Computer Simulation of a Hardwood Processing Plant

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Abstract

The overall purpose of this paper is to introduce computer simulation as a decision support tool that can be used to provide managers with timely information. A simulation/animation modeling procedure is demonstrated for wood products manufacturing systems. Simulation modeling techniques are used to assist in identifying and solving problems. Animation is used for reducing the time it takes to develop a simulation model and for communication purposes such as illustrating "how" and "why" a given solution can be effective. The application and utility of the simulation/animation tool is demonstrated using a furniture rough mill system characteristic of the eastern region of the United States.

Introduction

The wood household furniture, cabinet, and millwork industries represent one of the nation's large industrial segments, employing over 385,000 people and consisting of a total annual payroll exceeding $6.6 billion (Bureau of the Census, 1989). The value added by manufacturing of wood products for these industries total over $15 billion annually. However, this industry faces serious economic and technical problems that are limiting its profitability and growth. The increasing cost of high-quality hardwood timber resources along with labor-intensive manufacturing methods have pushed manufacturing costs close to unprofitable levels. Furthermore, most of the increased demands for furniture in the U.S. have been captured by foreign imports, hence, competitive pressures from foreign companies have threatened the industry. If these industries are to survive and grow under such pressures, they must be able to recognize and solve some fundamental manufacturing problems.

One problem in this industry involves inefficient utilization of wood resources. For example, conversion of lumber into furniture parts can range between 35 to 65 percent in yield efficiency for the furniture industry. Since lumber costs can be as much as 50 percent of the total furniture manufacturing cost, even a small increase in yield efficiency can substantially increase profit margins. Another important problem involves inefficient manufacturing systems. For example, a furniture part can spend less than 5 percent of its time undergoing processes that increase its value such as machining, assembly, and finishing. Hence, over 95 percent of its time is spent in non-value adding activities such as handling, waiting, and storage. This means a furniture product that takes 100 hours to produce actually spends less than 5 hours increasing its value.

To address some of these problems, most research has focused primarily on developing better processing equipment technology. Computer vision, robotics, and computer-integrated manufacturing are examples of recent technology innovations which have been successful in other manufacturing industries such as the automotive industry. Such technologies have been proposed for modernizing furniture manufacturing facilities

(Conners et al., 1990; Klinkhachorn et al., 1989; Culbreth and Pollpeter, 1988; McMillin et al., 1984). Although modern equipment is very important to a wood products manufacturing plant of the future, improving equipment technology alone is not enough to address all of the industry's problems.

A more complete solution to the problems of the wood furniture, cabinet, and millwork industries involves determining a combination of technology and management that is best for the overall manufacturing system. Studying only one component of such a broad system in isolation from other components does not produce the overall desirable results. For example, sophisticated sawing sequences may be one solution to increase the conversion efficiency of hardwood lumber to furniture parts. This added sophistication may require much more processing time. Additional time can cause a bottleneck in a furniture mill that can be severe enough to reduce the amount of furniture parts produced in a day. This situation, which does frequently happen, could be very costly under certain market and resource constraints. Therefore, the best design and management of furniture manufacturing systems requires precise modeling techniques that take into account the whole manufacturing system.

Computer simulation has been an effective operations research tool for analyzing whole manufacturing systems. The advantage of computer simulation is that alternate processing technology, management techniques, and control strategies can be thoroughly studied before their costly introduction into a real manufacturing system. Several systems simulation models have been developed to assist in designing and evaluating hardwood lumber and furniture manufacturing systems (Townsend et al.,1988; Adams 1984; Anderson, 1983; Araman, 1977). These simulation models have proven very successful in solving some of the problems in the industry. However, only a small potential of this modeling capability has been tapped for the wood products industry.

Objective

Managers of wood processing facilities need timely information on which to base important decisions such as when to add costly equipment, when to renovate, or how to improve their throughput subject to time-varying demands. The objective of this paper is to illustrate the utility of computer simulation techniques in providing such timely information and in assisting in making effective management decisions for wood products manufacturing systems. The application and utility of computer simulation will be demonstrated using a furniture rough mill system characteristic of the eastern region of the United States.

Model Development

Furniture Rough Mill

In the wood household furniture industry, the rough mill is the area where rough, dry hardwood lumber is cut up into parts for processing throughout the rest of the manufacturing operation. Dry hardwood lumber enters the rough mill in the shape of boards with random widths and lengths. The main purpose of the rough mill is to cut the proper number of parts of a given length and/or width from the random length, random width boards. Furthermore, natural features in wood such as wane, knots, and decay that are objectionable are cut out and discarded.

Figure 1 shows a floor plan of a possible rough mill layout for the eastern region of the United States. Table 1 lists by name each of the 19 stations that are used to model this rough mill layout. Stacks of dried lumber enter the mill on a kiln truck which is typically 2.44 m (8 ft) high, 1.83 m (6 ft) wide, and 5.18 m (17 ft) long. The lumber un-stacker is a materials handling device that moves the lumber from the kiln truck onto the infeed table of the cross cut saw. There are typically two cross-cut saws that cut the entering random length boards to the required length for the various furniture parts that are desired. After the cross-cutting operation, the planer surfaces the lumber to a specified uniform thickness. Finally, four rip saws are typically used to rip the lumber to the widths required for furniture parts. These "rough" dimension parts are then stored until needed. Material to and from the rough mill is transported either by forklift or hand trucks. Belt and/or chain conveyors are used to move the material from one station to the next within the rough mill. Clark et al., (1987) provide a more detailed discussion on the rough mill layout and the typical processing stations required.

TABLE 1
Description of the 19 stations used to depict the rough mill.

Station	Description
1	Rough dry lumber holding area
2	Un-stacker infeed position
3	Cross cut saw #1 conveyor infeed position
4	Cross cut saw #2 conveyor infeed position
5	Cross cut saw #1 infeed
6	Cross cut saw #2 infeed
7	Cross cut saw #1 cross-over chain infeed position
8	Cross cut saw #2 cross-over chain infeed position
9	Planer conveyor infeed position
10	Planer conveyor outfeed position
11	Rip saw #1 conveyor drop-out position
12	Rip saw #1 pallet area
13	Rip saw #2 conveyor drop-out position
14	Rip saw #2 pallet area
15	Rip saw #3 conveyor drop-out position
16	Rip saw #3 pallet area
17	Rip saw #4 conveyor drop-out position
18	Rip saw #4 pallet area
19	Dimension parts holding area

Model Implementation

The rough mill model was implemented using the SIMAN/CINEMA[2] simulation language (Pegden, 1989; Systems Modeling Corp., 1988). SIMAN is a FORTRAN-based simulation language that contains a number of built-in features that make it particularly useful for modeling manufacturing and material handling systems as well as providing the means of animating the simulated processes (CINEMA). Another important feature in SIMAN/CINEMA is its capability to run on IBM PC/AT compatible microcomputer systems and on mini/main-frame computer systems.

Details on the development of the furniture rough mill simulation model are given by Kline et al. (1990). Also, the simulation code for the model is not reported herein due to its voluminous nature. More detailed

[2] Mention of commercial products or company names does not imply recommendation or endorsement by Virginia Polytechnic Institute and State University over others not mentioned. The authors' familiarity with this simulation language was the main reason that this particular software product was used in the implementation.

simulation model representation and SIMAN/CINEMA code for the model can be obtained from the senior author upon request.

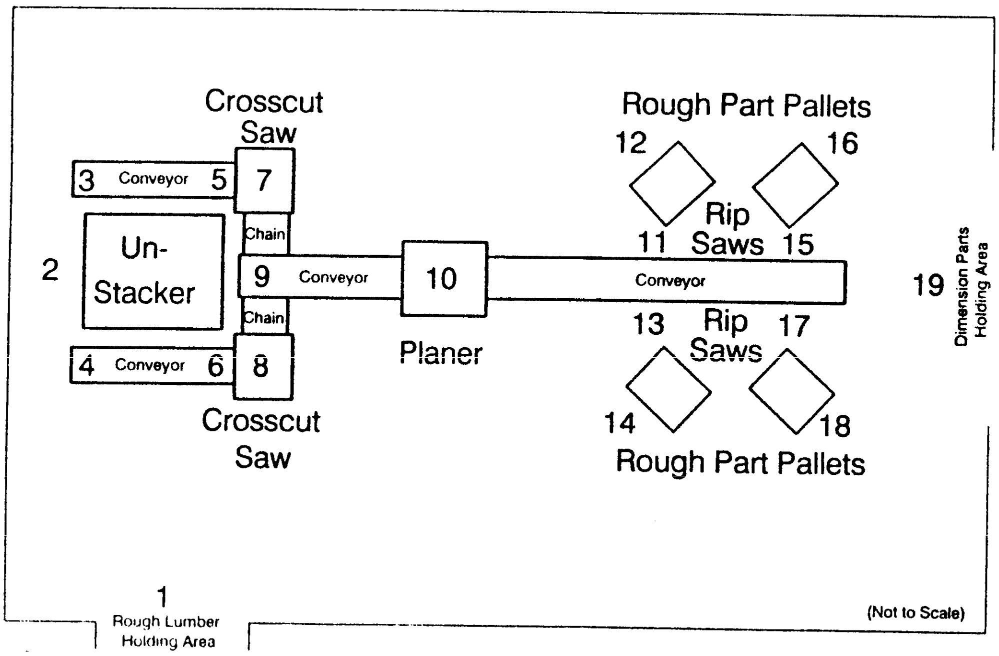

Figure 1. Floor plan of a typical rough mill layout with the 19 station locations.

Results and Discussion

The utility of simulation/animation model is illustrated on an example rough mill that is typical in the eastern region of the United States. It is assumed that the mill processes random width, random length, mixed grade 4/4 (25.4 mm or 1 in thick) red oak lumber. The lumber was purchased air-dried and kiln dried on site in a standard, normal temperature dry kiln. The part sizes cut in the mill experiment are listed in Table 2. Table 3 shows the parameters of the random variables considered in the study. The only costs that are assumed in the study is the red oak purchase price of $282 per m^3 ($666 per thousand board feet, mbf), a drying cost of $55 per m^3 ($130 per mbf), and 16 employees hired at an average wage rate of $5.30 per hour.

TABLE 2
Cutting order simulated in the hypothetical rough mill.

Cutting	Length mm (in)	Width mm (in)
1	355.6 (14)	38.1 (1.50)
2	558.8 (22)	57.2 (2.25)
3	711.2 (28)	63.5 (2.50)
4	914.4 (36)	50.8 (2.00)

To demonstrate the features of the simulation/animation procedure, the rough mill model was simulated for a 10 hour day under the above conditions. After the simulation experiment, the model gives a brief statistical summary in four areas: (a) mill throughput, (b) mill operation expense, (c) mill inventory levels, and (d) delays due to processing bottlenecks. At the end of the simulated 10 hours, for example, an average of 3.59

m^3 (1.52 mbf) of parts manufactured per hour at an average cost of $753 per m^3 ($1778 per mbf) with an average of 3.92 m^3 (1.66 mbf) of waste produced per hour. Hence, the average conversion efficiency of the operation (yield of parts vs. waste) was 47.7 percent. Also, a total of 413 pallets of parts were stored in inventory (100 parts per pallet). The processing bottleneck considered in this example is the rip sawing operation where an average of 83 pieces of lumber are waiting to be processed.

TABLE 3
Simulation model input distribution parameter values

Input	Distribution
Surface area of lumber in each pallet of rough dry lumber, m^2 (ft^2)*	Triangular: Minimum = 25.8 (278) Mode = 38.7 (417) Maximum = 45.2 (486)
Length of boards, m (ft)	Triangular: Minimum = 2.4(8) Mode = 3.7 (12) Maximum = 5.2 (17)
Width of boards, mm (in)	Triangular: Minimum = 101(4) Mode = 254 (10) Maximum = 406 (16)
Chance for each of the cutting lengths	Discrete Probability Cutting 1 = 0.2 Cutting 2 = 0.2 Cutting 3 = 0.3 Cutting 4 = 0.3
Forklift loading and unloading rates, min	Uniform: Minimum = 0.05 Maximum = 0.17

* Surface area is considered for only one face of the lumber.

Figures 2 through 5 show the type of graphical information that was produced in a simulated hour for the hypothetical mill starting at minute 120. In Figures 2, 3, and 4, the mill throughput, waste, and operation expense, respectively, randomly vary about an average value. In Figure 5, there appears to be an increasing trend in the pieces of lumber that pile up in front of the rip saws.

In terms of utilizing information from Figures 2 through 5 for improving production, changes to the system can be aimed at simultaneously maximizing throughput, and minimizing expense and waste. Controls that minimize the unpredictable random fluctuations in throughput, expense, and waste statistics can also be implemented. Furthermore, controls can be implemented on the material flow upstream to prevent the occurrence of pile-ups in front of the rip saws or decisions can be made to upgrade the rip saw workstations such that more material can be processed. Any such process control and management procedures can be tested with the simulation model before their costly introduction in the real manufacturing system.

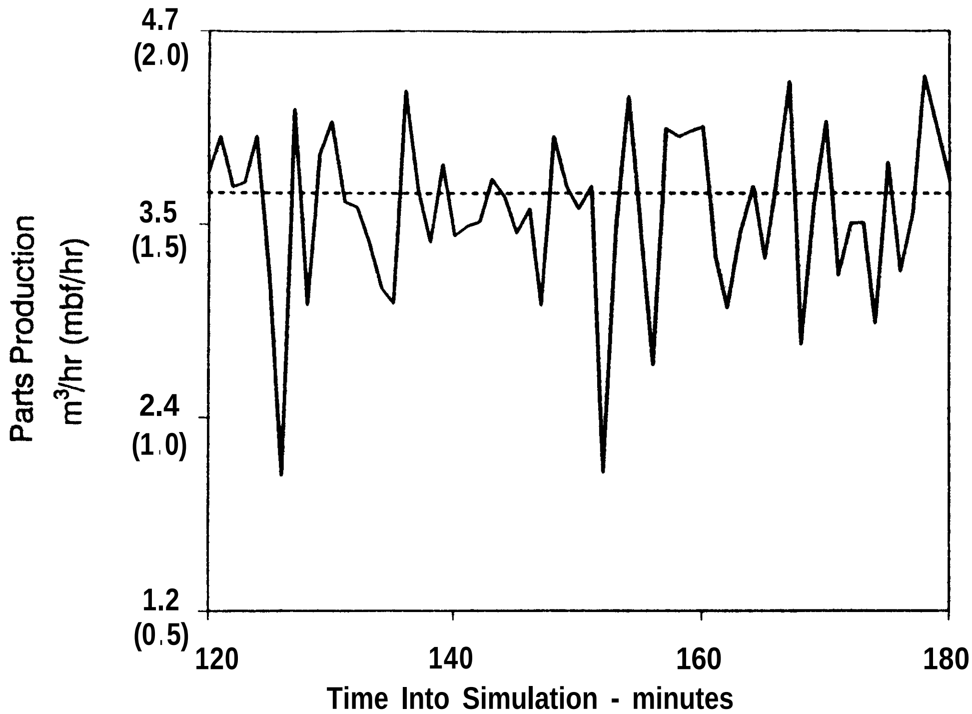

Figure 2. Mill parts throughput is shown for one hour of the simulation. The dashed line represents an average parts production rate of 3.59 m^3/hr (1.52 mbf/hr) for the entire 10-hour simulation.

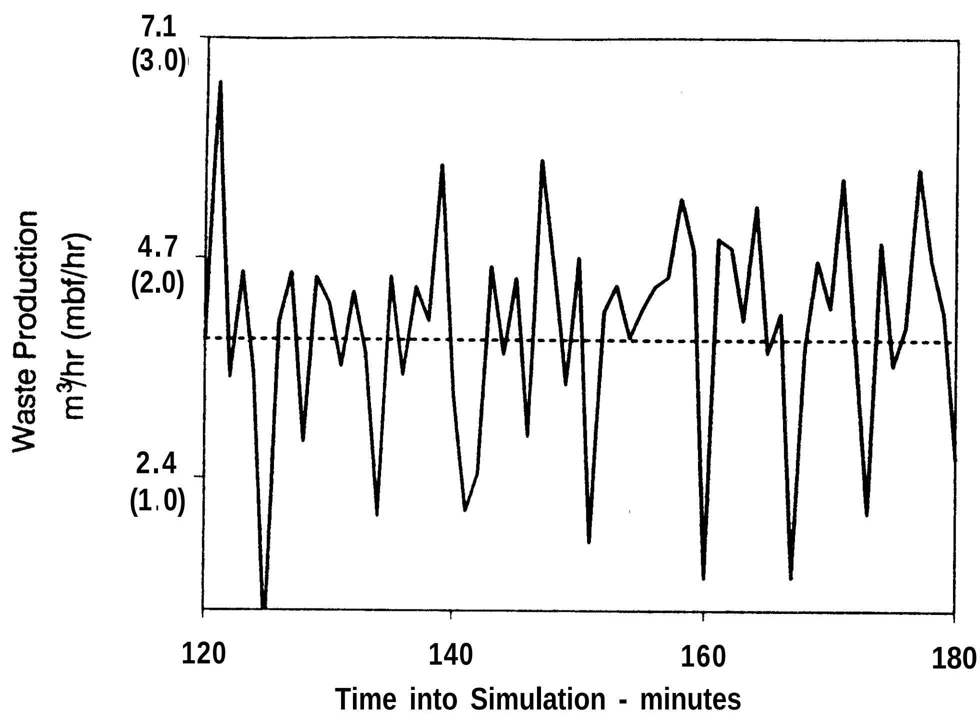

Figure 3. Mill waste production is shown for one hour of the simulation. The dashed line represents an average waste production rate of 3.92 m^3/hr (1.66 mbf/hr) for the entire 10-hr simulation.

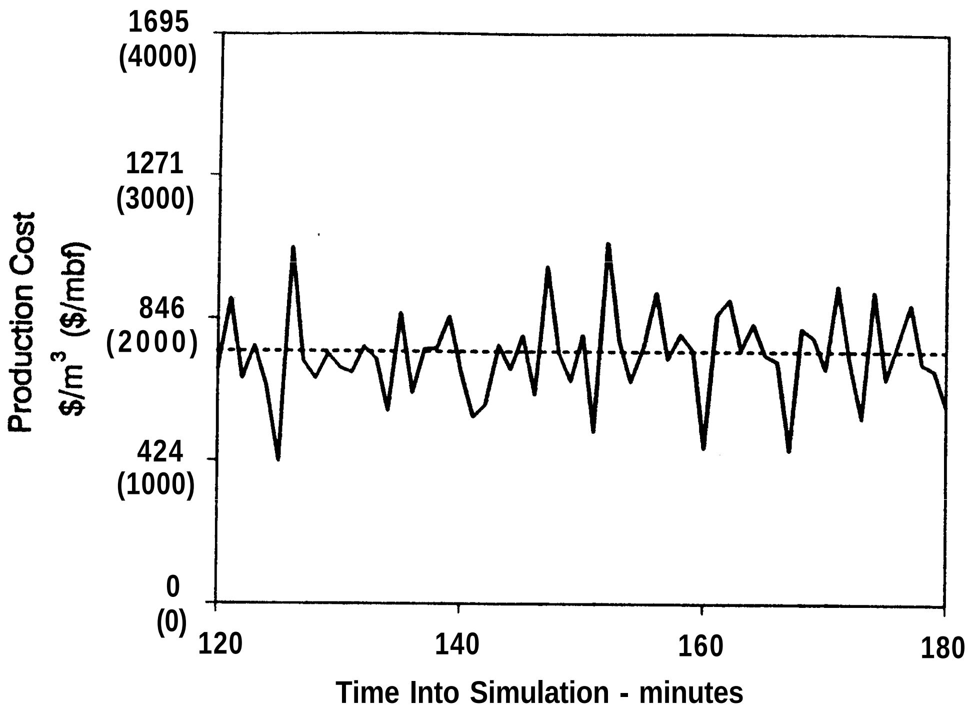

Figure 4. Mill production cost is shown for one hour of the simulation. The dashed line represents an average production cost of $753 per m^3 ($1778 per mbf) for the entire 10-hr simulation.

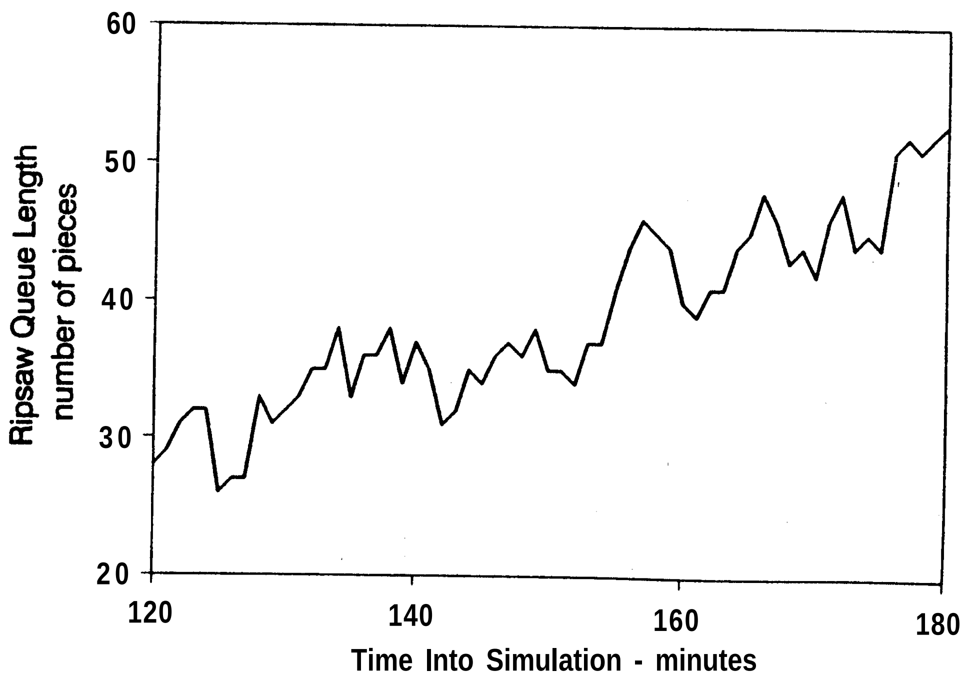

Figure 5. Amount of lumber waiting to be processed by the rip saws is shown for one hour of the simulation.

To demonstrate a simple control to reduce the amount of material waiting to be processed at the ripsaws, the simulation model was altered by slowing down the throughput rate at the crosscut saw by 83 percent. With this alteration, an average of 3.61 m^3(1.53 mbf) of parts were manufactured per hour at an average cost of $666 per m^3($1571 per mbf) with an average of 3.23 m^3(1.37 mbf) of waste produced per hour for the same simulated 10-hour day. The change resulted in a 77 percent decrease in the material waiting to be processed at the ripsaw or an average queue length was 19 which is more desirable than in the original simulation run. The alteration also led to a substantial increase in conversion efficiency (52.8 vs. 47.7). The improved efficiency for the second simulation can be attributed to the fact that the slowdown afforded the crosscut saw operators more time to measure-up the defects in the lumber and make the all important saw placement decisions.

As demonstrated above, simulation can be a very powerful tool to evaluate a hardwood processing facility and to test alternate management strategies. However, the usefulness of the tool for management applications depends upon its ability to answer crucial questions as quickly as possible. The optional animation feature of the simulation technique provides a means to enhance the usefulness of the mill model.

The animation feature provides a real-time visual representation of the rough mill model. At any point in time during the animated simulation, selected information can be observed. For example, Figure 6 shows a snapshot of the animation at simulated minute 253. At this instance in time, the mill is producing 2.97 m^3(1.26 mbf) of parts per hour at a cost of $866 per m^3($2044 per mbf) with a waste of 4.39 m^3(1.86 mbf) per hour. Presently stored in the parts inventory are 49,34,41, and 47 pallets of 355.6 mm (14 in), 558.8 mm (22 in), 711.2 mm (28 in), and 914.4 mm (36 in) lengths, respectively.

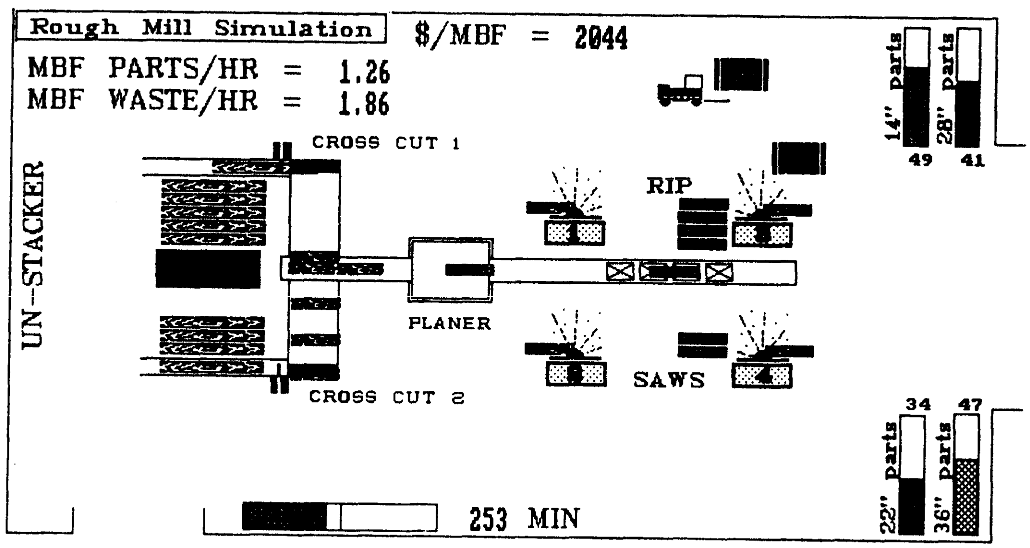

Figure 6. Snapshot of the simulation/animation model of the rough mill at time = 253 minutes.

Although the dynamic nature of the animation cannot be shown here, the observer can see the changes in the material flow and in the size of the queues in front of each saw within the rough mill as the simulation progresses. For example, the length of the ripsaw queues can be observed in the animation to be steadily increasing. This observation supports the trend shown in Figure 5. From the animation, it can be quickly observed that the speed at which the crosscut saws operate contributes to this steady increase. This observation would be difficult to represent in the traditional table or figure format. Therefore, providing a dynamic visual representation of the system is an efficient method to find a problem as well as to find the cause of the problem.

In terms of simulation model development, the animation feature can significantly reduce amount of time it takes to verify and validate a simulation model. Any reduction in the time to arrive at the final answer is significant in making timely management decisions. In terms of communication and documentation, it is much easier for managers to understand familiar pictures than tabulated values and graphs. Therefore, providing a real-time visual representation of the system enables those not familiar with the interpretation of traditional simulation output to feel more confident and understanding of the results.

Future Research

This paper demonstrates the potential usefulness of computer simulation techniques to assist in making management decisions for hardwood processing systems. However, the usefulness of computer simulation to the wood products industry is presently limited in two ways. First, computer simulation models are not general and are limited to only certain wood processing applications. Second, developing or modifying computer simulation models for new situations requires much time and expertise. Both of these limitations must be addressed before such computer simulation tools will be of use to personnel in the hardwood industry. Research is continuing to address these limitations by making simulation modeling procedures general for common types of wood products manufacturing systems and by incorporating knowledge-based programming methods to make computer simulation more user-friendly.

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