

Canadian National Railways' Terminal Interactive Model (TRIM)

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Historically, Canadian National Railways (CN) had analyzed operating and design changes to classification yards by using manual simulation. This approach was costly and time consuming, permitting the examination of only one or two alternatives. Recognizing the need for a better approach, CN embarked on the development of a computerized terminal interactive model (TRIM) to replace the tedious and costly manual simulation. The objective of TRIM is to retain the benefits provided by a manual simulation (applicability to both hump yards and flat yards of any configuration, maintenance of a high degree of accuracy and level of detail, use of skills of experienced yardmasters) and add the benefits of computer simulation (faster execution, lower labor intensity, greater detail, rapid analysis of simulation results, flexibility of specification). TRIM is an event-based simulation in that it moves forward through time from one activity to the next. More than one yard analyst at a time can participate in the simulation. A typical scheme would parallel the sphere of control by a yardmaster in a tower. TRIM has been used to study two important yards in western Canada—Kamloops and Thornton (Vancouver), British Columbia.

In the 1980s Canadian National Railways (CN) must expand or redesign most of its yards in western Canada in response to anticipated major growth and changes in demand for service. Because of the magnitude of the investment required, it is necessary for CN to rigorously evaluate its approach to improving and expanding yards. The objective is not only to expand yards to cope with projected traffic volumes but to make terminals more efficient in the process.

Historically, CN had analyzed operating and design changes by using manual simulation. This approach was costly and time consuming; only one or two alternatives could be examined. Recognizing the need for a better approach to analyzing yard changes, CN, working with Peat, Marwick, Mitchell and Company, embarked on the development of a computerized terminal interactive model (TRIM) to replace the tedious and costly manual simulation approach.

The objective of TRIM was to retain the benefits provided by manual simulation (applicability to both hump yards and flat yards of any configuration, maintenance of a high degree of accuracy and level of detail, and use of skills of experienced yardmasters) and incorporate the benefits of computer simulation (faster execution, lower labor intensity, greater detail, rapid analysis of simulation results, and flexibility of specification). The result was a tool that combined the best of both approaches through an on-line interactive computer model.

TRIM enables CN to evaluate capital investment alternatives in greater detail than was previously possible with manual techniques. Because the time required to evaluate a proposed design modification is drastically reduced, CN is able to examine a broader range of alternatives than was possible before the development of TRIM. That capability translates into designs more precisely tailored to the demands expected to be placed on the yards. In turn, CN will achieve more effective application of its capital investments, because the minimum investment necessary to meet demand can be more easily identified through extensive analysis of alternatives.

Before embarking on the development of TRIM, CN first surveyed the industry to determine whether an

existing modeling technique met the company's needs. Several attempts have been made over the past 15 years to create fully automated models of yard operations to supplement the manual techniques most commonly used in the industry. But none of these replicated actual yard operations as successfully as manual simulations, and therefore none was in extensive use. The shortcomings of most previous attempts at computer simulation of yard operations were fourfold:

1. Attempts at mathematical model formulations were either too simplistic (assuming away most of the problem being tested) or overly complex (because of an inability to select an appropriate number of parameters for inclusion in the model);

2. Attempts at logic-based simulations were limited in their flexibility by the requirements of the computer representation used, frequently ignoring important elements of the yard's resources;

3. Data requirements for many simulations were prohibitively large and required some computer knowledge on the part of the analyst; and

4. Many simulations were highly location specific; they worked well for the yard under study but would require almost a total redesign or rewrite for use in a different yard.

In addition, most models are oriented toward hump yards and permit little or no flexibility in the simulation of various kinds of yards. The dynamic interaction of the various components of a yard is lost in these models because of the difficulties in simulating this kind of interaction. Thus, CN determined that existing models would not meet its criteria for accurate replication of both flat- and hump-yard operations, including all of the flexibility and critical yard and terminal dynamics that a detailed simulation requires.

One of the main features of TRIM is that it is designed to be used by railroad personnel. A knowledge of computers and scientific modeling is not required. The system converses with the analyst entirely in railroad terms. A familiarization period of a few weeks is required for the analyst to become comfortable in the use of the model and aware of its numerous features. In performing the simulation, the analyst or analysts simultaneously play more than one role. Part of their function is to be a yardmaster, determining the overall strategy of operating their portion of the yard. In addition, they are also switching foremen and inspection crew foremen as they carry out the more detailed work of the yard.

HOW TRIM WORKS

General Objectives

Because the objective was to design a model that could be used to study a yard in great detail, TRIM has the ability to handle all major operations that occur in a yard. The study team is free to choose the amount of detail that is appropriate to the objectives of the yard under study. For example, in evaluating a particular yard design, it may be sus-

pected that insufficient departure tracks result in frequent congestion in the classification yard as trains are made up. In this case, the specific track geometry of these parts of the yard would be represented in the model. In other cases, the track geometry could simply be approximated, combining or ignoring certain tracks that were not expected to have any significant impact on yard performance. A second example of optional detail would be crew management and utilization. TRIM can specifically model the detailed work carried out by inspection crews. If there are too few crews, the result will be trains waiting for inspection; too many crews would later result in low crew utilization. Should these human resources not be a constraint (or of interest) in a particular evaluation, they could be ignored completely. TRIM also allows the time window for yard activities to be adjusted. For many types of simulation, specifying the duration time of any activity to be a minimum of 1 min (or more) results in no significant loss of accuracy.

In the discussion that follows, the detailed operations that TRIM can handle will be presented. It is important to remember that much of the detail is optional if the study objective is not compromised by its omission.

Resources

TRIM requires the analysts to manage four major kinds of yard resources.

Structural Resources

Tracks and their connection pattern define the yard under study. Track length is the only other required parameter. If desired, TRIM can also model the foul-point locations from either end and the location of inert retarders. Unless the analysts want to specifically model throwing switches by hand, these can be ignored and the model will infer the switch characteristics from the permissible track transitions specified.

Passive Resources

The cars on inbound trains and those cars initially in the yard are the only passive resources. No other information need be provided about cars other than an average car length and the number of cars and their sequence on each inbound train. Nevertheless, the user will typically want to include additional information about each car because it is this information that implicitly defines the work to be done. The most important optional items are

1. Car initial and number,
2. Car length,
3. Car weight,
4. System destination,
5. Local destination,
6. Special handling instructions,
7. Contents (commodity), and
8. Bad-order information.

Because TRIM allows the user to examine these items (typically by examining all cars on a specified track), the decision on how to handle a car will be based on the system destination, whether a car is bad ordered (in need of repair), and so forth.

Active Resources

Work in a yard is done by locomotives and crews. Typically, road engines bring trains into and out of the yard and switching engines perform the work in

the yard. Crews are used to operate the locomotives and to perform switching and inspections. Therefore, it is these two resources--crews and locomotives--with which the analyst is most actively concerned. For example, TRIM does not allow car movement unless an engine is associated with it. Nor will it allow a train to be inspected if an inspection crew is not available at the appropriate track.

Information Resources

TRIM simulates the major information documents on the basis of which a yardmaster would run the yard. Detailed knowledge about inbound trains is from an advance consist. Switch-hump lists must be prepared by making use of predefined (and modifiable) switching tables. Also, as described later, a major yard inquiry subsystem is available to the yardmaster.

Simulation Concept

The major consideration in using the TRIM model is that it does only what it is specifically instructed to do. More than one yard analyst at a time can participate in the simulation. The active resources--locomotives and crews--are assigned to the specific analysts, and they then issue commands to accomplish specific functions. An analyst can issue commands controlling only his own assigned resources. Those resources can be reassigned, if desired. A typical scheme would parallel the sphere of control by a yardmaster in a tower. For example, one analyst may be in control of the receiving yard, another the departure yard, and a third the hump operation. It is by proceeding in this deterministic manner that the plant and operating rationale is evaluated.

The TRIM commands that control the yard operations fall into four main categories.

Movement Commands

Movement commands advance locomotives (with or without coupled cars) along a route specified by the analyst. As part of the command, the analyst specifies the destination and duration of the move. Optionally, the analyst can kick or set off cars. Other commands permit the analyst to switch cars or hump a train. To support these latter activities, TRIM maintains switching tables, which are automatically referenced when an analyst prepares a switch list. Of major interest is the detection and handling of conflicts in the yard. Should a track already be occupied along a route, for example, the system warns the analyst. If so instructed, the simulation will advance the locomotive to the blockage, wait until it has been cleared, and then resume the balance of the move.

Crew-Movement Commands

Crew-movement commands affect control of the crew resources. Included is the ability to call or relieve crews, assign them throughout the yard to tracks or to locomotives, and issue commands for them to inspect trains. As with car and locomotive movement, the analyst specifies the duration of the foregoing activities.

Coordination Commands

Commands that allow the analyst to control yard environment but that are not specifically associated with movement are coordination commands. Such commands as requesting notification when specified yard conditions arise, waiting for specified periods of

time, performing switching-table maintenance and preparing switch lists, and setting and removing blue flags on tracks would be included.

Inquiries

Because it is not possible to control yard resources without a detailed knowledge of where they are, a comprehensive inquiry system has been incorporated into TRIM. It is based on CN's computer-based Yard Inventory System (YIS) now in use at CN hump and flat yards. Car lists for specified tracks can be obtained, for example, that show not only the detailed car data but also the specific car locations on the track. Other inquiries allow information to be summarized by system destinations, advance consists of trains due in the yard, and so forth.

Numerous additional capabilities will be added to TRIM over the years. The most important ones will be those that automatically handle certain basic decisions, removing these burdens from the analyst. One example is the incorporation of standards into the model. Based on locomotive dynamics, number of cars, and total length, the time for a move could be determined automatically. Similarly, the time to switch a set of cars could be determined from the sequence of system destinations in a switch list. Eventually, certain sequences of commands could be generated automatically. For example, a train could be automatically made up for departure, trains automatically switched in sequence, and so forth.

Evaluating the Results

Although the study team will have developed a certain feel for the performance of a tested yard alternative at the conclusion of a simulation run, this must be backed up by more-detailed statistics.

It is in this area that TRIM exhibits a distinct advantage over manual techniques. TRIM records in a log file all activities as they occur in the yard. With the data recorded in this form, it is possible to create any type of analysis report. When done manually, preparation of analysis reports could take months. Thus, not only does TRIM speed up the simulation of a yard, it also permits a more timely analysis of the simulation results. The following report types are produced:

1. Graphical representations of track population over time for specified track groups; percent utilization and cars handled are also maintained;
2. Statistics about crew utilization--time working, time in transit, time idle;
3. Statistics about locomotive utilization--total miles loaded, total miles light, time working, and time idle; and
4. Statistics about conflicts and delays in the yard.

DETAILS OF TRIM'S OPERATION

TRIM is applied in three distinct phases: preprocessing, or preparing and validating the input data; simulation, or performing the simulation; and post-processing, or producing and analyzing the results. Figure 1 shows the relationships among the phases.

Preprocessing

Input data for the model are collected in the first phase and subsequently validated by TRIM for correctness and consistency. Considerable effort must go into creating the input files if realistic yard activities are to be produced by the analysts. Up to five input files may be prepared.

Tracks

The track file is mandatory and would most likely take an analyst from 1 to 4 weeks to prepare depending on yard size. A large yard may have approximately 1,000 track sections. All tracks are assigned unique names and the legal movements between tracks must be specified. TRIM validates this file when constructing the network and informs the user of errors and inconsistencies.

Switches

Although the user can specifically name the switches that connect tracks, this file would usually be omitted. During a simulation, the analyst would probably never have to be concerned with switch names.

Initial Population

The initial-population file is optional. If it is omitted, however, an extra day or two of simulation may have to be performed to reach a stable car population in the yard. The data contained in the file are the yard's locomotives, cars, and crews and the specific track locations.

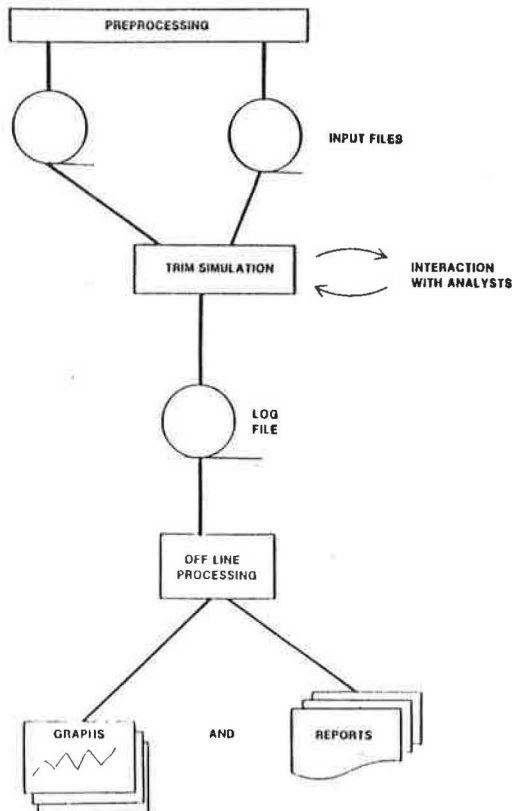
Crew Schedule

The crew-schedule file is optional. If it is included, the model will call crews automatically at the specified time.

Inbound Trains

Although it is optional, the inbound-train file is usually a key file as is the track configuration.

Figure 1. Relationships among phases.



For each train, the file contains the time of arrival and the arrival track, the number and type of locomotives, and the sequence and detailed information for each car. Each element is important. For example, incorrectly specifying the number or type of locomotives would make it difficult to dispatch trains later because of a lack of power in the yard. Unrealistic marshalling of cars on inbound trains would significantly change the work to be done in the yard. CN uses its computer-assisted network analysis tool (CANAT) forecasting system to generate inbound trains. A realistic workload can be obtained for up to 10 years in advance. This forecast is then scrutinized and, if necessary, edited manually so that any changes can be made before it is used for TRIM. The value of a computerized forecasting system is apparent when it is considered that up to 15,000 cars can enter a large hump yard during the course of a 3-day simulation. Nevertheless, numerous shortcuts are possible if the study does not require that all the detail be included.

Although not strictly part of the input files or preprocessing, the determination of a realistic train service design for outbound trains is an im-

portant activity before simulation. This sets the goal for the work to be carried out.

Simulation

TRIM is an event-based simulation in that it moves forward through time from one activity to the next. The model examines the jobs it has to do (based on the commands that have been entered), selects the one that will be completed first, and moves the simulation clock ahead by that amount of time. It then adjusts all yard resources to their new position. As a result, certain resources will have reached their destination, others will have advanced only partially, and still others will remain where they were initially because no specific command was given to move them. Figure 2 shows the patterns when only one analyst is working.

As an example, suppose that two commands are given before the analyst instructs the simulation to continue:

1. Assign a crew to a track (traveling time is 5 min) and
2. Move a locomotive along a specified three-track route (traveling time is 7 min).

When the analyst gives the command to continue simulation, the simulation time would move forward 5 min. The crew would be located at the new track, and the locomotive would be on an intermediate track between its origin and destination.

In a large simulation, numerous commands could be only partially complete after the clock has advanced and control has returned to the analyst. When control returns, the analyst would be presented with a home screen (Figure 3). The home screen would inform him what the new simulation time was, describe what activity had just been completed, and provide a list of all other pending activities and their expected completion times. It would also indicate the current location and status of crews and locomotives, the resources that were capable of performing further work. Based on the home screen, the analyst could

1. Request a more-detailed yard status report to assist in determining what commands to enter,
2. Request a formatted screen so a new command could be entered, and
3. Instruct the simulation to continue without more commands.

Figure 4 shows a screen that an analyst has

Figure 2. Simulation sequence.

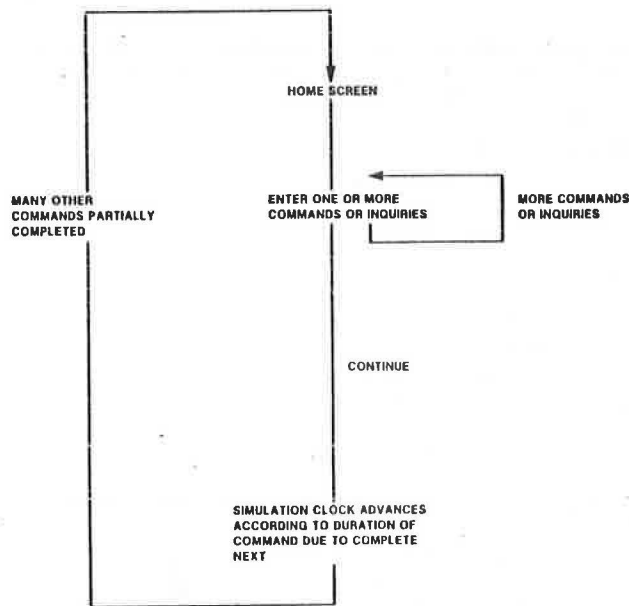


Figure 3. Home screen.

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HOME                               SIMULATION TIME 03/07:30:00
                                     *TOP*

YOUR FOLLOWING ACTIVITIES HAVE COMPLETED:
MOVE CARS 10 WITH EST ROUTE ELA. 2 A4 TIME 00:01:50

YOUR NEXT SCHEDULED ACTIVITIES & COMPLETION TIMES ARE:
03/07:34:00 LITE CONSIST 763 ROUTE R1 EPOW TIME 00:12:00
03/07:38:00 DEPT TRAIN 360 ROUTE R10 EDEP TIME 00:12:00

YOUR CONSIST STATUS:
CONSIST  TRACK  STATUS  CARS  CONSIST  TRACK  STATUS  CARS
763      TF.7    A      0    XYD1     YENG.2  W      0
EST      A4       W      32   360     ML.G    A      93
HUBLE   TRA.4    W      1

YOUR CREW STATUS:
CREW     MEN  CONSIST  TRACK  TYPE  STATUS  WARN
EAST2    1   EST     A4     SWIT  W
360     3   360    ML.G   ROAD  A
HUBLE   3   HUBLE  TRA.4  SWIT  W

                                     *BOTTOM*

scroll NEXT/PREV  ___ or next command  COMMAND___
    
```

Figure 4. Move command.

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MOVE                               SIMULATION TIME 03/04:26:00
MOVE 3 CARS                        WITH CONSIST IND
   TRACK                            ON TRACK
TO TRACK WRD.1
(VIA TRACKS WRD.2
_____ : _____ : _____ : _____ : _____ : )
(RESERVE ROUTE _ )
(SETOFF _ CARS (RETURN _ )        (SPOT _ FEET FROM EAST )
( KICK  _ CARS (RETURN _ )        ( _ FEET FROM WEST )
(AT TRACK _____ )             ( COUPLE C )
                                   ( CLEAR EAST _ )
                                   ( CLEAR WEST _ )
HR   MIN   SEC
(TIME: _ : 02 : 00 )
HR   MIN   SEC
(DELAY BY _ : _ : _ (REASON _____ ) )
NEXT COMMAND _____
    
```

filled out to specify a sample move command. Because most commands follow a fill-in-the-blank approach, they relieve the analyst from memorizing complex computer commands. The move command also offers the analyst a choice of how to specify the move. For example, he can specify the locomotive consist or the track that the cars are on. In this case, the consist was specified. Items on the screen directly underneath each other represent a choice. Furthermore, certain items are optional; these are indicated by parentheses. If time were not specified, the simulation would calculate it based on total distance to travel plus certain default track speeds. It can be specified that cars be spotted (aimed at a certain point) or the system can choose to default. In the latter case, cars are spotted clear of the switch foul point. In the next-command item, the analyst can name another command screen he wants next, continue the simulation, or take any of a number of other actions. TRIM performs numerous validation checks before a command is actually accepted into the queue for processing. Resource names must be correct and the resources available, routes must not be blocked, and so on. Appropriate errors and warnings are issued.

When more than one analyst is working on the yard, the simulation must, by its nature, stop when an activity has been completed by any one of them. Only one analyst, therefore, may be in a position to enter new commands. It would not be appropriate for other analysts whose commands are only partially complete to enter new ones. Nevertheless, they could perform inquiries into yard status as an aid to planning future commands. TRIM is currently designed to handle up to 10 analysts working at one time. It is estimated that two analysts would be required for a medium-sized flat yard; four or five analysts would be needed for a major hump yard.

An important feature built into TRIM is the ability to check the yard status at a particular time. If this is done on a regular basis, work already accomplished will not be lost in the event of computer malfunction or power failures. Such a check also allows different yard-operating strategies to be evaluated from a common base condition. For example, if the yard status at 1,400 hr is deemed unsatisfactory, it is possible to continue simulation from an earlier checkpoint and operate the yard under a different strategy.

Postprocessing

As the simulation proceeds, TRIM performs extensive data logging. The purpose is to record what hap-

pened during the simulation. Therefore, each car movement on and off each track is logged, along with the corresponding detailed locomotive and crew movements. The log tapes are then processed through a comprehensive reporting system, separate from TRIM itself. It is not necessary to wait until a simulation has concluded; analysis reports can be produced at any time. If different strategies have been followed from a common based checkpoint condition, the data from either path can be selected for the postprocessing. The log file captures virtually all the yard activity that transpired and is independent of any specific report. By further splitting the log file into subfiles, however, almost any type of report can be developed. At this time, the following reports are available:

1. Track population (graphical),
2. Receiving and departure (R&D) occupancy (graphical),
3. Lead occupancy (graphical),
4. System destination population (graphical),
5. Track throughput,
6. Throughput by car type,
7. Crew utilization (switching or inspection),
8. Locomotive utilization (switching or road), and
9. Conflict and delay.

Each report allows the analyst a great degree of flexibility. The analyst can choose to extract and consolidate only those operations in which he is interested. For example, the analyst may specify a time window to use for reporting results so that the activities performed in generating an initial population do not distort the overall statistics. Track population can be examined on an individual track basis or specified tracks may be grouped together to form an aggregate population. Individual reports are tailored to an analyst's requirements by preparation of a control table that governs the selection and consolidation of the associated reporting program.

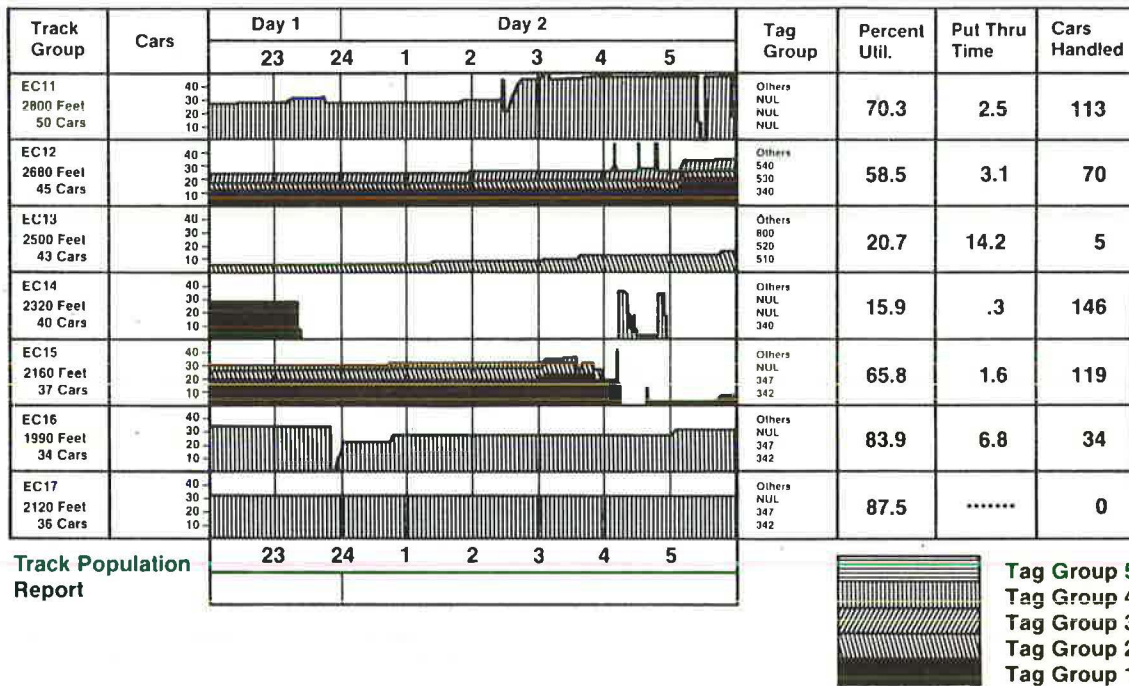
Two report types are illustrated. Figure 5 shows a graphical report of track population. It may be noted that the population is further broken down into its constituent system destination groups. Figure 6 shows a report on locomotive utilization that indicates how much time was spent in various working and idle categories plus total miles traveled in the yard.

COMPUTER CONSIDERATIONS

The nature of the TRIM simulation made it desirable

Figure 5. Track population graph.

Vancouver Flat Alt 1



for CN to acquire a separate computer to run the model. The primary reason was the intended heavy use of TRIM. In anticipation of extensive traffic growth in western Canada, virtually every yard in that part of the country will be analyzed by using the model. Because the model is to be used on a continuing basis, it was more cost effective to dedicate a computer to it than to pay recurring charges on CN's central computers. Another advantage of a dedicated computer is that for interactive simulations minicomputers offer many features that are more flexible and easier to use than do main-frame computers.

There were certain technical requirements that the computer system had to meet:

1. The programming language desired was PL1. Although it would have been possible to write the simulation with FORTRAN, PL1 offers much more flexibility in defining data structures, an important consideration in light of the complex relationship of yard resources.

2. The system had to have virtual memory--the ability to run a program larger than the capacity of main memory. This was important because yard data (tracks, cars, and so on) can, in a large simulation, require substantial storage.

3. The computer had to support multiprogramming.

4. The computer had to be upgradable in place to significantly higher capacity to be able to support more than one concurrent TRIM study as well as other transportation planning simulation models.

All the preceding requirements served to narrow down considerably the list of candidate computers. CN determined that a PRIME 550 system was the most cost-effective computer. The current configuration is as follows:

1. PRIME 550 central-processing unit,
2. A 2.25-MB main memory,

3. One 300-MB disk drive,
4. One tape drive,
5. One 300-line/min printer,
6. Six terminals, and
7. Communication capability with CN's main-frame computers.

A color-graphics terminal has been acquired and will be used to provide a bird's-eye view of yard status.

In the design of TRIM applications software, certain important features were considered:

1. All commands are entered via CRT terminals in a fill-in-the-blanks mode;

2. The model handles a varying number of analysts, who can attach to and leave the simulation as desired; and

3. TRIM is designed so that it is not permanently tied to any one computer system. For example, TRIM could in a relatively straightforward manner be changed to run on an IBM main-frame computer.

EXPERIENCES WITH THE MODEL

Three yards were studied with TRIM in 1982. Kamloops and Prince George are medium-sized flat yards, and Thornton is a major flat yard; all are in British Columbia.

In the case of Thornton, two flat and one hump configuration were simulated. The hump alternative had 11 departure and 12 receiving tracks, 48 tracks in the classification yard, and a surge yard with 12 tracks. The total number of tracks, including connecting tracks and crossovers, was more than 600. The overall goal of the simulation exercise was to evaluate several yards expanded to handle projected 1991 traffic volumes and requiring the handling of approximately 3,600 cars daily. The strategy employed was to use yardmasters experienced in Thornton operations, plus up to three yard analysts who

Figure 6. Locomotive utilization report.

LOCOMOTIVE REPORT
VANCOUVER - FLAT ALTERNATIVE I

CONSIST	SHIFT	CREW	HOURS			MILE		CARS	
			WORK	BLOCK	IDLE	LOADED	LITE	HANDLINGS	AVG/MOVE
East 1	01/2200-02/0600	East 1A	3.68	0.16	4.16	48.3	14.6	607	17.1
	02/0600-02/1400	East 1B	3.96	0.05	3.99	35.8	16.8	473	10.0
	02/1400-02/2200	East 1C	4.26	0.13	3.61	23.8	13.3	243	3.4
	02/2200-03/0000	East 1A	1.29	0.07	0.64	5.7	4.4	87	6.4
Sub Total			13.19	0.41	12.40	113.6	49.1	1410	
East 2	01/2200-02/0000	East 2C	0.10	0.08	1.82	0.1	1.0	1	-
	02/0000-02/0800	East 2A	3.87	0.27	3.86	32.0	15.3	400	6.7
	02/0800-02/1600	East 2B	3.81	0.05	4.14	25.4	15.5	348	6.3
	02/1600-03/0000	East 2C	4.20	0.01	3.79	32.7	7.1	569	19.0
Sub Total			11.98	0.41	13.61	90.2	38.9	1318	
West 1	01/2200-01/2300	West 1C	-	-	1.0	-	-	-	-
	01/2300-02/0700	West 1A	3.52	0.56	3.92	25.3	13.1	492	11.6
	02/0700-02/1500	West 1B	4.10	0.21	3.69	23.9	15.8	409	12.7
	02/1500-02/2300	West 1C	3.63	0.31	4.06	31.0	10.2	335	8.7
	02/2300-03/0000	West 1A	0.56	0.03	0.41	3.7	3.1	45	5.9
Sub Total			11.81	1.11	13.08	83.9	42.2	1281	
West 2	01/2200-02/0600	West 2A	3.52	0.15	4.33	40.9	15.7	445	11.7
	02/0600-02/1400	West 2B	4.19	0.19	3.62	29.2	24.4	453	7.1
	02/1400-02/2200	West 2C	4.16	0.24	3.60	34.5	16.6	264	6.6
	02/2200-03/0000	West 2A	0.92	0.19	0.89	5.2	3.3	58	7.1
Sub Total			12.79	0.77	12.44	109.8	60.0	1220	
Unit 1	01/2200-01/2300	Unit 1C	-	-	1.0	-	-	-	-
	01/2300-02/0700	Unit 1A	4.10	0.36	3.54	37.3	22.8	283	10.3
	02/0700-02/1500	Unit 1B	4.02	0.26	3.72	45.9	14.7	281	13.5
	02/1500-02/2300	Unit 1C	3.50	0.12	4.38	30.1	16.7	231	11.7
	02/2300-03/0000	Unit 1A	0.53	0.01	0.46	4.60	2.5	61	11.0
Sub Total			12.15	0.75	13.10	117.9	56.7	856	
Total			61.92	3.45	64.63	515.4	246.9	6085	

actually used the CRT screens to translate the yard-masters' general directives into more specific yard commands. Two analysts tended to handle most of the locomotive and car movement commands, whereas the other handled crew assignments and inspections.

Several lessons have been learned from the simulations carried out so far:

1. Each analyst should have about 2 or 3 weeks of training with TRIM before participating in a full-scale simulation. Although each individual TRIM command is straightforward, the training period is necessary because of the number of commands available and their options and the requirement to be able to develop a good overall familiarity with the current yard status.

2. The simulation team will require about a week of working together before a teamwork relationship develops fully. The team members will develop their own sharing of responsibilities, methods, and shortcuts to perform an efficient and well-coordinated simulation.

3. The amount of detail included in the simulation must be traded off with the time to complete the study. In the case of Thornton, certain track sections were consolidated (tracks going up a switching ladder, for example) in order to simplify

route specification. Some crew-related activities were simplified as well.

4. The time window for activities should be specified as being at least 2 or 3 min. Setting the value too small can cause the simulation time jumps to frequently be only several seconds long. It is more efficient to force the simulation to handle all activities up to the longer time-window mark. In this case, some resources would remain unnecessarily idle until the end of the window, when new commands could be entered. Nevertheless, little accuracy is lost with this scheme, and the increased opportunity for analyst coordination is a major benefit. This is especially important in the simulation of larger yards with more than two analysts at computer terminals.

5. The simulation rate achieved for Thornton was approximately 2 hr of yard simulation during each working day of the simulation or about one full yard day each 2.5 weeks of simulating. Intermediate and final graphical and tabular reports were available on request. A large flat yard such as Thornton takes longer to simulate because of the requirement for a large number of yard analysts. The hump alternative simulation proceeded significantly faster, as did that of the smaller flat yards. Inclusion of graphics and automatic time standards is expected to further increase the simulation rate substantially.