Manufacturing Hardwood Dimension Products Directly from Logs: Potential Opportunities

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Introduction

When a hardwood log is sawn into lumber, over 16 percent of the volume is converted to sawdust. Furthermore, 12 percent of the log is converted to slabs and 17 percent is converted to edging and trimming pieces, all of which are chipped. Hence, less than 55 percent of the log is actually converted to lumber (see Figure 1). Lumber must meet the requirements of specific NHLA grades and the traditional market expectation of minimal wane (see Figure 2). Lumber lengths commonly range from 8 to 16 feet in even-numbered foot increments. Odd-numbered foot lengths are allowed but are not common.

The lumber produced is then dried (5 to 10 percent shrinkage) and cut into dimension parts, eliminating undesirable features such as knots, splits, checks, stain, and warp. Typically, the part yield or the ratio of the volume of dimension parts to the volume of lumber is under 60 percent. Given all of these process conversion losses, the dimension yield from logs is less than 31 percent. This dimension yield can be well below 25 percent when considering low grade hardwood timber resources and the accumulation of inefficiencies for the many processing steps that are required.

Many techniques have been suggested to improve the overall dimension product yield from logs, including back-gages, thin kerf saws, and computer automation. However, as the price of the wood raw material increases and as availability and environmental constraints further limit the volume of high grade logs that can be harvested, all available options for better utilizing our precious raw materials need to be explored.

Virginia Tech has been investigating the option of cutting logs directly to parts, eliminating the lumber step. The objective of this investigation has been to determine if it is economically feasible to produce rough green dimension parts directly from No. 3 Grade red oak logs. This paper will highlight the findings of this investigation, including: 1) the potential dimension yield from No. 3 Grade red oak logs, 2) the productivity of a direct processing mill, and 3) the profitability of a direct processing mill.

Direct Processing Mill Overview

The proposed dimension mill that cuts logs directly to green dimension products (subsequently referred to as the *Direct Processing Mill)* combines sawmill operations with rough mill operations. Many different direct processing options can be considered including various combinations of headsaw breakdown patterns (live, cant, and grade sawing) and rough mill cutting sequences (cross-cut vs. rip first). The specific layout of the direct processing mill depends on which combination of these options are employed. In general (see Figure 3), logs enter the mill and are debarked and broken down as typically done in a hardwood sawmill. The flitches that result in this primary breakdown then go through a dimension rough mill process to be cut into green dimension blanks. The blanks are then stacked and kiln dried. After drying, the blanks are then remanufactured to market specifications. The primary breakdown pattern and rough mill sawing sequences affect the quality and yield of the dimension products, how material will flow through the mill, and the type and capacity of processing equipment required.

Potential Dimension Yield from No. 3 Grade Red Oak Logs

Many factors can influence the dimension yield from logs. This study investigated the green dimension yield attainable from No. 3 Grade red oak logs for two different primary breakdown patterns (live and cant sawing as defined in Figure 4) and for two different rough mill cutting sequences (cross-cut first and rip first). Three different cutting length categories were investigated: short length cuttings, long length cuttings, and mixture of short and long length cuttings. All dimension produced was clear-two-face, random width cuttings A cutting optimization program CORY (Brunner et. al., 1990) was used to calculate the optimum dimension yields for each of the processing options studied. CORY also provided detailed information from which material processing and sawing sequence information were derived for the four processing options. The following observations were noted regarding the yield (see Table 1) and quality of dimension products with a direct processing mill:

1. The highest potential yield was found to be <u>75 percent</u>[1] which represents a substantial increase over that attainable with conventional processing of low grade logs.

2. Cant sawing resulted in approximately 13 percent less dimension yield than live sawing because cant sawing produced 4" 4" cants that were not cut into dimension.

3. Cuttings from cant sawing resulted in more flat sawn grain than cuttings from live sawing.

4. Very small differences in dimension yield were observed between cross-cut first and rip first cutting sequences.

5. Rip first cutting sequences resulted in substantially longer cutting lengths than did cross-cut first sequences.

6. Cutting bills which specify only long cuttings (lengths ≥ 33 inches) can reduce part yield by over 15 percent compared to cutting bills which specify shorter cuttings.

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[1]This means that 75 percent of the log volume, based on the International ¼-inch scale, was converted to green dimension. Based on a cubic scale (cubic feet of log input/cubic feet of parts output), 43 percent of the actual log volume was converted to green dimension.

Productivity of a Direct Processing Mill

To predict the operational performance of the direct processing mill such as throughput and productivity, the number, type, and layout of equipment to be included in the mill needed to be determined. Systems simulation techniques were used to assist in designing the mill system. Various mill layouts were designed and simulated using the SIMAN/CINEMA simulation software (Pegden, et al., 1990). SIMAN/CINEMA contains a number of built-in features that make it particularly useful and easy to use for modeling manufacturing systems, SIMAN/CINEMA also provides the means for animating the simulated processes for verification and demonstration purposes.

Ten mill layout designs were created to carry out the different sawing patterns and cutting sequences. Many simulation trials were used to analyze bottlenecks and options for balancing the machine and labor utilization for the most efficient mill design. SIMAN/CINEMA animation feature was a valuable tool to help better visualize and understand the many complex and dynamic processing interactions that occurred with each of designs tested. Figures 5 through 8 illustrate the green dimension mill designs with the best performance representing each of the four processing methods listed in Table 1. Each of these mill layouts were designed with one circular headrig. All other processing equipment was sized such that at least 75 percent of the headrig capacity was utilized,

The data required as input into the simulation models included four different categories of data: 1) material processing information (CORY output), 2) machine center information (machine loading and unloading rates, machine capacity, and machine downtime), 3) worker information (machinery operator working rates), and 4) conveyor and transporter information (capacity and moving speeds). After all of the input data were characterized and the simulation models were validated, the production throughput rates and labor productivity for each of the four mill designs were then predicted. The following observations were noted regarding the throughput rates and mill productivity (Table 2):

1. In an eight hour working shift, a direct processing mill with one headrig saw can process 18 to 20 MBF of N0.3 grade red oak logs and manufacture 11 to 14 MBF 4/4 rough green dimension parts depending on the mill layout.

2. The throughput rate for the cant sawing mills was found to be about 15

percent less than for the live sawing mills.

3. A cant-crosscut-rip process took over 35 percent longer to process one log than for the other sawing processes. This longer processing time was because more wood pieces were created early on in the manufacturing process. More pieces going through more processes substantially increased the time it took to process a log.

4. The labor productivity (volume of parts produced per worker per day) was found to be about 20 percent greater for the live sawing mills than for the cant sawing mills.

Profitability of a Direct Processing Mill

Earlier, data on the potential cutting yield from No. 3 grade red oak logs and on the operational performance of several mill designs provided valuable insights on the characteristics of a direct processing mill. The high potential yield and high potential productivity of the direct processing mill all indicate that the option of processing low grade red oak logs directly to green dimension products is a promising technique to more efficiently utilize our timber resources. However, many questions regarding the economic performance of the direct processing system are still unanswered. Are direct processing mills economically feasible? Are they more profitable than current conventional processing of hardwood lumber into dimension. How sensitive is the profitability of the direct processing mill to factors such as log price, cutting yield, drying degrade, and dimension price? Questions such as these were addressed to determine under what conditions the direct processing system is profitable.

Since green dimension parts are not the final product to be sold at market, the economic performance of the direct processing system considered all aspects of the direct processing mill, including those operations after manufacturing green dimension. The operations after green parts manufacturing include drying, remanufacturing (cutting off drying defects and getting edge-gluing quality parts), and edge-gluing operations (see Figure 3). The capacity of these operations were selected such that they could keep up with the production capacity from the green dimension mill. Some key assumptions were made regarding the operations after the green parts. The volume loss of dimension parts due to drying shrinkage was assumed to be 8 percent and the volume loss of dimension parts due to remanufacturing was assumed to be 15 percent.

A thorough financial analysis using discounted cash flow methods was conducted to determine the economic feasibility and profitability of the overall direct processing mill. Initial investment of a totally new facility included buildings, equipment, land and working capital. Revenues included income from saleable residue and 4 X 4 cants as well dimension products. Operating expenses included costs from labor, raw material, utilities, drying, maintenance, administration, insurance, and taxes. Net present value (NPV) and internal rate of return (IRR) were used to evaluate the economic feasibility of the mill while return on sales (ROS) was used to evaluate the profitability.

Table 3 summarizes the NPV, IRR, and ROS for each of the four mill designs. The details of the cash flows for the direct processing mill designs are reported by Lin (1993). The following observations were made regarding the economic feasibility and profitability of the direct processing mills:

1. With high NPV's and IRR's, all mill designs were found to be economically attractive.

2. The ROS's of the mill design alternatives ranged between 11 and 18 percent. This range is substantially higher than the range (between 6 and 9 percent) reported for the hardwood dimension and flooring industry during the period from 1987 to 1991 (Dun and Bradstreet, 1992).

3. The Live-Rip-Crosscut mill design had the highest NPV, IRR, and ROS ($4.2 million, 30%, and 18 percent, respectively). This design was the most favorable not only because it was the most productive mill, but also because it produced a higher percentage of long length cuttings which were assumed to be more valuable.

4. Sensitivity studies revealed that the economic health of these mill designs was affected most by green dimension yield, dimension product price, and the level of drying degrade. Table 4 shows the breakeven price required for the dimension products at the various levels of possible green yield and drying

degradation for the Live-Rip-Crosscut mill design.

5. Sensitivity studies also revealed that the economic health of the mill designs was least affected by log costs, labor costs, and overhead costs.

Conclusion

As the price of our timber resources continue to rise and as the supply of high grade timber continues to decline, it is becoming increasingly important to find processing methods that do more with less. A direct processing mill that converts logs directly to dimension products is one such processing method that looks very promising. A direct processing mill offers the potential of converting over 40 percent of the volume of low grade logs into high value dimension products. Furthermore, a direct processing mill was designed and was found to be highly productive in terms of minimizing the amount of labor and machinery resources needed to manufacture dimension products. Finally, when looking at the profitability of such a direct processing mill, it was found to be highly competitive with the profitability of traditional manufacturers of dimension products.

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Table 1. Green dimension cutting yield from No. 3 grade red oak logs for various processing methods and cutting bills.

Processing Method	Cutting Yield (%)[1]		
	Short Lengths[2]	Mixed Lengths[3]	Long Lengths[4]
Live-Crosscut-Rip	75	73	58
Live-Rip-Crosscut	74	73	62
Cant-Crosscut-Rip[5]	65	63	53
Cant-Rip-Crosscut[5]	63	62	54

[1]Cutting Yield = Log Volume (International ¼-inch scale) /Part Volume * 100
[2]15,18,21,25,29, and 33 inches
[3]15,18,21,25,29,33,38,45,50,60, and 75 inches
[4]33,38,45,50,60, and 75 inches
[5]Cant sawing produced an additional 13 percent yield for 4" x 4" center cants

Table 2. Summary of the simulation results for the four direct processing mill designs.

Output Variable	Direct Processing Mill Design			
	L-X-R[1]	L-R-X[2]	C-X-R[3]	C-R-X[4]
Logs Processed (BF/day)[5]	19449	19454	20585	17842
Green Part Output (BF/day)	14062	14279	12989	11008
Labor Productivity (BF parts/day/worker)	827	892	684	734
Processing Time per Log (min)	21	22	31	23
Machine Utilization (%)	66	58	67	60
Labor Utilization (%)	65	65	63	55

[1]Live-Crosscut-Rip
[2]Live-Rip-Crosscut
[3]Cant-Crosscut-Rip
[4]Cant-Rip-Crosscut
[5]Volume based on the International ¼-inch log scale

Table 3. Summary of the financial analyses for the four direct processing mill designs

Processing Method	Net Present Value ($)	Internal Rate of Return (%)	Return on Sales (%)
Live-Crosscut-Rip	1,800,000	20	11
Live-Rip-Crosscut	4,200,000	30	18
Cant-Crosscut-Rip	1,800,000	20	11
Cant-Rip-Crosscut	1,800,000	21	11

Table 4. Dimension part breakeven price ($/MBF) vs. green yield and drying degradation for the Live-Rip-Crosscut mill Design.

Green Yield (%)	Drying Degradation (%)						
	10	15	20	25	30	35	40
50.0	1834	1942	2063	2201	2358	2540	2751
52.5	1751	1854	1970	2101	2251	2424	2626
55.0	1675	1773	1884	2010	2153	2319	2512
57.5	1606	1700	1806	1927	2064	2223	2408
60.0	1542	1633	1735	1850	1983	2135	2313
62.5	1484	1571	1669	1780	1908	2054	2226
65.0	1430	1514	1609	1716	1838	1980	2145
67.5	1380	1461	1552	1656	1774	1910	2070
70.0	1333	1412	1500	1600	1714	1846	2000
73.4	1275	1350	1435	1531	1640	1766	1913

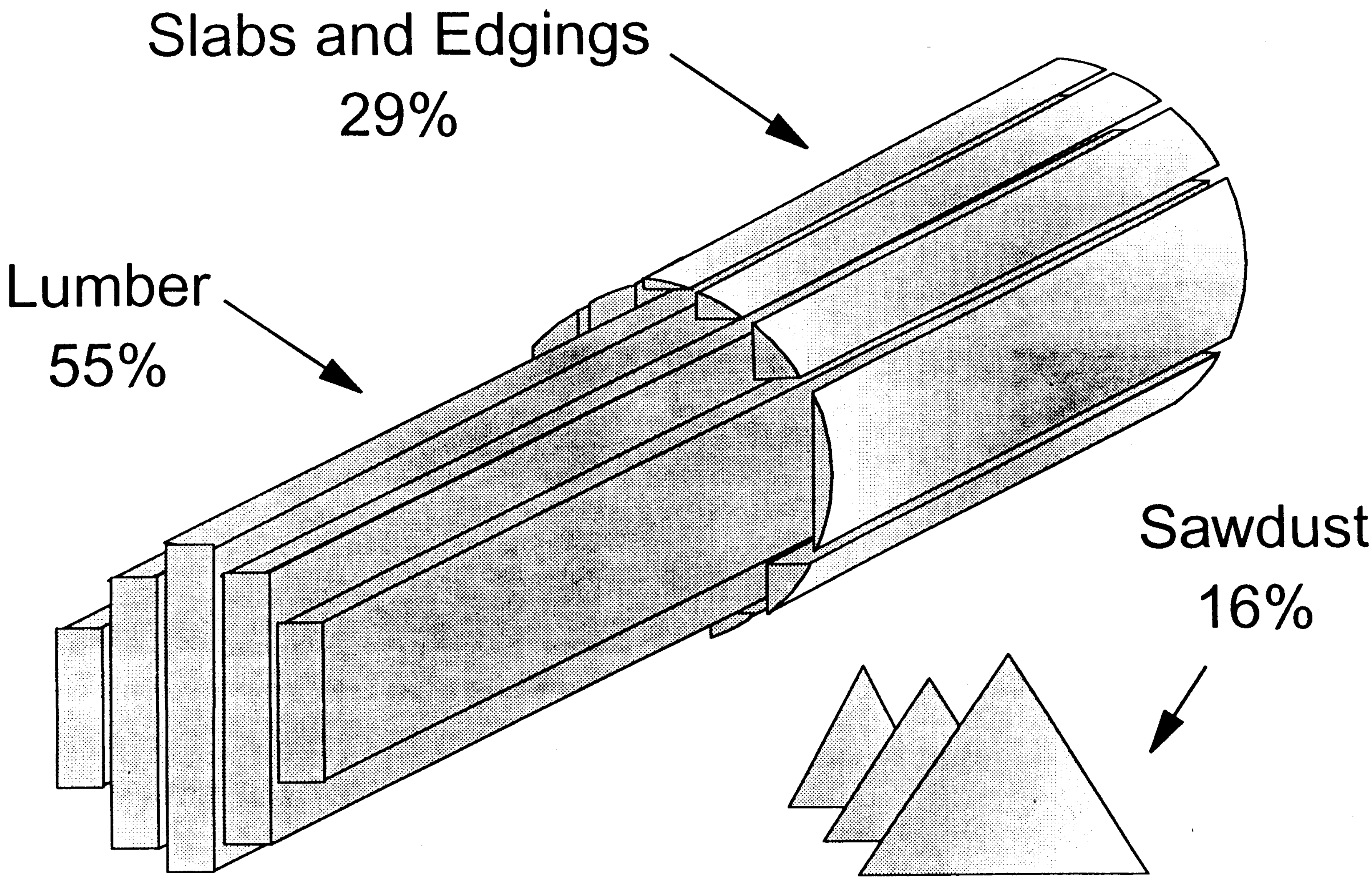

Figure 1. Less than 55 percent of a hardwood log ends up as lumber.

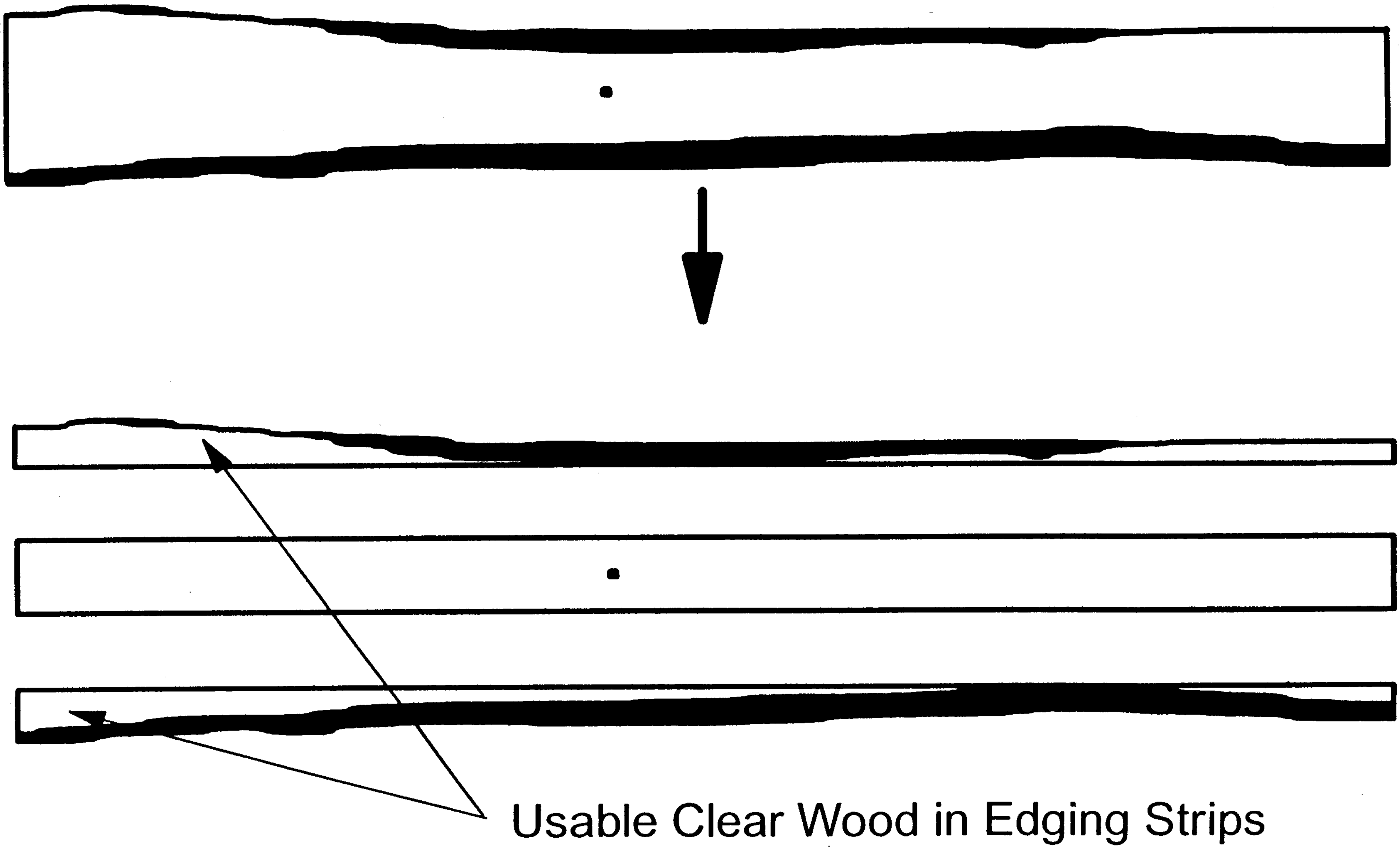

Figure 2. When flitches are edged to make marketable pieces of lumber, a substantial volume of clear wood that could be used for producing dimension ends up being chipped.

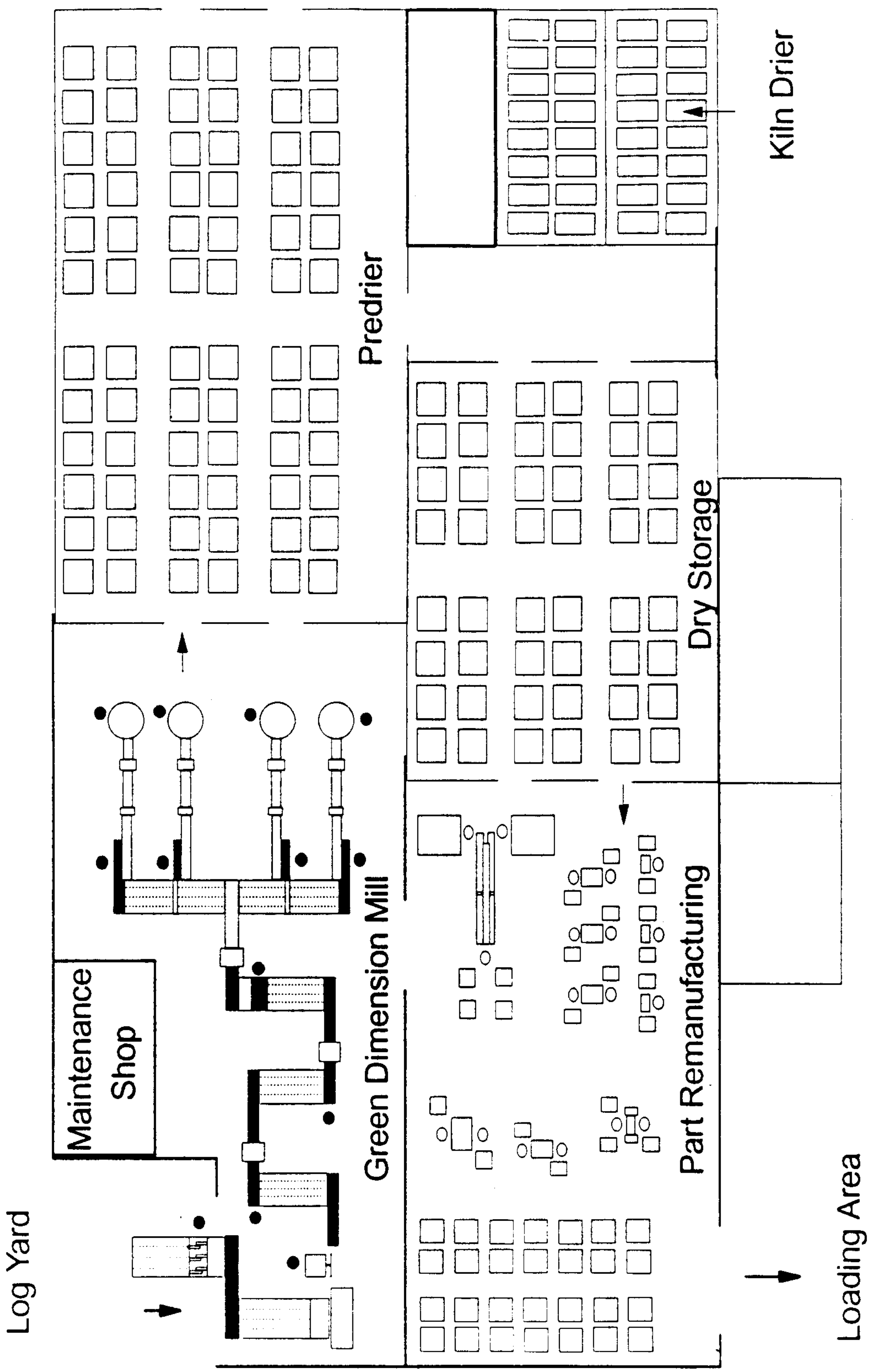

Figure 3. The overall layout of a direct processing mill.

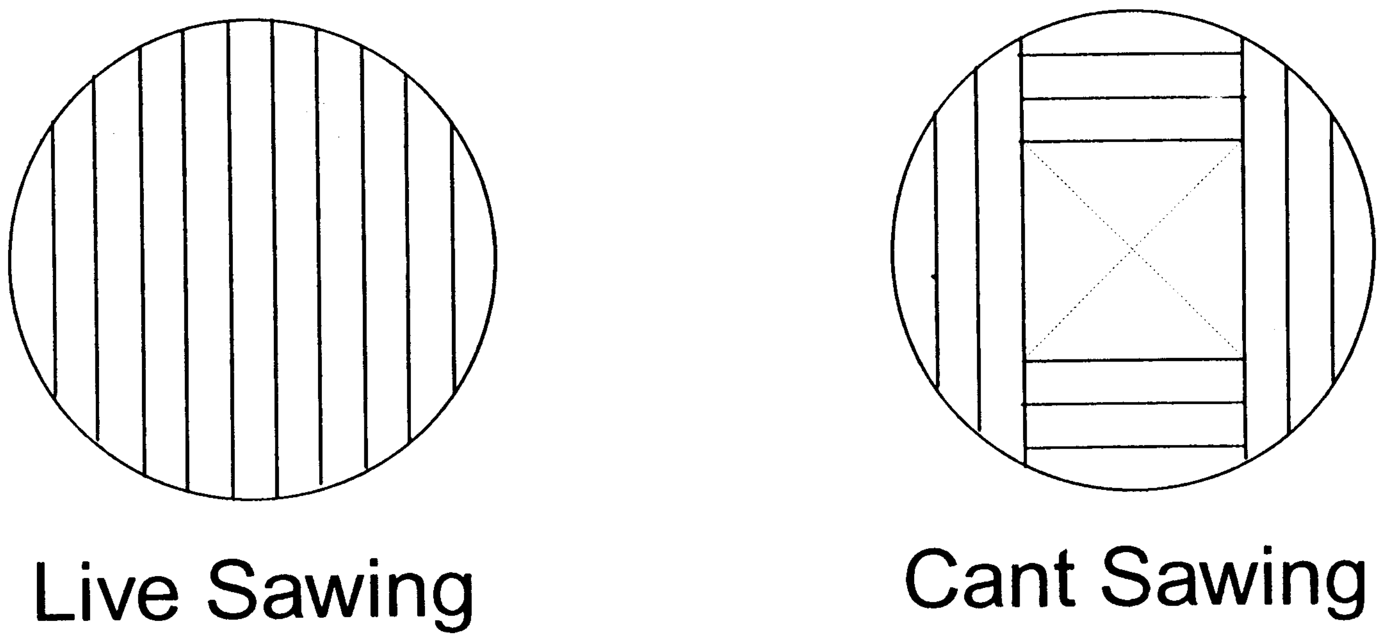

Figure 4. The definition of grade sawing and cant sawing used in the primary breakdown of the log.

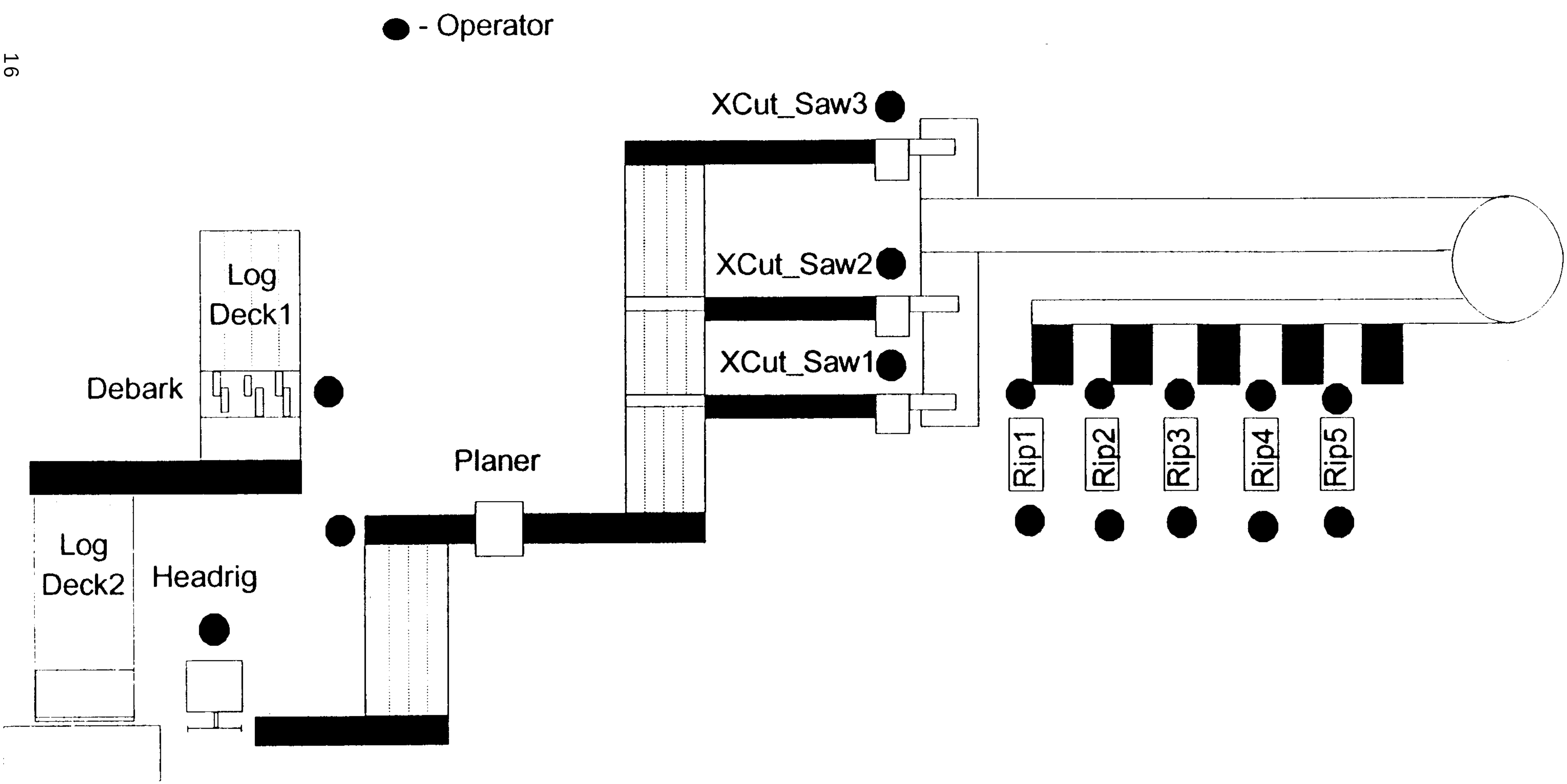

Figure 5. The mill layout for the Live-Crosscut-Rip processing mill.

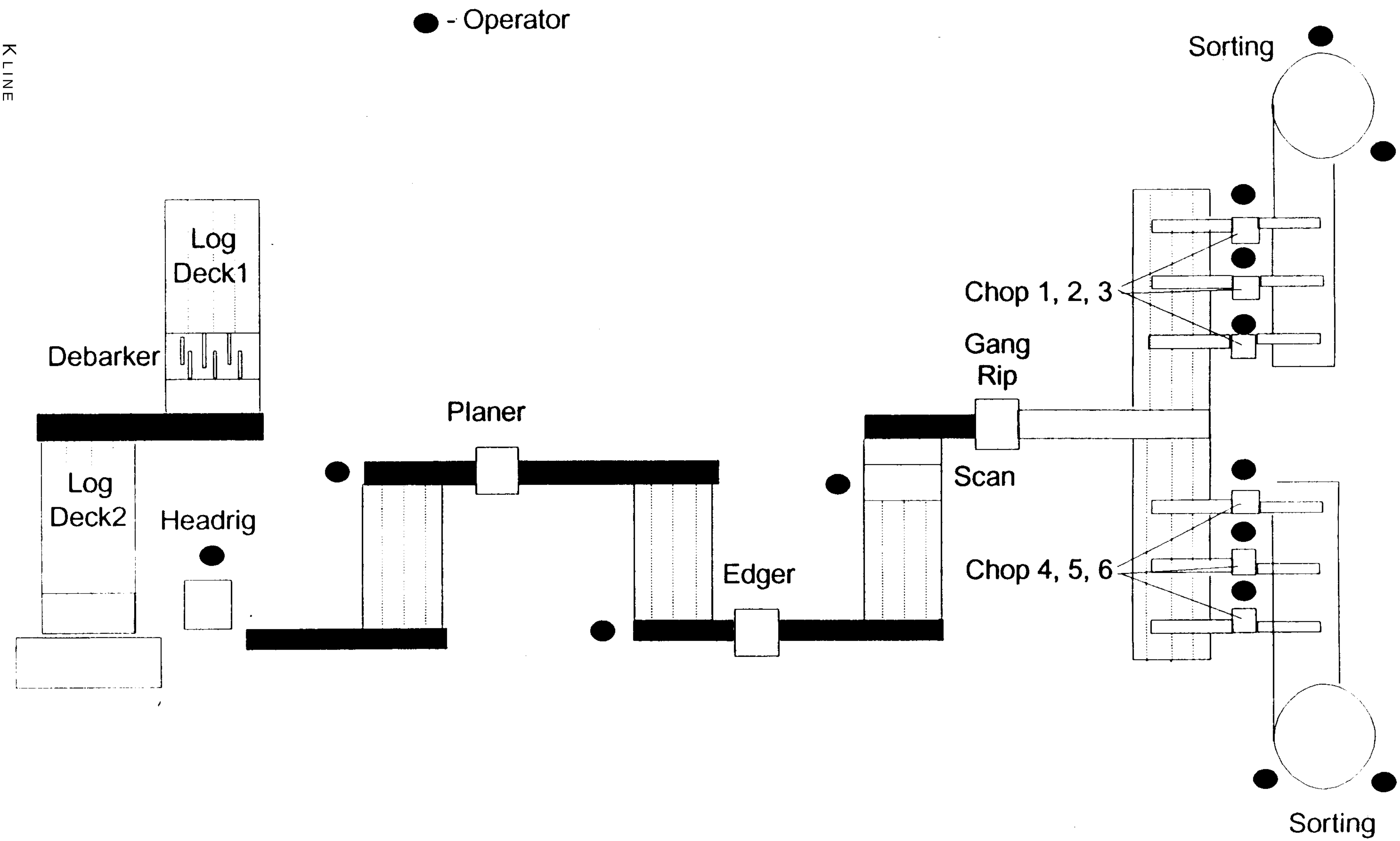

Figure 6. The mill layout for the Live-Rip-Crosscut processing mill.

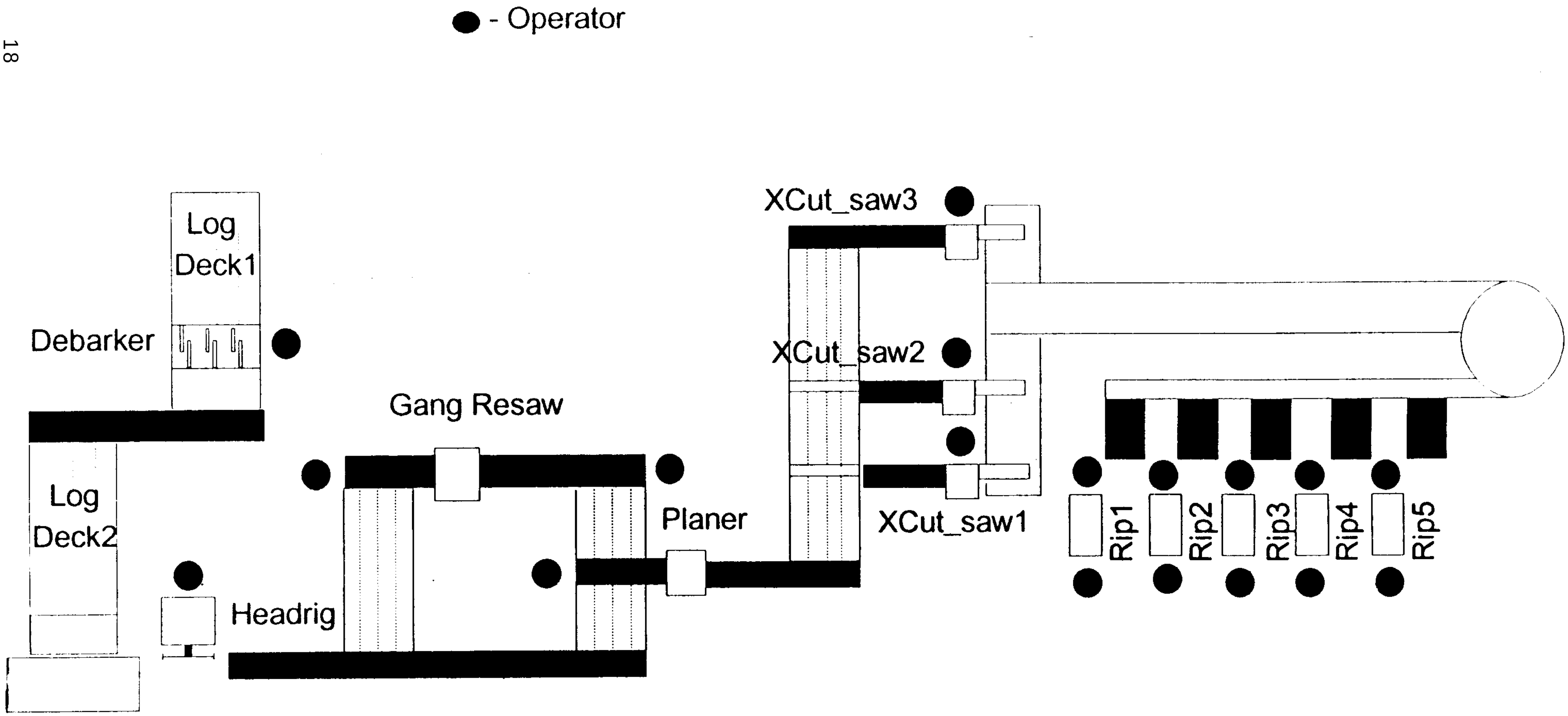

Figure 7. The mill layout for the Cant-Crosscut-Rip processing mill.

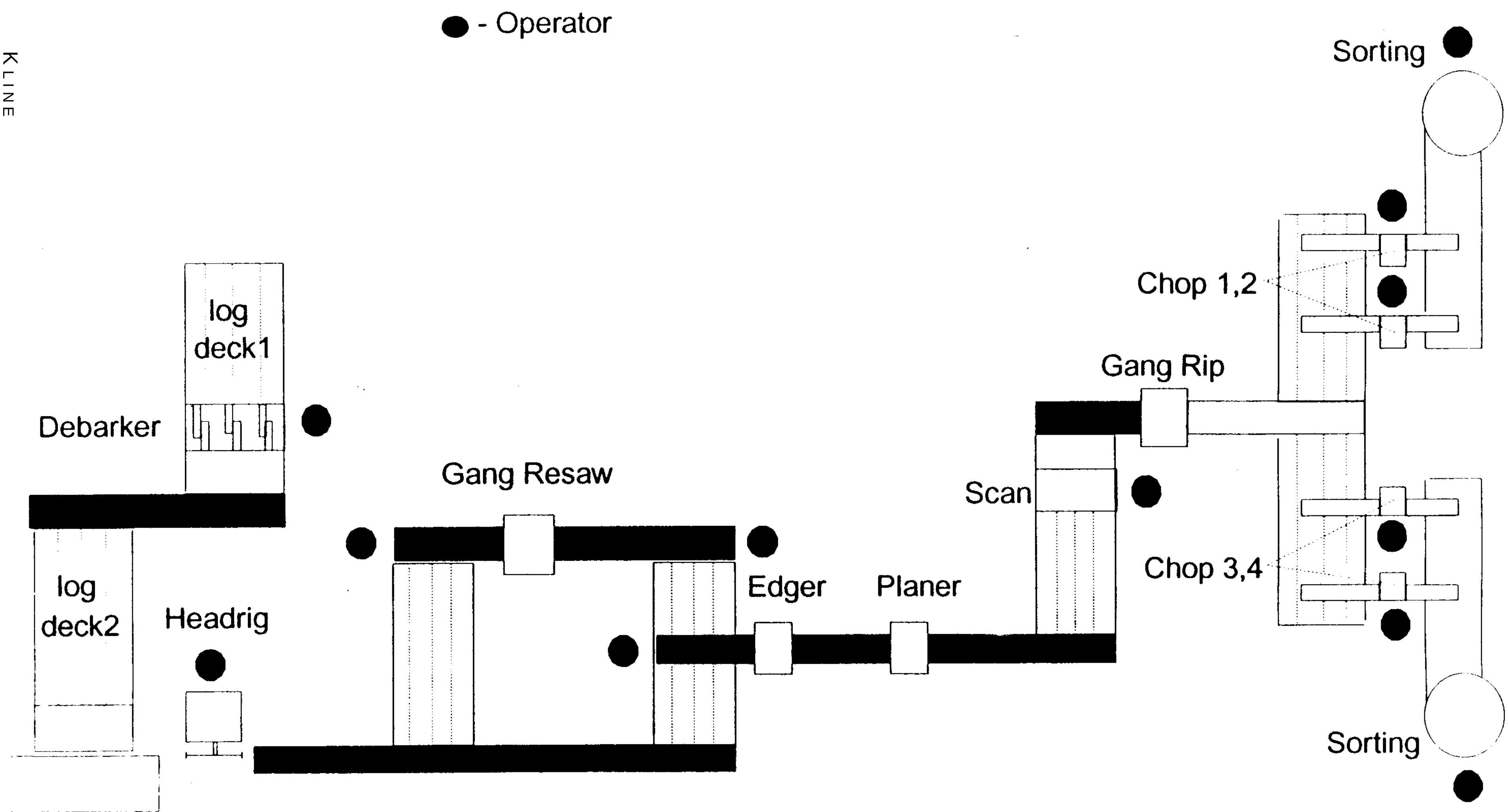

Figure 8. The mill layout for the Cant-rip-Crosscut processing mill.