TOFC Terminal Simulation Model

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A trailer-on-flatcar (TOFC) terminal simulation model (TSM) is currently under development, and it is being used in concert with the trucking subsidiary of a major class I U.S. railroad. TSM will provide a detailed simulation of the operation of an individual rail-highway intermodal terminal. Its purpose will be to support analyses of productivity and throughput of trains and trailers by the terminal facility. It will be able to address a variety of terminal configurations, terminal equipment types, and train service and traffic patterns. TSM will support both report and computer-graphic outputs. It will be a basic event-queue-processor simulation model, running against a 24-hr clock in daily increments. The model will be run from start-up through a designated number of daily increments; start-up and shutdown periods will then be discarded in order to analyze the terminal in a steady-state environment. As its primary output, TSM will generate a detailed audit file of all simulated activities; this file can then be used as input into a variety of postprocessor reporting and analytical programs. TSM will be written in FORTRAN in order to maximize its portability and installation options.

Given the recent increases in trailer-on-flatcar (TOFC) traffic moving on the railroads and the long-term opportunities for intermodal traffic growth driven by current and projected fuel costs, it is evident that virtually every major railroad is embarking on new programs. These programs are aimed at (a) diverting boxcar traffic to TOFC; (b) instituting dedicated intermodal train corridors; (c) eliminating low-volume TOFC terminals, especially nonmechanized ones; (d) upgrading or replacing existing intermodal terminals with new mechanized facilities; and (e) improving the overall profitability of intermodal traffic.

Transportation and Distribution Associates, Inc., has developed the terminal simulation model (TSM) to provide managers with an analytical tool that will allow them to answer the following questions:

1. What is the most efficient way to operate an existing terminal, in terms of use of tracks, loaders, jockeys, and so on, with existing train service? Conversely, how will changes in train schedules, facilities, or personnel affect the productivity of a terminal?
2. What is the best configuration for a new terminal to serve some planned intermodal service?
3. What changes in the operation of a terminal will optimize the servicing of priority traffic with the least degradation of service to other traffic?
4. How will major changes in traffic volumes through a terminal be accommodated?
5. What is the cost of operating a terminal under any of the options and configurations discussed above?

All of these questions are currently being or will be asked of railroad managers as the industry attempts to position itself in the transportation marketplace for the last two decades of the 20th century. Given the lead times for facility construction, and the capital costs and durability of such facilities, investment decisions for the intermodal sector must be made now, and correctly, in order to be in place when needed.

TERMINAL SIMULATION MODEL

TSM provides a detailed simulation of an individual intermodal terminal. It performs an analysis of the productivity and throughput of trains and trailers and containers at a terminal. It can support a variety of terminal configurations, train and traffic loadings, and report and graphic outputs. TSM permits evaluation of the productivity of a TOFC terminal (e.g., throughput rate and facility use) under a variety of configuration modes. TSM is a basic event-queue-processor simulation model. The simulation clock is a 24-hr one, advancing at fixed 1-min increments. The model is run from a start-up for some number of daily increments, such as for 21 days (3 weeks). The start-up and shutdown periods (first and last day) may then be discarded in order to analyze the terminal in a steady-state environment. All model input tables and parameters are stored in permanent files that can be modified to change the model's environment.

Work Units

Work units are the material that flows through the simulation. Work units are characterized by type and identity, as described below.

1. Flatcars are characterized as loaded (by stanchion count) or unloaded. They are placed in the main line, yard, or storage queues and are moved by switch engines. When cars are loaded, they are designated for a specific outbound train and for a specific destination block on that train. Cars are characterized by length (used for track capacity) and by a car-type descriptor. Each type or car can be loaded only with specific types or mixes of trailers and containers (i.e., containers only, a 45-ft trailer plus a 40-ft trailer, two 45-ft trailers, a single 48-ft trailer, and so on). The size limitations are maximums within a trailer type; thus, a car that can spot a 45-ft trailer could instead carry a 40-ft trailer in the same position.
2. Trains are identified by train symbol and date (in simulation); thus, TV-15 00950710 would be train TV-15 arriving on the 9th week, Thursday (day 5) at 7:10 a.m. Arriving loaded cars carry their train identification until unloaded. Departing loads receive a train designation when loaded. Train symbols can be given a priority to be applied to their traffic. Traffic characteristics are a function of each train and determine statistically the number and type of cars and trailers for each train. Trains that have the same symbol but run dissimilar schedules on different days are treated as separate trains by the model. Day of the week peaking of arriving or departing traffic (by destination) can be specified for each train.
3. Trailers are the basic work unit of TSM. They are characterized as inbound (from street to train) or outbound (from train to street), and by a block code that indicates a destination point for train-dispatched trailers. Trailers can be characterized as trailers, containers (not on chassis), or other unspecified equipment types. Each trailer can be given a statistically sampled length (up to five for each equipment type), such as 20-, 40-, 45-, 48-, and 50-ft trailers. Further, each trailer can be given a priority code, ranging from 0 to 10, to indicate priority handling of the traffic.

Events

Events are externally supplied and cause the insertion of work units (cars, trailers, trains) into one or another of the processor queues, as follows.

1. Train arrival is set for each train and is driven by a Monte Carlo sampling of earliest-likely, latest-likely, and most-likely arrival time, which is shaped into the so-called Beta (normal) distribution. Arrival time can be totally fixed, or it might be permitted to be nonoccurring on some probability basis.

2. Train departure is the scheduled departure time for originating trains. This serves as a target, with actual departure time resulting from the simulation outcome. Where the terminal is an intermediate point for a train, the departure time is a function of the simulated arrival plus processing time, so as to be ready for departure.

3. Trailer arrival is when the driver arrives at the gate with a trailer for loading. This event is driven by a Poisson distribution sampling mechanism, which is most appropriate for generating a random distribution of N events (trailer arrivals) over a fixed time period. The number and identity of arriving trailers are determined separately by a Monte Carlo sampling procedure.

4. Trailer departure is when the driver becomes available to remove a trailer from the terminal. Driver arrivals to pick up trailers that have come in on trains are normally distributed over a time interval that is offset from either the scheduled arrival or actual arrival time of each train.

5. Random events are subsequent refinements of TSM that are selectively introduced into the simulation. Such events encompass equipment failures, weather impacts (reduced processing rates), train nonarrivals, and so on. Also, trailers moving in and out of the terminal for storage and loading will be generated through this mechanism. This represents the additional load on the terminal imposed by the necessity to maintain an inventory of trailers for outbound loadings.

Queues

Queues hold work units that are awaiting some processor's attention. Queues are characterized by a capacity, which may be infinite. When a queue is full, work units must wait in a previous queue until space in the next queue is available. Queue categories are described below.

1. The main line, which is the holding area for inbound trains, is assumed to have infinite capacity but may be characterized as a first-come, first-served queue or one in which any train in the queue may be processed next, based on its priority. The former situation would be applied where trains must in fact line up for access to the terminal; the latter would be applied where adjacent siding or yard capacity would permit storage of trains and access when required.

2. Yard tracks are represented by the number and capacity (in cars and equivalent feet) that are available. Cars are placed on these tracks to be loaded or unloaded. The capacity used must include allowances for breaking cuts to keep crossings open. Additional support tracks for car and locomotive storage are not included in this queue category.

3. Storage tracks may be of infinite capacity and are external to the terminal simulation itself. Cars may be sent to storage tracks or fetched from storage without queue capacity or volume constraints. The problem of having sufficient flats available for required loading, or, conversely, of disposing of surplus cars, is beyond the current functionality of TSM. However, an inventory of surplus cars can be defined to act as a constraint on outbound loadings. If this inventory is defined as sufficiently large, then no constraint of flatcar availability would be imposed. However, TSM will contain a processor time for switch engines to move cars to or from such storage. The model will keep running if a flatcar shortage occurs, but it will record when and how many additional flatcars would be required by the terminal in order to keep the traffic moving. Also, if too many flatcars accumulate in the storage yard or yards because of inbound and outbound loading imbalances, surpluses of these cars will be dropped periodically from the storage yard to keep the model running. A message indicating that this has occurred will be issued.

4. The inbound gate (also called the street) holds trailers that arrive from the street that are awaiting clerical and inspection processing before entering the terminal. The capacity of this queue is infinite.

5. Outbound gate areas hold trailers that drivers have picked up while they are awaiting clerical and security checkout before leaving the terminal. Their capacities reflect the size of the interior gate areas.

6. Parking areas hold outbound trailers awaiting pickup by drivers for departure. They also hold inbound trailers awaiting loading onto flats. There may be several parking areas, and they are generally used in conjunction with the loading tracks closest to them.

7. Tarmac (or pad) areas provide trackside parking for trailers that have just been grounded by packers or cranes or that are awaiting loading. Generally, the capacity of the tarmac area is equal to the track capacity of the adjacent loading tracks. However, more than one yard track may be forced to use a single tarmac strip in a congested terminal.

8. Track queues are the trailer equivalent of the yard tracks for flatcars. Each yard track has a matching track queue, which represents the trailers loaded aboard the flatcars placed in the yard track queue. When cars from arriving trains are placed on their yard tracks, the trailers carried on the cars are placed in the matching track queue.

Processors

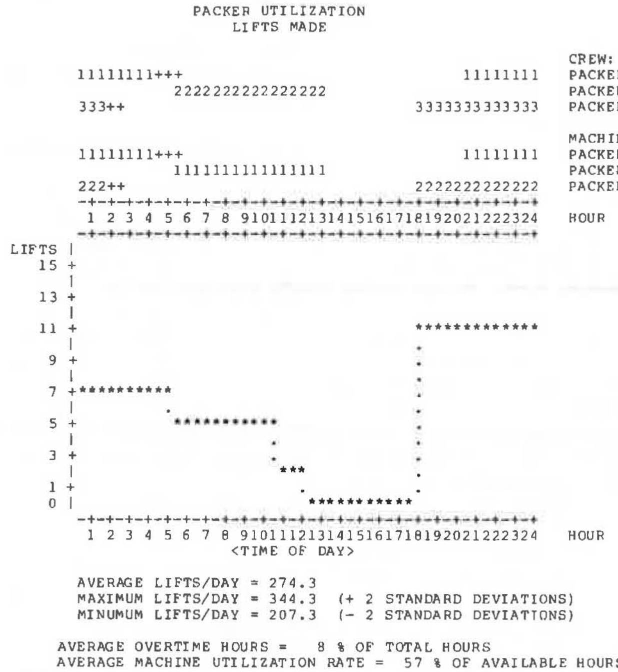
Processors move work units from one queue to another. Processors are characterized by the rate (in minutes) that they require to perform one such action and the numbers of each processor available. Although the TSM clock moves in 1-min intervals, processor work times may be specified in tenths of a minute. If a process is indicated to require an average of 8.3 min/cycle, then the model will use a process time of 8 min (7 out of 10 times) and 9 min (3 out of 10 times), which results in a average processing time of 8.3 min. A random-number generator is used to produce this fractional average. Processor times have a fixed time component (per operation) and a variable time component (per unit handled). In practice, this Ax + B process time is only used for switching, where a number of cars will be handled at the same time. Other processors handle single units only.

Processors are assigned crews, machines, day of the week availability, and starting and stopping times (including up to 10 breaks). Processors are essentially crew assignments (rather than machine assignments) that have defined shifts and breaks. If a processor is in the middle of a work process when a break occurs, it will complete the task and then extend the break period to make up the time worked. Similarly, if a crew is working, it can be relieved by another crew at break time or quitting time, and the relieving crew will finish any work task currently under way. Provision for crew over-time can be made if (a) work remains for the crew, and (b) there is no relieving crew available. There can be multiple processors of each type, which have different characteristics and processing rates.

Loading and unloading of trailers from flatcars can be performed by any combination of overhead cranes, sideloaders (packers), or circus ramps. The loading function moves trailers from the trackside tarmac queue to a flatcar. The processing rate includes actual loading time plus tie-down time. The unloading function removes trailers from a flatcar onto the trackside tarmac queue. The processing rate includes tie-down release, safety inspection, and actual grounding of the trailer. All loader and unloader processors must be explicitly moved from one trackside location to another. Where fixed overhead cranes are used, these cranes can only work designated tracks. Processor attributes are described below.

1. Packers load and unload trailers from trackside. Several packers can work a single track if necessary. Also, packers provide the maximum flexibility in their use through their greater mobility.
2. Cranes function similarly to packers in being able to load or unload at any spot on a track, but suffer from mobility problems when moved from one track to another.
3. Ramps, especially the loading and unloading rates for circus ramps, are a function of the number of cars standing at the ramp and the number of empty spots to be backed over to reach the farthest spot. Thus, the loading rate would speed up as the cut is filled, while the unloading rate would increase as the spots closer to the ramp were cleared. Ramps may be fixed in place or portable, and thus movable from one track to another.
4. Jockeys are used to move trailers between parking lots and trackside (tarmac). They are also used as part of the loading or unloading process by ramps or when handling containers (which require the jockey to position the container bogie).
5. Drivers are draymen or other drivers from outside the terminal who deliver or pick up trailers to or from the street. Drivers may fetch their trailers directly from the tarmac or from a parking lot. Drivers may take trailers directly to trackside for loading (if their train is being loaded next) or leave them in a parking area.
6. Gates handle the receipt of trailers from the street and the dispatch of trailers to the street. The gate crews perform clerical, inspection, and security processes on each arriving and departing trailer.
7. Train crews may be used to "yard" trains or pull them from yard tracks to the main line. Work rules or terminal layout may preclude their use at all or limit access by train crews to only some of the yard tracks. Generally, train crews will not be used if the train is not yarded within an hour of its arrival or if the train must be broken up to (or pulled from) more than one yard track. In lieu of using the train crew, a switch engine would have be be employed.
8. Switch engines are used to move cars from the main line to yard tracks (train breakup), from yard tracks to storage, from storage to yard tracks, and from yard tracks to the main line (train assembly). Each movement is characterized by a fixed time increment plus additional time per car handled in each movement. An additional switch engine process would be to "drill" a yard track, i.e., adding in more cars or digging one or more out.
9. Stanchion setup may be required before cars can be loaded. This processor uses a random-number generator to determine the probability of having to raise a stanchion (for a trailer) or lower it (for a container). A rate per stanchion is specified. Further, stanchion processing may be assigned to a packer crew or jockeys, or it can use a separate crew.

Figure 1. Sample report of utilization and productivity of packer crews.



MODEL OUTPUTS

The basic output of the simulation model program is the generation of three files that contain (a) a record of the terminal queue status whenever work units enter or leave a queue, (b) a processor activity file that records the completion of each activity undertaken by a processor, and (c) a work unit history file that shows the activities performed on each work unit. All files carry a standard time stamp (WWWDHRMN) and can be sorted to analyze the history of each work unit or processor or to display the concurrent activities of the terminal.

These files provide input to a series of program report generators. The report generators permit flexibility in both reporting format and content. A highly graphic output format is desired, although output analyses of mean and standard deviation performance, and minimum and maximum performance, are also included.

By using work unit history files and processor activity files of the generated detail, it is possible to build up a large population of terminal activity observations for use in analyzing the simulation results. Such results should be treated statistically because they are generated by using the Monte Carlo techniques of the simulation. The sample report in Figure 1 shows the results of a run in terms of the utilization and productivity of packer crews. The same report could be produced for a single crew, for traffic from a single train, or other options. Such man-machine diagrams are extremely useful in developing or changing crew shifts, breaks, personnel levels, and machine maintenance time.

Figure 2 shows the processing times for an arriving train on a ±90 percent scale of the observed

Figure 2. Sample report of processing times for an arriving train.

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                    DISPOSITION OF TRAIN TV-11

                  SCHEDULED ARRIVAL TIME 19:30

 1 2 3 4 5 6 7 8 9101112131415161718192021222324   HOUR
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
|
|                                 ********         ARRIVAL
|
|                                      *******>    PLACED ON
|***                                               YARD TKS
|
|                                           **>    TRAILERS
|*********                                         GROUNDED
|
|    ******************                            PARKING
|
|     *************************                    TRAILERS
|                                                  DISPATCHED
|
|
|
-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 1 2 3 4 5 6 7 8 9101112131415161718192021222324   HOUR
                    <TIME OF DAY>
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-90%	AVG.	+90%	
18:35	20:15	21:45	ARRIVAL TIME
20:33	22:50	01:20	YARDED
22:30	02:00	04:18	TRAILERS GROUNDED
02:55	06:00	12:30	TRAILERS PARKED
03:30	07:10	15:20	TRAILERS DISPATCHED
25	40	60	TRAILERS/TRAIN

start and stop times for the various processes needed to receive, unload, and dispatch onto the street the traffic of a single train. This type of information is especially helpful in evaluating the impact on service commitments (getting the trailers on the street) that result from changes in the terminal operation, train schedules, and so on.

MODEL DEVELOPMENT AND TESTING

TSM was designed around and patterned after Pennsylvania Truck Lines' (PTL) Kearny, New Jersey, TOFC facility. PTL provided data on yard layout, processing rates, train schedules, and volumes. Although the initial intent was to develop the model to simulate a simpler terminal, it was found that testing the model's treatment of the interreaction of the various terminal work functions could best be explored in a complex, busy terminal. Therefore, Kearny was chosen. PTL has been reviewing the results of the simulation to determine if it predicts and simulates terminal performance accurately.

Setting up the Kearny model required building up a fairly detailed description of the current traffic and operations at the terminal. Descriptions of the current train schedules and traffic volumes and types were assembled in standard input table format for TSM. The physical description of the terminal was converted to a queue description. The various shifts and their equipment resources were also encoded. The actual construction of these tables took only one afternoon. The key data to be captured are the tasks performed and the cycle times for various processor activities. This site-specific information is best accumulated through an industrial engineering field study of the terminal, but default cycle times are available, which can be checked quickly for local validity. These default times can also be used when evaluating a proposed new terminal.

Once the basic terminal description has been captured in the series of TSM input tables, use of the model becomes a simple matter of identifying the change to be made to trains and traffic, to terminal layout, or to work crews and work schedules, and making this change in the input table. A separate table exists for each train and for each processor. To facilitate these changes, the tables are well annotated. The model can be rerun as a batch program because no interaction is required. The results of the new run can be compared with either the base run for the terminal or some other run to establish the impacts on traffic schedules, processor productivity, or facilities use. For example, the sample report in Figure 1 could be used to compare packer utilization under two different sets of train schedules. The sample report in Figure 2 might be used to compare the service provided to trailers that arrive on one train (TV-11) with different numbers of packers or cranes on duty.

Applications of Computer Model Techniques for Railroad Intermodal Terminal Configuration, Equipment, and Operational Planning

PETER BOESE

Although apparently simple, the intermodal transshipment process is quite complex. The intermodal terminal has to coordinate the interface of two (or more) transportation systems of very different operational characteristics and company organizations. With the rapid growth of container and piggyback transportation volumes within the last decade, most road and rail intermodal terminals in large urban agglomerations of Western Germany ran into bottleneck situations. Capacities, economics, and service qualities of the intermodal transportation systems can only match future demands through substantial investments in existing and new terminal sites. The efficiency of these investments depends on the development and implementation of new terminal design concepts together with improved operational systems. Planning for optimum terminal layout, equipment, and operation for future demands can no longer rely on mere rule-of-thumb methodologies. Computer modeling of terminal functions becomes crucial for testing of new technical design and control concepts under near-realistic requirements before their practical implementation. The developed model contains a number of program modules for the different functional parts of a terminal. Under given cargo volume fluxes, types of load units, train schedulings, and selected rail operational strategies, the daily train operation is simulated in coordination with equipment capacities. The road counterpart is formed by Monte Carlo simulation of the stochastic properties of vehicle arrivals at the terminal, according to different truck operating patterns. The core module consists of the simulation of the single movements and actions of the transshipment equipment on the basis of the geometry of the given loading track, truck and storage lane configuration, and the dynamic properties of equipment. A dispatch control module decides on the transshipment sequences prescribed by train operation and truck arrivals, trying to maximize equipment productivity and minimize truck waiting times. A sample of practical results is presented, which shows alternative layout and equipment configurations and the influence on terminal throughput capacity, equipment productivity, and service levels. Some conclusions for terminal economies, improved operational strategies, and computer-aided control systems for future high-capacity terminals are made, together with an outlook on further model refinements.