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ROMI-RIP: ROugh MIll RIP-First Simulator

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Abstract

The ROugh MIll RIP-First Simulator (ROMI-RIP) is a computer software package that simulates the gang-ripping of lumber. ROMI-RIP was designed to closely simulate current industrial practices. The simulator allows the user to perform "what if" analyses on various gang-rip-first rough mill operations with fixed, floating outer blade and all-movable blade arbors. ROMI-RIP accepts cutting bills with up to 300 different part sizes. Plots of processed boards are easily viewed or printed. Detailed summaries of processing steps (number of rips and crosscuts) and yields (single boards or entire board files) also can be viewed or printed. ROMI-RIP requires IBM personal computers with 80286 or higher processors (80486 or Pentium computer is recommended).

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1. Introduction

The ROugh Mill RIP First Simulator (ROMI-RIP) is a computer program that simulates six different gang-rip-first operations on lumber. ROMI-RIP allows users to perform "what if" analyses on many rough mill operating parameters including: cutting bill, lumber quality and size, gang-rip saw configuration, and their interactions. The simulator reads digitized board information from user-specified data files. Gang-rip results, tailored to the user's specifications, are generated for each digitized board. Plots may be viewed or printed showing the location and size of each cutting in each board. Concise tables summarizing the entire simulation run are available for viewing or printing. This publication provides a technical overview of the ROMI-RIP gang-ripping process. A companion publication, *ROMI-RIP User's Guide* (Thomas 1995), describes how to install and use the program.

Previous Forest Service gang-rip-first computer programs --GR-1ST and AGARIS-- were based on the RIPYLD (Stern and MacDonald 1978) simulator and its unpublished successor, MULRIP, developed by A. R. Stern and E. H. Bulgrin at the Forest Products Laboratory, Madison, Wisconsin. These programs generated optimum gang-rip solutions for hardwood processing. The GR-1ST program (Hoff et. al. 1991), based upon the MULRIP program, added a movable outer blade arbor and emphasized primary part yield. AGARIS (Thomas et al. 1994) was based on the GR-1ST program. AGARIS added a new salvage algorithm and user-friendly setup and result routines.

The structure of these early programs limited both the types of simulations and the information available to the user. They could not respond to the specific needs of a cutting bill. The RIPYLD program family was limited to 10 part lengths and 3 specified part widths. More serious were the limited types of arbors and the number of spacings available on each arbor. AGARIS, the most advanced of the previous generation of programs, provided only three arbor types and a maximum of seven saw spacings.

ROMI-RIP is a completely new program designed to overcome the limitations of the RIPYLD family of programs. A key objective during the design and development of ROMI-RIP was to produce a simulator that could closely simulate current and potential gang-rip-first rough mill practices. To do this, ROMI-RIP was designed with completely new algorithms to simulate the cutting of primary and salvage parts. The resulting program has more features and is faster and more user-friendly than earlier Forest Service gang-rip-first simulators. One of the more important features is ROMI-RIP's ability to process lumber according to a cutting bill (a list of part sizes and associated quantities). Some other features of ROMI-RIP include:

- Part lengths: 30 primary, 12 salvage, or random
- Part widths: 10 primary, 8 salvage
- Salvage operations can use primary or salvage specific sizes
- 15 saw spacings with a maximum arbor width of 48 inches
- 6 arbor types
- Primary and salvage rip, crosscut, and strip counters
- Allowable defects can be specified
- Cutting bill support for as many as 300 part sizes
- Dynamic or value based cutting bill optimization
- Custom datafile creation with or without random board selection

ROMI-RIP was developed for IBM[1] compatible personal computers using the C and assembly programming languages. The *minimum* system requirements to run ROMI-RIP are:

1. An IBM compatible 286 computer (486 or Pentium recommended)
2. 512K of Random Access Memory (RAM)
3. A hard disk with at least 10 Mb free space
4. MS DOS 4.0 or later (MS DOS is a trademark of Microsoft Corp.)
5. A high-density 3.5-inch or 5.25-inch floppy drive
6. An EGA or VGA graphics display
7. A mouse (optional, but recommended)
8. A printer (optional, but recommended)

[1]The use of trade, firm or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

2. Process Overview

ROMI-RIP processes one board at a time. A board is first gang-ripped into strips. These strips are then examined for full-width areas that are clear or contain only acceptable defects. These clear areas are marked and crosscut to primary part lengths. A primary part is a full-width part that can be cut from a strip at the crosscut operation. Any remaining strip area is examined for salvage parts. Salvage parts are those cut from a strip following crosscutting with additional salvage ripping and crosscutting operations. This additional processing makes salvage more expensive to produce and, therefore, less desirable. Unused areas that remain after the salvage operation are regarded as waste. The processing steps and material flow between processes are summarized in Figure 2.

After a board is ripped, the strips are examined for primary parts. First, each strip is scanned along the edges for defects. Once the defect positions are noted, ROMI-RIP examines the interior of the strip, searching between the edge defects or strip ends for all clear primary areas. If any clear areas are found that meet the minimum length criterion, the coordinates of those areas are passed along to the crosscut process.

After the primary parts are cut, ROMI-RIP examines any remaining strip sections of sufficient length and width for salvage parts. The process of locating salvage parts requires a more complex search procedure than primary parts. For primary, a simple lengthwise search between defects is used to find clear, full-width strip areas. For salvage, the part can be anywhere within the remaining strip section. The only requirement, in addition to meeting the minimum size specifications, is that the salvage part edges are parallel to the strip edges.

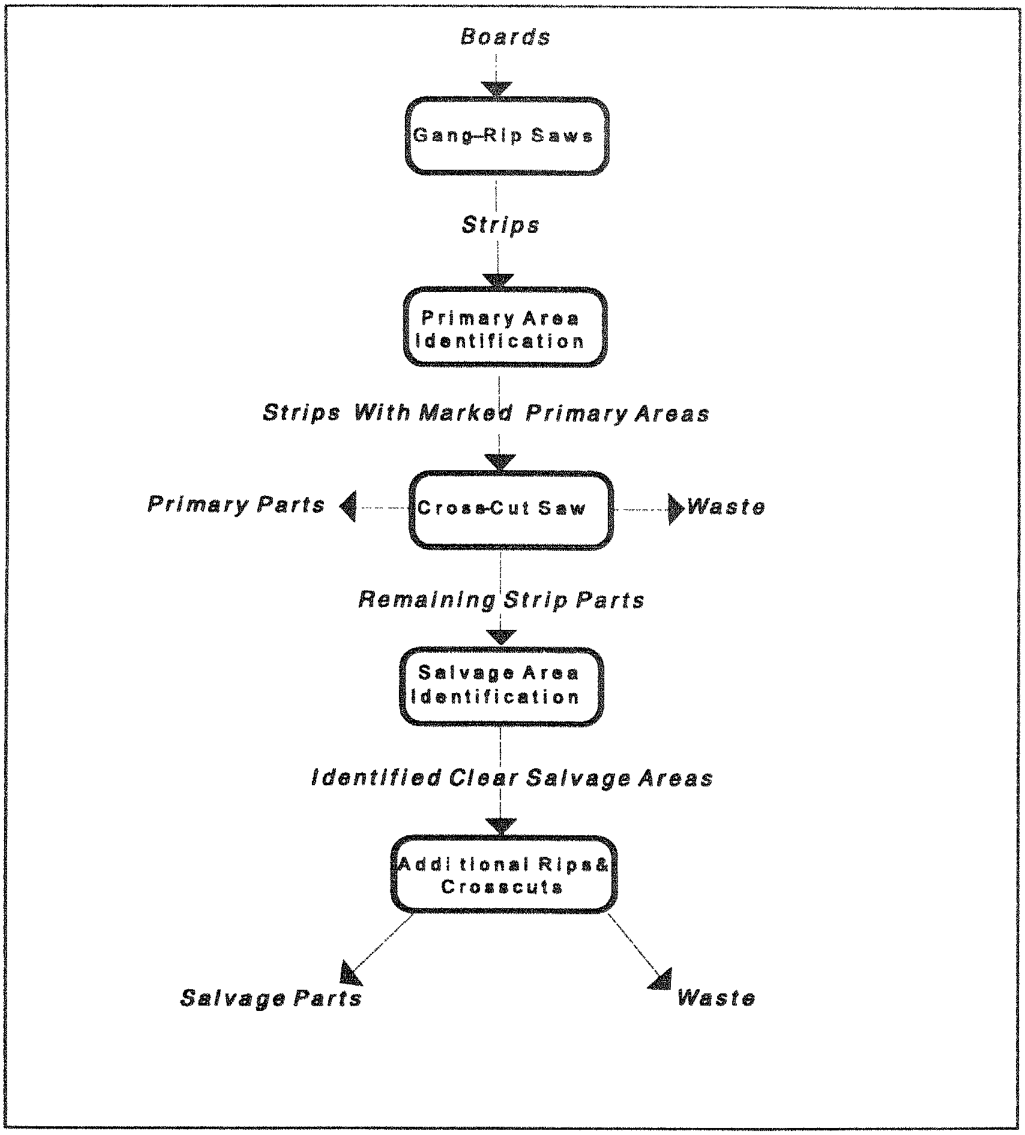

Figure 2. ROMI-RIP board processing flow.

3. Cutting Bill Operation

ROMI-RIP operates two ways. The first is with a setup list that specifies the part lengths, widths, and other processing options without regard to number of parts required. When run this way, ROMI-RIP will select the part widths and lengths that will generate the greatest yield in primary-part area. Running ROMI-RIP this way is a useful survey technique. The user can easily see if the minimum amount of needed parts can be found in a particular group of boards.

The second way to operate ROMI-RIP is with a cutting bill. Here, specific part quantities are assigned to different part sizes. The goal now is to cut only needed parts from as little lumber as possible, while minimizing the production of "orphan" parts (unrequired primary parts).

Interactions among length, width, and quality of boards and parts are critical to efficient processing. Longer and wider parts are much more difficult to obtain from the lower grades. Lumber quality varies from board to board within a lumber grade. To solve these problems, a method is needed to prioritize parts so that the simulator can make a decision regarding which part size to cut.

ROMI-RIP allows the user to select one of several part prioritizing strategies based on area, dollar value, or the newly developed dynamic exponent. The goal of these strategies is to meet all of a cutting bill's required cuttings while using the least amount of lumber. Value- and area-based strategies are included because they are historical and users might be more comfortable using these, at least initially. ALthough these are static in nature (the first and last pieces cut for a part size have the same priority), I have included a simple modifier for each that will make them somewhat dynamic. However, the recommended strategy is the dynamic exponent method.

3.1 Value-Based Part Prioritizing

ROMI-RIP contains two value-based part prioritization strategies: PART VALUE and DYNAMIC PART VALUE. PART VALUE is similar to strategies used in earlier mill simulations such as CORY (Brunner 1989). With part valuing, each part size is assigned a value. The decision on which parts to cut from a board is based on the maximum value of parts. Large part sizes or parts that are needed more are given a higher value. Smaller part sizes are given a lower value. Obviously, very different results can be obtained by using different part values. In reality, the values assigned to the different part sizes may or may not reflect the actual value of the part. The simulation is very dependent on the user's assumptions about the values.

Most dollar valuation systems cannot consider needed part quantities. If a part is valued high at the beginning of processing, it will have the same high value at the end of processing; even if the required number of cuttings are met shortly after processing begins. A better solution is to decrease the value of the part as its requirements are met (DYNAMIC PART VALUE). This shifts emphasis from quantity requirements for parts that are nearly satisfied to those that are not being met. If the required quantity for a part size is ***N***, the value of a part is reduced ***1/N*** each time a part is cut. For example, if you value a part size at $1.00 and require 50 of them, cutting one part of this size will reduce the value of the next part to $0.98.

3.2 Area-Based Part Prioritizing

ROMI-RIP contains two part prioritizing strategies based upon part area; L^2W and $L^2W*NEED$. The L^2W strategy is the same formula found in Thomas's YIELD program (Thomas 1962), Brunner's CORY (Brunner et al. 1989), and the Forest Products Lab's YIELD program (Wodzinski and Hahm 1966). L^2W builds in a preference for longer cuttings. It does not, however, consider part quantity.

Cutting bills where the numbers of different parts vary greatly are difficult to analyze. A simple improvement to the L^2W formula is the $L^2W*NEED$ strategy (Thomas, In press). L^2W multiplied by NEED, the current number of parts required for a particular part size, results in a L^2W strategy that is sensitive to quantity demands. Overall performance is improved. As a part is cut, the need for that part size is decreased by one. The $L^2W*NEED$ strategy can be regarded as a simple dynamic strategy.

3.3 Dynamic Part Prioritizing

Dynamic part-prioritizing strategies seek to overcome many of the problems associated with dollar- or area-based strategies. Dynamic strategies are distinguished from others by the ability to reduce priorities as part requirements are met. Rather than depend on part size alone or on an operator's judgment as to which values to assign to different part sizes, dynamic strategies assign each part size a priority based on its size and needed quantity. This allows cutting preference to shift from parts with quantities nearly met to those that require a greater quantity.

ROMI-RIP's dynamic strategies calculate exponential weighting factors that are based on the needed quantity of a part size. The value of these exponential factors typically range in value from 1.0 to 3.2, depending on the needed quantity of the part size. ROMI-RIP allows the user to pick from one of two exponential part prioritizing strategies: Simple Dynamic Exponent (SDE) or Complex Dynamic Exponent (CDE). As the name implies, CDE considers more information about the cutting bill's current requirements than SDE when assigning part priorities. For example, CDE is sensitive not only to how many parts are currently needed for each size, but also to how many have been cut. This is useful when a cutting bill contains large parts with relatively small needed quantities. Obviously, large parts will be harder to obtain. With only a quantity based exponential weighting factor, these parts may not be given high enough priority to be obtained opportunistically. CDE increases the priority of such parts so that they can be obtained at earlier, more opportune times in processing.

CDE and SDE should not be confused with dynamic variants of the value- and area- based strategies. The simple dynamic value and area strategies mentioned earlier reduce their priorities linearly; CDE and SDE reductions are exponential. A major drawback to linear reduction is that the priority of a part is reduced much more rapidly than with the exponential method (Fig. 3.3). The key advantage of the CDE and SDE strategies is that they maintain priority levels until most of the required cuttings for the part have been obtained. Figure 3.3 shows a comparison between the linear dynamic area strategy and the exponential CDE strategy. A full discussion of the evolution of the dynamic prioritizing strategies is found in *Prioritizing Parts From Cutting Bills When Gang Ripping First* (Thomas, In press).

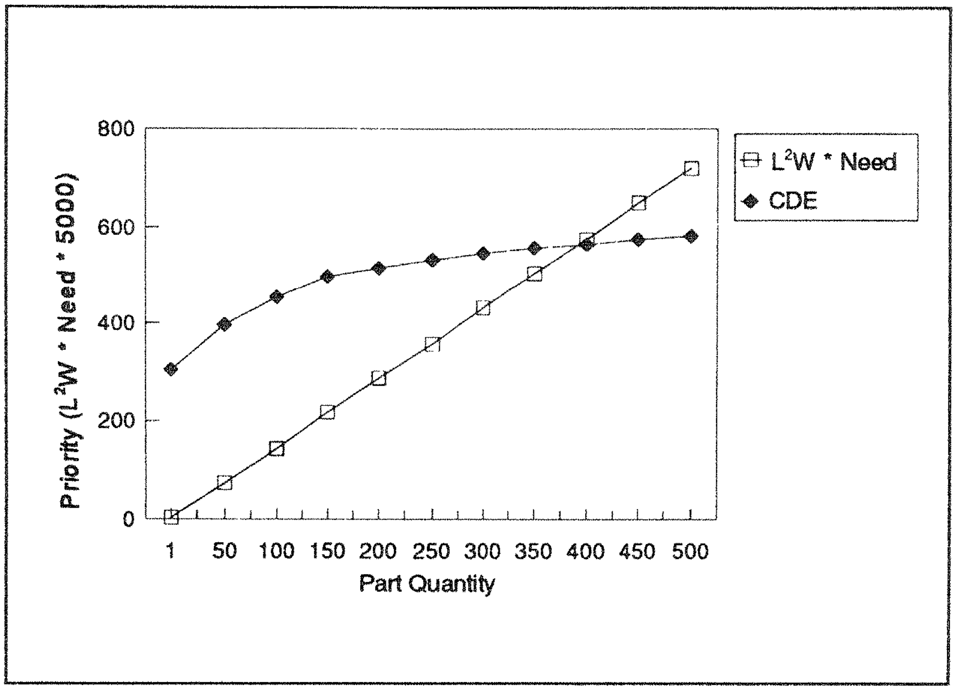

Figure 3.3. L^2W*Need and CDE prioritizing comparison for a 2 x 60-inch part.

3.4 Selecting a Part-Prioritizing Strategy

ROMI-RIP's default part-prioritizing strategy is CDE (Complex Dynamic Exponent). CDE prioritizes parts so they can be obtained from the least amount of lumber most of the time. However, this level of efficiency may be too high for some users. If chop saws are being run on a longest-length-first basis, the L^2W or L^2W*NEED strategy might predict yield better. Or, if a system requires a part valuing approach, ROMI-RIP's value-based strategies might be useful.

4. Arbors

ROMI-RIP has six different arbor types: (1) fixed arbor, (2) fixed arbor with movable outer blade, (3) a fixed-blade-best-feed arbor, (4) best-spacing-sequence, (5) best-spacing- sequence with movable outer blade, and (6) an all-blades-movable arbor. Unless otherwise specified, all arbors process the board from the right edge to the left edge, with the right edge being against the fence (Fig. 4). You may specify that the left edge be placed against the fence. This flips the board over before processing. When simulating a fixed-arbor saw, the spacings are specified so that the first spacing is closest to the rip fence.

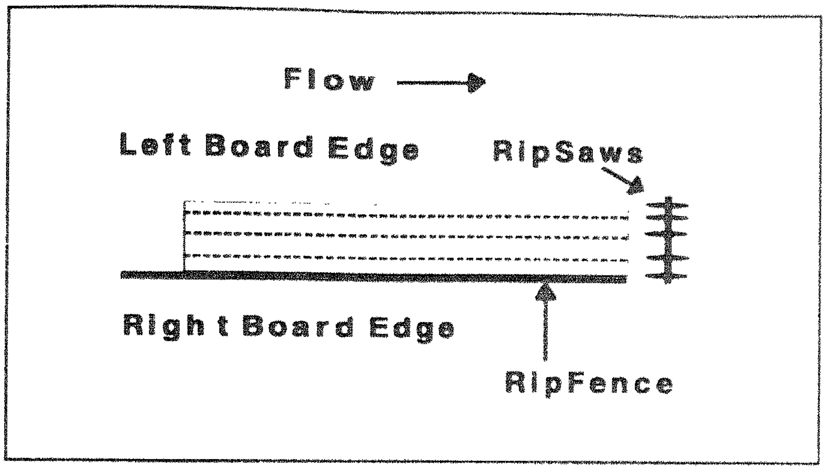

Figure 4. Rip-Fence, board and arbor relationship.

Note: ROMI-RIP uses a saw thickness of 1/4-inch for both rips and crosscuts.

4.1 Fixed Arbors

ROMI-RIP has three different fixed-arbor types: fixed, fixed with movable outer blade, and fixed-blade-best-feed. The fixed-blade-best-feed arbor simulates currently available optimizing lumber feeding systems. For all three fixed-arbor configurations, the user specifies the saw spacing sequence by specifying as many as 15 spacings and 10 different strip widths.

The fixed-blade arbor gang rips each board with its edge against a fixed position rip fence. This generates primary width strips and, most likely, an edging strip. The fixed-with-movable-outer-blade arbor avoids generating narrow, unusable edging strips. When using this arbor, ROMI-RIP requires the user to specify a minimum acceptable width for primary parts. When a board is placed against the fence, it is examined with respect to the saw spacings. If the current spacings would generate an edging-strip width less than the minimum acceptable primary width, the last blade is moved to the edge of the board and a single, wider, random-width strip is generated.

The fixed-blade-best-feed arbor uses a moving fence to select the feeding position that generates the best results. The layout of this arbor is shown in Figure 4.1. Each board is moved across the arbor in 1/4-inch increments. For each location, ROMI-RIP determines the yield. If a cutting bill is used, ROMI-RIP determines which arbor position will generate the most desirable parts. After all positions have been examined, the fence is moved to the optimum location and the board ripped.

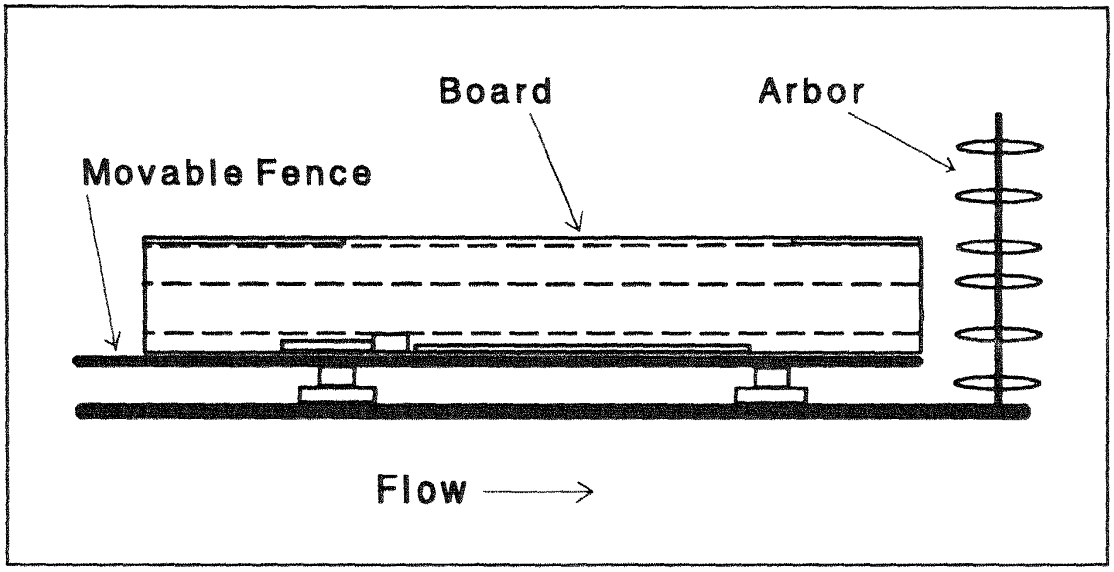

Figure 4.1. Fixed-blade-best-feed arbor layout.

4.2 Best-Spacing-Sequence Arbors

The best-spacing-sequence arbors optimize the sequence of the saw spacings. If a cutting bill is not being used, spacings are selected that will generate the greatest area of primary cuttings. If a cutting bill is used, spacings will be selected that will generate the most needed and hardest to get primary parts. See Section 3 for information on how a part is determined to be more desirable than others in a cutting bill.

The optimal placement of the saw spacings along an arbor is determined by an exhaustive search. Every possible combination of spacings is examined for each board. The actual number of spacings used is determined by an interaction between the board width and the specified cutting widths.

Earlier programs considered each possible combination of saw spacings separately. For example, consider the two saw space sequences: 2"-2"-1"-3" and 2"-2"-2"-3". RIPYLD and its successors would determine the yield from the first set of saw spacings and then determine the yield for the second set. The yield from the first two spacings (2"-2") would be determined twice. However, yields from the first two saw spacings need to be determined only once for any given board as the yield from the 2"-2" spacings will be the same. ROMI-RIP uses a recursive function to construct a series of possible strip sequences. The recursive function tracks the yield and strip sequence up to the current strip. Because each possible strip is examined only once, a dramatic decrease in processing time results.

ROMI-RIP's variable arbor with five to six widths usually runs faster than AGARIS's variable arbor with three widths. For example, consider a 6-inch-wide board using three primary part widths of 1, 2, and 3 inches and ignore kerf. AGARIS would examine a total of 204 strips. ROMI-RIP will examine only 81 strips. The greater the number of widths, the narrower the primary part widths, or the wider the board being processed, the greater the difference between simulators. Continuing the above example, if a 2.5-inch width could be added to the AGARIS arbor, AGARIS would examine 583 strips, ROMI-RIP would examine only 196 strips. Although AGARIS was limited to three part widths, this example serves to illustrate how primitive the earlier variable arbor function was.

The best-spacing-sequence arbor with movable outer blade operates much like the best-spacing-sequence arbor discussed above. A movable outer blade is added to eliminate any edging. This arbor assumes that random width pieces are acceptable. An additional strip width, narrower that all the primary widths, is specified and represents the minimum width acceptable for gluing up into panels. After ROMI-RIP determines the best spacing sequence, the remainder of the board is examined. If the remainder meets or exceeds the additional narrow strip width, the processing continues. If it is narrower, the last specified width is not taken. Then, the last saw blade is moved to the outer edge of the board and a wider random width strip is sawn. ROMI-RIP recalculates all yields for different combinations of blades and floats.

4.3 All-Blades-Movable Arbor

The all-blades-movable arbor is uniquely different from all other arbors that have at least one fixed-saw spacing. Because there is no preset width, the saw spacings are usually set by the amount of the highest priority cuttings that can be obtained. These will usually be the widest and longest cuttings. In addition, a new saw spacing called "null" was added. A null spacing is one from which no yield is expected. It will contain mostly defects. A board with wane along one edge would have a null spacing that would contain that wane. A board containing pith and associated knots in a straight line along the length could have these defects boxed in a null strip. The inclusion of null strips usually will result in wider strips that contain fewer defects. Null widths from ¾ inch to 2-1/2 inches can be generated depending upon the maximum yield of primary cuttings.

Simulating the all-blades-movable arbor is very similar to the best-spacing-sequence arbors discussed in Section 4.2. The only difference is that spacer widths are added to the primary widths to allow for the creation of null spacings. Spacer widths determine the possible random width distances between the fixed width primary strips. Three spacer widths-- ¾, 1, and 1-¼ inch-- are used to simulate all possible random width null spacings greater than ¾ inch. To limit the number of combinations that have to be examined, the maximum distance ROMI-RIP allows between primary width spacings, the maximum null spacing, is 2-½ inches and the minimum spacing between saws is ¾ inch. The ¾-inch minimum spacing is based on the fact that most currently available selective gang-rip saws with movable-blade arbors can move saws no closer than ¾ inch.

4.4 Optimizing Arbor Comparison

Each of the three optimizing arbors (best-spacing-sequence, fixed-blade-best-feed, and all-blades-movable) gives different yields. Figures 4.4A, 4.4B, and 4.4C show the different gang-rip solutions for the same board using different arbor types. Table 1 shows the cutting bill used for these examples. The CDE strategy was used in this example.

The best-spacing-sequence arbor generates for each board the optimum fixed-blade saw-spacing sequence. This removes the responsibility of arbor setup from the user. This can increase yield, because all possible saw space combinations are examined. However, since all saw spacings begin at the edge of the board, this arbor does not consider the potential yield increase that can result if the saw spacings began 1/4 inch or more from the board edge. The ability to do this would allow the arbor to rip variable width wane from the edges of the board.

The fixed-blade-best-feed arbor requires the user to specify the sequence of saw spacings on the arbor. For each board, the arbor optimizes board placement with respect to the saw spacings and saws the board using the "best" saw spacings. One benefit of this arbor is that it has the capability to rip a board so that edge defects are contained in narrow edging strips (Figure 4.4B). Another benefit to using this arbor is that it is like the optimizing fixed-blade arbors currently on the market. A shortcoming is that the sequence of saw spacings is fixed and all possible saw space combinations cannot be examined.

Table 1. Cutting bill used to process sample board.

Width (inches)	Length (inches)	Quantity
4	58	200
4	18	400
4	14	100
4	8	50
2.75	52	200
2.75	34	150
2.75	22	100
2.75	20	125
2.75	18	150
2.75	14	50
2.75	8	100

The all-blades-movable arbor, like the best-spacing-sequence arbor, examines all possible combinations of part widths that can fit each board. The all-blades-movable arbor also considers random width null spacings between each saw spacing. Null spacings can be as narrow as 3/4 inch and as wide as 2-1/2 inches. Null spacings enable the isolation of defects that occur along the edge or in the middle of the board into waste strips (Fig. 4.4C).

It is important to note that the all-blades-movable arbor was the only arbor that was able to obtain the 4- x 58-inch part size. The other arbors could only obtain required cuttings that were narrower. By placing a series of defects in the middle of the board in a single narrow random-width strip, the arbor could skip over the defects and obtain a longer wider cutting than could otherwise be obtained.

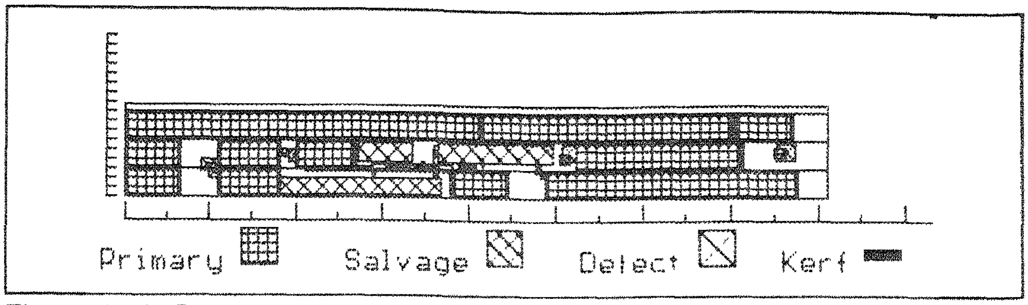

Figure 4.4A. Sample board sawn using best-spacing-sequence arbor.

1 2.75" x 52"	2 2.75" x 34"	1 2.75" x 22"
7 2.75" x 8"	1 2.25" x 8"	1 2.25" x 14"
1 2 x 22"		

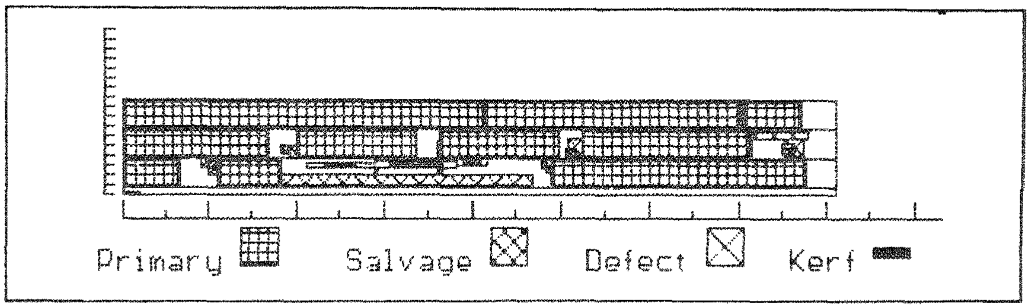

Figure 4.4B. Sample board sawn using fixed-blade-best-feed arbor.

1 2.75" x 52"	2 2.75" x 34"	3 2.75" x 18"
3 2.75" x 8"	1 1.25" x 34"	1 1" x 8"

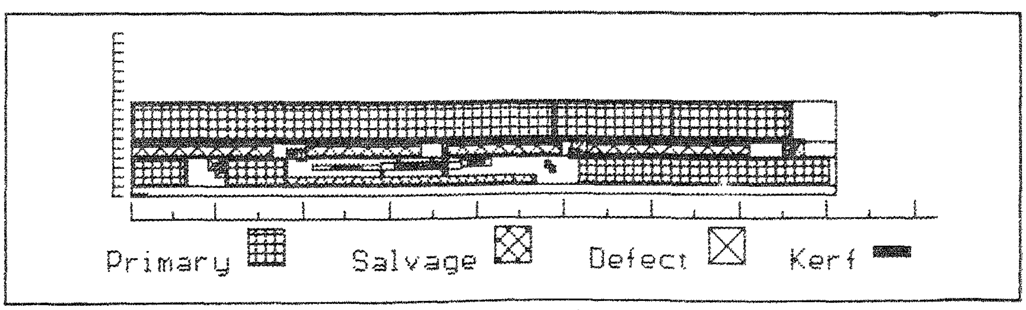

Figure 4.4C. Sample board sawn using all-blades-movable arbor.

1 4" x 58"	2 4" x 18"	1 2.75" x 34"
2 2.75" x 8"	2 1.25" x 14"	2 1.25" x 20"
1 1" x 34"		

5. Primary-Part Processing

ROMI-RIP processes ripped strips to primary parts of specified or random lengths. When specified lengths are used, the yields can be based solely on area or on numbers of cuttings (as with a cutting bill). When cutting random length parts, the user specifies minimum and maximum part lengths. ROMI-RIP cuts random-length parts with lengths varying inclusively between the minimum and maximum part lengths.

When using specified lengths, the user can specify that one-, two-, or three-longest lengths be cut first from each clear area. In the one-longest-length first option, the longest possible length that will fit the clear area is always taken, even if the total yield suffers. For example, if the clear area is 84 inches long, and primary-part lengths are: 15, 18, 25, 29, 33, 38, 45, 50, 50, and 72 inches, the program will cut a 72-inch length and waste 12 inches. In the three-longest-lengths method, the program searches for that combination of three lengths that will give the same or greater yield than the best combination of two lengths or the longest single length. In this example, the three-length method will yield 50-, 18-, and 15-inch strips (the best two-length yields are 50 and 33 inches). This allows the user to emphasize either the longer lengths (one-longest length), or the shorter lengths (two- and three-longest lengths first).

ROMI-RIP can simulate a communication link between the chop saw and the optimizing gang-rip system. The chop saw keeps count of how many parts are needed for each part size. If more parts in a particular width are required than in other widths, the gang-rip saw is instructed to saw more strips in that width. Similarly, if no parts are needed in a particular width, the gang-rip saw is instructed to avoid sawing strips of that width. This communication link between the chop saws and the gang-rip saw is beginning to be commercially available to rough mills.

You can disable the communication link to more closely simulate current mill practices. When operated in this manner, boards are ripped so as to generate the greatest clear strip area.

6. Salvage-Part Processing

Clear areas of a strip section that do not contain primary parts but can contain salvage parts are called salvage areas. Finding salvage areas requires a more complex search procedure than that used for finding clear primary area. ROMI-RIP performs three distinct steps during salvage operations: (1) locate all clear salvage areas, (2) determine which area to work on first, and (3) cut out the salvage part(s). The remainder of this section details these steps.

6.1 Locating Clear Salvage Areas

To find clear salvage areas, each strip section that remains after primary parts are removed is examined using a modified corkscrew method. From a starting point, a corkscrew is generated that moves out in a counter-clockwise direction. The corkscrew expands ½ inch in length for every ¼ inch in width. The corkscrew is expanded until an edge meets a cutting, defect, or strip edge. When this occurs to any edge, the remaining edges continue to be expanded until all edges touch a cutting, defect, or strip edge. Ultimately, a clear rectangular salvage area is described by the edges of the corkscrew.

For any strip section, there is one corkscrew starting point that will provide the greatest clear salvage area. The problem is how to find that starting point in a reasonable amount of computer time. ROMI-RIP's algorithm divides the strip section into small rectangles with several occurring across the width and length. The number and size of the rectangles vary with the size of the strip section being examined. For each rectangle, two arbitrary starting points along the diagonal between the lower left and upper right corners are selected. The generation of starting points on numerous diagonals is a methodical way of reducing the number of starting points to a reasonable minimum.

6.2 Selecting a Clear Area

Long, thin salvage is usually not wanted. To increase the preference for wider salvage cuttings, an exponential weighting factor is applied to the width of the clear areas. The formula for determining the weighted area for a clear area is:

$$\textit{Weighted Area} = \textit{Length} * \textit{Width}^{\textit{Weighting Factor}}$$

The weighted areas are then compared with one another. The weighting factor will cause a preference for a slightly wider and shorter area over a narrower and longer area, even if the longer, narrower section has more area. However, ROMI-RIP will take longer, narrower areas that are at least 10 to 15 percent larger than shorter wider areas.

In general, the preference for shorter, wider areas comes at the cost of longer, narrower cuttings and requires more crosscuts. As the weighting factor increases, so does the preference for shorter and wider cuttings. ROMI-RIP actually cuts parts that fill in the spaces between defects and other cuttings.

Several comparisons of different salvage weighting factors with different part sizes showed that the greatest increase in yield occurs when the weighting factor is less than 1.9. There was little difference in yield or part sizes when the weighting factor was between 1.6 and 2.1. If the weighting factor was increased significantly (above 2.5) , yield sometimes decreased while the number of salvage parts increased! The salvage width weighting preference for ROMI-RIP is set at 1.9. The number of rips required actually decrease slightly as the wider salvage parts are often located on one edge of the strip.

The effect of the weighting factor on total salvage yield is small: a 0.10 to 0.25 percent increase. However, the increase in yield occurs in wider parts with an overall reduction in the number of narrower parts. If a user is cutting to a cutting bill and needs a greater number of narrower parts, the wider salvage areas will naturally accommodate narrower parts.

6.3 Producing the Salvage Part

When the available clear area for a salvage part is identified, several options can be used to determine which part size to cut from the clear area. The simplest option takes the full width of the area to generate a random width part. For this method, the user only needs to specify the minimum acceptable salvage width. A second method rips the area to the widest possible specified primary-part width. The third method rips the area to the widest possible salvage-part width. Salvage-part widths are specified by the user separately from the primary widths and are used only for salvage.

There are three different methods that can be used to determine which salvage-part length to cut. The simplest method takes the longest random length possible with respect to the minimum and maximum primary-part lengths. The second method takes the longest primary-part length that will fit. A third method takes the longest salvage- part length. Salvage specific part lengths are specified separately from the primary lengths.

After the first salvage part has been cut, the remaining area is examined. Cuttings are removed until there is no area large enough for the smallest salvage cutting.

6.4 Smart Salvage

If a cutting bill is being used and salvage is specified to both primary widths and lengths, ROMI-RIP will attempt to cut a part that is needed by the cutting bill. ROMI-RIP first determines the widest possible primary width that will fit in the clear salvage area. Next, a check is made to see that there is a need for part lengths that will fit in the clear area. If any are needed, the most desirable (depending upon part prioritization strategy) primary sized part is cut. If there is no need for a part that size, the largest primary-sized part that fits the clear area is cut.

The benefits of salvaging according to the cutting bill are maximized when primary operations are prevented from cutting orphan or excess parts. This allows the salvage operations to look at larger areas and potentially cut larger parts that are needed by the cutting bill. This approximates the re-saw or re-rip operations found in rough mills and other simulators. Re-saw involves re-ripping a strip to a width that will yield parts needed by the cutting bill. This operation will be referred to as "smart salvage".

Figure 6.3A shows a strip where all possible primary parts have been cut from the full-width clear area and one salvage part cut from the right end. In this example, only the left-most parts are actually needed by the cutting bill. The remaining primary part is an excess or orphan part. Figure 6.3B shows the same strip processed where the primary operations cut only needed parts. This yielded two needed primary parts and one needed primary-sized salvage part.

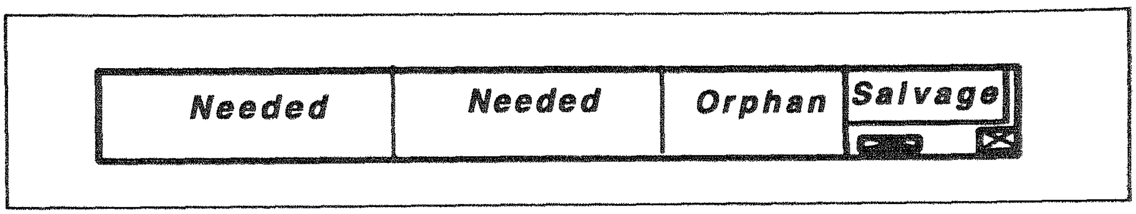

Figure 6.3A. Conventional primary operation.

Figure 6.3B. Smart salvage operation.

Although smart salvage reduces salvage yield, it has the potential to reduce the amount of lumber required to meet a cutting bill. ROMI-RIP simulations, comparing yields between smart salvage and standard operations across several cutting bills and lumber grades, show a reduction of 0.4 to 2.2 percent in the total amount of lumber required. Several factors that can influence this reduction, Obviously, if the cutting bill is well matched to the lumber (few orphans, acceptable yield) the benefits from using smart salvage will be lower. Sawing wider strips increases smart salvage chances of finding required cuttings.

7. Simulation Speed Control Factors

Simulations that are more complex require a longer processing time. Because processing times among computers vary considerably due to processor type, speed, configuration, and other factors, it is not practical to list specific execution times. Table 2 categorizes major processing options as Fast or Slow based on program execution time. Options that require the least processing time are listed under Fast. Options listed under Slow can require substantially more processing time. If the simulation requires the "slower" options, expect a longer run time. Unlisted options do not affect run times noticeably.

Table 2. Processing time comparison for major ROMI-RIP options.

Option	Execution time		
	Fast		Slow
Lengths	Random	15 Specified	30 Specified
Cutting Bill	Without a Cutting Bill		With Cutting Bill
Salvage	Standard Salvage		Smart Salvage
Primary Optimization	1-Longest Length	2-Longest Lengths	3-Longest Lengths
Arbor type	• Fixed Arbor • Fixed Arbor with Movable Outer Blade	• Best-Spacing-Sequence[a] (<5 Widths) • Fixed-Blade-Best-Feed (<8 Spacings) • All-Blades-Movable (<4 Widths)	• Best-Spacing-Sequence[a] (≥5 Widths) • Fixed-Blade-Best-Feed (≥8 Spacings) • All-Blades-Movable (≥4 Widths)

[a] Processing times for the best-spacing-sequence and the best-spacing-sequence with movable-outer-blade arbors are identical.

8. ROMI-RIP Output

ROMI-RIP provides many different output options. ROMI-RIP can provide detailed counts of parts, strips, rips, and crosscuts as well as yield information and cutting bill results in several different file formats. This section shows actual output samples from the ROMI-RIP program and demonstrates the types of output available.

8.1 Summary Tables

ROMI-RIP's summary tables provide detailed information on parts and yield. Included are the number of parts, area of parts, and percentage of parts in user-defined width and length groupings. Summary tables are generated by default. However, you may specify not to generate them.

The first page of the summary table file contains a summary of the setup options and a cumulative report table (Fig. 8.1A). The options summary describes the options that were used in that particular ROMI-RIP run. The yields/totals table that follows the options summary lists how much lumber was processed and how much processing was performed. For each simulation, ROMI-RIP lists the number of strips, rips, and crosscuts for both primary, salvage, and total operations. A sample yields/totals table is shown at the bottom of Figure 8.1A. Area amounts are in square inches. Divide by 144 to obtain area in board feet.

There are six tables that describe the distribution of yields. The first three tables give the yield distributions based on surface area. A sample of one of these tables is shown in Figure 8.1B. In each length-width cell, the upper number is the square inches of surface area and the lower number is the yield percentage. The percentages in each table add to 100. The first table is the distribution of total yield. The second and third tables contain surface area distributions for the primary and salvage cuttings. The last three tables are based on number of parts produced. These tables are organized in the same manner as the first three tables. In each length-width cell the upper number is the part quantity and the lower number is the percentage of total part quantity

ROMI Summary Screen

Part lengths are SPECIFIED.

Part lengths (max. 30) (inches): 12.00 18.00 28.00 38.50 54.00 65.00

Widths for primary parts (max. 10) (inches):
1.50 2.00 2.25 2.75 3.50

Arbor type is FIXED-BLADE-BEST-FEED
Order of saw spacing from RIGHT edge of board:
-1.50--2.00--2.25--2.75--3.50--1.50--2.25--1.50--3.50--2.75--2.00-

Width Ranges:

0.90	1.40	1.70	1.90	2.20	2.40	2.70	2.90	3.20	3.40
1.30	1.60	1.80	2.10	2.30	2.60	2.80	3.10	3.30	3.60

Boards will be edged 1/4-inch on both sides.
Boards will NOT be end trimmed.
Minimum width for salvage parts (inches) 1.00
Salvage uses primary lengths.
Chop saw feedback gang ripping
Parts are clear on both sides.

Accumulated yields/totals for this run:
Total Board area: 378186.50
Total boards: 414

	Strip Area	Part Area	Yield	# Strips	# Parts	X-Cuts	Rips
Primary	318827.50	220622.12	58.34	1147	3444	5275	1920
Excess		25762.62	6.81				
Salvage	8945.62	28575.50	7.56	58	1006	1425	923
Total	327773.12	274960.25	72.70	1205	4450	6700	2843

<<MORE>> H for HELP

Figure 8.1A. Summary table options and accumulated totals/yield header.

ROMI Summary Screen

SURFACE AREA YIELD OF PARTS (ALL PARTS)
(SURFACE AREA & PERCENT BY LENGTH AND WIDTH)

Width / Length	0.30 – 1.30	1.40 – 1.60	1.70 – 1.80	1.90 – 2.10	2.20 – 2.30	2.40 – 2.60	2.7 – 2.8
12.00	3519.00	9612.00	1323.00	2184.00	3915.00	720.00	12276.0
	1.41	3.86	0.53	0.88	1.57	0.29	4.9
18.00	2916.00	4347.00	1354.50	5328.00	5265.00	495.00	594.0
	1.17	1.74	0.54	2.14	2.11	0.20	0.2
28.00	1918.00	3066.00	441.00	13664.00	2646.00	210.00	539.0
	0.77	1.23	0.18	5.48	1.06	0.08	0.2
38.50	2435.12	20847.75	336.88	693.00	1299.38	96.25	12810.8
	0.98	8.37	0.14	0.28	0.52	0.04	5.1
54.00	337.50	19521.00	94.50	324.00	29281.50	0.00	0.0
	0.14	7.83	0.04	0.13	11.75	0.00	0.0
65.00	1251.25	11895.00	0.00	16250.00	585.00	0.00	10903.7
	0.50	4.77	0.00	6.52	0.23	0.00	4.3
Total	12376.88	69288.75	3549.88	38443.00	42991.88	1521.25	37123.62
	4.97	27.80	1.42	15.43	17.25	0.61	14.9

<<MORE>> H for HELP

Figure 8.1B. Sample surface area yield summary table.

8.2 Parts Reports

In addition to overall summaries, ROMI-RIP provides detailed parts information for each processed board. Included are the size of each primary and salvage cutting, and counts for the total number of primary and salvage strips, rips, crosscuts, part area, and yield. A sample parts listing and accumulated totals for board 68 is shown in Figure 8.2. At the bottom of Figure 8.2 are the accumulated yields and totals for all boards processed up to and including board 68.

```
                          ROMI Summary Screen
=========================================================================
Board: 68 2CM

Primary Parts:
  2.00 x  65.00  2.00 x  18.00
  2.25 x  54.00

Salvage Parts:
  1.50 x  28.00  1.75 x  12.00

 Yields/Totals for this board:
             Area     Yield     Parts     Rips   X-Cuts Strip Area  Strip Cnt
 Primary    287.50  53.751       3         4       3      413.31        2
 Excess       0.00   0.000
 Salvage     63.00  11.778       2         2       3        0.00        0
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Total      350.50  65.529       5         6       6      413.31        2
 Brd Area   534.88

 Accumulated yields/totals for this run:
 Total Board area:     6308.00
     Total boards:        8
          Strip Area  Part Area    Yield    # Strips  # Parts  X-Cuts   Rips
 Primary   5437.88     3887.75     61.63       21        67      101     35
 Excess                   0.00      0.00
 Salvage     91.56      413.00      6.55        1        19       23     19
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Total     5529.44     4300.75     68.18       22        86      124     54
=========================================================================

                                  <<MORE>> H for HELP
```

Figure 8.2. ROMI-RIP sample parts report.

8.3 Cutting Bill

The information ROMI-RIP generates when processing lumber to meet a cutting bill allows an analysis of the lumber cost and processing required to meet the bill. In addition, experiments can be conducted with different grade mixes and different cutting bills.

```
                          ROMI Summary Screen
 ==========================================================================
  Data file processed:   2C-MIX

  Part lengths are SPECIFIED.

  Part lengths (max. 30) (inches):    12.00   18.00   28.00   38.50   54.00
                                      65.00

  Widths for primary parts (max. 10) (inches):
    1.50   2.00   2.25   2.75   3.50

  Arbor type is   FIXED-BLADE-BEST-FEED
   Order of saw spacing from RIGHT edge of board:
    -1.50--2.00--2.25--2.75--3.50--1.50--2.25--1.50--3.50--2.75--2.00-

  Width Ranges:
       0.90   1.40   1.70   1.90   2.20   2.40   2.70   2.90   3.20   3.40
       1.30   1.60   1.80   2.10   2.30   2.60   2.80   3.10   3.30   3.60



  Boards will be edged 1/4-inch on both sides.
  Boards will NOT be end trimmed.
  Minimum width for salvage parts (inches) ..............    1.00
  Salvage uses primary lengths.

  Chop saw feedback gang ripping
  Parts are clear on both sides.

 Cutting Bill Processed: SAMPLE-1.CUT
 ==========================================================================
                              <<MORE>> H for HELP
```

Figure 8.3A. Cutting bill options report header.

The first part of the output is the datafile(s) processed, the options used, and the cutting bill used to process them (Fig. 8.3A). Next is the accumulated yield and totals information for the run (Fig. 8.3B). This information includes counters for the total number of primary and salvage strips, rips, crosscuts, part area and yields. The area and yield in orphan parts, as well as the total number of boards and area processed, is also provided. Recall that an orphan part is a primary part for which there is no need.

```
                              ROMI Summary Screen
________________________________________________________________________________

Cutting Bill Processed: SAMPLE-1.CUT

Accumulated yields/totals for this run:
Total Board area: 378186.50
    Total boards:     414
         Strip Area  Part Area   Yield   # Strips  # Parts  X-Cuts   Rips
Primary  318827.50  220622.12   58.34     1147      3444    5275    1920
Excess               25762.62    6.81
Salvage    8945.62   28575.50    7.56       58      1006    1425     923
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Total    327773.12  274960.25   72.70     1205      4450    6700    2843
-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
                                                              Page: 1

   Cutting Bill Results

   Cutting Bill used: SAMPLE-1.CUT Using COMPLEX DYNAMIC EXPONENT Strategy

   Part       Desired       Obtained     Parts From
  Length      Quantity      Quantity      Salvage

Cutting Bill for  1.50 parts:
   12.00        360           534          70
   18.00          0           161          32
   28.00          0            73           7
   38.50        360           361           6
   54.00        240           241           2
   65.00        120           122           2

________________________________________________________________________________
                                 <<MORE>> H for HELP
```

Figure 8.3B. Cutting bill yields/totals and partial parts listing.

The rest of the cutting bill output describes the specific parts produced while processing cutting bill. The parts are listed by width and length. Listed for each part size is the desired quantity, the achieved quantity, and the number of parts cut from salvage or re-rip (Fig. 8.3B). If the required number of parts is not obtained, the message ***UNMET*** is displayed to the right of its part counts. A summary listing of the accumulated width of orphan and salvage parts follows the part report. This table is useful when trying to determine the amount of material that is available for glue-up.

8.4 Board Plots

ROMI-RIP allows the user to view or print plots of individual boards before and after processing. To view board plots, you must run ROMI-DRAW, the plots and summaries program. This program allows you to view all of the boards or pick the ones you want to see. By default, all parts, defects, and kerfs are shown for each processed board (Fig. 8.4A). The board is displayed as if it were transparent, with defects from both sides visible at once. Defects from side 1 are displayed in a lighter color than those from side 2, allowing the user to discern which side a particular defect is on.

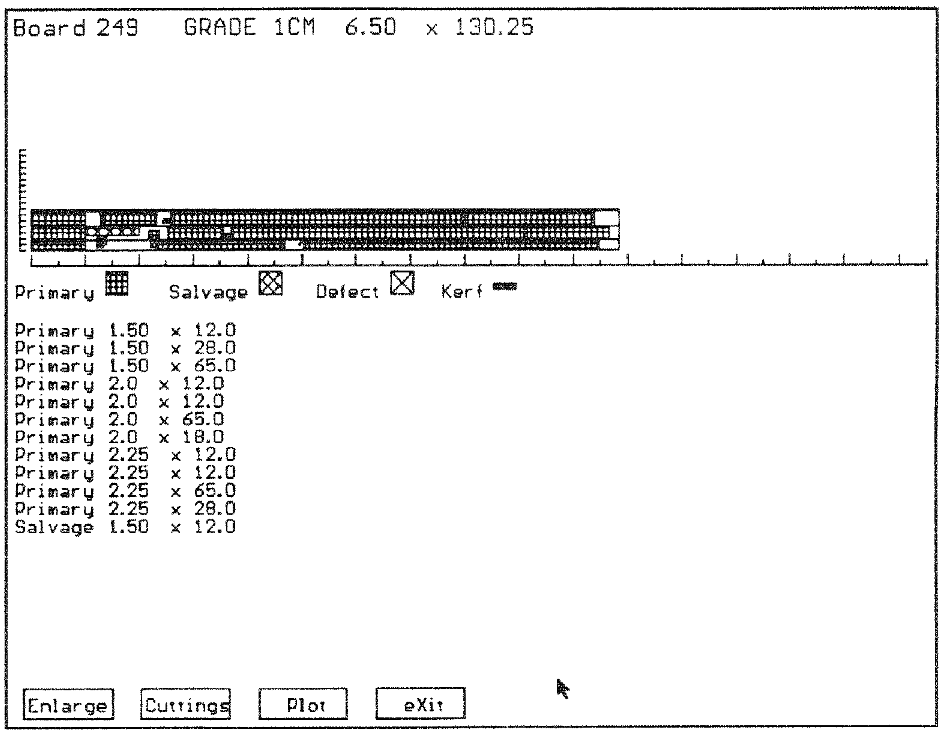

Figure 8.4A. Default board plot display.

If desired, the cuttings may be hidden so that only the board and its defects are shown (Fig. 8.4B). To examine the board closer, the plot can be enlarged (Fig. 8.4C). When enlarged, cuttings may still be hidden or displayed by the user, but only a few feet of the board can be displayed at one time.

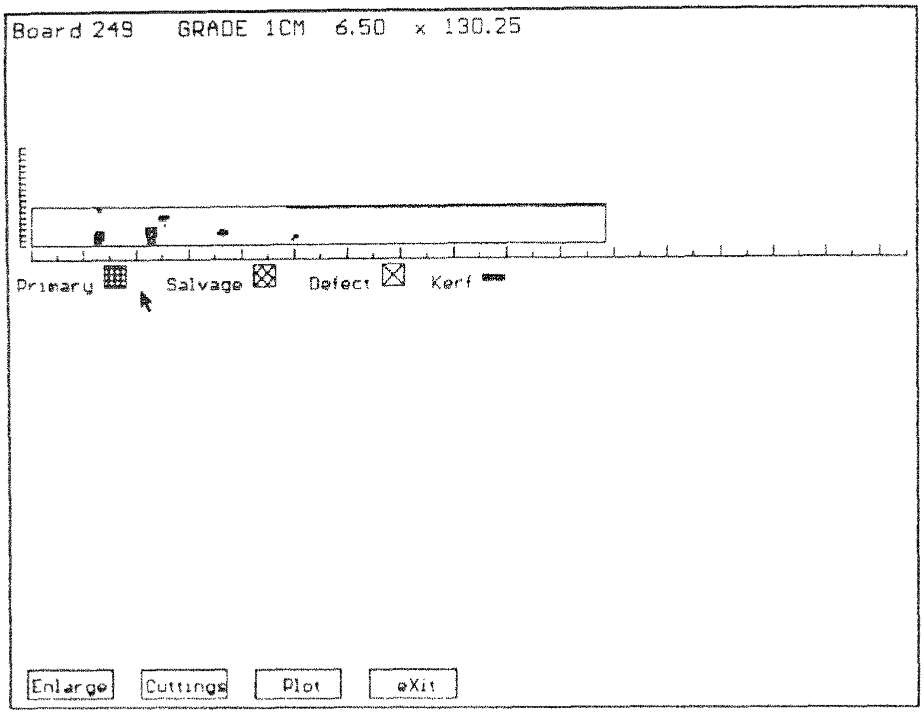

Figure 8.4B. Sample board with cuttings hidden.

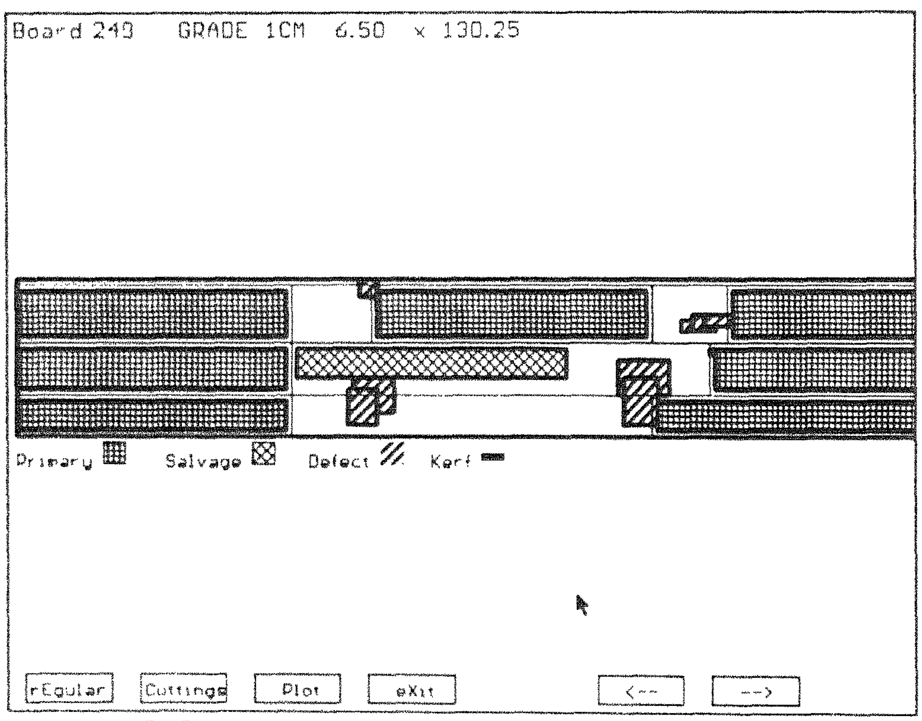

Figure 8.4C. Sample board enlarged to show detail.

Summary

ROMI-RIP is a computer software package that simulates the gang-ripping of lumber. ROMI-RIP was designed to closely simulate current and potential rough-mill practices. The simulator supports six different arbor types and several different chop-saw operating modes. In addition, ROMI-RIP supports cutting bills with as many as 300 different part sizes. A custom datafile creation program allows users to create samples of board data that approximate their current lumber supply.

ROMI-RIP is intended to be used as a "what-if" analysis tool, enabling rough-mill supervisors and researchers to examine interactions between cutting bill, arbor, lumber, and other mill practices. For each simulation run, ROMI-RIP generates summaries that list the amount of lumber processed, cutting bill counts and statistics, yield, and rough-mill processing required for the run.

Acknowledgment

The author would like to thank Charles Gatchell for his conceptual contributions as well as numerous discussions regarding ROMI-RIP and rough-mill practices. The author would also like to thank Jan Wiedenbeck and Phil Araman for their comments and testing of the ROMI-RIP simulator.

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