Management of wood products manufacturing using simulation/animation

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Abstract

Managers of hardwood processing facilities need timely information on which to base important decisions such as when to add costly equipment or how to improve profitability subject to time-varying demands. The overall purpose of this paper is to introduce a method that can effectively provide such timely information. A simulation/animation modeling procedure is described for hardwood products manufacturing systems. Object-oriented simulation modeling techniques are used to assist in identifying and solving problems. Animation is used to reduce the time for model development and for communication purposes such as illustrating "how" and "why" a given solution can be effective. The application and utility of the simulation/animation method is illustrated using a furniture roughmill system characteristic of the eastern region of the United States.

The wood household furniture, cabinet, and millwork industries employ over 385,000 people, have a total annual payroll exceeding $6.6 billion, and generate over $15 billion annually in value added manufacturing (6). 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, competitive pressures from foreign companies are threatening these industries. If the industry is to survive and grow under such pressures, it must be able to recognize and solve some fundamental manufacturing problems.

To address some of these problems, research has focused on developing better processing equipment technology. Innovative technologies such as computer vision, robotics, and computer-integrated manufacturing, which have been successfully employed in other manufacturing industries, have been proposed for modernizing furniture manufacturing facilities (8- 11). Although modem 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 may not produce the best overall results. Computer simulation is an effective operations research tool for analyzing whole manufacturing systems. Using computer simulation, alternate processing technologies, 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, evaluating, and managing hardwood lumber and furniture manufacturing systems. Some of the models have proven very successful in addressing specific questions within given forest

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Forest Prod. J. 42(2):45-52.

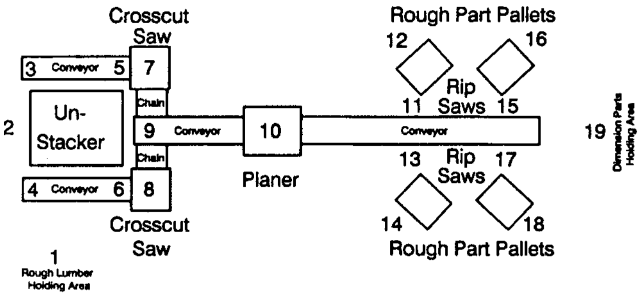


Figure 1. — Floor plan of a typical crosscut-first roughmill layout with the 19 station locations.

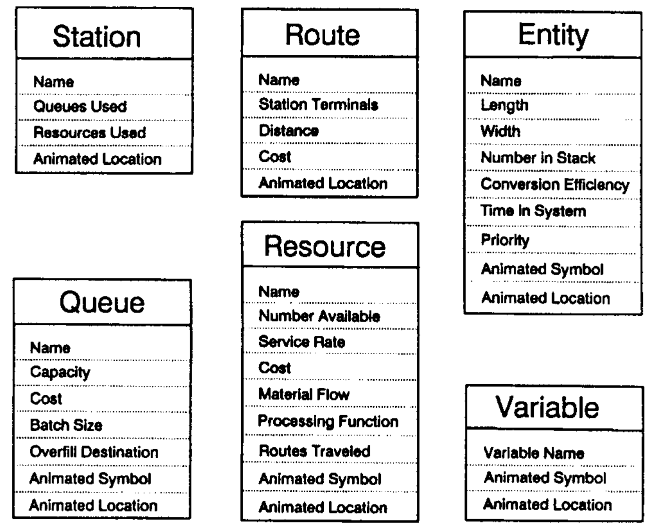


Figure 2. — Characteristics used to describe each of the six objects used to represent the roughmill.

products operations (3, 14). Others provide for the modeling of a variety of operations within a specific industry segment (1,2).

Although these systems simulation models have proven very useful, developing and utilizing such models requires a substantial amount of time and experience that the hardwood lumber and furniture industry cannot easily afford. Therefore, much work remains to make the models more "user-friendly" for the industry. One study that is currently underway employs some of the latest computing techniques such as expert systems, object-oriented programming, and animation to make simulation a more usable method for softwood sawmill personnel (4). A similar approach is taken in this paper to develop a decision support tool that can be used by managers of hardwood processing systems.

Objectives

The overall goal of this research was to develop methods that can effectively provide timely information and assist in making effective management decisions for wood products manufacturing systems. Specific objectives of this paper were to:

1. Describe simulation modeling procedures applied to wood products manufacturing systems;

2. Incorporate animation and other graphic features into the simulation procedures to assist in model development and in communicating important simulation modeling results;

3. Demonstrate the application and utility of the simulation/animation method on an example furniture roughmill for the eastern region of the United States.

Model development

Furniture roughmill

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

Figure 1 shows a crosscut-first roughmill layout that could be found in the eastern region of the United States. Stacks of dried lumber enter the mill on a kiln truck. The lumber unstacker is a materials-handling device that moves the lumber from the kiln truck onto the infeed table of the crosscut saw. There are typically two crosscut saws that cut the entering random length boards to the required length for the various furniture parts that are desired. After the crosscutting operation, the planer surfaces the lumber to a speci.tied uniform thickness. Finally, four ripsaws 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 roughmill is transported either by forklift or handtrucks. Belt, roller, or chain conveyors, forklifts, and handtrucks are used to move the material from one station to the next within the roughmill Clark et al. (7) provide a more detailed discussion of the roughmill layout and the typical processing stations required.

Simulation modeling procedures

Creating a detailed simulation model of such a roughmill system is an involved and the-consuming task. Mill managers have a good understanding of their system; however, they often lack the expertise needed to model the system. To minimize the amount of expertise needed to develop a computer simulation model, a general object-oriented procedure was developed to make the conversion of a real wood products manufacturing system to a computer model less complicated.

To define and organize the detail of such a complex processing system, the roughmill is viewed as an organization of distinct objects. Six primary object classes are used to represent the mill: 1) station objects; 2) route objects; 3) entity objects; 4) queue objects; 5) resource objects; and 6) system variable objects. System details are further described by defining specific characteristics associated with each object (Fig. 2). The first five objects carry a name and certain characteristic values that define their function. The system variable object is used to store information about the system such as production levels or conversion efficiency. Every object also carries some type of graphic representation of itself and is used for the simulation animation. These graphic aspects of objects will be discussed in more detail in a later section.

Station objects

Station objects define physical locations in a system such as the location of a workstation, transfer point, or storage area. Table 1 lists by name each of the 19 stations that are used to model the roughmill layout presented in Figure 1. Information carried by station objects is used to indicate which resources and queues are used at a particular station. At station 3, for example, there is a queue where boards wait for a space on the conveyor. The conveyor is the resource crucial to the activity that occurs at station 3. Hence, a board queue and a conveyor resource are required for the function at station 3. Table 2 lists the queues and resources that are required by each of the 19 stations.

Model detail and flexibility is a function of the number of stations chosen to represent the system. For example, the 19 stations chosen to represent the roughmill in Figure 1 do not include stations for waste material handling activities. Waste material is only tallied in the 19-station model for determining conversion efficiencies. More station and route objects would be required to build a more detailed model of the waste material handling activities with regard to how they compete for mill resources, and how they impact overall material flow.

TABLE 1. – *Description of the 19 stations used to depict the roughmill.*

Station	Description
1	Rough dry lumber holding area
2	Unstacker infeed position
3	Crosscut saw No. 1 conveyor infeed position
4	Crosscut saw No. 2 conveyor infeed position
5	Crosscut saw No. 1 infeed
6	Crosscut saw No. 2 infeed
7	Crosscut saw No. 1 cross-over chain infeed position
8	Crosscut saw No. 2 cross-over chain infeed position
9	Planer conveyor infeed position
10	Planer conveyor outfeed position
11	Ripsaw No. 1 conveyor drop-out position
12	Ripsaw No. 1 pallet area
13	Ripsaw No. 2 conveyor drop-out position
14	Ripsaw No. 2 pallet area
15	Ripsaw No. 3 conveyor drop-out position
16	Ripsaw No. 3 pallet area
17	Ripsaw No. 4 conveyor drop-out position
18	Ripsaw No. 4 pallet ares
19	Dimension parts holding area

TABLE 2. – *Queues and resources used at each of the 19 stations.*

Station	Queues used	Resources used
1	Lumber holding ares	Forklift
2	Unstacker infeed area	Unstacker
3	Conveyor infeed area	Crosscut No. 1 conveyor
4	Conveyor infeed area	Crosscut No. 2 conveyor
5	Crosscut No. 1 infeed	Crosscut No. 1
6	Crosscut No. 2 infeed	Crosscut No. 2
7	Crosscut No. 1 outfeed	Crosscut No. 1 cross-over chain
8	Crosscut No. 2 outfeed	Crosscut No. 2 cross-over chain
9	Conveyor transfer	Planer infeed conveyor
10	Conveyor transfer	Planer outfeed conveyor
11	Ripsaw No. 1 infeed	Ripsaw No. 1
12	Ripsaw No. 1 pallet area	Forklift
13	Ripsaw No. 2 infeed	Ripsaw No. 2
14	Ripsaw No. 2 pallet area	Forklift
15	Ripsaw No. 3 infeed	Ripsaw No. 3
16	Ripsaw No. 3 pallet area	Forklift
17	Ripsaw No. 4 infeed	Ripsaw No. 4
18	Ripsaw No. 4 pallet area	Forklift
19	Rough parts holding area	- -

Route objects

A route object is required to define each path that can be taken from one station to another. In the roughmill, paths between stations can represent any type of materials-handling system such as conveyors, belts, and transporters. Values of route objects include station terminals, distance, and cost of route. The definition of route objects must be such that the location, routes, and distances accurately represent the floor plan of the mill. Table 3 lists the station terminals and distances for all possible routes in the 19-station model. No costs are associated with the routes taken.

Entity objects

After the network of station and route objects is defined, entities that engage in station activities need to be defined. Entity objects represent materials such as lumber and parts that move throughout the system.

TABLE 3. – *Possible routes between the 19 stations of the roughmill model.*

Route	Station terminals		Distance
	Point 1	Point 2	(ft.)
1	1	2	150
2	3	5	20
3	4	6	20
4	7	9	15
5	8	9	15
6	9	10	15
7	10	11	25
8	10	13	30
9	10	15	35
10	10	17	40
11	1	12	150
12	1	14	150
13	1	16	155
14	1	18	155
15	1	19	225
16	2	12	100
17	2	14	100
18	2	16	105
19	2	18	105
20	12	19	70
21	14	19	70
22	16	19	70
23	18	19	70

TABLE 4. - *Service rate, material flow, process function, and routes traveled for the roughmill model resources.*

Resource	service rate (unit/min.)	Material flow[a]	Process function[b]	Routes traveled
Forklift	260 ft.	A	AA	l, ll to 23
Unstacker	2 layers	B	BB	0
Crosscut No. 1 conveyor	100 ft.	A	CC	2
Crosscut No. 2 conveyor	100 ft.	A	CC	3
Crosscut No. 1	20 pieces	A	DD	0
Crosscut No. 2	20 pieces	A	DD	0
Crosscut No. 1 chain	100 ft.	A	CC	4
Crosscut No. 2 chain	100 ft.	A	CC	5
Planer infeed conveyor	200 ft.	C	CC	6
Planer outfeed conveyor	200 ft.	D	CC	7 to 10
Ripsaw No. 1	5 pieces	A	EE	0
Ripsaw No. 2	5 pieces	A	EE	0
Ripsaw No. 3	5 pieces	A	EE	0
Ripsaw No. 4	5 pieces	A	EE	0

[a]Material flows are defined as: A = one incoming and one outgoing route; B = one incoming route and two outgoing routes (equal chance); C = two incoming routes (first-in-first-out) and one outgoing route; D = one incoming route and four outgoing routes (depends on length of part).
[b]Process functions are defined as: AA = transport; BB = create random length and width lumber; CC = convey; DD = create cuttings with length generated from a random distribution; EE = create cuttings with width determined by saw setworks.

For the 19-station example model, an entity object can be a stack of kiln-dried rough lumber, an unplaned board, a planed board, a rough dimension part, stacks of rough dimension parts, or waste material. Entity flow is dictated by the station and route network and its state is determined by activities that occur at a station.

As an example of entity flow the 19-station model, a lumber stack entity moves from the rough dry lumber holding area to the unstacker. At the unstacker, the lumber stack entity is split into two separate entities. One of the entities represents a piece of lumber that will be sent to one of the crosscut saws. The other entity represents the original lumber stack entity with one less board. This process of splitting and changing the state of entities continues until no boards are left in the stack. When the unstacker is almost empty, a control signal is issued to create another lumber stack entity to fill the unstacker. Lumber entities are split further into part entities and into leftover waste entities after being moved through the crosscut and ripsaws. Finally, part entities are regrouped into pallet entities that are stored in inventory, and waste entities that are tallied to provide conversion efficiency information.

Characteristic values for entity objects depend upon the entity's state in the processing system and carry values such as number of boards in a stack of lumber, lumber width and length, conversion efficiency, processing priority, and time spent in the system. When an entity represents a stack of lumber, for example, the number of boards per stack is assigned. When an entity represents a single board within the stack, its length and width values are assigned.

Queue objects

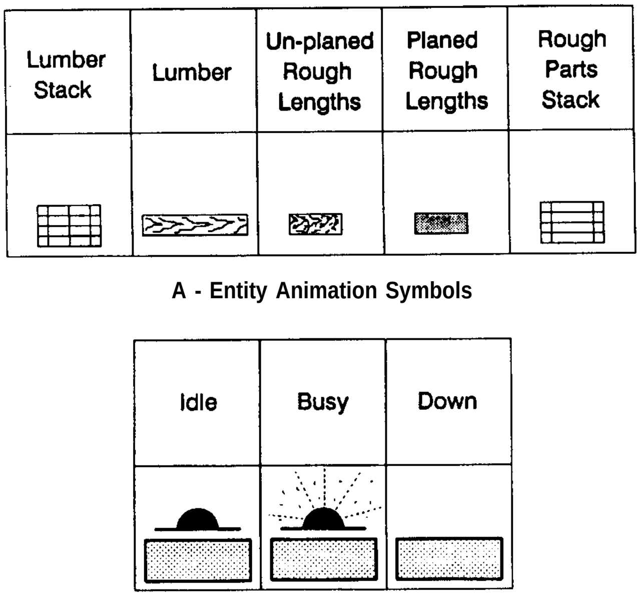
Queue objects define physical storage areas at a station where material waits to be moved or processed. Queue capacity, cost, batch size, and a destination for overflow entities are values used to characterize queue objects. In the 19-station model, all capacities of queues listed in Table 2 are chosen to be infinite, with no associated costs. Note that infinite queue capacities are selected for the purpose of model simplification. However, modeling the accumulation of material in a finite space, such as lumber in front of a ripsaw, can be accomplished by assigning a definite queue capacity value. If this value is exceeded, the overflow destination can be used to re-route overflow material or to send a signal to halt the flow of incoming material. The batch size value is used to define how many entities are needed before a free resource can process a batch. All queues in the model have a batch size of one, except for the four ripsaw pallet area queues, which have a batch size of 100. That is, 100 parts must be palletized before they can be moved to the dimension holding area.

Resource objects

Resource objects represent system components such as processing and materials-handling equipment and personnel that are required to process and move material to and from a particular station. Resource objects define the number of a particular resource available to do the same job, its service rate, cost, material flow, processing function, and routes traveled. In the 19-station model, there is 1 unit of each resource available and all associated costs are considered to be zero. Service rate, material flow, process function, and routes traveled for each resource are summarized in Table 4.

The material flow of a resource object defines how material will be selected from and assigned to different routes. If there are several queues in front of a resource (e.g., station 9), the order in which queues will be serviced is specified. Similarly, if there are several different routes behind a resource (e.g., stations 2 and 10), the order in selecting a route is specified. A resource object can also service entities with higher priorities before entities with low priorities. The entity's priority value is used for this function.

A function is used to describe how an entity is processed at a resource. For example, at the crosscut saws, a function is used to define how a board is cut



B - Rip Saw Animation Symbols

Figure 3. — Animation symbols for possible states seen by A) an entity object and B) a resource object.

into rough length lumber. Presently, the board-cutting function is a random distribution function. However, the function could alternatively make calls to a program containing a lumber cut-up optimization routine, such as the CORY program (5).

A list of routes traveled defines routes used to move material between stations. For example, station 1 is modeled as a queue for rough dry lumber. To move stacks of lumber from station 1 to station 2, a forklift resource is required, Furthermore, if the nearest forklift is at station 19, it must travel the distance from station 19 to station 1 before a stack can be moved. The list of routes traveled for the forklift object defines the routes between all stations serviced by the forklift. Routes traveled for a position on a conveyor that moves material between stations are also needed. Routes traveled are defined as zero for resources that do not transport or convey material, such as saws.

Simulation animation and graphic procedures

Animating the simulated roughmill involves graphically displaying the movement of dynamic objects such as lumber within an animated mill floor plan on a computer display monitor. The graphic representation of a floor plan includes all static components such as walls and permanent fixtures. The animated representation of dynamic objects are defined using graphic values in each of the five objects described earlier. Graphic values for objects include a location or display position within the static background. To animate moving lumber, holding areas, and resources, graphic symbols are included in entity, queue, and resource objects. Symbols are included for each possible state

TABLE 5. – *Cutting order simulated in the hypothetical roughmill.*

Cutting	Length	Width
	(in.)	(In.)
1	14	1.50
2	22	2.25
3	28	2.50
A	36	2.00

seen by an object. Figure 3A, for example, shows symbols used to animate the state of entity objects. In Figure 3B, a ripsaw resource object requires three symbols in an animation, one when busy, another when idle, and a third when down for repairs.

Finally, a system variable object is used to complete the animation development procedure. System variable objects (Fig. 2) allow the animation to access and to display dynamically important variables and statistics in the simulation model. The variable to access, representation symbol, and symbol location are used to describe the system variable object. Variables accessed in the roughmill model include resource usage, queue level, production level, waste level, cost, and material flow variables. These variables can be represented in the animation as symbols in the form of text, dials, levels, histograms, or graphs to provide dynamic information on the state of the mill system. System variable objects are positioned on the computer display according to the symbol location value.

Model implementation

After following the modeling procedures just discussed, the mill system is described as a collection of distinct objects. These objects define the essential elements needed to simulate the system. The final step is to translate the collection of objects into some modeling language and to run computer experiments on the model.

This step was implemented for the example roughmill using the SIMAN/CINEMA simulation language (12,13). 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 ability to run on IBM PC/AT-compatible microcomputer systems and on mini/main-frame computer systems. Although SIMAN/CINEMA made some of the modeling procedures easier, the object-oriented modeling approach is intended to be software independent so that other commercial programming languages can be used as well.

Due to its voluminous nature, the full object representation and corresponding SIMAN/CINEMA code for the model is not reported here. More detailed object representation and the SIMAN/CINEMA code for the model can be obtained from the senior author upon request.

Results and discussion

The utility of the simulation/animation model is illustrated using a crosscut-first roughmill layout that is typical for the eastern region of the United States. It is assumed that the mill processes random width, random length, mixed grade, 4/4 red oak lumber. The part sizes cut in the mill experiment are listed in Table 5. Table 6 shows the parameters of the random variables considered in the study. The only costs that are assumed in the study are the average grade red oak purchase price of $666 per thousand board feet (MBF) for green lumber, a lumber drying cost of $130 per MBF, and 16 employees hired at an average wage rate of $5.30 per hour.

To demonstrate the features of the simulation/animation procedure, the roughmill model was simulated for a 10-hour day. Upon completion of the simulation run, the model gives a brief statistical summary in four areas: 1) mill throughput; 2) mill operation expense; 3) mill inventory levels; and 4) delays due to processing bottlenecks. At the end of the simulated 10 hours, for example, an average of 1.52 MBF of parts were manufactured per hour at an average cost of $1,778 per MBF with an average of 1.66 MBF of waste produced per hour. 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 in this example is the ripsawing operation, where an average of 83 pieces of lumber are waiting to be processed.

During a simulation run, the output information can be stored in files for every simulated minute. This information can be graphed to observe the dynamic behavior of the simulation and to make comparisons with other simulation runs. Figures 4 through 7 show the type of graphic information that was produced in a simulated hour for the hypothetical mill starting at minute 120. In Figures 4,5, and 6, the mill throughput, waste, and operation expense, respectively, randomly vary about an average value. In Figure 7, the solid line shows an increasing trend in the ripsaw queue length toward its average value of 83.

Figures 4 through 7 can be used to determine where changes could be made to the system in an effort to simultaneously maximize throughput and minimize production expense and raw material waste. Controls that minimize the unpredictable random fluctuations in throughput, expense, and waste statistics can also be implemented. Furthermore, controls can be implemented to provide for a more even flow of material through the system (e.g., to reduce the length of the ripsaw queues). Any such process controls and man-

TABLE 6. – *Simulation model input distribution parameter values.*

Input	Distribution
Surface area of lumber In each pallet of rough dry lumber ($ft.^2$)[a]	Triangular: Minimum = 278, Mode = 417, Maximum = 486
Length of boards (ft.)	Triangular: Minimum = 8, Mode = 12, Maximum = 17
Width of boards (in.)	Triangular: Minimum = 4, Mode = 10, Maximum = 16
Conversion efficiency	Triangular: Minimum = 0.35, Mode = 0.55, Maximum -0.65
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

[a]Surface area is considered for only one face of the lumber.

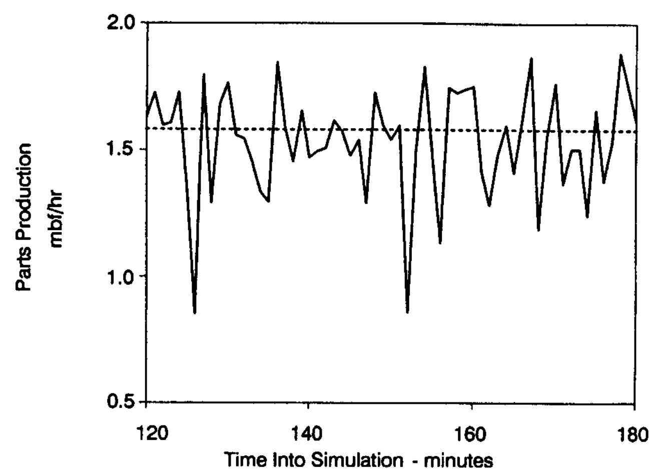


Figure 4. — Mill parts throughput is shown for 1 hour of the simulation. The dashed line represents the average rate of parts production for the entire 10-hour simulation (1.52 MBF per hr.).

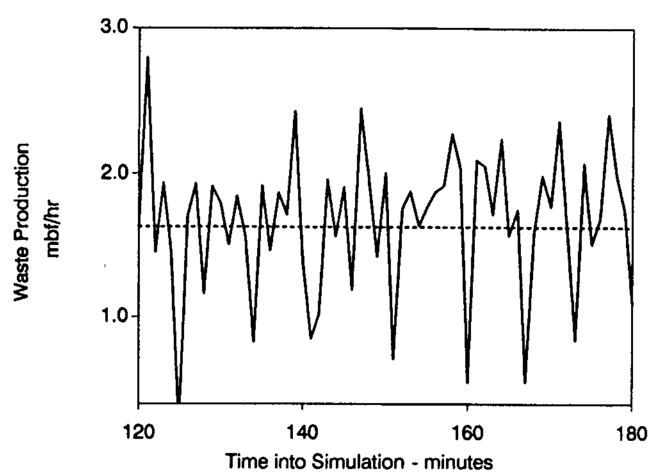


Figure 5. — Mill waste production is shown for 1 hour of the simulation. The dashed line represents the average rate of waste production for the entire 10-hour simulation (1.66 MBF per hr.).

agement procedures can be tested with the simulation model before their costly introduction into the real manufacturing system.

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. Given the additional time at the crosscut saw, it was assumed that the crosscut operators could afford more time to make better saw placement decisions. The change in operator performance was modeled by changing the material conversion efficiency parameters shown in Table 6 to 0.45, 0.60, and 0.65 for the minimum, mode, and maximum, respectively (10% average efficiency increase). With these alterations, an average of 1.53 MBF of parts were manufactured per hour at an average cost of $1,571 per MBF with an average of 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. The dashed line

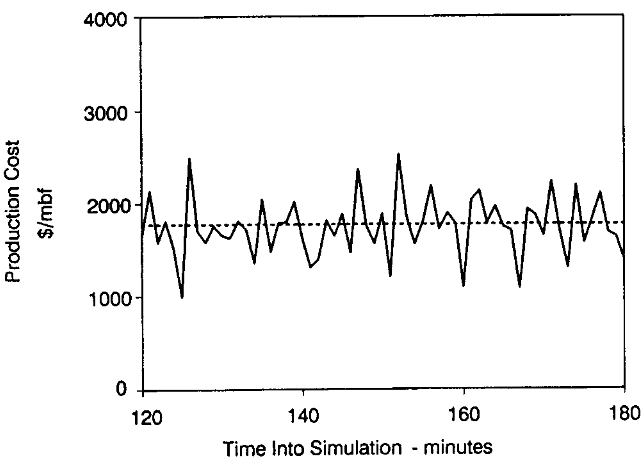


Figure 6. — Mill production cost is shown for 1 hour of the simulation. The dashed line represents the average production cost for the entire 10-hour simulation ($1 ,778 per MBF).

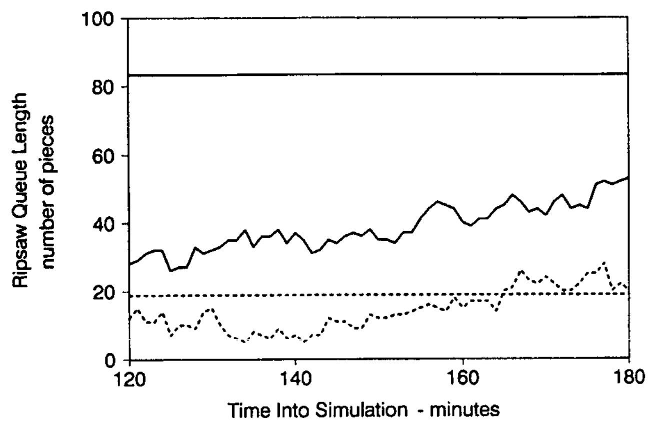


Figure 7. — Amount of lumber waiting to be processed by the ripsaws is shown for 1 hour of the simulation. Solid lines correspond to the original simulation (run 1) and dashed lines correspond to the altered simulation (run 2) where the crosscut throughput rate was reduced. The straight lines show the 10-hour average values in each case (83 for run 1, 19 for run 2).

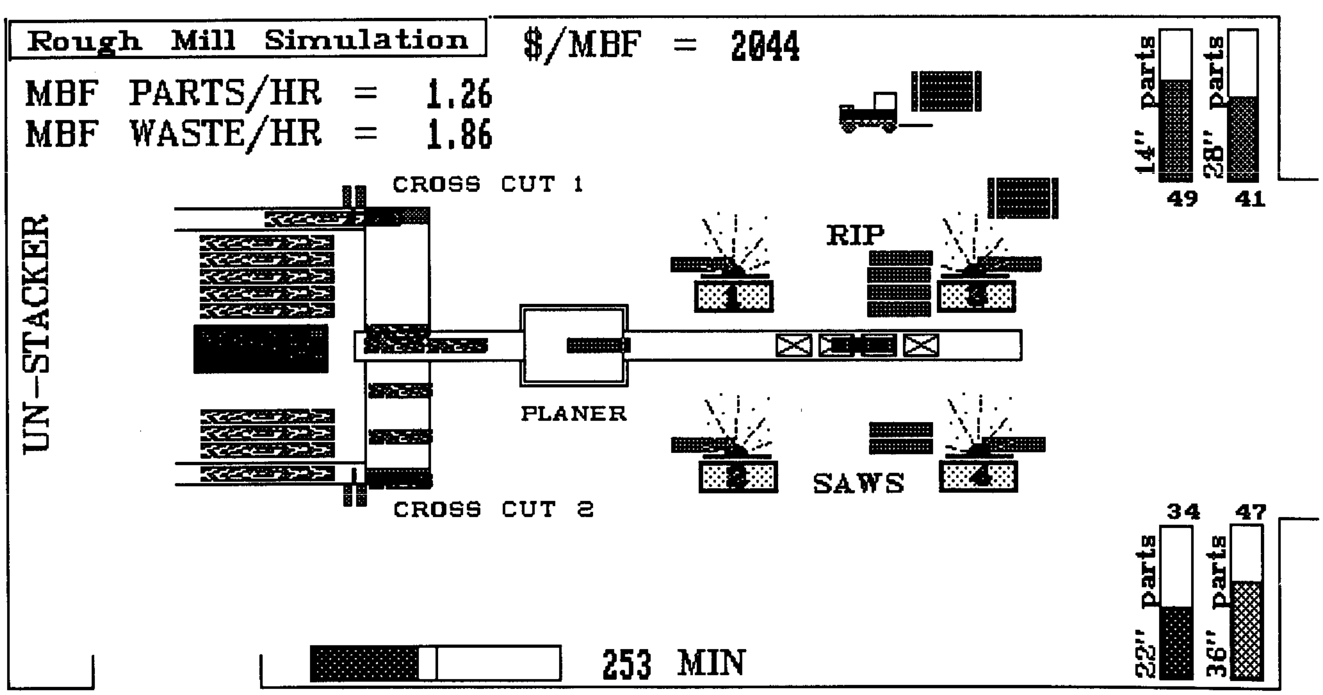


Figure 8. — Snapshot of the simulation/animation model of the roughmill at time = 253 minutes.

Figure 7 shows that the queue length varies randomly about an average of 19, which is more desirable than the original simulation run. The change also led to an increase in conversion efficiency (52.8 vs. 47.7).

As this example illustrates, simulation can be a very powerful method to evaluate different processing scenarios and to test alternate management strategies. However, the usefulness of the method 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 roughmill model. At any point in time during the animated simulation, selected information can be observed. For example, Figure 8 shows a snapshot of the animation at simulated minute 253. At this instance in time, the mill is producing 1.26 MBF of parts per hour at a cost of $2,044 per MBF with a waste of 1.86 MBF per hour. Presently stored in the parts inventory are 49, 34, 41, and 47 pallets of 14, 22, 28, and 36 iches in length, respectively.

Although the dynamic nature of the animation cannot be demonstrated here, the observer can see the changes in the material flow arid in the queue size for each saw within the roughmill as the simulation progresses. Using animation, for example, the length of the ripsaw queues can be observed to be steadily increasing. This observation supports the trend shown in run 1 of Figure 7. 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 a 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 the 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 arid 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 in understanding the results.

Summary

A simulation/animation modeling procedure was described for a hardwood crosscut-first roughmill layout that is typical of those found in the eastern United States. To minimize the amount of expertise needed to develop a model that is representative of the roughmill, a general object-oriented modeling procedure was introduced. The roughmill is viewed as an organization of six distinct objects: 1) station objects; 2) route objects; 3) entity objects; 4) queue objects; 5) resource objects; arid 6) system variable objects.

Simulation output information includes mill throughput, operation expense, inventory levels, processing efficiency, and material flow delays due to processing bottlenecks. The simulation model was used to compare and test alternate management decisions. The animation feature included with the simulation model provides a real-time dynamic visual representation of the system and the output summary information. Providing a visual representation of the system reduces the time to develop the mill model arid assists in pinpointing the cause of a problem.

Present research efforts are focused on expanding the simulation/animation method to encompass a wider variety of wood processing systems. Furthermore, research efforts are continuing to incorporate the methodology into a true object-oriented programming environment. Ultimately, an integrated decision support system will be developed such that simulation model development arid coding will be made transparent. Hence, users can concentrate on developing different simulation experiments that fully test proposed management strategies.

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