Rough mill simulator version 3.0: An analysis tool for refining rough mill operations

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Abstract

ROMI-3 is a rough mill computer simulation package designed to be used by both rip-first and chop-first rough mill operators and researchers. ROMI-3 allows users to model and examine the complex relationships among cutting bill, lumber grade mix, processing options, and their impact on rough mill yield and efficiency. Integrated into the ROMI-3 software is a new least-cost grade mix solver that determines the most inexpensive grade mix to process with regard to both purchase and processing costs. In addition, ROMI-3 now has a new gang-ripsaw optimizer that determines the optimal fixed-blade saw spacing sequence based on the user's lumber width distribution, cutting bill, and processing configuration. For each simulation, ROMI-3 reports the amount of lumber and number of cutting operations required to complete processing of a cutting bill, as well as part tallies by lumber grade and overall.

Small changes in rip-first and chop-first processing methods often have unexpected and undesirable consequences. The interactions among grade mix, arbor set-up, cutting bill requirements (part sizes, quantities, and qualities), equipment settings, and other factors make it difficult to predict the outcome of a single change. Simulation allows rough mill operators and researchers to examine the impact of a change without creating problems in the rough mill.

The ROMI-3 simulator (Weiss and Thomas 2005) is an enhanced version of the earlier ROMI-RIP 2.0 (Thomas 1999) and ROMI-CROSS 1.0 (Thomas 1998) rough mill simulators. As such, ROMI-3 can perform both rip-first and chop-first simulations using the same general processing options (kerf size, scheduling, prioritization, etc.), cutting bill, and lumber data. This was not possible with the ROMI-RIP and ROMI-CROSS programs, which used different cutting bill and lumber data formats.

ROMI-3 processes datafiles that contain information about board sizes, defect types, and locations. ROMI-3 uses the 1998 data bank for kiln-dried red oak lumber (Gatchell et al. 1998) that contains 3,487 boards and is graded to 1998 National Hardwood Lumber Association rules (NHLA 1998). ROMI-3 reads one board at a time from the datafiles and processes it into rough dimension parts according to user specifications. For rip-first processing, this first involves gang ripping the board into strips. Next, these strips are crosscut to primary part lengths, either specified or random. Any remaining strip sections are further processed by additional rips and crosscuts to salvage parts. Chop-first processing cuts the boards to primary part lengths and removes any wide defective areas. Next, the board segments are straight-line ripped to the required widths, specified or random. As with rip-first processing, any remaining board areas are further processed using additional rips and crosscuts to salvage parts.

The new simulator has a simplified user-interface and can analyze a wider variety of rough mill processing questions. Simulations can be set up to generate optimum yields (prioritizing cutting solutions based on maximizing part area for each board) or to meet cutting bill requirements (optimizing cutting solutions such that the combination of parts with the

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*Forest Products Society Member.

Forest Prod. J. 56(5):53-58.

highest total prioritized value is cut). For rip-first processing, a new arbor has been added that more accurately reflects real-world processing. The arbor, Simple-Fixed-Blade-Best-Feed (SFBBF) optimizes by maximizing the yield in strips for each board. Only the board width and the widths of the strips are considered, which simulates most gang-ripsaw optimization systems. Another addition to rip-first processing is a saw spacing optimizer that determines the optimal sequence of saw spacing widths for fixed-blade arbors given a cutting bill. However, the most important addition is a least-cost grade mix calculator that finds, for either rip-first or chop-first processing, the most inexpensive grade mix to process with respect to lumber cost, processing cost, and lumber availability by grade.

Cutting bill

Like the earlier ROMI-RIP 2.0 and ROMI-CROSS 1.0 simulators, ROMI-3 can produce solid, panel, and random-length (rip-first only) parts. All part dimensions and processing specifications can be specified to the nearest 1/16-inch (0.0625-mm) measurement. Further, ROMI-3 can produce parts using as many as 40 lengths and 20 widths, or 800 different part sizes. The cutting bill controls many aspects of processing within ROMI-3, including part prioritization, part scheduling and replacement, and part quality.

ROMI-3 supports several different methods of prioritizing cutting bills for efficient processing. When processing to meet a cutting bill's requirements, the goal is to cut all the required part sizes from a minimal amount of lumber while generating a minimal number of excess parts. This problem is made more difficult by variations in lumber grades and dimensions. To solve these problems in simulation, seven part prioritization strategies are available that range from simple to complex (Thomas 1996). The simple methods prioritize parts based on area (length × width). Complex methods generate part priorities based on each part's size and current required quantity. Complex methods are dynamic in that each part priority is updated continually as parts are cut and the remaining quantity of needed parts decreases. As the quantity requirements for a part size are met, emphasis shifts to other part sizes. The decision on which combination of parts to cut from a board is based on maximizing the total weighted area of parts for each board.

In the rough mill, there are often more part sizes than can be cut and properly sorted simultaneously. In these cases, a decision is made regarding which parts to process first and which parts are processed later as initial part quantity requirements are met. In ROMI-3, part scheduling and replacement are controlled within the cutting bill. When a cutting bill is entered with more part sizes than would normally be processed at once in the rough mill, the user can indicate which parts are scheduled to be processed first. For example, if a mill with 10 sorting bins is being simulated, 10 parts will be given a scheduling rank of "1." For the remaining parts, the user specifies their rank by assigning a number between 2 and 99. Rank 1 parts are processed first. As part requirements are met, ROMI-3 first checks parts in the order of their ranking and selects the part that is closest in width and length to the part whose requirements were just met. Further, if all of the rank 2 parts were already scheduled and a replacement part was needed, a part with a rank of 3, if any are available, would be selected and added to the processing.

A cutting bill links together the size, quantity, and quality specifications for each part. Part qualities are specified separately from the cutting bill, which allows many parts to refer to the same quality without having to define the same part quality multiple times. Using the ROMI-3 part grade editor, multiple qualities consisting of Clear-One-Face (C1F), Sound-Two-Face (S2F), and Clear-Two-Face (C2F) qualities can be defined and specified for cutting bills. As many as 99 part qualities can be specified and used for each cutting bill. ROMI-3 also allows users to define acceptable defect types that may be included in the parts along with an acceptable specific distance from the edge. This is useful for moulding and millwork parts where defects are acceptable so long as they are not in an area that will be machined.

Processing features

Gang-ripsaw arbors

The ROMI-3 computer program can simulate gang-rip-first processing using one of eight arbor types, of either fixed-blade and movable-blade configuration, or perform crosscut-first simulations. The simplest is the fixed-blade arbor, which performs no optimization, i.e., all boards are ripped with one edge against a fixed fence at the extreme left side of the arbor. A movable outer blade version of this arbor moves the rightmost blade to the edge of the board if an edging strip narrower than a specified minimum would be generated.

A more realistic choice is the SFBBF arbor. This arbor moves the board as with a moving fence such that the combination of saw spacings used gives the *optimum strip yield.* This uses a simple optimization method that seeks to maximize the board area occupied by strips. The Fixed-Blade-Best-Feed (FBBF) arbor operates much like the SFBBF arbor except that it uses the complete defect information available to determine the arbor feeding position that will result in strips that will yield the *optimum primary part yield.* Optimum primary part yield refers to yield in parts after ripping and chopping. Depending on the prioritization methods used, this will either be the set of parts with the highest volume of parts cut from a board or the group of parts with the highest total prioritized value.

The Best-Spacing-Sequence (BSS) arbor and the movable outer blade variant (BSS-MOV) are theoretical fixed-blade arbors and have no known real-world counterpart. These arbors determine for each individual board the best fixed-blade saw spacing sequence based on optimizing for primary part yield. The BSS-MOV arbor moves the rightmost blade to the edge of the board if an edging strip narrower than a specified minimum would be generated. Although these arbors are unrealistic, they are good for determining the maximum yield potential of a specific grade mix with respect to a cutting bill and processing situation. The other use for these arbors is to generate the series of optimum fixed spacing sequences that are used by ROMI-3 to arrive at the most desirable fixed-blade saw spacing sequence for the FBBF arbors.

The last two arbors, All-Blades-Movable (ABM) and Selective-Rip (SR), create gang-ripsaw strip solutions that are optimal with respect to primary part yield. The solutions are generated by moving all blades or just those selected by the user. One characteristic of these arbors is that a string of defects, such as pith and its associated defects, will often be boxed into a narrow waste strip. The flexibility of these arbors allows many more width combinations to be examined than with fixed-blade arbors. Although these arbors normally determine the highest yield possible, they do require longer execution times because of the greater number of permutations examined.

Optimizing fixed-blade saw spacing sequences

In the rough mill as in simulation, using an arbor with a less than optimal saw-spacing sequence results in waste and low yield. Often it is a difficult task to manually determine the optimal saw-spacing-sequence. This is because of the many interactions among cutting bill requirements, the lumber width distribution, and the potential arrangements of saw spacings. All of these interactions must be taken into consideration when constructing the arbor.

Mitchell and Zou (2001) at North Carolina State University developed a solution that examines all of these interactions. This is accomplished by processing the cutting bill using the specified lumber sample (selected by the user as being representative of their own lumber's grade, length, and width distribution) and the BSS arbors. Recall that the BSS arbors generate for each board the optimum sequence of fixed-blade saws. ROMI-3 tracks the optimum series of spacings used for all the boards processed and ranks them according to frequency. Any BSS arbor solution that was used on less than 2 percent of the board population is excluded from consideration while the optimum arbor is constructed. The optimum fixed-blade arbor is generated by examining every potential sequence and sequence combination generated by the BSS arbor optimizer. The sequence that yields the highest strip yield is presented to the user as the optimum arbor. By using simulation to construct the series of spacings used for each board, the arbor optimizer is able to consider the interactions of board width and cutting bill demands – the saw sequences embody the complete interaction.

Optimizing for the least-cost-grade-mix

Perhaps the most important feature in the ROMI-3 simulation is the addition of a least-cost-grade-mix solver, which determines the grade mix of lumber to process that will satisfy the cutting bill requirements at the lowest overall total cost (purchase + processing cost). Earlier attempts at solving the least-cost grade mix problem had used linear programming methods and assumed that the relationship between yield and lumber grade was linear. However, research shows that a linear relationship between grade mix and yield could not be guaranteed (Buehlmann et al. 2004). The solution of Buehlmann et al. does not use linear programming methods and therefore does not require the existence of a linear relationship (Zou et al. 2004). As such, the new least-cost grade-mix prediction model is more applicable and more accurate than previous models. The model described by Zou et al. (2004) bases its solutions on the yield and processing information generated by ROMI-3. Thus, the solutions are dependent on the processing configuration defined by the user. In the current model, grade mix combinations are optimized in 10 percent grade mix increments. This was done to decrease the amount of computer processing required to obtain a solution.

Sample analysis

To illustrate the processing powers of the ROMI-3 simulator, a comparison of the processing of a sample cutting bill (**Table 1**) using both chop-first processing as well as rip-first processing for the FBBF, SFBBF, and ABM arbors is presented. The part quality specification for all parts in the cutting bill is C2F. As part of the comparison, we will determine the least-cost grade mix for each processing method.

Table 1. — Sample cutting bill used in processing comparisons.

Part width	Part length	Quantity	Part type
------------(in)------------			
1.750	30.250	100	Solid
1.750	20.000	400	Solid
1.750	15.500	150	Solid
2.375	47.785	200	Solid
2.375	41.375	200	Solid
2.375	20.000	150	Solid
2.375	18.625	150	Solid
2.625	60.000	200	Solid
2.625	47.785	150	Solid
2.625	15.500	200	Solid
3.750	41.375	100	Solid
3.750	20.000	150	Solid
3.750	15.500	200	Solid
8.000	47.785	200	Panel
8.000	24.250	400	Panel

To perform the least-cost analyses, the processing cost for 1,000 board feet (BF) of rough dimension lumber for each grade needs to be calculated. The processing cost can be determined by using the total hourly operating cost for the rough mill and dividing it by the volume of lumber of a specific grade that can be processed in 1 hour. Two scenarios using different throughput volumes and rough mill hourly operating costs are examined. **Table 2** calculates the processing costs using a rough mill hourly operating cost of $1,000 while **Table 3** uses an operating cost of $650. The lumber costs are held constant and are based on current market prices for FAS, 1 Common, and 2A Common kiln-dried red oak lumber in the Appalachian region (Hardwood Market Report 2004). Prices for Selects and 3A Common were determined by adding the average kiln-dried premium price to the reported green prices for Selects and 3A Common.

To use the FBBF and SFBBF arbors, an optimal arbor sequence is needed. Because the cutting bill has a significant volume of panel parts, two optimal arbor sequences were generated: one that considers only the cutting bill solid part widths, and one that adds random-width spacings that complement the solid part widths. The addition of one or two random-width spacings allows for better optimization and more efficient panel part processing. Estimated strip yield for the first arbor solution is 95.5 percent, while the yield for the second solution was slightly better at 96.0 percent.

The first arbor solution (which included only cutting bill solid part widths) was:

3.75 - 1.75 - 3.75 - 1.75 - 2.625 - 2.375 - 3.75

The second arbor solution (which included random widths for panel optimization) was:

2.625 - 1.0 - 3.75 - 1.0 - 2.375 - 3.75 - 1.75 - 1.75 - 3.75 - 1.5

Other than the differences between rip-first (arbor) and chop-first processing, all other processing options were held constant for the simulations. The main processing options used were:

Table 2. — Scenario 1, processing and lumber costs.

Lumber grade	Processing volume	Processing cost[a]	Lumber cost
	(BF/hr)	($/1,000 BF)	($)
FAS	5,000	200	1,600
Selects	4,500	225	1,465
1 Common	4,000	250	1,115
2A Common	3,500	286	920
3A Common	3,000	334	860

[a]Based on a $1,000 per hour rough mill operating cost.

Table 3. — Scenario 2, processing and lumber costs.

Lumber grade	Processing volume	Processing cost[a]	Lumber cost
	(BF/hr)	($/1,000 BF)	($)
FAS	4,750	137	1,600
Selects	4,000	163	1,465
1 Common	3,250	200	1,115
2A Common	2,500	260	920
3A Common	2,000	325	860

[a]Based on a $650 per hour rough mill operating cost.

Table 4. — Least-cost grade mix cost analysis results.[a]

Arbor/ processing method	Cost scenario	Simulation determined least-cost grade mix solution	Predicted yield	Est. total processing cost
			(%)	($)
Rip-First FBBF[a]	1	40% FAS 60% Selects	71	6,888
Rip-First SFBBF[b]	1	80% FAS 20% 2A Common	48	9,726
Rip-First ABM[c]	1	100% 1 Common	70	5,557
Chop-First	1	40% FAS 60% Selects	72	6,848
Rip-First FBBF[a]	2	80% Selects 20% 1 Common	67	6,652
Rip-First SFBBF[b]	2	50% FAS 50% 1 Common	45	9,372
Rip-First ABM[c]	2	100% 1 Common	70	5,301
Chop-First	2	20% Selects 80% 1 Common	59	6,559

[a]FBBF = fixed-blade-best-feed arbor.
[b]SFBBF = simple fixed-blade-best-feed arbor.
[c]ABM = all-blades-movable arbor.

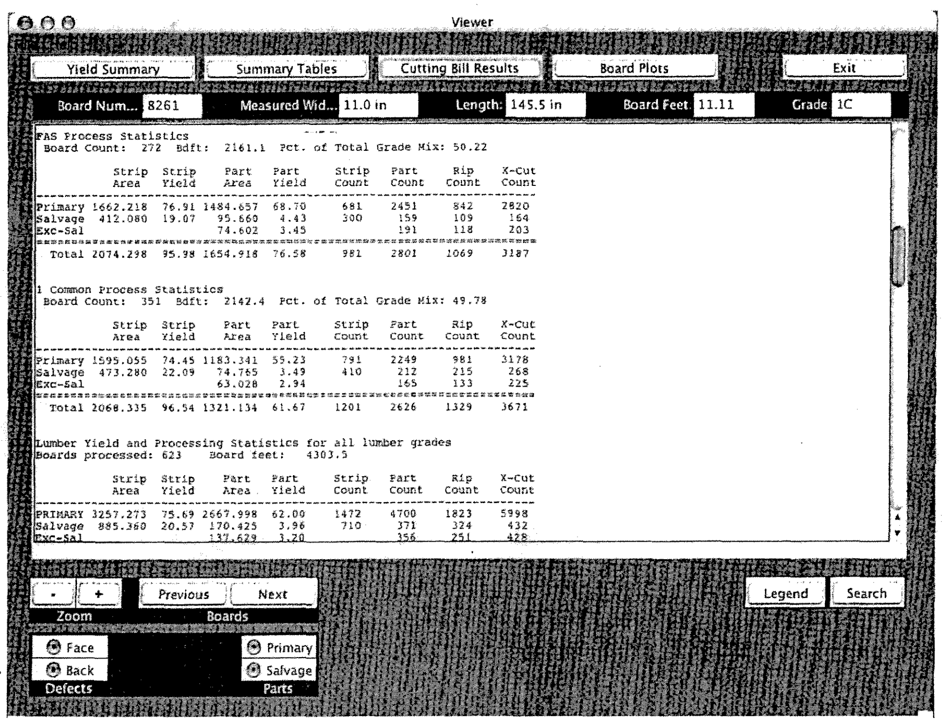

Figure 1. — Sample report showing yield and processing requirements by lumber grade.

ripsaw kerf = 0.125 inch

chopsaw kerf = 0.125 inch

primary operations avoid orphan parts

salvage cuts to primary part sizes

random widths acceptable in panel parts

no end trim allowance

parts prioritized using complex-dynamic-exponent method

The avoidance of orphan parts is a processing option that allows the simulator to turn off the production of parts when part requirements have been met. This is typical of well-run rough mills. Prioritizing parts with the complex-dynamic-exponent allows production to automatically emphasize large parts or parts with high quantity requirements. This is analogous to increasing the value of large and/or high quantity parts with a dollar or value prioritization mode in typical rough mills.

Two series of simulations were performed with different overhead and processing costs. The results of these analyses are listed in **Table 4**. The *Cost scenario* column in **Table 4** refers to the processing volumes, costs, and lumber costs for each grade as described in **Tables 2** and **3**. The *Estimated total processing cost* column is the sum of the lumber and processing costs. In general, the least-cost grade mix called for the use of lower-quality lumber in Scenario 2 where the processing cost was lower (**Table 4**). This is to be expected as lower processing costs make lower grades of lumber more economical to process. This is because more labor must be used to obtain the needed parts from lower grades. Similarly, if the cutting bill is an easy one, consisting mostly of short and/or narrow parts, then it is easy to obtain the parts from the lower grades.

When performing rip-first or chop-first analyses, ROMI-3 reports many different types of information that describe the

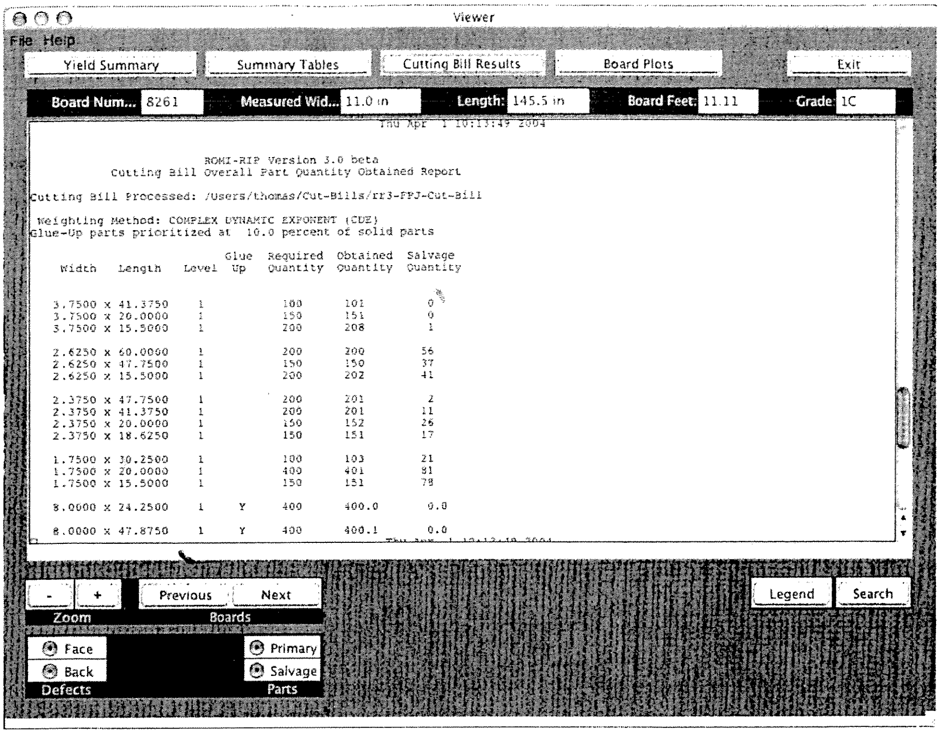

Figure 2. — Sample cutting bill report showing parts sizes, required quantity, and quantity obtained.

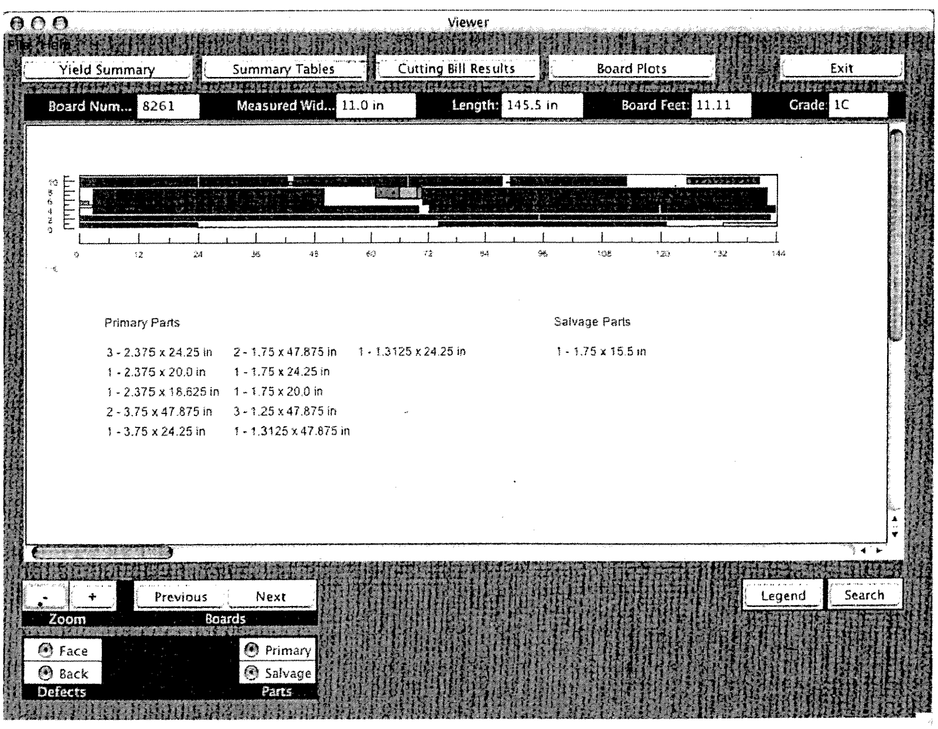

Figure 3. — Graphic showing cutting solution for a selected board.

results of the simulation. The cutting bill results file contains information that most users will find useful, such as yield and processing requirements by grade, strip yield by strip width (rip-first only), and a report listing the number of parts for each size obtained. **Figure 1** shows a sample yield report while **Figure 2** shows a sample cutting bill report that includes the parts sizes and quantities required as well as the number of parts obtained. The cutting solution for any board processed can be viewed (**Fig. 3**).

With the ABM arbor, the lowest overall cost was achieved for both scenarios. The ABM arbor returned a 70 percent yield in both scenarios and total estimated costs of $5,557 and $5,301 for scenarios 1 and 2, respectively. The ABM arbor adjusts the blades to achieve the optimal ripping solution from each board. This degree of optimization is not present in the other processing methods examined. Chop-first processing had the next lowest overall processing costs with total costs of $6,848 and $6,539 for scenarios 1 and 2, respectively. The results from the analyses using the FBBF were very similar to the chop-first results. For scenario 1, chop-first and FBBF analyses identified the same least-cost grade mix (40% FAS, 60% Selects). Estimated yield using the FBBF arbor is 71 percent while yield for chop-first processing was the highest at 72 percent. Further, the estimated total cost using the FBBF arbor was $40 higher than chop-first processing ($6,888 vs. $6,848). For cost scenario 2, the least-cost grade mixes for FBBF and chop-first were quite different, but differed in cost by only $93. The SFBBF had the lowest yield and the highest estimated total costs for both scenarios.

One implication of the least-cost-grade-mix analyses examined here is that it appears the more efficient and optimal a rough mill is, the more likely it is that it will be able to process lower grade lumber feasibly. However, more research is needed in this area to determine if this is true. This is a topic that will be explored in the future using the ROMI-3 simulator.

Summary

ROMI-3 is built on the validated and verified ROMI-RIP 2.0 rough mill simulator (Thomas 1999, Thomas and Buehlmann 2002, Thomas and Buehlmann 2003) and the ROMI-CROSS 1.0 simulator (Thomas 1996). As such, ROMI-3 provides a stable and flexible program for examining many day-to-day rough mill processing questions, such as: what is the most cost-efficient grade mix for this cutting bill? what is the optimal arbor layout for this cutting bill? how much lumber and processing will this cutting bill require? and many others. Built-in features of ROMI-3 include an optimal arbor layout generator, a least-cost-grade-mix calculator, and rip-first and chop-first processing capabilities.

The ROMI-3 program runs on IBM PC-compatible computers with 400 MHz or greater CPUs running Windows 98 and newer. In addition, versions of ROMI-3 are available for Solaris, Linux, and Mac OS X. ROMI-3 is available free from the USDA Forest Service. A copy of the program and user's guide may be obtained free-of-charge at the following website: www.fs.fed.us/ne/princeton/romi_3.html; or by contacting Ed Thomas, USDA Forest Service, Forestry Sciences Laboratory, 241 Mercer Springs Road, Princeton, WV 24,740; 304-431-2700.

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