USING SIMULATION TO ANALYZE SUPPLY CHAINS

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ABSTRACT

Supply Chain management, the management of the flow of goods or services from materials stage to the end user, is a complex process because of the level of uncertainty at each stage of the supply chain. Computer simulation, because it can be applied to operational problems that are too difficult to model and solve analytically, is an especially effective tool to help analyze supply chain logistical issues.

While most engineers have had some exposure to the tools and technology of computer modeling and simulation, the use of simulation for supply chain analysis has not been prevalent until recently. The software tool, Supply Solver, was developed in an effort to provide supply chain solutions using simulation as the foundation. In this paper, the goal will be to show how discrete-event simulation is used to analyze supply chain processes. This paper will also demonstrate what some of the considerations are in using Supply Solver to help solve supply chain design problems.

1   INTRODUCTION

The most effective supply chain management systems are designed to deliver high-quality products and services promptly and reliably at the least cost. To accomplish this goal, all the supply chain processes must be effectively coordinated.

One major obstacle in creating a seamless supply chain is uncertainty. In order to deal with this issue, managers must identify and understand the causes of uncertainty and determine how it affects other activities up and down the supply chain. Then they can formulate ways to reduce or eliminate it. Currently, tools for understanding uncertainty are limited to traditional mathematical formulas that do not account for variability. However, simulation is one of the best means for analyzing supply chains because of its capability for handling variability. Companies can use simulation to see how effective and costly an innovative inventory system such as just-in-time would be in their own environment without having to implement the system physically.

In the next section, an example of how a supply chain can be analyzed through simulation will be presented. Next, we will discuss a special tool called Supply Solver that was developed using the principles learned from this example.

2   COST AND LOGISTICS MODEL EXAMPLE

An armored vehicle manufacturer was developing a manufacturing concept for a new vehicle. There were several different methods, vendors, and locations that could be used to manufacture the vehicle each with different cost, risk, and time implications. To help solve the question of which combination of location, vendor and processes to use, the vehicle manufacturer decided to have a tool developed by Micro Analysis and Design, Inc. that could simulate a portion of the manufacturing process. The manufacturing portion modeled was the vehicle shell fabrication. The tool developed was written in Visual Basic and used Micro Saint with OptQuest as the simulation engine.

The shell fabrication process simulated is shown in Figure 1. This process was broken down into six sub-processes where several different options were available. Each option that is selected affects the flow time, labor cost, material acquisition cost, and/or capital cost in the model.
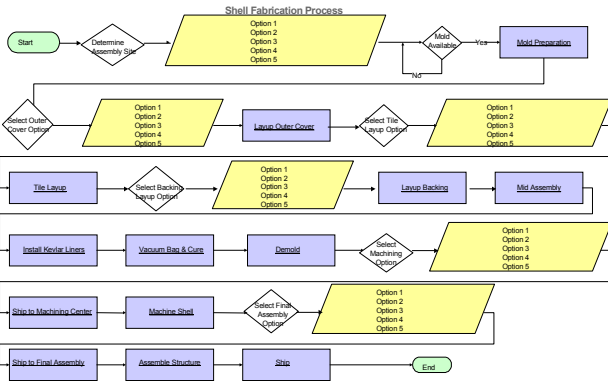
Figure 1: Shell Fabrication Process

2.1 LOGISTICS AND COST OPTIMIZATION TOOL

The tool allows users to either run selected option combinations one at a time, or run the simulation using the optimization tool OptQuest.

In order to exercise the simulation tool for one combination of options, users perform the following steps:

1. Choose one option for each of the six processes
2. Edit the location, cost, and/or time parameters for the selected options
3. View/edit the distance matrix showing mileage between option locations
4. Edit other model parameters such as production rate, number of shifts per day, number of work days per week, average transportation speed, number of assembly stations, and random number seed
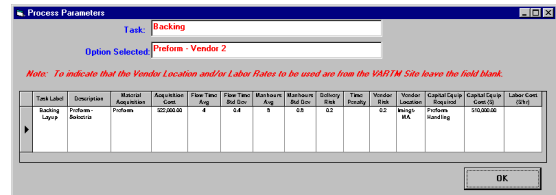5. Run the simulation
6. View results.

In order to run the simulation with OptQuest, users follow steps 2 through 6 above, but are not required to choose individual options for each process.

The tool developed allows users to select one option for each of the six different processes by selecting a radio button (see Figure 2).

Once an option is selected a window appears that shows the cost and time parameters for that option and allows any of the values to be changed (see Figure 3).

Users can also edit the distance between any of the possible locations by changing values in a distance matrix (see Figure 4).

Other model parameters are defined by filling in text boxes (see Figure 5).

Figure 2: Tool Interface

Figure 3: Process Parameter Window
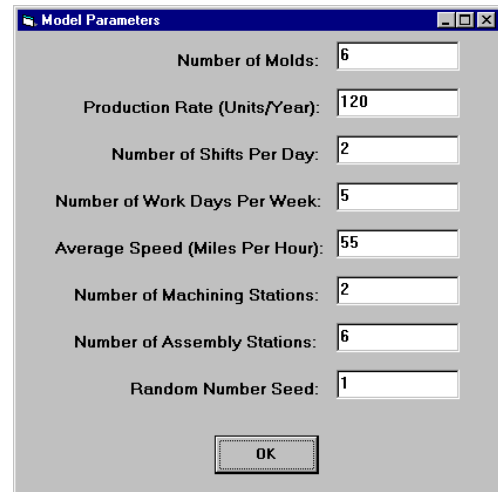

Figure 4: Distance Matrix

Figure 5: Other Model Parameters

Once the options have been selected, distances between cities verified, and other model parameters entered, the user can execute the simulation by clicking the "Run Model" button on the main screen (Figure 2). Once the "Run Model" button is clicked, a Micro Saint model is generated with the user-selected input parameters and Micro Saint is launched. While the simulation is executing, the user sees a graphical depiction of the U.S. (Figure 6) with moving icons showing the movement of materials between locations. Acquisition cost, capitalization cost, average labor hours, average labor cost, average flow time, and the number of shells assembled are also displayed and updated as the simulation runs.
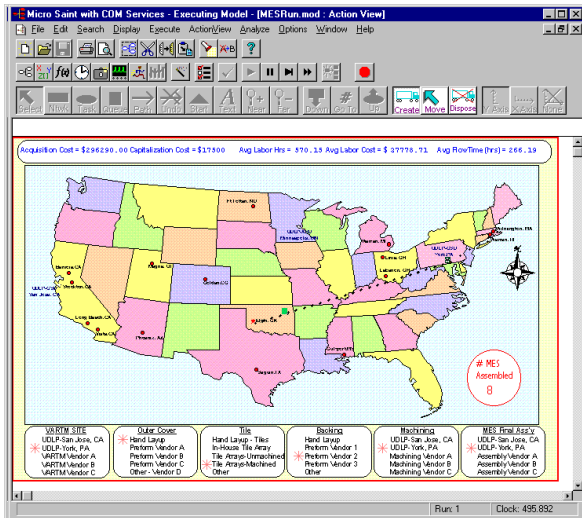

Figure 6: Micro Saint Animation Display

Once the simulation has completed, results are displayed to the user. If the production rate was met a screen similar to Figure 7 is displayed. If the desired production rate could not be met a screen similar to Figure 8 is displayed. The results shown include costs, man-hours, flow time, and station utilization. The simulation generates cost and flow time values given a user defined annual production rate. If the desired number of units per year can not be completed with the user-selected options, then additional molds, machining centers, assembly areas, etc would be required to get the job done, which would add to the unit cost. Additionally, a high risk could result in a time delay that would require additional equipment/facilities to meet the annual production rate.
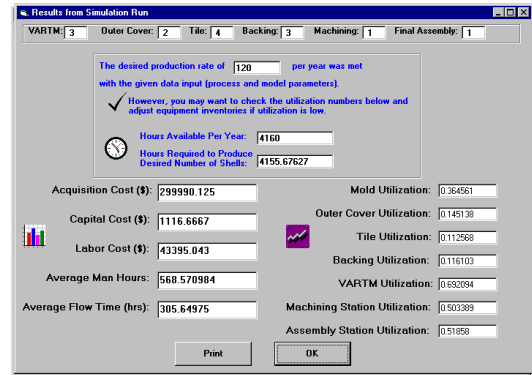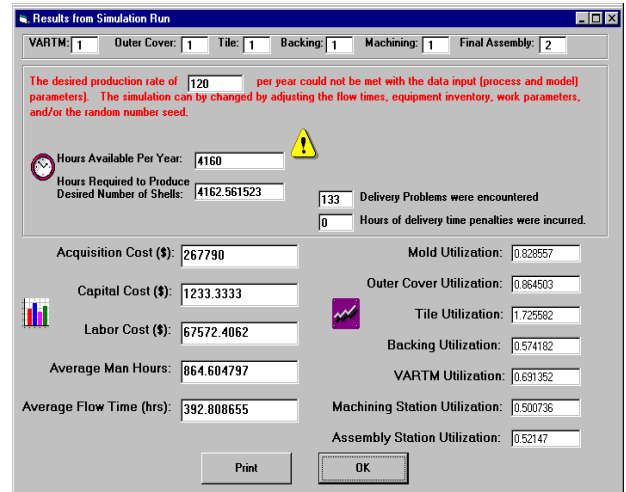

Figure 7: Result Window - Production Rate Met

Figure 8: Result Window - Production Rate Not Met

2.2 Optimization

When evaluating a system with many different combinations of options possible, it can be difficult to execute all possible combinations and identify all of the possible trade offs. The developed tool included an optimization routine to help users find the best solutions. Although users were able to play "what if" with input data and simulation scenarios to obtain potential solutions, the optimization subsystem helps to eliminate the need for random trial and error.

Earlier attempts to create methods for optimizing simulations have largely been based on ad hoc approaches that required the user to manually try many sets of input parameters. Not surprisingly, the results left a great deal to be desired. A systematic analysis of all possible alternatives may be examined. Although this approach guarantees optimal solutions, it has very limited application.

Micro Saint includes an optimization subsystem called OptQuest that allows for the complete automation of this optimization procedure. OptQuest efficiently searches for the best set of input parameters by evaluating carefully

selected simulation runs. This process obtains high-quality solutions in reasonable amounts of time with little or no user supervision. This technology greatly enhances the utility of the simulation models.

2.3 Results

Vehicle manufacturing personnel were able to successfully utilize the tool to determine the best combination of options in terms of lowest overall cost and feasible flow times. The solution set consisted of using option 1 for the initial assembly site, option 2 for the outer cover, option 4 for the tile process, option 3 for the backing, option 1 for machining and option 1 for the final assembly. The overall cost using this combination was $278,382 and average flow time of 248.5 hours.

Using Micro Saint and a customized front-end tool, the vehicle manufacturing company was able to successfully simulate a manufacturing design concept that had many different possible combinations of process options. Each option had implications on: acquisition cost, capital cost, labor cost, transportation cost and time, man-hours required, process task time, and delivery risks. The simulation was used to illustrate the effects different combinations would have on overall cost and flow time.

3 METHODOLOGY

As a result of the aforementioned example, a tool called Supply Solver was developed to help companies simulate and model their supply chains so they can analyze options on how to effectively meet customer needs. Supply Solver, which is built on the Micro Saint simulation engine, gives the user the analytical power to evaluate a variety of supply chain scenarios. Using simulation software that has been specifically designed for supply chain analysis allows users to build models of their supply chains without needing to be simulation experts.

By providing Supply Solver with information about the supply chain and the supply chain sequence, Supply Solver will automatically build a Micro Saint model custom to the users needs and designs. In addition, users will be able to test various scenarios according to the users' goals. The final results report provided to the user will allow the user to examine cost trade-offs for various scenarios.

4 SUPPLY CHAIN DEVELOPMENT

A manufacturing supply chain is composed of a series of "processes;" these processes can include manufacturing facilities, warehouse and distribution centers, and retail and service operations. In Supply Solver, the user can evaluate up to ten processes at one time. In addition, Supply Solver provides "what-if" power by letting the user choose up to

five different options per process. The Supply Solver process information screen is presented in Figure 9.

Figure 9: Process Options Screen

The user must also specify how many lots can be handled at one time for each process. This number can vary from process to process.

4.1 Process and Options Information

The process and option information screen is the driving force behind Supply Solver. This is where the user enters all the data for each process and option in the supply chain. The Supply Solver process and option information screen is presented in Figure 10.

Figure 10: Process and Option Information Screen

4.1.1 Timing Information

The "process time" is the total amount of time required to produce one lot. For example, if the process is a warehouse, then the process time is the time it takes to deliver the lot of product from the warehouse to the next process. If the process is a manufacturing plant, then the process time is the time it takes to produce one lot of product and deliver it to the next process in the chain.

If the user is interested in analyzing the supplier's impact on the supply chain, the user may associate a

delivery risk to that supplier. The delivery risk is actually a percentage that the lot will be produced or shipped late. It gets implemented as a time penalty against the total process.

4.1.2 Cost Information

Examining the cost trade-offs of various suppliers is often the driving force behind supply chain decisions. Supply Solver allows the user to analyze make vs. buy decisions. If the user wants to analyze making a product versus purchasing it, then the user must enter data like average man-hours required and labor rate. The "acquisition cost" is the cost for acquiring a product from a supplier or buying materials from a supplier for in-house manufacturing. "Additional costs" can account for any additional costs that might be associated with the process, such as work-in-progress, inventory etc.

4.1.3 Miscellaneous Info

The location of the process can be selected from a drop down menu and currently, Supply Solver only has selections for major cities in the United States. The "number of lots per year" is the target number of lots for the overall supply chain and the model will keep running until all of the lots are built. The "number of eight hour shifts per day" is the number of shifts being run at each facility and is used in calculating labor costs. The number of workdays per week that the plant runs must also be specified.

4.2 Process Sequencing

The flow of the supply chain must also be specified and is done easily with a point and click interface. Supply Solver allows the user to create virtually any type of supply chain flow. For example, if a laptop computer manufacturer builds the processor and keyboard base of the laptop, but orders the monitor from a supplier, the final manufacturing process of putting the two pieces together cannot occur until both parts have arrived. Supply Solver will wait for parts to come back together before continuing on to the next process.

4.3 Animation

Using the information provided by the user, an animated map of the United States allows the user to watch the flow of their supply chain in action. Information such as acquisition cost, capitalization cost, average labor hours, average labor cost and average flow time is updated in real time. See Figure 11 for an example of the Supply Solver map.
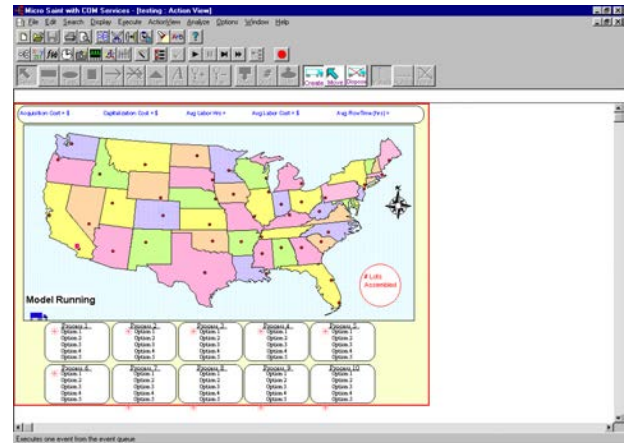

Figure 11: Supply Solver Map

5 RESULTS

Using automatic data collection, Supply Solver collects certain cost and utilization data (see Figure 12). This data can either be printed out to a hard copy or an output file can be created for use in an external statistical package such as Microsoft Excel. If the user wishes to change the options selected or change the flow of the supply chain and compare it to the last analysis, Supply Solver allows the user to add data on to the last output file for convenient comparison of the two supply chains. Through the results of the simulation analysis, users can assess the relative merits of alternative supply chains as well as predict their impact on costs and delivery.
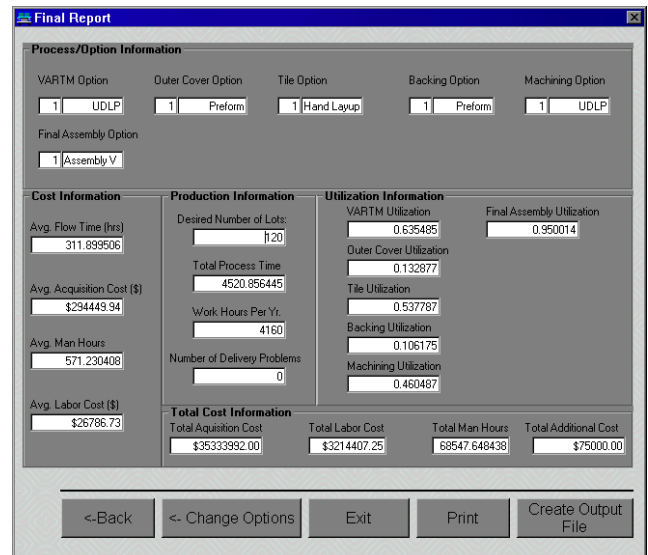

Figure 12: Supply Solver Report

6   SUMMARY

Supply Solver is a powerful tool for evaluating the dynamic aspects of supply chains within a wide variety of manufacturing areas. Supply Solver's primary strength is its "self authoring" system in which each supply chain can be built for any specific manufacturing area. With its easy-to-use graphical interface, users can quickly develop supply chains that accurately represent their system. Users are then able to evaluate "what if" scenarios with a variety of inputs to find the optimal solution. Using simulation to evaluate supply chain design can lead to better decisions, saving money, increased productivity, and improved customer service

Based on the success of the Micro Saint tool we developed for the armored vehicle manufacturer we were able to apply those best practices to our Supply Solver tool. Now other companies can benefit from the power of simulation by using Supply Solver to model their own supply chains.

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