Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

THE USE OF SIMULATION MODELING FOR INTERMODAL CAPACITY ASSESSMENT

Beth C. Kulick
James T. Sawyer

Automation Associates, Incorporated
512 Via de la Valle, Suite 209
Solana Beach, CA 92075-2714, U.S.A.

ABSTRACT

Simulation modeling that has been successfully used to analyze intermodal capacity issues for a wide variety of facilities. Simulation technology provides an analysis mechanism for large intermodal facilities that are difficult to duplicate with other methods due to the interaction of many variables. Automation Associates, Inc. (AAI) is a simulation consulting services company that has been providing models for the transportation and intermodal industry for over ten years. AAI has developed many models to support major architecture and engineering projects as well as provide analysis support for intermodal operators. Through this experience, there have been modeling projects built to address different objectives based on the project requirements. A survey of the major categories of modeling projects based on their unique objectives and scope is presented in this paper. Additionally, two actual model implementations are discussed relative to this outline.

1 GENERAL USES OF MODELS FOR INTERMODAL SYSTEM CAPACITY ANALYSIS

Simulation models are especially useful for analyzing intermodal facilities because they are usually large, expensive to build and operate, and there are often complex system interactions that need to be understood and analyzed. Additionally, there are often significant constraints due many facilities occupying invaluable marine/harbor real estate. Simulation provides a convenient "test bed" for exploring the impact of many variables. Some of these variables include:

- Equipment and resource types (cranes, hostlers, side loaders, etc.)
- Infrastructure, layouts, and networks (tracks, parking spaces, storage locations).
- Forecasted demands (normal, peak conditions).
- Arrival and departure schedules (train/vessel arrivals, departures).
- Tactical operation rules (teams, first available, etc.).
- Strategic options (simultaneous load/discharge).

When conducting simulation projects for intermodal terminals and facilities, there is sometimes the preconception that all of the design work must be finalized and that a lot of data must be available to support a useful analysis. In our experience in conducting studies for a variety of intermodal applications, it has been found that models can be useful during many phases of a project life cycle—from early conception through the justification of capital improvements of an existing facility. A survey of how simulation is often used during the design, implementation, or operation of an intermodal facility includes the following categories of models:

1.1 Proof of Vision

When: Little design work has been completed, very general project goals.
Objective: Either to show general economic viability or possibly an animation to demonstrate, visualize, or "sell" a project.
Level of Detail*:* High level of abstraction—often little layout specifics, hypothetical data, generalized operation rules, etc.
Cost/Time: Usually quickest type of model to implement due to the "black box" nature of equipment/resource operations. Implementation could span days or weeks.

1.2 Proof of Concept

When: Some design work has been completed, goals of project are becoming more specific.
Objective: Assess level of infrastructure, equipment, and resources needed to support project goal. Often used

to compare multiple concepts and perform sensitivity analysis.Level of Detail: Incorporate some layout details, specific equipment/resources, and some real data. Also, ability to "dial up/down" resource quantities, etc. Ability to explore multiple concepts with comparable detail.

Cost/Time: More time to implement due to more explicit representation of equipment/resource operations. Also, multiple scenarios/concepts are typically explored such that implementation typically spans multiple months.

1.3 Proof of Engineering

When: Most/all engineering and design work has been completed, goals of project are very specific.

Objective: Verify if design will work to meet goals. Verify if planned level of infrastructure, resources will really work. Is system "over or under" designed?

Level of Detail: Detailed layout (CAD drawing), specific equipment/resources and some real data.

Detailed operating plan is usually included. Ability to "dial up/down" resource quantities, etc.

Cost/Time: Implementation typically spans one or more months due to very detailed representation of layout and corresponding operation plan.

1.4 Proof of Operations

When: System already exists.

Objective: Periodic assessment of capacity due to business environment changes (internal or external).

Level of Detail: Similar to Proof of Engineering must include "as-built" details.

Cost/Time: Potential use of live/historical data and validation of performance with actual system usually requires multiple months of model development time.

Many times when conducting a simulation analysis there are decisions that need to be made within a relatively short period of time. This necessitates that the simulation models be developed within the following framework:

- Be developed to analyze multiple scenarios within a reasonable timeframe—usually a couple of months or less.
- Competitive environment and budgets do not allow for models to be "scrapped and rebuilt" when new scenarios are defined.
- Often requires that users other than the model developers be able to run and analyze models.

To accommodate these requirements, many of the models implemented to accomplish the goals outlined goals are created using the following methodology:

- Models are built with an open architecture to enable functional extensions, alternate scenarios, as well as ability to move from conceptual to engineering level of detail if needed.
- Ability to integrate an easy-to-use user interface to allow others to run and demo models.
- Ability to develop to a modeling solution that uses a simulation "engine" with real world data and other programs as appropriate.

2 MODEL APPLICATION 1: NEW YORK CROSS HARBOR TUNNEL

2.1 Objectives

Due to natural geographical restrictions, the city of New York has a centuries-old problem where there is a tremendous difficulty of getting freight into this highly populated area. Most freight must be trucked in from New Jersey harbors such that they clog up major highway and bridge arteries that feed into the City. The New York Economic Development Corporation is evaluating a series of proposals to remedy this problem. Some of the more likely prospects are a cross-harbor freight tunnel and a railcar float/barge system.

This model was used to perform a proof of concept analysis to explore the feasibility of moving freight into/out of New York using either a new freight tunnel system or a railcar float system. A number of general issues needed to be addressed consisting of:

- How effectively would a rail freight tunnel function (in terms of levels of service, travel times, etc.) with different levels of traffic and different design configurations (travel speeds, number of tracks)?
- How would the primary alternative to a rail freight tunnel—a railcar float system—compare to a rail tunnel in terms of performance and functionality? If the railcar float system is not the long term preferred alternative, what would be the optimal float system to handle near term demand, prior to completion of the tunnel?
- How would the entire rail tunnel and/or float operation be integrated into the region's rail infrastructure? What would be the "downstream" impacts, and what service deficiencies could be expected? What types of improvements—either physical or operational—would be needed elsewhere in the system to overcome these impacts?

2.2 Model Scope

2.2.1 Cross Harbor Freight Tunnel Operations

This analysis was concerned with "proof of concept" for baseline tunnel operations. It included modeling all rail traffic through the proposed tunnel. Four design variations for the tunnel were modeled, consisting of single and double track tunnels for the two proposed alignments (Staten Island and Greenville Yard). These variations were modeled with projected year 2020 demand estimates. The geographic area modeled included the tunnel itself, along with connections to supporting rail yards and mainline connections. The area encompasses about 200 square miles of tunnel and connecting rail network.

An illustration of the tunnel alternatives and the magnitude of the study area (as animated by the simulation model) are shown in Figure 1.

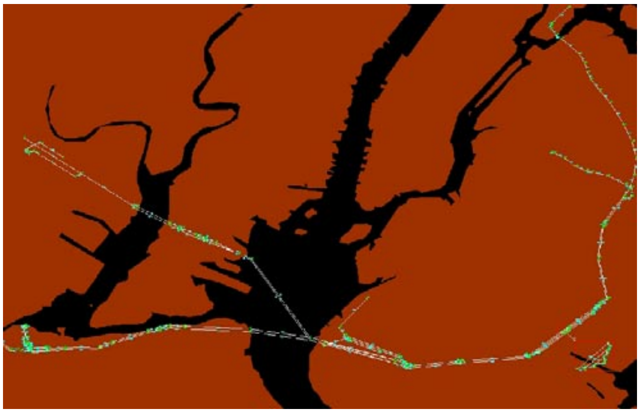

Figure 1: NY Cross-Harbor Tunnel Options

2.2.2 Railcar Float Alternative

This analysis examined the primary alternative to a rail freight tunnel—a railcar float system—in terms of its performance in lieu of a cross harbor rail freight tunnel, and in terms of its ability to serve as an interim "stopgap" service while a rail freight tunnel is being constructed. The geographic area covered the same area as the tunnel scenarios (Edwards and Kelcey 2000). Three major service options were explored.

2.3 Data Requirements

Since this was a conceptual model, there was limited actual data available concerning train schedules—projections of railcar volumes and expected operational schedules were used.

Actual track network data and maps were used to create the connecting rail to the tunnel. For the tunnel configuration, expected design characteristics (allowable speed, switches, etc.) were used.

2.4 Model Analysis Results

The simulation produced results documenting the ability of each of the alternatives to handle anticipated traffic volumes. This analysis proved that all of the alternatives are capable of handling the forecasted freight demand. The model also identified several instances where additional track or connection resources are needed to facilitate rail operations (Edwards and Kelcey 2000).

3 MODEL APPLICATION 2: BNSF SIMULATION-BASED CAPACITY ANALYSIS PLATFORM

3.1 Objectives

This model was used to perform a proof of operations analysis to support periodic capital justification analysis for currently operating intermodal rail terminal facilities, specifically with respect to track and yard capacity. The model was designed to be flexible such that it is capable of analyzing many terminals in BNSF's network without a major redevelopment effort.

The model is designed to address some very specific infrastructure investment decisions:

- What specific improvements (loading/unloading tracks, cranes, etc.) are needed to support projected increases in cargo movements?
- If an infrastructure improvement is implemented, how much additional cargo can be accommodated?
- Is it possible to increase the level of service of a facility if specific resource investments are purchased?

3.2 Model Scope

The model included the ability to create many possible infrastructure scenarios for a given terminal. The model also needed to show the capability of a proposed modification to address projected increases in demand for the different cargo classes that an intermodal terminal must support.

The types of infrastructure scenarios that the model had to support are:

- Track types: fast tracks, loading/unloading tracks, storage tracks, and other.
- Track geometry and switching capabilities.
- Switch engine resources.
- Yard block configuration: storage capacities, stacked/wheeled storage, travel distances.
- Yard handling equipment: cranes, straddle carriers, yard trucks.

The model also supported the application of varying demand schedules and volumes based on projected business conditions. This was accomplished using a train schedule where frequency of inbound/outbound trains with class, car mix, and destination information can be varied.

3.3 Data Requirements

Since this was a model that incorporated significant realistic detail and the terminals under investigation are in active operation, actual data was used for many system definitions. Actual terminal track layouts and maps were used as a basis of infrastructure definition and historical cargo unit arrival logs were used to define demand profiles.

3.4 Model Analysis Results

The simulation provides results that illustrate how well an intermodal terminal is capable of responding to increases in demand and changes in business conditions. The model provides a basis to understand if a given investment of infrastructure or equipment will provide the necessary capacity to respond to demand changes or increases.

4 CONCLUSION

When implementing or operating an intermodal facility, there are capacity issues that impact costs and level of service capabilities. Simulation models are valuable tools to assist designers and operators with analyzing complex intermodal systems and their ability to respond to projected demand volumes. Simulation is a tool that has broad applicability for these problems—it has provided benefit to help sell a project idea to funding agencies, for refining concepts during the early design phase, and during the continued operation of an existing facility.

ACKNOWLEDGMENTS

Special thanks to Alan Meyers (Cambridge Systematics) for his vision and creativity in using the simulation results for the New York City Economic Development Corporation. Also, thanks to Kevin Bennett (AAI) and Kurt Reichelt (HDR) for their contributions to the design and development of the BNSF terminal simulation model.

REFERENCE

Edwards and Kelcey Engineers, Inc. 2000. Cross Harbor Freight Movement Major Investment Study. New York City Economic Development Corporation, PIN X500.19.

AUTHOR BIOGRAPHIES

BETH C. KULICK is Vice President of Automation Associates, Inc. She joined Automation Associates in 1988 as a Simulation Analyst and has created customized simulation models for a variety of industries. She received a M.S.I.E. from Texas A&M University and a B.S.M.E. from Purdue University. Her interests include creating advanced business analysis tools that are based upon simulation models. Her email is `<bkulick@aaisim.com>` and her corporate web address is `<www.automationassociates.net>`.

JAMES T. SAWYER is a Senior Simulation Analyst for Automation Associates, Inc. He joined AAI in 1996 and has over seven years experience in designing and developing simulation-based software solutions across a wide variety of application domains. James received his M.S. in Industrial and Systems Engineering from Georgia Tech in 1996, and his B.A.S. in 1) Mathematical/Computational Sciences and 2) Music Technology from Stanford University in 1992. His email is `<jsawyer@aaisim.com>` and his corporate web address is `<www.automationassociates.net>`.