# ROMI 4.0: Updated Rough Mill Simulator

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**Abstract**

In the secondary hardwood industry, rough mills convert hardwood lumber into dimension parts for furniture, cabinets, and other wood products. ROMI 4.0, the US Department of Agriculture Forest Service's ROugh-MIll simulator, is a software package designed to simulate the cut-up of hardwood lumber in rough mills in such a way that a maximum possible component yield is achieved. ROMI 4.0 simulates the cut-up of lumber using two common processing modes: rip first and chop first. Additionally, this latest version of ROMI includes a novel feature that allows users to analyze each board's yield when processed in either rip-first or chop-first mode. This permits yield gains to be achieved, resulting in lower material costs for industry participants. The software also allows a user to model, simulate, and examine the complex relationship among cutting bills; part dimensions, quantities, and qualities; processing options; and lumber grade mix. ROMI 4.0 includes many improvements over the previous version, including the combined rip-and-chop option and various improvements to the user interface. We subjected the software to a complete review to assure functionality and user-friendliness. This article discusses these improvements and demonstrates the usefulness of ROMI 4.0 for hardwood dimension mills for researching yield and process improvement opportunities.

Rough mill processing currently involves complex interrelated operations, in which changes to a mill's operational settings can have unexpected outcomes. In addition to determining an optimum cutting solution for existing lumber, rough mill managers also must optimize the lumber grade mix they purchase and assure effective execution of operations in their facilities. To obtain a better understanding of existing purchasing and cut-up options and their potential outcomes—including interactions between cutting bills, operational settings, and raw materials—simulation offers the easiest and least expensive way to test the merits of alternate scenarios.

Hardwood lumber costs account for up to 70 percent of the total product costs in the US secondary hardwood products industry (Kline et al. 1998, Mitchell et al. 2005, Buehlmann et al. 2011). According to Luppold (2011), approximately 5.3 billion board feet of hardwood lumber is consumed annually in the United States for the production of solid wood products and dimensional parts. Considering that the average cost of lumber used in the United States is an estimated US$750 per thousand board feet (Buehlmann et al. 2011, Hardwood Review 2012), the estimated nationwide total lumber expense in the United States for rough mills is approximately US$4.0 billion annually. Hence, improving the efficiency (yield) of all rough mills in the nation by 1 percent would reduce US lumber requirements by 53 million board feet and save the industry an estimated US$40 million per year. Kline et al. (1998) showed the importance of lumber costs on a microeconomic level by estimating that a 1 to 2 percent improvement in yield results in lumber cost savings of US$150,000 to US$300,000 per year in an average rough mill. Indeed, in modern rough mills, yield is considered the single most important metric and manufacturers aspire to minimize the costs of their raw materials (Buehlmann 1998). Therefore, intensive endeavors have been conducted in rough mill operations to increase and optimize lumber yield. Also, to save costs, rough mills are trying to use progressively lower quality lumber material for their dimension parts production (Thomas and Buehlmann 2003, Araman 2012).

To increase yield in a rough mill operation, a complex set of interrelated variables needs to be considered. Since no

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mathematical model exists that can account for the many interrelationships that exist in a rough mill, simulation is the preferred way of investigating rough mill operations performance. Therefore, a critical way to find yield improvements is the use of lumber cut-up simulation, followed by optimization of the actual production process prior to cut-up of actual lumber.

## Brief History of Rough Mill Simulation

The earliest rough mill simulators were produced by the Forest Products Laboratory and performed either rip-first or chop-first operations (Wodzinski and Hahm 1966, Stern and MacDonald 1978, Giese and Danielson 1983). However, these early simulators ran on mainframe computers, were not designed for ease of use, and considered a limited array of processing options. Later simulators were designed to handle more processing options, to be easier to use, and to run on personal computers. One of the first of these was GR-1ST, a rip-first-only simulator (Hoff et al. 1991), and CORY, a chop-first-only simulator (Andersen et al. 1995). RIP-X was the first simulator that allowed users to simulate either rip-first or chop-first processing (Steele et al. 2001). In addition, RIP-X could process cutting bills with needed quantities of parts, while GR-1ST and CORY could not.

In the years since, rough mill simulations have been proven to be a realistic way to assess potential improvements of rough mill operations (Buehlmann and Thomas 2001; Thomas and Buehlmann 2002, 2003). Since the introduction of computers into the daily operations of rough mills, scientists and industry participants have utilized the computer's power for simulation purposes (Buehlmann and Zuo 2008). Identifying ways to more effectively and efficiently process lumber into wood products can be extremely difficult and complex due to the interactions among processing technology, optimization settings, lumber grade, machine capability, and product requirements. To help solve these problems, the US Department of Agriculture (USDA) Forest Service developed the ROMI (ROugh MIll) simulation software package (Weiss and Thomas 2005).

ROMI 4.0 is an improved version of the previously validated versions of ROMI: ROMI 3.0 (Weiss and Thomas 2005), ROMI-RIP 2.0 (Thomas 1999; Thomas and Buehlmann 2002, 2003), and the ROMI-CROSS 1.0 simulator (Thomas 1996). ROMI 4.0 replaces all previous versions of the USDA Forest Service's ROMI software. ROMI 3.0 was the first version of the USDA Forest Service's rough mill simulation software able to perform rip-first and chop-first simulations using the same processing options such as part scheduling, prioritization, cutting bills, and lumber data options. ROMI-RIP and ROMI-CROSS were not able to interchange data because they used different cutting bill and lumber data. ROMI 4.0 is able to simulate changes in lumber grade mix composition, cutting bill requirements, panel specifications, inclusion of random width/length parts, arbor set-ups, sawblade configurations, sorting station capacities, allowable defects, and other technical parameters influencing rough mill operation and lumber yield. ROMI 4.0 also can handle data from all previous versions of ROMI and simulate rip-first, chop-first, and combined rip-and-chop operations.

## ROMI 4.0—New Features and Functions

Improving the ease of use of ROMI in version 4.0 was of considerable importance to this project. While the core functions remain the same or very similar to previous versions of ROMI, and while full compatibility with earlier versions of ROMI is assured, ROMI 4.0 offers several new functions and features to facilitate the use of the software package. Figure 1 shows the newly developed main graphical user interface with active cutting mode selection window (top left), cutting bill information (bottom right), and a new checklist for simulation parameters (middle right).

As in the previous version of ROMI, the cutting modes are located at the top left part of the main user interface, while the combined rip-and-chop option is a new feature of ROMI 4.0. The user can choose the cutting mode for the simulation and define the parameters in the option windows below the cutting bill information on the main user interface. The simulation checklist on the right-hand side of the main user interface shows the main parameters of the simulation and checks them as the user completes or confirms the settings of a component. As such, the checklist reminds the user which parameters need attention before the simulation can be run. The cutting bill information allows the user to identify the most important information about the simulated cutting bill.

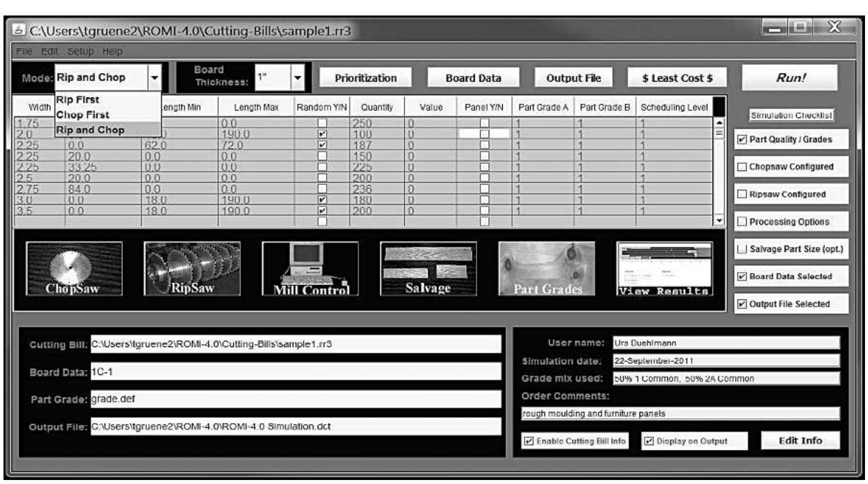


*Figure 1.—New main user interface in ROMI 4.0, shown with active cutting mode selection window.*

## Cutting bill information

ROMI 4.0 features improved usability for the novice user through in-depth tracking of information, which is displayed in the main user interface. ROMI 4.0 tracks the data defining the cutting bill in a ''cutting bill information'' file. Being able to track specific information about a cutting bill or a simulation helps the user to know what version of a given file he or she is looking at or when a modification took place. Keeping track of the most recent version of a cutting bill ensures that updates are appropriately considered during scheduling and production of dimension parts. In ROMI 4.0, the ''cutting bill information'' feature is displayed on the main user interface and includes user name, simulation date, grade mix used, and order comments (additional information about the cutting bill). All this information can be displayed on the results to better track differences among simulations. Figure 2 shows the cutting bill information window on the main user interface. Additional information includes modified by, modification date, company, and misc. comments, which can be helpful in identifying a given cutting bill and its current status (e.g., modifications or updates, special requirements, and production information).

## Rip-and-chop option

In the user interface of ROMI 4.0, the user can choose between three cutting modes: chop first, rip first, and rip and chop (Fig. 1). The rip-and-chop option is a new feature of ROMI 4.0. This option performs a complete rip-first and chop-first optimized cut-up on each board, noting the total prioritized part value from the cut-up methods. The part priorities assigned to the parts are determined by the user's part prioritization specifications (Thomas 1996). The solution from the method that obtained the best results is kept as the optimal solution for that board. ROMI 4.0 tracks the volume and number of boards, primary and salvage yield for the rip-first and chop-first processing methods, and overall statistics for both methods combined.

## Thickness option

Previous versions of ROMI did not allow the user to simulate the cut-up of lumber in any other than the standard 4/4 (1-in.) thickness on which the red oak database of Gatchell et al. (1998) is based. ROMI 4.0 offers the user choices among thicknesses based on the National Hardwood Lumber Association (NHLA) guidelines (NHLA 2011). The user can simulate standard thicknesses ranging from 3/8 to 24/4 inches. The resulting yield (in a given rough mill operation) and calculated board footage will strongly depend on the real processed lumber quality and thickness, since the simulation of ROMI 4.0 still refers to the 1998 Gatchell Red Oak database (basis for the simulation process within all ROMI simulation and optimization processes) and may result in different yield results compared with a real world rough mill operation. The ''yield summary table'' output files consider the thickness selected, and the processed board footage will be calculated accordingly. For example, to show the use of the thickness option, if the user is simulating a given cutting bill on the standard thickness of 4/4 inches, the processed board footage to satisfy the cutting bill requirements reaches 5,130 board feet. With the same cutting bill as before but with the material at 10/4 inches, the processed board footage will result in 13,192 board feet. While actual yield in the mill would differ from simulated yield with thicknesses other than 4/4 inches, the difference would be slight. Specifically, yield would be impacted if a defect encapsulated in a board is discovered during a cutting process and results in a rejected part. Thus, the greatest differences would be with the thicker boards. No yield difference would be expected with boards thinner than 4/4 inches.

## Predefined part grades option

ROMI can process multiple part grades for any simulation run performed. With ROMI 3.0, users could specify a variety of defect types, sizes, acceptable distances from the part edge(s), and whether each defect was acceptable on the face side, back side, or on both sides (faces). There was no limitation in the number of part grades the user could define, though a part size could only have one part grade definition. ROMI 4.0 expands the software's capabilities with respect to part grades. In ROMI 4.0, a set of predefined part grades has been added based on the Wood Component Manufacturers Association (WCMA) ''Rules and Specifications for Dimension and Woodwork'' (WCMA 2007). These are part of the part grade definition menu and allow users to create

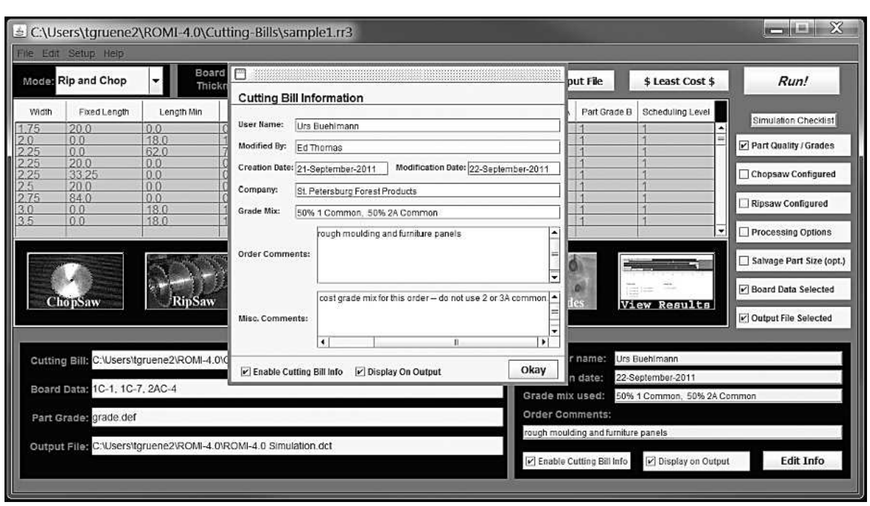


*Figure 2.—ROMI 4.0 cutting bill information window.*

lumber cut-up simulations consistent with WCMA (2007) rules. These WCMA (2007) part grades are predefined in three different part quality grades (e.g., ''slight,'' medium,'' and ''heavy'' defects). For example, the WCMA (2007) part grades define the maximum size of sound knots for the three quality grades. In particular, for slight, the highest quality grade, sound knot sizes must be $\leq$1/4 inch; for medium, $\leq$1/2 inch; and for heavy, $\leq$1 inch. However, due to missing information in the 1998 red oak database (Gatchell et al. 1998), some character marks defined in WCMA (2007) could not be implemented in these predefined part grades. Examples include discoloration or mineral streaks. Also, users who are taking advantage of these predefined part grades can modify the selected part grade as they see fit to better mirror their business's needs.

## Sample Simulation

The capabilities of ROMI 4.0 are illustrated with a sample simulation. The parameters for the simulation in this article were kept consistent with Thomas and Weiss's (2006) work to allow for comparisons and are shown in Table 1. The sample cutting bill shown in Table 2 is simulated using the three cutting modes of ROMI 4.0, and the resulting yield is compared. The part quantity specification for all parts in the cutting bill is clear-two-face lumber (C2F). Thomas and Weiss (2006) simulated the same cutting bill to illustrate several other features of ROMI 3.0, such as the least-cost grade mix option, different cutting modes and arbor setups, and the integration of rough mill processing costs into the least-cost grade mix feature. To simulate the fixed-blade-best-feed (FBBF) and simple-fixed-blade-best-feed (SFBBF) arbors, an optimal arbor sequence is needed. Due to the significant volume of panel parts, two optimal arbor sequences were generated: one arbor setup that considers the cutting bill solid part widths and one arbor setup that adds random-width spacings that complement the solid part widths (Thomas and Weiss 2006). While the first arbor would be satisfactory for processing the cutting bill, the second would result in higher yield due to its efficient generation of panel stock. These two arbor choices reflect two common ways of designing rip-first arbors.

Table 2 shows the dimensions and quantities of the sample cutting bill used for all three cutting modes: rip-first, chop-first, and the combined rip-and-chop option.

Table 3 shows the results of the repetition of Thomas and Weiss's (2006) simulation using their cutting bill (Table 2) and parameters (Table 1). The rip-first cutting mode resulted in a predicted yield of 67.38 percent and required a total of 545 boards (Table 3), whereas the chop-first cutting mode resulted in a predicted yield of 52.78 percent and required a total of 663 boards. Thus, rip first resulted in 27.66 percent higher yield, a result supported by earlier research that rip-first cutting modes result in higher yield when lower grades of lumber are processed (e.g., Shepley 2002, Wiedenbeck et al. 2004). Interestingly, the combined cutting mode, rip and chop, resulted in a predicted yield of 67.44 percent, only slightly better than the rip-first cutting mode. In fact, ROMI 4.0, in rip-and-chop-first mode, only processed 10 boards in chop-first mode, whereas 537 boards were processed in rip-first mode. Therefore, only a slight difference in the predictive yield could be observed. However, the reader has to be aware that predicted yields for simulation runs using different parameters and lumber grades may be considerably different. Nevertheless, the comparison between the chop-first cutting modes (chop-first mode and the chop-first cutting mode of the combined process [rip-and-chop option]), showed a difference in predictive yield of 5.94 percent.

*Table 1.—Simulation parameters for sample simulation.*

| Simulation parameters | |
|---|---|
| Ripsaw kerf = 0.125 in. | Chopsaw kerf = 0.125 in. |
| 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 | |
| Arbor settings: fixed-blade-best-feed (FBBF), simple-fixed-blade-best-feed (SFBBF), all-blades-movable (ABM) | |
| First arbor solution: 3.75, 1.75, 3.75, 1.75, 2.625, 2.375, 3.75 | |
| Second arbor solution: 2.625, 1.0, 3.75, 1.0, 2.375, 3.75, 1.75, 1.75, 3.75, 1.5 | |

*Table 2.—Sample cutting bill used for cutting mode comparison.*[a]

| Part width (in.) | Part length (in.) | Part quantity | Part type |
|---|---|---|---|
| 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 | 47.825 | 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 |

[a] The cutting bill is identical to the sample cutting bill in Thomas and Weiss (2006).

## Summary

The USDA Forest Service's rough mill simulation software (ROMI) is a powerful tool to help the secondary hardwood industry minimize raw material costs and increase processing efficiency. ROMI 4.0 allows industry participants to simulate day-to-day rough mill operations. ROMI 4.0 can determine the most cost-efficient lumber grade to buy, find the optimal arbor sequence for a given

*Table 3.—Cutting mode comparison on resulting yield.*

| Cutting mode | % predicted yield | No. of processed boards |
|---|---|---|
| Rip first | 67.38 | 545 |
| Chop first | 52.78 | 663 |
| Rip-and-chop option with | 67.44 | 547 |
| Rip first | 67.58 | 537 |
| Chop first | 58.72 | 10 |

cutting bill, and determine the lumber requirements to satisfy that cutting bill. New features added to ROMI 4.0 allow users to simulate either rip-first, chop-first, or rip-and-chop-first cutting modes; different lumber thicknesses (albeit all simulations are based on the original 4/4-in. lumber); and to select predefined part grades using WCMA standards. The ROMI 4.0 simplified simulation checklist and improved cutting bill information give novice users easier access to ROMI than did earlier versions. The ROMI 4.0 simulation software and the user's guide are available free of charge by contacting Ed Thomas, USDA Forest Service, Forestry Sciences Laboratory, 241 Mercer Spring Road, Princeton, WV 24740. They also may be downloaded from http://woodproducts.sbio.vt.edu/ROMI4/ROMI4.zip.


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