Proceedings of the 1994 Winter Simulation Conference
ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila.

SIMULATION OF A RAILROAD INTERMODAL TERMINAL

Thomas Sarosky
Terry Wilcox

Consolidated Rail Corporation
2001 Market Street 12-C
P.O. Box 41412
Philadelphia, PA 19101-1412, U.S.A.

ABSTRACT

This paper describes the design and application of a SLAMSYSTEM model for an intermodal freight terminal in the rail industry. The model was built to examine various what-if questions relating to the design and operation of individual terminals within Conrail's intermodal network. An example application of the model will be given to determine the feasibility of eliminating one terminal from the corporation's system and shifting the traffic volume to a remaining terminal. The study is based on current as well as forecasted future traffic volumes.

1 INTRODUCTION

The fastest growing segment of the rail industry over the past several years has been intermodal service. This is traffic which combines both rail and at least one other form of transportation, usually truck. Goods are transported in trailers (or containers on chassis) by truck for the short haul and by rail for the long haul. The distribution chain may even involve water as goods are transported in containers from overseas, placed on chassis and driven by truck, and then placed on railcars. The transfer from truck to rail and, conversely, from rail to truck occurs at an intermodal terminal.

The construction and operation of an intermodal terminal requires a great deal of planning. The most important issue is to build the terminal to optimally meet the required capacity. The terminal must be able to handle volume peaks without creating unnecessary overflow and potentially service-damaging delays. However, because of the extremely high cost of terminal construction, the capacity should be no larger than necessary.

There are three factors that determine the capacity of any given terminal: track capacity, parking capacity, and gate capacity. Track capacity relates to the number and length of loading/unloading tracks as well as storage tracks. This capacity is also directly proportional to the turnover rate of the track. The faster a track can be unloaded and reloaded, the greater the total capacity of that track.

Gate capacity is the amount of vehicles that may be processed through the gate during a certain period of time. Each container or trailer requires some type of processing to identify material, origin, destination, billing information, etc. Gate capacity is affected by the number of lanes, designation of lanes, number of clerks, and in-lane process time. As with most service queuing systems, the intermodal gate is subjects to peaks and valleys depending on the time of day, day of week, etc.

Parking capacity is the amount of trailers, containers, and chassis that may be stored in the terminal before leaving by rail or by truck out the gate. The largest determining factor of parking capacity is the dwell time of the trailers or containers in the terminal. The outbound side of the operation does not pose a major problem to capacity as most trailers or containers that are to be shipped out by rail arrive to the terminal within a twelve hour period, some even arrive just in time to be dropped directly trackside and loaded onto the railcar without going to a parking lot. However, the inbound side of the operation accounts for significant parking capacity problems. Due to agreements between Conrail and our customers, the shipping companies are often granted up to 5 days of free storage after arrival in the facility. Shipping companies often use Conrail's intermodal terminals as a warehouse for their own equipment, especially empty trailers/containers. Parking requirements also exhibit a cyclical trend based on the hours of operation of trucking companies. Although rail terminals typically receive trains 7 days/week, most trucking companies do not work on weekends. Therefore, parking requirements tend to peak on Monday mornings until trailers begin to be removed from the terminal.

Planning must also go into the type of equipment used at the terminal. Trailers and containers are lifted on and off railcars by some type of lift device, usually either a rubber-tired crane which straddles at least one track or a side-loader which, as the name implies, picks the load from the side without straddling the track. Associated with each type of equipment is a certain productivity as well as a certain cost. These costs include purchase cost and paving costs. The crane, because it straddles the track has a limited range of motion and therefore requires only a thin strip of thick pavement on both sides of the rail. The sideloader, being more flexible, has a much larger range of movement, and therefore requires a larger area around the track to be thickly paved for support. However, a single lift time of a crane is slightly lower than that of a sideloader. The bottom line is that all of these factors need to be taken into consideration when planning.

2 MODELING

2.1 Model Objectives

Discrete simulation modeling represents a relatively inexpensive way of experimenting with new designs and operating techniques for intermodal terminals. With the help of Vickerman·Zachary·Miller consultants, Conrail has developed an intermodal terminal simulation model using SLAMSYSTEM. This model gives Conrail management and engineers the capability to:

- use a realistic, detailed model of an intermodal terminal including all switching, loading, unloading, parking, and gate activity
- simulate terminal activity throughout an entire week
- answer what-if questions relating to changes in traffic volume and makeup, changes in equipment, technology, and operating techniques, and changes in employee staffing and scheduling.

2.2 Model Input

The model inputs may be classified into two categories:

- train schedule information
- operational information

Train schedule information creates the inbound trains at their scheduled time of arrival and creates the individual units to arrive for the outbound trains. It also determines the size and makeup of all trains.

Operational information contains the order of activities that must occur to operate an intermodal terminal. These activities include spotting trains, loading and unloading units, positioning units within the yard, and queuing and processing vehicles at the ingate/outgate.

2.2.1 Train Schedule Information

In the model, inbound trains are created at the time of arrival to the yard. This time is based on the scheduled arrival but randomness may be factored in to account for late or early arrivals. The amount of units on a given train, as well as the makeup of those units is generated as a random sample from a historical distribution. (However, for the purpose of validation, the size was given as an exact amount based on historical data.) The makeup of the train indicates the amount of trailers vs. containers, the load/empty status of each unit, and the customer type of each unit. All of these attributes dictate the type of activities needed to handle each unit. If the unit is a container, a request is generated for a hostler to bring a chassis from the storage pool and park it trackside so that the container will be directly placed upon the chassis by the crane or sideloader. If the unit is a trailer, it can be lifted directly from railcar to ground. These attributes also influence the parking assignment, the dwell time in the terminal, and the outgate process time. Conrail's intermodal database CATS contains historical information relating terminal dwell time to the customer type, load/empty status, and train type. A sample probability mass function for dwell time of a given trailer on a given train is given in Figure 1. This represents the relative probability by hour after arrival that a unit is picked up by a drayman. The hourly dwell distribution is dependent upon the time of arrival, but the largest portion of units leave within 24 hours. The peaks in the graph correspond to the hours of operation of the drayman. The probability mass function is converted to a cumulative probability distribution to obtain a sample in-terminal dwell time. The dwell time then becomes an attribute of each unit.

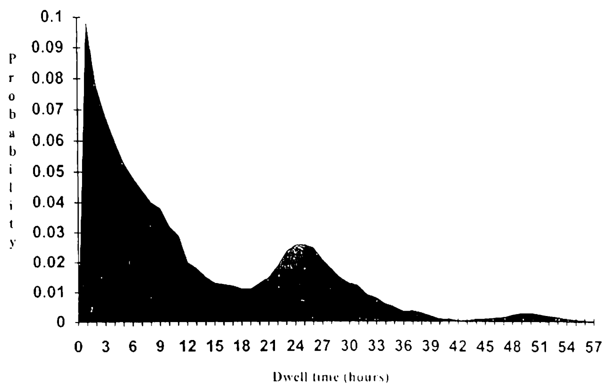

Figure 1: Probability Mass Function of In-Terminal Dwell Time for Inbound Rail Units

Upon the arrival of an inbound train, the total number of units are unbatched into individual trailers and containers and sent to a file where they await a crane or sideloader. Each unit is also assigned a unit type(trailer/container), customer type(J.B. Hunt, UPS, etc.), load/empty status, and dwell time. All of these attributes are based on historical data for each train. Each unit is cloned to represent a haul-away driver which will pick up the unit. This clone is sent to the gate network with an activity delay time equal to the dwell time of the unit. This delay could be as much as 5 days or more.

For outbound trains, the units must be created ahead of time to account for outbound dwell time. However, almost all outbound units arrive within 24 hours of train departure. Therefore, the outbound trains are created 24 hours (1440 minutes) before the time loading is begun. Based on the size of the train to be loaded, the unit type, customer type, and dwell time of each unit is assigned at this time. The units are then released to the gate with a delay time of 1440 minutes-dwell time.

2.2.2 Operational Information

The operational logic in the model is contained in three individual networks: unloading, loading, and gate. The unloading network contains all the logic for an inbound train from spotting the railcars, unloading the individual units, parking the units, to releasing the track for the next task. The loading network contains similar logic for outbound trains. Figure 2 contains simplified flow charts of the unloading and loading network logic, respectively. The gate network contains all logic for drayman dropping off and picking up units at the terminal including queuing and information processing.

In the loading and unloading networks, each track, the number of empty cars per track, the total number of empty cars, the cranes, and the sideloaders are modeled

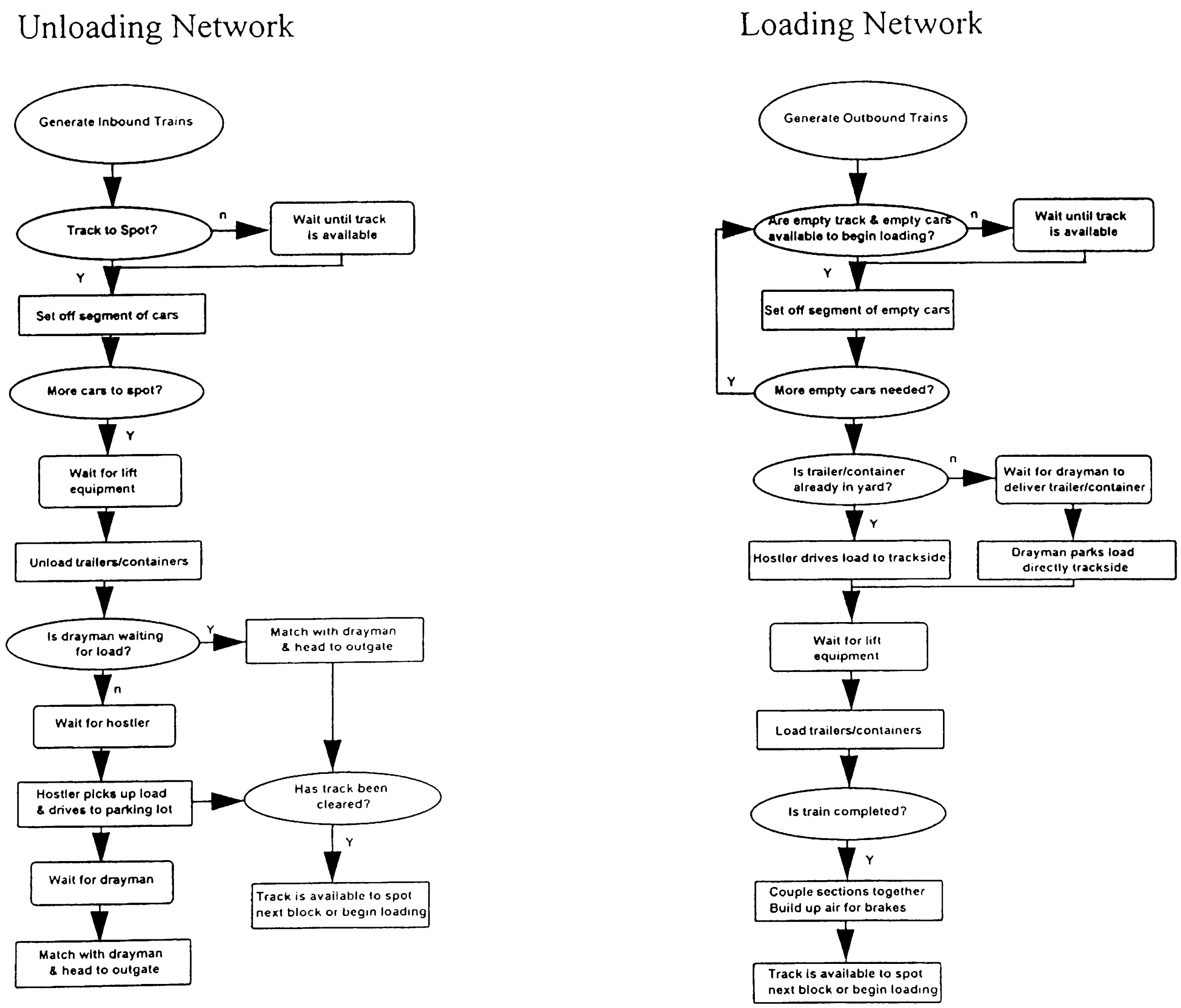

Figure 2: Flowchart Logic for Unloading and Loading Networks

as resources. The decision to spot a section of an inbound train is based on whether there is empty track available. In order to begin loading an outbound train, not only must a sufficient amount of track be available, but enough empty railcars must also be present. A user-written ALLOC routine determines if and what track will be seized by a train segment and also how many empty railcars need to be repositioned for an outbound train.

Hostlers are yard tractors with hydraulic lifts used to reposition trailers or containers on chassis within the yard. The hostlers are modeled as entities rather than resources. This is because they perform a number of different tasks. This allows us to track the productive and non-productive time of the hostlers more effectively. Also, the staff size and scheduling of the hostlers varies throughout the day.

The current task of each hostler is determined by a user-written subroutine written in FORTRAN which examines the current "requests" for the hostler. These "requests", which reside in certain files, consist of spotting a unit from parking to trackside, spotting a chassis from parking to trackside, pulling a unit from trackside to parking, pulling a chassis from trackside to parking, or going offshift. Initially, the hostler will look at all job requests and choose the one which has been waiting the longest. After this initial assignment is completed, the hostler will perform the same task as long as there are requests of the same type waiting in queue. If not, the hostler will look at all requests again. If the hostler is scheduled to move an individual unit, the hostler entity gets the same unique identification attribute as that of its request. The hostler and unit then match based on the identification attribute. We determine if the hostler should go off duty by checking the current staff size against the scheduled hourly staff size, both of which are tracked by global variables. If there are no current requests for the hostler but he is not scheduled to go off duty, then he remains idle. The entity is routed back to the subroutine after a few minutes time delay and repeats the search to find his next task.

In the gate network, the gate lanes, inspectors, and clerks are modeled as resources. Certain lanes are designated for specific traffic based on whether or not they need to be inspected and differences in information process requirements. For example, a bobtail (tractor by itself) is not required to pass any information to the gate clerk. Therefore, a lane is designated strictly to bobtails. Other lanes may be designated as express lanes for preferred customers. For example, J.B. Hunt has a dedicated lane because it is a high volume customer, doesn't require inspection, and also uses Electronic Data Interchange (EDI) which shrinks the process time required at the gate.

2.3 Model Output and Animation

The simulation model is capable of generating a wide range of statistical output on the performance of the entire terminal, both in table and graphical format. This includes process time information such as the load and unload time of trains, capacity requirement information such as the number of units in parking, and bottleneck information such as number of drivers in the gate queue, and number of railcars waiting for track. We can also track the utilization of each track, crane, sideloader, hostler, clerk, and inspector.

To present these results, the model is animated using the SLAMSYSTEM Animator. Two animation files are written, one to depict the loading and unloading of a certain track showing current parking requirements, the other to depict the ingate and outgate showing queue sizes and waiting times. We found the animations to be quite helpful as a presentation tool, particularly in combination with other graphs/charts displaying the results.

3 APPLICATION

3.1 What-If Question

One of the applications in which Conrail has used the intermodal terminal simulation model described above is to answer a what-if question relating to the consolidation of intermodal terminals. Specifically, Conrail operates two intermodal terminals (47th St. and 63rd St.) in Chicago within 10 miles of each other. Being a hub for many different railroads, Chicago is a critical center point in the intermodal industry. Many trailers and containers reach Chicago terminals from western railroads and are then driven across town to one of the Conrail terminals to be shipped by rail to the East coast. Nearly 33% of all Conrail intermodal traffic passes through one of these two terminals. Both of these terminals are in need of capital improvements for general upkeep such as paving and street overpass maintenance.

Therefore, Conrail would like to determine if the activity at both terminals may be combined to a single 47th St. Intermodal Terminal to take advantage of economies of scale in facility sharing, i.e. a single gate, gate building, police staff, etc. This may also allow savings in equipment and assets over the combined amount needed to support the two separate facilities, i.e. employees, lift equipment, track, paving for parking areas and for lift equipment operation.

Under the current train schedule, the combined terminal will receive 8 inbound trains to be unloaded, and will load blocks for 9 outbound trains. Figure 3 shows the scheduled arrival and departure times for these trains. Solid arrows represent arrivals and outlined arrows represent departures. As can be seen, the activity occurs over a limited window, particularly on the inbound side with all trains arriving between 10pm and 9am. During this period, crews will be busy unloading trains. In the early afternoon, crews begin to load the outbound trains for the evening.

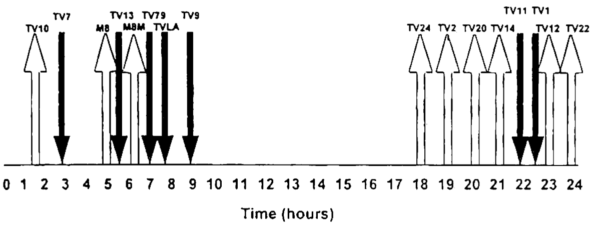

Figure 3: Train Schedule of Inbound Arrivals and Outbound Departures

A conceptual design of the combined terminal was drafted, maximizing track and parking capacity. The design would involve current building demolition, track relocation and addition, and new paving. This design produces a total loading/unloading track length of 27,000 feet (approximately 270 railcar spots), storage track length of 24,000 feet, and a total parking capacity of 1900 spots.

3.2 Model Assumptions

We wanted the physical size of the facility, and not the amount of employees or equipment, to determine the maximum capacity. Therefore, we increased the number of hostlers, cranes, and sideloaders by a reasonable amount so that they would not act as bottlenecks. We assumed that the physical size of the gate, 5 inbound lanes and 3 outbound lanes, will remain unchanged. However, the number of gate clerks and inspectors were increased to one per lane. We assumed inbound trailers and containers would be parked according to closest available spot, rather than dedicated lots for certain customers. This method utilizes the available parking space more effectively and also increases the effective track capacity by decreasing the unloading time of trains because the hostlers have less distance to travel when parking units. We also assumed that inbound unit dwell times will follow today's distribution. The combined terminal was simulated for a period of one week. The traffic volume and customer mix used for the experiment was based on sales and marketing projections for a peak week in the year 2000.

3.3 Results

The results of the simulation indicated that, based on the volume projections, the parking, gate and track capacity of the combined terminal will be exceeded. Figure 4 indicates the parking requirements for the sample week. The peak parking requirements on Sunday and Monday exceed the total capacity of 1900 spots. Figure 5 shows the amount of vehicles in queue at both the ingate and outgate for the sample week. Both of these queues exceed the maximum allowable queuing space. Any queue larger than 27 vehicles at the ingate will back up into the street access to the terminal. At the outgate, a queue over 22 vehicles will cut off access to in-terminal parking. Figure 6 shows the amount of trains waiting in queue for track to be unloaded or loaded. Up to six trains may be waiting for track. There is not enough storage track to accommodate these trains while they wait.

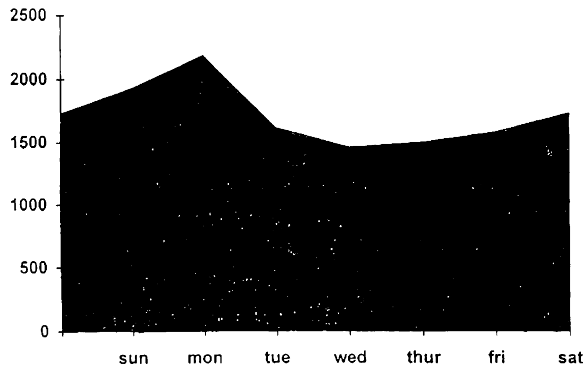

Figure 4: Total Parking Requirements for Combined Terminal

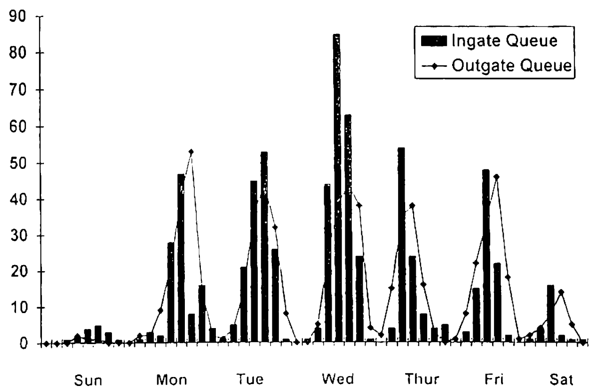

Figure 5: Amount of Trucks Waiting at Gate

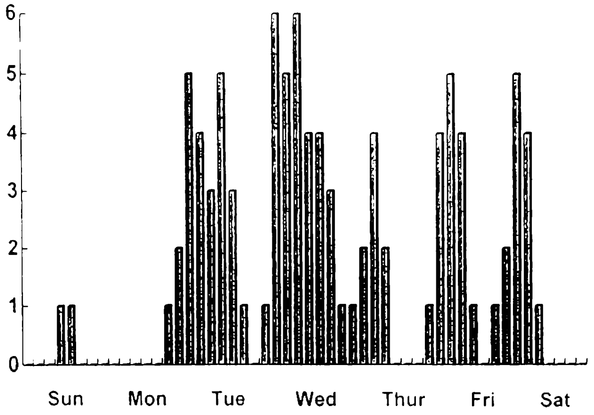

Figure 6: Amount of Trains Waiting for Track

The current layout of the terminal does not physically allow the gate to be expanded. It is obvious from the results that to handle traffic volumes that accompany the combination of terminals would require additional lanes, even under process improvements. This would require expansion of the gate facility including both the building and the number of lanes themselves. The conceptual design also does not include provisions for any locomotive storage tracks, maintenance and repair facility, terminal operator facilities, hostler and sideloader parking, or employee parking. All of these additions will require additional land, thereby decreasing the amount of land available for track and parking.

3.4 Conclusion

Based on these results, it is concluded that without acquiring additional adjoining land, the conceptual combined terminal design will not have sufficient capacity to handle the projected traffic volume, and is therefore undesirable. Therefore, Conrail will pursue individual upgrades of both the 63rd and 47th St. terminals. In addition, Conrail will begin to plan for a load-centering terminal to handle traffic exchanges from western railroads directly by rail, thus taking some of the volume away from the intermodal terminals and cutting the cost of cross-town drayage. We expect simulation modeling to be an important factor in planning the layout, operation, and staffing requirements of each of these individual projects.

ACKNOWLEDGMENTS

The authors would like to thank the consulting staff of Vickerman·Zachary·Miller, and Nora Ryan in particular, for her substantial work in developing the intermodal terminal simulation model.

AUTHOR BIOGRAPHIES

THOMAS SAROSKY is a member of the Engineering-Analysis department at Consolidated Rail Corporation. He received a B.S. in Industrial Engineering and a M.S. in Industrial Engineering and Operations Research, both from Pennsylvania State University. His research interests include transportation and production system modeling.

TERRY WILCOX is Assistant Director of the Engineering-Analysis Department at Consolidate Rail Corporation. He received a B.S. in Mechanical Engineering from St. Lawrence University and Industrial Engineering studies at Maynard Institute. His interests are in modeling applications and process improvements in rail transportation systems.