Proceedings of the 1991 Winter Simulation Conference
Barry L. Nelson, W. David Kelton, Gordon M. Clark (eds.)

CAPACITY PLANNING IN WOOD PRODUCTS INDUSTRY USING SIMULATION

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ABSTRACT

Simulation has traditionally been associated with the design and analysis of systems. This paper presents an analysis of an office furniture manufacturing facility for its capacity and in-process storage related problems. SLAM II simulation language is used in this study. Several scenarios were also developed to determine alternate solutions to the stated problems. Important simulation results are also discussed for each of these scenarios.

Key words: Capacity Planning, Network Model, Verification,
Simulation, Experiment, SLAM II

1 INTRODUCTION

Simulation modeling is a powerful decision support tool which is experiencing wide-spread growth in application in both manufacturing and service industries. Simulation modeling is being used to describe, analyze, design, and predict the behavior of complex systems. Rapid growth in the use of simulation modeling is likely to continue as advances in computer hardware and software technology result in simulation systems that are more readily available and are increasingly easy to use. A few of the facts supporting its popularity and success are:

1. identification as a key technology for manufacturing engineers in the twenty-first century, with its use predicted to increase from a current base of 17% to 40% by the year 2000 (Bergstorm, 1988),

2. endorsement by the U.S. Department of Defense as one of the top 20 critical technologies based on performance and potential for strengthening the industrial base (Challenges, Council on Competitiveness, 1990), and

3. projected growth rate exceeding 20 % per year in the manufacturing market (Musselman, 1990).

Simulation modeling is suited for situations where there is a high degree of uncertainty and where experimentation with actual systems is either costly or otherwise impractical. It helps one understand the potential impacts of various events on complex systems, avoids risk or disruptive experimentation on an actual system, and compresses time so that long range effects can be analyzed.

Herman Miller Inc., located in Zeeland, Michigan, is one of the three largest office furniture manufacturer in the country. The other two major furniture manufacturers, SteelCase and Haworth Inc., are also located in fifty miles radius. The company is seventy five years old and specializes in a wide variety of office furniture.

2 HISTORY AND PROBLEM DOMAIN

Lately, one of their division has been facing frequent capacity problems. Often deliveries are not made on their scheduled dates. The manufacturing facility is also experiencing serious backlog of in-process material. This has resulted into a strong belief among production supervisors that the designated storage areas are not adequate to keep up with the increasing demand.

Eight main product families were identified in office furniture category, the differences being pronounced mainly by 1:shape of the product - rectangle/corner, 2:type of lamination-HPL/veneer and 3:shape of edges-AOE-/Etho (AOE has all straight edges while Etho has one or two rounded edges). A complete product family list in this category is as follows:

1) AOE/HPL - Rectangle
2) AOE/Veneer - Rectangle
3) Etho/HPL - Rectangle
4) Etho/Veneer - Rectangle
5) AOE/HPL - Corner
6) AOE/Veneer - Corner
7) Etho/HPL - Corner
8) Etho/Veneer - Corner

Of these eight families, each has different products, the differences pronounced by length, width and color bringing the total no of products to more than 300. The production takes place in batches. Wood laminations are produced in hot press whereas HPLs are laminated either in lamline or in cold press. These laminations are arranged in batches of twenty on skids for rectangle or corner product families. The batches of jobs are then transported to the storage area S1. Here on each of these batches is referred to as a job. All rectangles are processed for edgebanding operation in one of the two (T2 and T4) edgebander in the rectangle product area. All corners are processed in one of the two Hi-Frequency edgebanders (T3). Among rectangles, T2 edgebander processes rectangle-HPL jobs while T4 edgebander processes rectangle-veneer only. Each edgebander processes these jobs for a time that includes pass time and the set-up time. AOE jobs require two passes and hence are routed back to the edgebander for further processing. After the jobs are completely processed on edgebanders they are routed to the second storage area S2. The jobs from S2 are either sent to bullnosing or to packing. About 70% of etho-rectangles are required to be bullnosed whereas remaining 30% can go together with AOE-rectangles directly to the packing area. All bullnosed jobs are also sent for packing subsequently.

Corner jobs are processed in a manual line. From the storage area S1 corner-veneer jobs are routed out of the facility while corner-HPL jobs are processed further. Of these AOE jobs go through vinyl pounding while Etho jobs go through bull nosing. After this they are processed in one of the 2 available Hi-Frequency T3 edgebanders. The jobs finished in T3 edgebanders are routed to storage area S2 before packing.

The final activity in the facility is boring and packing. There are two packing lines P1 and P2 for this purpose. These lines are used on a certain preferred order basis. P1 preferentially processes rectangle-bullnosed (Ethos) jobs, however if it is free it also processes rectangle-nonbullnosed (AOEs) jobs. P2 preferentially processes corner jobs, however if it is free it also processes rectangle-nonbullnosed jobs.

3 PROBLEM DEFINITION AND OBJECTIVES OF THE STUDY

As mentioned earlier, the facility is experiencing capacity and in-process storage problems. Several options were being considered to improve the production rate to meet the demand. These options included: (1) expanding the floor space and install additional equipment. The list of equipment included - i. an identical edgebander ii. bullnosing station and iii. packing station, all in the rectangle line area; (2) increasing the buffer storage capacity in S1 and/or S2 locations; and (3) adopting different scheduling and operating strategy for edgebanding. Also there was an interest among decision makers as to find out if there is any useful relationship between production batch size, effective production capacity and in-process storage capacities. Therefore, the following objectives were defined for this study:

1. Model the facility to analyze capacity and in-process storage problems, and

2. Establish relationship between parameters of interest such as, batch size, production capacity, throughput time and in-process storage.

4 METHODOLOGY

The specific steps taken to perform the study were as follows:

4.1 Assumptions

Several assumptions were made to model the real world system. Some of these assumptions are as follows:

1) There are three important attributes to classify the entire range of products manufactured on the dedicated lines. Each attribute has two values making a total of eight product types.

2) The weighted average properties for each product type will provide a satisfactory approximation for estimating system performance. Processing time, setup time, waiting time in different queues and batch size are some of the properties of interest for this study.

3) The stack size for rectangle line is 20 for all operations except shipping. Ten finished packs form a unit load for shipping.

4) Jobs that require more than one pass for edgebanding operation are processed lot wise for each pass. The lots are stacked to be returned to the feeding station. The setup is made for the next pass. Travel time is assumed internal to the setup time.

5) Whenever the queues in front of the packing line selection overflows, the overflow jobs are balked to the back of the second storage area.

4.2 Data Collection

The data collection was focussed in determining:

1) Product demand level and any seasonal pattern.
2) Operation sequence and material flow for each product type.
3) Operation and setup times for various operations and products.
4) In-process storage capacities at various stages.
5) Priority rules and resource allocation criteria for critical operations.
6) Production batch size and unit load for transportation.

4.3 Development and refinement of the simulation model

Development of the SLAM II model was straightforward once the necessary preliminary information had been obtained. The model was developed by breaking product flow into three distinct segments: Lamination; Edgebanding and Bullnosing; and Packing. Network diagrams and code were developed and tested independently for each segment. The three segments were then combined to allow the simulation experiment to be run.

4.4 Execution of the simulation experiment

The simulation experiment consisted of seven individual runs of the model under different units of critical resources, batch sizes, resource allocation criteria and demand rate assumptions. Each of the seven runs were designated as a case which are as per the following list:

Case 1: Basecase
Case 2: Basecase + 3rd Packing line
Case 3: Basecase + Edgebander Flexibility
Case 4: Case 2 + Case 3
Case 5: Case 4 + 30 blanks per job
Case 6: Case 4 + 10 blanks per job
Case 7: Case 4 + 50% increased throughput

4.5 Aggregation and analysis of simulation output

Data from the histograms and tabular output of SLAM II were aggregated and used to develop graphs showing the relationship production capacity, queue lengths, batch size, and throughput time.

4.6 Formulation of the Model and the Network Diagram

The model was formulated and run in the SLAM II modelling language. As mentioned earlier, the product classification was done with eight different types. Eight arrays define the process time for the eight types of jobs. Each array consists of three entries, the entries being first pass time, second pass time and packing time. The products were coded one through eight which unambiguously determined the array number corresponding to a product. This strategy of using arrays for process times rather than using individual attributes helps us cut the amount of memory used drastically.

The edgebanders T2, T4 and T3(2 of them) are all defined as RESOURCES in this model. The spaces in front of the edgebanders SP1, SP2 and SP3 (2 of them) are also defined as resources.

A main CREATE node was used to create the jobs at an uniform rate with the Time Between Arrivals calculated on the assumption that the facility runs two shifts a day and 250 days a year. Each job represents a batch of 20 blanks. The creation time (job arrival time) is marked on the first attribute of the arriving job. From here the jobs are routed to one of the eight different ASSIGN nodes according to the probabilities of each where three different attributes are assigned. The attributes being N: define the type of job (coded 1 through 8), TYP: 0 for HPL and 1 for veneer, NP: Number of passes of edgebanding the job has gone through.

Following these the jobs are routed for lamination. HPL jobs can go to either the Lamline or the cold press. Veneer jobs go to the hot press. So HPL jobs are routed to Que1. Both Lamline and cold press serve this queue on a preferred order basis with lamline being preferred over the cold press. The incoming HPL job would wait in Que1 if both lamline and cold press are busy. Veneer jobs go to Que2 that feeds to the hot press. Following this all jobs go through a transport activity. Here the rectangle jobs are sent to Que14 and the corner jobs are sent to Que4. Que14 and Que4 put together represent storage area S1.

From Que14, HPL jobs are processed by T2 edgebander and veneer jobs are processed by T4 edgebanders. In practice, when the operator finds that he needs a job for processing he gets a fresh batch to the space in front of the edgebander for processing in the edgebander. To model the processing of job requests that is determined by the current status an in-process job, a different logic is employed.

A special create node is used to create dummy job requests. In this section, a total of 4 dummy jobs are created per run. Of these 4 dummy jobs, 2 are sent to Que16 with attribute TYP equal to 0 and 1 is sent to Que15 with attribute TYP equal to 1 and 1 more to Que 15 with attribute TYP equal to 0. These dummy jobs are designed to control the flow of real jobs through the edgebanders.

A MATCH node M1 matches the entries in Que14 and Que15. When a match is found the job from Que14 is sent to a GOON node G3 and the job from Que15 is destroyed as this was a dummy job. The job in the GOON node G3 can be either an HPL job or a veneer job. From here HPL jobs are sent to Que5 where they wait for SP1(space) and veneer jobs are sent to Que6 where they wait for SP2. Once SP1 is assigned to a particular job it is sent to Que7 where it waits for the edgebander T2.

Once an edgebander is assigned, the job is released from the node and is processed for 6.17+passtime*15 minutes. After this the job is duplicated. One of the resulting jobs frees resource SP1 and is sent for 'Job nearing completion checking routine'. All AOE jobs require 2 passes and all Etho jobs require only one pass. So an AOE job that has gone through only one pass is not nearing completion as it has to go through another pass. Based on this logic, if a job is about to be completed the job is routed to Que15 as a dummy job request. The second job goes through further processing for another 5*passtime minutes. After that if the job requires a second pass it is routed back to Que5 for the second pass, else T2 is freed and the job is sent to Que9, the second storage area S2. The edgebander process five blanks in a flow line pattern and that's the reason why the space is freed 5*passtime minutes before the edgebander.

The veneer jobs are processed by T4 edgebanders and the model follows exactly the same logic. This logic ensures that the practical situation is represented accurately by the model.

The corner jobs from lamination come to Que4 where they are stored pending edgebanding. Here there are two edgebanders(T3) and the operator accepts a job whenever an equipment is free. Hence a logic similar to that applied for the rectangular jobs is used here. Que16 contains the dummy job requests.

After T3 is assigned to a corner-veneer job, the job goes through the edgebanding activity for 20*passtime minutes. After this SP3 is freed and the job is duplicated. Of the two duplicated jobs one is sent back to Que16 to serve as a dummy request. The other goes through a further activity for 5*passtime minutes. After this the edgebander is freed and the job is sent to Que12.

From Que9 70% of the Etho jobs go through Bullnosing after which they go through packing. 30% of the Etho jobs and all the AOE jobs go to the packing lines directly. The jobs that do not require bullnosing are sent to Que17. However this Que has a maximum capacity of 5 jobs and in case it overflows the jobs are balked back to Que9 with a certain transport time. The jobs that require bullnosing are routed to Que18 from where they are sent to the Bullnosing activity. Que18 has a maximum capacity of 1 job and in case it overflows the jobs are sent back to Que9 with a certain travel time. The jobs that come out of the bullnosing activity are sent to Que13. Que13 has a maximum capacity of 10 jobs and in case it overflows the bullnosing activity is blocked.

The final activity in the process is the packing activity. The packing activity includes the boring activity also. There are two packing lines P1 and P2. Jobs are routed to these packing lines from Que13, Que17 and Que12 based on the following priority rules:

P1 chooses jobs from Que13(bullnosed rectangles) and in case Que13 is empty it chooses jobs from Que17(non-bullnosed rectangles).

P2 chooses jobs from Que12(corners) and in case Que12 is empty it chooses jobs from Que17(non-bullnosed rectangles).

After packing the jobs are sent to a main collect for collecting statistics for time spent in the system and after that they are sent to one of eight collect nodes where type wise statistics are collected. And finally the jobs leave the system and are terminated.

5 RESULTS AND DISCUSSION

The developed SLAM II model was run for 15K mins. All statistical counters were initialized at 5K mins to ensure steady state conditions in the system. Thus, the results are based on the observations collected in 10K mins which is an equivalent of one-half month of production time on two shift basis. A total of 8700 (435*20) units of finished products were produced. The production line appears to be quite imbalanced in the current state. Lamination is the first operation and each part type undergoes this operation. It is performed on the lamline or hot press. Only 27% of lamline capacity is currently utilized. The packing area is utilized to its maximum capacity. Thus, to increase the plant capacity packing area needs to be improved. Among the two edgebanders (T2 and T4) for the rectangle line, T4 is idle 85% of the time. This is attributed to the fact that T4 is allocated to rectangle-veneers which is a low volume product with only 15% of the total volume.

Several scenarios were analyzed to find out possible alternate solutions to the capacity problem. These scenarios are listed as different cases below.

Case 1: Basecase
Case 2: Case 1 + 3rd Pack
Case 3: Basecase + Edgebander Flexibility
Case 4: Case 2 + Case 3
Case 5: Case 4 + 30 blanks per job
Case 6: Case 4 + 10 blanks per job
Case 7: Case 4 + 50% increased throughput

Scenario 1 designates the base case. Case 2 through Case 7 are developed with specific changes in the base case. Case 2 assumes a third identical packing line, the packing area being the current bottleneck. The rectangle-AOEs' were assigned the highest priority for processing on this line since these jobs experienced one of the longest waiting time. The most significant advantage due to the third packing line was found for the throughput time which reduced to almost one-third (449 mins) of the original time (1210 mins.) in scenario 1. The overall system output improved by about 8% (468 units from 435 units). The resource utilization level remained high with 63% utilization of the third packing line. The average queue sizes for all product types in storage area 1 (S1) remained unchanged however, significant improvements were observed for storage area 2 (S2). The average and maximum queue lengths reduced to 1.55 and 10 from 34.7 and 50 respectively. The average waiting time reduced to 38.7 mins from 835.3 mins. This improvement can be converted into sizeable savings in the form of reduced work-in-process inventory. The waiting time and average/maximum queue lengths for the non-bullnosed job also reduced significantly.

Scenario 3 assumed that the two edgebanders in the rectangle production line were allocated indiscriminately for all varieties of rectangle product lines. This made T2 and T4 edgebanders available for all rectangle jobs. The remaining description of the system was similar to scenario 1.

6 CONCLUSION

Simulation has been successfully used to model a fairly complex system. Seven simulation experiments were conducted to determine possible outcomes of specific options. Once the simulation model with base case was developed, further enhancement to evaluate performance with defined modified condition was quick. The model was used at each stage of analysis for the stated capacity and in-process storage problems.

ACKNOWLEDGEMENTS

This work was supported by Herman Miller Inc., Zeeland, Michigan. The authors would like to specially thank Mr. Jim Reno, Operations Manager, for his assistance in providing all necessary information as well as several important suggestions throughout this work.

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