A RAILROAD CLASSIFICATION YARD SIMULATION MODEL

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1. INTRODUCTION

The yard simulation model discussed in this paper simulates the operation of the railroad hump yard. The purpose of the model is to test new innovations in railroad car blocking/classification, track assignment, and resource allocation schemes under given traffic dynamics. The model can also be used to assess the effects of capital improvements such as additional tracks.

Railroad freight operations can be divided into two types: road operations and switching operations. These two types affect each other; thus, both must be considered if improvements in rail freight services are to be effected. The capacity and efficiency of the large rail classification yards must be estimated to establish the feasibility of any rail network operational plan. This consideration led to the design and development of the yard simulation process described in this paper.

Railroad classification yards are designed to support the rail operations by sorting and gathering of rail traffic destined for the same location. The largest types of rail classification yards usually sort traffic into blocks according to the city or railroad company to which the cars are to be passed. The cars are then sorted by consignee in a smaller yard at the destination. Thus, these classification yards are important in the expeditious and efficient flow of freight in the rail network.

A classification yard has four parts: a collection of receiving tracks (called a receiving yard or transfer yard), a single or sometimes double main lead track (called a hump or switch lead), a set of classification tracks, and a group of departure tracks (called the departure yard). Classification yards are divided into two principal categories of flat yards and hump yards. The largest classification yards are generally hump yards. In hump yard operation, cars are pushed over a short incline called the hump and allowed to coast by gravity into the classification tracks. The flat yard, on the other hand, uses the switch engine to provide the momentum for getting the cars into the classification tracks.

Because of the major role that large hump yards play in rail operations, the initial yard model has been designed to simulate the operation of the hump yard. Expanding the model to simulate flat yards is a possibility, but is not implemented currently.

The yard analysis model is divided into two programs: a preprocessor and the yard simulation. Their use will be described in Section 3, Model Uses. The principal program is the yard simulation. It is written in the FORTRAN IV language with over 2,000 FORTRAN statements. The compiled program and data locations required approximately 43,000 words (CDC 6400) of core memory. The computer time for a simulation run ranges from 60 to 120 seconds, depending on the size of the problem. The model design emphasizes easy man/computer interaction and the model's responsiveness to the user. The traditional "black box" approach purposely is avoided; instead, the model is sensitive to user-oriented criteria and gives ample output data in both text and graphic forms with which the yard managers, planners, and analysts are familiar. During the development, the user-oriented approach was achieved through close interaction between the United States Railway Association (USRA) and SRI. In this regard the efforts of Messrs. Charles Hoppe, Hugh Randall, and Louis Hill of USRA were especially important. Additional operational advice of great value was provided by Messrs. James Page and Thomas Strawser of Central Pennsylvania Transportation Company. We would also like to acknowledge the contribution of Mrs. Barbara Wheeler of SRI for computer programming of the model.

2. DESCRIPTION OF THE MODEL

This section provides an overview of the man/computer interaction aspects of the model. In addition, a brief description is given of some of the most significant output.

2.1 Man/Computer Interface

The yard simulation process was developed with user-oriented criteria in mind. The model is deterministic and event-oriented; therefore, the computer run time is relatively fast. Because the simulation logic is straightforward, the off-line analysis is uncomplicated. The model has no built-in automatic "optimization" scheme. The criteria for a good solution are dependent on the objective and the user's operational insight. Therefore, the model may be viewed as a sophisticated calculator only to assist the analyst or the planners in operational planning decisions, but not to assume the role of a decision-maker itself. Figure 1 shows schematically how the programs and the analyst interact during the yard analysis process.*

The detailed yard analysis process consists of two stages. In the first stage, the designer can use a preliminary program to analyze, on a quick check-up basis, the building up of various blocks (to be in the yard) as a function of arriving and departing trains and of the sequence of humping the arriving trains. The output of the preliminary program can be helpful in making preliminary decisions related to class track assignments and possible time-sharing of tracks. In the second stage, the detailed yard simulation is actually used. Some of the specific output from these two stages will be discussed in the next section. A more complete description of the programs is available in reference (1).

2.2 Examples of Output

The programs are designed to start either with some prespecified initial conditions or with totally empty yard tracks at 0 hours (midnight) on the first day. The simulation process is repeated for Day 1, Day 2, ..., until a steady-state stabilized process is established--that is, when the yard operations for the next day become almost identical with those of the previous day. This happens typically within two or three days, depending on the traffic patterns. Much of the significant information about yard operations is available after the second day's simulation.

The following sample outputs have been included:

. Arrival to hump event list

. Block build-up scenario.

. Crew utilization analysis.

. Receiving and departure track utilization list and display chart.

. Hump and block arrival display.

. Class track loading matrix.

. Yard transit times statistics.

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*For reader convenience, all figures are placed at the end of this paper.

2.2.1 Arrival-to-Hump Event List--Figure 2 shows a portion of the prehump and humping scenarios. The entries under ARR TIME, REC TIME, and other headings of five digit number columns are to be interpreted as follows: The leftmost number indicates the simulation day; for example, Day 1 in the sample shown. The next two numbers are the hour of the day and the last two numbers are minutes of the hour. The entries under INST TIME, QUE TIME TO HUMP, etc., are indicated also in hours and minutes. This output provides detailed calculations regarding events that occur for each arrival train; for comparison purposes delays and inspection times for all trains also are tabulated. This display can be used to study the effects of different arrival sequences and to look at problems at the critical area of the hump.

2.2.2 Block-Build-Up Scenario--Figure 3 shows graphically a sample of Block 77 build-up output generated by the preliminary program of the yard analysis process. Graphic presentation gives a readily understandable perspective that is useful particularly in spotting time gaps when no cars are arriving for certain blocks. Studying such gaps could open up the possibilities of track time-sharing. Graphic displays also enable fast assignment of classification tracks of the proper length for the block. These assignments are required inputs later in the yard simulation program.

2.2.3 Crew Utilization Analysis--A summary of how each crew was used is provided both in a tabular and a graphical form. Figure 4 shows the tabular form display of the activities of inbound crews. A similar display is provided for departure engine crews and outbound inspection crews. Meanings of various entires are self-explanatory. For convenience, the information displayed in tabular form also is provided in a graphical form as shown in Figure 5. In this figure, the numbers 1, 2, 3, ... in the left column refer to the crew numbers. The rows on the top indicate the time. Each dot represents 15 minutes and the numbers 1, 2, 3, ... refer to hours 1, 2, 3, ... 24. Because of space limitations, the hours are broken into 8-hour groups and are displayed in three sets of 1 to 8, 8 to 16, and 16 to 24 hours. The XX marking against each crew indicates the busy period. Each character--that is, X, L, U--or space represents 5 minutes. Looking at Figure 5, we see that Crew 1 starts working at 0630 and inspects train Number 8 and 9 (the numbers are shown above the set of XX) until 0745 hours. The U marks following the X marks are the durations of unavailable time indicating the inherent delay between the end of the inspection of one train and the beginning of the inspection of another. The L markings indicate lunch periods. The D symbol indicates crew downtime at the start and end of the trick (shift).* Empty spaces indicate idle time.** Study of this output allows the analyst to assess the effects variations in crew resources from run to run.

2.2.4 Receiving and Departure Track Utilization--This output summarizes the usage of each of the receiving tracks in both tabular and graphical form. Similar outputs are provided for departure tracks. The two displays are identical to the displays shown for crew utilization and are thus not reproduced. These displays can be used to determine the possible effects of adding capital improvements such as additional departure trackage.

2.2.5 Hump Utilization and Block Arrival Display--This is one of the most useful outputs. It shows a time scenario of the way cars belonging to various blocks of the outgoing trains are being formed as the arriving trains are humped. Figure 6 shows part of the output for the hours from midnight (0 hours) until 0800 hours. The topmost row, which starts with 0 and has dots between the numbers 1, 2, ..., represents time starting from 0 hours. Each dot represents 15 minutes. The numbers in the second row--31, 32, 33, 1, 2 and 3--are numbers of incoming trains being humped. Consider arrival Train 31. Numbers in this column represent the numbers of cars brought by arrival Train 31 for various blocks shown under the BLOCK column. When Train 31 is humped (indicated by XX under number 31), one car for Block 32 is sent to its respective track, and so on. Similar remarks apply for other incoming trains.

The outgoing train associated with each block also is shown in the column under the heading NO. For example, Blocks 32 and 300 are associated with departure Train BT201 and Train BD003. The numbers under the first column on the left are the desired departure times of outgoing trains. The star sign, *, attached with some of the entries in the block column means that time history of that particular block is already being displayed above with reference to some other departure train.

The usefulness of this output is the provision of an overall interface between arriving and departing trains. The designer gets a feel for the status of various blocks after the humping of each train. Based on this information, the sequence of humping can be changed as needed to form certain blocks earlier than others.

2.2.6 Class Track Loading--This is another very useful output. Figure 7 shows the loading of each class track as a function of time while cars are being sent to and pulled out from the tracks. As in the previous figures, the day is divided into three eight-hour segments across the top of the page (the first eight hours only are shown in the figure). The dots each represent 15 minutes. The classification tracks are shown to the left under the heading TR. Numbers in the body of the matrix are the cars in the track at the time shown across the top. Any overloaded track is noted with an asterisk to draw the analyst's attention to it. The program has no logic to optimize the use of the class tracks, because the intent is to allow the analyst to make such decisions based upon his experience in the real world.

2.2.7 Yard Transit Time Statistics--This output gives the overall performance of the yard in terms of transit time of cars and total number of cars handled per day. A histogram of transit time also is shown. Figure 8 is a sample output of transit times. As indicated in this figure, the mean transit time in the simulated yard is 14 hours. The standard deviation is 6 hours and 52 minutes. The histogram shown in the bottom of the figure gives the number of cars having transit times of 1 through 31 hours. Each star, *, in the histogram shown graphically on the left side represents five cars. The numbers 1000 and 2000 indicate the time scale. The same information is displayed in a tabular form on the right side.

3. MODEL USES

This section provides some insight into the methodology for using the yard simulation programs. The first subsection covers initial yard strategies and some philosophy for using the programs. The second subsection describes some of the effects in qualitative terms of variations in some input parameters.

3.1 Basic Approach to Output Evaluation

The first step in an evaluation is to establish reasonable base-case simulation outputs that either prove

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*Labor practices: 5-10 min at the beginning and end of each shift for crew preparation time.

**Idle time: crew available for work, but not being used.

the yard will operate, or that can be used as a bases of comparisons for further analysis. The analyst's philosophy is that the program should provide a structure conducive to making judgments about yard loadings and operations on more rational grounds.

Implementation of the evaluation requires that an "average day" of arrival trains be studied. On the basis of his knowledge of the yard, the analyst makes the judgment as to whether the results are realistic. Such yard characteristics as average transit time, hump utilization, crew utilization, and departure events are contributing measures of the base-case simulation operation. Such a philosophy considers the simulation as a tool not to exactly duplicate reality, but rather to aid in structuring the analyst's approach to the yard analysis and in substantiating his intuitive evaluation.

The analyst will move arrivals and departures as justified by the average real operation of the yard. He may change the crew schedule or adjust the hump rate on successive runs until he is reasonably satisfied with the general correspondence between simulation results and actual utilization schedules, mean transit time, and other measures. After the yard has been loaded with the first day's arrivals, the principal concern in this type of analysis is the second day's (simulation time) output.

3.2 Preliminary Program Runs

After the initial data collection has been completed and formatted for input, the actual simulation begins. The first run (and perhaps several runs thereafter) uses the preliminary program. The results of these runs give the analyst a rough idea of the flow of traffic through the yard. An estimate of the size of each block can be made, and this facilitates assignments of class tracks for the yard simulation program. The operation of arrival and hump events also can be analyzed in an approximate fashion.

3.3 Main Yard Simulation Program

After the results of the preliminary program have been applied to the assignment of classification tracks, humping order and departure sequencing of the full simulation can be run. The analysis of the output proceeds iteratively and the analyst makes changes on successive runs to balance the yard.

Our experience indicates that this process strategy is to maintain balance loading among the three critical areas in the yard. These areas are the hump, the classification tracks, and the departure schedule. The first step is usually to develop a strategy of class-track swings and early pull outs that will neither overload the classification tracks nor overtax pull engine resources. The second step is to make further adjustments to arrival processing and perhaps hump sequence to ensure that cars designated for a particular departure make the train. The analyst usually works back and forth between these two "ends" of the yard until he is satisfied with the results.

Side issues of the analysis usually are considered after the basic operation of the simulation is achieved. For example, once the analyst has balanced the yard he may want to reduce the allowable overtime for particular crews so as to achieve more efficient utilization of these resources.

After a satisfactory base-case simulation is obtained, the analyst studies various possible changes in the input. The next few sections describe some of these alternatives.

3.4 Variations in Hump Speed

A real world situation corresponding to changes in hump speed would be the addition or removal of hump engines. Increasing the fraction of a minute required to hump each car slows down the hump operations even though the operations themselves have been found to be rather insensitive to such changes. In contrast, receiving track occupancy and departure train sizes can be controlled rather dramatically with this parameter. To have any effect at all, a change of 0.1 min/car is required.

3.5 Hump Gap Usage

Hump gaps can be inserted to simulate the closure of the hump (for repairs and the like). Also, they can provide more realistic hump utilization information in yards where hump engines do a large amount of trimming.

Another use of the hump gap is to provide time for pulling class tracks in yards where class tracks are closed before pulls. If practical, this use should be avoided because it is not a close representation of real operations. Hump gaps also have been used to close the hump to simulate rehumping type of operations that may be occurring during the gap.

3.6 Variations in Crew Resources

The addition or deletion of crew resources can be accomplished in two ways. The total number of crews can be increased, or the rate and inspection constants can be changed. The choice between these possibilities depends on several things. The first consideration must be whether or not the crew could inspect the trains faster in reality. If the inspection rate could be increased (with the addition of a man, for example) then this is a valid approach. Real-world considerations make it doubtful that more men can inspect the same train faster. In addition, extensive changes in crew inspection rates do not affect time spent waiting to be inspected. If a large number of short trains are to be inspected at about the same time, the delay will remain about constant because the trains still must wait (only a slightly shorter time) for the crew to finish inspection of previous trains. The best approach to variations in crew resources is to add or delete entire crews.

3.7 Variations in Train Schedules

Schedules can be varied in two ways. First, the actual arrival or departure time can be changed. The second variation concerns scheduled sequence of events in the program. The program will perform hump or departure calculations according to the order of the departure train input or the hump number. For example, a departure scheduled for 0100 will get a pull engine before a departure scheduled at 0030 provided that the 0100 departure input is listed before that of the 0030.

3.8 Variations in Traffic Volume

One of the first considered and most interesting types of variations in inputs is the variation of traffic volume. This can be accomplished by adding and deleting cars from blocks or by adding extra trains. Additions and deletions of traffic should be realistic in terms of destination of the incoming cars and numbers of cars. An iterative approach works to best advantage. The analyst gains insight into the resource sensitivities as changes of about 100 cars per day are applied in each successive run. We have found that a gross addition of many cars tends to complicate analysis of the effects because too many restrictions to the traffic flow are developed simultaneously.

3.9 Variations in Class Track Assignment

This can be the most critical parameter in balancing yard operations in a yard having a large number of short classification tracks. Tracks can be reassigned for a period of minutes or they can be assigned to a completely different track.

4. CONCLUSIONS

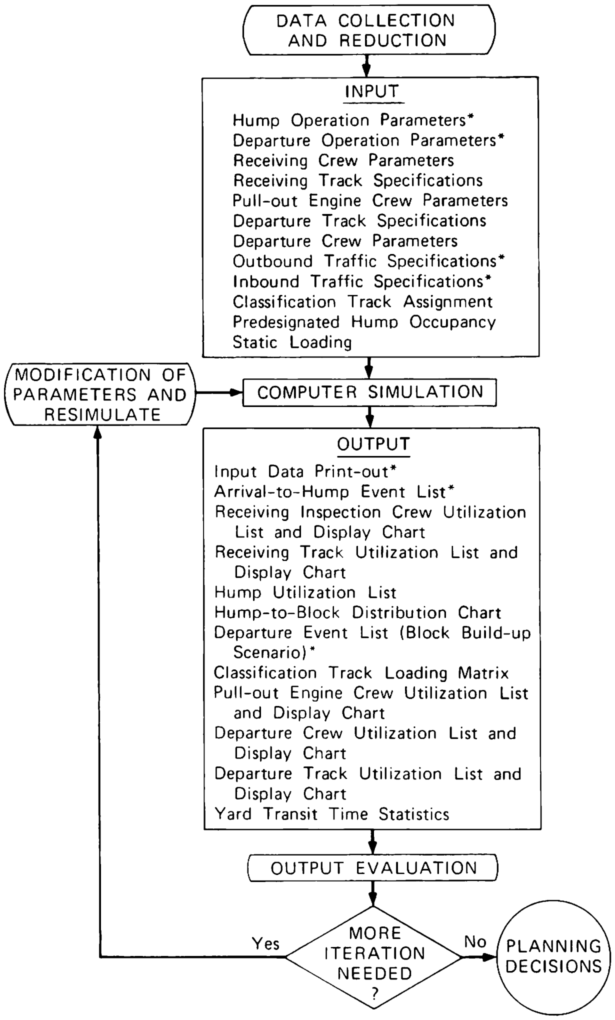
We have discussed a simulation model that can be used to analyze the operation of a railroad hump yard. Two types of analysis are possible. One type consists of establishing maximum capacities in existing yards, testing new allocations of resources, and studying different track assignment schemes. The second analysis uses the model to determine the effects of proposed capital improvements.

The model design intentionally allows the user to interact easily with the process. This has been achieved by keeping the programs deterministic and by judiciously designing the output displays. Several examples of the output have been described to show the program's utility.

Possible variations in the model input parameters have been described. Other variations could be conceived. The effects on different yard efficiencies also could be measured with the model.

REFERENCES

1. Paul L. Tuan, et al., "Users Manual for Yard Operations Analysis Computer Program," Stanford Research Institute, Menlo Park, California (October 1975).



*Preprocessor Program and Yard Simulation Program

TA-710522-270

FIGURE 1 GENERAL SCHEMATIC OF THE YARD ANALYSIS MODEL

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     TRAIN   NO.      ARR      REC   REC    REC     INSP    INSP   INSP     INSP  READY   QUE TIME  START    HUMP    END
NO.          CARS     TIME     DELAY TRACK  TIME    CREW    DELAY  TIME     TIME  TO HUMP  TO HUMP  HUMP     TIME    HUMP

 1   LOCAL   136     10000      0     5    10000     3        0   10000     44   10049       0    10049      53    10142
 2   BT204    61     10040      0     4    10040     3        9   10049     25   10119      33    10152      24    10216
 3   BB703    72     10045      0     6    10045     3       34   10119     28   10152      34    10226      28    10254
 4   LH001    72     10130      0    11    10130     3       22   10152     28   10225      39    10304      28    10332
 5   LH003    78     10410      0     4    10410     3       20   10430     30   10505       0    10505      30    10535
 6   BB401    89     10455      0     5    10455     3       10   10505     32   10542       3    10545      35    10620
 7   FB001   119     10513      0     6    10513     3       29   10542     40   10627       3    10630      46    10716
 8   AB007    94     10605      0     4    10605     1       30   10635     34   10714      12    10726      37    10803
 9   FB002    84     10659      0     5    10659     1       15   10714     31   10750      23    10813      33    10846
10   BB205    58     10755      0     3    10755     1        0   10755     25   10825      31    10856      23    10919
11   BT203    76     10800      8     4    10808     1       17   10825     29   10859      30    10929      30    10959
12   BB704   128     10845      6     5    10851     1        8   10859     42   10946      23    11009      50    11059
13   DB002    83     10854      0     6    10854     1       52   10946     31   11022      47    11109      32    11141
14   2BB20   102     10925      0    11    10925     1       57   11022     36   11103      48    11151      40    11231
15   LH004    77     11015      0     4    11015     1      115   11130     29   11204      37    11241      30    11311
16   DB006    78     11117      0     5    11117     1       47   11204     30   11239      42    11321      30    11351
17   BT204    61     11240      0     6    11240     1        0   11240     25   11310      51    11401      24    11425
18   DB002    83     11254      0    11    11254     1       16   11310     31   11346      49    11435      32    11507
19   CB008    93     11300      0     9    11300     1       46   11346     33   11424      53    11517      36    11553
20   CB006    94     11305      0    10    11305     2      130   11435     34   11514      49    11603      37    11640
21   AB001   113     11425      0     4    11425     2       49   11514     38   11557      53    11650      44    11734
22   CB001    85     11553      0     5    11553     2        4   11557     31   11633     111    11744      33    11817
23   BB603   115     11635      0     6    11635     2        0   11635     39   11719     108    11827      45    11912
24   CB002    73     11645      0    11    11645     2       34   11719     28   11752     130    11922      28    11950
25   FB003   102     11705      0     9    11705     2       47   11752     36   11833     127    12000      40    12040
26   2B203    90     11725      0    10    11725     2      108   11833    103   11941     109    12050      35    12125
27   AB006    68     11746      0     4    11746     2      155   11941     27   12013     122    12135      27    12202
28   BB205    58     11955      0     3    11955     2       18   12013     25   12043     129    12212      23    12235
29   CB009    53     11959      0     2    11959     2       44   12043     23   12111     134    12245      21    12306
30   AB008   124     12010      0     5    12010     2      101   12111     41   12157     119    12316      48    20004
31   BB204    70     12125      0     6    12125     2       32   12157     28   12230     144    20014      27    20041
32   BT204    61     12140      0    11    12140     3       55   12235     25   12305     146    20051      24    20115
33   BB208   106     12200      7     4    12207     3       58   12305     37   12347     138    20125      41    20206
             =====             ====                         ====          =====          =====            =====
             2856                21                         1922          1758           10417            1834
```

FIGURE 2 ARRIVAL-TO-HUMP EVENT LIST

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                    BLOCK     77
        BINSIZE IN MINUTES    30
             STARTING TIME 20000
               ENDING TIME 30000

NOTE, EACH MAJOR DIVISION IS 10 UNITS
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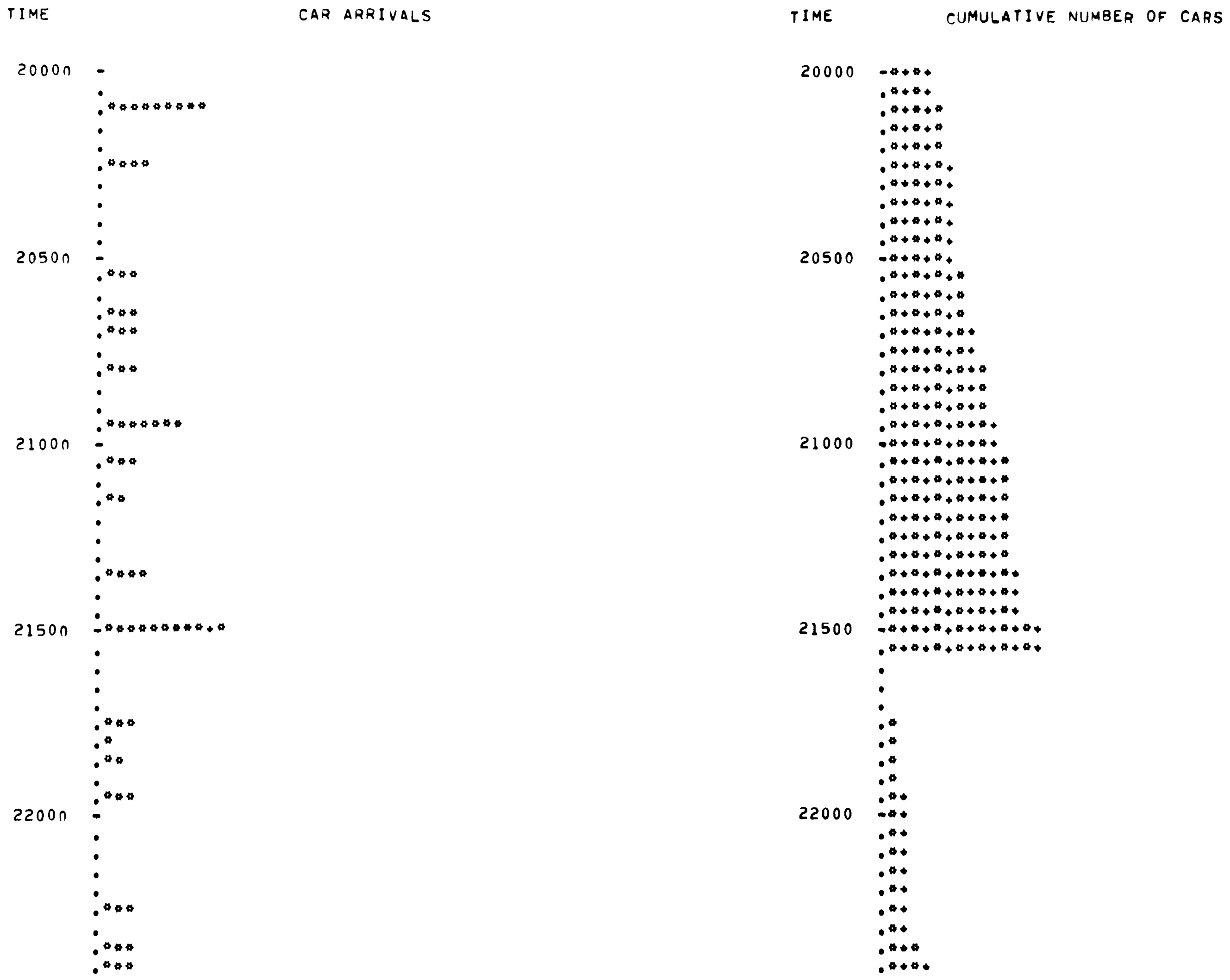

FIGURE 3 BLOCK BUILD-UP SCENARIO

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IB   INSP   CREW    1     UTILIZATION = 78.3 PERCENT

       TRAIN      START       SERVICE     END         IDLE      NONPROD
        NO.       TIME         TIME       TIME        TIME       TIME

-3                10630           0       10635          0          5
 8     AB007      10635          34       10709          0          5
 9     FB002      10714          31       10745          5          5
10     BB205      10755          25       10820          0          5
11     BT203      10825          29       10854          0          5
12     BB704      10859          42       10941          0          5
13     DB002      10946          31       11017          0          5
14     2B820      11022          36       11058          0          0
-2                11100           0       11130          0         30
15     LH004      11130          29       11159          0          5
16     DB006      11204          30       11234          1          5
17     BT204      11240          25       11305          0          5
18     DB002      11310          31       11341          0          5
19     CB008      11346          33       11419          1          5
-3                11425           0       11430          0          5
                               ====                   ====       ====
                                616                      7        135

IB   INSP   CREW    2     UTILIZATION = 79.8 PERCENT

       TRAIN      START       SERVICE     END         IDLE      NONPROD
        NO.       TIME         TIME       TIME        TIME       TIME

-3                11430           0       11435          0          5
20     CB006      11435          34       11509          0          5
21     AB001      11514          38       11552          0          5
22     CB001      11557          31       11628          2          5
23     BB603      11635          39       11714          0          5
24     CB002      11719          28       11747          0          5
25     FB003      11752          36       11828          0          5
26     2B203      11833          27       11900          0          0
-2                11900           0       11930          0         30
26     2B203      11930           6       11936          0          5
27     AB006      11941          27       12008          0          5
28     BB205      12013          25       12038          0          5
29     CB009      12043          23       12106          0          5
30     AB008      12111          41       12152          0          5
31     BB204      12157          28       12225          0          0
-3                12225           0       12230          0          5
                               ====                   ====       ====
                                623                      2        135
```

FIGURE 4 CREW UTILIZATION TABLE

```
                                    IH  INSP  CREW  UTILIZATION   DAY 1

    0  .  .  .  1  .  .  .  2  .  .  .  3  .  .  .  4  .  .  .  5  .  .  .  6  .  .  .  7  .  .  .  8
                                                                                     8     9
1                                                                                  DXXXXXXXXXXXXXXU

2
       1        2     3     4                                5     6     7
3    XXXXXXXXXXXXXXXXXXXXXXXXXXXXU                   LLLLLLXXXXXXUXXXXXXXXXXXXXXXXDD

    8  .  .  .  9  .  .  . 10  .  .  . 11  .  .  . 12  .  .  . 13  .  .  . 14  .  .  . 15  .  .  . 16
      10 11    12          13    14             15    16    17    18       19
1    XXXXUXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXLLLLLLXXXXXXXXXXXXXUXXXXXUXXXXXXXXXXXXXXUD
                                                                                    20    21
2                                                                                  DXXXXXXXXXXXXXXXXU

3

   16  .  .  . 17  .  .  . 18  .  .  . 19  .  .  . 20  .  .  . 21  .  .  . 22  .  .  . 23  .  .  . 24

1
      22    23       24    25       26          27    28    29    30       31
2    XXXXXXUXXXXXXXXXXXXXXXXXXXXXXXXXXXXXLLLLLLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXD
                                                                                    32    33
3                                                                                  DXXXXXUXXXXXXXXU
```

FIGURE 5 CREW UTILIZATION GRAPHIC DISPLAY

```
                                          HUMP UTILIZATION AND BLOCK ARRIVAL DISPLAY      DAY 2


                                 0 . . . 1 . . . 2 . . . 3 . . . 4 . . . 5 . . . 6 . . . 7 . . . 8

                                  31     32   33        1         2    3      4    5      6      7        8
                              1  XUXXXXXXXUXXXXXUUXXXXXXXXXXUXXXXXXXXXXXXUXXXXXXUXXXXXXXUXXXXXXUXXXXXXXUXXXXXXXXUXXXXXXXXXXUUXXXXX
 TIME        NO.    BLOCK
  301       BT201    32           1       0   13       10         0   13      0    1      8      0       24
  301       BD003   300          20       0    4        4         0    5      0    0     32      0        1
  315       BA006    42           1       0    0       11         0    8      0    0      0      0        0
  330       BB104     5           0       4    0        8         4    1      8    2      0     48        1
  400       BB701    26           0       2    2        2         2    0      1    8      1      1        7
  400       BB701    29           0       1    0        1         1    0      0    0      0      0        4
  405       BB103     2           0       3    0        8         3    0     17    4      0     15        0
  430       BB702    28           0       0    6        2         0    0      3   10      1      3       13
  500       BT201    32*
  630       BD004   230           4       1    2        2         1    4      0    0      4      0        0
  700       BD003   300*
  730       BB501    35           0       5   13        3         5    2      0    1      3      0        0
  735       BF002   260           3       0    3        1         0    0      0    0      4      0        0
  735       BF002   440           8       0    4        1         0    0      0    0      4      0        0
  735       BF002   460           9       0    8        1         0    0      0    0      9      0        0
  900       BB104     5*
  915       BB402    22           0       1    0        8         1    1      3    5      0      7        6
 1000       BC007   151           2       2    1        0         2    0      0    0      1      0        0
 1000       BB101     9           0       2    0        8         2    1      8   21      0      9        0
 1020       BB102     1           0       7    0        5         7    2     11   11      0     11        1
 1045       BC002   140           2       0   11        5         0    3      0    0      5      0        0
 1100       BB103     2*
 1115       BT201    32*
 1115       BC004   110           4       7    8        4         7    3      0    0      0      0        0
 1130       BB109     3           0       1    0        1         1    0      3    1      0      3        0
 1130       BB109     8           0       0    0        0         0    0      2    1      0      2        0
 1130       BA006    39           0       2    0        1         2    2      0    0      0      0        0
 1200       BA001    72           3       4    5       30         4    3      0    0      0      0        0
 1200       BA001   120           1       1    2        1         1    0      0    0      2      0        0
 1200       BD003   300*
 1300       BB104     5*
 1300       BB602    24           1       0    4        2         0    3      0    4      1      0       24
 1400       BB105     6           0       2    0        2         2    1      4    6      0     12        0
 1400       BB702    28*
 1420       BC004   110*
 1435       BA006    42*
 1530       BB110    16           0       5    0        0         5    0      0    0      0      0        2
 1545       L0002    30           2       2    8        2         2    2      0    0      2      3        6
 1600       BB402    22*
 1600       BB402    23           0       0    0        0         0    1      0    0      0      0        2
 1600       BB501    33           0       0    1        0         0    0      0    0      0      0        0
 1600       BB501    35*
 1700       BT201    32*
 1700       BA006    34           0       0    0        0         0    0      0    1      0      0        0
 1700       BA006    39*
 1700       BA006    42*
 1715       BB102     1*
 1730       BB110    16*
```

FIGURE 6 HUMP UTILIZATION AND BLOCK ARRIVAL DISPLAY

```
                                  CLASS TRACK LOADING MATRIX, DAY  2

TR.   8   .   .   .   9   .   .   .  10   .   .   .  11   .   .   .  12   .   .   .  13   .   .   .  14   .   .   .  15   .   .   .
  1  49  49  49  62  62  62  62  62  66  66  66   0   2   2   2   2   2   2   2   2   2   2   2  14  14  18  18  18  18  18  18  23
                                        *   *   *

  2  47   0   0  12  12  12  12  12  14  14  14  14  15  15  15  15  15  15  15  15  15  15  15  35  35  38  38  38  38  38  38  38

  3  35  35  35  38  38  42  42  42  44  44  44  44  44  44  44  44  44  44  44  44   0   0   0   3   3   5   5   5  32  32  32  32

  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   8   8  15  15  15  31  31  31  20

  5  38  38  38  41  41  41  41  41  43  43  43  43  47  47  47  51  51  51  51  51  51  51  51  54  54  56  56  56  60  60  60  60
                                                                                                                        *   *   *   *

  6  48  48  48  59  59  59  59  59  59  59  59  59  62  62   0   0   0   0   0   0   0   0   0   9   9  11  11  11  11  11  11  25
                    *   *   *   *   *   *   *   *   *   *   *

  7   0   0   0   0   0   0   0   0  15  15  15  15  31  31  31  31  31  31  34  34  34  34  34  39  39  39   0   0   0   0   0   0

  8   1   1   1  12  12  12  12  12  14  14  14  14  17  17  17  33  33  33  33  33  33  33  33  33  33  33  33  33  33  33   0   5

  9  46  46  46  46  46  54  54   0   0   0   0   0   3   3   3   3   3   3  14  14  14  14  14  14  14  18  18  18  18  18  18  18

 10  69  69   0   2   2   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   0   0   0   0   0   0  11
        *   *

 11  38  38  38  38  38  38  38  38  40  40  40  40  48  48  48  48  48  48  48  48  48  54  54  54  54  54  54  54  54  54  54  54
                                                                                        *   *   *   *   *   *   *   *   *   *   *

 12  51  51  51  53  53  53   0   0   0   0   0   0   1   1   1   7   7   7   7   7   7   7   7  10  10  10  10  10  16  16  16  19
        *   *   *   *   *   *

 13  42   0   0   0   0  10  10  10  14  14  14  14  18  18  18  18  18  18  29  29  29  34  34  34  34  34  34  34  34  34  34  34

 14  38  38  38  45  45  47  47  47  49  49  49  49  49  49  49   8   8   8  11  11  11  12  12  16  16  16  16  16  24  24  24  32
                            *   *   *   *   *   *   *   *   *   *

 15  34  34  34   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   7   7   7   7   7   7   7

 16   4   4   4   4   4   5   5   5   6   6   6   6   8   8   8   8   8   8   9   9   9  12  12   0   0   5   5   5   5   5   5   8

 17  45  45  45  47  47  47   0   0   1   1   1   1   1   1   1   6   6   6   6   6   6   6   6   7   7   8   8   8  13  13  13  14
        *   *   *   *   *   *

 18  18  18  18  18  18  23  23  23  25  25  25  25  30  30  30  30  30  30  37  37  37  38  38  38  38  39  39  39  39  39  39  39

 19  13  13  13  17  17  17  17  17  17  17  17  17  18  18  18  26  26  26  26  26  26   0   0   3   3   4   4   4  12  12  12  14

 20  23  23  23  26  26  26  26  26  28  28  28  28  30  30  30  32  32  32  32  32  32  32  32  32  32  33  33  33  35  35  35  35
```

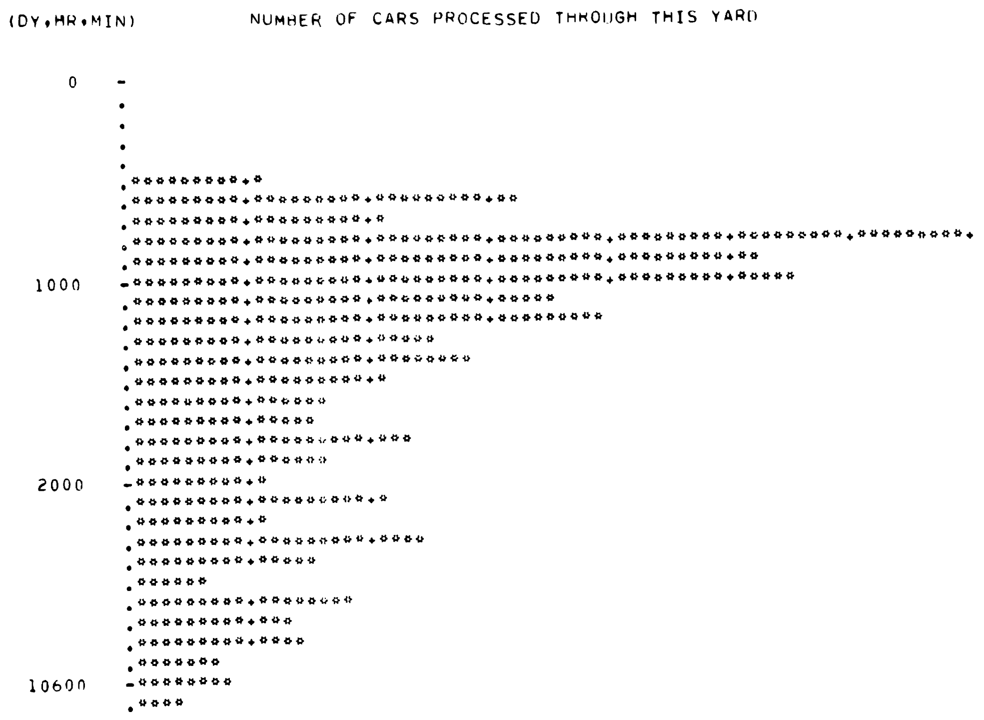
FIGURE 7   CLASSIFICATION TRACK LOADING MATRIX

```
            SAMPLE STATISTICS (DY,HR,MIN)

         TOTAL NUMBER OF CARS      3057
            MEAN TRANSIT TIME      1400
   STANDARD DEVIATION OF TIMES      652

          HISTOGRAM BIN SIZE        100


                                        NOTE  EACH * REPRESENTS    5 CARS.
```



```
          BIN          CARS   PERCENT


     0 -   100           0       0.0
   101 -   200           0       0.0
   201 -   300           0       0.0
   301 -   400           1        .0
   401 -   500          53       1.7
   501 -   600         160       5.2
   601 -   700         103       3.4
   701 -   800         349      11.4
   801 -   900         261       8.5
   901 -  1000         273       8.9
  1001 -  1100         174       5.7
  1101 -  1200         193       6.3
  1201 -  1300         125       4.1
  1301 -  1400         142       4.6
  1401 -  1500         107       3.5
  1501 -  1600          81       2.6
  1601 -  1700          77       2.5
  1701 -  1800         114       3.7
  1801 -  1900          78       2.6
  1901 -  2000          55       1.8
  2001 -  2100         105       3.4
  2101 -  2200          55       1.8
  2201 -  2300         122       4.0
  2301 - 10000          75       2.5
 10001 - 10100          31       1.0
 10101 - 10200          89       2.9
 10201 - 10300          66       2.2
 10301 - 10400          71       2.3
 10401 - 10500          36       1.2
 10501 - 10600          40       1.3
 10601 - 10700          21        .7
```

FIGURE 8   YARD TRANSIT TIME STATISTICS