A SEGMENTAL ANALYSIS OF CURRENT AND FUTURE SCANNING AND OPTIMIZING TECHNOLOGY IN THE HARDWOOD SAWMILL INDUSTRY

SCOTT A. BOWE*
ROBERT L. SMITH*
D. EARL KLINE*
PHILIP A. ARAMAN*

ABSTRACT

A nationwide survey of advanced scanning and optimizing technology in the hardwood sawmill industry was conducted in the fall of 1999. Three specific hardwood sawmill technologies were examined that included current edger-optimizer systems, future edger-optimizer systems, and future automated grading systems. The objectives of the research were to determine differences between user groups for advanced scanning and optimizing technologies and to identify company expectations of these technologies. Three comparison groupings were used including company size, sawmill technology, and National Hardwood Lumber Association affiliation. These objectives were chosen because timely information for this technology was not available. The survey consisted of a mail questionnaire sent to over 2,000 hardwood sawmills. Adoption decision factors for scanning and optimizing technologies were rated on a 7-point Likert-type scale. *Improved raw material recovery* and *increased lumber revenues* were the two most highly rated factors for both current edger-optimizer and future edger-optimizer systems. *Accuracy of grading* and *system lifespan* were the most highly rated factors for automated grading systems. Responding companies expressed concern over the high initial cost of such technology; however, a short return on investment outweighed the high initial cost issue in many cases. For those that have adopted advanced scanning and optimizing technology, production-related issues were the driving factors.

Over 13 billion board feet of hardwood lumber is consumed in the United States each year (3). This material is utilized by value-adding industries producing products worth tens of billions of dollars (8). The hardwood sawmill is the primary producer for these value-adding industries.

Many segments of the forest products industry have seen significant technological leaps. For example, new production technologies have developed engineered wood products, and adapted to an underutilized, as well as a changing raw material base. These new technologies and new products are instrumental in meeting the increasing demand for wood products. In the softwood lumber industry, scanning and optimizing technology has become the standard, not the exception. Advanced technology has been successfully integrated to meet the market's demands and the industry's needs.

The hardwood lumber industry has not followed this trend. Sixty-three per-

The authors are, respectively, Assistant Professor and Wood Products Specialist, School of Natural Resources, Dept. of Forest Ecology and Management, Univ. of Wisconsin-Madison, 120 Russell Labs., 1630 Linden Dr., Madison, WI 53706-1598; Associate Professor and Extension Specialist, College of Natural Resources, Center for Forest Products Marketing and Management, Dept. of Wood Sci. and Forest Products, Virginia Polytechnic. Institute and State Univ. (VPI), Blacksburg, VA 24061; Associate Professor, College of Natural Resources, Dept. of Wood Science and Forest Products, VPI; Project Leader, USDA Forest Serv., Southern Res. Sta., Blacksburg, VA 24061. This research project was supported by the USDA Southern Res. Sta. and the USDA National Needs Fellowship Program. The authors would like to thank these institutions for their support and thank those individuals that participated in the project. This paper was received for publication in December 2000. Reprint No. 9236.
*Forest Products Society Member.

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cent of hardwood sawmills do not have any type of scanning or optimizing technology. Only 10 percent have advanced scanning and optimizing technology, such as optimized edgers (1). Technologically, there is a great deal of room for improvement in the hardwood sawmill industry.

The demographics of the hardwood sawmill industry may in part drive this reluctance to adopt new technology. Despite the recent trend toward consolidation in the hardwood sawmill industry, a significant portion of the sawmills are small. Over 46 percent of the hardwood sawmills that responded to a recent study were classified as small, with fewer than 20 employees (1). Companies of this nature may not have the capital or the supporting market share to justify purchasing advanced technology equipment. Estimates from the *1998 Lumber and Panel North American Factbook* suggest that the 50 largest sawmills only represent 15 percent of the total hardwood production with no single company producing more than 1.5 percent (5). A significant number of large and medium mills do exist, however, and are a potential markets for scanning and optimizing technology.

The existence of several manufacturers of commercial scanning and optimizing technology demonstrates that there is a market for this equipment. Yet this market is not well developed. A small segment of hardwood sawmills have adopted advanced scanning and optimizing technology such as edger-optimizers and trimmer-optimizers. As the names suggest, these technologies are designed to optimize (or partially optimize) production. From a business perspective, scanning and optimizing technology is designed to produce higher grade yield, quality, and consistency, which leads to higher profit margins for the sawmill. From an environmental perspective, scanning and optimizing technology is designed to utilize the raw material more efficiently.

The *newness* of scanning and optimizing technology is a combination of adapting it from the softwood industry to the needs of the hardwood industry and engineering the scanning ability to much higher levels. Several problems arise because the hardwood sawmill customer is not well understood. First, the differences between those companies that adopt this technology and those companies that do not adopt are unknown. These differences need to be identified to better define the market. Second, several manufacturers produce scanning and optimizing equipment yielding similar yet different benefits. The hardwood sawmill industry's expectations from this technology must be understood. Third, the hardwood sawmill industry's expectations of the next generation of technology must be understood.

The information from this research will provide scientists and developers of this technology with needed information to assist in the development and adoption of scanning and optimizing technology. Ultimately, adoption of this technology will provide increased yields and more efficient use of our renewable hardwood resources.

Scanning and optimizing technology was classified into two groups including *current* scanning and optimizing technology and *future* scanning and optimizing technology. *Current* scanning and optimizing technology includes all of the currently available scanning and optimizing systems such as bucking-optimizers, headrig-optimizers, edger-optimizers, trimmer-optimizers, grade mark readers, and automated sorting systems. These systems only partially optimize since decisions are based on profile information only (size and wane). *Future* scanning and optimizing technology refers to prototype systems that are not commercially available. This technology truly optimizes based on total defect information (profile, knots, splits, etc.). An example of this technology is the Automatic Lumber Grading System under development at Virginia Tech (6).

Objectives

The overall goal of this study was to better understand scanning and optimizing technology in the hardwood sawmill. The specific objectives were:

1. identify company expectations of current and future hardwood lumber scanning and optimizing technology including the cost and the feature levels of hardwood lumber scanning and optimizing technology systems that will be accepted by the hardwood lumber industry;

2. determine the differences in technology attitudes between user groups for hardwood lumber scanning and optimizing technology.

Methodology

Population

The population of interest was hardwood sawmills in the United States. Given the nature of the hardwood forest resource in the United States, the majority of the sawmills sampled were in the eastern half of the United States; however, the sample was not limited to this region.

Subsets of the hardwood sawmill population such as Amish sawmills and micro-mills[1] would not likely represent a significant (if any) portion of the hardwood sawmills interested in or suitable for hardwood lumber scanning and optimizing technology. These mills were not included in the survey.

Sample frame

Two recently compiled hardwood sawmill mailing lists were acquired. These included the National Hardwood Lumber Association's (NHLA) hardwood sawmill membership list and a non-NHLA member hardwood sawmill list compiled from state directory and NHLA data. Since there may be an inherent bias in any trade association membership list, it was important to incorporate this second group. A total of 2,042 sawmills were used, including all NHLA hardwood sawmill members (602 mills) and a random selection of the non-NHLA member hardwood sawmills (1,440 mills).

Data collection

Questions were designed to gather timely information on advanced scanning and optimizing technology in the hardwood sawmill. These questions examined current edger-optimizers based on wane-only information; future edger-optimizers based on NHLA grading rule information (full defect information); and future automated grading systems based on full-defect information. The questions used a 7-point Likert-type scale (1 = least important; 7 = most important). These questions consisted of an array of factors related to scanning and optimizing technology. The factors were determined by interviews with university and industry personnel.

Scientists from Virginia Tech and the USDA Forest Service Southern Research Station assisted in questionnaire devel-

[1] The term micro-mills describes the large number of small portable and band mills popular for hobbies or side businesses.

opment. Question types and formats were pre-tested at the spring 1999 Hardwood Lumber Manufacturers trade show in Charleston, South Carolina. During the summer of 1999, the completed survey was faxed to 10 hardwood sawmills for final pre-testing. Eight companies responded. Only minor formatting issues were identified and changed during the pre-testing phase.

International technology trends were also incorporated into the questionnaire design. Visits to the Ligna World Fair for the forestry and wood industries in Hannover, Germany (May 1999) provided design information leading to specific technology based questions. All hardwood lumber scanning and optimizing technology manufacturers worldwide were represented at this show. In addition, several hardwood sawmills were visited in Northern Germany, where feedback was provided on the technology in German hardwood sawmills; that information was incorporated into the questionnaire.

The survey mailing occurred in the fall of 1999 and was patterned after the Total Design Method (7). This involved four mailings including two questionnaire mailings each followed by reminder postcards. The questionnaire mailings included a cover letter that explained the nature and importance of the survey. It also stressed company anonymity for any information provided. To assure that the survey results reflected opinions of the sawmill decision makers, questionnaires were addressed with the name of the sawmill owner or manager.

Data analysis

The returned questionnaires were examined for completeness and usability. Usable surveys were coded and entered into an SPSS® Statistical Data Analysis package computer spreadsheet. To understand the differences and similarities in technology attitudes among groups, comparisons were generated from the questionnaire data. The primary comparisons were made among three groupings: company size, trade association affiliation, and existing sawmill technology.

Employee numbers were used to define company size. Companies with 19 or fewer employees were defined as small, while companies with 20 or more employees were defined as large. This breakdown was consistent with other research in the wood products industry (4).

The second comparison group used trade association affiliation. The NHLA was chosen for three reasons. First, the NHLA has historically and currently set the standards and certified hardwood lumber grades. Second, the NHLA is the largest trade association for hardwood sawmills. Third, our mailing database was segregated by NHLA members and non-NHLA members, which made for logical comparisons.

The third comparison group separated the responding companies by adopters and non-adopters of *current* installed scanning and optimizing technology. This equipment included bucking-optimizers, headrig-optimizers, edger-optimizers, trimmer-optimizers, grade mark readers, and automated sorting systems.

Results and discussion

Response

Questionnaires were mailed to 2,042 companies. From these, 212 were returned undeliverable. Undeliverable questionnaires included companies that had gone out of business or companies that moved without a forwarding address or had an expired forwarding address. Nineteen companies requested by phone or by letter to be removed from the study. One company was determined to be a duplicate between the two mailing lists. Subtracting these companies from the total number left 1,810 companies as potential respondents.

In total, 600 questionnaires were returned. Usable responses from hardwood sawmills totaled 424, bringing the adjusted response rate to 23.5 percent. Unusable responses were those returned by companies that were not or were no longer in the hardwood sawmill business. In addition, seven of the returned surveys were deemed unusable due to lack of completeness with few or none of the questions answered.

Non-response bias

A sample of the companies that did not respond was randomly selected, contacted by phone, and asked five questions as they were printed on the questionnaire. A total of 30 calls were completed. Given the small sample size, nonparametric statistical methods were used to check for statistical differences between the survey respondents and non-respondents. No significant differences were found between the respondents and non-respondents (Mann-Whitney test, alpha = 0.05).

Hardwood sawmill technology

The study had three primary sections on hardwood sawmill technology. Each individual section sought information on cost and features that are important when deciding to install a given technology. These sections are arranged in a chronological order with the first section examining current edger-optimizer systems (wane-only information); the second section examining future edger-optimizer systems that are currently being developed (future edger-optimizers fully optimize based on full defect information); and the third section examining future automated lumber grading systems (full defect information).

Participants were asked if they believed that scanning and optimizing technology would benefit their sawmill. Seventy-three percent indicated *Yes* and 27 percent indicated *No.* When asked to expand on their answers, the most frequent response dealt with the ability of scanning and optimizing technology to improve recovery, yield, consistency, and speed. Sixty-three companies responded in this way. The second most frequent response dealt with a negative perception of scanning and optimizing technology; 47 respondents stated that the initial cost was too great, and that their company was too small to incorporate this technology. Fourteen respondents questioned the cost effectiveness of the technology, stating that it may not pay for itself. Fourteen other respondents stated that scanning and optimizing technology would not physically fit into their mill or that it would be of little value since they do not cut grade lumber. Ten respondents specifically stated that a benefit of scanning and optimizing technology is the removal of human error. Conversely, one respondent stated that he would not want to remove the human factor. This statement was supported by several other respondents claiming that the technology has not yet been proven or that they remain uncertain and continue to look into the technology. Finally, eight respondents said that an automated hardwood lumber grading system would benefit their mill and the industry as a whole. One common misconception of scanning and optimizing technology is that it will save labor. Several companies stated

TABLE 1. — *Factor importance for current edger-optimizer systems.*

Factor	Rank	Mean importance	Subsets (alpha = 0.05)						
Improved raw material recovery		6.5	*[a]						
Increased lumber revenues	2	6.5	*						
System lifespan	3	6.0		*					
Improved lumber quality	4	5.9		*					
Ability to upgrade	5	5.9		*					
Availability of vendor support	6	5.8		*					
Increased production levels	7	5.8		*					
Improved lumber consistency	8	5.7		*					
Ease of use	9	5.7		*					
Initial cost	10	5.7		*					
Maintenance costs	11	5.2			*				
Existing mill layout restrictions	12	5.2			*				
Training from vendor	13	5.1			*				
Operational costs	14	5.1			*				
Installation down time	15	4.8			*	*			
Advice from production supervisors	16	4.7				*	*		
Training of new operators	17	4.6				*	*		
Advice from customers	18	4.4					*	*	
New mill installation	19	4.1						*	
Advice from sales department	20	3.7							*

[a] Asterisks indicate significantly different group means at an alpha level of 0.05 using Tukey's Honestly Significant Difference test for homogeneous subsets (*n* = 355).

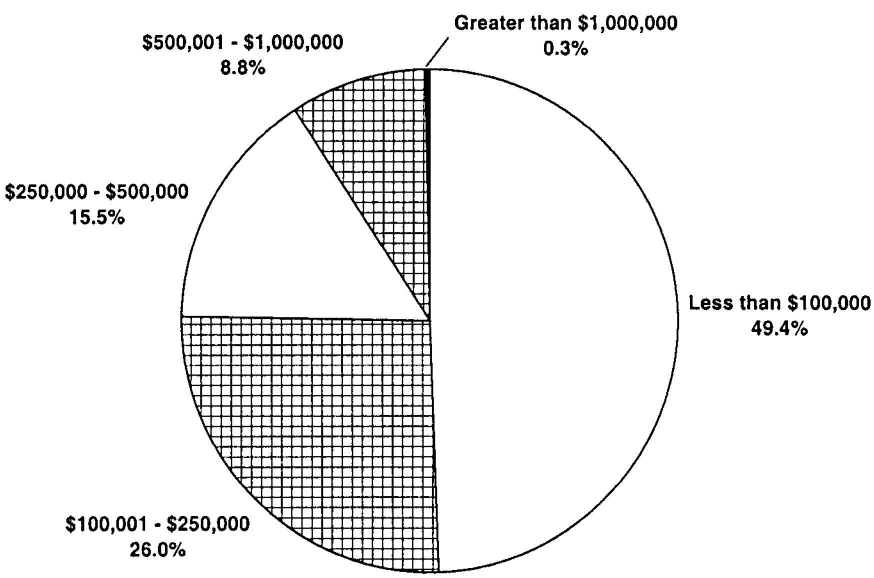

Figure 1. — Acceptable cost for current edger-optimizers (*n* = 362).

this as a benefit when the same number of operators may be needed to tend machinery using scanning and optimizing technology.

Respondents were also asked if they believe that there is truthful and accurate information available on scanning and optimizing technology; 74 percent responded *Yes* and 26 percent responded *No.*

CURRENT EDGER-OPTIMIZER SYSTEMS

Using a 7-point Likert-type scale, the respondents were asked to rate factors important in edger-optimizer adoption. Two factors, *improved raw material recovery* and *increased lumber revenues,* tied with the highest rating **(Table 1).** These high ratings demonstrate the importance of profit margins in the hardwood sawmill industry. To promote the adoption of this technology, equipment manufacturers should focus their attention on these factors. *Advice from customers* and *advice from sales department* rated at the bottom of the 20-factor list. In general, production-related factors were rated higher and non-production-related factors were rated lower.

An important question to ask is if the differences in these ratings are significant. Analysis of variance (ANOVA) found that there were significant differences between factor ratings (alpha = 0.05). One method to identify which factors rate similarly and which factors rate differently is Tukey's Honestly Significant Difference test (HSD) (2). Tukey's HSD groups like means together. **Table 1** shows the factors that demonstrated like means according to Tukey's HSD (alpha = 0.05). Asterisks grouped by column show the factors where the differences were not significant. It must be noted that at alpha = 0.05, Type 1 error may result within the 20 factor ratings.

One factor, *initial cost,* was expected to be rated highly but fell into the second Tukey HSD group **(Table 1).** This result may be explained later from data in the open-ended questions. Initial cost may present a barrier for the smaller mills; however, potential payback and lumber value gain from the technology was a larger issue.

In addition to the factors that the respondents thought were important, information was collected on what they would be willing to pay for an edger-optimizer. It was clearly stated that the price included the scanners, computers, and edger but *not* the material-handling system. Nearly 50 percent chose the lowest cost category, *less than $100,000.* Only one company chose the highest cost category of *greater than $1,000,000.* This particular company has several pieces of hardwood sawmill technology including a headrig-optimizer, a trimmer-optimizer, a grade mark reader, and an automated sorting system. This may help explain their selection of the highest price category **(Fig. 1).**

Attitude differences between sawmill groups. — Three comparisons were conducted to see if sawmill groups rated current edger-optimizer factors differently. These comparisons were large versus small companies, technology

TABLE 2. — Current edger-optimizer factor rating group comparisons.

Factor	All	Large vs. small		Tech vs. non-tech		NHLA vs. non-NHLA	
		Large	Small	Tech.	No tech.	NHLA	Non-NHLA
Improved raw material recovery	6.5	6.7	6.3*[a]	6.6	6.4*	6.6	6.3*
Increased lumber revenues	6.5	6.6	6.3*	6.6	6.4*	6.6	6.3*
System lifespan	6.0	5.9	6.1	6.0	6.0	6.0	6.0
Improved lumber quality	5.9	5.9	5.9	6.0	5.8	6.0	5.9
Ability to upgrade	5.9	6.0	5.7	6.0	5.8	5.9	5.8
Availability of vendor support	5.8	6.0	5.6*	6.0	5.8	6.0	5.5*
Increased production levels	5.8	5.8	5.8	5.7	5.9	5.8	5.8
Ease of use	5.7	5.7	5.8	5.7	5.8	5.7	5.8
Improved lumber consistency	5.7	5.7	5.8	5.7	5.8	5.8	5.7
Initial cost	5.7	5.6	5.8	5.5	5.8*	5.6	5.9*
Maintenance costs	5.2	5.2	5.3	5.2	5.3	5.2	5.3
Existing mill layout restrictions	5.2	5.2	5.1	5.1	5.1	5.2	5.1
Training from vendor	5.1	5.2	5.0	5.2	5.1	5.3	4.8*
Operational costs	5.1	5.0	5.2	5.0	5.2	5.0	5.4*
Installation down time	4.8	4.9	4.8	4.9	4.8	4.9	4.8
Advice from production supervisors	4.7	4.8	4.4*	4.9	4.6	4.9	4.2*
Training of new operators	4.6	4.4	4.8*	4.5	4.6	4.5	4.7
Advice from customers	4.4	4.3	4.5	4.2	4.5	4.4	4.5
New mill installation	4.1	4.0	4.3	4.1	4.2	4.1	4.2
Advice from sales department	3.7	3.6	3.8	3.5	3.8	3.6	3.8

[a] Asterisks indicate significant difference between information source ratings, independent sample t-test at alpha = 0.05. All companies: n = 355; large companies: n = 200; small companies: n = 152; technology companies: n = 127; no technology companies: n = 208; NHLA members: n = 235; non-NHLA members: n = 119.

versus non-technology companies, and NHLA members versus non-NHLA members. Significant differences were found for five factors between small and large companies (alpha = 0.05). Even though both large and small companies rated *improved raw material recovery* highly, large companies rated it significantly higher than small companies. This may indicate that with higher raw material costs and tighter profit margins, large companies consider the benefits of improved raw material recovery to be more critical than smaller companies **(Table 2).** Large companies also rated *increased lumber revenues* significantly higher than small companies. This is despite the fact that *increased lumber revenues* was the highest rated factor by small companies. This may demonstrate more urgency by the large companies. Large companies rated *availability of vendor support* significantly higher than small companies. This may, in-part, be due to newer or more sophisticated equipment or a larger array of equipment in large hardwood sawmills. *Advice from production supervisors* was rated higher by larger companies. A possible cause may be that large companies are more likely to have a production supervisor on staff, while small companies have one person, such as the owner or sawmill manager, play multiple roles within the sawmill. Finally, *training of new operators* was rated significantly higher by small companies. On this issue, the large companies may feel that they have the expertise on staff to deal with the training and operation requirements of new technology.

Comparing companies that have technology to companies that do not have technology, three significant differences were identified (alpha = 0.05). Recall that companies with technology were those that had systems such as bucking-optimizers, headrig-optimizers, edger-optimizers, trimmer-optimizers, grade mark readers, and automated sorting. Both *improved raw material recovery* and *increased lumber revenues* were rated significantly higher by companies with technology as compared to companies without technology **(Table 2).** This is not surprising given that the companies with technology parallel the large companies, and the companies without technology parallel the small companies. Finally, companies without technology rated *initial cost* significantly higher. This is reasonable since *initial cost* could be the barrier preventing the adoption of technology by the small and non-technology companies.

Seven significant differences were found between the factor ratings of NHLA member and non-NHLA members (alpha = 0.05). *Improved raw material recovery, increased lumber revenues, and availability of vendor support* were all rated significantly higher by NHLA members **(Table 2).** This parallels the company size comparisons **(Table 2).** *Initial cost* and *training from vendor* were also rated significantly different. Non-NHLA members rated *initial cost* higher, which likely represents small companies where cost is a barrier. Finally, *operational costs* and *advice from production supervisors* were rated significantly different between the groups. *Operational costs* was rated higher by non-NHLA members, which likely represents small companies where cost is a significant barrier **(Table 2).**[2]

[2] The number of responding mills listed at the bottom of the tables and figures differs for two reasons: 1) the three comparison groups (size, technology, and NHLA affiliation) were not of equal size; 2) a given mill may have chosen not to answer certain questions, These two factors cause variation in the number of responding mills.

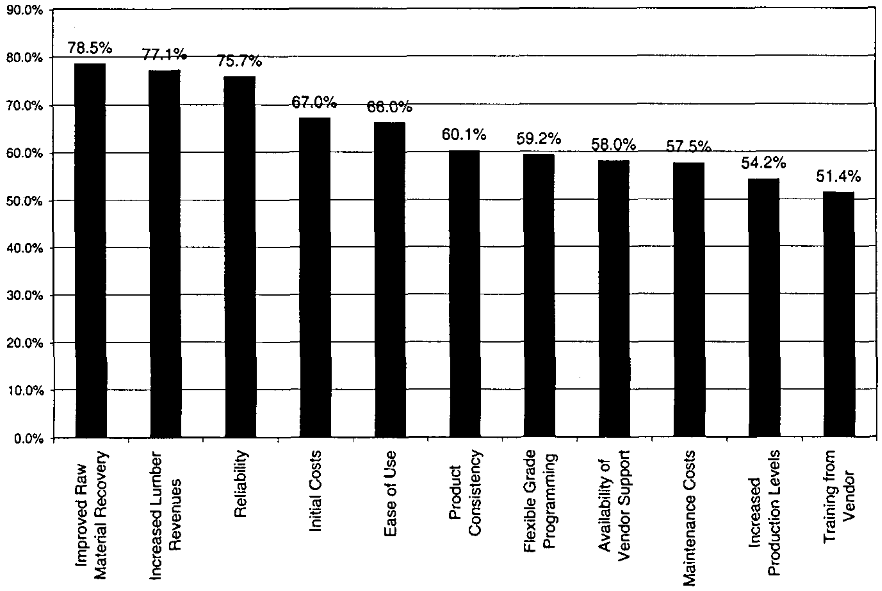

Figure 2. — Feature selection for future edger-optimizer systems (n = 424).

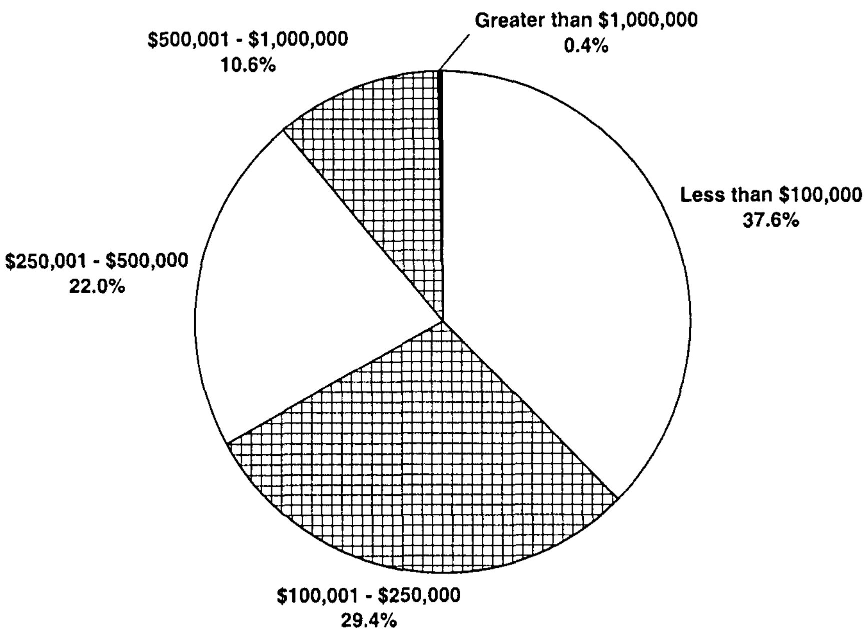

Figure 3. — Acceptable cost for future edger-optimizers (n = 282).

Based on comparisons with the non-response bias calls and conversations with the industry, the authors believe that the *less than $100,000* category was often used as a default category. Respondents that were not familiar with these technologies or aware of their capabilities may have selected the lowest cost category even though they would not consider installing the technology at this time. In hindsight, a sixth category, *would not install at this time,* might have alleviated this problem. Also, these acceptable costs may be skewed to the low side. A sawmill may be willing to pay more for scanning and optimizing equipment if they understand the full benefits and payback.

FUTURE EDGER-OPTIMIZER SYSTEMS

Similar information was collected for future edger-optimizer systems as for the current edger-optimizer systems. Feature and cost data were collected. In addition, information was collected on the expected payback time for such technology.

The study participants were asked to consider future edger-optimizer systems based on NHLA grading rules (complete defect information). When asked what features or abilities these new systems would need to have, *improved raw material recovery* and *increased lumber revenues* were selected most frequently **(Fig. 2).** It was surprising to see, however, that *training from vendor* was selected the least amount of times. This was different with levels of technology. Sixty-three percent of companies with technology selected *training from vendor* as compared to 44 percent of companies without technology.

There was a large separation between *increased lumber revenues* and *increased production levels.* Often these two terms are considered as one in the same. This clear separation in frequencies may imply that the respondents understand that board upgrade is a key goal for increased revenues. Increased production with no attention to board upgrade may not necessarily increase revenues.

Based on the features that respondents thought were important, information was collected on whether the respondent would consider installing a future edger-optimizer. Sixty-eight percent said they would consider installing the technology, and thirty-two percent said they would not. When asked what they would be willing to pay for a future edger-optimizers, 37 percent chose the lowest cost category, *less than $100,000* **(Fig. 3).** Again, it was clearly stated that the price included the scanners, computers, and edger but *not* the material-handling system. Only one company chose the highest cost category of *greater than $1,000,000.* Overall, respondents may be willing to pay more for future systems versus current systems. Saw-millers may see the advantage afforded by total defect information versus wane-only information.

Finally, the respondents provided information on the expected payback, in years, for future edger-optimizer technology. The mean payback was 3.6 years. The median and mode of the payback were both 3 years. Only a few companies considered payback periods greater than 5 years.

Future Automated Hardwood Lumber Grading Systems

As with current edger-optimizers and future edger-optimizers, we were interested in identifying the important factors and cost levels of automated grading systems. The respondents were asked to rate a number of factors that would be important for adopting future automated hardwood lumber grading systems. *Accuracy of Grading* was rated the highest by a large margin **(Table 3).** It was significantly different (alpha = 0.05) from the second rated factor *system lifespan.* This may demonstrate the hardwood sawmill industry's concern for such technology. The second and third rated factors, *system lifespan* and *durability,* demonstrate the importance of the durability of such an investment. *Color sorting capabilities* was rated last. As with the current edger-optimizer systems, *training from vendor* was rated near the bottom.

In addition to the factors that the respondents thought were important, information was collected on what they would be willing to pay for a future automated grading system. Again, it was clearly stated that the price included the scanners and computers but *not* the material-handling system. Forty-eight percent chose the lowest cost category, *less than $100,000.* As with the current edger-optimizer systems question, this category may have been used as a default. Zero companies chose the highest cost category of *greater than $1,000,000.* Overall, these results were not much different from those for the current edger-optimizer or future edger-optimizer systems **(Fig. 4).**

Attitude differences between sawmill groups. — Differences in automated hardwood grading factor ratings by groups were examined. These groups were organized by company size, company technology, and NHLA affiliation. Concerning company size, significant differences were found between three factors: *initial cost, speed,* and *training from vendor* (alpha = 0.05) **(Table 4).** *Initial cost* was rated significantly higher by small companies. Initial cost can be seen as a barrier to small companies. The rating for *speed* was significantly higher for large companies versus small companies. The high production rates of larger companies would require an automated grading system with speeds capable of handling high volumes and high feed rates. Large companies also rated *training from vendor* significantly higher than small companies. This result was the exact opposite of the training issues rated under the current edger-optimizer question **(Table 2).** It is possible that these large companies felt comfortable with their current technical experience on existing technology but were uncertain about their expertise on future technology. It is also possible that smaller companies would not consider an automated hardwood grading system and saw no need for training.

Company technology was also used as a basis for comparing automated

TABLE 3. — Factor ratings for future automated hardwood grading systems.

Factor	Rank	Mean importance	Subsets (alpha = 0.05)						
Accuracy of grading	1	6.6	*[a]						
System lifespan	2	5.9		*					
Durability	3	5.9		*	*				
NHLA grading rules	4	5.8		*	*	*			
Ability to upgrade	5	5.8		*	*	*			
Initial cost	6	5.8		*	*	*			
Reduction of grading costs	7	5.8		*	*	*	*		
Tallying capabilities	8	5.8		*	*	*	*		
Simplicity of operation	9	5.7		*	*	*	*		
Ease of use	10	5.7		*	*	*	*		
Ability to modify NHLA grading rules	11	5.7		*	*	*	*		
Availability of vendor support	12	5.6		*	*	*	*	*	
Speed	13	5.6			*	*	*	*	
Training from vendor	14	5.5				*	*	*	
Ability to quickly switch species	15	5.5				*	*	*	
Equipment warranty	16	5.4					*	*	
Compatibility with existing equipment	17	5.4					*	*	
Sorting capabilities	18	5.4					*	*	
Training of new operators	19	5.3						*	
Color sorting capabilities	20	4.8							*

[a] Asterisks indicate significantly different group means at an alpha level of 0.05 using Tukey's Honestly Significant Difference test for homogeneous subsets (*n* = 359).

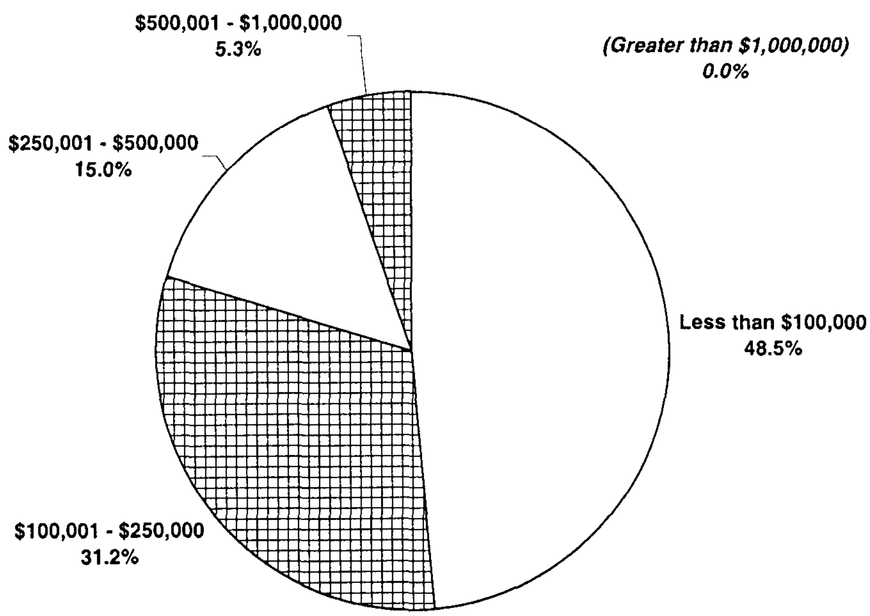

Figure 4. — Acceptable cost for automated hardwood grading systems (*n* = 359).

TABLE 4. — *Future automated hardwood grading system factor rating group comparisons.*

Factor	All	Large vs. small		Tech vs. non-tech		NHLA vs. non-NHLA	
		Large	Small	Tech.	No tech.	NHLA	Non-NHLA
Accuracy of grading	6.6	6.7	6.5	6.8	6.5*	6.7	6.4*
System lifespan	5.9	5.9	5.9	6.0	5.9	5.9	6.0
Durability	5.9	6.0	5.8	6.0	5.9	5.9	5.9
NHLA grading rules	5.8	5.9	5.7	6.0	5.8	5.9	5.7
Ability to upgrade	5.8	5.9	5.7	6.1	5.6*	5.9	5.7
Initial cost	5.8	5.6	6.0*	5.7	5.9	5.7	6.1*
Reduction of grading costs	5.8	5.9	5.6	5.9	5.8	5.8	5.8
Tallying capabilities	5.8	5.8	5.7	5.8	5.7	5.9	5.5*
Simplicity of operation	5.7	5.7	5.9	5.7	5.8	5.7	5.8
Ease of use	5.7	5.7	5.8	5.7	5.7	5.7	5.8
Ability to modify NHLA grading rules	5.7	5.8	5.6	5.9	5.6	5.9	5.5*
Availability of vendor support	5.6	5.7	5.4	5.9	5.4%	5.8	5.3*
Speed	5.6	5.8	5.3*	5.9	5.4*	5.7	5.4*
Training from vendor	5.5	5.1	5.3*	5.7	5.4*	5.7	5.2*
Ability to quickly switch species	5.5	5.5	5.5	5.6	5.5	5.6	5.5
Equipment warranty	5.4	5.4	5.6	5.5	5.4	5.4	5.6
Compatibility with existing equipment	5.4	5.4	5.6	5.5	5.4	5.3	5.7*
Sorting capabilities	5.4	5.5	5.4	5.5	5.4	5.5	5.3
Training of new operators	5.3	5.2	5.4	5.3	5.3	5.3	5.3
Color sorting capabilities	4.8	4.9	4.7	5.1	4.5*	4.9	4.6

[a] Asterisks indicate significant difference between information source ratings, independent sample t-test at alpha= 0.05. All companies: n = 359; large companies: n = 206; small companies: n = 147; technology companies: n = 135; no technology companies: n = 197; NHLA members: n = 242; non-NHLA members: n = 114.

hardwood lumber grading systems. Six significant differences were found between the two groups (alpha = 0.05) **(Table 4).** *Accuracy of grading* was rated the highest by both technology and non-technology companies. However, it was rated significantly higher by the technology group. This may represent existing experience with technology. The technology companies may understand that accuracy is key in successful optimization. Experience with technology may also explain why *ability to upgrade* was rated significantly higher by technology companies.

Availability of vendor support, speed, training from vendor; and *color sorting capabilities* were all rated significantly higher by technology companies. Over 50 percent of the responding companies with technology had some degree of vertical integration. These companies often require color sorting and color matching capabilities.

The final comparison of future automated hardwood grading systems was based on NHLA affiliation. Eight significant differences in factor ratings were found (alpha = 0.05). As with the technology companies, *accuracy of grading* was rated significantly higher by NHLA members and was the highest rated factor **(Table 4).** Interestingly, *ability to modify NHLA grading rules* was rated at 5.9. It was not surprising that it was rated higher by the NHLA members than by the non-NHLA members since they may not use the rules; however, it may indicate the NHLA members' desire to modify the rules for specific customer preferences. This was further supported by several comments in the qualitative responses.

Tallying capabilities, availability of vendor support, speed, and *training from vendor* all were rated significantly higher by NHLA members. Finally, *initial cost* and *compatibility with existing equipment* were rated significantly higher by non-NHLA members. Again the non-NHLA members paralleled the smaller companies and initial cost was a significant barrier. Equipment compatibility can also be seen as a cost barrier based on mill and existing equipment modification expenses.

Human graders are highly paid and often difficult to find. This in itself could drive the adoption of a proven automated grading system. Other features of the system such as integration into secondary manufacturing and customer confidence in grade tallies would help demonstrate a favorable result.

Qualitative responses

The respondents were given the opportunity to respond to several open-ended questions. These questions gave the respondents the opportunity to expand on their concerns or address specific issues not contained in the questionnaire.

When asked what negative things they have heard about hardwood lumber scanning and optimizing technology, the most common response was the high cost. The second most frequent response was simply *none*. This could represent two possibilities: they really have not heard any negative comments in their discussions or they have not discussed this technology at all. Other comments questioned the performance of hardwood lumber scanning and optimizing technology. Issues of accuracy, reliability, consistency, complexity, and speed were cited. Service and training from the vendor also were concerns. One respondent stated, "All that glitters isn't gold!"

The respondents were also asked what specific features an edger-optimizer, trimmer-optimizer, or automated grading system would need to have before they would install it in their sawmill. Two closely related themes, low cost and short payback, were cited most frequently. Another barrier was if the new systems would physically fit into their sawmill. Still other companies felt that they were too small to consider such technology. Similar to the previous open-ended question, issues of accuracy, reliability, ease of maintenance, and ease of use are necessary features. One important feature is the flexibility of the technology. Can the grade rules be changed or is there a manual override?

When asked if we had missed any of their concerns, most of their responses reiterated responses to earlier questions; however, several responses suggested an abandonment of the NHLA rules in favor of a simpler rule system or a rule system based on automated scanning technology. A few individuals commented on how the technology just wasn't for them. Others made statements praising such technology. One respondent stated, "I truly believe if we are going to stay in business for the long term optimization is inevitable."

Conclusions

This research provided a perspective on current and future scanning and optimizing technology in hardwood sawmills. To further develop and promote these technologies to the hardwood sawmill industry, timely information on the sawmill customers' expectations of such technology was needed.

Over 73 percent of responding companies believe that these types of scanning and optimizing technologies would help their sawmill. They believe it could help improve overall yield, recovery, consistency, and speed, yet previous research shows that only 10 percent have advanced scanning and optimizing technology, such as optimized edgers (1).

For the three systems (edger-optimizer, future edger-optimizer, and automated grading), *raw material recovery, lumber revenues*, and *accurate grading* were rated highly. These issues must be promoted through demonstration. Clearly documented examples of return on investment are necessary to further promote adoption. Cost issues become less important when payback is clearly demonstrated; however, current cost levels and physical space requirements will preclude the smaller mills. Increasing raw material costs will further promote this technology's ability to increase recovery and upgrade lumber.

In addition to what the technology can do, the promoters and manufacturers must pay attention to the service aspects of scanning and optimizing technology. Vendor/sawmill relationships are generally important, with some groups expressing higher interest in the service attributes than others,

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