Adoption of Scanning Technology in the Secondary Wood Products Industry

by

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Masters Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of:

Masters of Science

in

Wood Science and Forest Products

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ABSTRACT

A mail survey of wood cabinet, furniture, dimension, and flooring manufacturers was undertaken across the US to assess the market potential for automated lumber grading technology in the secondary wood products industry. Two hundred and nine usable responses were received providing information related to the identification of adopters of scanning technology, the optimum benefit bundle to increase the marketable success of automated lumber grading technology, and the best methods of promotion to this industry.

The results indicate that potential adopters of automated lumber grading technology will most likely be larger companies both in terms of annual sales and number of employees. In addition, adopter companies will be more likely to market their products in international markets. Results show that dimension and flooring manufacturers perceive this technology as more beneficial to their industries than cabinet and furniture manufacturers.

Analysis showed that significant differences existed between the four industry sectors on various machine attributes. In addition, dimension and flooring manufacturers rated machine attributes higher than cabinet and furniture manufacturers where significant differences were detected. This indicates that dimension and flooring

manufacturers place more importance on various machine attributes than cabinet and furniture manufacturers when considering the adoption of automated lumber grading technology. Optimal benefit bundles were characterized for each industry sector. While these benefit bundles differed among sectors, the differences where slight. Machine accuracy, simplicity of operation, technical support, and reduction in labor costs were important attributes to most sectors.

The best methods of promotion to the secondary wood products industry included trade shows, peer discussions, and plant visits. In addition, these three methods were most effective in promotion for the individual industry sectors as well. Advertisements, meetings and symposiums, scientific journals, and unsolicited sales literature were not rated as highly effective methods of promotion to the cabinet, furniture, dimension, and flooring industries.

DEDICATION

This study is dedicated to my wife, Stacy E. Cumbo, who has provided me with love and support through the most difficult of times. From the time we met she has given me unconditional love and support without fail. She has always been able to help me see the bright side of every situation. In addition, I would like to recognize my parents, Danny W. Cumbo Sr., Ruth S. Hankins, and Sue W. Cumbo. I thank them all for helping me become the man I am today. Also, many thanks to my family for giving me those occasional words of encouragement that help in ways that cannot be described. Thank you all.

ACKNOWLEDGEMENTS

I would like to thank the following people for their support of this project:

My most sincere appreciation to **Dr. D. Earl Kline** and **Dr. Robert L. Smith** for providing me with the opportunity to work on such a challenging and rewarding project. They have provided immeasurable support, assistance, and guidance throughout the past sixteen months.

My sincere appreciation to **Dr. Fred M. Lamb** for serving on my graduate committee and providing me with answers to many questions.

My sincere appreciation to **Dr. Geza Ifju**, who gave me the opportunity to continue my education.

My thanks to **Joanne Buckner** and **Susan Gibson** for their friendship, and help with this project.

My thanks to my fellow graduate students: **Chris Surak, Scott Bowe, David Olah, Daryl Corr, Ren-Jye Shiau, Delton Alderman, Nathan Hosterman, David Carradine, Stephanie Gomon, and Pete Urhig** for their friendship and support, and for creating the necessary diversions to work that are helpful in a project of this magnitude.

PREFACE

This thesis consists of four sections. Chapter One provides justification for this research, defines the objectives of this research, and reviews literature relevant to the adoption of scanning technology in the secondary wood products industry. The remainder of the thesis consists of three sections. Chapter Two discusses overall industry demographic information used to characterize the market as a whole, and characteristics of potential adopters of automated lumber grading technology. Chapter Three discusses the benefit bundle that will increase the overall marketable success of automated lumber grading technology in the secondary wood products industry, and the best methods of promotion to this industry. Chapter Four consists of a summary of the results and conclusions, prescribes recommendations for future research, and outlines the limitations to this study. In addition, some duplication of information between manuscripts, to allow them to stand alone, was unavoidable. The author apologizes for any inconvenience this may cause the reader.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

CHAPTER 1

ABSTRACT

The forest products industry is becoming a high-tech industry. As technology advances, and technologies from other industries become available, many companies are searching for ways to automate their operations, increase efficiency, and improve quality. Scanning technology, first introduced to the softwood lumber industry in the 1970s, has more recently been utilized in hardwood lumber production and secondary manufacturing of wood products. Scanning systems are now being used in automated chop saw operations, quality control systems, and other wood optimizing systems. Current research and product development projects are focusing in the area of defect detection scanning systems. These systems are designed to distinguish clear wood from defects such as knots, wane, and decay. Information generated can be used to saw lumber for optimum yield, better match lumber to specific products, or assign grades to lumber. This study investigated the differences in factors affecting the adoption of technology, among four segments of the secondary wood processing industry. The four sectors investigated include furniture manufacturers, cabinet manufacturers, wood dimension manufacturers, and flooring manufacturers. In addition, this research was designed to characterize adopters from non-adopters, and predict the best methods to promote scanning technology to each industry segment

INTRODUCTION

The secondary wood products industry is comprised of a variety of manufacturers utilizing a wide range of species and grades of wood. Greater than 90% of all hardwood lumber produced in the US is consumed by eight secondary wood processing markets. These markets include pallets, furniture, dimension parts, exports, millwork, flooring, cabinets, and railway ties. Hardwood lumber consumption for these markets has been estimated at over 13 billion board feet in 1997 (Hansen and West 1998). Consumption figures for 1997 show an increase of over two billion board feet since 1991 (Dempsey and Luppold 1992). In the eight markets previously mentioned, only the pallet industry failed to show an increase in hardwood lumber use in this decade. With the strong economic climate in the US expected to persist, continued increases can be expected.

While the wood products industry has not been traditionally known for its utilization of high technology equipment, many within the industry are seeking methods to automate their processes to increase lumber yield and product value. In addition, many companies are searching for methods to regulate the precision of their processes, improve their quality control operations, and facilitate the tallying and sorting of materials. Patterson et al. (1997) noted that 36% of furniture manufacturers and 55% of cabinet companies had some type of computer numeric control (CNC) machinery in place. In addition, greater than 39% of the furniture companies and 13% of the cabinet manufacturers indicated that they planned to purchase a CNC machine within 12 to 24 months. The most common types of CNC machinery observed were routers, carving machines, double-end tenoners, sanders, moulders, shapers, boring machines, and grinders.

Scanning technology, which was first introduced into the softwood lumber industry some twenty years ago as a component of yield optimization systems, has more recently been utilized in the secondary wood products segment as well. Currently, a great deal of research persists in defect detection and specialized interpretation and utilization of data generated by defect detection systems (Pham and Alcock 1998).

Laser scanning is used to locate such aspects as wane, voids, and board shape. Color and black and white camera scanning technology can be implemented in color sorting and matching in processes such as cabinet door panel production, as well as in the identification of mineral streaks, surface knots, and pith. X-ray scanning technology can be used to detect internal defects such as internal knots, internal voids, and honeycomb (Kline et al. 1998). Other scanning technologies exist which detect and utilize differences in wood cell structure to identify defects in lumber.

Lumber scanning technology for grading and processing hardwood lumber is now in the development stages. It is expected to become more commonplace in the industry as the proficiency of the technology advances and is proven to the industry. Current justification for purchasing a scanning system is the reduction of labor. However, the value of information that can be received from scanners may be of more importance. Kline et al. (1998) state that *"The primary cost savings from an automated lumber grading system will be realized by producing a more uniform and consistently graded product and by producing a higher value product through optimum lumber* *remanufacturing."* The ability to optimize yield and value are perhaps the most important attributes of lumber scanning systems, however, these systems are limited by the information they receive (Mullin 1998). This implies that the algorithm generated by an automated grading system is only as reliable as the information received from the scanning heads.

It is obvious that the adoption of lumber scanning technology by the secondary wood products industry depends largely on the performance of these systems in actual industrial applications. Rosenberg et al. (1990) noted that technology adoption in the forest products industry is influenced by the role of innovations imported from other industries, the effect of raw material shortages, the importance of economic factors in adoption of innovations, and problems associated with the heterogeneity of wood raw material and finished products.

Technology is often developed at the expense of one industry, while other industries later enjoy the benefits of the technology. For example, x-ray technology has been used in the medical field for a number of years, and in the case of automated lumber grading systems, it is now diffusing into the forest products industry. In addition, wood products manufacturers will focus more on improving processing operations in periods of economic recession and at times when raw material quality is not consistent. These scenarios lead to greater emphasis on increasing product value and part yield, and result in more innovation within the industry.

From the marketing perspective, the adoption of industrial high technology products can be evaluated on their perceived attributes. Mittal et al. (1998) state that negative performance on an attribute has a greater impact on overall satisfaction than positive performance on the same attribute. In addition, overall customer satisfaction shows diminishing sensitivity to attribute-level performance. By installing systems that possess attributes desirable to specific manufacturing operations, overall satisfaction level will increase.

Lehmann and O'Shaughnessy (1974) define industrial products as Type I, II, III, or IV products. A Type I product is routinely ordered and used. Type I products are expected to do the job and there is no question as to how to use it. *"For Type II products, the buyer is confident that the product can do the job. However, problems are likely, because personnel must be taught how to use the product"* (Lehmann and O'Shaughnessy 1974). The buyer will favor the supplier whose offering is perceived as likely to minimize the time and difficulty associated with learning the operation of the product. *"With Type III products, there is doubt as to whether the product will perform satisfactorily in the application for which it is being considered. It is argued that the buyer will favor the supplier who can offer appropriate technical service, provide a free trial period, and who appears flexible enough to adjust to the demands of the buyer's company"* (Lehmann and O'Shaughnessy 1974). Type IV products may result in problems within the company. With Type IV products, it is likely that there will be difficulty in reaching agreement among those affected by adoption of the product. Defect detection, lumber scanning systems display characteristics of both Type II and Type III products. Manufacturers of products with these characteristics must provide systems that are simple to operate. In addition, the company must be flexible relative to buyer demands. This research is designed to identify the specific attributes that will increase the marketable success of automated lumber grading technology. There has been no research conducted, which addresses scanning technology adoption factors in the cabinets, furniture, dimension, and flooring industries.

PROBLEM STATEMENT AND JUSTIFICATION

Secondary wood products manufacturers are facing the problem of continually increasing production efficiency and part yield to remain competitive. As resources become scarce, competition increases due to expanding global competition, and alternative materials continue to target markets historically dominated by wood, manufacturers of wood products must attempt to improve their production processes. Process automation, increased efficiency, increased yield, and improved information exchange will become issues of growing importance throughout the industry. Christianson (1998) showed levels of automation and machine purchases among wood products manufacturers to be increasing into the next millenium. The top industry concern in this study was recruiting and retaining skilled workers. It was also noted that more large companies classified their shops as technologically above average while smaller companies tended to view themselves as below average. In addition, among most companies, the need to up-grade technology was not only caused by competitive and market pressures, but also by reliance on a diminishing pool of skilled workers who require salaries at levels many companies cannot offer.

The secondary wood manufacturing industry is made up of a variety of producers manufacturing a heterogeneous mix of products. To remain competitive in a more sophisticated global marketplace, secondary manufacturers must become increasingly technologically advanced thereby increasing efficiency and optimizing product yield. Yield is perhaps the most important aspect of the manufacturing process for most forest products firms. Huber et al. (1985) state that analyses of furniture plant operations have shown that improvements in yield are key to the success of the rough mill. The affect on yield is a significant concern when forest products firms consider changes in the manufacturing process. Furthermore, firms must be aware of potential marketing implications associated with technology adoption. Innovation and technology adoption may result in changes in marketing strategy.

"Most policy makers believe adoption of advanced technologies is fundamental to wood manufacturers' competitiveness in global markets" (Hoff et al. 1997). In manufacturing, competitiveness is heavily influenced by productivity, product quality, and the introduction of new products. Some progressive furniture manufacturers have dealt with the threat of foreign competition by automating their processes and thereby becoming more efficient. In a labor-intensive industry, automation typically results in loss of jobs. However, subsequent increases in productivity and efficiency have allowed some companies to expand operations creating other jobs that offset lost jobs. In addition, Hoff et al. (1997) suggest that firms who possess advanced manufacturing technologies tend to be more proficient in responding to changing customer demands.

PROBLEM DEFINITION

The overall goal of this study is to understand the factors that influence the adoption of emerging technologies in the secondary wood products sector. The four segments of the secondary wood products industry selected for this project include furniture, cabinets, dimension, and flooring manufacturers. They were chosen based on the relative importance of lumber grading in their processing operations. These segments represent the most value-added products in the secondary wood products industry. Other products in this industry including railway ties, millwork, and pallets do not grade sufficient amounts of lumber to be relevant to this study. The emerging technology, considered in this study, is automated lumber grading technology (AGS) (Figure 1). Research is currently being conducted in the area of automated lumber grading technology. (Kline et al. 1998, Pham & Alcock 1998, and Mullin 1998). It is important for manufacturers of automated lumber grading systems to understand the market potential, "benefit bundle," and methods of promotion to bring this technology to market. The term "benefit bundle" is defined in this study as the system capabilities and product attributes offered by automated lumber grading system manufacturers and/or required by secondary wood manufacturers. It is thought that a lack of productive communication and understanding exists between manufacturers of scanning technology and secondary wood processing companies.

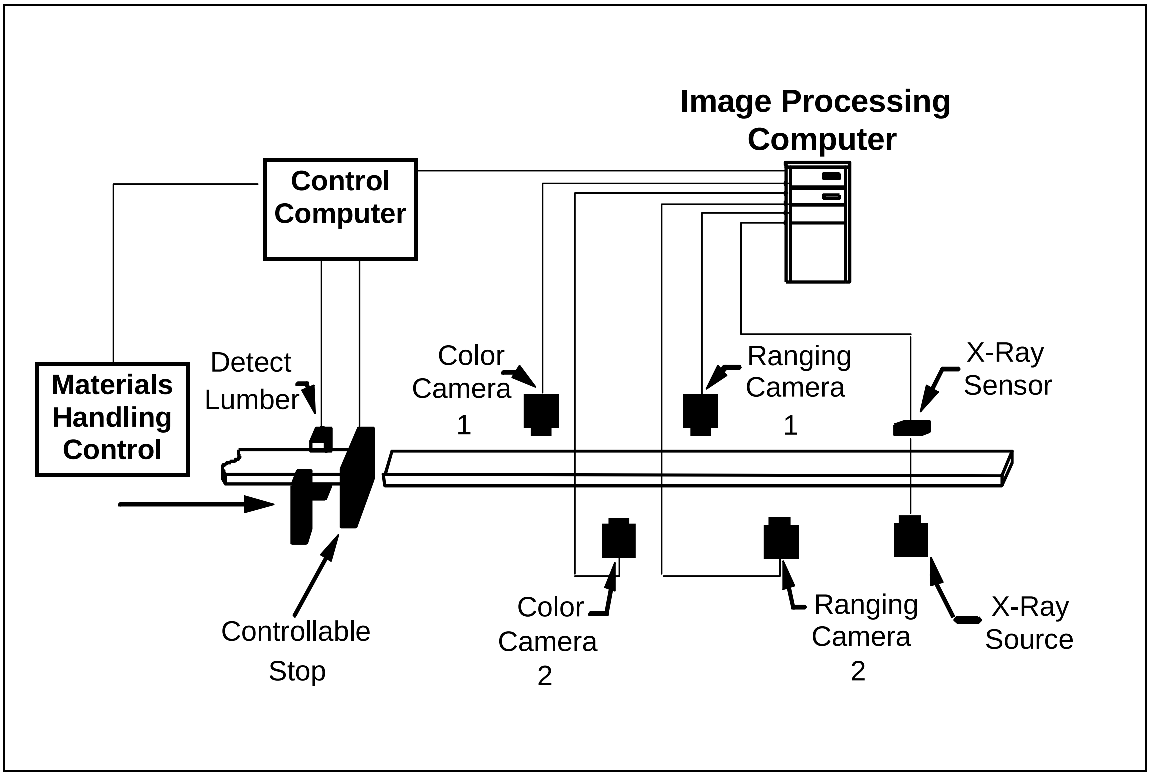

Figure 1: Overview of AGS

RESEARCH OBJECTIVES

This study is designed to characterize the potential market for an automated lumber grading system in the four specified sectors of the secondary wood products industry. In determining market potential, other characteristics of the market are investigated to accurately estimate potential adoption of the product. The specific research objectives are:

1. to identify factors which characterize firms as potential adopters or non-adopters of automated lumber grading technology;

2. to characterize the "benefit bundle" that will increase the marketable success of an automated lumber grading system by secondary wood processors;

3. to identify the best methods of promotion to secondary manufacturers of wood products.

LITERATURE REVIEW

SECONDARY WOOD PROCESSING

Secondary processors of hardwood lumber add value through processing beyond the rough green lumber stage. Lumber serves as the input raw material, which is further processed into a new value-added product. Products such as wood cabinets, furniture, dimension, flooring, millwork, and railway ties represent secondary wood products. In 1997, roughly 52% of all hardwood lumber produced in the US was consumed by four sectors of the secondary wood products industry. These sectors include furniture, dimension, cabinets, and flooring. Hardwood lumber consumption in 1997 was estimated at over 7.7 billion board feet among these four sectors (Hansen and West 1998).

Lumber Grading

Hardwood lumber is sold according to grade and volume. The universal grading system, used in the US and abroad, is based on a set of rules developed by the National Hardwood Lumber Association (NHLA) (Table 1). The rules were written with the end user in mind (NHLA, 1999).

The highest grade of lumber under NHLA rules is First and Seconds (FAS). FAS is also the most expensive grade of lumber. Below the FAS grade are the FAS-1 Face and Selects grades. These are the only grades that are not based on the poorest face of the board. The FAS-1 Face and Selects grades indicate that only one face of the board can meet FAS specifications, while the other face must be graded 1C. These two grades are often grouped together and sold as Face & Better, or Selects & Better lumber. The Selects grade differs from the FAS-1 Face in that Selects are subject to lower board size constraints (Table 1). Following FAS-1 Face and Selects in value is the No. 1 Common (1C) grade. No. 1 Common lumber is the average grade of lumber sold. No. 2 Common (2C) is the next most valuable grade, and No. 3 (3AC) is the lowest grade for hardwood lumber.

Table 1. NHLA grades

Grade	Minimum board length	Minimum board width	Minimum cutting size	Minimum area of clear cuttings
FAS	8’	6”	4”x 5’ or 3”x 7’	83%
Selects	6’	4”	4”x5’ or 3”x7’ FAS 4”x2’ or 3”x3’ 1C	83% FAS 67% 1C
1C	4’	3”	4”x 2’ or 3”x 3’	67%
2C	4’	3”	3”x 2’	50%
3AC	4’	3”	3”x 2’	33%

The most subjective aspect of lumber grading is determining what is and what is not a defect; i.e., knot, decay, wane, etc., so that clear cutting areas can be established. Lumber is graded from the poorest side of the board in terms of defects, with the exception of Selects or FAS-1 Face. Misinterpretation of defects is perhaps the most influential on grading accuracy.

Lumber is graded at the sawmill according to NHLA grading rules. In most secondary wood processing operations lumber is delivered from the sawmill at which time it is again graded by a certified grader employed by the receiving company. The processing operation and individual company policy determines the point at which lumber is graded. Each company, depending on the process, will have a target acceptable grade mix. Any material that does not meet the acceptable standards is typically sorted out for return to the sawmill. At the grading station, a certified grader inspects each board keeping a grade tally, which is then used to verify invoices from the sawmill.

Inaccurate grading has varying effects on different manufacturing operations, depending on the process and the product. Therefore, it is important to understand the different sectors of the secondary wood processing industry to fully understand the effects. Different sectors within the industry consume varying quantities, grades, and species of wood.

Furniture

The wood furniture industry showed a 50% increase in hardwood lumber consumption between 1991 and 1997 (Hansen and West 1998). Important species to the furniture industry include red oak, yellow poplar, black cherry, hard maple, black walnut, and white oak. According to Hansen et al. (1995) red oak accounts for approximately 33% of all wood furniture, while yellow poplar makes up roughly 16% of the species mix. Some softwoods such as white pine, southern yellow pine, and ponderosa pine are also utilized by the furniture industry. Eastern white pine accounted for 53% of the softwood lumber used, while ponderosa pine and southern yellow pine were estimated at 18% and 17%, respectively. Furniture manufacturing uses a wide range of lumber grades as well. In 1993 lumber graded as No. 1 Common made up roughly 60% of the grade mix for furniture manufacturers. No. 2 Common accounted for approximately 26% and nearly 12% was designated as FAS and Selects (Hansen et al. 1995).

Dimension and Wood Components

The dimension and wood components industry showed an 85% increase in hardwood lumber consumption between 1991 and 1997 (Hansen and West 1998). Dimension and wood components are defined as intermediary, value-added products, which are used in other secondary wood processing operations such as millwork, furniture, and cabinet manufacturing. *"Wood components, such as dimension parts, are dried and processed to a point where the maximum waste is left at the mill and the maximum utility is delivered to the customer."* (Vlosky 1996). In some cases furniture manufacturers own and operate their own dimension mills, and often dimension mills are affiliated with sawmills, but most are independent companies. According to Vlosky, (1996) dimension manufacturers are often the focus of state economic development initiatives in an attempt to add value to hardwood resources.

Dimension and component operations utilize a wide range of lumber grades and species. Vlosky (1996) showed red oak to be the predominant species at roughly 39% of the species mix. Following red oak were yellow poplar, white oak, maple, and cherry at 16%, 15%, 10.5%, and 5%, respectively. The study also noted that geographically, the North Central US dominated in red oak, while the Northeast was the largest user of cherry, and the South used mostly poplar, white oak, and maple. Hass and Smith (1997) showed hardwood components made from red oak accounted for 35% of the value of components sold in 1994. Following red oak was hard maple at 16%, yellow poplar at 12%, white oak at 10%, cherry at 6%, ash at 5%, and hickory at 3%. It was also noted that the two largest domestic and international end users of dimension and component parts were wood furniture, and moulding/millwork manufacturers.

Cabinets

From 1991 to 1997 hardwood lumber consumption in the cabinet industry increased by 33% (Hansen and West 1998). According to Punches et al. (1995) the US cabinet industry consists primarily of a relatively small number of large companies. In a study by Adams (1999) it was noted that cabinet sales for use in rooms other than kitchens and bathrooms has steadily increased throughout the 1990s. Eighteen of 36 cabinet companies surveyed responded that they sell other-room cabinets. In addition, it was noted that the cabinet industry has experienced 33 consecutive months of growth in sales since 1996, and both stock and custom manufacturers have averaged double-digit growth in 1998.

Oak is credited with approximately 80% of solid wood use. Cherry, maple, and birch follow with an average use of roughly 4% to 8%. Pine is estimated at less than 2% of total solid wood use. Doud et al. (1992) noted that the most common lumber purchasing strategy for cabinet manufacturers in Pennsylvania was to buy lumber graded as FAS only. However, this strategy may differ according to geographic region and raw material availability.

Other grade mixes included FAS and Selects, FAS and No. 1 Common, No. 1 Common and Selects, or No. 1 Common. These lumber purchasing strategies were less common than the FAS only strategy in the study by (Doud et al. 1992). In addition, short length lumber, 4 to 8 feet in length, was shown to dominate due to lower prices. Nonconformity to National Hardwood Lumber Associations grading rules was cited as the reason for lower prices of short length lumber (Doud et al. 1992).

Smaller companies in the cabinet manufacturing industry tended to use a mixture of solid wood, wood-veneered, and non-veneered panels while larger companies used more non-veneered panels. This can be explained by the increased emphasis on stock cabinets in larger companies compared to smaller companies who place more emphasis on custom cabinets (Punches et al. 1995).

Flooring

From 1991 to 1997 hardwood lumber consumption in the flooring industry increased by 120% (Hansen and West 1998). Recently wall-to-wall carpet and PVC flooring have begun to lose their market share to wood flooring as a result of increasing health and environmental concerns among consumers (Weinig 1999). Weinig states, *"Reservations about chemicals and fear of house dust by many allergy sufferers has led to a decrease in carpet sales versus wood flooring."*

Wood flooring utilizes a variety of species and grades. The National Wood Flooring Association lists oak, ash, hard maple, beech, birch, and pecan as the most significant species. However, other species are used such as locust and some pine species (NWFA, 1999). In addition, there are several types of wood flooring to choose from. These include unfinished, pre-finished, solid wood, wood laminate, and acrylic impregnated wood flooring. Solid wood flooring is produced in strip form, plank form, or as parquet flooring. Strip flooring is manufactured to ½" or ¾" thickness and widths of 1 ½", 2", and 2 ¼". Plank flooring is manufactured to greater widths than strip flooring, 3” to 8”, and parquet flooring is made up of geometric patterns, which are composed of individual wood slats. Parquet flooring is typically manufactured from short pieces 6 to 12 inches in length. Unlike the wide range of grades utilized by other secondary manufacturers, flooring manufacturers compete for a grade mix comprised mostly of lower grade material (Hansen and West 1998). In general, flooring manufacturers utilize primarily No. 1 Common and lower grades of wood.

Recovery and Yield

Perhaps the most important issue concerning manufacturers of forest products today is recovery or yield obtained from raw materials, logs for primary wood processors, and lumber in secondary wood processing. Secondary manufacturers of wood products are constantly evaluating the yield percentages achieved in the mill. Furthermore, most mill managers are striving to at least maintain a certain level, if not improve, yield. Yield can be considered a measure of efficiency, a reflection of productivity, and a potential area of savings for both the company and the customer. It has been noted that improving yield is the key to rough mill success (Huber et al. 1985). There are a number of techniques for measuring yield, but ultimately every mill has a set percentage they attempt to maintain. For example, a furniture manufacturer may be satisfied with roughly 60% lumber utilization in the production process, while a dimension mill may expect a higher yield percentage. It should be noted that with a yield of 60%, 40% of the raw material is not being utilized in the form of a final product. This presents an area for significant potential savings. Many operations are looking to optimizing scanning systems to obtain the most usable material possible. Huber et al. (1985) suggest that the ultimate solution for maintaining productivity and yield in the rough mill is the virtual elimination of human error through use of computer-aided manufacturing methods and technology such as computer vision.

DEVELOPMENT OF OPTIMIZATION SYSTEMS

During the lull in the market for forest products in the late 1970s and early 1980s, many sawmill operations began to feel the need to embrace automation, computer control, and overall process management more vigorously. Softwood lumber manufacturers realized that by precisely controlling processing operations using automated control systems they could increase lumber recovery and more easily adjust to changes in demand. In the early 1980s some Canadian firms began using light emitting scanners with cameras and integrated circuits to measure log dimensions prior to bucking. In addition, scanning systems were introduced as components of chipping-canting systems for pre-setting chipping heads (Saunderson 1982).

Scanning technology gained significance in the forest products industry as optimization systems used for primary processing of softwood timber. Optimization technology did not gain significance in the hardwood lumber industry until the late 1980s. The first edger-optimizer designed specifically for hardwood production was installed in a sawmill in Pennsylvania in 1988 by INOVEC. Edger/trimmer optimizing systems can be separated into three basic components; the scanner, the decision-making software, and the mechanical apparatus that carries out the solution. Early edger-optimizers claimed 92% recovery compared to the 70% to 85% that was common with manual systems. The first edger-optimizer in the US was installed at Cottage Grove, OR, in a small log softwood sawmill owned by Weyerhaeuser Co. in 1976. The mill was touted as Weyerhaeuser's most automated small log mill (White 1977). The system was developed and built in Sweden, and the purchase cost was listed at $285,000. Boards were scanned by a photodiode array, and edged according to data stored in computer memory.

Another significant contributor to the increase in use of scanning systems, and automation in general, was the increasing trend to manufacture lumber from smaller logs in the 1970s. As environmental regulations changed and smaller second growth trees were harvested, log processing operations were forced to adapt. Williston (1979) suggested that the Best Opening Face Method (BOF) of log breakdown, developed by the USDA Forest Products Laboratory at Madison, Wisconsin, resulted in further advances in scanning technology, computing, and positioning devices. Today, the most widely used log scanning systems measure only external features employing log profile sensing techniques (Kline 1998).

In 1977 the Forest Products Lab in Madison developed a defect scanning system known as the Defectoscope, which used ultrasound to detect irregularities in wood grain (Anonymous 1977). Sound waves were passed through the board detecting defects such as knots and decay. A computer directed a line plotter to reproduce the image of the board indicating where defects were located, then marked where cuts should be made for maximum yield. Potential yield increases using the Defectoscpoe were calculated at 15%. Based on this data, it was noted that a $100,000 investment could be paid off within six months from the increased yield alone in a medium sized mill (Anonymous 1977).

Hardwood lumber grading differs from softwood lumber grading in that hardwood lumber is graded based on aesthetic quality rather than strength limiting defects, therefore, hardwood lumber production and grading focus more on product value than volume. In the past hardwood lumber scanning systems have been based on a single sensing modality; e.g., black and white or color camera, sensing only gross wood features (Kline 1998). *"In secondary lumber processing, a completely automatic lumber inspection system must not only accurately detect the size and shape of lumber, the system must also accurately find the location and type of defect with sufficient precision and resolution"* (Kline 1998).

CURRENT SCANNING TECHNOLOGY

Today, lumber-scanning technology is much more sophisticated and it is currently in a state of continual development. Much of the current research in lumber scanning is focused in the area of defect detection. Pham & Alcock (1998) suggest that the speed at which lumber is graded and the level of stress involved have contributed to the desire to remove human error from the grading process through automation. Modern secondary wood products production speeds require lumber grading at higher speeds, however, accuracy must be maintained. Human error and fatigue associated with manual lumber grading may result in decreased grade accuracy and precision.

Today, most wood scanning technology utilizes the machine vision system (MVS) framework. Conners et al. (1999) note that machine vision systems contain the following three features: (1) a combination of electrical hardware and computer software sensing and measuring spatially varying characteristics of a specimen, (2) sensing produces an image that can be processed as a 2-dimensional or 3-dimensional array of measurements, and (3) computer hardware/software automatically interprets those measurements as an image in order to infer important properties associated with the specimen. These activities are designed to function with little or no human intervention.

Some manufacturers are now offering systems that promise reduced trim loss, reduced grader fatigue, and higher percentages of "on grade" packages. Grade scanning optimizers for chop saw lines are being touted as defect detection systems that have the ability to optimize based on grade or value. Advertisements claim scanning speeds of up to 700 lineal feet per minute. In addition, manufacturers are offering systems equipped with a variety of components in a variety of combinations, while promising new features as technology advances. The limitation of these systems, as they exist now, is the decrease in accuracy and precision that results when scanning green rough-surfaced wood. Higher moisture content lumber causes problems, especially in the color and x-ray images, due to color and density variation caused by wet pockets in the wood. In addition, machine and dirt marks on lumber are often falsely recognized as defects by the scanning cameras (Kline et al. 1998).

MARKETING ISSUES

It is important to note that technology for technology's sake should not be the motivation for product development. A technology product, as with any new product, must supply a need. Furthermore, it must be presented to the market in a timely fashion, and in a manner such that maximum market share can be obtained. *"The most serious mistakes companies make are usually the result of poor planning. By the time a company finds itself going after the wrong market, with the wrong product, at the wrong time, it is usually in such a tight box that only Houdini could get it out"* (Davidow 1986). Often, errors in product planning are not apparent until after design and production of the product. By recognizing at this stage that the wrong market has been targeted significant loss of resources can occur, both monetarily and in terms of time.

During the early stages of microcomputer development, Intel a well-known company in the electronics market, developed the successor to the 4004, the world's first microcomputer. The company knew the 4-bit 4004 model was too slow, and that an 8-bit system could be built at no additional cost. In addition, the new model would make use of several Intel proprietary technologies, which would be difficult for competitors to duplicate. Customers showed enthusiasm for the new system and the 8048 was born. However, in spite of all of the euphoria, the 8048 was not successful. Fairchild, a fading company from which no one expected competition, developed the 3870. Unknown to anyone, Fairchild had hired a number of talented people with backgrounds in consumer electronics. They had conducted research on the high volume accounts such as automobile and telephone manufacturers, and knew what they wanted. Intel had planned the 8048 for the traditional Intel customer base, which manufactured lower volumes of more sophisticated systems. The 8048 had many features that were of little value to the larger consumers, and as a consequence lacked features that were important to them (Davidow 1986).

Intel had developed a technology that was useful only to a small market. It did produce the intended results and it was an improvement on an existing technology. However, it was poorly planned and therefore manufactured for the wrong market. Manufacturers of scanning technology aimed at the forest products industry must understand the need and potential of the target market to effectively design and promote the product, and gain market share. *"The commercial viability of a new product rests in the hands of its potential customers; and therefore a solid understanding of the marketplace together with an effective market launch effort is vital to new product success"* (Cooper 1979).

Industrial Product Introduction

Industrial marketing is defined as the marketing of products and services to industrial and institutional customers for use in the production of goods and services (Choffray and Lilien 1980). Marketing to industrial customers differs from marketing to household consumers in that success in the industrial market depends, to a larger degree, on other functional areas of the firm. Engineering, research and development, manufacturing, and technical service all play important roles in the industrial planning process. Therefore, planning in the industrial market involves greater functional interdependence and an overall closer relationship to the corporate strategy (Hutt and Speh 1981). The need for greater functional interdependence when planning industrial products is based on the complexity often associated with industrial products as well as increased costs associated with developing a complex or sophisticated product.

Deviations from corporate strategy may result in higher development, production, and marketing costs.

Cooper (1994) states that new product innovation has primarily been a hit-and-miss affair. However, eight factors driving the success of new products are given. The factors are as follows:

1. A unique superior product that delivers unique benefits and value to the customer;
2. a strong market orientation, a market driven and customer focused new product process;
3. up-front research and planning before product design;
4. sharp and early product definition before product development;
5. a cross-functional team approach to new product development;
6. sharp focus and evaluation of time and resource requirements;
7. quality of execution of the innovation process; and
8. a multi-stage-and-gate "Game Plan."

Summarizing Cooper's eight factors influencing new product success, the firm must offer a product for which there is little or no substitute. The new product must be perceived as superior to similar products and unique in the benefits offered. The firm must also be market-oriented as opposed to production-oriented. A market-oriented company has a better understanding of its customer's needs. Market research must come before product design to plan the appropriate product for the corresponding market. In addition, the new product should be clearly defined early in development to help guide the process. The firm should make efforts to include all areas of the company in the design of new products. This approach allows for insight from people with different backgrounds in the company. Firms must attempt to accurately estimate resource requirements in the planning process so development can be kept within budget constraints. The innovation process must be executed in a timely and deliberate manner. The product must ultimately be accepted by the customer to be successful. Finally, it is beneficial to segment the entire planning, developing, and marketing process to more easily react to unexpected events, and more closely track the process.

The failure of new industrial products has been largely attributed to failure to adequately manage the product development process. More (1986) suggests that the real failure has been in understanding and managing strategic relationships with potential adopting organizations. In addition, structural and process characteristics in both the developing and adopting organization are strongly linked. Managers in adopting organizations face similar decision processes as those in the developing organization. For example, developers must attempt to decide between possible product configurations, while adopters attempt to choose the most beneficial product among several product offerings.

Cooper (1979) lists three barriers to the success of new products. These are:

1. Having a high priced product relative to competition with no economic advantage to the customer;

2. being in a dynamic market with many new product introductions; and

3. being in a competitive market, where customers are already well satisfied.

In the case of automated lumber scanning systems, this is a sophisticated industrial product, which is expected to demand a relatively high price. However, competition is scarce as automated lumber scanning technologies are now emerging. This is a new product, and as such targeting a new market, therefore market dynamics are developing. However, as scanning technology is increasingly accepted by the forest products industry more firms will enter the market.

High Technology Products

Technology, broadly defined, is “know-how,” more specifically it is the information needed to produce and/or sell a product or service. In business, experience and information, i.e., know-how are valuable assets. In marketing products, know-how relative to customer needs is important as well. In this context, know-how may result in a competitive advantage for the company. Three components of know-how can be identified: product technology (ideas that are embodied in a product), process technology (ideas involved in manufacturing a product), and management technology (the set of procedures associated with business administration and selling a product) (Capon & Glazer 1987).

Marketers of high technology products must plan the development of products not devices. Products are designed to fulfill customer needs, while devices are of little or no use to customers. By virtue of the “high-tech” product classification, these products are serving new functions in new markets. In a new market firms may not have the luxury of learning from their competition. There are no lessons to be learned from competitors who do not exist; therefore, comprehensive planning becomes vital. In high-tech firms, however, planning often becomes a sidebar to new product development and the customer is often the last consideration. High-tech companies are reliant upon strong research and development departments to maintain the competitive advantage associated with being high-tech. The result of over-emphasizing research and development is typically the development of a product for which there exists little or no market. Often, an engineer in the laboratory will think of something new. The new idea causes excitement within the company and a new project is begun. As the program matures, marketing is expected to find customers who need the new device (Davidow 1986). This method of product development is the opposite of the marketing-oriented approach where a need and a market are identified first. The potential of the market is then evaluated followed by design, promotion, production, and ultimately sales.

Designers must consider the manner in which the product will be used as well as product durability when developing new high-tech products. Products that are "user-friendly" have been noted to be more successful than those that are not. In most situations, a high performance product that is difficult to maintain or operate will see success only under specific conditions. Furthermore, it is important for managers to conduct the timing and staging of product design to allow for the intensity of effort associated with breakthroughs followed by recovery time. In a high-tech market that is driven by technological advances managers may feel pressure to maintain a sustainable competitive advantage; however, this may be an unrealistic goal. Perhaps the emphasis should be placed on maintaining the capabilities to design new product strategies on an on going basis. For example, the ability to rapidly prototype could facilitate and hasten the design of new product strategies.

Rhyne (1994) suggests that companies wishing to remain competitive in high-tech markets must:

1. Focus on developing teams that will function together over time;
2. recognize the need for continuous improvement over time despite temporary set backs; and
3. recognize that experience in the industry remains critical.

In high-tech markets it is important that those responsible for product development be part of a productive working team. Any activity that hinders team focus can be detrimental to the task at hand. High-tech firms must also be committed to constant product improvement. As technology advances, manufacturers of forest products will likely expect automated grading systems to be capable of processing more information quicker and with less human interaction. In addition, it is important for high-tech firms to understand that experience in the industry is vital. In time manufacturers of automated lumber grading systems will come to better understand the forest products industry they serve. This knowledge may lead to better product development and new machine features in the future.

Innovation Attributes

Ostlund (1974) suggests that perceived innovation attributes are strong predictors of new product adoption. The study listed six perceived innovation attributes as important to new product adoption; i.e., predictors of innovativeness. The attributes are:

1. relative advantage (degree to which an innovation is perceived superior);
2. compatibility (degree to which an innovation is perceived consistent with existing values, habits, and past experiences);

3. complexity (degree to which an innovation is perceived too difficult to understand and use);

4. trialability (degree to which an innovation is perceived available on a trial basis without a large commitment);

5. observability (degree to which the results of an innovation will be apparent and possible to communicate to others); and

6. perceived risk (degree to which risks are perceived to be associated with the innovation).

The significance of perceived innovation attributes in new product adoption reinforces the importance of planning in high-tech product development. It is important for managers to understand the ranking of the potential new product on the attributes related to the product. In addition, specific product attributes play a significant role in the adoption of high-tech products. In the example of automated lumber grading systems, producers of different secondary wood products may place varying degrees of importance on different attributes.

Product Bundling

Often, various product or service attributes are bundled and offered together as a single product. *"Bundling is selling separable products or services to buyers as a package, or bundle"* (Porter 1980). For example, IBM has bundled computer hardware, software, and technical support for many years. Bundling implies that all buyers are supplied the same package regardless of differences in need. Buyers often differ in the intensity of their need for different products and services; therefore, buyer receptiveness to bundling may vary.

Porter (1980) suggests several ways in which bundling can create a competitive advantage. First, a firm may lower costs by providing a single package rather than a customer specific mix. Firms can better share activities in the value chain that provides parts of the bundle. This can result in economies of scale for the firm. Second, bundling may allow a firm to differentiate itself from other firms selling only parts of the bundle. In this context bundling can prevent the need to compete with other companies in the areas of their greatest strength. In addition, compatibility among items in the bundle can be facilitated if a single firm provides the entire package of goods or services required to satisfy the customer. In the case of automated lumber grading systems, the compatibility issue can be important if the market dictates that the system must perform tasks other than grading. Third, bundling may provide firms with enhanced opportunities for price discrimination. In cases where buyers have different sensitivities to various parts of the bundle, individual parts can be offered at prices that sum to more than the bundle price.

Bundling involves risks as well. It makes the assumption that a significant number of buyers are willing to purchase the bundle; therefore, the diversity of buyer's needs is not considered. Lack of attention to specific buyer's needs may result in vulnerability to firms that take a more focused approach. Vulnerability may arise if specialists focus on parts of the bundle, thereby achieving lower costs or differentiation in producing them (Porter 1980). An automated lumber grading system may be offered as a bundled product consisting of hardware, up-gradable software, and technical support. It could be bundled as a product consisting of those attributes in addition to tallying, sorting, or cut-up capabilities. It will be important for manufacturers of automated lumber grading systems to be aware of the risks associated with bundling without attention to customer needs.

It is hypothesized that an automated lumber grading system may have to perform tasks other than simply assigning a grade to lumber. Depending on the production process, machine requirements may vary. The potential benefit bundle for an automated lumber grading system might include some or all of the following attributes:

- tallying capabilities
- sorting capabilities
- color sorting capabilities
- high through-put speed
- high durability
- simple operation
- manual override
- extended machine warranty
- extensive technical support

The importance of these attributes on machine purchase decisions among the industry sectors mentioned earlier, furniture, cabinets, dimension, and flooring will be discussed later.

METHODOLOGY

For this research, a mail survey was used to collect data. The population of interest included the furniture, cabinet, dimension, and flooring industries. A questionnaire was initiated based on the study objectives. The questionnaire was reviewed by members of the faculty at Virginia Polytechnic Institute and State University for relevance to the objectives. This preliminary questionnaire was used as a script in personal interviews with one company in each industry sector. A questionnaire was then designed using the information obtained from the personal interviews. This questionnaire was faxed to three companies in each sector to pretest the questionnaire before distribution to the four sectors of the sample. Final adjustments were made using information obtained from the pretest, and the revised questionnaire was mailed out to 1,256 companies in May 1999.

SAMPLE DEVELOPMENT

For this study, the population was the secondary wood products industry, the sample frame consisted of the four sectors of interest; wood furniture (SIC 2511), wood cabinets (SIC 2434), wood dimension (SIC 2426), and wood flooring (SIC 2426). Sampling was conducted primarily from members of trade associations. It was assumed that members of trade associations would represent the more innovative companies in the industry; therefore, sampling from this group could introduced bias toward more innovative companies. In addition, this study assumed that relatively innovative firms represent the most likely adopters of an automated lumber grading system. The total number of survey questionnaires to be mailed to each industry sector was based on an expected 25% response rate. The most important questions in the survey addressed the factors involved in secondary manufacturer's adoption of an automated lumber grading system, and sources from which they receive technological information. These questions addressed the central issues outlined in the project objectives, the optimum benefit bundle, potential adopting firms, and promotion strategy.

Ballenger and McCune (1990) state that when sampling multiple populations for parameter studies, the following equation can be used to determine sample size. The equation is based on a seven point rating scale (1 = least important, 7 = most important).

$$n = [(Z_{\alpha/2})^2(\sigma)^2]/h^2$$

where: n = sample size;

$Z_{\alpha/2}$ = reliability coefficient;

σ = estimated population standard deviation;

h = allowable tolerance level.

A confidence interval of 95% was used for this study; therefore, sample size calculations are as follows:

$Z_{\alpha/2} = 1.96$;

σ = (max. value – min. value)/6 = 7-1/6 = 1;

$h = \pm 0.2$ for $\alpha = 0.05$;

$n = [(1.96)^2(1)^2]/(0.2)^2 = 96.04$ rounded to 97

This sample size coincides with the general consensus that a sample containing approximately 100 units will result in significant statistical power in testing. Rossi et al. (1983) state, as a general rule, that the sample should be sufficiently large so that there are approximately 100 units per category. Adjusting the calculated sample size for an expected 25% response rate, at least 388 survey questionnaires were mailed to each sample group. Due to the limited number of wood flooring manufacturers, relative to the other three sample groups, this sample was based on an attempted census of the entire industry, 92 companies; i.e., the entire known population was surveyed. The total number of flooring manufacturers in the US is thought to be approximately equal to the minimum sample size calculated for this survey. A total of 1,256 survey questionnaires were mailed to the sample frame. Actual response rates differed from the minimum expected response rates. This is discussed further in Chapter Three.

QUESTIONNAIRE OUTLINE

One questionnaire (Appendix A) was mailed to each company in the selected sample frame from cabinets, furniture, dimension, and flooring manufacturers. Identical questionnaires were mailed to each sector to compare results obtained from each sector. The questionnaire consisted of four sections; a scanning technology section, a lumber grading section, an automated grading system section, and a demographics section. The questionnaire was designed to engage the respondent with simple qualifying questions at the beginning, move on to more technical questions in the body, and conclude with open-ended questions.

Scanning questions were designed to determine which companies had scanning technology in place, and the factors that influenced their decision to invest in this equipment. Important factors were expected to include such aspects as increased efficiency, accuracy, and part yield. Lumber grading questions asked for information concerning where and when lumber was graded in the operation, and attempted to assess the cost of manual lumber grading both monetarily and in terms of time. Questions related to automated grading systems were designed to identify factors that would influence the purchase decision for an automated grading system, and to determine key system features influencing adoption of this technology. It was hypothesized that important factors influencing purchase decisions might include aspects such as sorting capabilities, tallying capabilities, technical support, and machine warranty. These questions are important in characterizing the benefit bundle that will increase the marketable success of automated lumber grading systems.

Finally, the demographic section was designed to help estimate company demographics such as, company size, sales, and production levels to be used in characterizing potential adopter firms and non-adopter firms. The questionnaire concluded with open-ended questions allowing respondents to expand on the issues addressed earlier in the document. Prior to analyzing the data, all responses were coded and entered into a spreadsheet. SPSS statistical software program was used to statistically analyze the data.

DATA ANALYSIS

The first objective, characterizing the benefit bundle that will increase the marketable success of automated lumber grading systems, was addressed by questions in the survey such as question 3, question 5, and question 8. Question 3 asked participants to indicate factors that influenced the decision to purchase scanning technology in the past, if applicable. Participants were asked to indicate the factors that influenced their decision to invest in scanning technology as well as list any factors that did not appear on the list. Included in the list of factors were *increased efficiency*, *automation*, *part yield*, and *accuracy*. This type of question, resulting in categorical data, was analyzed using summary statistics. Frequency tables were produced to compare the relative importance of each factor in purchase decisions among the four sectors.

Question 5 asked participants to rate a list of factors, *invoice verification, matching grade to product,* and *facilitation of lumber grading* on their importance in lumber grading. The rating hierarchy was based on a 1-7 scale (1=least important, 7=most important). This type of question was analyzed using multivariate analysis of variance (MANOVA) to test for significant differences among the four sectors; therefore, a mean was calculated for each of the four industry sectors. The MANOVA methodology allows for simultaneous examination of multiple samples on multiple variables (Lehmann et al. 1998). The MANOVA technique was used to test for statistical differences between industry sectors at a confidence level of 95%. A 95% confidence level implies an alpha level of .05. The alpha level is the probability of type 1 error in the statistical hypothesis, i.e., we are 95% confident that the actual mean rating value for the population studied will, on average, be equal to the mean rating value reported in the statistical test. Fisher's Least Significant Difference (LSD) technique was used as a post hoc test to detect differences between specific industry sectors.

Question 8 asked participants to rate a given set of factors on their importance in purchasing an automated lumber grading system. Respondents were asked to rate a list of 14 factors, on a 7-point scale (1=least important, 7=most important), on their potential importance in a decision to invest in an automated lumber grading system. The list of factors included: *system accuracy, machine cost, technical support, equipment warranty, reduction in labor costs, machine durability, simplicity of operation, tallying* *capabilities, throughput speed, sorting capabilities, ability to switch species, ability to switch grading rules, compatibility with existing equipment,* and *color sorting capabilities*. Question 8 was analyzed using (MANOVA) as well. MANOVA was used to test for significant differences among the four sectors at a confidence level of 95%. Rencher (1995) states that "MANOVA consists of a collection of methods that can be used when several measurements are made on each individual object or object in one or more sample." Fisher's LSD was used to detect significant differences between specific industry sectors.

Objective two, identifying potential adopters and non-adopters of automated lumber grading technology, was addressed by questions such as question 2, question 7, and question 19. Question 2 asked the participant to indicate if they had scanning technology in place at the time of this study. It was thought that many potential adopters of automated lumber grading technology would have invested in other scanning technologies in the past. For this question, frequencies were produced to assess the percentage of each sector that had previously invested in scanning technology. Cross-tabulations were produced to determine the relationship between technology adoption and other demographic information.

Question 7 asked participants to estimate the number of man-hours that were spent grading lumber, as a percentage of total man-hours. It is was thought that the average percentage would be relatively low and that those companies who responded with relatively high percentages may view this as added justification for investing in an automated lumber grading system. Frequency tables were produced for question 7.

Question 19 related to company demographics. It asked participants to estimate total gross sales for his/her company in 1998. It was hypothesized that there would be a division between potential adopters and non-adopters of automated lumber grading systems in terms of company earnings, i.e., adopters on average would consist predominantly of companies whose gross sales were equal to or greater than some dollar amount.

The third objective, to identify the best method of promotion to secondary manufacturers of wood products, was addressed by questions such as question 3 and question 14. Question 3, which also relates to the first objective, asked participants to indicate factors that influenced their decision to invest in scanning technology in the past, if applicable. Frequency tables were produced for data obtained from question 3. It was thought that automated lumber grading promotional efforts should focus on those factors that influenced investment in other scanning technologies in the past.

Question 14 asked participants to rate 9 factors on their importance to the company in learning about new technology and industrial equipment, on a 7-point scale. The list included: *advertisements, trade shows, plant visits, scientific journals, sales calls, meetings, trade journals, peer discussions*, and *unsolicited sales literature*. In addition to the 9 factors previously noted, participants were provided with an “other” category to list factors not provided. MANOVA was used to detect significant differences among industry sectors at a confidence level of 95%. Fisher’s LSD was used to detect significant differences between specific industry sectors.

NON-RESPONSE BIAS

This study used a sample frame consisting of cabinet, furniture, dimension, and flooring manufacturers from across the US; however, not all manufacturers receiving a questionnaire participated in the survey. To be sure that the sample was truly representative of the population, comparisons were made between respondents and non-respondents. Ten companies in each industry sector were contacted by phone and asked a series of questions selected from the questionnaire. Questions from which means could be calculated were chosen for the comparison.

Questions 8 and 17 were selected. Question 8 consists of fourteen system attributes for which respondents were asked to rate their importance in the adoption of automated lumber grading technology on a 1-7 scale (1=least important, 7=most important). For brevity only five attributes were used in the phone survey. These attributes included *system accuracy, machine cost, technical support, tallying capability*, and *sorting capability*. Question 17 asked participants to estimate the company's annual lumber input volume in board feet. ANOVA was used to compare means between respondents and non-respondents on questions 8 and 17 at a confidence level of 95%. No significant differences were detected on the *technical support, tallying capabilities, sorting capabilities,* or *annual lumber input* variables. However, significant differences were detected on *system accuracy* and *machine cost*. No significant differences were detected among industry sectors on annual lumber input volume.

Another method often used to test how well the sample represents the population studied is to compare early respondents to late respondents. It is thought that late responses are a valid representation of non-responses. A comparison was performed between the first and last thirty responses received using a t-test of the means. The t-test was performed at a 95% confidence level. Significant differences were not detected for *machine cost*, *technical support, tallying capability*, *sorting capability*, or *estimated annual lumber input*. However, a significant difference was detected between early and late respondents on the *machine accuracy* attribute. It was reassuring to find that significant differences were not detected between, neither respondents versus non-respondents, nor early versus late respondents on most variables. However, the presence of significant differences on system accuracy in both comparisons indicates that our findings on this attribute may not be representative of the population.

PROJECT SUMMARY

The overall goal of this study was to assess, not quantify, market potential for an automated lumber grading system in the secondary wood processing industry. This study was designed to determine why a secondary wood processing company would or would not invest in automated lumber grading technology.

A mail survey was used to collect data from companies in the four sectors, furniture, cabinets, dimension, and flooring manufacturers. The questionnaire was designed to meet the objectives of this project. The objectives were as follows: (1) to characterize potential adopters and non-adopters of automated lumber grading technology, (2) to characterize the benefit bundle that will increased the marketable success of an automated lumber grading system in the secondary wood processing industry, and (3) to identify the best methods of promotion to the secondary wood processing industry.

This study was designed to assist manufacturers of wood scanning technologies in understanding product attributes that are important to the secondary wood processing industry and differences in those attributes among the four sectors. In addition, this study was designed to help manufacturers of wood scanning technologies with product planning and development. This study will assist manufacturers of wood scanning technologies in targeting potential markets and identifying those companies that are more likely to invest in this type of equipment. Finally, this study identified important product attributes on which to focus in promotional efforts, and the most beneficial methods of promotion to the secondary wood processing industry.

Chapter Two will address objective one, differences between adopters versus non-adopters of scanning technology, and discuss overall market demographic information. Chapter Three will address objectives two and three, characterization of the benefit bundle that will increase the overall marketable success of automated lumber grading technology, and identification of the best methods of promotion to the secondary wood products industry. Chapter Four will summarize this research and conclusions relative to the objectives and prescribe recommendations for future research.

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CHAPTER 2

ABSTRACT

In determining potential markets for scanning technology, specifically an automated lumber grading system (AGS), it is important to understand demographic differences that exist between segments of the target market. For this research scanning technology is defined as process optimization technology, which uses various sensing technologies coupled with computer memory to perform such tasks as defect detection, optimized sawing, grading, sorting, and tallying of materials. Four groups were evaluated in this study, cabinets, furniture, dimension, and flooring manufacturers to characterize the market for lumber scanning technology in the secondary wood products industry, and identify differences between adopters and non-adopters of automated lumber grading technology. The cabinet and furniture samples in this study were predominantly comprised of smaller companies. This information is important to manufacturers of scanning technology in marketing their products and to the wood products industry in receiving information concerning this technology relative to their individual businesses. This study found that potential adopters of automated lumber grading technology will most likely be larger companies, both in terms of sales and number of employees. The majority of adopting firms reported annual sales in excess of $5 million and employed greater than 100–200 people. In addition, analysis showed that dimension and flooring manufacturers may better represent adopters of automated lumber grading technology due to higher lumber throughput volumes and higher lumber grading costs.

INTRODUCTION

The secondary wood products industry represents a potential market for scanning technology, due to the high volumes of hardwood lumber throughput that are characteristic of companies in this industry. For this research scanning technology is defined as process optimization technology, which uses various sensing technologies in conjunction with computer memory to perform such tasks as defect detection, optimized sawing, lumber grading, and sorting and tallying of materials. The secondary wood products industry produces a wide range of products, which require similar but different processing techniques. Products produced by this industry range from railway ties to bedroom furniture. In addition, due to increased competition, changes in policies influencing the availability of raw materials, and a changing global economy, companies in this industry are searching for ways to improve their production processes and remain competitive. Scanning technologies, used in other industries for years, coupled with computer technology, can help secondary wood products manufacturers achieve their goals of improving production efficiency and part yield, among other manufacturing concerns. The goal of this study was to characterize potential adopters and non-adopters of lumber scanning technology, specifically automated lumber grading technology. This information is necessary in identifying the target market for this technology in the secondary wood products industry.

The secondary wood products industry is a sizeable industry in terms of hardwood lumber consumption. Greater than 90% of all hardwood lumber produced in the US is consumed by eight secondary wood processing markets. These markets include pallets, furniture, dimension parts, exports, millwork, flooring, cabinets, and railway ties. Hardwood lumber consumption for these markets has been estimated at over 13 billion board feet in 1997 (Hansen and West 1998). The four sectors included in this study, furniture, cabinets, dimension, and flooring, consumed approximately 52% of all hardwood lumber produced in the US in 1997, an estimated 7.7 billion board feet. In addition, all four sectors showed an increase in hardwood lumber consumption in this decade (Hansen and West 1998). US consumption figures for 1997 show a total hardwood lumber consumption increase of over 2 billion board feet since 1991 (Dempsey and Luppold 1992).

While the wood products industry has not been traditionally known for its utilization of high-technology equipment, many within the industry are seeking methods to automate their processes to increase part yield and product value. In addition, many companies are searching for methods to regulate the precision of their processes, improve their quality control operations, and facilitate the tallying and sorting of materials. Patterson et al. (1997) noted that 36% of furniture manufacturers and 55% of cabinet companies had some type of computer numeric control (CNC) machinery in place. In addition, greater than 39% of the furniture companies and 13% of the cabinet manufacturers indicated that they planned to purchase a CNC machine within 12 to 24 months.

An area of automation that is currently diffusing into the wood products industry is scanning technology, which uses various types of sensors to scan lumber and computer memory to gather and interpret data from the scanning apparatus. Technologies such as camera, laser, and x-ray represent some of the technology available in scanning systems today. The information gathered by these scanning systems can be used in defect detection, automated lumber grading, and sawing optimization. Lumber scanning technology for grading and processing hardwood lumber is now in the development stages. However, it is expected to become more commonplace in the industry as the proficiency of the technology advances and is proven to the industry.

"Most policy makers believe adoption of advanced technologies is fundamental to wood manufacturers' competitiveness in global markets" (Hoff et al. 1997). Current justification for purchasing a scanning system is the reduction of labor. However, the value of information that can be received from scanners may be of more importance. Kline et al. (1998) state that *"The primary cost savings from an automated lumber grading system will be realized by producing a more uniform and consistently graded product and by producing a higher value product through optimum lumber remanufacturing."* The ability to optimize yield and value are perhaps the most important attributes of lumber scanning systems, however, these systems are limited by the information they receive (Mullin 1998). In considering the impact on yield using automated lumber grading technology, it is important to understand that any increase in yield will not be directly related to more accurate lumber grading. It is thought that an automated lumber grading system may contribute to increased yield by providing the optimum cut-up algorithm through accurate defect mapping. This implies that the algorithm generated by an automated grading system is only as reliable as the information received from the scanning heads. In addition, scanning systems are

currently new industrial products, which may require different marketing strategies compared to new household consumer products.

"*Marketing new products to industrial firms remains a mystery to many manufacturers*" (Berkowitz 1986). Different firms take different approaches to marketing their products to industrial end-users. Some production-oriented firms believe that if they develop a superior product and get it into the hands of the end-users then sales will naturally follow. Some sales-oriented firms believe that they can gain market share by simply offering a lower price than their competitors, while other firms believe that an expensive advertising campaign is necessary. The truth may be, however, that there is a complicated process involved in marketing industrial products (Berkowitz 1986). This process involves such tasks as identification of a need, market analysis, product development and testing, and sales. Of particular importance is the identification of potential adopters of the product. By identifying demographic characteristics of potential adopters, firms can avoid targeting the wrong markets for their products.

It is obvious that the adoption of lumber scanning technology by the secondary wood products industry depends largely on the performance of these systems in actual industrial applications. Rosenberg et al. (1990) noted that technology adoption in the forest products industry is influenced by the role of innovations imported from other industries, the effect of raw material shortages, the importance of economic factors in adoption of innovations, and problems associated with the heterogeneity of wood raw material and finished products.

Technology is often developed at the expense of one industry, while other industries later enjoy the benefits of the technology. For example, x-ray technology has been used in the medical field for a number of years, and in the case of automated lumber grading systems, it is now diffusing into the forest products industry. In addition, wood products manufacturers will focus more on improving processing operations in periods of economic recession and at times when raw material quality is not consistent. These scenarios lead to greater emphasis on increasing product value and part yield, and result in more innovation within the industry.

OBJECTIVES

The goal of this study was:

- to characterize the market segments that may utilize hardwood scanning technology.

The objective of this study was:

- to identify differences which may exist between potential adopters and non-adopters of hardwood scanning technology.

METHODOLOGY

A questionnaire was initiated based on the study objectives. The questionnaire was then reviewed by faculty at Virginia Polytechnic Institute and State University for its content. The questionnaire was developed by personally interviewing persons from one company in each industry sector. These interviews were used to identify important information that should be included in the questionnaire. Further adjustments were then made to the questionnaire and it was pre-tested by fax with three companies in each industry sector. The questionnaire was pre-tested to ensure that questions were clear and followed a logical format. Participants were asked to return the completed survey along with any suggested changes. Final adjustments were made following the pre-test, and the revised questionnaire was mailed in May 1999 to the sample frame which included 1,256 companies.

The sample frame consisted of four sectors of the secondary wood products industry; cabinets, furniture, dimension, and flooring manufacturers. The sample frame was predominantly comprised of members of various trade associations. It was assumed that members of trade associations would represent companies who would be more likely to adopt new technology. This sample frame may be biased toward more innovative companies. The study objectives sought to identify companies who would most likely become adopters of automated lumber grading technology.

RESULTS

Data was entered into SPSS statistical software package for analysis when received. A total of 439 responses were received. Of those, 209 were useable responses resulting in an overall response rate of 16.6%. Adjusting the overall response rate for undeliverable questionnaires (175), and companies performing operations not applicable to the sample (55), the overall adjusted response rate was calculated at 20.4%. The numbers of questionnaires received according to market segment were: cabinets (45), furniture (35), dimension (92), and flooring (37). These responses resulted in response rates of 11.6% for cabinet manufacturers, 9% for furniture manufacturers, 23.7% for dimension manufacturers, and 40.2% for flooring manufacturers. Adjusting the response rates per industry segment resulted in 13.6% for cabinet manufacturers, 12.4% for furniture manufacturers, 28.4% for dimension manufacturers, and 45.1% for flooring manufacturers.

MARKET CHARACTERIZATION

Questions were included in the study to be used in comparing the relative size of each industry sector in terms of such company characteristics as sales volume, lumber throughput, and number of employees. In addition, this type of information was used to understand the relationship of demographic information to adoption of new technology. The sample mean for annual lumber throughput for all manufacturers was calculated at 7.3 million board feet. Mean values for annual lumber throughput, given in Figure 2, were calculated at 1.3 million board feet for cabinet manufacturers, 2 million board feet for furniture manufacturers, 7.7 million board feet for dimension manufacturers, and 18.3 million board feet for flooring manufacturers.

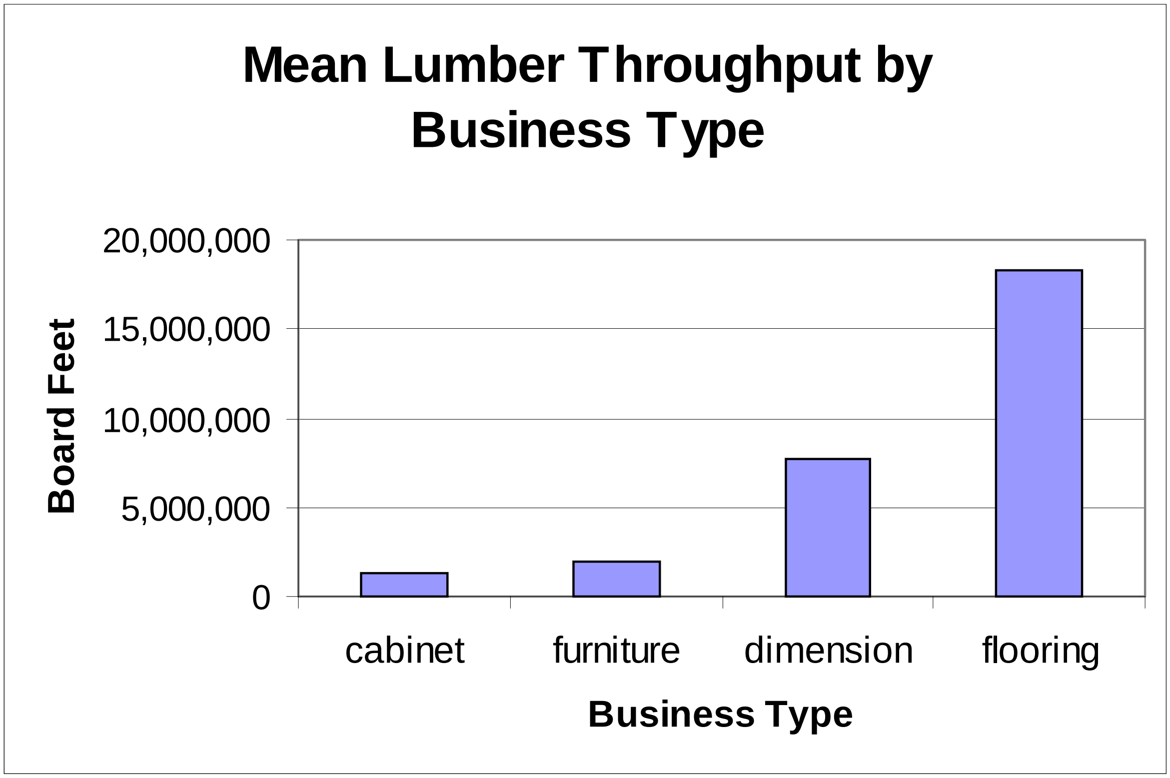

Figure 2: Mean lumber production volumbe according to industry group

Table 2 shows that of the four industry sectors in the study, greater than 41% of the cabinets, dimension, and flooring sectors responded with annual sales in excess of $10 million. The majority of furniture manufacturers who responded, 55.2%, reported annual sales in the range of $1 million to $5 million. In addition, the cabinet sector reported the largest percentage, 22%, of companies with annual sales less than $500,000.

Among respondents from the four industry sectors, all reported a majority of companies employing fewer than 200 people (Table 2). The cabinet, furniture, and dimension sectors reported a majority of companies employing fewer than 100 people. In addition, the cabinet and flooring sectors reported the largest percentage of respondents with greater than 400 employees at 15% and 13.5% respectively. This information indicates that the sample frame represents smaller cabinet and furniture manufacturers.

Table 2: Percentage of sales and employees per industry sector

	Response Frequency				
Annual Sales 1998	Cabinets	Furniture	Dimension	Flooring	Overall
Less than $100,000	0	0	2.3%	0	1.1%
$100,000 - $500,000	22%	6.9%	2.3%	0	7.9%
$500,001 - $1,000,000	7.3%	0	4.7%	3%	4.2%
$1,000,000 - $5,000,000	24.4%	55.2%	30.2%	15.2%	30.2%
$5,000,001 - $10,000,000	4.9%	13.8%	18.6%	15.2%	14.3%
Greater than $10,000,000	41.5%	24.1%	41.9%	66.7%	43%
Full-time Employees					Overall
Fewer than 25	37.5%	21.9%	21.1%	10.8%	22.6%
25 - 50	20%	25%	23.3%	13.5%	21.1%
51 - 100	2.5%	21.9%	18.9%	21.6%	16.6%
101 - 200	7.5%	12.5%	22.2%	29.7%	19.1%
201 - 300	10%	6.3%	7.8%	8.1%	8%
301 - 400	7.5%	3.1%	1.1%	2.7%	3%
Greater than 400	15%	9.4%	5.6%	13.5%	9.5%

Respondents from the cabinet and furniture sectors reported that the majority of both industry sectors did not market their products internationally, 83.8% and 68.8% respectively. In contrast, the dimension and flooring sectors reported a majority of respondents selling products in foreign markets, 56% and 67.6% respectively (Table 3). In addition, respondents from all sectors reported that greater than 84.5% of companies in each sector was privately owned. The cabinet sector showed the largest percentage of publicly owned companies at 15.5%.

Participants were asked to indicate if they had any scanning technology in place at the time of this study. Table 3 shows all sectors reporting a majority of companies answering no to this question. Eighty-one percent of the cabinet sector did not have scanning technology in place at the time of this study, while 85.7% of the furniture sector did not have scanning technology in their plants. Percentages of companies in the cabinets and furniture sectors that had invested in scanning technology were 19% and 14.3% respectively. These findings may be influenced by the relative smaller sizes of cabinet and furniture manufacturers in the sample frame. Percentages reported by the dimension and flooring sectors were similar as well. Greater than 61% of the dimension sector and almost 63% of the flooring sector did not have scanning technology in place at the time of this study, while 38.5% and 37.1% of the dimension and flooring sectors respectively had invested in scanning technology.

Table 3: Percentage of international marketing, company ownership, scanning tech adoption according to sector

	Response Frequency				
International Marketing	Cabinets	Furniture	Dimension	Flooring	Overall
No	**83.8%**	**68.8%**	44%	32.4%	53.5%
Yes	16.2%	31.3%	**56%**	**67.6%**	46.5%
Company Ownership					Overall
Public	15.5%	9.4%	7.7%	8.1%	9.4%
Private	**84.5%**	**90.6%**	**92.3%**	**91.9%**	90.6%
Have Scanning Tech					Overall
No	81.0%	85.7%	61.5%	62.9%	70%
Yes	19.0%	14.3%	38.5%	37.1%	30%

A lumber grading section was included in the questionnaire to assess the cost of grading lumber both in monetary costs and in terms of time. A mean of $14.66 per man-hour was calculated for the entire sample frame. Figure 3 shows a mean cost of $12.11 per man-hour was calculated for the cabinet sector, while the furniture sector reported a mean cost of $12.31 per man-hour. The dimension and flooring sectors reported higher lumber grading costs than the cabinet and furniture sectors. Mean lumber grading costs were calculated at $18.21 and $16.01 per man-hour for the dimension and flooring sectors respectively.

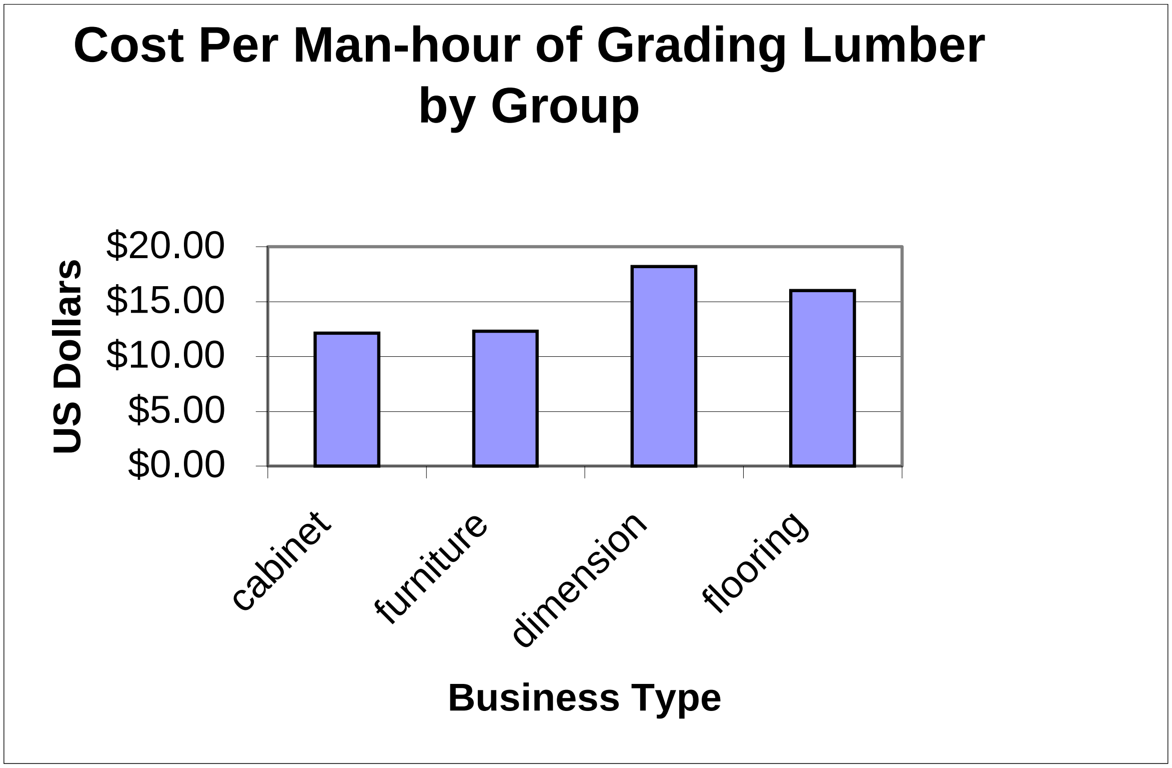

Figure 3: Mean man-hour cost of lumber grading according to industry group

Participants were asked to indicate how many man-hours were spent in their plants grading lumber as a percentage of total production man-hours. Table 4 illustrates the cabinets and furniture sectors reporting a majority of companies in both sectors dedicating less than 2% of total man-hours to grading lumber. Percentages of companies in the cabinets and furniture sectors utilizing less than 2% of total man-hours to grade lumber were 81.3% and 85.2% respectively. In comparison, the dimension and flooring sectors showed more companies spending more time grading lumber. Percentages of companies in the dimension and flooring sectors dedicating less than 2% of man-hours to lumber grading were lower at 27.6% and 50% for dimension and flooring respectively. In addition, 16.1% of dimension manufacturers and 15.6% of flooring manufacturers indicated that greater than 10% of total man-hours in their plants were dedicated to lumber grading, while the cabinets and furniture sectors reported no companies spending greater than 10% of man-hours grading lumber.

Participants were also asked to indicate what their expected payback period would be for the purchase of an automated lumber grading system. A range of less than two years to greater than ten years was provided. The majority of the four sectors in the study responded with expected payback periods of less than six years (Table 4). Greater than 85% of cabinets manufacturers, 60% of furniture manufacturers, 87.9% of dimension manufacturers, and 80.6% of flooring manufacturers responded with a payback period of less than six years. The cabinet sector reported the highest percentage of respondents with expected payback periods of less than two years at 48.1%. In addition, the furniture sector reported the highest percentage of respondents with expected payback periods greater than ten years, 24%.

Table 4: Percentage of man-hour costs of grading lumber, payback period for automated lumber grading system according to industry group

	Response Frequency				
Man-hours Grading Lumber	Cabinets	Furniture	Dimension	Flooring	Overall
Less than 2%	81.3%	85.2%	27.6%	50.0%	50%
3% - 5%	12.5%	11.1%	39.1%	18.8%	26.4%
6% - 9%	6.3%	3.7%	17.2%	15.6%	12.9%
Greater than 10%	0	0	16.1%	15.6%	10.7%
Expeted Payback for AGS					Overall
Less than 2 years	48.1%	20%	34.9%	30.6%	33.9%
3 - 5 years	37%	40%	53%	50%	48%
6 - 10 years	3.7%	16%	4.8%	8.3%	7%
Greater than 10 years	11.1%	24%	7.2%	11.1%	11.1%

Analysis of overall response shows that the dimension and flooring sectors process more lumber volume, on a board foot basis, than the cabinet and furniture sectors. However, demographic information indicates that our cabinet and furniture industry samples were comprised of predominantly smaller companies. This explains the relatively low, mean lumber throughput values reported among companies in the cabinet and furniture sectors. Furthermore, dimension and flooring manufacturers incurred higher lumber grading costs compared to cabinets and furniture manufacturers and were found to spend more time grading lumber, as a percentage of total man-hours. The flooring sector reported the largest percentage of companies with annual sales in excess of $10 million. It was also found that more dimension and flooring manufacturers market their products internationally compared to cabinet and furniture manufacturers, and a large majority of study participants were privately owned. In addition, larger percentages of the dimension and flooring sectors had adopted lumber scanning technology than the cabinet and furniture sectors. Again, these findings may be influenced by the relatively small companies, which comprised the majority of both the cabinet and furniture samples. Overall response information implies that the market for automated lumber grading technology, in the secondary wood products industry, may be concentrated in the dimension and flooring sectors. Overall demographic information is useful in identifying adopters versus non-adopters of hardwood scanning technology. This information can be used to characterize a company profile for potential adopters of scanning technology.

DIFFERENCES AMONG ADOPTERS AND NON-ADOPTERS

Identifying potential adopters and non-adopters is important to manufacturers of scanning technology in determining appropriate markets for their products. This study identified differences between potential adopters and non-adopters of scanning technology in the secondary wood products industry. The study focused specifically on automated lumber grading technology, in the cabinet, furniture, dimension, and flooring industries.

The study determined if participants believed that an automated lumber grading system would benefit their business. A clear distinction was found to exist between the cabinet and furniture sectors and the dimension and flooring sectors. Table 5 summarizes the cabinet and furniture sectors 65.7% and 78.3%, respectively, stating that an automated lumber grading system would be of no benefit to them. The dimension and flooring sectors reported 67.1% and 72.4% respectively responding positively to the benefits of automated lumber grading technology. This was supported by the demographic findings that dimension and flooring manufacturers spend both more time and money grading lumber in their operations. An explanation of differences in perception of the benefit of automated lumber grading technology may be that these differences are related to the variation in production processes among these sectors. In other words, it may be more difficult for cabinet and furniture manufacturers to see the benefit of automated lumber grading technology due to their longer production chains compared to dimension and flooring manufacturers. In the dimension and flooring industries the entire production process is concentrated in the rough mill, while the rough mill represents only the beginning of the process in cabinet and furniture production. In addition, it should be noted that our cabinet and furniture samples were predominantly comprised of smaller companies. The concentration of smaller companies in these samples indicates that our findings are representative of a subset of the cabinet and furniture industries.

Table 5: Percentage of companies finding automated lumber grading system beneficial, companies contacted by competitors concerning new equipment according to industry sector

AGS Beneficial	Cabinets	Furniture	Dimension	Flooring	Overall
No	**65.7%**	**78.3%**	32.9%	27.6%	45.2%
Yes	34.3%	21.7%	**67.1%**	**72.4%**	54.8%
Contacted					Overall
No	52.8%	55.6%	39.8%	45.9%	45.7%
Yes	47.2%	44.4%	60.2%	54.1%	54.3%

The study determined if companies in each industry sector contacted other companies in their industry to inquire about high-technology equipment. Participants were asked to indicate whether they were or were not contacted by other companies. This information was used to help understand how technology information is shared within each industry sector. In addition, it was used to determine if there were companies in the sample frame that were considered to be sufficiently innovative such that other companies would contact them about high-tech equipment they were considering. It was believed that this would be a factor in determining perceived innovativeness of a company. Table 5 illustrates the furniture and cabinet sectors reported nearly equivalent percentages. Greater than 52% of the cabinet sector responded that they had not been contacted concerning high-tech equipment they were considering, while 55.6% of the furniture sector reported that they had not been contacted. In contrast, the dimension and flooring sectors reported that 60.2% and 54.1% of companies respectively had been contacted concerning high-tech equipment. This finding implies that information is shared more freely among companies in the dimension and flooring sectors.

The previous discussion indicates that cabinet and furniture manufacturers find little benefit in automated lumber grading compared to dimension and flooring manufacturers, and that dimension and flooring manufacturers are more likely to share information concerning new processing technologies with competitors. The following discussion will explore more specific relationships influencing these findings. This discussion includes demographic relationships between likely adopters and non-adopters. Participants were asked to estimate their average cost per man-hour of grading lumber. Mean costs of $12.11, $12.31, $18.21, and $16.01 per man-hour were found for the cabinets, furniture, dimension, and flooring groups respectively (Figure 3). Analysis of variance (ANOVA) was used to compare mean values to determine if significant differences existed among the industry sectors (Table 6). Fisher's LSD technique was used as a post hoc test to determine between which sectors differences had occurred. A significance level of .01 was calculated indicating that a difference did exist among the sectors. Significant differences were detected between the cabinet and dimension sectors and the furniture and dimension sectors. Significance levels for these comparisons were less than .01 for both comparisons. This indicates that the dimension sector on average incurred higher lumber grading costs, on a man-hour basis, than the cabinet and furniture sectors among the companies sampled in this study. This information is consistent with demographic findings that the dimension and flooring sectors, on average, processed more lumber than the cabinet and furniture sectors among the companies sampled in this study.

Table 6: Mean man-hour cost of grading lumber according to industry sector

	Cabinets (1)	Furniture (2)	Dimension (3)	Flooring (4)	Significance Level
Mean Cost Grading Lumber	12.11	12.31	18.21[1,2]	16.01	***0.01****
	Significance level: cabinets and dimension comparison				***< .01***
	Significance level: furniture and dimension comparison				***< .01***

***Represents significant differences among groups using analysis of variance**
[1,2] Represents significant differences between specific groups

In addition to greater lumber grading costs in the dimension and flooring industries, demographic information shows these sectors overall utilizing more scanning technologies than the cabinets and furniture sectors. It was noted in Table 3 that the majority of all four sectors did not have scanning technology in place at the time of this study, however the dimension and flooring sectors reported more companies using scanning technology than the cabinets and furniture sectors. Percentages of companies in the sample using scanning technology were 38.5% for the dimension sector and 37.1% for the flooring sector compared to 19% for the cabinets sector and 14.3% for the furniture sector.

In addition, responses were used in cross-tabulations to show the relation of scanning technology adoption to demographic information such as company sales, international marketing activity, and number of employees (Table 7). It was thought that this information would help in developing a profile of potential adopters of automated lumber grading technology. While the majority of respondents did not have scanning technology, no company with less than $500,000 in annual sales had invested and only one company with less than $1 million in annual sales had invested in scanning technology. Of those companies who had scanning technology in place, 89% reported greater than $5 million in annual sales. Of those companies who had not invested in scanning technology, only 42.5% reported greater than $5 million in annual sales. This implies that adopters of scanning technology will most likely be large companies in terms of annual sales.

Furthermore, Table 7 illustrates the relationship between adoption of scanning technology and international product marketing activity, it was noted that approximately 50% of those companies who had invested in scanning technology also marketed their products internationally. Of those companies who did not have scanning technology in place, approximately 20% sold their products in foreign markets. International marketing activity is often perceived as a characteristic of innovative firms. Therefore, by this logic it is implied that adopters of scanning technology will most likely be perceived as more innovative companies within the industry.

Using cross-tabulation to show the relationship between the adoption of scanning technology and number of employees, it was noted that 61.7% of those companies who had invested in scanning technology employed more than 100 people (Table 7). In addition, of those companies who did not have scanning technology in place, only 30.1% employed more than 100 people. This implies that adopters of scanning technology will most likely be large companies in terms of number of employees.

Table 7 also illustrates the relation of adoption of scanning technology to expected cost of an automated lumber grading system. It was noted that the majority of companies who had invested in scanning technology expected higher machine costs than companies who had not invested in scanning technology. Greater than 59% of those companies who had scanning technology in place expected an automated lumber grading system to cost in excess of $150,000. In comparison, approximately 33% of companies who did not have scanning technology in place expected an automated lumber grading system to cost greater than $150,000. This indicates that companies who have previously invested in scanning technology may expect higher costs associated with hardwood scanning systems than those who have not invested in scanning technology.

Participants were asked to rate a list of system attributes in terms of their importance in investing in automated lumber grading technology. The rating scheme was based on a (1-7) rating scale, where (1=least important, 7=most important). The list of attributes included: (*machine accuracy, cost, durability, compatibility with existing equipment, throughput speed, ability to quickly switch species, ability to quickly switch grading rules, simplicity of operation, technical support, equipment warranty, reduction in labor costs, tallying capabilities, sorting capabilities,* and *color sorting capabilities*). Analysis of variance (ANOVA) was used to test for significant differences between the two groups, past adopters and non-adopters, at a confidence level of 95%.

Table 7:Relation of adoption of scanning technology to company demographic information

Total Sales in 1998	Have scanning tech No	Have scanning tech Yes	Total
Less than $100,000	2		2
$100,000 - $500,000	13		13
$500,001 - $1,000,000	7	1	8
$1,000,001 - $5,000,000	51	5	56
$5,000,001 - $10,000,000	14	11	25
$Greater than $10,000,000	40	39	79
Total	127	56	183
Market Internationally	**Have scanning tech** No	Yes	Total
No	85	48	134
Yes	20	40	60
Total	105	88	194
Number of Employees	**Have scanning tech** No	Yes	Total
Fewer than 25	42	3	45
25 - 50	31	9	40
51 - 100	20	11	31
101 - 200	21	16	37
201 - 300	8	8	16
301 - 400	3	3	6
Greater than 400	8	10	18
Total	133	60	193
Expected Cost of AGS	**Have scanning tech** No	Yes	Total
Less than $50,000	29	4	33
$50,000 - $150,000	43	16	59
$150,001 - $250,000	19	11	30
$250,001 - $500,000	10	13	23
Greater than $500,000	6	5	11
Total	107	49	156

Table 8 illustrates that overall mean values exceeded the average value of (4) for all listed factors, therefore the listed factors were considered to be at least somewhat important. In addition, *machine accuracy* was rated overall highest at 6.08, while the *color sorting capabilities* factor was rated the overall lowest at 4.35. Significant differences were detected between adopters and non-adopters of scanning technology on *throughput speed*, *tallying capabilities*, and *sorting capabilities*. Significance levels were

.03 for the *throughput speed* factor, .03 for the *tallying capabilities* factor, and .01 for the *sorting capabilities* factor. In all cases companies who had invested in scanning technology rated these factors higher than those who had not invested in scanning technology. This indicates that these factors were more important to past adopters of scanning technology in their decision to invest in automated lumber grading technology compared to companies without scanning technology in their operations. This may be an indication of characteristics of potential adopter firms, i.e., potential adopters of automated lumber grading technology may operate at higher production speeds, and have a greater need for enhanced lumber tallying and sorting capabilities.

Table 8: Comparison of past adopters vs. non-adopters on system attributes

System Attribute	Overall Mean	Mean Rating (1-7 scale) Have Scanning Tech Y/N		Significance Level
		No	Yes	
Equipment warranty	6.23	5.47	5.42	0.82
Accuracy	6.08	5.93	6.32	0.14
Technical support	5.94	5.87	6.09	0.32
Reduction in labor costs	5.82	5.88	5.64	0.35
Durability	5.73	5.67	5.87	0.39
Simplicity of operation	5.69	5.69	5.64	0.84
Tallying capabilities	5.52	5.33	5.89	***0.03****
Speed	5.46	5.26	5.79	***0.03****
Cost	5.28	5.38	5.02	0.16
Sorting capabilities	5.19	5.00	5.68	***0.01****
Ability to switch species	4.89	4.84	4.89	0.89
Compatibility	4.56	4.48	4.64	0.60
Ability to switch grading rules	4.50	4.49	4.51	0.94
Color sorting capabilities	4.35	4.24	4.53	0.39

*** Represents significant differences using analysis of variance**

Participants were asked to rate a list of methods of learning about new technology as well. This question was also based on a (1-7) rating scale, where (1=least important, 7=most important). The methods provided included: *tradeshows, plant visits, peer discussions, trade journals, personal sales calls, advertisements, meetings and* *symposiums*, *scientific journals*, and *unsolicited sales literature*. Analysis of variance (ANOVA) was used to test for significant differences between the two groups, past adopters and non-adopters of hardwood scanning technology, at a confidence level of 95%.

Table 9 shows that some methods of learning about new technology rated below the mean rating value of (4), while others were rated above (4). In addition, *tradeshows* were rated highest overall at 5.26. *Plant visits* (5.19) and *peer discussions* (5.05) were rated high as well. *Advertisements, meetings and symposiums, scientific journals,* and *unsolicited sales literature* all rated below the mean rating value of (4). Significant differences were detected between adopters and non-adopters of hardwood scanning technologies on the *personal sales calls*, and *scientific journal methods* of learning about new technologies equipment (Table 9). Significance levels of .02, personal sales calls, and < .01, scientific journals were reported. Moreover, non-adopters rated both of these methods of learning about new technologies higher than adopters, i.e., non-adopters rate both *personal sales calls* and *scientific journals* higher in importance in learning about new technologies than adopters.

Table 9: Mean ratings of methods of leraning about new technologies, adopters vs. non-adopters

Method of Learning About New Technology	Overall Mean	Mean Rating (1-7 scale) Have Scanning Tech Y/N		Significance Level
		No	Yes	
Tradeshows	5.26	5.27	5.29	0.93
Plant visits	5.19	5.10	5.41	0.22
Peer discussions	5.05	4.95	5.21	0.28
Trade journals	4.42	4.50	4.19	0.19
Personal sales calls	4.38	4.57	4.00	***0.02****
Advertisements	3.99	4.06	3.75	0.19
Meetings, symposiums	3.76	3.77	3.74	0.92
Scientific journals	3.23	3.43	2.75	***<.01****
Unsolicited sales literature	3.16	3.26	2.91	0.15

*** Represents significant differences using analysis of variance**

CONCLUSIONS

Analysis showed dimension and flooring manufacturers view automated lumber grading technology as more beneficial than small cabinet and furniture manufacturers. Demographic information indicated that our cabinet and furniture samples represented a subset of these populations; i.e., the cabinet and furniture samples represent smaller companies in these two industries. In addition, in the case of dimension manufacturers, the perceived benefit may be influenced by the significantly higher costs of grading lumber they incur compared to cabinet and furniture manufacturers. In this scenario, potential savings may be achieved through automated lumber grading technology. In the case of flooring manufacturers, the perceived benefit may be influenced by the significantly higher production volumes, which are characteristic of the flooring industry. With increased lumber production volume more resources are required to grade lumber. This results in higher lumber grading costs on a man-hour basis.

Companies currently using scanning technology in their production processes are more likely to also market their products internationally than companies who do not have scanning technology in place. International marketing activity is often considered a characteristic of more innovative and progressive companies. Moreover, companies who have adopted scanning technology are relatively larger companies both in terms of annual sales and number of employees. The study found that the majority of companies who had invested in scanning technology employed more than 100-200 people, and reported greater than $5 million in annual sales. This finding was expected due to the capital investment required to purchase scanning equipment. The study found that larger companies with increased costs and resources are more likely to adopt scanning technologies. It should be noted, however, that our cabinet and furniture samples were predominantly comprised of smaller companies; therefore, we found these sectors to be less likely to adopt scanning technologies, specifically automated lumber grading technology.

Compared to other companies, those who have adopted scanning technologies expect the cost of an automated lumber grading system to be higher. Moreover, companies that had adopted scanning technologies found more importance in tallying capability, sorting capability, and production speed. This may indicate areas where further development or improvement of scanning equipment is necessary.

In addition, the dimension and flooring sectors tend to share information concerning high-tech equipment more readily than the cabinets and furniture sectors. The majority of respondents from the dimension and flooring sectors reported that they had been contacted, concerning high-tech equipment, by other companies within their industry. The opposite was found to be true with the cabinet and furniture sectors. Therefore, information about the performance of this type of equipment will most likely be shared between companies in the dimension and flooring sectors through word-of-mouth.

In summary, potential adopters of automated lumber grading technology will most likely be larger companies reporting greater than $5 million in annual sales and employing more than 100 people. In addition, due to greater lumber throughput volumes and greater costs associated with grading lumber, dimension and flooring manufacturers may better represent potential adopters of automated lumber grading technology compared to cabinet and furniture manufacturers; however, our sample is representative of smaller cabinet and furniture manufacturers. Moreover, due to the degree to which production is concentrated in the rough mill and the relatively high production volumes associated with this industry, it is thought that large dimension manufacturers represent the best market for automated lumber grading technology in the secondary wood products industry. Overall, a market does exist for this technology; however, early adopters will most likely be larger companies with sufficient resources to invest in high-tech equipment.

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CHAPTER 3

ABSTRACT

In assessing markets for scanning technology in the secondary wood products industry it is important to understand differences in machine attributes among different sectors of the industry, and to identify the best methods of promotion to those sectors. For this research scanning technology is defined as process optimization technology, which uses various sensing technologies to perform such tasks as defect detection, optimized sawing, and sorting and tallying of materials. Four industry sectors were surveyed in this study, cabinets, furniture, dimension, and flooring, to identify the "benefit bundle" that would increase the overall marketability of an automated lumber grading system (AGS). In this study the cabinet and furniture samples were predominantly comprised of smaller companies. In addition, for this study the benefit bundle is defined as the set of system attributes and machine capabilities required by the secondary wood products industry. This information is important to manufacturers of scanning technology in identifying viable markets and determining the requirements of potential customers. Furthermore, this research is important to the wood products industry in providing suppliers with information specific to their businesses such that manufacturing innovations can move more readily to the industry. The study found increased yield and efficiency to be important system attributes. It was thought that automated lumber grading technology could influence part yield by providing an optimum cut-up algorithm based on accurate defect mapping and lumber grading. In addition, technical support and equipment warranties were found to be important attributes to the secondary wood products

industry. Tradeshows were found to be important to the four sectors of the industry in learning about new technology. Moreover, companies expressed interest in observing a working system in an industrial setting before investing in this technology.

INTRODUCTION

The secondary wood products industry is a diverse industry manufacturing a wide range of products, while utilizing different raw material mixes and production processes. Products produced by this industry range from kitchen cabinets to railway ties. Improving production efficiency and part yield are common interests among the many companies in this industry. This study focused on scanning technology as a tool to improve production efficiency and part yield, and to address other production concerns such as improving the quality and consistency of products. For this research scanning technology is defined as process optimization systems, which use various sensing technologies to perform such tasks as defect detection, optimized sawing, and sorting and tallying of materials. In identifying the benefit bundle that will increase the marketable success of an automated lumber grading system, it is necessary to understand the importance of system attributes among companies in the target market. For this research, the benefit bundle is defined as the important system attributes and machine capabilities required by companies in the target market. In this study, the target market was the secondary wood products industry, specifically the wood cabinet, furniture, dimension, and flooring industries. In identifying the most effective methods of promotion to these sectors it is helpful to understand how companies in this industry receive information concerning high-tech industrial products as well. This information is important in the diffusion of scanning technology into the secondary wood products industry.

The secondary wood products industry is a large industry in terms of hardwood lumber consumption. Greater than 90% of all hardwood lumber produced in the US is consumed by eight secondary wood processing markets. These markets include pallets, furniture, dimension parts, exports, millwork, flooring, cabinets, and railway ties. Hardwood lumber consumption for these markets has been estimated at over 13 billion board feet in 1997 (Hansen and West 1998). The four sectors in this study, cabinets, furniture, dimension, and flooring, consumed approximately 52% of all hardwood lumber produced in the US in 1997, an estimated 7.7 billion board feet. In addition, these sectors showed an increase in hardwood lumber consumption in this decade (Hansen and West 1998). US consumption figures for 1997 show a total US hardwood lumber consumption increase of over 2 billion board feet since 1991 (Dempsey and Luppold 1992).

From 1991 to 1997 hardwood lumber consumption in the cabinet industry increased by 33% (Hansen and West 1998). According to Punches et al. (1995) the US cabinet industry consists primarily of a relatively small number of large companies. In a study by Adams (1999) it was noted that cabinet sales for use in rooms other than kitchens and bathrooms has steadily increased throughout the 1990s. Eighteen of 36 cabinet companies surveyed responded that they sell other-room cabinets. In addition, it was noted that the cabinet industry has experienced 33 consecutive months of growth in sales since 1996, and both stock and custom manufacturers have averaged double-digit growth in 1998.

The U.S. wood household furniture industry is a fragmented industry made up of several large multi-plant firms and many small single-plant firms (West 1990). Recent increases in imports have resulted in increased competition in the furniture industry. "*The U.S. is the largest net importer of furniture in the world*" (Taylor 1999). In 1996

U.S. furniture imports showed a 71% increase over 1990 figures. This increase in imports was valued at nearly US$7 billion (Taylor 1999). In addition, the wood furniture industry showed a 50% increase in hardwood lumber consumption between 1991 and 1997 (Hansen and West 1998).

The dimension and wood components industry showed an 85% increase in hardwood lumber consumption between 1991 and 1997 (Hansen and West 1998). Dimension and wood components are defined as intermediary, value-added products, which are used in other secondary wood processing operations such as millwork, furniture, and cabinet manufacturing. *"Wood components, such as dimension parts, are dried and processed to a point where the maximum waste is left at the mill and the maximum utility is delivered to the customer."* (Vlosky 1996). In some cases furniture manufacturers own and operate their own dimension mills, and often dimension mills are affiliated with sawmills, but most are independent companies. According to Vlosky, (1996) dimension and component manufacturers are often the focus of state economic development initiatives in an attempt to add value to hardwood resources.

From 1991 to 1997 hardwood lumber consumption in the flooring industry increased by 120% (Hansen and West 1998). Recently wall-to-wall carpet and PVC flooring have begun to lose their market share to wood flooring as a result of increasing health and environmental concerns among consumers (Weinig 1999). Weinig states, *"Reservations about chemicals and fear of house dust by many allergy sufferers has led to a decrease in carpet sales versus wood flooring."* In addition, consumer preferences have shifted more toward wood flooring products in relation to home interior design fashion in recent years.

The four industry sectors previously outlined represent potential markets for scanning technology. These sectors produce different products, and utilize different raw material mixes and production processes. In assessing markets for automated lumber grading technology, differences in system requirements between industry sectors and effective promotion methods must be identified. From the marketing perspective, the adoption of industrial high technology products can be evaluated on their perceived attributes. Mittal et al. (1998) state that negative performance on an attribute has a greater impact on overall satisfaction than positive performance on the same attribute. Overall customer satisfaction with a product shows diminishing sensitivity to product attribute-level performance; i.e., as overall satisfaction increases, customers become less sensitive to specific product attributes or more tolerant to deficiencies related to specific attributes. By installing systems that possess attributes desirable to specific manufacturing operations, overall satisfaction level will increase.

Differences in system attributes and machine requirements were expected to occur between the industry sectors in this study due to the variation in manufacturing processes, products, raw materials, lumber grades, and company demographics that characterize each sector. For example, the wood furniture industry manufactures a wider range of products, which typically require more intensive processing compared to the wood flooring industry. In addition, the wood furniture industry utilizes a lumber grade mix consisting predominantly of lumber graded No. 1 Common and higher (Hansen et al.

1995). This scenario is different from the flooring industry, which utilizes a mix of lower grades of lumber, No. 1 Common and below (Hansen and West 1998). It was hypothesized that differences such as these would contribute to variation in technology requirements among the four groups in this study.

OBJECTIVES

The objectives of this study were:

1. to characterize the benefit bundle that will increase the overall marketable success of and automated lumber grading system, and
2. to identify the best methods of promoting this technology to the secondary wood products industry.

METHODOLOGY

A questionnaire was developed based on the study objectives. This questionnaire was reviewed by faculty of Virginia Polytechnic Institute and State University for relevance to the objectives. The questionnaire was further developed in personal interviews at one company in each industry sector. These interviews were used to identify important information that should be included in the questionnaire. Further adjustments were made to the questionnaire and it was pre-tested by fax with three companies in each industry sector. The questionnaire was pre-tested to ensure that questions were clear and followed a logical format. Participants were asked to return the completed survey along with any suggested changes. Final adjustments were made following the pretest, and the revised questionnaire was mailed in May, 1999.

A total of 1,256 identical questionnaires were mailed out to the sample frame consisting of four sectors of the secondary wood products industry; cabinets, furniture, dimension, and flooring manufacturers. The sample is predominantly comprised of members of various trade associations. It was assumed that members of trade associations would represent the more innovative companies in the industry; therefore, by sampling from this group there could have been bias introduced toward more innovative companies. In addition, this study assumes that relatively innovative firms represent the most likely adopters of an automated lumber grading system, hence the sample bias is justified. A sample consisting of companies not likely to adopt this technology would conflict with our stated objectives and potentially negatively influence our results and conclusions.

RESULTS

Survey data was entered into SPSS statistical software package for analysis when received. A total of 439 responses were received. Of those, 209 questionnaires were useable, resulting in an overall response rate of 16.64%. Adjusting the overall response rate for undeliverable questionnaires (175), and companies performing operations not applicable to the sample (55), the overall adjusted response rate was calculated at 20.4%. The numbers of survey questionnaires received according to business type were, cabinets (45), furniture (35), dimension (92), and flooring (37). These responses resulted in response rates of 11.6% for cabinet manufacturers, 9% for furniture manufacturers, 23.7% for dimension manufacturers, and 40.2% for flooring manufacturers. Adjusting the response rates per industry segment resulted in 13.6% for cabinet manufacturers, 12.4% for furniture manufacturers, 28.4% for dimension manufacturers, and 45.1% for flooring manufacturers.

A sample size of 97 respondents was calculated based on a 25% response rate for the cabinets, furniture, and dimension sectors. The flooring sector consists of a known population that is smaller than the calculated sample size of 97; therefore, the entire known population of US flooring manufacturers was surveyed.

Moreover, due to the relative frequency with which these industry segments are surveyed we did not receive the anticipated 97 responses per industry sector. Smith (1999) states that it is necessary to have more observations per group than total variables for adequate statistical power in MANOVA. Our largest number of variables for a rated question was 14 well below our smallest number of observations for one group, 35. In addition, our total number of observations was adequate for MANOVA at 209. The MANOVA was repeated at a confidence level of 90%, which generated results that were identical to those from the 95% test. Significance levels were similar for the two tests; therefore, the conclusions formulated in this study are statistically valid.

THE BENEFIT BUNDLE

The first objective of this study was to identify the benefit bundle that would increase the marketable success of an automated lumber grading system in the secondary wood products industry. Differences in the importance of various machine requirements were expected to exist between industry sectors due to inherent variability associated with producing different products. A list of factors dealing with system attributes and machine capabilities was developed, and respondents were asked to rate the importance of each factor in the list in their decision to adopt an automated lumber grading system. Factors included in the questionnaire were *accuracy, cost, durability, compatibility with existing equipment, throughput speed, ability to switch grading rules, ability to switch species, simplicity of operation, technical support, equipment warranty, reduction in labor costs, tallying capabilities, sorting capabilities,* and *color sorting capabilities*. The rating hierarchy for each factor was based on a (1-7) scale where (1=least important, 7=most important). Multivariate analysis of variance (MANOVA) was used to detect statistically significant differences between industry sectors on the 14 factor ratings. Fisher's LSD technique was used as a post hoc test to detect significant differences between specific groups. MANOVA analysis was used to detect significant differences among industry sectors at a confidence level of 95%. A confidence level of 95% indicates an alpha level, or probability of type 1 error, equal to .05. This means that we are 95% confident that the actual mean rating values of the population studied, on average will be equal to the mean rating values reported in the statistical tests.

All sectors rated every factor in the list at or above the average importance value of (4) indicating that all 14 factors were at least of average importance when considering the adoption of an automated lumber grading system. Of the 14 attributes listed, *equipment warranty* rated highest, on average, among all respondents. A mean rating value of 6.23, on a (1-7) rating scale, was reported for this attribute among all respondents in the study. *Accuracy* was rated second highest among all respondents with a mean rating value of 6.08. Among the lowest rated factors were *switching species* (4.89), *compatibility* (4.56), *switching grading rules* (4.50), and *color sorting capabilities* (4.35) (Table 10).

Table 10 shows significant differences detected between groups on the *equipment warranty, accuracy, technical support, reduction in labor costs, durability, simplicity of operation, tallying capabilities, throughput speed, machine cost, sorting capabilities, ability to switch species, compatibility with existing equipment, ability to switch grading rules,* and *color sorting capabilities* factors. Multivariate significance levels calculated for these factors were; less than .01 for the *accuracy* factor, .04 for the *durability* factor, .06 for the *compatibility* factor, and .02 for the *speed* factor. Other significance levels were *species switching ability* (.04), *reduction in labor costs* (.04), *tallying capabilities* (< .01), and *sorting capabilities* (.03).

When running multiple comparisons on each sector and factor, a significant difference was detected between the furniture and cabinet sectors on the *accuracy* factor (Table 10). A significance level of .05 was reported for this comparison. This indicates that these industry sectors differ in their rating of the importance of *accuracy* in the decision to adopt an automated lumber grading system. In addition, the cabinet sector reported a higher mean rating value of 5.74 compared to 4.84 for furniture; therefore the cabinet sector places a significantly higher degree of importance on this factor than the furniture sector. Differences were also detected between the furniture and dimension sectors and the furniture and flooring sectors on this factor. Strongly significant values for both comparisons were calculated at less than .01. A strongly significant difference such as this indicates a strong difference in the importance rating of these sectors on the accuracy factor. In both comparisons dimension and flooring manufacturers reported substantially higher mean rating values than furniture manufacturers for this factor, 6.35 for dimension and 6.46 for flooring compared to 4.84 for furniture.

Significant differences were detected between the cabinet and dimension, and furniture and dimension sectors on the *reduction in labor costs* factor (Table 10). Significance levels for these comparisons were calculated at .03 for the cabinet sector compared to the dimension sector and .04 for the furniture sector compared to the dimension sector. In both cases dimension manufacturers reported a higher mean rating value, 6.13 compared to 5.37 for cabinet manufacturers and 5.32 for furniture manufacturers, respectively. This indicates that dimension manufacturers consider this factor to be more important than cabinet and furniture manufacturers in the decision to adopt automated lumber grading technology. These findings are consistent with the high lumber grading costs associated with the dimension and flooring industries.

Significant differences were detected between cabinet and flooring, and furniture and flooring manufacturers on the *machine durability* factor (Table 10). Significance levels were calculated at .03 and .01 for the two comparisons respectively. Moreover, the flooring sector reported a higher mean value in both comparisons, 6.11 for flooring manufacturers compared to 5.37 for cabinet manufacturers and 5.16 for furniture manufacturers. Therefore, on average, flooring manufacturers rate *machine durability* higher than cabinet and furniture manufacturers in their decision to adopt automated lumber grading technology. These findings are consistent with demographic information showing the relatively high throughput of lumber associated with the dimension and flooring industries.

In multiple comparisons between sectors on the *tallying capabilities* factor, significant differences were detected between the cabinet and dimension, and cabinet and flooring sectors, and furniture and dimension, and furniture and flooring sectors (Table 10). Significance levels for these comparisons were calculated at .02 for the cabinet sector compared to the dimension sector, .01 for cabinet compared to flooring, < .01 for furniture compared to dimension, and < .01 for the furniture sector compared to the flooring sector. The dimension and flooring sectors reported higher mean rating values, 5.8 for dimension and 5.97 for flooring compared to 5.0 for cabinet and 4.16 for furniture. Moreover, strong significance levels calculated for the furniture and dimension, and furniture and flooring comparisons indicate a strongly significant difference in the importance ratings of these sectors on this factor.

Significant differences were detected between the furniture and dimension, cabinet and flooring, and furniture and flooring sectors on the *production speed* factor (Table 10). Significance levels for these comparisons were calculated at .02 for the furniture sector compared to the dimension sector, .04 for the cabinet sector compared to the flooring sector, and < .01 for the furniture sector compared to the flooring sector. A significance level of < .01 indicates a strongly significant difference. The dimension sector reported a higher mean rating value than the furniture sector, 5.59 compared to 4.74, indicating that dimension manufacturers rate this factor higher than furniture manufacturers. Moreover, the flooring sector reported a higher mean rating value than the cabinet and furniture sectors, 5.89 compared to 5.11 for the cabinet sector and 4.74 for the furniture sector. In the case of the furniture and flooring comparison, the strongly significant difference indicates a strong difference in the importance of *speed* in the decision to adopt automated lumber grading technology. As with the *durability* factor, these findings are consistent with the high volumes of lumber throughput associated with the dimension and flooring industries.

Significant differences were detected between the furniture and cabinet, furniture and dimension, and furniture and flooring sectors on the *sorting capabilities* factor (Table 10). Significance levels for these comparisons were calculated at .03 for the furniture sector compared to the cabinets sector, < .01 for the furniture sector compared to the dimension sector, and .03 for the furniture sector compared to the flooring sector. In all comparisons the furniture sector reported a lower mean rating value than the other industry sectors, 4.16 compared to 5.22 for cabinet, 5.38 for dimension, and 5.14 for flooring. This indicates that furniture manufacturers place a lower degree of importance on this factor than cabinet, dimension, and flooring manufacturers. Moreover, the strong significance level calculated for the furniture and dimension comparison indicates a stronger degree of difference in the importance placed on *sorting capabilities* by the dimension sector compared to the furniture sector.

Table 10: Mean ratings of machine attributes according to industry sector

System Attribute	Overall Mean	Mean Rating (1 - 7 scale)				Significance Level
		Cabinets (1)	Furniture (2)	Dimension (3)	Flooring (4)	
Equipment warranty	6.23	4.74	6.68	6.85	5.83	0.46
Accuracy	6.08	5.74	4.84 [1 3 4]	6.35	6.46	**_<.01*_**
Technical support	5.94	5.52	5.42	6.13	6.11	0.07
Reduction in labor costs	5.82	5.37	5.32	6.13 [1 2]	5.57	**_0.04*_**
Durability	5.73	5.37	5.16	5.81	6.11 [1 2]	**_0.04*_**
Simplicity of operation	5.69	5.59	5.42	5.68	5.89	0.69
Tallying capabilities	5.52	5.00 [3 4]	4.16 [3 4]	5.80	5.97	**_<.01*_**
Speed	5.46	5.11	4.74 [3]	5.59	5.89 [1 2]	**_0.02*_**
Cost	5.28	5.04	5.32	5.39	5.20	0.76
Sorting capabilities	5.19	5.22	4.16 [1 3 4]	5.38	5.14	**_0.03*_**
Ability to switch species	4.89	4.85	4.05	5.29 [2 4]	4.46	**_0.04*_**
Compatibility	4.56	4.59	3.53 [1 3 4]	4.65	4.91	**_0.05*_**
Ability to switch grading rules	4.50	4.96	4.00	4.62	4.09	0.17
Color sorting capabilities	4.35	5.04	3.95	4.30	4.11	0.23

[1,2,3,4] Represent significant differences between specific groups

*** Represents MANOVA significance, at least one difference among groups**

In multiple comparisons between sectors on the *ability to switch species factor,* significant differences were found between the furniture and dimension, and flooring and dimension sectors (Table 10). Significance levels for these comparisons were calculated at .01 for the furniture sector compared to the dimension sector and .04 for the flooring sector compared to the dimension sector. In both cases dimension manufacturers reported a higher mean rating, 5.29 compared to 4.05 for the furniture sector and 4.46 for the flooring sector. This indicates that dimension manufacturers rate the importance of this factor higher than furniture and flooring manufacturers in the decision to adopt automated lumber grading technology.

In multiple comparisons between sectors on the *compatibility* factor, significant differences were detected between the furniture and cabinet, furniture and dimension, and furniture and flooring sectors (Table 10). Significance levels for these comparisons were calculated at .05, for the furniture and cabinet comparison, .02, for the furniture and dimension comparison, and < .01, for the furniture and flooring comparison. The furniture sector reported a lower mean rating value in all comparisons, 3.53 for the furniture sector compared to 4.59 for the cabinet sector, 4.65 for the dimension sector, and 4.91 for the flooring sector. This indicates that the cabinet, dimension, and flooring sectors all consider the *compatibility* factor to be more important than the furniture sector.

Most significant differences found to exist between industry sectors were differences between the cabinet and furniture sectors, and dimension and flooring sectors in general. Overall, the dimension and flooring sectors reported higher mean rating values on all attributes for which a difference was found. These findings could be translated into an overall lack of interest or need in this technology by the furniture and cabinet industries, or an overall higher interest or need by the dimension and flooring industries. It should be noted that our cabinet and particularly our furniture samples were comprised of predominantly smaller companies; therefore, conclusions will be relevant to smaller companies in the cabinet and furniture industries.

Moreover, while *equipment warranty, accuracy, technical support*, *reduction in labor costs*, and *machine durability* rated high overall among the four sectors, cabinet, furniture, dimension, and flooring, some differences were present among the optimal benefit bundle characterized for each sector. Table 11 illustrates that the cabinet sector rated *accuracy* (5.74), *simplicity of operation* (5.59), *technical support* (5.52), *reduction in labor costs* (5.37), and *machine durability* (5.37) among the fourteen variables provided. The furniture sector reported mean ratings of 6.68 for *equipment warranty*, 5.42 for *technical support*, 5.42 for *simplicity of operation*, 5.32 for *reduction in labor costs*, and 5.32 for *machine costs*. Top mean ratings for the dimension sector included, *equipment warranty* (6.85), *accuracy* (6.35), *technical support* (6.13), *reduction in labor costs* (6.13), and *machine durability* (5.81). The flooring sector reported top mean ratings of 6.46 for *accuracy*, 6.11 for *technical support*, 6.11 for *machine durability*, 5.97 for *tallying capabilities*, and *throughput speed* and *simplicity of operation* were both rated at 5.89 among the fourteen factors provided. In addition, the flooring sector was the only one to cite production speed and tallying capability as attributes in the bundle. The furniture sector was the only one to cite machine cost as an important attribute.

Table 11: Optimum benefit bundle according to industry sector

	Mean Rating (1-7 scale)
System Attribute	Cabinets
Accuracy	5.74
Simplicity of operation	5.59
Technical support	5.52
Reduction in labor costs	5.37
Machine durability	5.37
	Furniture
Equipment warranty	6.68
Technical support	5.42
Simplicity of operation	5.42
Reduction in labor costs	5.32
Machine cost	5.32
	Dimension
Equipment warranty	6.85
Machine accuracy	6.35
Technical support	6.13
Reduction in labor costs	6.13
Machine durability	5.81
	Flooring
Machine accuracy	6.46
Technical support	6.11
Machine durability	6.11
Tallying capabilities	5.97
Throughput speed	5.89
Simplicity of operation	5.89

Participants were asked to rate a list of 3 factors (*invoice verification, better matching of grade to product,* and *facilitation of lumber sorting*) on their importance to lumber grading in their companies. A (1-7) rating scale was used where (1=least important and 7=most important). Mean rating values for all sectors were greater than the average importance rating of (4) indicating that all four sectors in the study found the listed factors to be of greater than average importance in lumber grading (Table 12). In addition, the highest mean rating value was reported for the invoice verification factor at 5.45.

Multivariate analysis of variance (MANOVA) was used to make comparisons between sectors on the listed factors. The MANOVA was used to test for significant differences between industry sectors at a confidence level of 95%. MANOVA resulted in no significant differences between the four sectors in this study on the three listed factors. Significance levels showed no difference among the industry sectors on the three variables. This indicates that the four sectors did not significantly differ in their importance rating of the listed factors as they relate to lumber grading. While there were no differences in the reasons for grading lumber among the four sectors, invoice verification was rated most important among the listed factors. Verification of lumber invoices is important to companies to ensure that grade mixes and payments to vendors are consistent with orders.

Table 12: Mean ratings of factors in lumber grading according to industry sector

Influential Factors	**Overall Mean**	**Mean Rating (1 - 7 scale)**				Significance Level *
		Cabinets (1)	Furniture (2)	Dimension (3)	Flooring (4)	
Invoice verification	5.45	5.04	5.35	5.45	5.94	0.24
Matching grade to product	5.33	5.87	4.88	5.51	5.06	0.15
Facilitates lumber sorting	4.37	4.29	4.35	4.41	4.44	0.99

*** Multivariate analysis of variance**

In addition to determining the reasons for grading lumber among the industry sectors, participants were asked to indicate those factors that influenced their decision to invest in scanning technology in the past, if applicable. Included in the list were increased efficiency, automation, yield, and accuracy. Table 13 shows that 100% of cabinet manufacturers who responded noted that increased efficiency was a factor in their decision to invest in scanning technology. Eighty percent of the furniture industry, 75.7% of the dimension industry, and 61.5% of the flooring industry noted efficiency as a factor influencing their decision to invest in scanning technology. Therefore, the ability to increase production efficiency is an important machine capability to the secondary wood products industry.

Greater than 71% of cabinet manufacturers and 80% of the furniture sector noted automation as a factor in their decision to invest in scanning technology, while in contrast only 48.6% of dimension manufacturers and 38.5% of flooring manufacturers noted automation as a factor. These results could have been influenced by the relative smaller size of most companies in the cabinet and furniture samples; i.e., the desire to increase production automation may be perceived as a higher priority among smaller manufacturers. As expected, increased yield influenced the majority of companies in all four sectors in their decision to invest in scanning technology in the past. Greater than 71% of the cabinet sector, 80% of the furniture sector, 89.2% of the dimension sector, and 92.3% of the flooring sector responded that yield was an influential factor in their decision to invest in scanning technology in the past. It is thought that automated lumber grading technology could influence yield by providing an optimum cut-up algorithm through accurate grading and defect mapping. These findings indicate that while increased automation is more important to smaller cabinet and furniture sectors, the potential to increase yield is an important factor to all industry sectors.

In addition to identifying the factors influencing adoption of scanning technology, it is important to understand where in the operation such equipment would be most beneficial. This discussion focuses on the location or locations inside the plant where an automated lumber grading system should be installed. It was thought that an automated lumber grading system would logically fit best where lumber was being graded. To determine the location inside the plant where an automated lumber grading system would be most beneficial, participants were asked to indicate at what point or points in their operation lumber was graded. Participants were asked to indicate various locations from a list provided. The list included *at delivery*, *first-in-first-out*, *before drying*, and *after drying*. Table 13 illustrates the majority of all four sectors indicated that they graded lumber at least at delivery. Greater than 72.7% of cabinet manufacturers, 63.3% of furniture manufacturers, 55.7% of dimension manufacturers, and 68.8% of flooring manufacturers graded lumber upon delivery to the plant. Among the four sectors, dimension manufacturers graded the largest amount of lumber before drying, 26.1%. This factor was of course influenced by the presence of dry kilns at the plant.

It was found that many companies graded lumber more than once in their operation. The cabinet sector was found to also grade lumber on a first-in-first-out basis and in some cases after drying the lumber. Some companies in the furniture and flooring sectors graded lumber at three points in the production process, first-in-first-out, before drying, and after drying. The dimension sector reported some companies grading lumber before and after drying in addition to grading at delivery.

Table 13: Percentage of adoption factors, location of lumber grading, and expected machine cost according to industry sector

Influential Factor in Adoption of Scanning Tech	**Response Frequency**				
	Cabinets	Furniture	Dimension	Flooring	Overall
Increased efficiency	100%	80%	75.7%	61.5%	75.8%
Automation	71.4%	80%	48.6%	38.5%	51.6%
Yield	71.4%	80%	89.2%	92.3%	87.1%
Accuracy	71.4%	40%	43.2%	41.7%	45.9%
Points of Lumber Grading					Overall
At delivery	**72.7%**	**63.3%**	**55.7%**	**68.8%**	62.3%
First-in-first-out	15.2%	13.3%	5.7%	9.4%	9.3%
Before drying	3%	16.7%	26.1%	18.8%	19.1%
After drying	9.1%	6.7%	12.5%	3.1%	9.3%
Expected Machine Cost					Overall
Less than $50,000	38.5%	33.3%	17.7%	6.1%	20.8%
$50,000 - $150,000	34.6%	38.1%	39.2%	39.4%	38.4%
$150,001 - $250,000	11.5%	14.3%	24.1%	15.2%	18.9%
$250,001 - $500,000	11.5%	14.3%	12.7%	24.2%	15.1%
Greater than $500,000	3.8%	0	6.3%	15.2%	6.9%

Once the factors influencing adoption and the most beneficial location in the plant were identified, it was considered important to determine the perceived value of automated lumber grading technology. In determining the expected cost of an automated lumber grading system participants were asked to indicate, from a list of price ranges, what they would expect an automated lumber grading system, with all the desired features, to cost. A range of less than $50,000 to greater than $500,000 was provided. The majority of companies in the four sectors, except for the flooring sector, responded with expected machine costs of $150,000 or less (Table 13). Greater than 73% of cabinet manufacturers, 71.4% of furniture manufacturers, 56.9% of dimension manufacturers, and 45.5% of flooring manufacturers expected an automated lumber grading system to cost less than $150,000. Moreover, the furniture sector was the only sector in the study in which no companies responded in the greater than $500,000 range. The flooring sector reported the largest percentage of companies, 15.2%, expecting an automated lumber grading system to cost in excess of $500,000.

We asked participants to list any factors that would prevent them from purchasing an automated lumber grading system, assuming that the technology was proven and effective. This was an open-ended question. A total of 61 responses were received, 29.2% of total responses. Of those who responded, 42.6% reported cost as a factor that would prevent them from purchasing an automated lumber grading system. Other factors listed were inability to meet target payback, lack of need, lack of plant space, and lack of sufficient technical support.

We then asked participants to list factors that would convince them to invest in an automated lumber grading system. A total of 75 responses were received, 35.9% of total responses. Of those who responded, 16.7% reported affordable cost as a factor that would influence them to invest in an automated lumber grading system. Approximately 10% listed meeting their target payback, and 14.2% reported that observing a proven system in use in an industrial setting would convince them to purchase an automated lumber grading system.

Participants were asked to cite specific reasons why they were or were not satisfied with technology equipment in their plants, if applicable. A total of 170 responses were received, 81.3% of total responses. There were no prevailing responses reported. Responses were comprised of various factors. Labor savings, increases in production speeds, increased production efficiency, and competitive advantage were listed among those who were satisfied. Responses from those who were not satisfied included poor or non-existent technical support, system not yet refined, poor reliability, system was marketed before fully developed, low durability, and information not delivered in usable form. These findings are consistent with the high ratings of technical support and machine warranty among participants. This information provides further justification as to the importance of service related factors as they relate to automated lumber grading technology. In addition, these findings suggest that perhaps these types of systems had not been fully developed and tested before being marketed in the past.

In summary, significant differences were found to exist between the cabinet and furniture, and dimension and flooring sectors, in general, on *machine durability, machine speed*, *reduction in labor costs*, and *tallying capabilities*. The dimension and flooring sectors rate these attributes higher than the cabinet and furniture sectors. These findings are consistent with the greater volumes of lumber throughput and increased costs associated with the dimension and flooring sectors compared to the cabinet and furniture sectors. Again, it should be noted that the cabinet and furniture samples were comprised of mostly smaller manufacturers. In addition, increased part yield was rated high among all industry sectors. It was also found that the four sectors in this study do not differ significantly in their reasons for grading lumber. Invoice verification was the most important factor in lumber grading among all sectors. Moreover, system cost, technical support, and the ability to observe a system in an industrial environment were cited as important factors in the decision to invest in automated lumber grading technology. In addition, an automated lumber grading system must be able to meet short payback periods, and be proven to reduce overall production costs.

PROMOTION

The second objective of this research was to determine the best methods of promoting scanning technology, specifically an automated lumber grading system, to the secondary wood products industry. Differences in the ways in which different industry sectors receive information about technology equipment were expected to exist. It was hypothesized that the four sectors in this study would differ in the degree to which they shared technology information, and in the sources from which they sought information. A list of nine methods of learning about new technology was developed and respondents were asked to rate each method in importance in learning about new technology. The rating was based on a 1-7 scale (1=least important, 7=most important). Methods included in the questionnaire were: *advertisements, trade shows, plant visits, personal sales calls from manufacturers, meetings and symposiums, trade journals, scientific journals, peer discussions,* and *unsolicited sales literature*.

Multivariate analysis of variance (MANOVA) was used to make comparisons among the four industry sectors in this study on the nine variables listed. Fisher's LSD technique was used as a post hoc test to detect significant differences between specific sectors. The MANOVA analysis was used to test for significant differences between industry sectors at a confidence level of 95%.

Overall mean rating values for all nine methods of learning about new technology show *trade shows*, on average, rating the highest among all respondents at 5.26 (Table 14). In addition, *plant visits* and *peer discussions* were among the top three highest rated methods at 5.19 and 5.05. *Meetings and symposiums* (3.76), *scientific* *journals* (3.23), and *unsolicited sales literature* (3.16) all rated below average in learning about new technology, among respondents, i.e., mean rating values for these methods were below the mean rating value of (4), indicating that these methods were not important in learning about new technology.

Significant differences were detected between sectors on the *trade shows* and *advertisement* methods of learning about new technology. Multivariate significance levels were calculated at .03 for *trade shows* and < .01 for *advertisements*. In addition, most methods overall were rated higher than the mean rating value of (4).

When running multiple comparisons on each sector and method, a significant difference was reported between the furniture and flooring sectors, furniture and dimension sectors, and cabinet and dimension sectors on the *advertisement* method of learning about new technology. In comparing the furniture and flooring sectors on advertisements, a significance level of .03 was calculated. In addition, the furniture sector reported a higher mean rating value (4.85 compared to 4.03) for this method. This indicates that, on average, furniture manufacturers rely more on advertisements when learning about new technology than flooring manufacturers.

In addition, a significant difference was detected between the furniture and dimension sectors as well. A significance level of < .01 was calculated for this comparison. Again, the furniture sector reported a higher mean (4.85 compared to 3.54). This indicates that a strong difference exists in the degree of importance placed on advertisements in learning about new technology between furniture and dimension manufacturers. Furniture manufacturers rely significantly more heavily on this method than dimension manufacturers. Finally, a significant difference was detected between the cabinet and dimension sectors on the advertisement method as well. A significance level of .02 was calculated for this comparison. The cabinet sector reported a higher mean rating value (4.28 compared to 3.59); therefore it can be stated that cabinet manufacturers place more importance on advertisements than dimension manufacturers in learning about new technology.

In multiple comparisons between sectors on the *trade show* method of learning about new technology, significant differences were detected between the furniture and dimension, and furniture and flooring sectors. Significant levels for these comparisons were .02 for the furniture sector compared the dimension sector, and < .01 for the furniture sector compared to the flooring sector. In both cases the furniture sector reported a higher mean rating value (5.96) indicating that furniture manufacturers rely more heavily on trade shows in learning about new technology than dimension (5.16) and flooring (4.76) manufacturers. In the case of furniture manufacturers compared to flooring manufacturers, the difference between the two sectors was strongly significant.

Table 14: Mean ratings of methods of learning about new technology according to sector

Method Learning New Tech	**Overall Mean**	**Mean Rating (1 - 7 scale)**				Significance Level
		Cabinets (1)	Furniture (2)	Dimension (3)	Flooring (4)	
Trade shows	5.26	5.22	5.96 [3 4]	5.16	4.76	***0.03****
Plant visits	5.19	4.78	5.00	5.32	5.21	0.40
Peer discussions	5.05	5.00	5.15	5.15	4.79	0.67
Trade journals	4.42	4.47	4.85	4.32	4.09	0.28
Personal sales calls	4.38	4.47	4.08	4.28	4.59	0.57
Advertisements	3.99	4.28	4.85 [4]	3.59 [1 2]	4.03	***<.01****
Meetings, sypmposiums	3.76	3.44	4.15	3.79	3.56	0.34
Scientific journals	3.23	3.19	3.23	3.24	3.18	1.00
Unsolicited sales literature	3.16	3.16	3.31	3.16	3.03	0.92

[1,2,3,4] Represent significant differences between specific groups
*** Represents MANOVA significance, at least one difference among groups**

Analysis of overall response indicates that not only were trade shows, plant visits, and peer discussions of overall more importance in learning about new technology, but these three methods were rated the top three methods for each individual industry sector as well. Table 15 shows cabinet manufacturers rated trade shows highest at 5.22, peer discussions at 5.00, and plant visits at 4.78. Furniture manufacturers rated trade shows highest as well at 5.96, while the peer discussion method was rated at 5.15, and plant visits were rated at 5.00 among the nine methods provided. The dimension sector rated plant visits highest at 5.32, while trade shows were rated at 5.16, and peer discussions were rated at 5.14. The flooring sector rated plant visits highest as well at 5.21, while peer discussions were rated at 4.79, and trade shows were rated at 4.76 among the nine methods provided.

Table 15: Important methods of learning about new technology according to industry sector

Method of learning about New Technology	Mean Rating (1-7 scale)
	Cabinets
Tradeshows	5.22
Peer discussions	5.00
Plant visits	4.78
	Furniture
Tradeshows	5.96
Peer discussions	5.15
Plant visits	5.00
	Dimension
Plant visits	5.32
Tradeshows	5.16
Peer discussions	5.15
	Flooring
Plant visits	5.21
Peer discussions	4.79
Tradeshows	4.76

The furniture and cabinet sectors reported nearly equivalent percentages of yes and no answers to the following question: Do companies within your industry ever contact you to inquire about high-tech equipment you have or have not installed? Greater than 52% of the cabinet sector responded that they had not been contacted concerning high-tech equipment they were considering, while 55.6% of the furniture sector reported that they had not been contacted. In contrast, the dimension and flooring sectors reported that 60.2% and 54.1% of companies respectively had been contacted concerning high-tech equipment. This indicates that information is shared more freely among competitors in the dimension and flooring sectors compared to the cabinets and furniture sectors. This may have an influence on the appropriate method of promotion to different sectors of the industry.

CONCLUSIONS

This study sought to identify the benefit bundle that would increase the marketable success of automated lumber grading technology, and determine the most effective methods of promoting scanning technology, specifically automated lumber grading technology, to the secondary wood products industry. These four sectors of the secondary wood products industry, small cabinet and furniture manufacturers, dimension, and flooring manufacturers, expect to pay no more than $150,000 to $250,000 for an automated lumber grading system. For most companies in these sectors of the industry, high equipment costs would prevent them from purchasing an automated lumber grading system. Furthermore, the ability to meet target payback periods, and the ability to see a proven system in use in an industrial setting would be important factors in their adoption of this technology.

In addition, *equipment warranty* and *technical support* rated among the top three attributes in overall importance among all respondents. This finding indicates that industry concerns, when considering this type of technology are not only equipment related, but include services provided by the manufacturer as well. The ability to increase part yield is an important concern in all four sectors; therefore, this function would be an important component of the benefit bundle. It is thought that automated lumber grading technology could influence yield by providing an optimum cut-up algorithm through accurate grading and defect mapping thereby optimizing part yield from lumber. *Machine durability, throughput speed, reduction in labor costs*, and *tallying capabilities* are more important to dimension and flooring manufacturers than smaller cabinet and furniture manufacturers in the decision to adopt automated lumber grading technology. This finding is consistent with the increased costs, both monetarily and in terms of time, which characterize the dimension and flooring industries.

Cabinet manufactures indicated that the optimum benefit bundle for their needs would include *high system accuracy, technical support, simple operation, the ability to reduce labor costs*, and *high durability*. Furniture manufactures responded with *system warranty, technical support, simple operation, ability to reduce labor costs* and *affordable machine cost* as important attributes. Dimension manufacturers indicated that the optimum benefit bundle for their needs would include a *system warranty, high system accuracy, technical support, ability to reduce labor costs,* and *high machine durability*.

Finally, flooring manufacturers responded with *high system accuracy, technical support, high machine durability, tallying capability high production speed*, and *simple operation* as attributes in the optimum benefit bundle.

The furniture industry was found to place more importance on *advertisements* and *trade shows* than other sectors of the industry. It should be noted that our cabinet and furniture samples consisted of smaller companies; therefore, conclusions that relate to these two sectors represent small companies only. *Trade shows* are of overall importance along with *plant visits* and *peer discussions* in learning about new technology among the secondary wood products industry. In addition, the four sectors individually rated these three methods highest in learning about new technology; therefore, these methods should be utilized in promoting to the cabinet, furniture, dimension, and flooring sectors. *Advertisements, meetings and symposiums, scientific journals,* and *unsolicited sales literature* are of little importance in learning about new technology among the cabinet, furniture, dimension and flooring sectors; therefore, these methods would not be effective in promotion to these four sectors of the industry.

This study found that more dimension and flooring manufacturers, on average, receive contact by other companies concerning high-tech equipment than smaller cabinet and furniture manufacturers. This may be representative of the degree of perceived innovativeness among companies in the dimension and flooring industries. In addition, this factor suggests more open lines of communication between companies in these sectors of the industry. It would be beneficial for manufacturers of scanning technologies to form partnerships with members of the secondary wood products industry in developing and testing this technology. Moreover, based on responses from past adopters of scanning technologies, important system attributes to the focus of promotional efforts include the ability of the system to increase production efficiency and influence improvement of part yield from raw materials.

In summary, *trade shows* should be a focus in the promotion of scanning technology. In addition, the importance of *plant visits* and *peer discussions* suggests that manufacturers of scanning technology should also focus on installing a working system in an industrial setting as word-of-mouth is an important factor. Finally, scanning technology must be promoted to the secondary wood products industry as a tool for increasing efficiency and influencing increased part yield in the plant as these were found to be the most important affecting past scanning technology adoption in this industry. It is thought that increased yield could be achieved with automated lumber grading technology by providing an optimal lumber cut-up algorithm through more accurate defect mapping and lumber grading.

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CHAPTER 4

Research Summary

Secondary manufacturers of wood products are currently facing problems such as increased competition, and decreased availability of raw material. Problems such as these are resulting in a trend toward increased automation and innovation in the production process to increase plant efficiency and part yield, and to improve product quality. The goal of this research was to assess, not quantify, the market for scanning technology, specifically automated lumber grading technology, in the secondary wood products industry. Scanning technology was defined in this research as a method of optimizing the processing of wood through the use of various sensing components coupled with computer memory. This research focused on automated lumber grading technology. Automated lumber grading technology is defined in this research as a system, which detects and recognizes wood defects and automatically assigns a grade to lumber with little or no human assistance.

The research objectives were:

1. to identify potential adopters versus non-adopters of scanning technology,
2. to characterize the benefit bundle that would increase the marketable success of automated lumber grading technology, and
3. to identify the best methods of promotion to this industry.

A mail survey was used to collect data from wood cabinet, furniture, dimension, and flooring manufacturers. Approximately 1,200 questionnaires were mailed out to these four sectors of the secondary wood products industry. A total of 439 questionnaires were received, 209 of which were useable. Unusable questionnaires included questionnaires for which addresses could not be located, companies no longer engaged in activities relevant to this study, and questionnaires that were returned greater than 50% incomplete. The resulting adjusted response rate was approximately 20%.

Demographic findings indicated that the average company in the sample frame processed 7.3 million board feet of lumber per year, 98% reported annual sales of greater than $1 million, 79% employed fewer than 200 people, 47% marketed their products internationally, and 91% were privately owned. In addition, 70% of companies were not using scanning technology at the time of this study, 76% utilized less than 6% of total man-hours grading lumber, 82% required payback periods of less than 6 years, and the mean cost to grade lumber per man-hour was $14.66. Dimension and flooring manufacturers were found to process more lumber and spend both more time and money in grading lumber when compared to smaller cabinet and furniture manufacturers. Demographic information indicated that the cabinet and furniture samples were comprised of mostly smaller companies in these industries.

The first objective of this research was to identify adopters versus non-adopters of scanning technology. Dimension and flooring manufacturers perceived automated lumber grading technology as more beneficial than smaller cabinet and furniture manufacturers. This may be due to the variation in production processes among these sectors. For example, the rough mill comprises the entire dimension and flooring production process; therefore, the benefits of automated lumber grading technology may be less difficult to see in these industries. Moreover, the relative small size of companies in the cabinet and furniture samples may have influenced these findings. In addition, past adopters of scanning technologies perceive tallying capability, sorting capability, and production speed as more important product attributes than non-adopters when considering automated lumber grading technology. These perceptions may indicate areas where improvement or development in scanning technology is needed. Adopters are more likely to be larger companies who market their products internationally. Due to the high concentration of production activity in the rough mill and high lumber input volumes, large dimension manufacturers may represent the best market for automated lumber grading technology in the secondary wood products industry.

The second objective of this research was to characterize the benefit bundle that will increase the overall marketable success of automated lumber grading technology in the secondary wood products industry. The dimension and flooring industries showed an overall greater interest in this technology compared to smaller cabinet and furniture manufacturers. The dimension and flooring sectors rated machine attributes higher than the cabinet and furniture sectors where significant differences were detected. This research found overall important system attributes to the secondary wood products industry including machine warranty, system accuracy, technical support, reduction in labor costs, and machine durability. In addition, material sorting capability, species and grade switching ability, compatibility with existing equipment, and color sorting capability were of overall minor importance among the companies in the sample frame.

Technical support and equipment warranty from the manufacturer were desirable attributes to all four sectors as well. The importance of service attributes such as these indicate that manufacturers of scanning technologies must be attentive to customer needs to be successful. In addition, the relative lack of sophisticated information systems among many companies in the wood products industry may suggest that companies in this industry expect service in the form of a human representative who provides on-site service. Machine accuracy, ability to reduce labor costs, simplicity of operation, and machine durability were included in the optimal benefit bundle for the majority of the four sectors studied. Attributes included in the benefit bundles differed slightly among the four sectors. The flooring sector was the only one to cite production speed and tallying capability as attributes in the bundle. In addition, the furniture sector was the only one to cite machine cost as an important attribute. Finally, the secondary wood products industry expects automated lumber grading technology to cost no more than $250,000. Moreover, automated lumber grading systems must be able to meet short payback periods and be proven to increase part yield. Observing a system in use in an industrial environment was cited by many as critical to their decision to invest in automated lumber grading technology as well.

The third objective of this research was to identify the best methods of promotion to the secondary wood products industry. Overall important methods of learning about new technology among companies in the sample frame included, tradeshows, peer discussions, and plant visits. While different mean rating values were reported, these three methods were rated highest for each of the four industry sectors as well. Advertisements, meetings and symposiums, scientific journals, and unsolicited sales literature were all found to be of little importance in learning about new technology;

therefore, these methods would have little or no effect on promotion of scanning technology to the secondary wood products industry. In addition, the dimension and flooring industries demonstrated more open lines of communication between companies compared to small cabinet and furniture manufacturers. This may indicate that word-of-mouth promotion is important in this industry.

IMPLICATIONS TO THE SECONDARY WOOD PRODUCTS INDUSTRY

The secondary wood products industry is becoming increasingly high-tech in its processing operations. Scanning technologies can already be found in rough-mill optimized sawing systems and defect detection systems. Any place in the operation where part yield can be increased and savings can be realized is being considered for automation. This study shows that scanning technology, while in the development stages in terms of automated lumber grading is becoming increasingly accepted in the industry. However, analysis indicates that only those companies with sufficient capital and high lumber grading costs will represent potential adopters of automated lumber grading technology such as larger dimension manufacturers. Moreover, it is thought that automated lumber grading technology may be better utilized in the primary wood products industry; i.e., lumber could be machine graded at the sawmill and a bar code attached containing the optimum cut-up algorithm. The bar code could be interpreted and algorithm used in optimized cut-up operations in secondary processing eliminating the need to grade lumber at the secondary processing facility.

Over half of the companies in the sample frame responded positively to the benefits of automated lumber grading technology. While the majority of companies in the sample frame did not have scanning technology at the time of this study, those who did were larger companies. In addition, competition within the secondary wood products industry has increased while becoming increasingly global. If one assumes that increased utilization of scanning technology is in the future of wood processing automation and the adoption of this technology can increase company competitiveness, it is logical to deduce that smaller companies may be at a technological disadvantage in the future.

MARKETS FOR SCANNING TECHNOLOGY

From the perspective of manufacturers of scanning technology, the secondary wood products industry appears to represent a potential market for automated lumber grading technology. Specifically, large companies whose production process is concentrated in the rough mill such as larger dimension manufacturers, represent potential adopters of automated lumber grading technology. In addition, the primary wood processing industry may represent a potential market for automated lumber grading technology. It is thought that primary processors could offer their secondary wood processing customers a value-added product in machine-graded lumber that included an optimal bar-coded cut-up algorithm.

The current trend toward increased plant automation provides potential for increased innovation of all types in the industry. In addition, the important role of word-of-mouth promotion and the open lines of communication found to exist in the industry indicate that there is potential for success for a company who can deliver an effective system operating in an industrial environment.

AREAS OF FUTURE RESEARCH

This research has shown that a market for automated lumber grading technology does exist in the secondary wood products industry. This research indicates that the majority of this industry has not adopted scanning technology, and that a clear distinction exists between industry sectors on the perception that automated lumber grading technology would be beneficial to their industry. Moreover, adopters of this technology will be characterized by large company size and relatively high lumber grading costs. In addition, this research shows that slight differences exist between industry sectors in the machine capabilities that are important to them, and the most effective methods of promoting this technology to these sectors of the industry. It should be noted, however, that conclusions are skewed toward smaller cabinet and furniture manufacturers.

This research addressed fourteen system attributes and nine promotion methods. Other factors could be applied to broaden the scope. Machine attributes could be segmented into factors related to the machine, factors related to the manufacturer, and factors related to the wood raw material. Factorial analysis could be used to delineate these and other categories. In addition, research could focus more on the decision-makers in each industry sector, in terms of how they receive information and how to relay information to them. Moreover, it is thought that the number of professional certified lumber graders is diminishing. As certified lumber graders become more difficult to find, the cost of not grading lumber becomes an issue. No research has addressed this issue; therefore, future studies could focus on the cost of not grading lumber in the secondary wood products industry.

LIMITATIONS TO THE STUDY

As with most research, not every aspect can be identified or anticipated. This study was developed to assess the market for scanning technology in the secondary wood products industry, using automated lumber grading technology as a case study. The fact that the perception of scanning technology in the US is influenced by scanning manufacturers marketing systems in different regions could influence the results of this study. Personal interviews with persons in the industry indicate that perception of scanning technology in the secondary wood products industry is often influenced by the perception of the manufacturer with which one is familiar rather than the actual capabilities of the technology.

In addition, the sample response rate was lower than anticipated, particularly for the cabinets and furniture samples. This could have been influenced by the frequency with which these sectors of the industry are surveyed. In addition, it appears from our demographic information that the cabinet and furniture samples were comprised of predominantly smaller producers. This makes our conclusions more applicable to the smaller producers in these sectors of the industry.

APPENDIX A: SURVEY QUESTIONNAIRE

Scanning Technology in the Secondary Wood Products Industry

The forest products industry is becoming a high-tech industry. As technology advances, many wood products firms are finding ways to automate their operations, increase efficiency and yield, and improve quality. However, to adequately provide the technology that is beneficial to wood products firms, manufacturers of high technology equipment must fully understand their needs. This questionnaire is designed to better understand the factors that are important to users of this technology. This information will allow manufacturers to produce scanning technologies that better meet your needs. For the purpose of this research, scanning technology is defined as: camera, laser, x-ray, etc. used in cut-up operations, defect detection, quality control scanning, or color matching.

1. Which category best describes the nature of your business? (Please check the appropriate box.)

Cabinet manufacturer
Furniture manufacturer
Dimension mill
Flooring manufacturer

2. Do you currently have scanning technology in place?

No → **If No, please go to question 4.**
Yes **(Please describe.)**

3. If you currently have scanning technology in place, what factors influenced the decision to invest in the equipment? (Please check all that apply.)

Increased efficiency
Automation
Yield
Accuracy
Other **(Please list.)____________________**

Lumber Grading

4. When in your operation is lumber graded? (Please check all that apply.)

At delivery
First-In-First-Out
Before drying if applicable
After drying if applicable

5. Please rank the following factors on their importance to lumber grading in your company. (1=least important, 7=most important)

	Least Important		**Average Importance**			**Most Important**	
Invoice verification	1	2	3	4	5	6	7
Better matching of grade to product	1	2	3	4	5	6	7
Facilitates lumber sorting	1	2	3	4	5	6	7
Other **(Please list.)______**	1	2	3	4	5	6	7

6. What would you estimate your average cost per man-hour of grading lumber to be?

$_________________/hour

7. **How many man-hours would you estimate grading lumber requires in your company as a percentage of total man-hours?**

Less than 2%
3% - 5%
6% - 9%
Greater than 10%

A general definition of scanning technology was given in the introduction (camera, laser, x-ray scanning, etc. used in cut-up operations, defect detection, quality control, etc). The next section introduces automated lumber grading systems defined as: systems using camera scanning mechanisms and programmable computer software to assign a grade to lumber.

8. How important would the following factors be in your decision to purchase an automated lumber grading system? (1=least important, 7=most important)

	Least Important		Average Importance			Most Important	
Accuracy	1	2	3	4	5	6	7
Cost	1	2	3	4	5	6	7
Durability	1	2	3	4	5	6	7
Compatibility with existing equipment	1	2	3	4	5	6	7
Speed	1	2	3	4	5	6	7
Ability to quickly switch grading rules	1	2	3	4	5	6	7
Ability to quickly switch species	1	2	3	4	5	6	7
Simplicity of operation	1	2	3	4	5	6	7
Technical support	1	2	3	4	5	6	7
Equipment warranty	1	2	3	4	5	6	7
Reduction in labor costs	1	2	3	4	5	6	7
Tallying capabilities	1	2	3	4	5	6	7
Sorting capabilities	1	2	3	4	5	6	7
Color sorting capabilities	1	2	3	4	5	6	7

9. **Do you believe that an automated lumber grading system would benefit your business?**

No
Yes

10. **How much would you expect an automated lumber grading system with all desired features to cost? (Please check one.)**

Less than $50,000
$50,000 - $150,000
$150,001 - $250,000
$250,001 - $500,000
Greater than $500,000

11. **What would be your expected payback period for an automated lumber grading system? (Please check one.)**

Less than 2 years
3 –5 years
6 – 10 years
Greater than 10 years

12. **Has a manufacturer of automated grading systems (AGS) ever approached you concerning purchasing an AGS?**

No
Yes

13. **Do companies within your industry ever contact you to inquire about high technology equipment you have or have not installed?**

No
Yes

14. How important to your company are the following in learning about new technology and equipment? (1=least important, 7=most important)

	Least Important		Average Importance			Most Important	
Advertisements	1	2	3	4	5	6	7
Trade shows	1	2	3	4	5	6	7
Plant visits	1	2	3	4	5	6	7
Personal sales calls from manufacturers	1	2	3	4	5	6	7
Meetings, Symposiums	1	2	3	4	5	6	7
Trade journals	1	2	3	4	5	6	7
Scientific journals	1	2	3	4	5	6	7
Peer discussions	1	2	3	4	5	6	7
Unsolicited sales literature	1	2	3	4	5	6	7
Other: __________ **(Please specify.)**	1	2	3	4	5	6	7

15. Does your company wish to be the industry leader in adopting new technology?

No
Yes

16. Do you have a professional engineer on staff?

No
Yes

Company Demographics

17. What would you estimate your company's annual lumber input volume to be in board feet?

________________board feet

18. Do you market your products internationally?

No
Yes

19. What were the total gross sales for your company in 1998? (Please check one.)

Less than $100,000
$100,000 - $500,000
$500,001 - $1,000,000
$1,000,001 - $5,000,000
$5,000,001 - $10,000,000
Greater than $10,000,000

20. **Is your company publicly or privately owned?**

Public
Private

21. **How many full-time employees work for your company? (Please check one.)**

Fewer than 25
25 – 50
51 – 100
101 – 200
201 – 300
301 – 400
Greater than 400

22. Given that the technology is proven effective and available, what would <u>prevent</u> you from purchasing an automated lumber grading system?

23. Ultimately, what would <u>convince</u> you to purchase an automated lumber grading system?

24. Please cite specific reasons why you are, or are not satisfied with technology equipment currently in place, if applicable.

25. Is there anything else you wish to share with us concerning scanning technology, or lumber grading?

Thank you for your help! Please fold the questionnaire, such that the return address is visible, and return by mail. **The postage is prepaid.**

APPENDIX B: SURVEY COVER LETTER

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

CENTER FOR FOREST PRODUCTS
MARKETING AND MANAGEMENT

Department of Wood Science and Forest Products
1650 Ramble Rd., mail code 0503
Blacksburg, Virginia 24061
Phone: (540) 231-5876 Fax: (540) 231-8868
dcumbo@vt.edu http://vtwood.forprod.vt.edu/

5-21-99

Mr. John Wood
President
Secondary Wood Products Inc.
1234 Lumber Road
Forest Products, VA 12345

Dear, Mr. Wood

As you know, the forest products industry is becoming increasingly automated. Secondary manufacturers of wood products are continually searching for new methods to increase part yield and product quality, and to increase the efficiency of their operations. Newly developed scanning technologies may offer secondary manufacturers of wood products the necessary tools to achieve these goals. To assist in understanding your needs as a manufacturer of wood products, we are attempting to identify important attributes of scanning technologies. This information will allow manufacturers of scanning technology to meet your requirements and assist in improving product yields in your manufacturing facility.

Your name was chosen at random from a list of companies involved in secondary manufacturing of wood products. We hope that you will help us by completing the enclosed questionnaire. Please know that your response is extremely important in the success of this study.

All responses you provide will be kept confidential. The questionnaire has been numbered to allow us to remove your name from the list when your response is returned. In addition, you can be assured that neither your name nor your organization will be used in the study results.

I would like to take this opportunity to thank you in advance for your help. If you should have any questions or comments please contact me at (540) 231-5876 or (540) 231-8868 (Fax) or dcumbo@vt.edu (e:mail).

Sincerely,

Dan Cumbo

Dan Cumbo
Graduate Student

A Land-Grant University - The Commonwealth Is Our Campus
An Equal Opportunity / Affirmative Action Institution

APPENDIX C: REMINDER POSTCARD

Dear Secondary Wood Products Manufacturer:

We need your help! Two weeks ago I mailed you a copy of a questionnaire titled **"Scanning Technology in the Secondary Wood Products Industry."** I am contacting you to ask you to complete the questionnaire. If you have completed and returned it, please accept my sincere appreciation. The questionnaire is designed to gather information to assist in understanding your needs as a manufacturer of wood products. We are attempting to understand important attributes of scanning technologies that will allow manufacturers of this technology to meet your requirements.

Since your name was chosen at random, your participation is critical for the success of the study. The information you provide will be kept strictly confidential. The number on the questionnaire allows us to remove your name from future mailings. If you have any questions, please contact me at 540-231-5876. Our fax number is 540-231-8868. Thank you in advance for your participation.

Sincerely

Dan Cumbo
Graduate Student
Virginia Tech

VITAE

Dan W. Cumbo II, son of Danny W. Cumbo Sr. and Ruth S. Hankins, was born in Danville, Virginia on October 19, 1971. After graduating from George Washington High School in 1989, Mr. Cumbo attended Danville Community College where he received a diploma in Graphic Arts and Printing Technology in 1991. Mr. Cumbo returned to Danville Community College in 1993 to the Science curriculum. In 1995 Mr. Cumbo transferred to Virginia Polytechnic Institute and State University where he received a Bachelor of Science degree in Wood Science & Forest Products in 1998. Mr. Cumbo continued his education by earning a Master of Science degree in Wood Science & Forest Products from Virginia Polytechnic Institute and State University in 1999. Mr. Cumbo will begin his career in the wood products industry as Project Manager with Visador Company in Marion, Virginia.