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SIMULATION OF AN INLAND WATERWAY BARGE FLEET DISTRIBUTION NETWORK

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ABSTRACT

This paper discusses how a discrete event simulation model was developed using *ProModel* Software for application as a PC based decision support tool in the logistical management of a marine based distribution system. The system is operated on an inland waterway network with a dedicated fleet of barges and tugboats to transport products from several source plant loading points to multiple distribution sites at other locations along the waterway network. The general problem addressed here is the determination of proper fleet sizing, and appropriate resource allocation to meet potential delivery requirements in a timely manner.

A familiar argument was found to exist here: operations personnel in the field claimed that a shortage of resources (barges) preclude them from achieving required system performance, while management claimed that available resources are sufficient but are not being applied in the most effective manner. With cost estimates for new barge investments being in the neighborhood of $250,000 each, an appreciation and understanding of the true resource requirements presents a worthwhile undertaking.

Proper development and analysis of an appropriately thorough, and visually enhanced, simulation model of the system is well suited as a potential solution in settling the argument.

1 INTRODUCTION

The nature of this barge system, as with many marine distribution systems, tends to pose complexities which present a significant challenge to obtaining optimally effective operation. Random variability in transit times between points on the water due to constant changes in weather conditions, as well as issues in maintaining marine equipment reliability are the more prevalent of several system characteristics which all combine to create this challenge.

For the purpose of this discussion, the respective marine distribution system is categorized into two subsystems:

1.) The upriver region network where primarily the product loading function is performed at multiple sites.

2.) The downriver region network, where product unloading to multiple distribution yards and customer sites is the primary function.

There are approximately 100 barges in the fleet and effectively 12 tugboats used to shuttle the fleet of barges. The total system network extends approximately 150 miles from end to end. The resulting system network configuration follows a hub and spoke arrangement with both subsystems each having one hub used as a regional consolidation point. These hubs are located approximately 90 miles from one another.

There are two distinct possibilities for the use of a simulation model of this system. One being the evaluation of the strategic, or long term management horizon, which may involve capital investment and changes in overall operating policy. Examples of this would be the addition or elimination of barges or tugboats in the fleet, or significant adjustments to site operating schedules. The second, being for responses of a short term tactical nature, such as determining the appropriate answers to daily allocation and routing decisions - much the same as a system dispatcher performs on a regular basis. For this initial phase of developing, and applying a simulation model of the overall system, a more strategic, long term focus has been the primary objective. Future evolution of the model may include using it for decision support over a short term horizon.

2 SYSTEM DESCRIPTION

The two regional subsystems are both comprised of multiple sites, each having its own operating characteristics such as: respective operating schedule, number of cranes, equipment load / unload rate, and dock capacity. Furthermore, several of the upriver production sites load unique product offerings. A recent count resulted in the identification of over 50 different products for all production sites combined.

Some downriver unloading sites may require a varied mix of these products to be delivered at any given time; while others tend to consistently use predictable amounts of a certain product on a regular basis

The tugboats operate, for the most part, continuously around the clock, seven days per week. Certain larger (long haul) tugboats are primarily used for longer haul shuttles between the two subsystems, while the remaining smaller tugs are dispatched regionally in their respective subsystem. While the tugboats each have individual operating characteristics which differ somewhat, the characteristic of most significance in this situation is the number of barges which a given tugboat can handle at one time on any given waterway segment. This number has historically varied from one, to as many as nine barges at a time for a given tugboat.

The barges have respective characteristics in terms of capacity (measured in tons), and in some cases product class restrictions. Certain barges are also restricted to being used only in certain locations due to poor overall condition making them unsuitable for long distance transit.

3 MODEL DESCRIPTION

The *ProModel 4.0* software was found to be suitable for handling this system model. The desire to develop a thorough, visually descriptive and efficient simulation model having reasonable execution speed called for taking a well planned approach regarding the management of simulation events and integration / manipulation of data. The modeling structure of *ProModel 4.0*, which suggests a paradigm for putting objects in terms of *Entities*, *Locations*, and *Resources*, directly fits the components of the distribution system. The *Path Networks* module accommodates the transit aspects of time and capacity for each of the navigational waterway segments.

Barges were set up as *entities* and had attached associated attributes designated for capacity, identification number, and destination. In the case where barges were combined together for transit, the *Group* function was employed and a corresponding respective entity graphic for group size was also applied for visual accuracy in the animation.

A barge status code was devised for the model as an instantaneous point indicator of the status of each barge at any moment in the system. This indicator code was assigned as follows:

0 Barge empty in staging
1 Barge being loaded
2 Barge loaded and waiting for tugboat
3 Barge loaded in tow
4 Barge Arrived – waiting to unload
5 Barge being loaded
6 Barge Unloaded – waiting for tugboat
7 Barge empty in tow
8 Barge loaded in staging

Creating a single dimensional array with 100 cells corresponding to barge ID made for an elegant approach to address these instant status codes throughout a model run period. Also the posting of instantaneous status for every barge on the animation screen allows for monitoring a given barge or a certain group of barges during the simulation. A cumulative indication of the number of barges in a given status at any time is also directly provided.

Tugboats were defined as *Resources* in the model. Since the system generally employs three larger tugs for long haul transits, these were set up as one resource type of 3 units. The upriver network subsystem suggested the creation of a separate resource type with units corresponding to the smaller regional tugs. In a similar fashion the downriver network subsystem had its complement of local tugboats set up as yet another resource type. With this structure in place, the result was a prescriptive elemental domain for each of the three types of resources. This helped to provide a good head start in managing the resources appropriately in each of their networks.

Locations (load / unload sites) in the model were referenced to respective shift patterns. One of the issues surfacing as a significant "what-if" candidate included the question of what shifts to operate at several locations. Perhaps around the clock operation of some sites could be shown to be non cost effective under certain conditions. Or possibly one or two sites might be eliminated altogether, yielding a positive effect to the bottom line of the entire operation.

One particularly interesting approach for streamlining the model's efficiency came to light when it was found that intuitively modeling product in terms of common entity units created an unusually (and unnecessarily) large quantity of entities in the model at any given time. As is often the case, putting entities in a discrete form consistent with a common unit of measure can be the most intuitively direct approach in simulation modeling, however it can also be the farthest from the most efficient use of the simulation engine. In this case, a common industry measure of the product is often given in units of tons. It logically follows that one might model the system with an entity being equivalent to a ton of product / material. While a workable approach, the entity volume was found to be several orders of magnitude greater than necessary. A more appropriate solution was found whereby an entity was equated with a given product load at each site. A generic routine with a simple load calculation and rate algorithm was created to determine loading time for each site by product while simulating movement of tons of product using an on screen variable. It was later found that a relatively recent *tank construct* included in *ProModel* accomplishes a similar function for dealing with continuous flow products in the process industry.

4 USE OF THE MODEL

The synthesis of the model, in large part, initially stemmed from the forecast demand structure in use for directing the operation of the system. The demand for products to be delivered is aggregately determined on a weekly basis. Basically this involves a general consensus reached between sales and production personnel in conjunction with the marine operations department. The objective is determined for the following week and a plan put in place.

It was thought that a model of the system which evaluates the activity associated with an upcoming week of system operation would be directly applicable as a tool for assessing how to best meet the demand objective with resources available. There are a few obstacles which complicate using the simulation model in this manner. While simulation lends itself particularly well to analysis of systems exhibiting random variability in their components, the situation associated with this particular marine distribution system's variability is exceedingly large over the short term. Equipment reliability and weather conditions over the span of a horizon of several days combine to make for a level of confidence which is also exceedingly large.

However, the model does prove to be a valuable asset in determining and communicating what resources should be allocated to what functions over an extended period of time. It also aids in conducting a sensitivity analysis for identifying opportunities for modifying , renovating, and revising components and operating policies respectively.

AUTHOR BIOGRAPHY

JULIAN A. SWEDISH is President and founder of J.A. Swedish & Associates, Inc. / Modeling Technologies Group, a provider of simulation and modeling software product solutions since 1990. Formerly with Technology Management Corporation, Julian has over 12 years of professional experience as an industrial engineering consultant and provider of simulation modeling based solutions for applications involving manufacturing, logistics, material handling, and business process improvement. He received a BS, in Industrial Engineering & Operations Research from Virginia Tech in 1982. He currently serves on the Advisory Board of the Virginia Modeling , Analysis & Simulation Center (VMASC). Also he is a Senior Member of the Institute of Industrial Engineers and is a past president of the IIE Southeastern Virginia Chapter.