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DISCRETE SIMULATION DEVELOPMENT FOR A PROPOSED SHIPYARD STEEL PROCESSING FACILITY

Daniel L. Williams

Electric Boat Corporation
75 Eastern Point Road
Groton, CT 06340, U.S.A.

Daniel A. Finke
D. J. Medeiros

Department of Industrial & Manufacturing Engineering
310 Leonhard Building
The Pennsylvania State University
University Park, PA 16802, U.S.A.

Mark T. Traband

Applied Research Laboratory
The Pennsylvania State University
P.O. Box 30
State College, PA 16804, U.S.A.

ABSTRACT

This paper describes the efforts required to convert conceptual designs and undefined processes for a proposed advanced steel processing shipyard facility into a discrete event simulation. Modeling of a completely non-existent entity poses many difficulties, yet the results can still be beneficial. The lack of actual production data and corresponding business rules, causes an in-depth review of all available information combined with that which can be extrapolated from vendor specification sheets or human experience. Most of the equipment required for this advanced processing facility will be custom built to suit the needs of this highly technical complex. This facility which will ultimately support construction of vessels, was driven by high expectations of improved production efficiencies. The model is expected to support not only the pre-construction design phases of the building, but also to serve as a post-construction production planning tool.

1 INTRODUCTION

Discrete event simulation, has primarily been used to show decision makers the dynamics of the current system and present alternatives as to how it could be improved, but when the facility does not exist yet, the first component of normal analysis does not exist. Creating a simulation with little or no a priori information is difficult at best. In cases like this the most common thing to do is to mine information out of existing, related systems, and use this information to create statistical approximations of the system being analyzed. This paper describes the process and the difficulties of creating a simulation with very little information provided up front. Discrete simulations require information such as, processing time required by individual components on all proposed machines, intra shop material flow, machine capabilities and limitations, as well material handling methods.

The system under consideration is an advanced steel processing facility. This multi-million dollar, state of the art facility is intended to support the production of cut plate and extruded shapes for ships.

Raw stock (mostly steel) will be fed into one end of the building, where it will be sand blasted as necessary, to remove any surface scale. The plate material will be laser marked, before being moved to cutting machines. The facility will feature numerically controlled (NC) laser, plasma, and water jet cutting machines for processing plate stock. An NC band saw will be utilized for cutting the extruded shapes. After the cutting operations are complete, the skeleton plate and cut pieces will be separated and grouped according to their designated sub-assemblies. Some of the components may receive additional processing such as hand beveling, bending, and/or roll forming within the facility. The groups or "kits" will then exit the opposite end of the building and move to assembly areas.

Unlike most automated production facilities, this one will produce very few "like" components. The vast majority of components that are to be produced are totally unique. Each has its own geometry and scheduled due date. Sub-assembly components that happen to share the same material and have very close schedule requirements might be "nested" together for processing. The likelihood of that particular combination re-occurring is almost non-existent, therefore, the exact same operations are seldom, if ever, repeated.

These hurdles had to be overcome in order to produce a discrete event model and associated simulations to support the requirements of the proposed steel processing facility both during its design stages and ultimately into production planning activities after construction is completed.

2 GOALS FOR FACILITY

The proposed advanced steel processing facility is being built and outfitted with several goals in mind. The primary goal is to reduce the costs associated with the production of structural sub-assemblies for vessels.

One of the major cost saving steps is the implementation of plate marking to eliminate 2-Dimensional (2D) drawings from the structural assembly process. The intention is to mark the plate with as much construction information as possible. Information such as footprint lines for placement of "to-be-attached" components, joint identification numbers, specific welding requirements, and miscellaneous construction notes would be scribed onto the plate to aid the subsequent assembly processes.

In a pilot study, two mirror-imaged sub-assemblies were constructed. The first was processed using traditional methods which required an experienced ship-fitter and numerous sheets of 2D drawings. The second was constructed using pre-marked components and no 2D drawings. A two-page document containing general instructions and an isometric drawing of the completed sub-assembly, accompanied the components. These components were given to a less experienced ship-fitter for construction. The implementation of the "marked" process showed more than a 20% reduction in construction time.

An additional cost saving measure to be incorporated into the facility is an increased velocity of cut parts. A 5-day cycle has been targeted as the goal for kit completion and delivery to the assembly areas. Currently, parts can be produced weeks before they are required to support sub-assembly construction. The elimination of excess storage will help reduce costs.

3 GOALS FOR MODEL

The creation of a discrete event model was implemented as a means of fulfilling several goals related to the proposed facility. Once created, the model would use simulation to visualize steel processing activities as well as provide a tool used to analyze material flow and potential processing bottlenecks within the proposed facility.

The model was to be jointly developed at two separate sites. Both sites would work closely together to assure that all the requirements were obtained. The site of the proposed facility would provide overall guidance and direction toward the desired requirements. The second site, would primarily be responsible for the implementation of the requirements.

Additionally, the simulation of the model was intended to help assess alternative production scenarios during the design stages of the facility. As a result of the frequent modifications, there were several versions of "the model" created. Figure 1 represents one of the modeled versions. Each version reflected the latest concepts and ideas for the proposed site, to date.

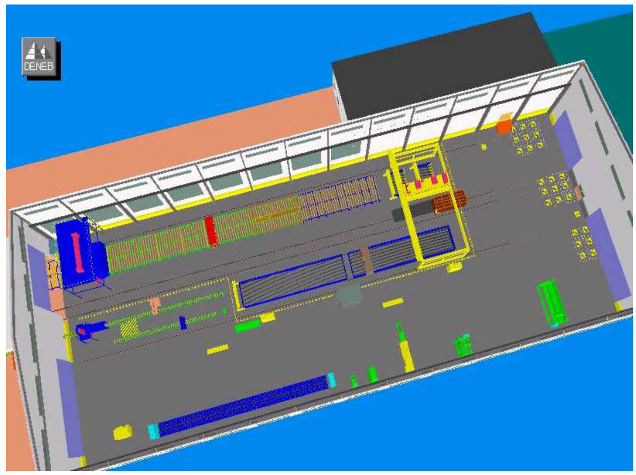

Figure 1: Model of Proposed Facility

All of the intended processes were to be included within the model and corresponding simulations. It was intended that existing production process data would be utilized when available. It was anticipated that statistical distributions would be used to represent data that was not readily available. This would certainly include the information related to the automated marking process. It was hoped that the use of simulation would help to determine marking's impact on production.

The model was to survive the design phase of the building and persist to support the actual production of steel. It was intended that the model would always be available to use as a planning tool for resource analysis and to help define manning requirements for the facility.

One of the last goals for the model, was to expand the use of simulation technology within the company and for possible incorporation into other production programs.

4 DISCRETE EVENT SIMULATION TOOL

The discrete event simulation tool used to analyze this system was *Quest*, which is software product from the Troy, Michigan based Delmia Corporation. The former Deneb

Robotics was merged with other companies and renamed Delmia. *Quest* is an object oriented discrete event simulation package with very powerful 3-Dimensional (3D) visualization capabilities. It also provides two programming interface languages, that enable a great deal of control for displayed graphics and "custom" machine processing behaviors during simulation.

The *Quest* modeling software pre-existed at the modelers' sites, and was therefore, the obvious choice of tools. An existing software tool, at the site of the proposed facility, enabled CAD geometry to be pulled directly into the *Quest* simulation package.

5 MODELING DIFFICULTIES AND SOLUTIONS

The fact that this modeling task was assigned to a very much undefined facility caused a great deal of problems. The equipment and its configuration changed frequently. Equipment would need to be custom-built to support the large scale requirements of ship construction., thus presenting more unknowns to the model. Processes were to be modeled and simulated, that had never been attempted previously by the ship builder. There were no "house" rules related to production, in place to help guide model development. Vital pieces of data required to accurately simulate the desired processed were missing. The default processing as provided by *Quest*, typically did not work for simulation of shipbuilding processes. Most processing modules required custom software.

5.1 Changing Model Geometry

The geometry for the facility was created on the shipbuilder's CAD platform. It would then be translated and converted into the format used by the discrete event modeler. From the start of the project, the only thing that stayed constant was the overall dimensions of the building. The model layout changed frequently. Each change would result in a near complete make-over of the model. The equipment would typically be relocated or would be modified in such a manner that the previous version was useless. Sometimes, equipment would be removed completely. In an attempt to keep up with these seemingly endless changes, some methods were implemented to assist the "rebuilding" process for the model.

Models of individual components were created and saved with localized "footprint" origins. Spreadsheets were created that contained the component names and location offset values to position each component within the building. Subsequently, macros were written to read the spread sheet data and programmatically re-position the components within the model. These tools provided an easy method of keeping up with the frequent changes to the equipment arrangements. Most changes would only require spreadsheet modifications.

5.2 Undefined Equipment

The equipment required for large-scale steel processing is typically custom-built to suit the needs of the "steel manufacturer". This equipment tends to be very expensive and therefore, has a tremendous effect on the capital budget for a project. Equipment specifications are given to several potential suppliers for proposal bids. Final equipment selection is then determined as a result of these returned bids.

Modeling equipment which exists only in the format of a proposal, is most difficult. There is typically no actual geometry available, making the allocation of floor space and the physical operation of the machine a "best guess" entity. All shapes and sizes are approximated. The motions performed by the machine during processing, are likely not well defined, thus affecting the model's kinematic behavior.

Additionally, the processing speed(s) can only be estimated by the equipment supplier and may not be very realistic. These processing speeds play a critical role within a discrete event simulation. Each simulated process requires some amount of time to be executed by the "machine". The inter-relationship of these timed events provide the basis of a simulation. It is near impossible to obtain good analysis results, when the major controlling factors are relative unknowns.

There is little that can be done to minimize the work accompanying the different geometric versions of the "same" equipment. The best that can be attempted is to assure that the custom written "processing" software, is flexible enough to be quickly modified to suit the configurations from individual vendors.

Since all "flavors" of a machine perform the same generic functions, the same terminology can be applied to their process calculations. It is highly suggested that software defined constants be used to contain the values associated with specific processes, in lieu of using numeric values for the required formulas.

Processing characteristics, such as the speed of an operation, for a machine were assigned as user-defined machine attributes within the model. Likewise, user-defined part attributes were assigned to contain specific characteristics (such as the length of edges to be cut), that influence the processing for individual components. The calculations for operation times, could then be based upon part and machine attributes. The corresponding software would thus, not require modifications as alternate machines were swapped into the model.

Machine attributes can be easily modified through the software's user interface. Most part attributes are read in as part of the schedule data file, which is also easily modified. In some cases where part attributes are generated based on distributions fit to collected data (marking information, for example) changes to the code are required.

5.3 No Business Rules

All of the machines and their associated processing capabilities will be new when the steel facility comes on-line. As discussed previously, the capability rules that apply to individual machine processes are "fuzzy" at best.

Of greater importance are the business or "house" rules that apply to the network of individual machines that comprise the entire facility. These rules would typically define the interaction between the individual components of the system. Examples would include the anticipated mix of materials to be processed, the desired manning of the facility, or the handling of "in-process" materials as it moves from one machine process to the next.

These decisions might be based on safety concerns or the pre-existence of "tried and true" equipment. The workers may belong to a union that restricts the functions that can be performed by an individual. There may be business rules that define the number of daily work shifts. There are numerous reasons that formulate a company's business rules.

In the situation, where a new facility is being defined that utilizes advanced technology, things will definitely not be done as in the past. A certain amount of "cultural shock" is inherent with the new processes. This complicates the development of business rules.

The development of a discrete event model and its associated simulations requires that the applicable business rules be included. Without a set of business rules to guide the model development, modeling is most difficult. Having rules that continually change, pose a significant challenge to model development as well.

One tool that was implemented was a spreadsheet for each machine. This sheet was used to identify individual processes and/or sub-processes and the data anticipated for process calculations. Additionally, the data values were marked for their likely source and availability. Any business rules that may have been suggested for the particular machine, are also included on the sheet. This served as a convenient method to organize the known data.

5.4 Data Collection

It was determined that significant amounts of the data required to support model simulations was unavailable. A great deal of effort was focused on obtaining this data. Vendor supplied processing information was collected. Numerous interviews were held with people possessing a strong knowledge of the current system. Large samples of data were collected from the currently used 2D drawings. The data samples were extrapolated, analyzed and fitted with formulas. These were then used to statistically estimate "missing" values for the simulations.

Not all of the data was missing, however. It was determined that existing schedule data could be utilized as the primary driving mechanism for the simulations. This was a major asset to the modeling effort as well as a "confidence bolster" for the shipyard management.

The model was developed to function in one of two modes of operation. The first one would strictly adhere to the scheduled events. Each piece of raw material would enter the system only when released by the scheduled date. In the other mode, the schedule would be used to identify the required raw materials, but they would be released into the system without regard for scheduled dates. This allows the maximum capacity of the facility to be analyzed or alternate schedule scenarios to be utilized.

It should be noted that in this particular application, projected schedules exist for individual parts going out years into the future based upon programmatic requirements. This is likely not the case for most steel processing facilities.

5.5 Undefined Kitting Areas

One of the largest problems encountered was the modeling of the part collection or kitting areas. Essentially, pallets are used to collect all the pieces for a single sub-assembly. These pallets are stored within the facility until all required components are completely processed. The goal was to not allow any single pallet to remain within the facility longer than five days. This would serve to reduce the amount of space required for kits and also provide the follow-on assembly processes with "just-in-time" components.

The amount of area to be allocated for pallet storage, like all other elements of this effort, was undefined. The amount of area required for each pallet varies greatly depending upon the size of the components being collected. The actual quantity of kitting areas within the facility was also unclear. It had not been decided whether the pallets would be stored and loaded on the floor, or if some sort of a vertical rack system would be used. Would a combination of horizontal and vertical areas be required? What would happen if there wasn't enough room to physically store the active pallets? Again there were many hurdles to be overcome by the modelers.

The kitting areas were modeled with numerous possible locations on which the pallets could be stacked. An algorithm was created that would programmatically position these stack points based on kitting information supplied by the user. The quantity, locations, sizes and specific type of areas were defined at the start of the simulation. The corresponding areas were created "on-the-fly" and subsequently used by the current simulation.

Kits that physically could not be placed within the defined areas, would be allowed to "float" in the space above the designated kitting areas. This would allow the simulation to continue running without interruption. Any kit that reached the "overflow" area would be graphically shown as a red pallet. This would allow immediate recognition of kitting problems within any simulation run. As "valid" kits would fill and exit the system, overflow kits could move down into the "now available" area as permitted by size.

Each kit would keep track of the amount of time it was in the system. If part of the time was spent in overflow, that portion would be tracked and reported separately. Kits also keep track of the quantity of components received and change geometry accordingly. The intention is to allow the kitting area(s) to be visually analyzed during the simulation.

The designed purpose of the kitting area software was to assist with the actual design of the kitting areas for the facility. At the time the model was created, very little thought had been given to the kitting areas. This tool would allow numerous "what-if" configurations to be tried for the kitting area design. The same schedule would be executed repeatedly to evaluate the various alternatives.

5.6 Steep Learning Curve

There is a significant learning curve associated with effective discrete modeling and simulation. Individuals must gain a thorough understanding of numerous areas, in order to produce the desired results.

Discrete event simulation tool packages provide easy methods to create simple models that execute default processes. Typically, the modeling tools have many intricacies that combine to create the entire package. All of the details related to the package must be understood to determine those that can be applied directly to the modeling task at hand. Depending on the complexity of the tool, this could represent a substantial amount of "educational" time.

Typically, individuals creating the actual models and the corresponding simulations do not possess an initial understanding of the system being modeled. Therefore, a significant amount of time must be spent extracting "production" information from the "system knowledgeable" people. This information must then be converted into terms of the discrete event modeling and simulation package. The production people typically do not understand the modeling tool nor its requirements. Therefore, the learning curve is applied to both groups of individuals as they combine their skills to produce a computer model of a production system.

As the simulated processes become more complex, there is an increased requirement for custom designed software. This requires not only an understanding of the processes being modeled, but also a certain amount of programming skills. Internal programming languages provided within the modeling tool must be learned by the model developer to support the needs of the application. The "process" modules must be designed and coded to effectively interface the capabilities of the modeling software package and the requirements of the model.

If the model is to ultimately be "turned over" for use by production people, certain amounts of "user interface" code must be developed in addition to that required to support the actual modeled processes. This typically requires the skill to produce the menus, pop-ups or other methods employed to communicate the needs of the user, toward the current simulation's execution. An understanding of the end-user's knowledge level and his/her production-related terminology is critical to making an effective interface.

6 POTENTIAL FUTURE MODELING

The modeling of the proposed facility was incomplete at the time of this writing. Additional efforts required include the incorporation of "end of shift" status collection and the corresponding reallocation of "work in progress" for subsequent executions. Additionally, the expansion of the model to include the extensive storage yard for plate and extruded-shape raw materials, needs to be accomplished.

A logical follow-on modeling task would involve the actual construction of the sub-assemblies in other buildings that may or may not exist.

7 SUMMARY

In summary, creating a simulation of a nonexistent facility can be very difficult, however, some of the difficulty can be alleviated through communication between the decision makers and simulation analysts.

Modeling tasks of this sort, should be approached, knowing in advance, that everything is going to change. Therefore, efforts should be made to anticipate these areas and provide mechanisms that facilitate this evolution, right from the start of the project. Flexibility must be incorporated into every aspect of the modeling and simulation development.

Attempts should be made to "automate" model construction steps that are typically performed manually. It is very likely that the model will be built several times before the "final" version is created. Time spent developing macros that locate and "connect" geometry for instance, will save significant time as the model changes occur.

The software modules should be designed to be flexible. Constants and variables should be named so that their meanings are very clear. The formulae used to define the production processes should be as generic as possible. The goal is to allow high-level changes to quickly fulfill all of the required modifications to the code. The modules should be well commented to provide an understanding of the intentions of the code

Efforts should be applied to developing tools that allow the "current" model to assist with the design of the facility. Areas with "fuzzy" processing definitions can be better defined by examining alternate configurations within the model. A simple "user-interface" can be installed to facilitate the definition of these configurations. As these areas become more thoroughly defined, the value of the model improves.

The development of a 3-Dimensional discrete event model and its associated simulations can be very beneficial to evaluating a completely new production facility. Some of these benefits include the ability to "see" the new facility and its anticipated production processes.

This visualization provides tremendous value toward the "selling" or describing of the intended facility. Certainly a computer model is easier and cheaper to modify that an architectural "scale" model would be. The ability to simulate the processes cannot be accomplished by a scale-model.

The ability to analyze production bottle-necks, machine efficiencies, the application of labor, or the affects of machine breakdowns on production, can easily be accomplished through discrete simulations. No other tool would provide information of this nature.

The identification of information missing from current applications, but of great importance to the new methodologies, is an important by-product of the modeling development. Methods can subsequently be determined to ascertain such missing data for inclusion in actual production support.

Models can be developed to support production needs beyond the initial design phases of a new facility. A successful implementation of discrete event modeling could easily satisfy both pre- and post-design requirements. Models can easily be used to periodically evaluate production schedules on the new facility as time advances.

AUTHOR BIOGRAPHIES

DANIEL L. WILLIAMS is a Software Engineering Specialist at Electric Boat Corporation. He has worked at Electric Boat since 1981. He received an A.S. in Data Processing from Thames Valley State Technical College in 1981 and his B.S. in Computer Technology from the University of New Haven in 1985. He has been involved with various types simulations for over 18 years. He has worked on or lead projects involving Simulation-Based Design, kinematic, ergonomic, as well as discrete event simulations for various types of vessels. These simulations support design and construction activities for these vessels. His email address is <dwillia1@ebmail.gdeb.com>.

DANIEL A. FINKE is a graduate student at The Pennsylvania State University pursuing an M.S. in Industrial Engineering and Operations Research. He received his B.S in Industrial Engineering from New Mexico State University in 2000. His current interests include simulation-based optimization and decision improvement. His email address is <daf903@psu.edu>.

D. J. MEDEIROS is an Associate Professor in the Industrial and Manufacturing Engineering Department at The Pennsylvania State University. She holds a B.S.I.E from the University of Massachusetts and M.S.I.E and Ph.D. from Purdue University. She has served as Track Coordinator, Proceedings Editor, and Program Chair for WSC. She is a member of IIE. Her research interests include manufacturing systems control and CAD/CAM. Her email address is <djm3@psu.edu>.

MARK T. TRABAND, Ph.D has been employed as a Research Associate at the Applied Research Laboratory, The Pennsylvania State University since 1990 (ARL Penn State). He is currently the head of the Manufacturing Systems Division. Dr. Traband received a B.S. degree in Industrial Engineering from Virginia Polytechnic Institute and State University in 1985. He was selected as an Office of Naval Research Graduate Fellow in 1985. He received his M.S. and Ph.D degrees in Industrial Engineering from The Pennsylvania State University in 1987 and 1995. His email address is <mtt1@psu.edu>.