Tactical Planning for Coordinating Railroad Operations

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Tactical (shift-by-shift) planning procedures for improving operations on the Grand Trunk Western Railroad are described. The tactical planning procedures are designed to improve the decision-making ability of dispatchers and yardmasters by explicitly requiring them to plan and coordinate their activities for the entire shift at the beginning of the shift. The procedures are centered around a systemwide nominal operating plan, which is adjusted during each shift on the basis of predictions of train and yard activities obtained from a simulation called the Dynamic Movement Predictor. Because of the systemwide planning and coordination inherent in these tactical planning procedures, the result should be improved labor productivity, car transit time, and trip reliability.

This paper describes tactical (short-term) planning procedures for improving the dispatching and yard operations of the Grand Trunk Western (GT) Railroad.

The decision makers who directly control the movement of cars on a railroad on an operational basis are the dispatchers and yardmasters. Dispatchers control the movement of trains on the line-haul portion of the railroad, and yardmasters control the movement of cars within a yard and terminal district. Dispatchers and yardmasters historically have had to react to problems and have not been able to plan the optimization of their own local operations and coordinate them with total systemwide operation. This lack of tactical planning and systemwide coordination contributes to the problems of low labor productivity, inefficient use of the physical plant, excessive car transit times, trip unreliability, and low car utilization.

The tactical planning process requires accurate current and predictive data on yard inventory, train consist, and train movement. These data are provided by GT's Railroad Automated Identification Location System (RAILS), which uses the advanced technologies of automatic-car-identification (ACI) scanners and advanced computer and communications hardware to instrument and monitor the entire GT railroad (1). Predictive yard-inventory, train-consist, and train-movement data are provided by the Dynamic Movement Predictor (DMP), which is a systemwide railroad simulation model constructed by Stanford Research Institute International to interface with RAILS and to run sufficiently fast to be useful in a tactical operating environment (2).

OVERVIEW OF TACTICAL PLANNING PROCESS

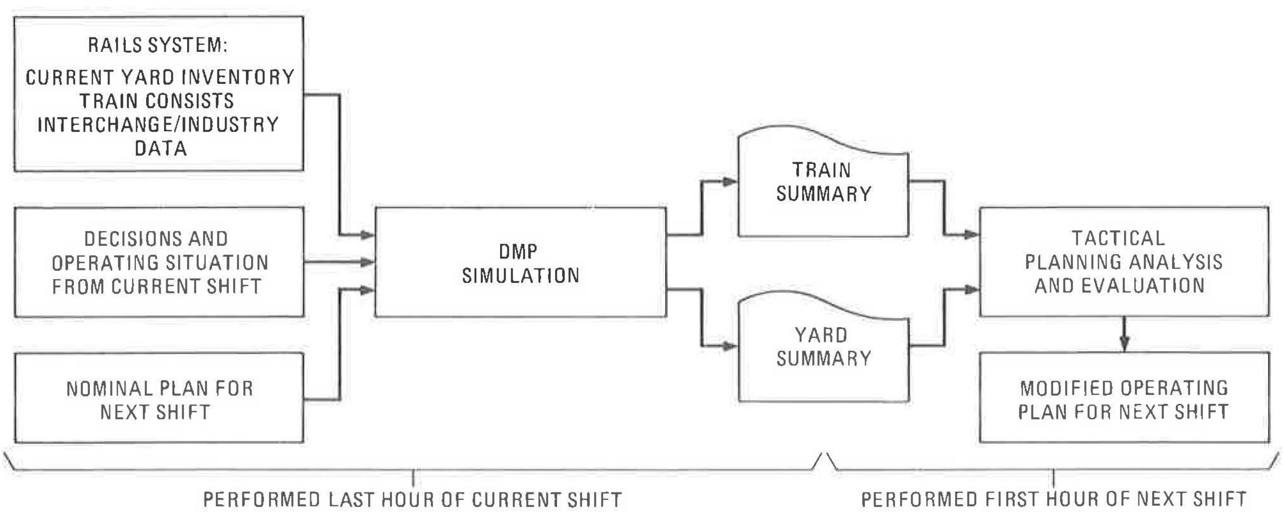
Figure 1 shows an overview of the tactical planning process. The DMP simulation is run at the end of each shift so that the outputs can be ready for evaluation at the beginning of the next shift. This requires that, at the end of each shift, the following information be input to the DMP:

1. RAILS data on current yard inventory and train consists and predictive interchange and industry data,
2. Decisions and operating situations from the current shift, and
3. Nominal schedule of operations for the next shift.

Much of the RAILS data will be automatically input to the DMP; a large amount of the interchange and industry data will be obtained manually via telephone calls to appropriate yards or foreign roads. The DMP simulation requires information on the current operation of trains that will still be in operation during the next shift and on any abnormal system problems (e.g., track outages and slow orders). The DMP also requires a nominal schedule of operations for the next shift (essentially a forecast of how the next shift should be run).

The DMP simulation will process the above inputs and produce the train summary and yard summary as outputs. These outputs, which are presented to the dispatchers and yardmasters for tactical planning at the beginning of the next shift, predict what the yard inventories and train consists would be if the nominal operating plan were actually implemented. Each dispatcher and yardmaster develops a plan of his or her own local activities at the beginning of the shift on the basis of an attempt to implement a systemwide nominal operating plan. Changes in the nominal operating plan, based on examination of the

Figure 1. Tactical planning process for dispatching.



DMP predictions of yard inventory and train consists, are determined early in the shift and negotiated between the dispatchers and yardmasters as the need arises. Modifications to the nominal plan may result from traffic conditions, operating constraints, and plant conditions not accounted for in the nominal plan.

In this manner, the nominal operating plan provides the central mechanism for ensuring that local decisions are made with a systemwide perspective. Decisions to deviate from the nominal plan are efficiently communicated and coordinated as modifications or exceptions to the plan. As a consequence, the planning process allows dispatchers and yardmasters to

1. React to daily traffic and operating variabilities in a coordinated manner,
2. Consider the systemwide consequences of decisions,
3. Provide a basis for more precise coordination between the dispatching and yardmastering operations, and
4. Consider the impact of current decisions on future events.

TACTICAL PLANNING PROCESS FOR DISPATCHING

General

The main intent of the tactical planning process for dispatching is to provide the dispatching function with an operating plan for the next shift. Such a plan should expedite the movement of traffic from a systemwide viewpoint, keep yards from becoming congested, and allow efficient use of dispatching resources (e.g., engines and crews) and of yard resources.

At the beginning of the shift, the dispatching office is presented with DMP predictions on train and yard activities based on a nominal operating plan. The dispatching planner analyzes these predictions to determine whether modification to the nominal plan should be made to account for day-specific traffic levels and operating conditions, such as light or heavy traffic demand, shortages of locomotives or crews, and track repair and outages.

In the case of light traffic demand, some trains must be canceled, and the work of these canceled trains must be reassigned to other train crews (subject to the federal regulation that the operating crew can work for a period of not more than 12 h). The starting time of trains whose work is reassigned may be rescheduled to accommodate the new traffic. In the case of heavy traffic demand, extra trains may be added, and trains may run heavy, which slows them down. The work of these heavy trains may have to be reassigned so that they will carry fewer blocks (groups of cars classified for movement to the same yard or terminal).

If the traffic increases unexpectedly or if there is an unexpected number of locomotive failures, a shortage of locomotives and crews may occur in the short term. Under the circumstances, trains may be heavy and therefore run more slowly. Changes to the nominal plan may be made to minimize the systemwide impacts of these shortages by reblocking trains so that they run more heavily and the priority traffic is moved on time.

Frequently, portions of track are out of use or there are orders to slow down for varying amounts of time due to track repairs. These track disruptions can significantly affect the running times of trains. The scheduled departure time may have to be adjusted to account for these track conditions.

In general, the dispatching planner can modify the nominal plan by

1. Canceling trains or adding extra trains,
2. Changing the starting time of a train,
3. Adding or canceling scheduled stops of trains, and
4. Changing the blocks (classifications) picked up or set out at the stops.

There are fundamental constraints on the degree of modification to which the nominal operating plan can be subjected on a daily basis, after the work rules, the 12-h law, the nature of the train, terminal restrictions, and traffic priorities have been taken into consideration. Because decisions about individual trains affect other trains, these decisions should be planned and orchestrated from a systemwide viewpoint. In the tactical planning procedure for dispatching, the modifications to the nominal plan should be finished by the dispatching planner approximately one hour into the next shift; this modified plan is then given to the dispatcher for implementation.

DMP Predictions

At the beginning of each shift, the dispatching office receives the DMP predictions for an initial nominal operating plan for the shift. The predictions of train activities and yard activities are in the form of train-summary and yard-summary reports, respectively. Trains are designated by a three-digit number (e.g., 391); an extra section of the train is designated by placing the number 2 in front of the usual train number (e.g., 2391). Yards and stations are coded with a three-digit number, and blocks are coded with a two-digit number.

A sample train summary is shown in Figure 2. "Yard number" indicates the scheduled yard stops. For each train and each yard stop, the train summary provides the following information:

1. The arrival time, the day (Julian date, which is the number of days elapsed in the year), and the number of cars that arrived on the train;
2. The number of cars that have been set out for each block;
3. The number of cars that have been picked up for each block;
4. The departure time, the day (Julian date), and the number of cars that departed on the train; and
5. The gross tons and car miles accumulated by the train up to that stop.

A sample yard summary for Battle Creek Yard (Yard 837) is shown in Figure 3. Similar outputs are available for all yards in the system. The blocks are listed in the first column. The arrival and departure of trains and the time and Julian date of the arrival or departure are given across the top of the summary. For each train arrival or departure, the net change in the number of cars in each block is indicated and the cumulative total of cars that remain in the block is noted. Traffic not brought to the yard by a GT main-line train but from interchange or local industry is treated like a train arrival but would be denoted "Traffic."

Development of a Modified Nominal Plan

To produce an operating plan, the dispatching planner analyzes the train-summary and yard-summary reports in a manner similar to the following:

1. For each yard in the yard summary, the time at

which priority blocks become exceptionally large is circled, and the time at which the yard is expected to be congested is marked.

2. Trains predicted to be light, heavy, or late are circled and noted on the train summary.

3. Trains identified as running light are reviewed to see whether they can carry some of the large blocks in the congested yards that were

Figure 2. Train summary.

TRAIN NUMBER	YARD NUMBER	ARRIVAL TIME	ARRIVAL DAY	WITH CARS	******** SETOUT ********* NO. OF CARS (BLOCK NO.)			******** PICKUP ********* NO. OF CARS (BLOCK NO.)			DEPARTURE TIME	DEPARTURE DAY	WITH CARS	GROSS TONS	CAR MILES
371	837	0	0		0(0)	0(0)	0(0)	52(5)	0(0)	0(0)	1400	209	52	2149	0
	842	0	0	52							1430	209	52	2149	1138
	903	0	0	52							1540	209	52	2149	4102
	913	0	0	52							1625	209	52	2149	5990
	918	0	0	52							1659	209	52	2149	7436
	951	0	0	52							1712	209	52	2149	8002
	952	0	0	52							1716	209	52	2149	8106
	954	1722	209	52	52(5)	0(0)	0(0)	0(0)	0(0)	0(0)	0	0	0	0	8268

TRAIN NUMBER	YARD NUMBER	ARRIVAL TIME	ARRIVAL DAY	WITH CARS	******** SETOUT ********* NO. OF CARS (BLOCK NO.)			******** PICKUP ********* NO. OF CARS (BLOCK NO.)			DEPARTURE TIME	DEPARTURE DAY	WITH CARS	GROSS TONS	CAR MILES
385	811	0	0								600	209	26	1302	1128
	815	625	209	26	0(0)	0(0)	0(0)	6(18) 3(7) 5(11)	3(1) 8(8) 0(0)	2(5) 8(10) 0(0)	725	209	61	3002	1643
	819	0	0	61							725	209	61	3002	1649
	823	745	209	61	3(21) 1(25) 0(0) 0(0)	5(23) 1(27) 0(0) 0(0)	1(24) 0(0) 0(0) 0(0)	18(1) 5(7) 16(11) 1(14)	1(2) 11(8) 1(12) 1(15)	13(5) 9(10) 7(13) 7(17)	835	209	140	5486	2387
	830	0	0	140							933	209	140	5486	7021
	831	0	0	140							1009	209	140	5486	7035
	837	1120	209	140	21(1) 8(7) 29(11) 1(14) 6(18)	1(2) 19(8) 3(12) 1(15) 1(44)	15(5) 17(10) 7(13) 11(17) 0(0)	0(0)	0(0)	0(0)	0	0	0	0	12859

Figure 3. Sample yard summary: Battle Creek Yard (Yard 837).

CLASS	398 ARRIVES 547/209	511 DEPARTS 615/209	513 DEPARTS 745/209	500 DEPARTS 800/209	387 ARRIVES 811/209	-386 DEPARTS 1000/209	512 ARRIVES 1019/209	385 ARRIVES 1120/209	391 ARRIVES 1121/209	433 ARRIVES 1127/209
CHICAGO	0(88)	0(88)	0(38)	0(88)	0(88)	0(88)	0(88)	22(110)	35(145)	21(166)
CHGO CNW	0(19)	0(19)	0(19)	0(19)	0(19)	0(19)	0(19)	0(19)	0(19)	4(23)
RAILPORT	0(7)	0(7)	0(7)	0(7)	0(7)	0(7)	0(7)	0(7)	4(11)	0(11)
BISL CNW	0(29)	0(29)	0(29)	0(29)	0(29)	0(29)	0(29)	15(44)	1(45)	7(52)
BLUE I.	0(14)	0(14)	-14(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
ROCK I.	0(48)	0(48)	0(48)	0(48)	0(48)	0(48)	0(48)	8(56)	7(63)	7(70)
MILW	0(33)	0(33)	0(33)	0(33)	0(33)	0(33)	0(33)	19(52)	0(52)	12(64)
HARVEY	0(20)	0(20)	0(20)	0(20)	0(20)	0(20)	1(21)	17(38)	3(41)	8(49)
THORNTON	0(113)	0(113)	0(113)	0(113)	3(116)	0(116)	1(117)	29(146)	8(154)	7(161)
GRIFFITH	0(44)	0(44)	-44(0)	0(0)	0(0)	0(0)	0(0)	3(3)	4(7)	2(9)
HASKELLS	0(17)	0(17)	-16(1)	0(1)	0(1)	0(1)	0(1)	7(8)	0(8)	2(10)
S BEND	0(11)	-10(1)	0(1)	0(1)	0(1)	0(1)	0(1)	1(2)	0(2)	3(5)
K'ZOO	5(68)	-49(19)	0(19)	0(19)	1(20)	0(20)	0(20)	1(21)	1(22)	5(27)
S BEND F	0(15)	-15(0)	0(0)	0(0)	1(1)	0(1)	1(2)	0(2)	0(2)	2(4)
B CREEK	3(3)	0(3)	0(3)	0(3)	10(13)	0(13)	9(22)	11(33)	26(59)	16(75)
BC CR	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	6(6)	0(6)	0(6)
FLINT W	0(11)	0(11)	0(11)	0(11)	0(11)	0(11)	0(11)	0(11)	0(11)	3(14)
LANSING	7(67)	0(67)	0(67)	0(67)	0(67)	0(67)	17(84)	0(84)	0(84)	0(84)
DURAND	1(15)	0(15)	0(15)	-13(2)	0(2)	0(2)	9(11)	0(11)	0(11)	0(11)
HOLLY N	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(1)	0(1)	0(1)	0(1)
GR RAPD	1(5)	0(5)	0(5)	-4(1)	0(1)	0(1)	3(4)	0(4)	0(4)	0(4)
FLINT	6(121)	0(121)	0(121)	0(121)	0(121)	0(121)	12(133)	0(133)	0(133)	0(133)
FLINT E	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
PT HURON	1(12)	0(12)	0(12)	0(12)	0(12)	-11(1)	1(2)	0(2)	0(2)	0(2)
SARNIA X	15(36)	0(36)	0(36)	0(36)	0(36)	-21(15)	0(15)	0(15)	0(15)	0(15)
CNT	3(73)	0(73)	0(73)	0(73)	0(73)	-58(15)	1(16)	0(16)	0(16)	0(16)
CNB	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	6(6)	0(6)	0(6)	0(6)
CNP	0(2)	0(2)	0(2)	0(2)	0(2)	0(2)	2(4)	0(4)	0(4)	0(4)
CN SAND	0(6)	0(6)	0(6)	0(6)	0(6)	0(6)	11(17)	0(17)	0(17)	0(17)
PONTIAC	4(45)	0(45)	0(45)	0(45)	0(45)	0(45)	1(46)	0(46)	0(46)	0(46)
DETROIT	6(97)	0(97)	0(97)	0(97)	0(97)	0(97)	1(98)	1(99)	0(99)	0(99)
TOLEDO	0(22)	0(22)	0(22)	0(22)	0(22)	0(22)	0(22)	0(22)	0(22)	0(22)
DET CR	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)	0(3)
OVER AGE	0(263)	0(263)	0(263)	0(263)	0(263)	0(263)	0(263)	0(263)	0(263)	0(263)
TOTAL	52(1310)	-74(1236)	-74(1162)	-17(1145)	15(1160)	-90(1070)	77(1147)	140(1287)	89(1376)	99(1475)

identified in step 1. If so, these light trains are reassigned to pick up extra traffic. The starting time of reassigned trains may have to be changed to pick up the extra traffic; the expected time at which this reassigned block is ready for pickup can be estimated by using the yard summary. In particular, the yard summary indicates for each block the net change in size of the block and the block size as a function of time. By noting when cars enter the yard for the block and by estimating the time necessary to switch the cars, estimates can be made of when the block is ready for pickup.

4. If there are no more trains available to relieve the congested yards identified in step 1, extra trains must be scheduled; their starting times are scheduled to relieve yard congestion before the predicted congestion time.

5. For those trains predicted to be both heavy and late (identified in step 2), a scheduled pickup of a block can be canceled and rescheduled for pickup by a light train. The train summary can indicate blocks (and their size) that may be canceled from heavy trains and potential light trains that may pick up the block. If a suitable light train is identified, the work is reassigned. The starting time of reassigned trains may have to change to wait for reassigned traffic; the expected time at which this reassigned block is ready for pickup can be estimated by using the yard summary and the process discussed in step 3.

6. If yards are uncongested and a substantial number of trains are running light (as identified in steps 1 and 2), the pool, or low-priority, trains on a train summary may be canceled one at a time and their work may be reassigned to the preferred, or higher-priority, trains until all the trains are at capacity. Some trains that have reassigned work may have their starting times set back while they wait for traffic; the expected time by which this reassignment is ready for pickup can be estimated by using the yard summary and the process discussed in step 3.

In the process of analyzing the train and yard summaries, any decisions to deviate from the nominal operating plan are communicated and coordinated with the affected yards.

The output of the tactical planning process is a modified operating plan that is used to aid the on-line dispatching process. This operating plan is recorded on a work sheet called the train instruction sheet. On this work sheet, the planned call and departure times are noted for each train. Next the planned stops for the train are specified. For each stop, the number of cars of each classification to be picked up or set out is noted.

The modified nominal plan in the form of the train instruction sheet should be completed approximately one hour after the beginning of the shift. The modified plan is given to the dispatchers as a guide to their decision making.

TACTICAL PLANNING PROCESS FOR YARDS

General

The new tactical planning process for yards is designed to enhance a yardmaster's ability to plan the activities for the entire shift at the beginning of the shift. By properly organizing and presenting RAILS-DMP data, more planning time will be available so that better sequencing decisions can be made on work assignments. In the new procedure, a work sheet is used to show which connections all cars in the yard and cars projected to be in the yard must make. The procedure makes the effect of alternative sequences of work more evident to yard managers than it has been in the past. The new procedure has been designed to anticipate line-haul power and crew availability, to smooth shift-turnover transition by providing an orderly transfer of knowledge to the next shift, and to train more-skilled yardmasters to impart their knowledge to less-skilled yardmasters.

Yardmasters affect the performance of yard operations by the sequence of tasks for switch-engine crews, by the change of classification track assignments, and by the negotiation with the dispatcher of departure time, classifications, and size of outbound trains to be made up at the yard. The purpose of the new yard-planning process is to provide yardmasters with an operating methodology that improves yard performance within the context of a systemwide operating plan.

Yard-Planning Work Sheet

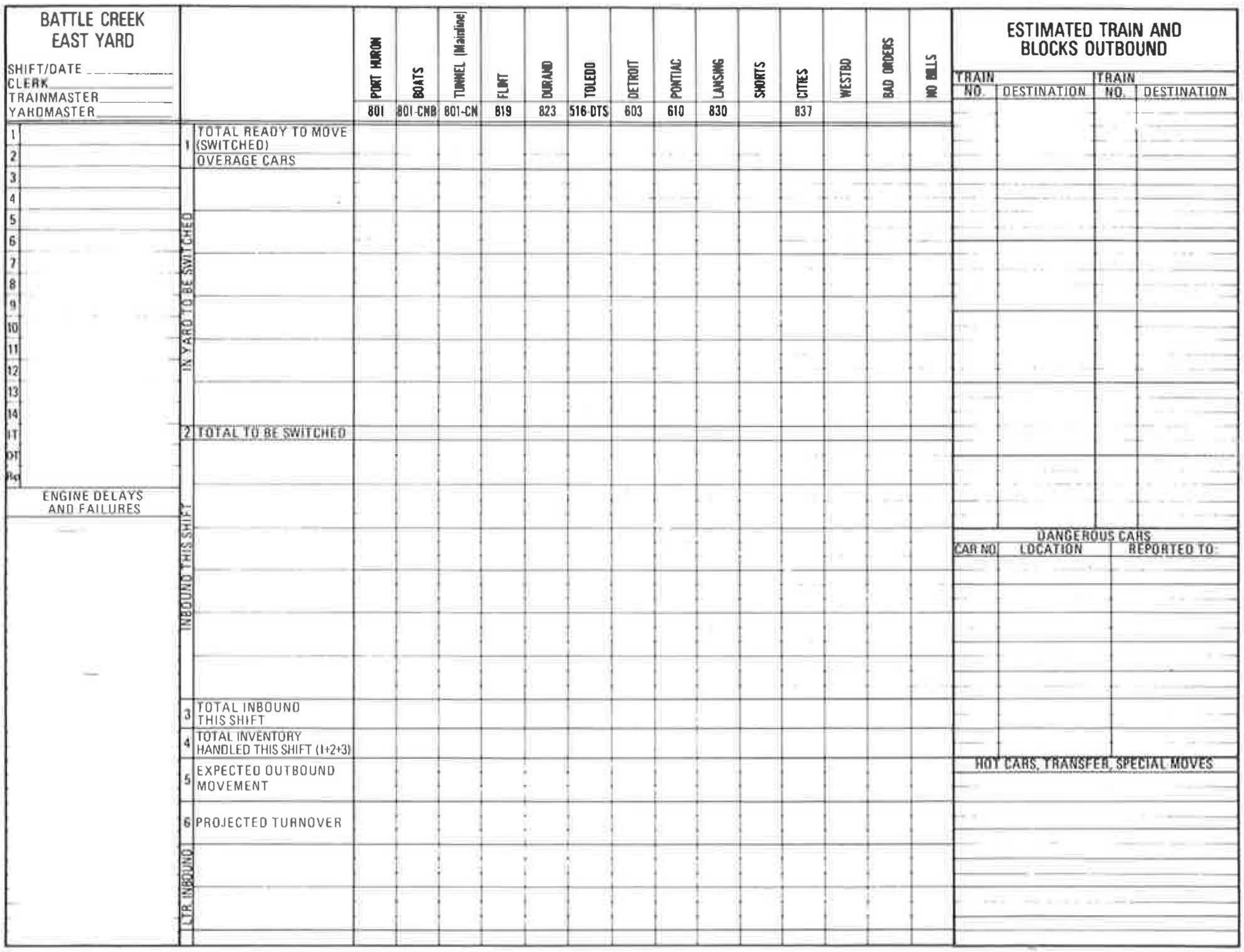
The details of the tactical planning process for yards are shown on the sample work sheet for Battle Creek Yard in Figure 4. The format of the left-hand and right-hand columns of the work sheet is described below.

1. The upper part of the left-hand column (Battle Creek East Yard) contains information on the yard's turnover; the status of the yard at the end of the previous shift is detailed for the new yardmaster at the beginning of the next shift. Specifically listed are the number and type of cars on each track.
2. The lower part of the left-hand column (Engine Delays and Failures) contains the factors and times that the switch engines were unavailable for work.
3. The upper part of the right-hand column (Estimated Train and Blocks Outbound) lists the outbound trains expected to run, their expected call times, the expected blocks to be put on the train, and the expected number of cars in each block. An initial estimate of this information is provided by the nominal operating plan. The information is continually refined during the yard-planning process and through negotiation with the dispatcher.
4. The middle part of the right-hand column (Dangerous Cars) provides information about the location of dangerous cars in the yard and which crews have been notified of this fact before the dangerous cars are moved.
5. The lower part of the right-hand column (Hot Cars, Transfer, Special Moves) contains special instructions for priority movement of cars, blocks, or trains. Hot cars are those cars that must make certain connections.

The column headings across the top of the middle portion of the work sheet give the various outbound classifications and their station numbers. The following information can be entered in the column for each classification:

1. The total number of cars that have already been switched [Total Ready to Move (Switched)] is listed in the first row; the number of cars already switched that are considered overage is noted. This information is obtained from the yard summary. The next rows (In Yard to Be Switched) list the number of cars for each classification for each train received in the yard but not yet switched. This information is obtained from switch lists.
2. The row below these (Total to Be Switched) totals the cars in the yard to be switched (i.e., the sum of the entries under In Yard to Be Switched). Below this (Inbound This Shift) the number of cars expected for each future train to be received in the yard during the shift is noted.

Figure 4. Yard-planning work sheet.



Advanced consist information from RAILS is used for trains that have already departed from a neighboring yard and are to arrive in the near future. DMP projections are used for trains not yet made up.

3. The row below that (Total Inbound This Shift) totals the cars not currently in the yard that are expected to be switched during the shift (i.e., the sum of the entries under Inbound This Shift).

4. Next, Total Inventory Handled This Shift gives the total number of cars already switched plus the cars expected to be switched during the shift (i.e., the sum of rows 1, 2, and 3).

5. Expected Outbound Movement gives the totals for each classification that are expected to leave the yard during the shift. This information is obtained from the number under Estimated Train and Blocks Outbound in the upper right-hand column of the work sheet.

6. Projected Turnover gives the number of cars by classification expected to be in the yard (i.e., row 5 subtracted from row 4).

7. The last entries (Later Inbound) give the number of cars expected for each classification for trains expected to arrive during subsequent shifts. This information would come from DMP projections and is mainly advisory for the current shift.

Details for Use of Yard-Planning Work Sheet

The tactical planning procedure for yards begins toward the end of a shift. On the work sheet, the inbound-traffic demand on a yard is organized from RAILS advanced consists and DMP projections so that it can be scanned to detect major trends or special problems. Assignment to scheduled trains of nominal connections of blocks of cars can be achieved, and the need for any additional trains far in advance of their required call times can be anticipated. When the yardmaster comes on duty for the next shift, the work sheet is scanned, it is discussed with the trainmaster if necessary, and the specific standing inventory lists of cars then in the yard is reviewed. By using these data, the yardmaster can annotate the worksheet with actual connections and assign work to the switch crews to balance transit-time considerations and car-handling factors. The work sheet can be continually annotated throughout a shift and thus be used as an evaluation and planning device. Because the yard-planning work sheet is the focal point of the tactical planning procedure for the yard, the steps in the planning procedure that involve the work sheet are described below.

Step 1

A yardmaster assistant uses a RAILS terminal and yardmaster work assignments to fill out data required for yard planning on the work sheet. These data are as follows:

1. The projected yard turnover, which consists of the content of each track in the form of either number of cars and their classifications or an

inbound or outbound train number and number of cars, is placed in the upper part of the left-hand column (Battle Creek East Yard).

2. The number of classified cars for each block that are already switched is entered under Total Ready to Move. This information is obtained from RAILS, adjusted for the cars that will be added to or deleted from the track by switching that is assigned by the yardmaster by means of switch lists that have been issued through RAILS.

3. The number of unswitched cars for each block for each unswitched received train is entered under In Yard to Be Switched. Each grouping is identified by train number, interchange source, or other grouping, such as crossovers or industrial movements. These block counts will be available from previous planning sheets for long-standing trains from advanced-consist summary reports transmitted by RAILS.

4. The number of cars for each block on each known inbound train is listed by train number, interchange, or industrial connection and entered under Total Inbound This Shift. Advanced-consist summaries and lists from RAILS are required to obtain these data. Occasionally critical data must be obtained by telephone or estimated (estimated data should be followed by the notation "est").

Step 2

A yardmaster fills in the upper part of the right-hand column, Estimated Train and Blocks Outbound, with the numbers of scheduled outbound trains (including any specials or extras) called by the dispatcher. The times and the preferred classifications for those trains are filled in, a preliminary assignment of blocks to those trains is made, and any particularly short connection times or train-sizing problems are noted. The number of cars for each destination would not be filled in initially. However, during the planning process, the sum for each classification on each train would be estimated and noted beside each outbound train; these estimates would be continually refined.

Step 3

The incoming yardmaster reviews the planning sheet. If potential schedule or connection problems are spotted, they are immediately noted and the dispatcher or trainmaster or both are contacted to negotiate possible changes or anticipated problems.

Step 4

The yardmaster gives switching assignments to the crews by annotating the work sheet. As estimates of the classifications and numbers of cars making outbound trains become clear, they are written for each outbound train in the section labeled Estimated Train and Blocks Outbound. At this time, the number of cars either switched or to be switched for each classification specified in the middle rows is also annotated with the connecting outbound train number.

Step 5

The yardmaster continues to annotate the work sheet throughout the shift in the manner described in step 4. Information on later inbounds is added throughout the day from RAILS advanced-consist summaries.

Step 6

The yardmaster continually projects train and other requirements for 12 h or so in advance and notifies the trainmaster or dispatcher of the desirability of potential operating changes to the nominal plan. Factors that could modify the nominal plan for the yard's viewpoint include

1. Unacceptable bunching of inbound trains,
2. Unacceptable (e.g., too-large) sizing of inbound trains,
3. Unusual block buildups (e.g., too few or too many of a given classification for a train or track),
4. Unusual car distributions on a train (e.g., 20 cars for Flint, Michigan, already blocked on a train that can leave on a through track and be added to other cars for Flint already in the yard),
5. Desirability of running extra trains or canceling scheduled trains, and
6. Desirability of mine-running certain traffic from or through the yard (i.e., not sorting the cars on the train).

Step 7

The yardmaster assistant continues to monitor and update the work sheet. Actual connections and train composition should be annotated when a train leaves.

Step 8

A yardmaster assistant uses the work sheet for the next shift by extrapolating turnovers and by copying unswitched-inventory information.

Step 9

The work sheets are stored and saved for evaluation of schedule and operating policy on a regular basis.

Step 10

Yardmasters compare DMP yard projections with actual operating plans. Discussions between dispatchers and yardmasters center around exceptions to the nominal plan.

CONCLUDING REMARKS

The operational demonstration took place during the week of July 25, 1977. This demonstration included a period of 48 consecutive hours during which the GT railroad was operated by using the tactical planning procedures developed during the project. Tactical planning of train and yard operations 8-12 h into the future was routinely accomplished; for certain trains the planning horizon was extended from 16 to 20 h. On the basis of a shift's tactical plan, dispatching and yard operations, power scheduling, and crew assignments could be coordinated. These procedures have now been implemented on the entire GT Chicago Division, which extends from Port Huron in Michigan to Elsdon in Illinois.

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REFERENCES

1. P. J. Wong and others. Grand Trunk Western Improved Railroad Operations Using a Railroad Automated Identification and Location System: New Procedures for Tactical Operating Planning

Decisions, Volume 1. Federal Railroad Administration, Rept. FRA-OPPD-77-18, Oct. 1977.
2. M. G. Tashker and others. Grand Trunk Western Improved Railroad Operations Using a Railroad Automated Identification and Location System: Dynamic Movement Predictor (DMP), Volume 2. Federal Railroad Administration, Rept. FRA-OPPD-77-19, Oct. 1977.

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Determination of the Effectiveness of Railroad-Car-Distribution Decision Making

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Most railroad organizations have defined and divided functions narrowly—around their visible physical activities such as moving trains, switching cars, and setting prices—because it appeared to be the most efficient way to manage such a complex production process. Unfortunately, adoption of such a structure has meant that the level of service provided to shippers and the use of the railroad's capital assets are the indirect result of numerous and often unrelated decisions rather than the focus of managerial activity. To understand this problem, a single function—car distribution—has been chosen for detailed investigation because it is an important determinant of both level of service and use of the freight-car fleet. Numerous operations research studies of car distribution have been conducted in recent years, but most have defined car distribution narrowly and ignored the broader organizational context within which car distribution actually functions. A framework is developed that is used to structure the analysis in a manner that permits consideration of both the physical elements of the production process and the managerial elements required to control it. Car-distribution organization, information, and decision structures are described and analyzed. Eight major areas in which improvement appears to be necessary are identified, and the direction of future research in this area is briefly discussed.

The railroads pioneered the development of organizational structures and practices to permit the management of large industrial concerns (1, p. 87), yet today there is a growing awareness that these decision-making and organizational structures (which have been used by the railroad industry for the last 100 years) may require change if the industry is to remain competitive with other transportation modes. This is no small task. Drucker, in his most recent text on the problems of management (2, pp. 590-591), cites railroads as one of the few businesses "for which we do not possess an adequate principle of organization"; he notes in particular the dilemma that faces managers responsible for the major capital assets--cars and locomotives--who must decentralize to attain efficiency but centralize to ensure effectiveness.

The solutions to this problem that have surfaced most recently focus principally on the form and structure of the organization as a whole (3, p. 176). While useful, such prescriptions may not address the problem at the level of the individual decision maker, whose behavior requires change. This study demonstrates that a focus on individual decision making is helpful in understanding the relevant organizational, information, and decision support systems of the transportation firm where the production process itself is complex.

To illustrate the proposed methodology, a single function--car distribution--has been selected as the subject of this decision-making diagnosis and design study. Car distribution was selected because

1. It is a function that has high leverage; even small improvements will have a major financial impact due to the rapidly increasing value of the freight-car fleet;
2. It is a relatively well-defined activity in the organization that has identifiable actors and procedures;
3. It has been the subject of numerous studies by operations researchers, who have adopted a traditional engineering view of the problem;
4. Institutional changes within the industry, which include the Clearinghouse (a mechanism to allocate equipment between railroads), hourly car hire, and the dramatic increase in the number of cars provided by third-party investors, have a significant impact on car distribution; and
5. Change is likely to be forced on it by external pressures--significant deregulation will remove many of the barriers that now constrain distribution activities and force a reassessment of policies and practices.

Car-distribution activity concerns the transfer of emptied cars from their unloading points to the next prospective shipper. Usually defined as an operating function, it is a support task to the primary productive activity of the railroad, which is to move loaded freight cars from shippers to receivers.

Car distribution is defined by car distributors themselves to be the process of identifying destination points for empty cars, given an available supply and potential demands, in a manner that minimizes cost. Defined in this way, the only problem faced by the car distributor is the matching of a given set of available empty cars with a given set of specified destinations. Most operations research studies have focused on the problem as defined in this way, since solutions can be generated by a variety of mathematical programming techniques. A review of attempts to apply mathematical programming to the car-distribution problem may be found elsewhere (4).

A main tenet of this study is that it is more fruitful to investigate the role of car distribution in the context of the railroad's total production function. This requires that the focus be not on a narrow interpretation of what car distribution produces--the movements of empty cars--but on the interdependencies that necessarily exist between car distribution and the rest of the railroad organization. From this perspective it is clear that (a) the choice of the empty cars to be distributed from those available and (b) the selection of which demands are to be satisfied are themselves problematic and interdependent decisions that must