TRIM Simulation of Canadian National Railways' Thornton Yard

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The Canadian National Railways terminal interactive model (TRIM) was used to simulate five selected design alternatives to choose the best design for Thornton Yard. Cost estimates were developed for each design, ecological and property impacts were assessed, and interference with existing operations during construction was determined. The first set of simulations reduced the five alternatives to three—two flat-yard designs and one hump-yard design. Further simulation resulted in the selection of one of the flat-yard designs. Additional simulations were run to fine tune the design selected.

Vancouver, British Columbia, is Canada's largest West Coast port. Major export commodities include coal, grain, potash, and sulfur with lesser volumes of forest products, chemicals, mineral concentrates, and general cargo. Imports include phosphate rock, automobiles, and various other containerized and general commodities for both Canadian and U.S. markets. In addition to the international movements, greater Vancouver (approximate population 1.5 million) generates a considerable volume of inbound and outbound local traffic.

Canadian National Railways (CN), which is the larger of Canada's two transcontinental carriers, captures a significant share of rail traffic to and from Vancouver. In addition to export and local volumes, CN interchanges traffic with Burlington Northern Railroad, British Columbia Railway, Canadian Pacific Railway, and British Columbia Hydro Railway.

Thornton Yard, located in suburban Surrey, is the hub of CN's operation in greater Vancouver. It is the classification, distribution, surging, and inspection point for all Vancouver traffic as well as the servicing and repair point for most rolling stock moving through the region.

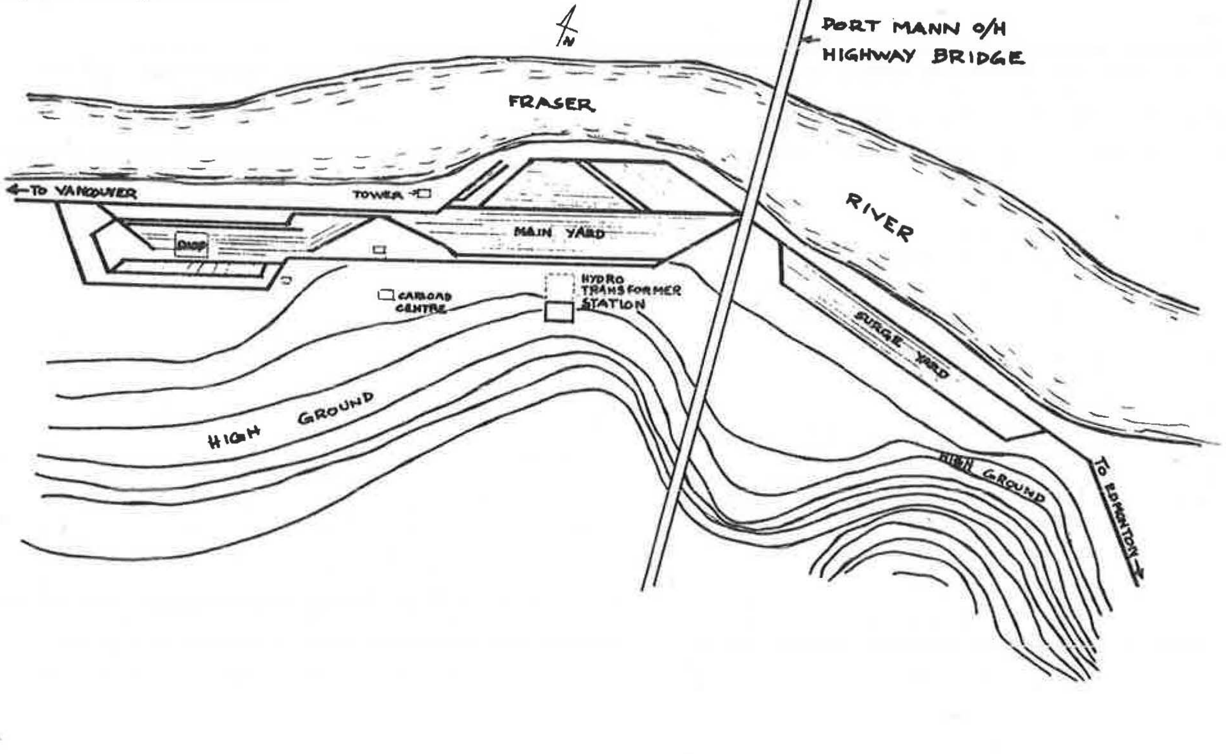
Thornton, a flat yard with a standing capacity of 4,700 cars, now dispatches some 650,000 cars per year. This is forecast to increase by more than 50 percent during the next 10 years. Current operating conditions clearly indicate that Thornton, like many other CN yards in western Canada, will be unable to cope with this level of growth. It was therefore decided to design an expanded plant that would be capable of handling traffic growth projected for the next 10 to 15 years.

DESIGN CONSTRAINTS

As shown in Figure 1, Thornton Yard is located on a narrow strip of relatively unstable land, bounded by the Fraser River on the north and rapidly rising topography to the south. Other constraints include a large electric utility station and the Port Mann Bridge, a major four-lane structure. In addition, railway facilities such as the carload center (yard office), car and diesel shop, and the yardmasters' tower are located throughout the west end of the property.

Despite these constraints to plant expansion, a preliminary analysis ruled out relocation of Thornton Yard facilities to another site on economic and operational grounds. Therefore, it was decided to expand the existing Thornton Yard. The high cost of grading and structure relocation and the ecological impact of expanding into the river dictated a judicious use of all available property.

Figure 1. Existing Thornton Yard.



STUDY METHODOLOGY

The optimum design for a system as complex as a major freight yard is difficult, if not impossible, to define. Nevertheless, the best design can be selected from a range of alternatives by using simulation techniques. Selected alternatives can be further refined through analysis of simulation data and additional simulations.

CN's terminal interactive model (TRIM) is probably the most powerful yard simulator available today. It was clear that a series of TRIM simulations would produce a design that would make the most effective use of available property and satisfy most other design criteria while providing a balance between capital and operating costs.

The general study methodology using TRIM involved six basic steps:

1. Development of design-day workload,
2. Identification of alternatives,
3. Input of simulation data,
4. Simulation process,
5. Analysis and evaluation of simulation results and selection of best alternative, and
6. Fine tuning of selected alternative.

Note that data and methodology are similar to those of a yard study using manual simulation techniques. The major difference is level of detail.

Workload Development

Before the design-day workload could be developed, a thorough understanding of current Thornton traffic patterns was necessary. Export coal, potash, and sulfur move in 98-car unit trains that require no switching as they pass through Thornton on the way to the tidewater bulk terminals. On the return (eastbound) move, bad-order cars are switched out of the empty unit trains and replaced with serviceable equipment. Unit trains make up about 55 percent of Thornton traffic. Most grain arrives in 100-car solid trains that require substantial switching at Thornton, because some grain must be delivered to specific elevators. Solid grain trains make up 15 percent of total traffic.

An additional 10 percent of the traffic moves in 15- to 30-car blocks because of specific origin-destination patterns. This includes cars carrying wood chips, chemicals, copper concentrates, alfalfa pellets, and some grain and potash. These blocks stay intact when switched at Thornton Yard. The remaining 20 percent is general carload traffic that requires car-for-car switching.

Future yard workloads for various traffic segments are determined on the basis of 10-year forecasts provided by CN's Marketing Department. CN's computer-assisted network analysis tool (CANAT) is used to translate these forecasts (which are expressed in tonnages) into a design-week train service pattern. Data generated by CANAT for non-unit-train traffic are further refined by CN's CANATerm model, which marshals and blocks cars on arriving trains in line with historic performance, future service design specifications, and projected customer demands. Minor manual modifications to the CANAT and CANATerm data were required to account for some Thornton Yard idiosyncrasies and to develop the internal yard workload for such operations as weighing cars, repairing bad-order cars, releasing cars being held, and handling dangerous commodities.

In line with current CN practice, the day of the design week with the second highest workload was selected as the design day. The design-day workload thus exhibits a peak about 30 percent higher than the annual daily average.

With the inbound and internal yard workloads defined, the final step in workload development was defining the initial yard population. This was one of the most difficult aspects: Historic samples were not adequate because the traffic levels and the plant were unlike those experienced in the past. The procedure used was to first develop a preliminary estimate of an initial yard population by using manual approximation methods. This population level was used as the basis for a preliminary simulation of a 24-hr period. The yard inventory at the end of this preliminary simulation was then used as the initial population for the simulations of the design-day operation.

The outbound workload is, of course, primarily a function of the simulated performance of the yard. Outbound train patterns and marshalling for nonunit trains were based on projected service design specifications. Outbound unit-train service depended on the arrival time of the corresponding inbound trains, which in turn was based on a random historic pattern.

Identification of Alternatives

Plant

At the outset, 11 alternative plant design concepts were defined through discussions between system and local planning and operating personnel. By a process of elimination and further discussion, this number was reduced to five designs that broadly satisfied all design parameters. Each of the five alternatives was sized for future workload by using projected throughput and occupancy calculations. Leads were designed on the basis of current design standards and crossovers were placed in locations dictated by discussions of various operating moves. This facilitated drawing of each alternative to scale. It was now possible to develop detailed cost estimates for each design, assess ecological and property impact, and determine interference with existing operations during construction.

The result of this process was the elimination of two more alternatives; this left two flat designs and one hump design for further analysis. These designs, which are shown in schematic form in Figures 2, 3, and 4, were further assessed for cost, interference with operations during construction, and ecological ramifications. These assessments resulted in additional design refinements. Once the necessary changes had been made, the three alternative plant designs were ready to code for TRIM input.

Operation

A variety of operating options was developed as an integral part of discussing each design alternative. Leads, crossovers, and various yard segments of each alternative were actually designed on the basis of specific operating parameters.

These operating parameters were reassessed and organized to satisfy the layout of each yard. Features such as arrival and departure routes, receiving and departure yard segments, and classification and train make-up patterns were defined. Internal flow of bad-order cars and cars to be weighed, distribution of empty cars, and storage of cars being held and dangerous cars were also ascertained and incorporated into the total operating package for each alternative. These operating strategies then served as the basic rules of operation during each simulation. To put the basic operating differences

Figure 2. Thornton Yard: flat plan 1.

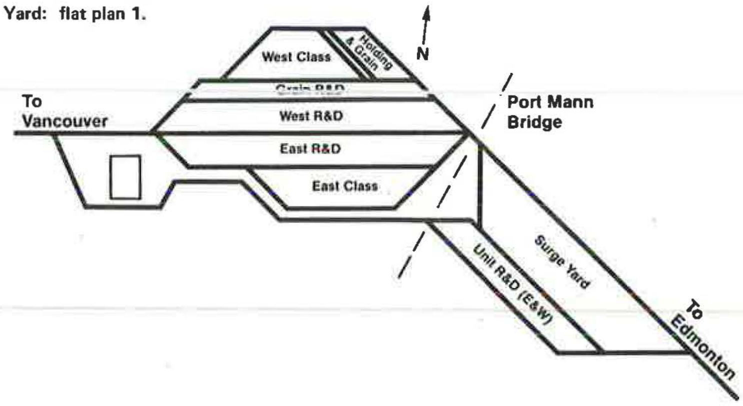


Figure 3. Thornton Yard: flat plan 2.

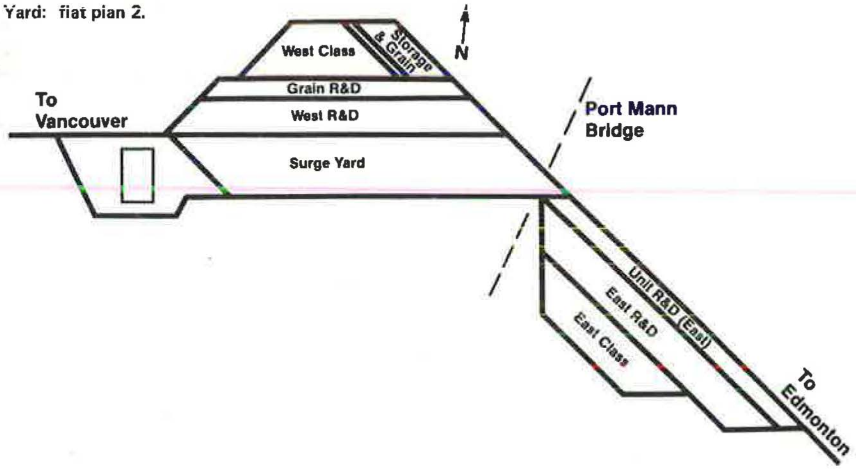
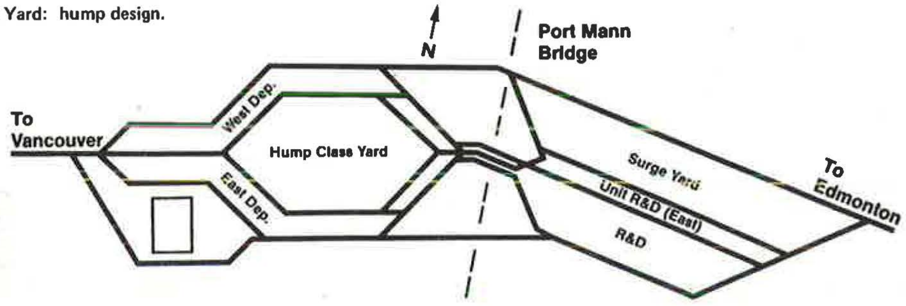


Figure 4. Thornton Yard: hump design.



into perspective, a brief description of the operating rationale for each alternative follows.

Operating Alternatives

Flat Plan 1

In flat plan 1 traffic flow through the yard is separated into three segments. All unit-train traffic in both directions is handled in the unit receiving and departure (R&D) yard and surge yard located east of Port Mann Bridge. Loaded westbound unit trains bypass the surge yard and main Thornton Yard (located west of Port Mann Bridge) on their way to the unloading terminals. If a unit train cannot proceed directly to the unloading point, it is held in the surge yard until required by the bulk terminals for unloading. In the eastward direction empty unit trains again bypass main Thornton Yard along the south side and are held in the unit R&D tracks. Inspection, servicing, and bad-order replacement take place in this yard; switching activity is confined to dedicated leads.

Non-unit-train traffic flows through the main body of Thornton Yard bidirectionally. Westbound trains bypass the unit-train yard and arrive at the west R&D yard. Classification of this traffic takes place at the west end of the west R&D and west classification yards. Westbound transfers are then made up from the west classification yard to west R&D tracks by pulling in a westerly direction on dedicated switching leads.

Westbound grain trains are held in the grain R&D tracks and are switched from the grain R&D yard to grain classification and storage tracks at the east end. Once again this takes place on separate leads. In this entire process eastbound movements and unit-train movements are not affected by the westbound flow.

Eastbound transfers are held in the east R&D yard. All classifying takes place at the east end of this yard on separate leads. Train makeup from the east classification yard to east R&D tracks can be performed on either end, independent of westbound and unit-train movements.

Flat Plan 2

Flat plan 2 separates the traffic flow by direction. All westbound traffic, unit and nonunit alike, is held in the west R&D yard, grain R&D yard, or the surge yard. West classification and grain classification processes are identical to those for flat plan 1. All switching and train makeup takes place on separate leads. The surging function is performed in the surge yard when required.

All eastbound movements bypass the west yard (i.e., trackage west of Port Mann Bridge) along the south side and arrive into R&D tracks in the east yard. Unit-train bad-order switching takes place on dedicated leads at either end of the unit R&D yard. Classification of non-unit-train traffic is done on separate leads at the west end of east R&D and east classification yards. As in flat plan 1, train makeup can be done from either end.

Hump Operation

In this design the surge yard, unit-train R&D yard for eastbound trains, and receiving yard for non-unit-train traffic were located east of Port Mann Bridge. Classification took place in a westerly direction by shoving from the receiving tracks and humping into the classification tracks west of the bridge. Train makeup was performed by pulling from the classification tracks in a westerly direction and making up east and west departure trains in their respective departure yards. Loaded unit trains moving in the westerly direction had the option of bypassing the entire plant along the north side or being held in the surge yard. One of the major problems with the hump design was the conflict between eastbound trains arriving into the receiving yard and the westward humping process.

Simulation Data Input

Workload

Design-day traffic flow generated by CANATerm is produced in TRIM format. Consequently, the train file (i.e., arriving traffic during the simulation) was constructed by simple electronic transfer of data from CANATerm to TRIM.

Plant

A scale drawing of each alternative was translated into a schematic showing all necessary track data, such as track identification code (track name), track length, switch clearance points, crossover connections, and leads. Figure 5 shows a portion of flat plan 1 schematically coded for TRIM input. Data from these schematics were organized on a code sheet and entered into TRIM via a keyboard to create the track file.

Yard Resources

Discussions dealing with yard design and operating options produced an approximation of yard-engine requirements for each alternative. These requirements were refined by examining future workload and design of each plant in detail, which culminated in a rigid definition of number of assignments, their respective starting times, and work areas for each yard assignment.

With respect to train inspection crews, standard times were developed for inspection and servicing. These standards were applied to the projected workload to produce an estimated number of inspection crews required. This number was used as the available number of inspection crews throughout the simulations.

Initial Inventory

As discussed earlier, the initial yard population for the projected workload and new plant was produced by a 24-hr simulation of each alternative. The volume and location of traffic produced by this preliminary simulation constituted the yard status at time zero of the design day. These data were defined as the initial population file in TRIM.

Simulation Process

TRIM Simulation Room

The TRIM simulation room, located at CN System Headquarters, is equipped with two rows of desks, a number of CRTs, and a printer as shown in Figure 6. For Thornton Yard simulations the three CRTs located

Figure 5. Flat plan 1 coded for TRIM input.

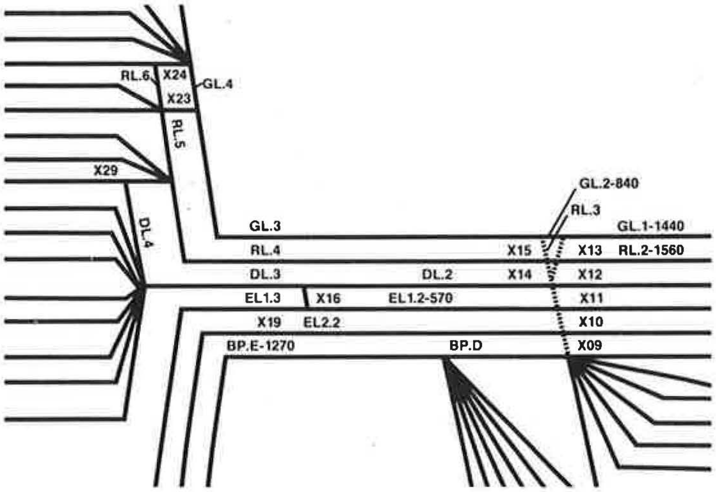


Figure 6. Simulation room layout.

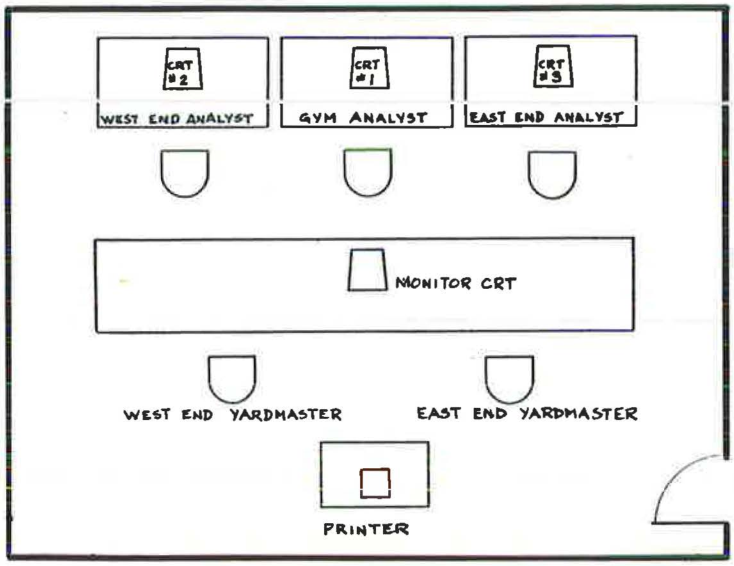


Figure 7. Sample track list.

```
LIST FOR TRACK ERD4      FROM EAST TO WEST TIME 01/22:30:00          PAGE    1

 SEQ  POSE  POSW  L/E  TAG  SPINS SPEC   COMMOD    DEST   BO  LEN   WT
 ---  ----  ----  ---  ---  ----- -----  --------  -----  --  ---  ----

 001  5345  1635   L   346                 30      91370        60     0
 002  5405  1575   E   346                 31      91370        60     0
 003  5465  1515   E   346                 31      91370        60     0
 004  5525  1455   E   346                 31      91370        60     0
 005  5585  1395   E   346                 31      91370        60     0
 006  5645  1335   E   346                 31      91370        60     0
 007  5705  1275   E   346                 31      91370        60     0
 008  5765  1215   E   346                 31      91370        60     0
 009  5825  1155   E   346                 31      91370        60     0
 010  5885  1095   E   346                 31      91370        60     0
 011  5945  1035   E   346                 31      91370        60     0
 012  6005   975   E   346                 31      91370        60     0
 013  6065   930   L   346                 30      91370        45     0
 014  6110   870   E   346                 31      91370        60     0
 015  6170   810   E   346                 31      91370        60     0
 016  6230   750   E   346                 31      91370        60     0
 017  6290   690   E   346                 31      91370        60     0
 018  6350   630   E   346                 31      91370        60     0
 019  6410   570   E   346                 31      91370        60     0
 020  6470   510   E   346                 31      91370        60     0
 021  6530   450   E   346                 31      91370        60     0
 022  6590   390   E   346                 31      91370        60     0
 023  6650   330   E   346                 31      91370        60     0
 024  6710   270   E   346                 31      91370        60     0
 025  6770   210   E   346                 31      91370        60     0
 026  6830   150   E   346                 31      91370        60     0

  TOTALS:  CAR =  26    LENGTH = 1545 FEET    WEIGHT =      0 TONS
```

at the front of the room were manned by three analysts.

The east-end analyst was responsible for switching work at the east end of the yard. The west-end analyst handled the work at the west end of the yard and movements of bad orders to or from the car shop plus other internal moves. The general yardmaster (GYM) analyst at the middle CRT was responsible for deploying inspection crews and yard crews and scheduling all arriving and departing trains.

The two yardmasters located behind the analysts were local operating officers experienced in Vancouver operations. Their role was that of decision makers throughout the simulation, as yardmasters are in a yard tower. The east yardmaster was responsible for work at the east end of the yard, whereas the west yardmaster controlled all the work at the west end and most of the internal moves. Located on the yardmaster's desk was a monitor CRT displaying a constantly updated condition of yard resources. At the rear of the room was a printer that produced hard copies of switch lists, train lists, and advance consists.

Simulation

Because the yardmasters (operating officers) were the decision makers, the simulation could not begin until the first element of yard work was defined.

At the outset the yardmasters were provided with information specifying the initial status of the yard in detail and a list of trains scheduled to arrive into the system in the ensuing 8 hr. The initial condition is defined on hard copies of track lists. A sample track list is shown in Figure 7. In these lists the track is identified, cars are listed in sequence, and the distance from the east and west ends of the track to the cars is given. In addition, classification code (tag number and spin number), commodity code, destination station number, and length in feet are specified. In the column headed BO, bad-order cars are identified and in the column headed SPEC special instructions such as dangerous cars, cars to be held, cars not to be humped, and so forth are given.

In the inbound-train list (Figure 8) trains projected to arrive into the system are specified. Information such as train number, expected time of arrival, and number of loads and empties is given. Also provided is total weight of the train, total length, and number of locomotives powering the train.

If desired, a car-by-car listing of each train's consist is also available. Figure 9 is a train consist for train K044C. These advance train consists provide such information as car sequence from the engine, loaded or empty status, and weight of each car.

Destination station number, commodity code, length in feet, and tag number (last column) are also specified for each car. In columns 8, 9, and 10 special instructions, bad orders, and cars to be cleaned are given. As an example W in the special instructions column indicates that the car is to be weighed, whereas HLD identifies a car destined to the hold track.

This information coupled with predefined service design specifications and operating plan are used by the yardmasters as the basis for planning and assigning yard work during the simulation. The process is similar to that experienced in yard towers during a typical shift. Having analyzed the preceding information, the yardmasters set the simulation process in motion by assigning work to yard assignments. Decisions about classifying, train makeup, available departure, and internal yard moves are also made. These decisions are passed on to the analysts for execution. Information regarding switching, train makeup, and internal yard moves is generally passed to the analysts by means of an annotated switch list, an example of which is shown in Figure 10. In addition to the switch lists, yardmasters verbally instruct the analysts what routes are to be used for specific moves and estimate the time for completion of each move.

Having received the instructions, analysts instruct the computer to make the required move. These instructions (commands) are issued by filling in the blanks on a formatted screen. An example of a move command is shown in Figure 11. In this particular case the analyst instructed the model to move four cars with engine WEST 1 to track C5 via tracks L1, X10, and L2 and to couple the four cars to those al-

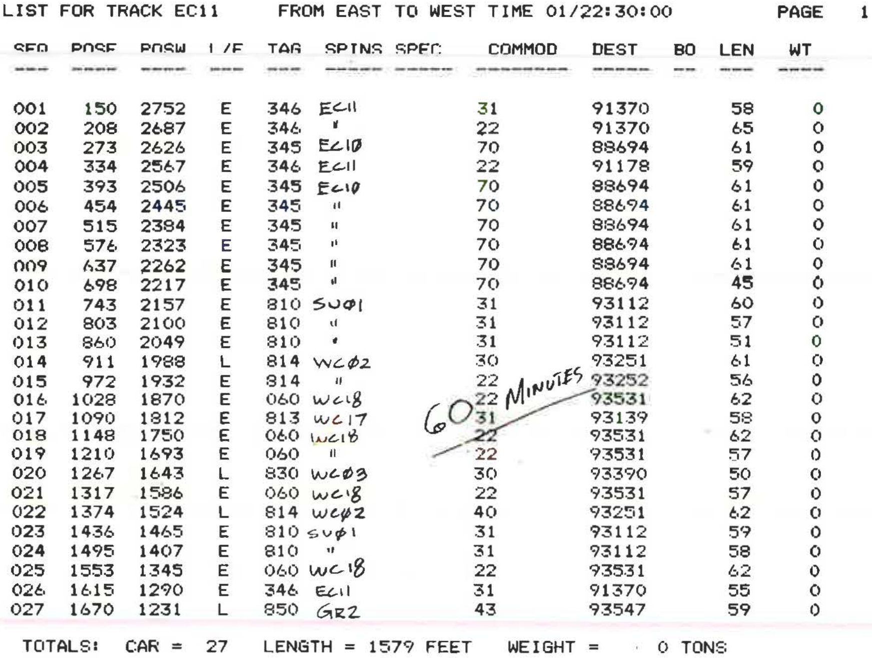
Figure 8. Inbound-train list.

```
                           TRAIN LIST - INBOUND     SIMULATION TIME 01/22:30:00

 TRAIN        ETA        LOAD MPTY TOTAL   WGHT   LENG LOCOS  TOT LEN ENTRY TRK
K046A    01/23:10:00  14    2     16    1285   915    2     1035      ARRW
B841     01/23:45:00  86    3     89   10736  5223    2     5343      WARR
 238     02/00:25:00  20    4     24    1209  1999    2     2119      ARRE
K042B    02/02:00:00   1   11     12     402   788    2      908      ARRW
K044C    02/02:30:00  23    1     24    1777  1473    1     1533      ARRE
 791     02/03:30:00  99    1    100   13098  5886    2     6006      WARR
 771     02/03:50:00  94    1     95   13754  6061    2     6181      WARR
 218     02/05:30:00  48   12     60    3066  4995    3     5175      ARRE
```

Figure 9. Advance consist for train K044C.

```
ADVANCE CONSIST FOR TRAIN K044C    ETA 02/02:30:00                PAGE   1

SEQ   L/E   WEIGHT   DEST    BLK    COMMOD     LEN   SPEC INS   BO   CLNR   TAG
---   ---   ------   -----   ---   ---------   ---   --------   --   ----   ---

001    L       63    41975   000   21           94       W                  302
002    L       63    33273   000   21           94                          301
003    L       63    33273   000   21           94                          301
004    L       73    33273   000   30           55                          301
005    L       69    93330   000   30           58                          820
006    L       55    81690   000   30           53                          341
007    L       92    92894   000   30           58                          800
008    L       66    81690   000   30           52     HLD                    341
009    L       76    93330   000   30           90                          820
010    L       76    87511   000   30           59                          341
011    L       70    33273   000   30           49                          301
012    L       85    76920   000   30           62                          347
013    L       67    64345   000   30           58     HLD                    303
014    L       73    41975   000   30           44                          302
015    L      109    61580   000   30           54                          303
016    L       68    93112   000   30           53                          810
017    L       82    64345   000   30           59                          303
018    L      109    61580   000   30           54     HLD                    303
019    L      104    33273   000   30           55     HLD                    301
020    L       77    61580   000   30           57                          303
021    L       62    92310   000   30           54     HLD                    344
022    L       76    52230   000   30           56     HLD                    301
023    E       32    93333   000   31           59                B         030
024    L       67    87930   000   30           52       W                  341

TOTALS : LOADS =  23 : EMPTIES =   1 : TOTAL =  24 :  1473 FEET :  1777 TONS


LOCO CONSIST FOR TRAIN K044C

      NAME     LEN    MODEL
      ------   ---   -------

      011209   060      GR17
```

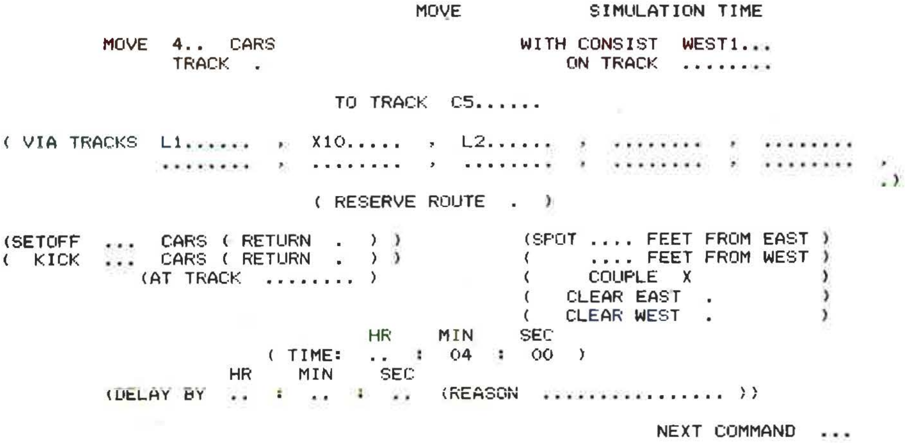
Figure 10. Annotated switch list.



```
LIST FOR TRACK EC11     FROM EAST TO WEST TIME 01/22:30:00          PAGE   1

 SEQ  POSE  POSW  L/E  TAG  SPINS SPEC   COMMOD    DEST    BO  LEN   WT
 ---  ----  ----  ---  ---  ----- ----  --------  -----    --  ---  ----

 001   150  2752   E   346  EC11           31      91370        58    0
 002   208  2687   E   346   "             22      91370        65    0
 003   273  2626   E   345  EC10           70      88694        61    0
 004   334  2567   E   346  EC11           22      91178        59    0
 005   393  2506   E   345  EC10           70      88694        61    0
 006   454  2445   E   345   "             70      88694        61    0
 007   515  2384   E   345   "             70      88694        61    0
 008   576  2323   E   345   "             70      88694        61    0
 009   637  2262   E   345   "             70      88694        61    0
 010   698  2217   E   345   "             70      88694        45    0
 011   743  2157   E   810  SU01           31      93112        60    0
 012   803  2100   E   810   "             31      93112        57    0
 013   860  2049   E   810   "             31      93112        51    0
 014   911  1988   L   814  WC02           30      93251        61    0
 015   972  1932   E   814   "             22      93252        56    0
 016  1028  1870   E   060  WC18           22      93531        62    0
 017  1090  1812   E   813  WC17           31      93139        58    0
 018  1148  1750   E   060  WC18           22      93531        62    0
 019  1210  1693   E   060   "             22      93531        57    0
 020  1267  1643   L   830  WC03           30      93390        50    0
 021  1317  1586   E   060  WC18           22      93531        57    0
 022  1374  1524   L   814  WC02           40      93251        62    0
 023  1436  1465   E   810  SU01           31      93112        59    0
 024  1495  1407   E   810   "             31      93112        58    0
 025  1553  1345   E   060  WC18           22      93531        62    0
 026  1615  1290   E   346  EC11           31      91370        55    0
 027  1670  1231   L   850  GR2            43      93547        59    0

  TOTALS:  CAR =  27   LENGTH = 1579 FEET   WEIGHT =     0 TONS
```

60 MINUTES

Figure 11. Simulation format for move command.



```
                                  MOVE            SIMULATION TIME

         MOVE  4..  CARS                      WITH CONSIST  WEST1...
               TRACK  .                            ON TRACK  ........

                             TO TRACK  C5......

( VIA TRACKS  L1.......  ,  X10.....  ,  L2......  ,  ........  ,  ........
              ........   ,  ........  ,  ........  ,  ........  ,  ........  ,
                                                                             .)

                          ( RESERVE ROUTE  .  )

(SETOFF  ...  CARS ( RETURN  .  ) )          (SPOT .... FEET FROM EAST )
(  KICK  ...  CARS ( RETURN  .  ) )          (      .... FEET FROM WEST )
           (AT TRACK  ........ )             (      COUPLE  X           )
                                             (    CLEAR EAST  .         )
                                             (    CLEAR WEST  .         )
                               HR    MIN    SEC
                       ( TIME:  ..  :  04  :  00  )
                   HR    MIN    SEC
        (DELAY BY  ..  :  ..  :  ..   (REASON  ................ ))

                                                  NEXT COMMAND  ...
```

ready on track C5. The estimated time for this move was 4 min. An X in the blank after the word "couple" is the instruction to couple. The instruction could as easily have been to spot (place) the four cars a certain distance from either end or to spot them in the clear. When the move has been completed, yard engine WEST 1 will be highlighted as ready for another task. This information is reflected on the analysts' CRTs and yardmaster's monitor screen.

As switching moves are carried out, trains are scheduled for arrival and departure, and other moves are completed, new track lists can be generated. These in turn end on the desks of yardmasters, who analyze and issue further instructions for continuing work. Throughout the simulations all pertinent data are logged for postsimulation production and analysis.

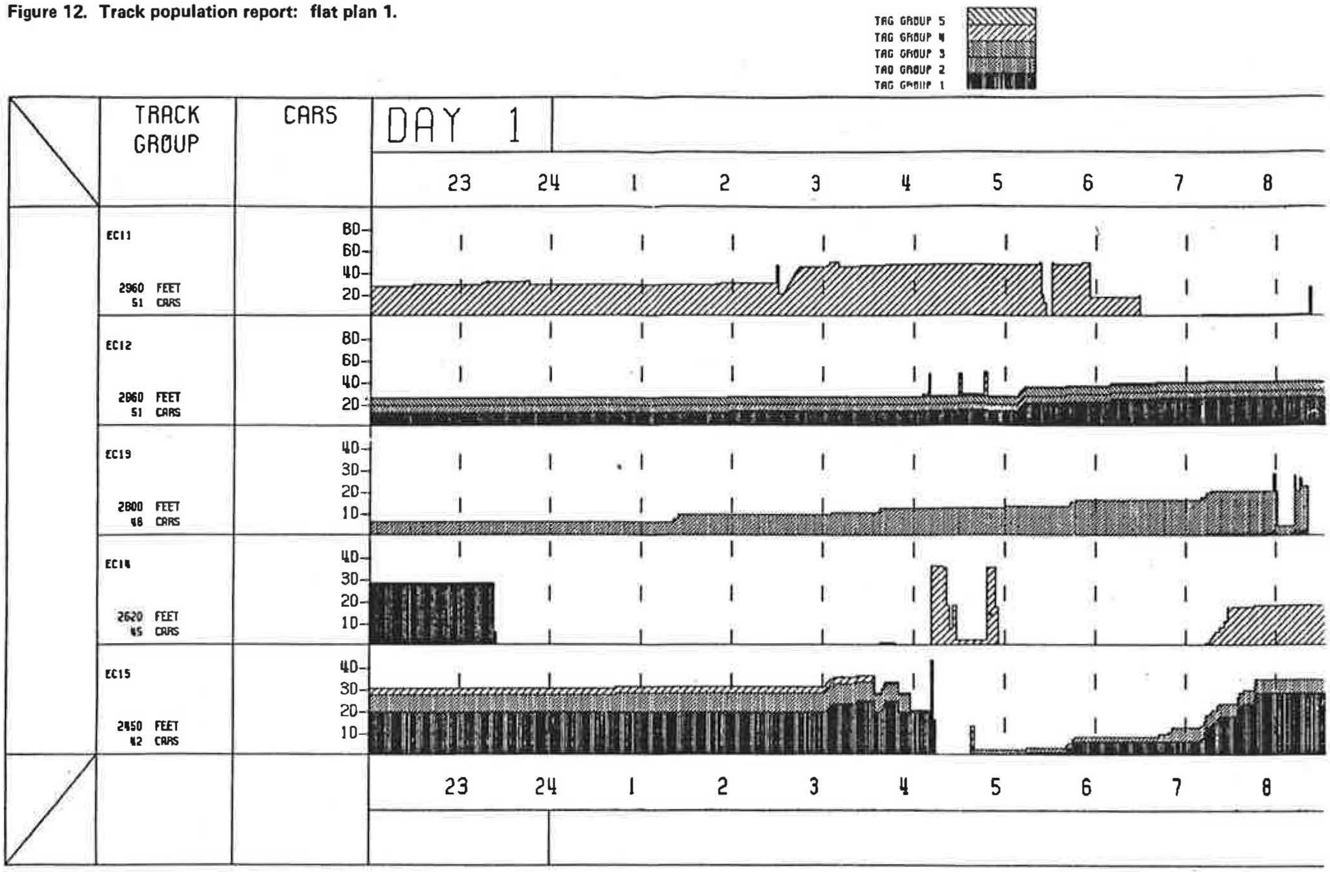
One of the most significant benefits of TRIM is its ability to highlight plant and operating deficiencies during the course of the simulation well before the results are plotted or tabulated and analyzed. For example, if a move was made to skirt a potential conflict but the plant was incapable of accommodating such a move, the problem would be highlighted immediately. It is possible to stop the simulation at that point, make the necessary track changes, and continue.

Classification-track capacity is another example in which TRIM immediately points out plant deficiencies. When a classification track is filled during a switching process, the program requests a swing track (an alternative track) for remaining cars of the same tag. A frequent swing request immediately indicates classification-track capacity shortfalls. From the operating viewpoint, a repeated conflict between yard assignments may indicate improper deployment of yard engines, whereas a yard assignment conflicting with a train movement may be indicative of poor operation or plant.

Evaluation

Plant and engine utilization data and crew produc-

Figure 12. Track population report: flat plan 1.



tivity data are generated by the postprocessing program. All plots and tables are computer generated, which requires limited manual organization before comparison and analysis. Examples of some of the plots and tables most frequently used in analysis are given in the following paragraphs.

Track utilization data generated in plot and tabular form are the most beneficial statistics in sizing the plant. Figure 12 shows 8 hr of occupancy for classification tracks EC11 to EC15. Usable track length in feet and car capacity for each track are indicated in the left-hand column. Occupancy plots reflect that the population of each track varies with time. Shading represents various tag groups. In addition the track utilization percentage is calculated. Classification-track occupancy is calculated on the basis of car hours, whereas R&D and lead calculations are made on a simple time-occupancy basis.

Figure 13 shows an example of lead occupancy plots. Engine activities are identified by the shaded coding defined at the bottom of the figure. In this case three segments of DL lead (DL.1, DL.2, and DL.3) are plotted individually, whereas total DL lead occupancy is shown by the fourth plot.

Figure 14 gives an example of R&D track occupancy. As in classification-track plots, track capacities are identified and percentage occupancies calculated. In addition trains that have recently arrived or are ready to depart are identified by number. (Note train K013G on track GR1 and train B841 on track GR2.)

In addition to plots, detailed tabular reports are produced for yard engine performance and crew utilization. Table 1 gives a summarized example of the inspection-crew report for flat plan 1 in shift format. For example, inspection crew INS 11 was on duty from 0800 to 1600 hr on day 2 and consisted of two workers. They worked 4.1 hr, were in transit for 1.2 hr, had 0.8 hr of personal time, and were idle waiting for instructions for a period of 1.7 hr. Inspection-crew productivity was examined by comparing various activity segments for the three alternative designs.

Table 2 shows a similar table for the switch-crew performance for flat plan 1. For example, the shift for yard crew West 2A started at 2200 hr on day 1 and terminated at 0600 hr on day 2. During these 8 hr the three-person crew worked for 3.23 hr, was in transit for 0.70 hr, used up 0.67 hr of personal time, was idle awaiting work for 1.72 hr, and was given 1.68 hr early quit. Individual and total times were compared for the three alternatives in determining productivity levels.

Analysis and Comparison

Track occupancy plots and cost played the most significant roles in alternative selection. Receiving, departure, and surge-track occupancies favored the flat-1 alternative as indicated in Table 3. These tracks were collectively occupied for 51.4 percent of available track time in flat 1 compared with 59.4 percent in flat 2. Flat 1 did, however, have one additional track (i.e., 4.2 percent more track capacity). The hump alternative exhibited a 54.3 percent occupancy of 30 available tracks. Occupancy of classification tracks and leads also favored flat 1 as did the crew productivity and engine utilization.

Total project cost favored flat 1 by a small margin when compared with flat 2, whereas the cost of the hump alternative turned out to be prohibitive. Flat 1 cost was estimated at $93 million; flat 2 was

$3 million higher. The cost of the hump alternative was estimated at $143 million.

Flat plan 1 performed best in each comparative category. Nonquantifiable operating features as perceived by the local operating officers favored this alternative as well. Consequently, simulation results, costs, and operating experience led to selection of flat plan 1 as the design for the expanded Thornton Yard.

Fine Tuning of Flat Plan 1

Once flat plan 1 had been selected as the best alternative, simulation results and simulation experience were used to refine the design. Track occupancies were used to size various yard segments more accurately. Lead occupancies, crossover occupancies, and movement conflicts were examined to refine the throat designs. Lead lengths and ladder designs

Figure 13. Lead occupancy report: flat plan 1.

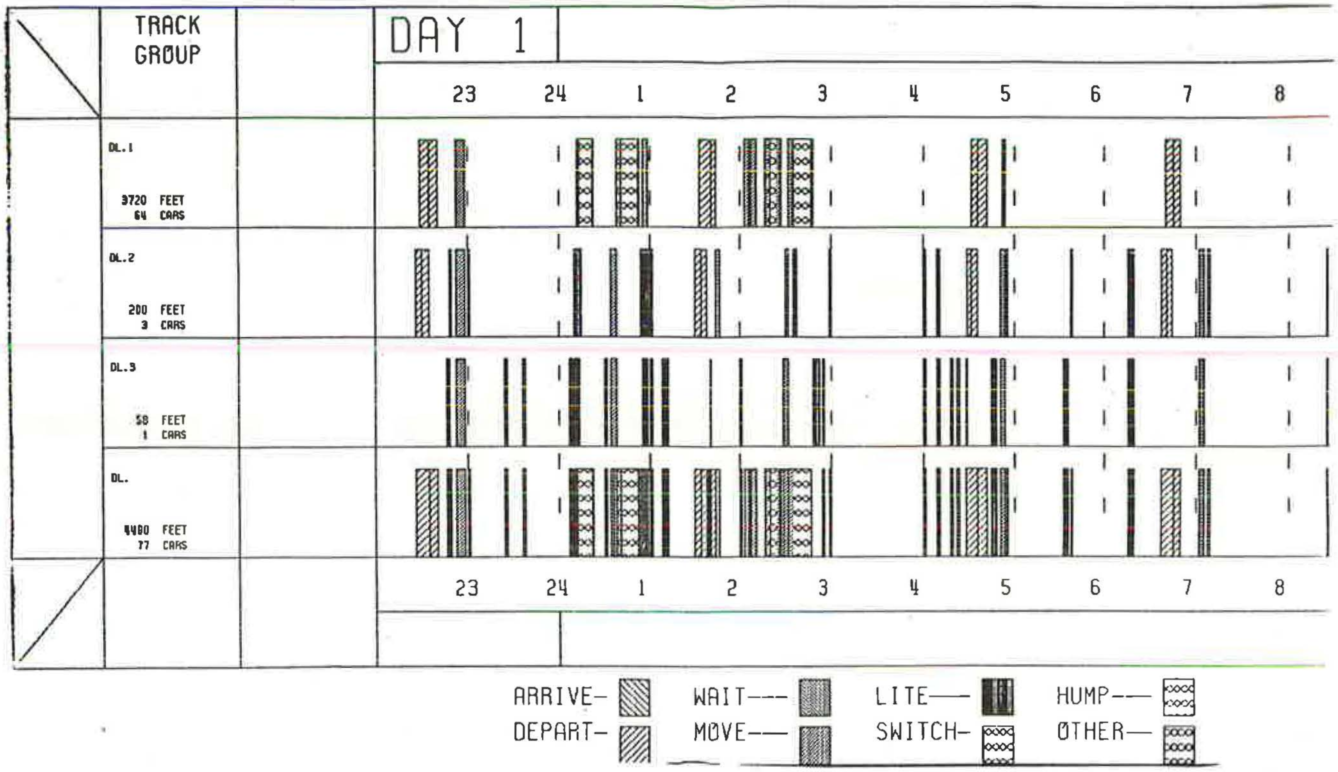
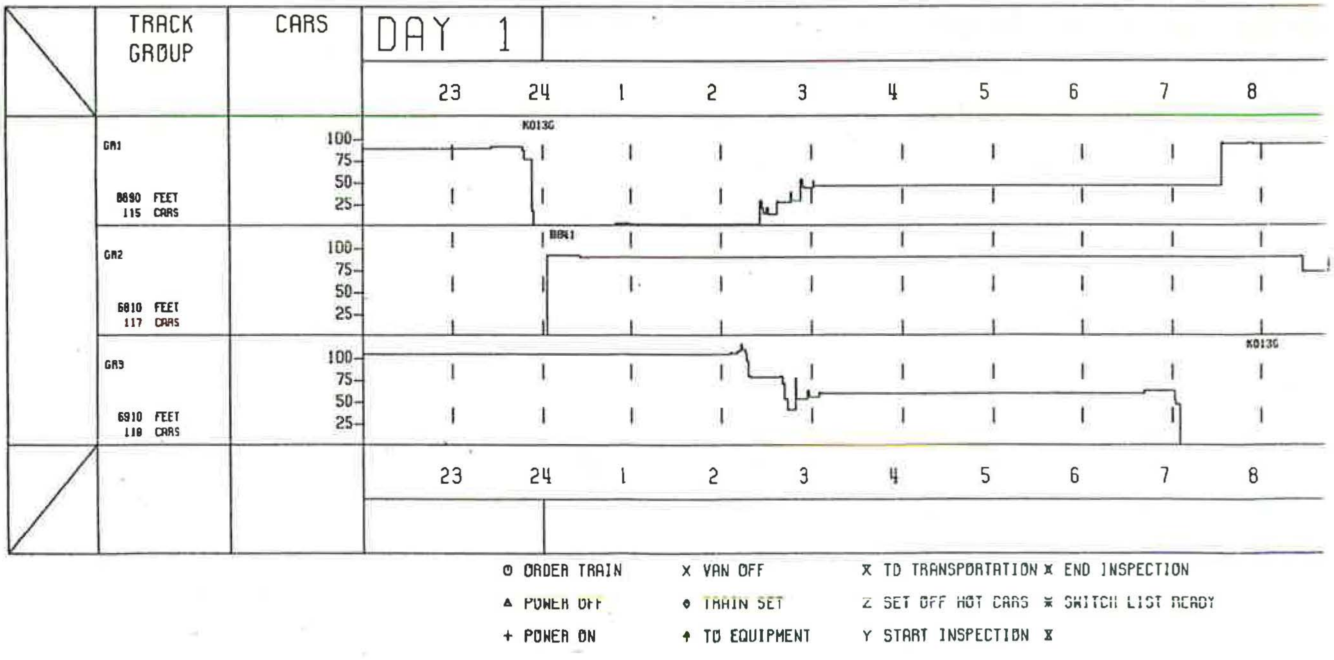


Figure 14. R&D occupancy report: flat plan 1.



were also modified on the basis of initial simulations. The refined flat plan 1 was then redrawn to scale.

Resimulation of Flat Plan 1

As in the initial case, the new flat plan 1 was translated into a schematic form and coded for TRIM input. Because of plant revisions, yard resources were adjusted in line with analysis of first simulation results. The operation was also marginally modified as necessitated by the plant revision.

On the basis of the new data flat plan 1 was resimulated. The results of this simulation were used to better gauge the true potential of the proposed yard and to make necessary final design changes. Thornton Yard master plan was produced on the basis of these final simulation results.

Table 1. Inspection crew report: flat plan 1.

			Time Allotment (hr)					
					Idle			
Crew Identification	Shift	No. of Workers	Work	Transit	Personal	Awaiting Instructions	Early Quit	Total
INS 7	01/2300-02/0700	2	2.4	1.0	0.8	3.5	0.4	16
INS 1	02/0000-02/0800	2	2.3	1.0	0.8	3.5	0.4	16
INS 2	02/0000-02/0800	2	2.5	1.2	0.8	3.2	0.4	16
INS 3	02/0000-02/0800	2	2.4	1.4	0.8	3.1	0.4	16
INS 4	02/0000-02/0800	2	2.5	1.4	0.8	3.0	0.4	16
INS 5	02/0000-02/0800	2	2.2	0.9	0.8	3.8	0.4	16
INS 6	02/0000-02/0800	2	2.3	0.8	0.8	3.7	0.4	16
INS 14	02/0700-02/1500	2	1.6	1.2	0.8	4.0	0.4	16
INS 10	02/0800-02/1600	2	2.0	0.8	0.8	4.0	0.4	16
INS 11	02/0800-02/1600	2	4.1	1.2	0.8	1.7	0.3	16
INS 12	02/0800-02/1600	2	3.1	1.4	0.8	2.3	0.5	16
INS 13	02/0800-02/1600	2	2.4	0.9	0.8	3.6	0.3	16
INS 8	02/0800-02/1600	2	1.4	0.8	0.8	4.8	0.3	16
INS 9	02/0800-02/1600	2	2.7	1.3	0.8	3.0	0.3	16
INS 21	02/1500-02/2300	2	1.7	0.9	0.8	4.4	0.3	16
Total		30	35.6	16.2	12.0	51.6	5.6	240

Table 2. Switch crew report: flat plan 1.

			Time Allotment (hr)						
					Idle				
Crew Identification	Shift	No. of Workers	Work	Transit	Personal	Awaiting Instructions	Early Quit	Total	Total No. of Moves
East 1A	01/2200-02/0600	3	2.80	0.87	0.75	2.15	1.43	24	62
West 2A	01/2200-02/0600	3	3.23	0.70	0.67	1.72	1.68	24	64
Unit 1A	01/2300-02/0700	3	2.75	1.42	0.75	1.36	1.72	24	48
West 1A	01/2300-02/0700	3	2.60	0.93	0.67	2.48	1.33	24	69
East 2A	02/0000-02/0800	3	3.15	0.81	0.75	3.21	1.53	24	36
East 1B	02/0600-02/1400	3	3.02	0.94	0.75	1.42	1.87	24	42
West 2B	02/0600-02/1400	3	2.98	1.36	0.75	1.22	1.70	24	42
Unit 1B	02/0700-02/1500	3	3.19	0.91	0.75	1.35	1.80	24	59
West 1B	02/0700-02/1500	3	3.24	0.93	0.75	1.02	1.80	24	31
East 2B	02/0800-02/1600	3	2.98	0.97	0.83	1.29	1.83	24	30
East 1C	02/1400-02/2200	3	2.91	1.10	0.75	1.34	1.90	24	25
West 2C	02/1400-02/2200	3	3.03	1.15	0.97	1.16	1.70	24	44
Unit 1C	02/1500-02/2300	3	2.48	1.17	0.75	1.29	2.30	24	38
West 1C	02/1500-02/2300	3	2.55	0.96	0.75	1.77	1.97	24	46
East 2C	02/1600-03/0000	3	3.85	0.60	0.83	0.51	2.20	24	49
Total		45	44.76	14.82	11.47	23.27	26.76	360	685

Table 3. Comparison of throughput for three alternatives.

	Flat Plan 1				Flat Plan 2				Hump Operation			
Yard	Percentage Used	Throughput	Cars Handled	No. of Tracks	Percentage Used	Throughput	Cars Handled	No. of Tracks	Percentage Used	Throughput	Cars Handled	No. of Tracks
East R&D	65.5	4.6	1,895	8	73.5	5.8	1,959	8	75.5	6.2	713	4
West R&D	45.3	6.3	1,232	9	45.5	4.6	1,791	9	30.0	2.7	1,469	7
Receiving	–	–	–	–	–	–	–	–	57.0	8.6	1,511	12
Unit R&D	49.6	6.1	1,588	6	74.4	8.0	834	4	70.4	6.2	1,073	4
Surge	27.4	10.1	141	2	43.7	8.0	389	3	50.6	8.2	487	3
Avg or total	51.4			25	59.4			24	54.3			30

CONCLUSIONS

Redevelopment of Thornton Yard presented many planning challenges. The need to greatly increase capacity contrasted sharply with the limited property available for expansion. This contrast heightened the need to investigate a wide range of plant and operating alternatives, select the one that best balanced capital and operating requirements, and further test and refine the chosen alternative. The TRIM simulation model was the only way of ensuring that these needs would be realistically met within a reasonable time frame. CN's Transportation Planning Department is confident that through the use of TRIM, an excellent yard design has been developed. This belief is shared by senior CN management and executives, who have approved the proposed flat plan 1 design as the basis for long-term expansion at Thornton Yard.

Engineering Design and Operational Study of Coyotepec Yard

SANTIAGO CARDOSO-CONTRERAS AND PETER J. WONG

Coyotepec Yard, near Mexico City, is being designed to handle 6,000 cars on a peak day. The basic design and the results of computer evaluation studies are presented. Topics addressed include trim-end design; capacity of the yard; humping rate; size of receiving, classification, and departure yards; and number of inspection and yard engine crews.

National Railways of Mexico has planned a large hump yard, Coyotepec Yard, with a capacity of 6,000 cars per day, the largest in the Western Hemisphere. Supplementing an existing, obsolete facility north of Mexico City, the new yard will become a key point for the country's rail network. The design of such a high-capacity facility required departures from conventional practice. In final form, the design represents a collaboration of the efforts of railroad representatives and consultants from Mexico, the United States, and Canada. When the yard has been completed, service will be improved and efficiency increased on the Mexican rail network.

Mexico has a large railway system in place today, which consists of 15,850 miles of track (1,000 miles under construction), 50,000 freight cars (plus 10,000 foreign cars on line at any given time), and 1,400 diesel-electric locomotives. This system handles 70 million tons of freight annually. Freight traffic is expected to grow at 6.8 percent annually through the year 2000.

A large percentage of the country's rail freight traffic must pass through Mexico City; not only do the routes of many cars terminate there, which serves the needs of the city's 16 million inhabitants (projected at 25 million by the year 2000), but all lines between northern and southern Mexico pass through the city as well. The burgeoning freight traffic threatens to overwhelm the existing Terminal Valle de Mexico (TVM) facility. Additional capacity is required, and it was decided not to expand the existing facility but to design a completely new yard to be located astride the new Mexico-Queretaro Main Line currently under construction. Several benefits will result from the new facility:

1. Reduction in transit time,
2. Reduction in operating costs,
3. Improvement in customer service,
4. Reduction in freight-car cycle time, and
5. Technology transfer.

Technology transfer has acquired great importance. The economic recession and tremendous inflation that have wracked Mexico recently have made it almost impossible to contract a large project such as Coyotepec to a foreign enterprise.

DESIGN PROCESS AND SPECIFICATIONS

The overall yard design was divided into the following categories:

1. Yard layout,
2. Yard data system,
3. Process-control system (PCS),
4. Trim-end design,
5. One-spot system and engine facilities,
6. Operating philosophy,
7. Operating management control points,
8. Key operating buildings,
9. Communication and signals (intrayard communication, interlocking design, and control of yard movements), and
10. TV monitoring system.

The purpose was not to complete a design in final detail but to develop each of the foregoing items in sufficient detail to know how these systems should work so that necessary performance specifications could be prepared for the invitation of bids. An exception was made for the critical crest and switching portions, for which a detailed design was made from the outset.

Yard Layout

The most important part of a yard project like Coyotepec is probably the yard layout, which consumes the most time in the conceptual phase of a large yard. Many days and weeks were spent on yard layout by the planning team for the Coyotepec Yard.

Three major constraints had to be considered in working on the yard layout. First, there were those imposed by the boundaries of the land site selected for the yard. Second, there was the division of the whole terminal into two phases, each of which would be able to handle 6,000 cars in the year 2000. The first is the North-South Phase (receiving yard, hump, classification yard, trim end, departure yard)