order traversed, defining this trip.

The next set of data required for the consist and route data file contains general information about the train. These data are given in Table 3. The name given to this train is COAL. The departure time is set at 00:00 (midnight) so that all times given are elapsed times. Wind is assumed calm. The train is given seven locomotives. The adhesion limit is 0.23; that is, the power axles can transmit a force, longitudinal to the rail, no greater than 23 percent of the weight on that axle before slipping. The 23 percent figure is representative of dry rail under normal conditions. The maximum speed of the train is set at 80 mph. This will override any greater speed limits found in the route profile data (if any). The brake pipe pressure (air brakes) is set at 80 psi. The coasting overspeed switch is off; so rather than apply brakes, the train will be allowed to exceed speed limit slightly when coasting.

**TABLE 3 General Train Data**

Item	Value
Train name	COAL
Departure time	00:00
Wind speed/direction	0
Number of locomotives	7
Adhesion limit	0.23
Maximum speed	80
Brake pipe pressure	80
Coasting overspeed	0
Consist code	2
Number of cars	101
Curving resistance code	0
Resistance equation code	2
Tangent lubrication resistance factor	1

The consist code of 2 tells RECAP II that this is a unit train with standard car loaded-weights of 263,000 lb. The number of cars in this train is 101 (100 hoppers and one caboose). The curving resistance code of 0 indicates that the cars contain standard trucks and that the standard Davis formulation for curving resistance is to be used. The resistance equation code of 2 selects the Davis equation for train resistance as modified by the Canadian National. The program will calculate reduction of resistance due to tangent lubrication through the input of the tangent lubrication resistance factor. The value of 1 here indicates that 100 percent of tangent rolling resistance will be used and no resistance reduction due to lubrication on tangent track is being modeled.

Data for the locomotive units in the consist are given in Table 4. In this train there are seven SD-40-2 units in the consist. The data for each, as given in Table 4, are relatively straightforward and standard for these units. The last few items on the data list could use additional illumination, however. The low-speed and high-speed breaks refer to points on a graph of tractive effort versus velocity where the slope of the curve changes. The transmission conversion factor is an indicator of transmission efficiency. No resistance coefficients are being supplied, so the model will assume standard coefficients. The economic factors of life, availability ratio, and running/cost per mile are all

TABLE 4 Locomotive Data

Item	Value
Name	SD-40-2
Total weight	195 tons
Weight on drivers	195 tons
Unit length	66 ft
Rated horsepower	3,000 HP
De-rated horsepower	3,000 HP
Total number of axles	6
Number of driven axles	6
Energy rate running	0.0559
Energy rate idling	0.092
Low-speed break	12
High-speed break	13
Transmission conversion factor	308
Resistance coefficients	Standard
Economic factors	
Price new (\$)	1,250,000
Life	20 years
Availability ratio	0.90
Running cost/mile (\$)	1.16

based on the railroad's experience with this model locomotive. The price new would be the current purchase price for an SD-40-2 locomotive or its equivalent.

Data for the cars in the consist are provided in Table 5. The car name is an arbitrary label that must be unique for each type of car in the train. Because RECAP II will be run separately for the heavy and light cars, both cars are labeled Hopper without risking ambiguity. Data on the 100-ton hopper are given in the first column and data on the 112-ton hopper are given in the second column. The loaded weight for all cars is equal to the tare weight of the car plus the weight of the lading. The length of the car is the coupler-to-coupler length. The remaining general data are self-explanatory. The resistance coefficients used in this case are standard Davis equation coefficients. The cross-sectional area of the heavy car has increased to account for its larger size, however. The streamlining and exponent values for aerodynamic characteristics do not apply here. The per diem and mileage charges shown in the economic data section are the time and distance rates for the cars when off-line. It should be noted that the 112-ton capacity hoppers may be more expensive or have a shorter life, thus requiring a higher per diem; or they may be more costly to maintain, requiring a higher mileage charge. In this study, costs are compared assuming no increase in these figures; however, performing alternative analyses with variations in these amounts would be a useful sensitivity study.

The crew compensation data file contains the following four numbers on crew pay: basic daily rate,

TABLE 5 Car Data

General data	Hopper	Hopper	Caboose
Car name	Hopper	Hopper	Caboose
Loaded weight	131.5 tons	143.0 tons	30 ton
Length	52 ft	52 ft	35 ft
No. of axles	4	4	4
Lading volume	4000 ft <sup>3</sup>	4450 ft <sup>3</sup>	0
Tare weight	31 tons	31 tons	30 tons
Resistance coefficients			
Rolling friction	0.6	0.6	0.6
Bearing friction	20	20	20
Flange friction	0.010	0.010	0.010
Air drag	0.0005	0.0005	0.0005
Cross sectional area	140	148	140
Streamlining	n/a	n/a	n/a
Exponent	n/a	n/a	n/a
Economic data			
Per diem (\$)	18.00	18.00	9.00
Mileage charge (\$)	0.13	0.13	0.07

mileage charge, arbitrary allowance, and fringe benefit rate. The file requires these four numbers for each crew staffing the train as it traverses the route. In this example, all crews have identical pay rates, as follows:

Basic daily rate	394.16
Mileage rate	3.6629
Arbitrary allowance	184.88
Fringe benefit rate	0.35

For a typical crew traveling 129 miles in 7 hours, cost would be calculated as follows:

$$\text{Crew cost} = (\text{Basic daily rate} + 29 \times (\text{mileage rate} + \text{arbitrary allowance})) \times (1 + \text{fringe benefit rate})$$

or

$$\text{Crew cost} = (394.16 + 29 \times 3.6629 + 184.88) \times (1.35)$$

$$\text{Crew cost} = \$925.11$$

The financial data file contains information about projected inflation rates, discount rates, and tax rates. In this example, the following values were used:

Item	Value (%)
Inflation rate	5
Discount rate	8
Tax rate	46
Investment tax credit rate	10

The output file from RECAP II contains an echo of inputs, an analysis of the simulated train run and a cost analysis. Because this paper focuses mainly on the cost analysis features of RECAP II, only those output pages relating to cost are provided here. The cost analysis begins on page 16 of the output, shown in Figure 3.

Page 16 of the output shows the crew cost summary. Starting, ending, and elapsed time and miles are shown along with a variety of cost categories. In this case, each crew receives a total compensation of \$900 to \$950 per trip, which is approximately \$7.00 to \$7.25 per mile. Because no trip exceeded 8 hours, no overtime pay is necessary.

Page 17 of the output (Figure 4) provides a summary of equipment costs. The table indicates running and ownership costs for each type of equipment in the train. In this case, most of the cost is car running cost. Overall, equipment costs are about 3.7 times the crew cost.

Page 18 of the output (Figure 5) shows a fuel cost summary divided by stopping points along the route. The information provided in this table is essentially the same as in the run summary and time-tables noted earlier; however, the emphasis in this table is to clearly show the cost of fuel. In this case, fuel costs are about 2.7 times crew cost and about 2/3 of the equipment cost.

A track maintenance cost summary is provided on page 19 of the output (Figure 6). The costs given in this table are marginal costs. That is, the amounts represent the track maintenance money that would have been saved if the operation of this particular consist had not occurred. As expected, the cost of maintaining curved track is much higher per mile than the cost of maintaining tangent track.

The last page of the output (Figure 7) summarizes the cost for this run. For each category of cost, the following unit costs are provided: cost per gross ton-mile, cost per net ton-mile, and cost per cubic foot-mile. The total cost for this run is \$30,982.47 or 0.60¢ per net ton-mile (NTM). If the cost appears low, remember that the cost of the

## CREW COST SUMMARY:

CREW NUMBER	CREW DISTR.	START TIME	END TIME	TOTAL TIME	START MILE	END MILE	TOTAL MILES	BASIC PAY	O-MILE PAY	O-TIME PAY	ARBIT. ALLOW.	BENEFIT ALLOW.	TOTAL COMP.
01	1	0: 0	5:38	5:38	0.00	129.67	129.67	394.29	108.60	0.00	184.80	240.69	928.38
02	1	5:38	11:13	5:34	129.67	256.27	126.59	394.29	97.34	0.00	184.80	236.75	913.17
03	1	11:13	16:35	5:23	256.27	381.20	124.93	394.29	91.25	0.00	184.80	234.62	904.97
04	1	16:35	20:10	3:35	381.20	512.55	131.35	394.29	114.74	0.00	184.80	242.84	936.67
TOTAL		0: 0	20:10	20:10	0.00	512.55	512.55	1577.16	411.93	0.00	739.20	954.90	3683.19

FIGURE 3 Crew cost summary—base case.

## EQUIPMENT COST SUMMARY:

EQUIP-MENT TYPE	NUMBER OF UNITS	PURCHASE PRICE (EACH)	HOURLY OWNERSHIP COST	TOTAL HOURS OPER.	TOTAL OWNERSHIP COST	RUNNING COST CTS/MILE	TOTAL MILES OPER.	TOTAL RUNNING COST	TOTAL COST
SD-40	7	1250000.	9.75	20.17	1376.66	116.000	513.	4161.90	5538.56
HOPPER	100		0.75	20.17	1512.85	13.000	513.	6663.13	8175.99
CABOOSE	1		0.38	20.17	7.56	7.000	513.	35.88	43.44
TOTAL		108			2897.08			10860.91	13757.99

FIGURE 4 Equipment cost summary—base case.

## FUEL COST SUMMARY:

STOP NUMBER	MILE-POST	ARRIVE TIME	DEPART TIME	IDLE TIME	FUEL CONS. AT STOP	CUM. FUEL CONSUMED	CUM. FUEL EXPENSE
1	129.33	3:36	5:36	2: 0	77.28	2670.82	2270.19
2	255.97	9:11	11:11	2: 0	77.28	6255.90	5317.51
3	380.91	14:33	16:33	2: 0	77.29	8829.41	7505.00
*****	512.60	20:10	****FINAL DESTINATION****			11564.33	9829.68

FIGURE 5 Fuel cost summary—base case.

## TRACK MAINTENANCE COST SUMMARY:

SEGMENT	LENGTH	TOTAL MGMT	CONSIST MGMT	MILES OF TANGENT	TANGENT TRACK MAINT. COST	MILES OF CURVED TRACK	CURVED TRACK MAINT. COST	TOTAL TRACK MAINT. COST
HUB A	129.70	3891.00	1.88649	114.38	766.26	15.32	123.80	890.06
WAYSVILLE	126.60	3798.00	1.84140	95.99	645.68	30.61	275.17	920.85
JCT. TOWN	124.90	3747.00	1.81667	96.38	650.18	28.52	277.76	927.94
UPTOWN	131.40	3942.00	1.91121	99.29	669.04	32.11	303.93	972.97
TOTAL	512.60	15378.00	7.45577	406.04	2731.16	106.56	980.66	3711.82

FIGURE 6 Track maintenance cost summary—base case.

## COST OF RUNNING SPECIFIED CONSIST:

CATEGORY	TOTAL COST	COST /GTM	COST /NTM	COST /CFM
CREW COST	3683.19	0.00049405	0.00071503	0.00001797
LOCOMOTIVE COSTS:				
OWNERSHIP COST	1376.66	0.00018466	0.00026726	0.00000671
RUNNING COST	4161.90	0.00055827	0.00080796	0.00002030
CAR COSTS:				
OWNERSHIP COST	1520.42	0.00020395	0.00029516	0.00000742
RUNNING COST	6699.01	0.00089859	0.00130050	0.00003268
FUEL COST	9829.48	0.00131850	0.00190822	0.00004794
TRACK COST	3711.81	0.00049789	0.00072058	0.00001810
TOTAL COST	30982.47	0.00415592	0.00601471	0.00015112

FIGURE 7 Total cost summary—base case.

empty return trip has not been tabulated, and no overhead costs are included.

As mentioned earlier, the primary purpose of this study is to determine whether coal can be transported more inexpensively using 286,000-lb cars instead of 263,000-lb cars. Because a run of RECAP II has provided costs for a run of 263,000-lb cars, it is now necessary to run the model using 286-lb cars.

The input file for making the second run will differ only slightly from the first input file. The job data (Table 2) and route data will remain the same. The general train data (Table 3) will have two changes. First, the number of cars in the consist will be reduced from 101 to 91 to keep total lading weight as constant as possible. The base train contained 100 hopper cars, each with 100.5 tons of lading, for a total of 10,050 tons. This train contains 90 hopper cars, each with 112 tons lading, for a total of 10,080 tons. Second, the consist type code will be changed from 2 (standard unit train) to 1 (heavy unit train).

None of the inputs that describe the locomotives (Table 4) has been changed. The inputs that describe the cars (Table 5) inputs are shown in the second Hopper column of Table 5.

A portion of the output generated by running RECAP II with the revised input file is shown in Figures 8-12. The crew cost summary (Figure 8) indicates that there is no significant difference in crew costs for the two runs. Because crew rates are mostly determined by miles traveled, this is not unexpected.

The equipment cost summary (Figure 9) indicates a significant decrease of \$825 from the previous run. This is partially because the second run took 3 minutes less than the first run. This 0.25 percent re-

duction in running time is due to the lower train resistance caused by reduced train gross weight (discussed in detail later). This running time reduction is responsible for saving 0.0025 x 13,758, or \$34 in equipment ownership costs. The remaining \$791 savings is a result of 10 fewer cars required to carry the same lading.

The fuel cost summary (Figure 10) indicates that this run used 11,610 gallons of fuel, which is 46 gallons more than the previous run, for an increase in cost of \$39. The slight increase is due to the greater aerodynamic cross section of the 112-ton cars. This is offset somewhat by the reduction in train gross weight. Although each loaded car is 8.75 percent heavier than before, there are 10 percent fewer cars. As a result, the train is lighter by 280 tons. Because lighter trains offer less resistance to acceleration, the travel time for the trip is reduced; however, the faster speed and greater aerodynamic cross section of the high-capacity car result in a slight net increase in fuel use.

The track maintenance cost summary (Figure 11) indicates that the track maintenance costs are 9.3 percent higher when running a consist with the heavier cars. On the one hand, higher track maintenance costs may be expected because of the larger axle loads. On the other hand, a reduction in track maintenance costs may be expected because fewer total gross tons are moving over the track. The effects of these two components can be evaluated by examining the Consist MGTM column and the Total Track Maintenance Cost column. For the first run, dividing the \$3,711.82 total cost by the 7.45577 million gross ton-miles (mgmt) yields a track maintenance cost of \$497.85 per mgmt. In the second case, the track maintenance cost per mgmt is

CREW COST SUMMARY:

CREW NUMBER	CREW DISTR.	START TIME	END TIME	TOTAL TIME	START MILE	END MILE	TOTAL MILES	BASIC PAY	O-MILE PAY	O-TIME PAY	ARBIT. ALLOW.	BENEFIT ALLOW.	TOTAL COMP.
01	1	0: 0	5:37	5:37	0.00	129.67	129.67	394.29	108.58	0.00	184.80	240.68	928.38
02	1	5:37	11:11	5:34	129.67	256.26	126.60	394.29	97.35	0.00	184.80	236.75	913.17
03	1	11:11	16:34	5:22	256.26	381.20	124.94	394.29	91.27	0.00	184.80	234.62	904.97
04	1	16:34	20: 7	3:33	381.20	512.55	131.35	394.29	114.74	0.00	184.80	242.84	936.67
TOTAL		0: 0	20: 7	20: 7	0.00	512.55	512.55	1577.16	411.93	0.00	739.20	954.90	3683.19

FIGURE 8 Crew cost summary—heavy train.

EQUIPMENT COST SUMMARY:

EQUIPMENT TYPE	NUMBER OF UNITS	PURCHASE PRICE (EACH)	HOURLY OWNERSHIP COST	TOTAL HOURS OPER.	TOTAL OWNERSHIP COST	RUNNING COST CTS/MILE	TOTAL MILES OPER.	TOTAL RUNNING COST	TOTAL COST
SD-40	7	1250000.	9.75	20.12	1372.93	116.000	513.	4161.90	5534.82
HOPPER	90		0.75	20.12	1357.87	13.000	513.	5996.82	7354.69
CABOOSE	1		0.38	20.12	7.54	7.000	513.	35.88	43.42
TOTAL	98				2738.34			10194.59	12932.94

FIGURE 9 Equipment cost summary—heavy train.

FUEL COST SUMMARY:

STOP NUMBER	MILE-POST	ARRIVE TIME	DEPART TIME	IDLE TIME	FUEL CONS. AT STOP	CUM. FUEL CONSUMED	CUM. FUEL EXPENSE
1	129.33	3:35	5:35	2: 0	77.28	2689.89	2286.41
2	255.97	9:10	11:10	2: 0	77.28	6276.36	5334.91
3	380.91	14:31	16:31	2: 0	77.28	8869.17	7538.80
*****	512.60	20: 7	*****FINAL DESTINATION****			11609.93	9868.44

FIGURE 10 Fuel cost summary—heavy train.

## TRACK MAINTENANCE COST SUMMARY:

SEGMENT	LENGTH	TOTAL MGTM	CONSIST MGTM	MILES OF TANGENT	TANGENT TRACK MAINT. COST	MILES OF CURVED TRACK CURVE MAIT. COST	TOTAL TRACK MAINT. COST	
HUB A	129.70	3891.00	1.85017	114.38	853.27	15.32	128.41	981.68
WAYSVILLE	126.60	3798.00	1.80595	95.99	718.36	30.61	283.18	1001.54
JCT. TOWN	124.90	3747.00	1.78170	96.38	725.47	28.52	289.04	1014.51
UPTOWN	131.40	3942.00	1.87442	99.29	744.66	32.11	313.82	1058.48
TOTAL	512.60	15378.00	7.31224	406.04	3041.76	106.56	1014.45	4056.21

FIGURE 11 Track maintenance cost summary—heavy train.

\$4,056.21 divided by 7.31224 or \$554.72. Thus, cost per mgmt rose 11.4 percent. Train gross weight declined from 14,545 tons to 14,265 tons, a decrease of 1.9 percent. These two effects explain the observed increase of 9.3 percent in total track maintenance cost. Although in this case track maintenance costs rose only 9.3 percent, it must be recognized that the entire route was assumed to contain 132 lb/yd hardened, continuous welded rail. With lighter weight rail and possibly poorer ballast, a shift from 100- to 112-ton hoppers could result in a much larger increase in track maintenance cost.

The total cost for the second run is shown in Figure 12. For this run, the total cost is \$30,540.57. The cost is 1.4 percent less than the cost for the first run, yet the train was carrying slightly more lading. The extent of actual savings is better measured by comparing costs per NTM. The second run's cost per NTM of 0.591¢ represents a 1.5 percent reduction from the first run's costs. Therefore, for this 513-mile trip the line-haul cost of moving one ton of coal can be reduced from \$3.0855 to \$3.0537 by using the heavier cars.

Several observations about this analysis are in order. First, the costs presented do not include any burdens of administrative overhead. Further, no switching, terminal, or dispatching costs have been included. Such additional costs must be measured in order to make pricing decisions. However, RECAP II can be used to determine the extent to which any change in technology or operating strategy will affect total avoidable line-haul costs.

To conduct a more complete analysis, several other operating strategies should also be tested. The operating strategy chosen in light of the new technology was, in the case presented, to keep the lading weight of the train constant. This resulted in a smaller train gross weight with fewer cars. This analysis would be reasonable if the size of the train were mostly dependent on the amount of commodity to be shipped. However, because the alternative train has a lower gross weight, it is reasonable to try running the model with one fewer locomotive in

the consist to determine (a) whether the train will be able to complete the run and (b) whether the benefits of dropping a locomotive will exceed the cost of adding time to the trip.

If the size of the train is mostly dependent on the size of available locomotive consists, it may be worthwhile to make a run with sufficient cars to make the two trains nearly equal in gross weight. If train size is mostly dependent on the logistics of assembling a certain number of cars in one place, then it may be worthwhile to make a run where the number of cars is held constant. The latter case may, however, result in the need for a larger locomotive consist due to greater train gross weight. In either of these two cases it would be necessary to compare costs on a per NTM basis because total NTM will vary considerably from the base case.

Table 6 gives a summary of the results of many of these additional runs. The base train loaded run and the 90-car heavy train loaded run are the two cases that have been reported. The 92-car case represents the results when the loaded train of heavier cars is sized to match the gross weight of the base train. The 100-car heavy train case represents the situation where the number of cars available for loading represents the train size constraint (i.e., it has the same number of cars on the base train). For each case, the corresponding empty run costs are given in the table.

The second section of Table 6 gives the cost by category for the various cases. As can be observed, all costs decline uniformly for the heavier cars and longer trains, except track maintenance costs, which rise due to the heavier wheel loads.

The third column in the table is the sum of the loaded and empty run costs and represents the total line-haul round trip costs. Of course, these costs cannot be compared directly because a different amount of lading is carried in each case, as indicated in the NTM column. Correcting for NTM, it is easy to see that costs decline as heavier cars are used, and decline still further as more cars are added to the train. Also, the table indicates that by considering the empty return, the cost advantage

## COST OF RUNNING SPECIFIED CONSIST:

CATEGORY	TOTAL COST	COST /GTM	COST /NTM	COST /CFM
CREW COST	3683.19	0.00050375	0.00071290	0.00001794
LOCOMOTIVE COSTS:				
OWNERSHIP COST	1372.93	0.00018778	0.00026574	0.00000669
RUNNING COST	4161.90	0.00056923	0.00080556	0.00002027
CAR COSTS:				
OWNERSHIP COST	1365.42	0.00018675	0.00026428	0.00000665
RUNNING COST	6032.70	0.00082510	0.00116766	0.00002939
FUEL COST	9868.22	0.00134968	0.00191004	0.00004807
TRACK COST	4056.22	0.00055477	0.00078510	0.00001976
TOTAL COST	30540.57	0.00417706	0.00591128	0.00014878

FIGURE 12 Total cost summary—heavy train.



TABLE 6 Costs for Several Alternative Trains

	Base Train (\$)	Heavy Trains		
		90 Cars	92 Cars	100 Cars
Total Costs				
Cost of loaded run	30,982	30,541	30,944	32,502
Cost of empty run	<u>22,407</u>	<u>21,653</u>	<u>21,891</u>	<u>22,826</u>
Round trip cost	53,389	52,194	52,835	55,328
Net ton-miles (000s)	5,152	5,167	5,282	5,741
Cost per 1,000 NTM	10.364	10.100	10.003	9.637
Percent savings from base	-	2.5	3.5	7.0
Cost by Category (per 1,000 NTM)				
Fuel cost	2.9150	2.8510	2.8289	2.6671
Crew cost	1.4299	1.4257	1.3947	1.2831
Track cost	.8201	.8775	.8751	.8667
Equipment cost	5.2797	4.9472	4.9044	4.7473

of the 90-car heavy train over the 100-car standard train is increased because there are fewer cars on the return trip.

From the preceding analysis, the following conclusions can be drawn:

1. By using 286,000-lb cars instead of 263,000-lb cars for this coal movement, in trains carrying nearly the same amount of lading, line-haul costs can be reduced by 2.5 percent, from \$10.36 per 1,000 NTM to \$10.10 per 1,000 NTM.

2. The various categories of round trip cost are affected as follows: (a) crew costs--down 0.3 percent; (b) equipment costs--down 6.3 percent; (c) fuel costs--down 2.2 percent; and (d) track maintenance costs--up 7.0 percent.

3. Significant additional economies are available using longer trains.

#### CONCLUDING REMARKS

The uses for the RECAP II computer model have been described and a case example showing how the model

can be used in route-specific rail cost analysis has been provided. RECAP II has been shown to be a powerful model that can evaluate the changes in avoidable line-haul operating costs that can be expected from the introduction of new technology or from changes in operating strategies. Because it is an engineering-based costing tool, RECAP II, unlike accounting-based cost models, is able to evaluate cost changes that result from new technologies and new operating strategies. The RECAP II model cannot be used, however, for regulatory cost analysis because engineering-based costing models only provide a lower bound for absolute cost. Care should be taken, therefore, that the RECAP II be used only to analyze changes in cost rather than absolute costs.

#### REFERENCES

1. Uniform Railroad Costing System: 1980 Rail Cost Study. Bureau of Accounts, Interstate Commerce Commission, Dec. 1982.
2. S.M. Howard, L.C. Gill, and P.J. Wong. Review and Assessment of Train Performance Simulation Models. In Transportation Research Record 917, TRB, National Research Council, Washington, D.C., 1983, pp. 1-6.
3. E.R. McIlveen, et al. Rail Wear Cost Model User's Manual. Canadian Institute of Guided Ground Transport Report 81-19, Transport Canada Report TP-3727E, Ottawa, Ontario, April 1982.

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