Proceedings of the 2004 Winter Simulation Conference
R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, eds.

THE USE OF SIMULATION TO SUPPORT MAJOR TRANSPORTATION PLANNING DECISIONS

Beth C. Kulick

512 Via de la Valle, Suite 310
Automation Associates, Inc.
Solana Beach, CA 92074, U.S.A.

ABSTRACT

When major transportation infrastructures such as freight corridors or port systems are being planned, there are typically multiple phases of preliminary engineering required. During these phases, there are design decisions made that have impacts on investment required, level of service provided, and the environment. The basic question that is typically asked during these phases is "What level of infrastructure is really needed to support the expected demands upon the system?" Simulation provides a framework to quantify the level of service provided when an infrastructure design is imposed with projected demands. There are numerous challenges associated with constructing a simulation model of the magnitude needed to support planning initiatives. This paper describes a simulation modeling approach that integrates needed planning flexibility with sufficient fidelity to understand infrastructure performance.

1 INTRODUCTION

This paper describes a simulation modeling framework—the Transportation Modeling Studio (TMS) that has evolved through over 7 years of experience working with transportation planners.

TMS incorporates many of the features that have been identified from applying simulation technology for planning studies and is able to flexibly create infrastructure network alternatives through a highly configurable user interface that automates the process of building networks. In addition to describing the capabilities of the TMS, this paper also describes a case study where it was used to make a significant planning decision—one where significant environmental impacts were reduced.

2 WHAT IS THE TRANSPORTATION MODELING STUDIO?

When using simulation for a transportation infrastructure planning study, there are numerous capabilities that are critical to executing the study. Among these are:

1. Ability to create a large network that may encompass numerous square miles and many terminal and/or other traffic generation locations.
2. Ability to change network configuration and associated routing patterns to reflect scenario differences.
3. Contain the model logic to track individual "trips" through the network and maintain the amount of delay incurred as each moves through the network.
4. Manage the individual trips through the network to avoid collisions and dynamically chose routes to avoid conflicting traffic.
5. Ability to integrate or "overlay" a demand schedule or operational plan over the network. It is often necessary to create a customized plan depending on network interrelationships, etc.
6. Ability to isolate/determine network problem areas (bottlenecks, areas of congestion, etc).

A significant implementation challenge during a planning level study can be understood from the analysis flow chart shown in Figure #1.

As the analysis unfolds, there are often congested or problem areas within the network that require some engineering changes. The ability to quantify these is a huge benefit of using a simulation model, but also an area that introduces a challenge with respect to how rapid changes must be incorporated to become useful for continued analysis. The complexity arises because a network change often has implications on the routing patterns and the way that traffic is managed through the infrastructure. All of these changes must be reflected in the network within a matter of hours or perhaps days to become useful for the

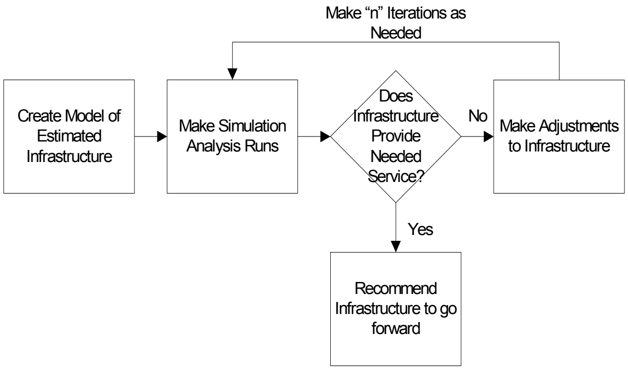

Figure 1: Typical Planning Level Analysis

analysis. TMS provides the functionality to make network changes and also automatically adjust the related variables that are impacted by the change. In previous modeling efforts these types of changes could take weeks—TMS accelerates network changes to be more responsive to the engineering process.

3 TRANSPORTATION INFRASTRUCTURE MODEL REPRESENTATION

The capabilities of the TMS framework can be further understood from looking at the elements of constructing a planning level infrastructure model. An overview of the TMS model architecture (as it was applied for the case study presented in this paper) is provided in Figure 2.

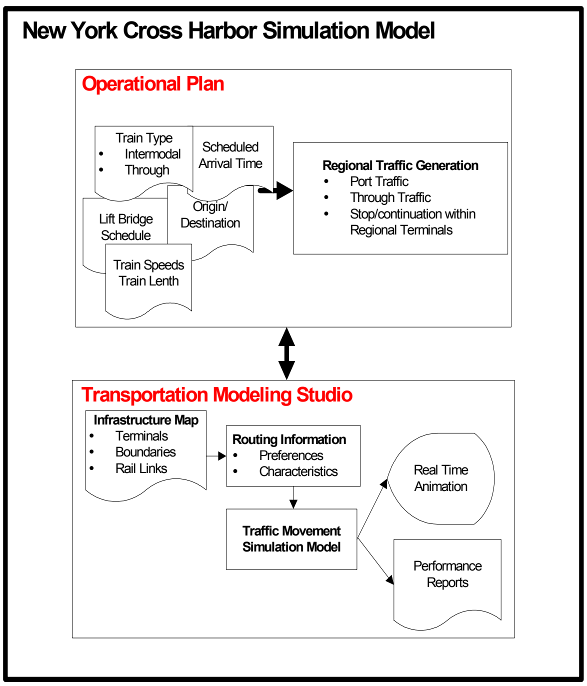

Figure 2: TMS Architecture

3.1 Network/Infrastructure Map Definition

These are the tools that provide the capability to define the entire network in terms of rail link connections throughout the study region. A map-like definition environment is implemented using a customized Microsoft Visio template. Through the Visio user interface, a network map can be imported and key locations such as terminals, network boundary points, and rail links (main lines, siding locations, etc.). Also associated with the links are the operating speeds and other special characteristics. Visio automatically translates this information for model use including distance information. Custom Visual Basic code is provided to translate the network information into routing alternatives—the user has the capability to prioritize, modify, or eliminate routes as needed via an interactive environment.

3.2 Reservation Logic

This is logic that "reserves" needed network infrastructure for a pending trip. An important part of the TMS model is that trips are allowed to access the network, but there may be times within a trip that require the train to stop at a siding, etc. The reservation logic provides network-wide data structures to enable the traffic management and movement module to make decisions as to which train can move next (collision avoidance, etc.) and where it can be routed.

3.3 Traffic Management and Movement

This is the logic that is the core of the simulation model component. This logic uses the information provided by the reservation and network infrastructure definition to actually move trips through the network. The simulation dynamically determines routing alternatives/permission, and maintains the physical location of the trip as it travels within the network. The simulation model performs this "real time" which also provides the mechanism for tracking trip performance in terms of travel delays as well as providing animation for public outreach sessions, etc.

4 CASE STUDY USING THE TMS FRAMEWORK

To illustrate the use and benefits of the TMS framework, a case study to support the New York Cross Harbor Environmental Impact Study is presented. The simulation model representation provided a key decision making platform that quantified the effectiveness of varying level of infrastructures to support a peak operational plan.

4.1 Study Background

During recent years, the New York Economic Development Corporation (NYEDC) has been exploring the economic feasibility of providing a Cross Harbor Freight Tunnel to connect New Jersey with New York (Manhattan). The ability to efficiently bring in freight to New York is a century-old problem and is continuingly increasing logistics problem.

The level of investment to accomplish this as well as the supporting infrastructure and its environmental impacts is of significant concern. The TMS simulation model representation was used to support major decisions associated with both the Major Investment Study (MIS) as well as the Environmental Impact Study (EIS). The analysis used to support the EIS is provided here as an example of the use and benefits of TMS.

4.2 Model Scope and Analysis Framework

The EIS planning and engineering team had various infrastructure alternatives that needed to be evaluated. The general objective of the simulation analysis was to determine the level of supporting infrastructure needed outside of the tunnel on the New York side of the network. The analysis was framed to determine the level of infrastructure, the one with lowest investment and environmental impacts that satisfies the projected operational requirements. The scope of the study area is provided in the schematic contained in Figure 3.

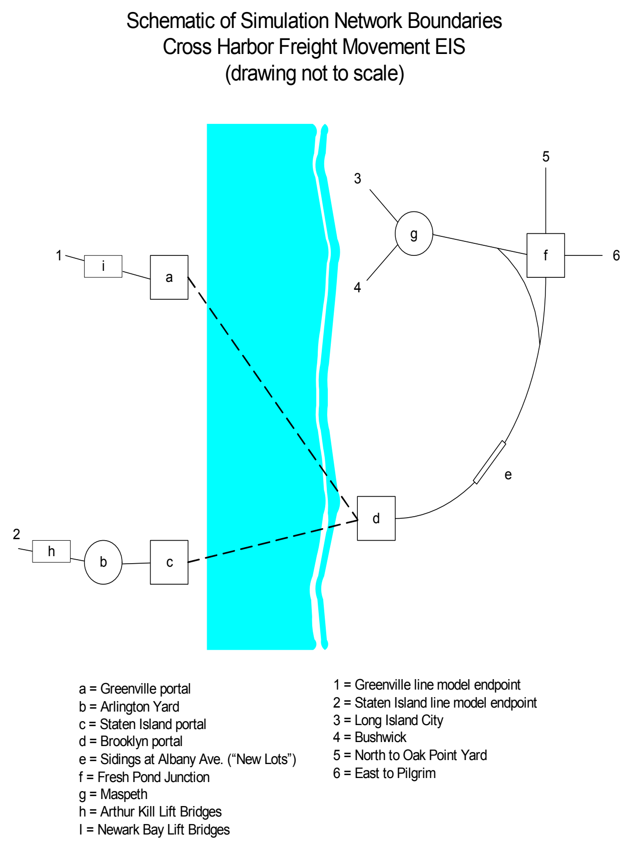

Figure 3: Overview of New York Study Area

The TMS was used to represent 3 different infrastructure scenarios that varied from high to low environmental impact:

- **High:** Two tracks in entire network east of the tunnel.
- **Medium:** A portion of the network that only contains one track with the remaining containing two tracks.
- **Low:** Same tracks as the Medium scenario, with even more of the network containing one track.

The analysis was conducted such that the same peak operational plan was used to evaluate the performance capabilities of each of the scenarios. The operational plan consisted of a schedule of all tunnel-based train traffic as well as "through" traffic on the New York side (that imposed by commuter and service trains).

For each scenario, the cumulative "amount of delay" experienced by the trip volume in using that infrastructure was tracked and reported by the model. As each train trip attempts to use the network to complete its trip, the model tracks the amount of time that each had to stop due to interfering traffic. This amount of delay was used as a primary measure of effectiveness for network comparison. The lowest level of infrastructure that provides acceptable level of service performance is determined to be the preferred solution. If possible, there was a particular interest in implementing only the "low scenario" in that it avoided the need to put in double tracks adjacent to a large Brooklyn residential area.

When performing the scenario comparison, the simulation model was run across multiple replications of a single peak operating day This allowed for normal variations in the operating schedule (time of arrival to the region, etc.) to be included within the analysis.

4.3 PROJECT RESULTS

The primary results of the simulation analysis are shown in Table 1.

Table 1: Simulation Results

Scenario	Avg. Time for Train to Access Network (HH:MM:SS)	Count of Times a Train had to Wait
Low	00:23:21	370
Medium	00:17:54	342
High	00:14:33	283

As shown in the table, the primary measures are based on the cumulative performance across all trains run within the scenario. As expected, when comparing the relative performance of each of the scenarios, the high level of infrastructure provided the best overall performance. However, considering this analysis was based on peak projections, the magnitude of the difference in performance was not considered significant enough to justify the level of investment and environmental impact imposed—especially in a peak situation where there may be time periods where traffic can be shifted. The EIS engineering team recommended that the low infrastructure scenario be pursued. This wound up being a significant recommendation in that it saved placing double tracks adjacent to a major residential area—even avoiding some demolition of existing buildings.

5 CONCLUSION

The ability of the TMS to provide a simulation-based framework for representing and assessing transportation infrastructure on a planning level provides a method for design and engineering teams to quantify needed requirements. The simulation model provides a "virtual test bed" to understand how projected operational scenarios are really impacted by network capacity—a capability that is difficult to attain using conventional methods.

For planning studies, the value that simulation models provide is immense when considering the potential investment and environmental impacts of transportation projects. The ability to quickly explore multiple scenarios is of significant benefit—it allows for results to be incorporated into the design and engineering process and for the best solution to be achieved.

ACKNOWLEDGMENTS

The case study presented in this paper was performed in conjunction with an overall planning and engineering team that consisted of individuals from STV Incorporated, Cambridge Systematics, and Automation Associates, Inc. In particular, Alan Meyers, Nick Mazzaferro, Gerri Pierri, and Dave Brann, were key contributors for defining and performing the analysis to support the New York Cross Harbor Environmental Impact Study.

AUTHOR BIOGRAPHY

BETH C. KULICK is a Senior Consultant at 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 and other software technologies. Email at: `<bkulick@automationassociates.net>`.