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SIMULATION OF TRANSPORTATION LOGISTICS

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ABSTRACT

In this paper, we discuss issues concerning the simulation of transportation systems. In particular, we demonstrate a number of implementation tricks that are designed to make the modeling and coding processes more efficient and transparent. We present examples involving the simulation of commercial airline and military sealift operations.

1 INTRODUCTION

Transportation is one of the most critical components in civilian and military logistics operations. The success of business and industry, as well as the military, relies heavily on efficient air and sea transportation systems. Perhaps the most efficient means of civilian transportation is via air, while civilian cargo delivery is usually accomplished via some combination of air, sea, and land methods. In addition, airlift provides a fast way of moving personnel and other materiel during military operations, but its capacity is quite limited, and its cost is very high. For example, only 5% of total materiel was delivered to the Gulf region during Desert Shield and Desert Storm using airlift, while the rest (95%) was delivered via ships. A ship, although slow, moves a vast amount material at a very low cost. So the proper mix of airlift and sealift must be carefully studied for successful military operations.

In this paper, we discuss issues concerning the simulation of transportation systems. In particular, we demonstrate a number of implementation tricks that are designed to make the modeling and coding processes more efficient and transparent. We present examples involving the simulation of a commercial airline (Section 2) and military sealift operations (Section 3). The models were developed using the Arena simulation package (Kelton, Sadowski, and Sadowski 2002).

2 AIRLINE SIMULATION

Here we are interested in simulating an airline's network of routes. One problem that may come up immediately when modeling such networks concerns the repetitive logic that must be coded for each node and segment of the network. In our implementation, carried out in Arena, we initially coded the same logic over and over for each city on the network, and tediously drew and connected all of the city nodes and segments by hand. In a network consisting of, say, 180 airports, one quickly tires of the task.

To ameliorate the programming labor, we need to create a generic airport (node), containing a collection of Arena blocks corresponding to (i) a plane's arrival into the airspace, (ii) its arrival at the airport, (iii) its departure from the airport, and (iv) its departure from the airspace to its next destination. We also need to parameterize every block. Further, we must position the nodes themselves geographically.

We accomplished the above tasks using a VBA implementation within Arena. How does it work? First off, we create a connectivity matrix with a list of names for stations, actually standard airport codes; this matrix simply determines which cities can be connected by a flight leg. The list of cities and the matrix of connectivity are read from an Excel spreadsheet. Second, we develop the generic airport process (i)–(iv) outlined above. Once launched, the program automatically draws and links up every city, and then supplies the necessary Arena blocks for each city.

Figure 1 illustrates the connectivity matrix. Figure 2 shows the resulting network of connected cities. Figure 3 displays the automatically generated Arena code for a number of generic cities. And Figure 4 illustrates the airline simulation in mid-stream.

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ALB	1	1	0	0	0	0	0	0	0	0	0
ABQ	1	1	1	0	0	0	0	0	0	0	0
ABE	1	1	1	1	0	0	0	0	0	0	0
AMA	1	1	1	1	1	0	0	0	0	0	0
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Figure 1. City-Pair Connectivity Matrix

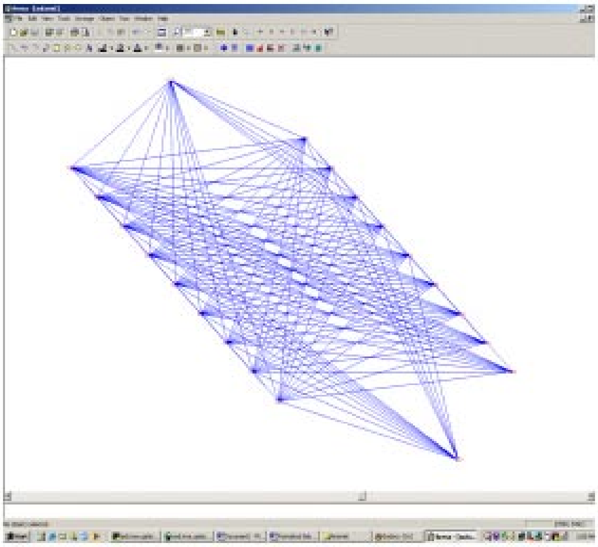

Figure 2. Crude Network of City Pairs

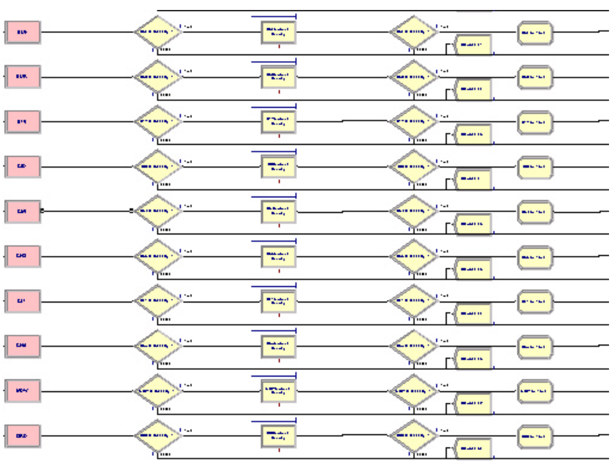

Figure 3. Sample of Arena Code

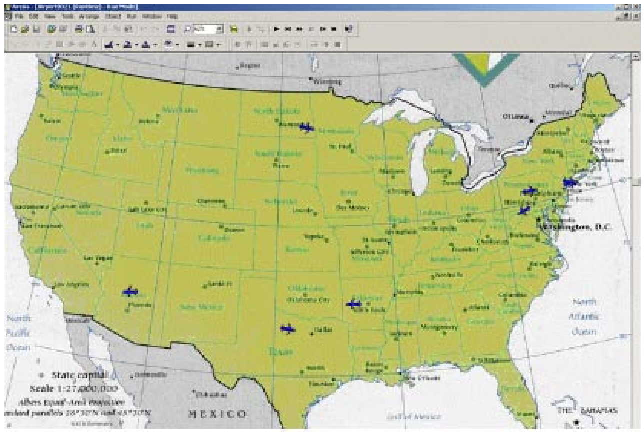

Figure 4. Airline Simulation.

3 MILITARY SEALIFT MODELING

In this section, we present two models to show how to model military sealift operations to meet surge requirements. The first model deals with strategic sealift, and the second model deals with port congestion analysis during the offloading operation. These models provide military planners with a flexible and accessible decision support tool to obtain advance planning information regarding strategic sealift capability and the effects of congestion at any port upon sealift capacity, under a variety of conditions.

3.1 Strategic Sealift

Suppose we have transportation requirements, as shown in Table 1, from the following SPOEs (sea ports of embarkation) to SPODs (sea ports of debarkation) at a contingency region, for example the Gulf region, Somalia, Afghanistan, or the Korean Peninsula. It is of great interest for military planners to determine if they have enough transportation capacity to meet such surge requirements. They are also interested in estimating the impact of having more or fewer ships on their mission.

The numbers in Table 1 represent the (randomly generated) amount of materiel (in stons) to be transported via a limited number of break bulk (BB) ships, roll-on-roll-off (RORO) ships, and container ships from each of the SPOEs to the contingency area of operation. The objective of this model is to estimate the time required to move the required materiel to the destination given a number of ships of each type. Each ship may have a different capacity and speed. The required materiel must be delivered over a time period to an embarkation port from various sources, for example, military bases or manufacturers. All these values are to be read from a text or a spreadsheet file. The distances from each SPOE to the debarkation port are input to the model. Arena modules in the Advanced Transfer Template provide easy handling for transportation modeling, e.g., assigning ships based on a certain selection rule, and computing travel time given a pair of ports and the particular ship selected for the mission. Figure 5 shows a sample screenshot of the sealift model for a hypothetical scenario.

This model can also be used to simulate airlift operations for surge requirements with minor modifications in the database. In this case, an airport distance matrix will replace the port distance matrix. Note that the air travel distance is different from that of ocean travel; for example, a ship located in Norfolk, Virginia must travel through the Suez Canal to the Gulf area, and she must travel via the Panama Canal to Asia.

Table 1: Transportation Requirements from Each Port of Embarkation (in stons)

SPOE	BB	RORO	Container
Bayonne, NJ	90,000	80,000	50,000
Beaumont, TX	80,000	60,000	10,000
Charleston, SC	80,000	50,000	10,000
Cheatham Annex, VA	70,000	40,000	10,000
Concord, CA	90,000	90,000	10,000
Guam	60,000	90,000	70,000
Houston, TX	70,000	80,000	80,000
Jacksonville, FL	50,000	50,000	60,000
Long Beach, CA	70,000	60,000	50,000
Morehead City, NC	80,000	60,000	40,000
Newport News, VA	60,000	60,000	90,000
Norfolk, VA	50,000	60,000	90,000
Oakland, CA	40,000	10,000	80,000
Port Hueneme, CA	90,000	80,000	50,000
Savannah, GA	90,000	60,000	50,000
Sunny Point, NC	80,000	50,000	60,000
Tacoma, WA	50,000	40,000	10,000
Wilmington, NC	50,000	90,000	60,000

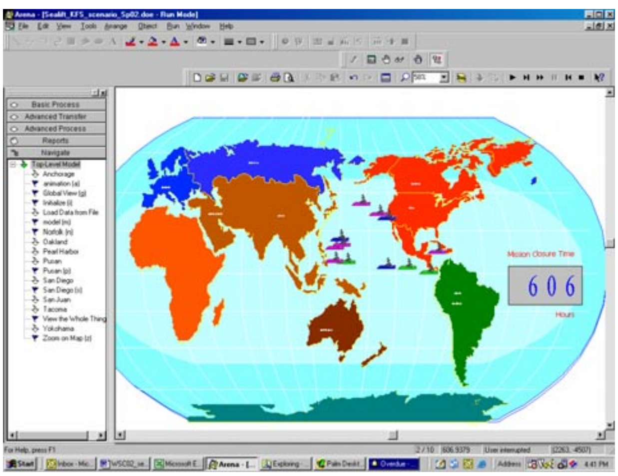

Figure 5: A Sample Screenshot of Strategic Sealift Model

3.2 Port Congestion Analysis

The second simulation model deals with the analysis of port congestion. History demonstrates how port congestion problems can negatively impact embarkation and debarkation planning and operations. After a ten-day trip to Vietnam in May 1966, a White House official cited "port congestion" as one of the three major problems affecting U.S.-led military efforts. "At the end of May the number of ... ships waiting off Saigon for their turn at unloading was 36," the official wrote, "[and the average] waiting time was 26 days ... [General] Westmoreland should be given what he needs to make the port function" (U.S. State Department 2002, paragraph 3b). With battlespace sustainment as one of the ways the Navy envisions achieving its goal of maritime power projection, one can just imagine the impact in a modern military scenario if congestion forced ships to wait 26 days to offload critical supplies!

Our primary concern is traffic congestion, caused by ships waiting in queue because either all useable berths are busy offloading other ships, or ships are already waiting for free berths ahead of them. The ability of seaports to receive, offload, and release sealift assets smoothly is a critical planning factor during military sealift operations. Once a ship arrives at the SPOD, heavy traffic, lack of resources (e.g., berths, material handling equipment, tugboats, personnel, etc.), and/or other external factors (weather, sabotage, air strike, etc.) might delay the unloading operation at the port. The unloading delay not only causes difficulty in sealift operations but also in the ground or air transportation operations from the debarkation port to the final destination. Figure 6 shows a sample animation.

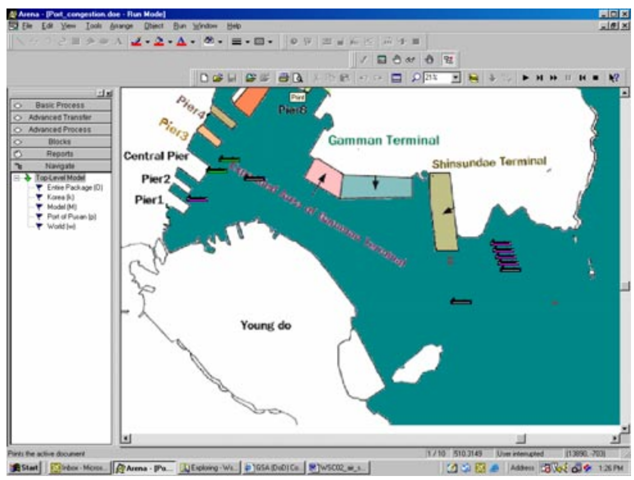

Figure 6: A Sample Screenshot of Port Congestion Model

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