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# Programs for Computer Simulation of a Crosscut-First Furniture Rough Mill

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## The Author

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## Abstract

Computer programs for simulating a crosscut-first furniture rough mill were developed to include all operations from the lumber breakdown hoist through the crosscut saws to the final machining-to-width on ripsaws. The programs allow the user to measure the effects of changes in the factors affecting production costs and to determine total processing costs for individual parts leaving the furniture rough mill. A combined continuous/discrete FORTRAN-based simulation language (GASP IV) was used.


## Note

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## Introduction

In any processing of wood, production costs on an individual-part basis are needed to accurately compare various types of rough-mill configurations. Analyzing the production costs in an existing crosscut-first furniture rough mill can be done by using a computer simulation technique (Anderson 1983). Two computer programs, MILLSIM 1 and MILLSIM 2, were developed at the Forestry Sciences Laboratory as simulation models of an existing rough mill to include all operations from the lumber breakdown hoist through the crosscut saws to the final machining-to-width on ripsaws.

The purpose of this paper is to present the computer models and documentation for an existing crosscut-first furniture rough mill. These models allow the user to measure the effects of changes in the factors affecting production costs and to determine total processing costs for individual parts leaving the furniture rough mill.

## The System Studied

We simulated the production processes of an existing rough mill. The processes are typical of those encountered in any well-run conventional crosscut-first rough mill. The choice of simulating an existing rough mill has several advantages over simulating a hypothetical rough mill. First, production figures from the existing mill provide benchmarks for evaluating the simulated production performance. Second, production parameters are well established in an existing mill. And third, cooperation of mill management assures that production parameters can be determined with greater accuracy than would otherwise be possible.

The crosscut-first furniture rough mill is a sequence of operations that begins with the input of graded, kiln-dried hardwood lumber and ends with the output of dimensioned parts of specific lengths and widths. Operations represented in the model are outlined in Figure 1.

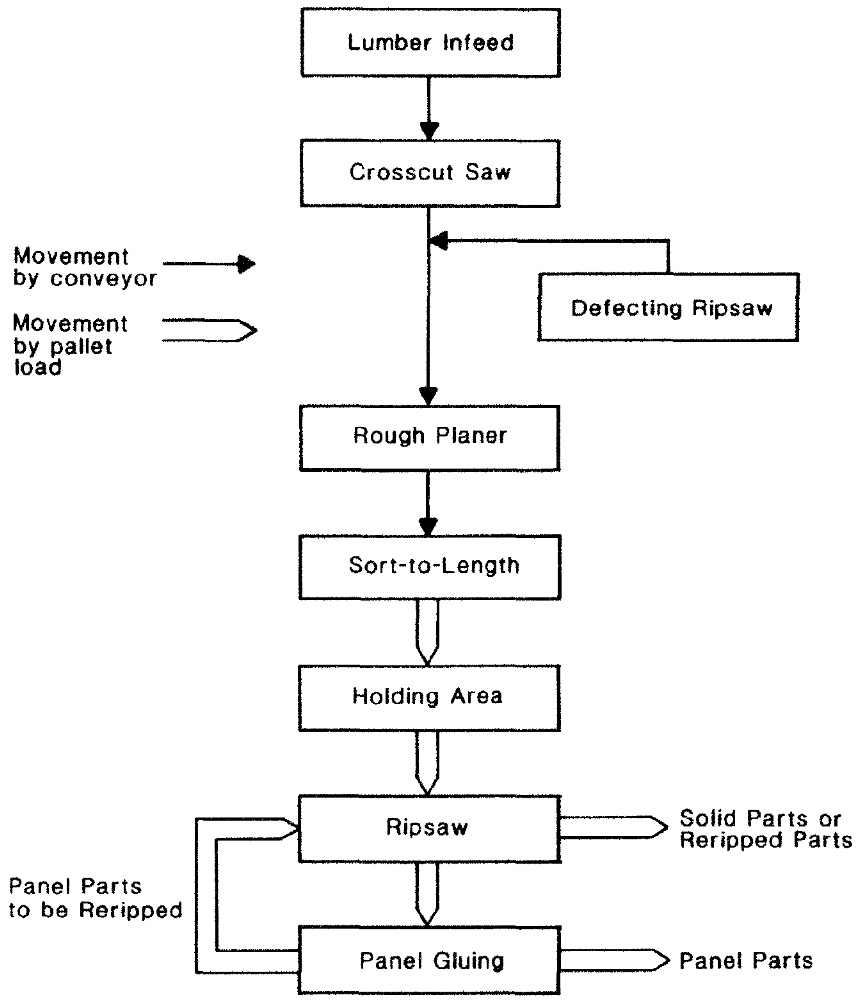


Figure 1.—Sequence of operations in rough mill.

Lumber enters the rough mill on a lumber breakdown hoist that unstacks boards onto a cross conveyor. After boards are removed from the cross conveyor at a crosscut saw, they are processed into cut-to-length, random-width parts. These parts drop onto a conveyor that takes them past a defect ripsaw, where excessive cup or other defects are removed, to a planer that skip planes the boards on both sides to a standard thickness. From the planer, parts move up a conveyor to a sort station where they are sorted by length onto pallets and moved to a holding area. As needed, parts are moved from the holding area to a ripsaw for one of four processing operations:

- rip to remove defects followed by rip to specified width
- rip to remove defects followed by rip to produce glue-line edge
- panel matching and sizing
- rip glued-up panels back to specified width

After panel matching and sizing, parts are glued up into panels that are either returned to the ripsaw or are moved on to further processing beyond the scope of the rough mill model.

As noted, from the lumber infeed to the sorting operation, the material is passed from one operation to the next by a system of fixed-speed conveyors. From the sort operation through the machining-to-final part size, all material is conveyed by pallet load. Each pallet contains parts of a single length and grade. Program MILLSIM 1 simulates those operations where parts are handled by conveyor. The output from this program is used as part of the input information for the second program, MILLSIM 2, which simulates those events after the sort operation where parts are handled by pallet load.

The method of conveyance is not the deciding factor in the decision to model the rough mill with two separate programs even though the two programs reflect two different methods of handling lumber or parts. The primary reason for using two programs centers around the delays that occur between the time a part leaves the sort operation, enters the holding area, and subsequently is scheduled for further processing at the ripsaw. The delays depend on several factors, including overall plant schedules, size of cutting orders being processed, and the amount of storage space available in the holding area. These delays are neither consistent nor predictable with any great accuracy. Therefore, if we model all of the processes on one side of the holding area separately from those on the other side, we are assured that the timing between each process is consistent with the actual mill operation. Also, the cost of handling parts can be divided between the processes before and after the holding operation.

## Model

The model was designed to identify and measure those parameters within the rough-mill system that affected the cost of processing each furniture part. The ultimate goal was to establish the processing cost for furniture parts throughout the sequence of operations. Input required includes data on the system's operating characteristics, information on lumber yield by grade, cutting orders for desired part sizes, and cost information for lumber and processing. Formats of input data for each program are shown in Appendix IV (MILLSIM 1) and Appendix V (MILLSIM 2).

Model output includes processing costs for individual operations within the system, costs per board foot for parts of specific lengths and widths, and yield of parts. Additional output includes productivity figures such as number of parts produced, total volume of parts produced, average volumes of material lost at each operation, and cycle times for the operations. Sample listings of input and output data resulting from an analysis of production costs in an existing crosscut-first rough mill (Anderson 1983) are available on request from the Forestry Sciences Laboratory, Princeton, WV.

### Simulation Language—GASP IV

The simulation is written in GASP (General Activities Simulation Program) IV: A combined continuous/discrete FORTRAN-based simulation language (Pritsker 1977). The programs include a main source program and processing-event subroutines that describe a system's dynamic behavior. These programs use variables, functions, and subroutines supplied by the GASP IV simulation language (listed in Appendix I) as well as user-defined variables (listed in Appendices II and III). In addition, the simulation model contains: lists and matrices that store information, an executive routine that directs the flow of information and control within the model, and support routines. These form an operating computer program that reflects the simulated system.

### Model Assumptions—MILLSIM 1

The following assumptions are made about the system's behavior in program MILLSIM 1, which simulates operations from the board infeed through the sort operation:

1. Board input is generated based on distributions of board sizes for different grades of lumber. Board input is scheduled to ensure that the cross conveyor carrying boards to the crosscut saws is between 75 and 100 percent filled. This ensures that no delays occur between the end of crosscutting one board and the availability of a new board on the cross conveyor. For example, boards are placed on the cross conveyor until the sum of the individual board widths equals the overall length of the cross conveyor. At this point, the cross conveyor is 100 percent filled, and individual boards can be pulled off the conveyor for processing at the crosscut saw. As each board is removed, the sum of remaining board widths is reduced. This process continues until the sum of board widths falls below 75 percent of the cross conveyor's length. At this time, additional boards are placed on the cross conveyor until the sum of board widths again equals the overall length of the cross conveyor.

2. The defecting ripsaw does not operate on every part that passes on the conveyor to the rough planer. Only a specified percentage of the total number of parts on the conveyor are ripped to remove either defects or excess cup. After these parts are ripped, they are returned automatically to the conveyor where they, along with all parts that bypass the ripsaw operation, are conveyed directly through the planer operation.

3. The sort operation is the control point for introducing a new length or deleting a length on the current cutting bill. As parts are removed from the conveyor at the sort operation, the number and quantity of parts in each length class are tallied. When the required quantity of a particular length part is produced, a change in the current cutting bill is made. The length for the part that has been produced in the required quantity is taken off the current cutting bill, and a new part length is added to the cutting bill.

## Model Assumptions—MILLSIM 2

Additional assumptions about the system's behavior in program MILLSIM 2, which simulates operations from the holding area through final machining to size, include:

1. In scheduling a specific part for processing at a ripsaw station, the model continues processing at the ripsaw station until the total input volume for that part has been exhausted. In the actual mill, material for a specific part arrives at the ripsaw on a pallet. Each ripsaw processes all of the material on a pallet before starting on a new pallet load of material. In the model, the ripsaw continues to receive pallet loads for the same size part until the total input volume for that part has been processed.

2. A ripsaw becomes idle when a specific part's cutting requirement is completed. Then, either a new part is scheduled for ripping or, if none remain, the ripsaw is scheduled to process a part size that another ripsaw may also be currently working on. In this way, the time a ripsaw is idle is held to a minimum. Also, large requirements for a specific part size are handled quickly by utilizing more than one ripsaw to meet the requirement.

3. Parts that have been ripped to produce a glue-line edge are scheduled to reach the gluing operation within the next 8-hour shift. This delay allows sufficient buildup of parts awaiting gluing so that the gluing operation is kept busy at all times.

## Program Operation—MILLSIM 1

MILLSIM 1 includes a main program and 10 user subroutines written in FORTRAN. The main program has three functions: (1) establish the array dimensions for common variables called in GASP and user subroutines, (2) read in values for all of the variables associated with the rough mill's operating characteristics, and (3) call subroutine GASP. Subroutine GASP is provided by GASP-IV simulation language. It supplies the controls necessary for the simulation to advance from one processing step to the next in a time-ordered sequence.

This program is currently written to operate in a batch mode. Thus, the program and data are combined in one file and submitted for each run. The output from each run is stored in a separate file for subsequent use in the second program.

The 10 user subroutines perform activities in three general areas: (1) define the starting state of the mill and the sequence of processing steps, (2) simulate each processing step, and (3) summarize and file the statistics that are generated during each simulation. These subroutines with a description of their functions follow:

| *Subroutine* | *Function* |
|---|---|
| INTLC | Establishes initial conditions in the mill |
| EVNTS | Identifies which operation is performed next |
| BREAK | Inputs new board dimensions |
| CUTOFF | Performs cutoff saw operation |
| DEFECT | Performs defecting ripsaw operation |
| PLANE | Performs rough planing operation |
| PSORT | Performs sort operation |
| PSAVE | Collects statistics on part characteristics |
| OTPUT | Controls printing and storage of results |
| DISCR | Generates discrete number distribution |

As the simulation moves from one processing step to the next, information about the parts currently in the system must be alternately stored and transferred from one subroutine to the next. This is done using a system of files defined by GASP. These files, or storage arrays, are contained in the arrays NSET/QSET. A set of values called attributes identify the part information that is stored or retrieved from the files. The values are contained in the vector identified as GASP variable ATRIB. Subscripts for the vector elements identify specific attributes or part information as shown in the following tabulation:

| *Subscript number* | *Part attribute identified in program MILLSIM 1* |
|---|---|
| ATRIB (1) | Time event or processing step occurs |
| ATRIB (2) | Type of processing step |
| ATRIB (3) | Time board enters system |
| ATRIB (4) | Length, in inches |
| ATRIB (5) | Width, in inches |
| ATRIB (6) | Cost, in dollars |
| ATRIB (7) | Cost added by current operation |
| ATRIB (8) | Volume of material lost in operation |
| ATRIB (9) | Crosscut saw number |
| ATRIB (10) | Level of cross conveyor |
| ATRIB (11) | Volume, board feet, in original board |
| ATRIB (12) | Volume, board feet, of part |
| ATRIB (13) | Thickness, in inches |

## Program Operation—MILLSIM 2

MILLSIM 2 includes a main program and 14 user subroutines written in FORTRAN. The main program has essentially the same functions as the previously described main program with one addition. MILLSIM 2 takes the physical and cost characteristics of parts coming from the sort operation and uses them to simulate the conversion to parts of specific length, width, and grade. Thus, one additional function is performed by the main program in MILLSIM 2 to read in values' output from MILLSIM 1 that describe the physical and cost characteristics of parts coming from the sort operation. This program is also a batch-mode program. The program and data from the preceding program are combined in one file and submitted for each run. After reading in the part information, the main program transfers control of the simulation to subroutine GASP. This subroutine again controls the sequence of processing steps simulated by the 14 user subroutines. These subroutines with a description of their functions follow:

| *Subroutine* | *Function* |
|---|---|
| INTLC | Establishes initial conditions in the mill |
| EVNTS | Identifies which operation is performed next |
| INFEED | Controls input of new part length |
| RIPARR | Schedules next part arrival at ripsaw |
| RIPDEP | Schedules next part departure at ripsaw |
| GLUARR | Schedules next part arrival at gluing operation |
| GLUDEP | Schedules next part departure at gluing operation |
| INTPRT | Controls intermediate printing of results |
| FPSAVE | Summarizes part costs |
| OTPUT | Controls printing of results |
| RIPTIM | Calculates time required for rip operation |
| CNDRM | Calculates normal distribution for costs |
| WNORM | Calculates normal distribution for widths |
| RQUEUE | Calculates mean, standard deviation, minimum and maximum values for part characteristics between the glue-line edge rip and the panel matching/sizing rip operations |

This program also uses the vector identified as GASP variable ATRIB to identify the part information as it is stored or retrieved from files during the simulation. Subscripts for the vector elements again identify specific attributes or part information as shown in the following tabulation:

| *Subscript number* | *Part attribute identified in program MILLSIM 2* |
|---|---|
| ATRIB (1) | Time event or processing step occurs |
| ATRIB (2) | Type of processing step |
| ATRIB (3) | Ripsaw number |
| ATRIB (4) | Length, in inches |
| ATRIB (5) | Width, in inches, of current part |
| ATRIB (6) | Width, in inches, of finished part |
| ATRIB (7) | Cost of current part |
| ATRIB (8) | Volume of material lost in operation |
| ATRIB (9) | Length class of panel |
| ATRIB (10) | Width, in inches, of panel |
| ATRIB (11) | Previous type of event |

## Summary

These programs were used to simulate the processing of a typical rough mill cutting order (Anderson 1983). Results of this simulation indicate that the programs realistically reflect the operation of an existing crosscut-first furniture rough mill. The programs, as listed in the Appendixes, can easily be modified, through changes in input variables and minor internal changes, to reflect the operating characteristics of any conventional crosscut-first rough mill.

## Literature Cited

Anderson, R. Bruce. **Furniture rough mill costs evaluated by computer simulation.** Res. Pap. NE-518. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 11 p.

Pritsker, A. Allen B. **The GASP IV user's manual.** 2d ed. West Lafayette, IN: Pritsker & Associates, Inc.; 1977. 100 p.

## Appendix I—GASP Program Variables

The following GASP variables (V), functions (F), and subroutines (S) may be found in both programs. A description of their application may be found in the GASP IV User's Manual (Pritsker 1977).

| | |
|---|---|
| ATRIB (V) | PPARM (V) |
| COLCT (S) | QSET (V) |
| COPY (S) | RMOVE (S) |
| DRAND (S) | RNORM (F) |
| FILEM (S) | SET (S) |
| MFA (V) | SSOBV (V) |
| MFE (V) | SUMQ (F) |
| MLE (V) | TIMST (S) |
| MMAXQ (V) | TTBEG (V) |
| MSTOP (V) | TTFIN (V) |
| NNQ (V) | TTNEX (V) |
| NSET (V) | UNFRM (F) |
| NSUCR (F) | |

## Appendix II—Variables—MILLSIM 1

Variables in program MILLSIM 1.

ABBDFT: Board foot required to satisfy an order for a specific part length in MILLSIM 2.

AVG: Average value for attribute defined by PXS in subroutine PSORT.

BC: Calculated cost of each board entering rough mill.

BDFTP: Array containing sum of board feet for each part length.

BFT: Calculated board-foot volume of each board entering rough mill.

BFTO: Array containing calculated board-foot overrun for each part length.

BOTCH: Current total width of boards on bottom infeed cross conveyor.

BRDOBS: Current number of parts having arrived at the sort operation.

CD: Array containing mean, standard deviation, and minimum and maximum value of part cost for each part length.

CHOIST: Calculated cost per board attributed to breakdown hoist labor.

CLABOR: Array containing labor costs per hour by type of operation and day or night shift.

COMPLT: Calculated percent of required board-foot input that has been processed.

COST: Material cost per board foot of lumber input —depends on grade of lumber input.

CP: Array containing total cost of parts by part length.

CPAVG: Average cost per part for each part length calculated by dividing total cost CP by total board feet BDFTP.

CPROB: Array containing cumulative distribution function for number of parts cut.

CPTAVG: Average cost per part for all part lengths.

CRAT: Operating rate for cutoff saw in board feet per minute.

CRRAT: Array containing times expected between cutoff saw and defecting ripsaw.

CRTIME: Expected time to perform cutoff operation for each part.

CTIME: Expected time to perform all cutoff operations on a given board

CV: Calculated coefficient of variation for a specified attribute.

CWASTE: Calculated trim loss on cutoff saw operation expressed as board feet.

CWCOST: Calculated cost of trim loss at cutoff saw.

FPWD: Array of panel widths for part lengths processed in MILLSIM 1.

FPWDC: Array of panel widths per part lengths processed in MILLSIM 2.

FTHIC: Specified maximum thickness of part leaving rough planing operation.

FWID: Array of final part widths for part lengths processed in MILLSIM 1.

FWIDC: Array of final part widths for part lengths processed in MILLSIM 2.

IBUSY: Array of flags to determine if cutoff saw is busy or idle.

IC: Number of cuts per board at the cutoff saw generated using a uniform discrete distribution.

IFI: Integer counter used in determining entry of new part length into cutting bill.

IGRADE: Array of part grade by length of part.

IT: Integer counter used in determining departure of part length from cutting bill.

IJ: Integer counter specifying a specific part length within several operations.

ILENC: Total number of length-width combinations input to the data storage for MILLSIM 2.

IM1: Integer counter used to sum individual probabilities into a cumulative distribution.

INBRD: Number of boards input onto cross conveyor following breakdown hoist.

INBRD1: Number of boards input on top chain of cross conveyor.

INBRD2: Number of boards input on bottom chain of cross conveyor.

INDX: Counter used in retrieval of board data from storage file QSET.

IPPAR1: Subscript for array of length parameters for specific board grade.

IPPAR2: Subscript for array of width parameters for specific board grade.

IPRIOR: Assigned priority for part lengths entering the cutting bill.

ISAV: Integer subscript used to specify attribute on which statistics are being collected.

ISAW: Integer subscript defining the crosscut saw that the operation is being performed on.

ISCHED: Next part length considered for entry into the active cutting bill.
ISHIFT: Current shift of operations, either first- or second-shift labor rates applied.
IT: Level of cross conveyor, top or bottom.
ITHK: Subscript defining array location of thickness parameters.
ITIJ: Saw number of current operation.
IX: Part length resulting from cutoff saw operation, specified as part number.
JJ: Subscript for attribute on which statistics are being collected.
JSJ: Same as JJ.
KLEFT: Number of part lengths left in active cutting bill.
KSCHED: Initial number of part lengths in the cutting bill actively being cut.
KSTART: Current shift of operations in which idle crosscut saw is restarted.
LABL1: Alpha-numeric label used in printing results.
LABL2: Alpha-numeric label used in printing results.
LBL1: Alpha-numeric label used in printing results.
LBL2: Alpha-numeric label used in printing results.
LBL3: Alpha-numeric label used in printing results.
LBL4: Alpha-numeric label used in printing results.
LENC: Array of part lengths to be processed in MILLSIM 2.
LEVEL: Level of cross conveyor, top or bottom, from which board was taken.
MBDFTP: Flag to determine if part length has entered the active cutting bill.
NCRDR: Unit number of input device.
NCUT: Number of cuts per board at the cutoff saw associated with a specific probability.
NJ: Counter used in selected printing of results.
NJBFT: Specified grade of lumber input.
NPART: Generated number of parts to be produced from a given board.
NPRNT: Unit number of output device.
NSBEG: Constant used in storage of data for further processing by MILLSIM 2.
NSCHED: Total number of part lengths to be processed.
NXN: Number of parts of a specific length that passed through the sort operation.
PARTL: Array of part lengths in active cutting bill, specified in inches.
PBBDFT: Board-foot volume available to satisfy a specific part order in MILLSIM 2.
PCUT: Number of parts associated with a specific number of crosscuts per board.
PLENCT: Array defining percentage of output for a specific length part that will be used as input in MILLSIM 2.
PLN: Array of part lengths in active cutting bill, specified in inches.
PRAT: Operating rate for planer in lineal feet per minute.
PRTCST: Processing cost associated with given operation.
PSCHED: Array containing part length, in inches, and volume required, in board feet, for all input lengths in the cutting order.
PSRAT: Expected time between planer and sort operations.
PWCST: Cost associated with trim waste in planer operation.
PXS: Value of attribute on which statistics are being collected.
RATR: Operating rate for defecting ripsaw in lineal feet/minute.
RBDL: Remaining board length after part length and/or trim loss have been subtracted.
REPLA: Part length, in inches, leaving active cutting bill.
REPLB: Part length, in inches, entering active cutting bill.
RN: Random number, between 0.00 and 1.00.
RPRAT: Expected time between defecting ripsaw and rough planer.
RQBFT: Total board-foot input required as calculated by summing requirements for each part length.
RTIME: Expected time to complete defect ripsaw operation for a specified part length.
RWCOST: Cost of material lost in processing at defecting ripsaw operation.
START: Time delay used in restarting cutoff saws that were idle.
STD: Computed standard deviation for specified attribute.
STDM: Computed standard deviation of the mean for specified attribute.
SUMBFT: Calculated sum of board-foot volume actually input to rough mill.
TBFT: Total board-foot volume of lumber input to the rough mill during the simulation.
TBF2: Board-foot volume remaining on cross conveyor at end of simulation.
TBREAK: Expected time interval between successive operations of lumber input to cross conveyor.
TCINC: Expected time for crosscut saw operation on a specific part.
TEMPA: Temporary variable used in longest to shortest ordering of lengths in current cutting bill.
TEMPP: Same function as TEMPA.
THICK: Input variable specifying nominal thickness of lumber input.
TNOW: Current time of simulation.
TOPCH: Current total width of boards on top infeed cross conveyor.
TPF1: Board-foot volume of parts in system prior to sort operation at end of simulation.
TPLNE: Expected processing time for specific part length in rough planer operation.
TRANP: Total time spent in processing from lumber infeed operation to sort operation.
TRIMF: Total length, in inches, of trim loss in processing at cutoff saw.

TRIMI: Initial trim loss, in inches, from board processed at cutoff saw.
TWAS1: Volume of material lost in processing, expressed in board feet, at end of simulation.
VARAN: Computed variance for specified attribute.
WD: Array containing mean, standard deviation, minimum and maximum value of part width for each part length.
WMAX: Observed maximum value for specific attribute on which statistics were collected.
WMIN: Observed minimum value for specific attribute on which statistics were collected.
WN: Number of observations for a specific attribute on which statistics were collected.
WP: Array of total width of parts, in inches, for all part lengths processed.
WS: Array containing sum of observations for a specific attribute.
WSS: Array containing sum of squared observations for a specific attribute.
X: Random number, ranging in value from 0.00 to 1.00.
XBDFT: Volume, in board feet, of material lost.
XCBFT: Volume, in board feet, of part arriving at defecting ripsaw operation.
XCCST: Current processing costs associated with part arriving at defecting ripsaw operation.
XKSC: Number of parts in current active cutting bill expressed as a real number.
XLN: Part length to be cut from board.
XN: Same function as WN.
XNPART: Same function as NPART, expressed as a real number.
XPCT: Percentage of part width to be removed in defecting ripsaw operation.
XRBFT: Volume, in board feet, of part arriving at rough plane operation.
XRCST: Current processing costs associated with part arriving at rough planing operation.
XRWD: Width of part, expressed in inches, of part after defecting ripsaw operation.
XS: Same function as WS.
XSS: Same function as WSS.
XTBDFT: Sum of board-foot volume of parts leaving the sort operation.
XTCP: Sum of processing costs for parts leaving the sort operation.
XTHIC: Thickness, expressed in inches, of material lost in processing at rough planing operation.
XWD: Width of part, expressed in inches, lost during defecting ripsaw operation.
YIELD: Calculated percentage of total volume of lumber input resulting in parts output.

## Appendix III—Variables—MILLSIM 2

Variables in program MILLSIM 2.

ABFT: Array containing board-foot volume available for processing by specific part length.
ALEN: Array containing lengths of parts, in inches.
APWD: Array containing panel widths, in inches.
AWID: Array containing finished part width, in inches.
CBFT: Average cost per finished part.
CD: Array containing mean, standard deviation, and minimum and maximum value of part cost for each part length entering system.
HRBFT: Specified percentage of required board-foot volume, used as a control to add ripsaws.
IBUSY: Array of flags to determine if ripsaw is busy or idle.
ICHRG: Number of panels in current charge of gluing operation.
ICNT: Length class of part or panel in current operation.
IFLAG: Array of flags to determine next ripsaw operation.
IGFLAG: Flag used to determine status of gluing operation.
IGRADE: Array of part grades by length of part.
II: Argument in RQUEUE subroutine used to determine whether summation of attributes by part length is complete.
IMATCH: Flag used to determine whether panel matching operation for specific part length is complete.
INDX: Variable determining number of observations stored in a specific array.
INPUTT: Length class of part or panel that is entering the current operation.
INRC: Previous type of event occurring prior to INFEED event.
INSAW: Number of ripsaw referred to in current operation.
IREVNT: Type of rip event occurring—solid part sawing, panel matching, reripping panels, etc.
IRIP: Number of ripsaw referred to in current operation.
IT: Length class of panel in current operation.
ITPCNT: Flag to prevent division by zero in summation routine in OTPUT and INTPRT.
ITYPE: Same function as IT.
IX: Argument in subroutine EVNTS that determines which operation is performed next.
JEND: Flag used at end of simulation to control printing of results.
JEVNT: Time-event code defined by ATRIB (2).
JJ: Argument in RQUEUE that specifies length class of part.

JKEND: Same function as JEND.
JMATCH: Flag used to determine whether panel matching has been scheduled for specific part length.
JQEND: Same function as JEND.
K: Argument in subroutine that specifies either length class or type of rip operation performed.
KPCNT: Flag used to determine whether all part lengths have finished ripsaw operation.
KPEND: Flag used to control intermediate printing of results.
KQEND: Same function as KPEND.
KRCNT: Total number of part length-width combinations in simulation.
LCPAN: Same function as ICNT.
NCRDR: Unit number of input device.
NFICNT: Same function as ICNT.
NGFLAG: Counter specifying number of part lengths awaiting availability of gluing operation.
NHRS: Number of hours between activation of intermediate print event.
NPANC: Number of finished-to-width parts that can be reripped from glued-up panels.
NPARC: Number of finished-to-width solid parts that can be ripped from current part length.
NPART: Number of parts of a specific size that have completed processing.
NPCHRG: Number of panels that are input to the gluing operation.
NPRNT: Unit number of the output device.
NRIPC: Flag used to control summarization of output for specific part length.
NRIPQ: Number of parts, by specific length, awaiting panel matching at the ripsaw.
NSBEG: Beginning number for part size that enters the system first.
NSCHED: Total number of part sizes to be processed.
NSEND: Ending number for part size that enters the system last.
NXTRIP: Variable used to define the previous type of operation and schedule the next operation.
PANCOS: Processing costs for individual parts going into a panel matching operation.
PANSUM: Sum of widths of individual parts going into a panel matching operation.
PANTYP: Control variable in panel matching operation used in scheduling next operation.
PARCOS: Processing cost for individual parts leaving the panel reripping operation.
RBFT: Array of input board-foot volume required to satisfy cutting requirements for specific part size.
RGCYCL: Cycle time for gluing operation, specified in minutes.
RLAYUP: Time required for layup of panels in gluing operation, calculated in minutes.
SUM: Sum of 12 random numbers used in calculating a standardized normal deviate.
TBFT: Total board-foot volume of each part size that has been completely processed.
TCOST: Total processing costs for each part size that has been completely processed.
TDEP: Expected time for complete processing of a part at a given operation.
TNOW: Current time of simulation.
V: Calculated standardized normal deviate.
VCC: Computed variance for cost of a specific part size.
VML: Computed variance for material lost in processing a specific part size.
VWC: Computed variance for width of part for a specific part size.
WBFT: Calculated board-foot volume lost in ripsaw processing of individual part.
WD: Array containing mean, standard deviation and minimum and maximum value of part width for each part length entering system.
XCC: Array containing sum of costs for all part lengths.
XMATCH: Generated random number used to determine whether or not panel match operation is scheduled.
XML: Array containing sum of board-foot volume of material lost for all part lengths.
XNC: Number of observations for a specific part length on which statistics were collected.
XPC: Processing cost for individual parts leaving the solid part ripping operation.
XTRIM: Quantity, in inches of width, of trim loss in ripping to produce glue-line edge operation.
XWC: Array containing sum of part widths for all part lengths.
XXCC: Array containing sum of squared part costs for all part lengths.
XXML: Array containing sum of squared volume of material lost for all part lengths.
XXWC: Array containing sum of squared widths for all part lengths.
YBFT: Calculated percent of total volume of part input resulting in part output.
ZCC: Array of mean, standard deviation, and minimum and maximum cost for all part lengths after processing.
ZML: Array of mean, standard deviation, and minimum and maximum volume of material lost for all part lengths after processing.
ZWC: Array of mean, standard deviation, and minimum and maximum width of part for all part lengths after processing.

## Appendix IV—Input Instructions for MILLSIM 1

All data for MILLSIM 1 can be input using a standard 80-column, card-image format. Columns between 1 and 80 that are not specifically numbered in the following input formats contain no data and should be left blank.

*Card 1*

| Columns | |
|---|---|
| 1-8 | Nominal thickness of lumber input, in inches (THICK) |
| 9-16 | Operating rate for cutoff saw in board feet per minute (CRAT) |
| 17-24 | Operating rate for defecting ripsaw (#1) in lineal feet per minute (RATR(1)) |
| 25-32 | Operating rate for defecting ripsaw (#2) in lineal feet per minute (RATR(2)) |
| 33-40 | Operating rate for planer (#1) in lineal feet per minute (PRAT(1)) |
| 41-48 | Operating rate for planer (#2) in lineal feet per minute (PRAT(2)) |

*Card 2*

| Columns | |
|---|---|
| 1-8 | Times expected between cutoff saw and defecting ripsaw (CRRAT(1,1)) |
| 9-16 | Times expected between cutoff saw and defecting ripsaw (CRRAT(1,2)) |
| : | : |
| 57-64 | (CRRAT(2,4)) |

*Card 3*

| Columns | |
|---|---|
| 1-8 | Time between defecting ripsaw (#1) and rough planer (#1) (RPRAT(1)) |
| 9-16 | Time between defecting ripsaw (#2) and rough planer (#2) (RPRAT(2)) |
| 17-24 | Time between planer (#1) and sort operations (PSRAT(1)) |
| 25-32 | Time between planer (#2) and sort operations (PSRAT(2)) |

*Card 4*

| Columns | |
|---|---|
| 1-7 | Material cost per board foot of lumber input (COST) |
| 8-10 | Total number of part lengths to be processed (NSCHED) |
| 11-13 | Number of part lengths actively being cut (KSCHED) |

*Card 5* (Repeated once for each part length in the cutting order)

| Columns | |
|---|---|
| 7-10 | Alpha-numeric label used in printing results (LABL2) |
| 11-20 | Part length, in inches (PSCHED(1)) |
| 21-30 | Part volume required, in board feet (PSCHED(2)) |
| 37-40 | Priority for part lengths entering cutting bill (IPRIOR) |
| 42-50 | Final part widths for part lengths processed (FWID) |
| 51-58 | Panel widths for part lengths processed (FPWD) |

*Card 6*

| Columns | |
|---|---|
| 1-10 | Labor costs, breakdown hoist, day, dollars per hour (CLABOR(1,1)) |
| 11-20 | Labor costs, breakdown hoist, night, dollars per hour (CLABOR(2,1)) |
| 21-30 | Labor costs, cutoff saw, day, dollars per hour (CLABOR(1,2)) |
| 31-40 | Labor costs, cutoff saw, night, dollars per hour (CLABOR(2,2)) |
| 41-50 | Labor costs, ripsaw, day, dollars per hour (CLABOR(1,3)) |
| 51-60 | Labor costs, ripsaw, night, dollars per hour (CLABOR(2,3)) |
| 61-70 | Labor costs, sort, day, dollars per hour (CLABOR(1,4)) |
| 71-80 | Labor costs, sort, night, dollars per hour (CLABOR(2,4)) |

*Card 7* (Repeated once for each number of cuts per board observed at the cutoff saw)

| Columns | |
|---|---|
| 1-5 | Number of cuts per board at the cutoff saw (NCUT) |
| 6-10 | First cell of cumulative distribution function (CDF) for number of parts cut (CPROB(1)) |
| 11-15 | Number of parts associated with first cell of cdf (PCUT(1)) |
| 16-20 | Second cell of cdf (CPROB(2)) |
| 21-25 | Number of parts associated with second cell of cdf (PCUT(2)) |
| 26-30 | Third cell of cdf (CPROB(3)) |
| 31-35 | Number of parts associated with third cell of cdf (PCUT(3)) |
| 36-40 | Fourth cell of cdf (CPROB(4)) |
| 41-45 | Number of parts associated with fourth cell of cdf (PCUT(4)) |

*Card 8*

| Columns | |
|---|---|
| 1-3 | Total number of length-width combinations input to the data storage for MILLSIM 2 (ILENC) |

*Card 9* (Repeated once for each part length-width combination input to MILLSIM 2)

| Columns | |
|---|---|
| 5-8 | Part lengths to be processed in MILLSIM 2 (LENC) |
| 19-28 | Final part widths for part lengths processed (FWIDC) |
| 29-38 | Panel widths per part lengths processed (FPWDC) |
| 39-44 | Part grade (IGRADE) |
| 45-54 | Percent of a specific length part's output that will be used as input in MILLSIM 2 (PLENCT) |

*Card 10* (This card and all subsequent cards are GASP IV input data, required to control simulation)

| Columns | |
|---|---|
| 1-12 | User's name (NNAME) |
| 16-20 | User's project number (NNPRJ) |
| 21-25 | Month (MMON) |
| 26-30 | Day (NNDAY) |
| 31-35 | Year (NNYR) |
| 36-40 | Number of runs (NNRNS) |
| 41-55 | GASP control variable (000002002002000) (LLSUP) |

*Card 11*

| Columns | |
|---|---|
| 1-5 | Number of sets of statistics collected by COLCT (NNCLT) |
| 6-10 | Number of sets of statistics collected by TIMST (NNSTA) |
| 11-15 | Number of histograms (NNHIS) |
| 16-20 | Number of parameter sets (NNPRM) |
| 21-25 | Number of plots (NNPLT) |
| 26-30 | Number of random number streams (NNSTR) |
| 31-35 | Maximum allowable number of entries in NSET (NNTRY) |
| 36-40 | Number of attributes per entry in QSET (NNATR) |
| 41-45 | Number of files in NSET (NNFIL) |
| 46-50 | Dimension of NSET (NNSET) |

*Card 12*

| Columns | |
|---|---|
| 6-10 | Index number (I) |
| 11-18 | Label associated with ith variable used in COLCT (LLABC) |

*Card 13*

| Columns | |
|---|---|
| 6-10 | Index number (I) |
| 11-18 | Label associated with ith variable used in TIMST (LLABT) |
| 21-30 | Initial value of variable (SSTPV) |

*Card 14*

| Columns | |
|---|---|
| 6-10 | Index number (I) |
| 11-18 | Label associated with ith histogram (LLABH) |
| 26-30 | Number of cells in Ith histogram (NNCEL) |
| 31-40 | Upper limit of first cell of Ith histogram (HHLOW) |
| 41-50 | Width of cell for Ith histogram (HHWID) |

*Card 15*

| Columns | |
|---|---|
| 1-5 | Ranking attribute for file 1 (KKRNK(1)) |
| 6-10 | Ranking attribute for file 2 (KKRNK(2)) |

*Card 16*

| Columns | |
|---|---|
| 1-5 | File 1 ranking system (1 = low-value first) (IINN(1)) |
| 6-10 | File 2 ranking system (3 = first in-first out) (IINN(2)) |

*Card 17*

| Columns | |
|---|---|
| 6-10 | Parameter set number (J) |
| 11-20 | Parameter values defined by user (PPARM(J,1)) |
| 21-30 | Parameter values defined by user (PPARM(J,2)) |
| 31-40 | Parameter values defined by user (PPARM(J,3)) |
| 41-50 | Parameter values defined by user (PPARM(J,4)) |

*Card 18*

| Columns | |
|---|---|
| 1-5 | Method of stopping (1 = stop at TTFIN) (MSTOP) |
| 6-10 | Key for clearing statistical arrays (1 = clear) (JJCLR) |
| 11-15 | Key for initializing variables (1 = initialize) (JJBEG) |
| 21-30 | Initial value of TNDW (TTBEG) |
| 31-40 | Ending time of simulation (TTFIN) |
| 41-45 | Key for initializing file system (JJFIL) |
| 46-50 | Random number seed (1) (IISED(1)) |
| 51-55 | Random number seed (2) (IISED(2)) |
| 56-60 | Random number seed (3) (IISED(3)) |
| 61-65 | Random number seed (4) (IISED(4)) |
| 66-70 | Random number seed (5) (IISED(5)) |

## Appendix V—Input Instructions for MILLSIM 2

All data for MILLSIM 2 can be input using a standard 80-column, card-image format. Columns between 1 and 80 that are not specifically numbered in the following input formats contain no data and should be left blank.

*Card 1*

Columns
1-3 Total number of part sizes to be processed (NSCHED)
4-6 Beginning number for part (NSBEG)
7-9 Ending number for part (NSEND)

*Card 2* (Repeated once for each part length in the cutting order)

Columns
1-10 Length of part, in inches (ALEN)
11-20 Finished part width, in inches (AWID)
21-30 Panel widths, in inches (APWD)
31-40 Board-foot volume available (ABFT)
41-50 Board-foot volume required (RBFT)
56-60 Part grade (IGRADE)

*Card 3* (Repeated once for each part length-width combination in the cutting order. Immediately follows card 2 for each part length-width combination)

Columns
11-18 Part width, mean (WD(1))
19-26 Part width, standard deviation (WD(2))
27-34 Part width, minimum (WD(3))
35-42 Part width, maximum (WD(4))
43-50 Part cost, mean (CD(1))
51-58 Part cost, standard deviation (CD(2))
59-60 Part cost, minimum (CD(3))
67-74 Part cost, maximum (CD(4))

*Card 4* (This card and all subsequent cards are GASP IV input data, required to control simulation)

Columns
1-12 User's name (NNAME)
16-20 User's project number (NNPRJ)
21-25 Month (MMON)
26-30 Day (NNDAY)
31-35 Year (NNYR)
36-40 Number of runs (NNRNS)
41-55 GASP control variable (002022002202202) (LLSUP)

*Card 5* (Same format as card 11 in MILLSIM 1)
*Card 6* (Same format as card 13 in MILLSIM 1)
*Card 7* (Same format as card 15 in MILLSIM 1)
*Card 8* (Same format as card 16 in MILLSIM 1)
*Card 9* (Same format as card 18 in MILLSIM 1)