TRACS: On-Line Track Assignment Computer System

PETER J. WONG, MARILYN R. HATHORNE, CAROLA V. ELLIOTT, AND MARY ANN HACKWORTH

Track Assignment Computer System (TRACS) is a yard computer system for dynamically assigning blocks to classification tracks with the dual objectives of maximizing use of classification tracks and minimizing trim-engine effort. To quantify the benefits of using the procedures and program logic, operational data were obtained for 6 days from Southern Pacific's Roseville Yard to simulate the use of TRACS in yard operations. The results from the simulation were compared with actual operations in the yard on those days. The results indicate that use of TRACS would have permitted classification of about 200 more cars per day because 200 fewer cars would have required rehumping. With fewer cars to be rehumped, the average car detention time would have been reduced by about 5 hr. Roseville Yard at the time data were collected was not at capacity and had substantial rehump traffic. The results at other yards could therefore be different. Nevertheless, the results of the TRACS simulation reported here demonstrate the value of the program.

Recent studies of railroad operations indicate that the rail classification yard is the primary culprit in adversely affecting freight car utilization and service reliability (1). These studies also show that substantial improvements can be attained through better operations and planning. A logical inference is that the control and planning of yard operations would be improved and high potential payoff realized through the application of modern computer technology and management techniques. This paper describes a state-of-the-art on-line computer program called Track Assignment Computer System (TRACS) that assists the yardmaster in assigning blocks to classification tracks (i.e., in dynamically swinging the bowl tracks).

Traditionally, computer technology has been applied to yard operations in the areas of process control, car inventory systems, and management reports. TRACS represents a substantial advance in the use of computers to control yard operations. It is one example of a new type of railroad computer system that has on-line decision-making capability to assist yardmasters in the real-time decisions required to operate the railroad. Specifically, TRACS makes real-time track assignment decisions that the yardmaster can approve, modify, or override. [An example of another on-line decision system may be found in a paper by Wong and others (2).]

The development of TRACS began in 1978 under the auspices of the Association of American Railroads (AAR) Freight Car Utilization Program (FCUP), in which Southern Pacific (SP) was the host railroad (3). The TRACS program was evaluated at SP's Roseville Yard in June 1981 (4). In this paper, we describe the program and the Roseville Yard evaluation.

DYNAMIC VERSUS STATIC TRACK ASSIGNMENTS

The purpose of a dynamic track assignment procedure is to assist the yardmaster in assigning cars to classification tracks on the basis of the current projected traffic demand and the current state of the bowl. The goals are to achieve maximum use of the classification tracks and to minimize trim-engine effort. To be specific, classifications should be reassigned daily to tracks that accommodate the projected number of cars for that day, and classifications for the same departing train should be grouped closely in the bowl to minimize trim-engine travel, trim-engine conflicts, and crossover moves. The overall effect of meeting these goals is an improvement in the movement of cars through the terminal.

Dynamic track assignment contrasts with the usual industry classification procedure in which the same blocks are assigned to the same tracks every day. The selection of the static track assignment is based on the average number of cars expected in the block. This is the normal procedure because it is the easiest to comprehend and administer by yardmasters and not because it is the most effective. The principal objections to static assignments are as follows:

1. The number of blocks required almost exceeds the number of classification tracks, which requires the unplanned mixing of several blocks on a single track and hence slows down trim-engine operations;
2. Because few days are average, many assigned tracks are either overflowing or underutilized; and
3. A large block of cars that arrives unexpectedly may be inadvertently reassigned to a track, which causes excessive trim-engine activity to build the departing train.

PROCEDURE AND PROGRAM LOGIC

Basic Definitions and Procedures

As a basis for understanding the TRACS procedure and program logic, the following terms are defined:

1. Primary area is the area in the bowl of first choice for track assignment to a block,
2. Secondary area is the area in the bowl of second choice for track assignment to a block,
3. Assigned block is the block that is already assigned to a track,
4. Starter block is the block that needs a track assignment or overflow cars for an assigned track,
5. Companion blocks are blocks that should be near each other to minimize trim work,
6. Locked track is the track unavailable for assignment,
7. Clear track is the track that has no cars and is unassigned to a block,
8. Idle track is the track that is already assigned to another block but has sufficient room in time and in space to accommodate a second block without mixing the two blocks, and
9. Rehump track is the track for cars to be rehumped later.

To minimize trim-end work, each block is assigned a primary area and a secondary area. For example, blocks to depart from the east departure yard are assigned to a primary and a secondary area on the east side of the classification yard; this eliminates the inefficiencies of a crossover move from one side of the classification yard to the other side of the departure yard. Furthermore, the blocks that are to make the same train should be assigned to the same area; this eliminates conflict between trim engines building different trains. Also, blocks that are in sequence on the same train are designated companion blocks and should be placed on adjacent tracks if possible to minimize the pull time of both blocks.

To maximize track utilization, the number of cars in a starter block is used to determine its track assignment--clear track, idle track, or rehump track. In particular, a block that does not have

Figure 1. Simplified planning worksheet.

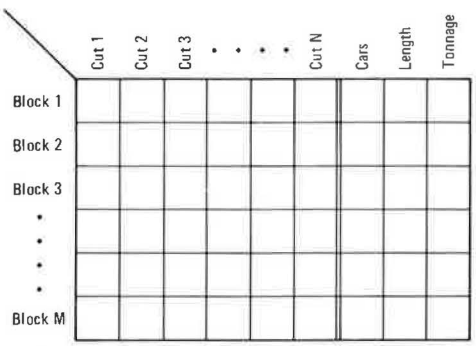


Figure 2. Overall assignment logic.

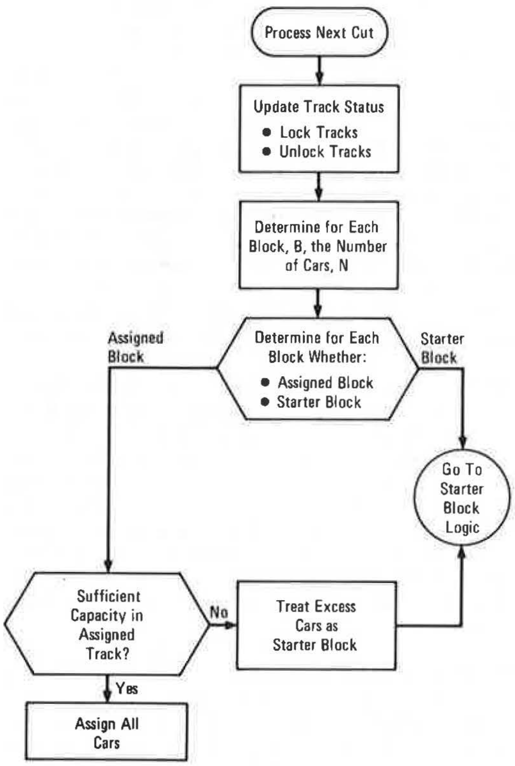
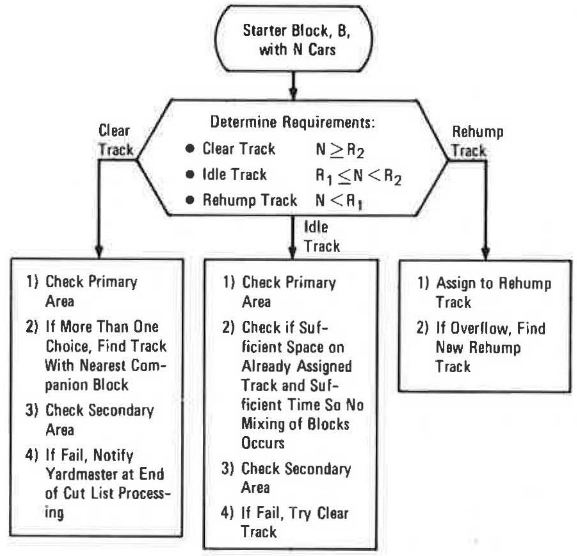


Figure 3. Starter-block logic.



enough cars to be assigned to a clear track but has too many cars to be assigned to a rehump track is assigned to an idle track. In this manner, tracks are assigned to fit the needs of the blocks without wasting track space.

Worksheet Planning Process

Periodically (e.g., at the beginning of each shift and as appropriate thereafter), the yardmaster specifies the sequence of cuts to be humped and TRACS produces a planning worksheet. The worksheet (Figure 1) is essentially a matrix; the blocks to be made in the yard are listed down the side and the sequence of cuts to be humped is listed across the top. The columns of the matrix display for each cut the number of cars for each block. These numbers reflect either cars already in the receiving yard or advance consist information. The rows display for each block the projected future accumulation of cars by cut sequence. The last three columns of the worksheet indicate projected total cars, total length, and total tonnage of incoming cars for each block.

The yardmaster examines the worksheet and determines for each block how many cars to be humped will be grouped together to make the same outbound train; this is called the split determination. The yardmaster specifies to the TRACS program the position of the split in the block count, that is, the hump cut and the car within the cut at which the split is to occur. The group of cars in a block up to the split are treated as a unit for purposes of track assignment. The worksheet process is repeated whenever changes occur in the hump sequence, yard conditions or operations, or incoming traffic conditions.

Track Assignment Logic

Figure 2 shows the overall TRACS assignment logic. When each cut is to be humped, the yardmaster indicates to the TRACS program any changes in track status (i.e., locked tracks or clear tracks). By using the split determination from the worksheet planning process, TRACS determines the appropriate number of cars (N) in each block. Next, each block in the cut is processed in order of size. If the block is an assigned block, the cars are designated to the assigned track.

The starter-block logic is shown in Figure 3. Each block is assigned two threshold numbers, R_1 and R_2, which determine whether the block is to be assigned to a clear track (i.e., $N \geq R_2$), to an idle track (i.e., $R_1 \leq N < R_2$), or to a rehump track (i.e., $N < R_1$). If a block is to be assigned to a clear track, the primary area for the block is searched for a clear track. If more than one choice is found in the primary area, the track with the nearest companion block is found. If no clear track is found in the primary area, the secondary area is searched. If no clear track is found in either the primary or secondary area, the yardmaster is notified so that a decision can be made.

If a block is to be assigned to an idle track (see Figure 3), the primary area is searched first for an idle track and then the secondary area is searched. If searching both areas fails to produce an idle track, a clear track is sought for the block.

If a block is to be assigned to a rehump track, the TRACS program assigns the block to one. If the rehump track is at capacity, the program determines a new track for the excess rehump cars.

ROSEVILLE YARD EVALUATION

Background

The purpose of the Roseville Yard evaluation was to quantify the benefits of using the TRACS program on the basis of operational data from an actual yard. The plan was to gather data for several days at Roseville Yard and then to replay those days off line by using the TRACS program to operate the yard. In this way, the effectiveness of the program could be compared with actual operations.

Roseville Yard is just outside of Sacramento, California, and is the main SP gateway in and out of northern California. The yard has approximately 20 receiving tracks in line to the hump, 49 classification tracks, an in-line west departure yard with 10 tracks, and an in-line east departure yard with 10 tracks. Generally, the yard is segmented into east and west traffic; there is a corresponding division of the receiving, classification, and departure yards. More than 2,000 cars/day can be classified.

Data Collection and Simulation

Data collection began at 12:01 a.m. on June 1, 1981, and continued around the clock until 12:00 midnight on June 6, a period of 6 days.

During the data-collection period, traffic volume was approximately 30-40 percent below yard capacity. The specific operating characteristics of the yard during this period were the following:

1. 1,100 to 1,400 cars classified per day;
2. 16 to 18 inbound trains per day (including run-through trains, which set out blocks);
3. 20 to 21 outbound trains per day (including run-through trains that were filled); and
4. 58 classifications per day.

A chronological log of all hump-engine and hump activity was kept, as was a log of extraneous events (such as malfunctioning switches blocking a bowl track). Copies of the following documents were collected: hump lists (with the yardmaster's notations), pull instructions (with departing train and set time indicated), classification track summary (after every humped cut), inbound line-up reports, receiving-yard reports, and hot sheets (identifying priority cars or traffic).

The data collected from Roseville Yard were used to simulate the use of the TRACS program in yard operations. The actual simulation took 16 working days.

Quantitative Results

A tabulation of the number of empty classification tracks as a function of the time of day for June 3 and 4, 1981, indicated that the TRACS program used slightly more tracks than were actually used on those days.

At first, this result was surprising because we had expected the TRACS program to use fewer tracks and thus create more empty tracks. Closer examination revealed, however, that the TRACS program and procedures performed as designed. Recall that the TRACS program logic attempts to assign a clear (or idle) track or rehump track to a block depending on the projected volume of cars in that block. By using the planning worksheet and examining advance consists and the status of the bowl, we determined that many clear tracks were available for assignment (because the yard was under capacity). Thus, a number of idle and rehump assignments were overridden and assigned to clear tracks. (For a yard at capacity, we would expect more idle-track assignments to create clear tracks for additional assignments.)

Table 1. Cars classified and humped.

	No. of Cars			
	June 3		June 4	
Category	Real	Simulated	Real	Simulated
Classified	1,397	1,582	1,108	1,319
Rehumped	371	208	478	223
Total	1,768	1,790	1,586	1,542

In the actual operations, the yardmasters appeared not to take advantage of the available clear tracks for assignment of small blocks. Thus, they assigned more cars to the rehump (or sluff) tracks for later reswitching. We do not know why the yardmasters did not use the available clear tracks. One reason may be that the clear tracks are traditionally assigned to blocks that on June 3 and 4 had either no traffic or so little traffic that the cars were sent to the sluff track. By using the TRACS program and the associated planning worksheet, the yardmaster can anticipate the need in 8 to 12 hr to reserve or use a clear track for traffic already in the yard and for traffic that will arrive in the yard.

Table 1 shows that on both June 3 and 4, approximately 200 fewer cars were rehumped (reswitched) under the simulation with TRACS than in actual operations. At Roseville Yard, a hump engine must travel down the hump to bring cars back over the hump for rehumping. During this operation, the hump and hump engine are occupied. Thus, use of the program would have permitted classification of approximately 200 more cars per day (Table 1) because the hump and hump engines would have had fewer rehump cars to process.

If fewer cars are rehumped by using the TRACS program, the associated yard-detention times should be shorter. This is because rehumped cars are not classified until after the second humping operation, which in certain cases was once a day. Thus, a rehumped car could spend an extra 24 hr in the yard. The data tabulated below indicate that the use of the TRACS program would have reduced the average car-detention time by approximately 5 hr:

	Car-Detention Time (hr)	
Data	June 3	June 4
Real	26.05	27.75
Simulated	21.59	22.48

Interpretation of Results

The traffic volume at Roseville Yard was considerably reduced during the simulation period. In this environment, the TRACS program attempted to maximize use of tracks by so assigning tracks that the number of cars rehumped was minimized. Minimizing rehumping resulted in the classification of approximately 200 more cars per day and a reduction in average yard-detention time of approximately 5 hr.

If we assume that the 5-hr reduction in yard detention can be translated to a reduction in system transit time, an average SP daily per-diem rate of $6.51 applied to 5 hr of savings for 1,400 cars per day processed by Roseville Yard could, in theory, translate to approximately $700,000 in savings per year in per-diem costs. These numbers are unrealistically optimistic, but if even a small fraction of these savings could be realized in practice, the worth of the TRACS program could more than justify its implementation in a yard.

The impact of TRACS on a yard at or near capacity may be different than that experienced at Roseville Yard, which was considerably under capacity and had substantial rehump traffic. Nevertheless, the results of the Roseville Yard simulation do justify the high expectations for the TRACS program.

CONCLUDING REMARKS

The worth of the concepts underlying the TRACS program has been demonstrated in the Roseville Yard evaluation. Under the sponsorship of the AAR, the program is being installed in SP's Terminal Control Computer (TCC) system. The first yard to use the program will be SP's West Colton Yard; once installed in the TCC, however, the program can readily be made available to other SP yards.

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REFERENCES

1. Studies in Railroad Operations and Economics, Volumes 2-9. Department of Civil Engineering, School of Engineering, Massachusetts Institute of Technology, Cambridge, 1972.
2. P.J. Wong, B. Conrad, J.M. Johnson, and N. Lay. Tactical Planning for Coordinating Railroad Operations. TRB, Transportation Research Record 758, 1980, pp. 2-8.
3. P.J. Wong and others. Demonstration of Dynamic Track Assignment Program. SRI International, Menlo Park, CA, Phase 1 Rept., June 1979.
4. M.R. Hathorne and others. Roseville Evaluation on the On-Line Dynamic Track Assignment Program. SRI International, Menlo Park, CA, Phase 2 Rept., Sept. 1981.

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Labor Productivity in Rail Transport

PAUL H. BANNER AND FRANCIS D. BROSNAN, JR.

Labor productivity is among the central economic issues in the railroad industry. Labor negotiations and federal price-control programs are examples of activities that have involved productivity considerations. Currently, the Interstate Commerce Commission is considering productivity adjustments in the rail cost recovery procedures that were mandated by the Staggers Rail Act of 1980. Historically, productivity has been measured as labor content per ton-mile. Such measures, however, typically have produced productivity gains that appear to be unreasonably large. This may be caused by the changing nature of the ton-mile itself as the railroads increasingly embrace new operating practices such as unit trains, larger freight cars, and so on. An allocation of rail labor inputs among several output measures, including train miles, car miles, and carloads, is proposed. It is shown that rail productivity gains have been modest, at best, and that there has been considerable variation in productivity gains among the major carriers.

Productivity is a perennial issue in rail transport. It arises in commonplace regulatory proceedings involving rail prices, costs, and inflation impacts. Currently, productivity is the central issue in an Interstate Commerce Commission (ICC) consideration of the propriety of its rail cost recovery index.

Productivity is a deceptively simple concept that becomes complex either when econometricians attempt to formulate equations of measurement or when a simple productivity equation is quantified. The literature is highly theoretical, yet claims of measured change are often cited in the trade journals. The railroad industry is no exception; we are regularly treated to numbers of ties laid per man and coal cars unloaded and, simultaneously, to a literature overloaded with transformation equations and mathematical symbolism--all in disagreement.

In the economic literature, production functions relate outputs and inputs. In measuring productivity, one can hold inputs constant and measure the change in output or hold output constant and measure the change in inputs, but basically the production function is a cost function related to some measure of physical output. Theory attempts to differentiate change related to scale economies from changes due to organizational and technological improvement. Theory can offer many reasons for, and include them in, the theoretical formulation of the production function, but for the practitioner, there is an immediate need for simplicity.

There is another more practical school, which measures single-factor productivity. This is more or less an engineering approach, easier to use in practice. But it is not the measurement of productivity in the theoretical sense. Output per person hour, a single factor, is not the same as productivity of all factors, but it has many advantages. For example, if there is some fixity in other factor input, e.g., capital, or if labor is left constant and a capital change is made, the net effect can be measured. For instance, if a tamping machine replaces labor, there will undoubtedly be a rise in output per person hour, even though total factor productivity may not rise. Such a result would be a function of whether the total cost of the activity