ABSTRACT

DEAVER II, MAURICE EVERETTE. Economic Feasibility of a Solid Hardwood Panel Manufacturing Enterprise. (Under the direction of Dr. Urs Buehlmann.)

The United States forest products industry faces many challenges that threaten its competitiveness as it enters the 21st century such as opposing the emergence of Asian imports, increased demands for non-wood alternatives and environmental pressures and constraints. Such pressures clearly show the need for innovative products and processes that satisfy the needs of today's global market.

A major concern, and potential opportunity, is the abundance of underutilized forest resources. This research defines underutilized resources as low-grade lumber, small-diameter roundwood and sawmill slabs. Current economic values of those resources do not encourage industry stakeholders to remove such material from the forests and process it. Creating value for this material through new products and processes has the potential to improve the profitability of local industry supply chains as well as the forest products industry as a whole. One potential value creating opportunity is to use such material in solid hardwood panels.

The purpose of this study is to assess the commercial potential of solid hardwood panels manufactured from underutilized resources. The knowledge gained from a review of the pertinent literature in conjunction with a computer simulation is used to develop a business model to manufacture 3.5 million board feet of hardwood panels a year. This model is introduced through a business plan that presents target markets, an organizational structure, the necessary capital investments and the perceived financial benefits of operating such a facility.

The proposed manufacturing model calls for a contractual agreement with area sawmills to provide low-grade lumber cut specifically from small-diameter trees and sawmill slabs. These resources would be processed in a rough mill similar to that of System 6, an earlier effort by the USDA Forest Service to promote the use of low-value timber. A computer simulation using ROMI 3, the USDA Forest Service's rough mill simulator package, is used to estimate the yields from such materials. The simulation resulted in a yield of 61.36 percent. Salvage parts were allowed and as a result increased the simulated yield.

Building a greenfield manufacturing facility would cost an estimated $7.5 million dollars including land and site preparation ($0.65 million - NC Piedmont Region), infrastructure ($1.32 million), machine investments ($2.4 million) and working capital ($1 million) to purchase raw materials and cover other expenses. This proposed venture would generate revenue through the sale of solid, edge-glued, finger-jointed panels manufactured from underutilized red oak forest resources. All panels are the standard 4 feet wide by 8 feet long and 1 inch thick. Office furniture and solid wooden door manufacturing are the markets of interest because these markets have historically shown a willingness to purchase edge-glued panels. Manufacturing costs are extrapolated using available market research. The estimated average cost to produce 1 board foot (BF) of panel is $3.325. The breakdown of the estimated cost shows raw materials account for 23.16 percent, variable manufacturing overhead accounts for 53.08 percent, direct labor account for 4.81 percent, variable sales and administration account for 1.35 percent, fixed manufacturing overhead accounts for 12.48 percent and fixed sales and administration costs account for 5.11 percent. A gross margin of 20 percent for low end panels and 40 percent for high end panels is factored into the total price. This results in a price range of $3.990/BF for low end panels to $4.655/BF for high end panels.

Unfortunately, under the assumptions presented in this research, the investment in a startup company producing solid hardwood panels does not seem economically feasible. Using conventional economic decision tools, this preliminary research shows the capital investment is too large when using the prices and output proposed. However, proposed business model assumes a "most expensive case" scenario. The plan might be more feasible by leasing land, buildings and certain equipment or even evaluating the opportunity in a less expensive location.

Economic Feasibility of a Solid Hardwood Panel Manufacturing Enterprise

By

Maurice Everette Deaver II

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APPROVED BY:

Chair	**Minor Representative**
Urs Buehlmann	**Robert Handfield**
Jan Wiedenbeck	**David Ashcraft**

DEDICATION

This thesis is dedicated to the loving memory of my father, Maurice (Buck) Deaver, who was not here to witness my trials, tribulations and joys of graduate school, but definitely would have been proud of my accomplishments.   To my mother, Martha, and my sisters, Morgan and Monica, who have graciously supported me in my endeavors, no matter how long they took! I love you all very much.

BIOGRAPHY

Maurice Everette Deaver II, son of Martha and the late Maurice (Buck) Deaver, was born in Greenville, NC on May 22, 1979. After graduating from D.H. Conley High School he attended North Carolina State University where he earned his B.S. in Wood Products with a minor in Business Management in the spring of 2003. Mr. Deaver continued his education at N.C. State and earned a M.S. degree in Wood Products with a minor in Business Management in the summer of 2006. Mr. Deaver began his career in the wood products industry as a Project Engineer with Marsh Furniture Company in High Point, NC.

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"Don't it make you smile?"

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LIST OF SYMBOLS AND ABBREVIATIONS

4/4 – 1 inch thick lumber
5/4 – 1 ¼ inch thick lumber
AHEC – American Hardwood Export Council
AWFS – Association of Woodworkers and Furnishing Suppliers
BF – Board Foot
C1F – Clear 1 Face
C2F – Clear 2 Face
CEO – Chief Executive Officer
CFO – Chief Financial Officer
CNC – Computer Numerically Controlled
COO – Chief Operations Officer
CPA – Certified Public Accountant
CSX – Common Railroad Company
DBH – Diameter at Breast Height
ft - Feet
ft^3 – Cubic Feet
F1 – Grade 1 Sawlog
F2 – Grade 2 Sawlog
F3 – Grade 3 Sawlog
FAO – Food and Agricultural Organization
FAS – First and Seconds – superior grade lumber
GCL – Gang Crosscut Length
GDP – Gross Domestic Product
IRR – Internal Rate of Return
IRS – Internal Revenue Service
IWF – International Woodworking Fair
JIT – Just-In-Time
m^3 – Cubic Meters
MDF – Medium Density Fiberboard
MBF – 1,000 Board Feet
MMBF – 1 Million Board Feet
NAICS – North American Industrial Classification System
NPV – Net Present Value
NHLA – National Hardwood Lumber Association
OSB – Oriented Strand Board
PTI – Piedmont Triad International Airport
ROI – Return on Investment
ROMI – Rough Mill Simulator
ROMI-Cross – Crosscut-First Rough Mill Simulator
ROMI-Rip – Rip-First Rough Mill Simulator
SKU – Stock Keeping Unit
SQFT – Square Feet
TSI – Timber Stand Improvement
USDA – United States Department of Agriculture
WCMA – Wood Components Manufacturing Association

Chapter 1

1. Introduction

1.1 Perspective

The need to find innovative products and new markets for underutilized forest resources is the number one research priority among the forest products industries and its research communities (NHLA 1996 as cited by Shepley et al. 2004). Underutilized forest resources, for the purpose of this research, are identified as low-grade lumber, small-diameter roundwood and low-value sawmill byproducts such as slabs. Small-diameter roundwood is a primary source of low-grade lumber. Sawmill slabs result from "squaring" logs in sawmills. This material is considered underutilized because its full potential is not realized in today's markets. In industry practice, low-grade material, as well as sawmill slabs, produce primarily short and narrow usable portions of clear wood at low yields. Removing the usable portions is often costly and unprofitable. Finding new innovative products and processing techniques, along with the introduction of these products to new and existing markets, will create value that can be captured throughout the local industries' supply chain. More importantly, this newly found marketable resource will provide landowners the incentive to remove this material from the forests, which in turn will improve forest health and provide future generations with a steady supply of high quality forest resources.

Traditionally, the nation's forests have supplied the forest products industry with sufficient quality logs. However, through years of heavy cutting and forest mismanagement, the quality of today's raw materials has been steadily declining. Currently, forests have an abundance of low-grade hardwood timber (LeVan-Green and Livingston 2001). This material is considered low-grade because of excessive knots, crookedness or small diameter. This low-grade resource, in general, cannot be profitably harvested and processed into lumber using conventional techniques. Therefore, it is left in the forests while the higher quality timber is removed. This selective harvesting technique results in a surplus of low-grade timber.

Proper forest management techniques call for the removal of this small diameter and lower quality stems from the forest. This would reduce overstocking and stagnation while promoting healthy growth (Irland 1988 as cited by Wiedenbeck 1993). Finding cost effective processes to remove lower quality material and viable products would offer economic incentives to landowners to remove this material when necessary. Eventually, selective harvesting techniques would decline to acceptable levels and the volume and quality of hardwood timber would return to that enjoyed by past generations.

Unfortunately, in the mean time, the industry will face an abundance of low-grade, small diameter material in the market. Such material is characterized by low yields and high processing costs. Sawmills are concerned with the profitability associated with processing, marketing and selling low-grade material. Secondary manufacturers are concerned with using low-grade lumber in their manufacturing processes. Therefore, neither industry wants to buy, process, or sell this type of material. In an effort to improve the profitability and competitiveness of the domestic industry, the industry should turn its focus to developing products and processes suitable to the availability and quality of this raw material.

One particular product of interest to the industry is solid hardwood panels. Solid hardwood panels are standard-sized, finger-jointed, edge-glued blanks manufactured from the roundwood of a deciduous tree. Panels provide an excellent opportunity for the value-added wood industry to compete internationally through innovation and cost competitiveness (Tabarsi et al. 2003). This solution offers a lower cost alternative to conventional rough mills and an opportunity to utilize species, grades of lumber and sawmill byproducts that have traditionally caused problems for primary and secondary manufacturers (Araman and Lamb 1990). Solid hardwood panel manufacturing offers the potential to (1) better utilize the raw material, (2) offer primary manufacturers a value-added product for low-grade lumber and sawmill residuals and (3) reduce the manufacturing costs for secondary wood processors. Evidence shows it to be a viable business in the U.S. as edge-glued panels account for roughly 13 percent of the wood components market (WCMA 2001 as cited in McDaniel 2003). These panels are marketed towards a broadly defined group of industrial manufacturers who produce furniture, doors, kitchen and bath cabinets and various other solid wood products (Tabarsi et al. 2003).

1.2 Research Objectives

The purpose of this research is to investigate the economic feasibility of manufacturing solid hardwood panels from underutilized and/or low-valued hardwood resources. A business model is developed that expresses the feasibility of such an enterprise. This knowledge will provide potential entrepreneurs and existing operations an understanding of the dynamics associated with this type of enterprise.

For such a solid hardwood panel manufacturing enterprise to be successful, it is necessary to identify:

- The quality and availability of the resources
- A suitable manufacturing strategy
- The potential markets
- The economic feasibility and profitability

Several questions are raised in this research. Each question arises from critical factors of the business plan. The objective of this project is to provide reasonable answers to these questions.

Questions are: 1) Does the current low-grade and low-value sawmill byproduct resource satisfy the constraints of manufacturing solid hardwood panels? 2) What is the best approach to manufacture these solid hardwood panels in the most efficient, economically, viable, way? 3) Can production capacity meet demand at a given price? 4) What is the Net Present Value (NPV), Return on Investment (ROI) and Break-even point for such an investment? Also, other important factors affecting the economic feasibility and profitability of such a firm need to be investigated.

In particular, the specific objectives of this research are:

1. Identify, define, and quantify potential low-value sources of raw materials available for the production of solid hardwood panels based on existing research and computer simulation.
2. Examine past and present technologies, processes and strategies for manufacturing solid hardwood panels from these materials based on current techniques.
3. Summarize current and potential markets.

4. Develop cost models to evaluate the feasibility of an enterprise, and sensitivity models for adjustments in raw materials cost, supply, and demands.
5. Propose a business plan for an enterprise to manufacture such solid hardwood panels.
6. Identify the necessary areas of improvement for such an industry to develop.

1.3 Research Statements and Hypothesis

<u>The goal of this research is to demonstrate that underutilized forest resources such as sawmill slabs, other low-value sawmill byproducts, low-grade lumber and small-diameter roundwood can be used as a raw material to manufacture solid hardwood panels in an economically viable way based on these underlying assumptions:</u>

1) Low-grade lumber, small-diameter roundwood, and sawmill slabs are underutilized and undervalued hardwood resources that are abundant in today's market. Processing such material to remove defects results in short and narrow clear cuttings. These short and narrow pieces can be finger-jointed for length and edge-glued for width to produce panels of various sizes and qualities.
2) Solid hardwood panels are already an important product in today's wood products industry. Several value added manufacturers supply secondary producers with such products. In-house operations exist who manufacture panels for internal consumption. Panels produced from low-grade material will potentially meet the same needs existing in today's value chain.
3) The development of technologies and processes has made a major impact on the value added wood industry. This innovation is expected to become more advanced as more opportunities develop.

This research proposes a business plan for such an opportunity. The hypothesis underlying this business plan is:

> H1: The currently available resources, manufacturing technologies and wood markets support the concept of manufacturing high-quality, value-added, solid hardwood panels from underutilized wood resources.

1.4 Research Design

An extensive literature review followed by a computer simulation are the two methods used to test the hypothesis and satisfy the objectives of this research This research leads to a better understanding for manufacturing solid hardwood panels, specifically in the context of using low-grade and sawmill byproduct resources as the main raw material.

The literature review begins by stating the purpose of a business plan. It then gives an overview of the hardwood industry and its current conditions. It includes consumption data, trade information, and manufacturing technology trends. Finally, past research on utilizing this resource, including the research conducted by the U.S. Department of Agriculture's Forest Service's[1] during the late 70s and early 80s on the concept of standard size hardwood panels and a feasible manufacturing system, is discussed. The literature review provides a starting point for the research and helps develop models, assumptions, and the research design for simulations to be performed. To realistically quantify the amount of usable wood from low-grade materials, ROMI 3.0, a rough mill simulator developed by the U.S. Department of Agriculture's Forest Service is used. The ROMI family of simulators has been an invaluable decision making support tool since its inception in 1995 by Ed Thomas (Thomas 1995). Results from the simulation will help develop and understand the raw material needs and costs for such an enterprise.

[1] Northeastern Forest Experiment Station

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Chapter 2

2 Literature Review

2.1 Business Plans

A business plan is a document used to communicate a project's goals, objectives, strategies, and performance evaluators (Anonymous 1997). It is usually geared towards recruiting investors and management team members necessary for a successful project. Therefore, it should sufficiently describe the products/services offered as well as the industry and markets one wishes to compete in. It also includes detailed information on the project's financial outlook and the necessary capital for its implementation. The business plan should convince stakeholders to take advantage of the business opportunity identified. Each business plan is unique in its own way and tailored for the product or process being introduced. The business plans sections pertinent for the solid hardwood panel proposal are explained as follows:

2.1.1 Executive Summary

The Executive Summary is a one page summary of the major points of the business plan, with a focus on communicating the company's proposed and distinctive competitive advantage (Anonymous 1997). It should also include a clear statement about investment needs. This is often the most important section of the business plan because it generally is the first section read by a potential investors and must provide enough information to draw their attention but not too many details to bore them. The Executive Summary should emphasize the key issues presented later in the business plan (Anonymous 1997). Therefore, most Executive Summaries are outlined by the sections included in the business plan.

2.1.2 Introduction

The Introduction offers the reader insight into the company, the industry, and the needs of the proposal (Howe and Bratkovich 1995). It gives the reader an idea on what to expect from the business plan. The Introduction should briefly describe the purpose of the business and includes descriptions of the company, the product or service and express the company's goals. Also, of importance is a broad overview of the industry the company wishes to compete in. An explanation of the industry, the market and the main competitors should suffice. The Introduction concludes with a financial summary of the company. This summary explains the capital needed for the investment and its use. It also lists the different methods the entrepreneur will use to raise money and the financial goals of the organization.

2.1.3 Problem / Solution

The Problem and Solution section is an extension of the introduction. Here, the reader gets insights into the problem the proposed product is able to solve. To explain the solution, a clear description of the product's core assets and competitive advantage is necessary. Also, to help the reader understand the importance of the product it is essential to quantify the size and severity of the problem. In the forest products industry this is usually explained in terms of value or yield.

2.1.4 Product and Process Description

The Product and Process Description portrays the unique competitive advantage this product offers and the manufacturing process designed to produce such products. This section discusses what attributes make it an ideal product and the value it will provide customers. Detailed explanations of customer benefits, intended uses and the level of quality offered are presented in this section (Howe and Bratkovich 1995). The alternative uses of the product are also discussed in this section if they exist. The process descriptions include flow diagrams and a list of major machinery and equipment.

2.1.5 Market Analysis

The Market Analysis should contain a description of the market in which the product is to compete. It is important to describe the market as it stands today, without the proposed product. This section discusses trends affecting product or service, demographics of the target market, competitors, and a comparison with competing products. One goal of this section is to persuade investors that current or future market conditions will support the proposed venture. Also of importance are key aspects of the market including types of customers targeted, reasons why someone would purchase this product, and the growth and size of the market (Howe and Bratkovich 1995).

2.1.6 Marketing and Sales Plan

The Marketing and Sales Plan is an explanation on how the company will approach the market described in the market analysis. It includes detailed information on the sales plan, unit volumes and product pricing. The first step is developing a market penetration strategy. This strategy is built upon timing, pricing, and an initial target market or markets. The marketing and sales plan also describes the company's selling and distribution methods, as well as how the company plans to promote the products. Finally, a good Marketing and Sales Plan should list the qualities and characteristics of the sales force and detail their activities.

2.1.7 Operations

The Operations section of the business plan discusses the delivery of the product to the customer. This explanation describes the procedures and capacities for securing raw materials, manufacturing products and delivering finished goods. Primary and secondary suppliers are identified as well as expected lead-times and contractual agreements. A discussion on the risk of raw material shortages and the plan to overcome such situations are also of importance. The Operations section should also list any operating competitive advantages that exist.

2.1.8 Management and Organization

The Management and Organization section is an opportunity to explain how the company will be run. This section provides detailed descriptions on organizational structure and the management team and includes any foreseen changes as the company grows. The organizational structure includes the formal structure of the company as defined to the Internal Revenue Service (IRS). An organization chart is a good depiction of the key personnel to the company. If a management team is not in place, the plan should include an account of the ideal characters. Also included in the Management and Operations section is an explanation of the ownership of the company. The principal owners and their involvement with the company are described (Howe and Bratkovich 1995).

2.1.9 Financial Plan

The Financial Plan is a description of the funding requirements and an overview of the project's financial projections. Generally, this section is created using two categories; start up expenses and operating costs. Startup expenses include initial capital investments in building and machinery, a startup inventory of raw materials and all other expenses expected in the startup stages of the project. The operating costs are those associated with keeping the project running. Most often the Financial Plan is detailed in 3 financial statements; a balance sheet, five-year income statement, and a cash flow statement. Additional financial analysis such as a break-even analysis, net present value, internal rate of return and return on investment are also part of the financial plan. The Financial Plan is also an opportunity to express the assumptions made throughout the business plan.

2.2 Overview of the Hardwood Industry

2.2.1 Wood Economy

Wood is the world's most abundant renewable resource and its importance to today's society is often underappreciated. Wood, as a raw material, is found in many of today's consumer products including paper, building structures, pallets, packaging, furniture, wood fiber composites and even toothpaste, just to name a few. It also acts as the main source of energy for several underdeveloped regions throughout the world. The global per capita consumption of wood is estimated to be 0.7 m^3, as a result, the weight of wood consumed annually is more than the combined quantities of steel, cement, plastics and aluminum (FAO 2003 and Buehlmann 2004). This dependence has created numerous markets for wood products and has made wood an important part of the economy by creating wealth and providing jobs.

From a value perspective, the U.S. forest products industry annually ships $311.8 billion worth of goods (wood products - $92.4 billion, paper products - $151.4 billion, and furniture - $68.0 billion) (Howard 2003 and U.S. Department of Commerce 2004). Accordingly, the forest products industry accounts for roughly 2.9% of the United States' $10.8 trillion GDP, estimated at the end of the second quarter of 2003 (U.S. Department of Commerce 2004).

From an employment perspective, the forest products industry in the United States employs more than 1.62 million workers, (wood products - 0.54 million, paper - 0.51 million, furniture - 0.57 million) making it one of the country's 10 largest manufacturing sectors (U.S. Department of Labor 2004).

Deciduous trees, commonly referred to as hardwoods, are a desired raw material in many processes. The hardwood value-chain can be described as all suppliers, manufacturers, and customers who in one form or another make a profit from the manufacturing or use of a product derived from a deciduous tree. This industry is highly fragmented. Firms range in size from high-value multinational enterprises to small family owned operations (ITP 2004). These manufacturers produce products that are sold in well established markets; primary markets include hardwood lumber, hardwood dimension parts and components, hardwood plywood and hardwood laminated composites to name a few. Consumer markets include cabinetry, furniture, hardwood flooring, and hardwood doors. Standards for such products are usually set by industry trade associations and are widely practiced throughout the industry (Bush et al. 1991). As the raw material is processed, its form, function, and value change. Therefore the standards used to measure the quality for such products change as well. For example, a hardwood log is sold to a sawmill and processed into lumber. The sawmill sells the lumber to a components manufacturer who produces dimension parts. The components manufacturer sells the dimension parts to a cabinet manufacturer who produces a product for the customer. At each trading point the customer uses a different measurement to place a value on the product he wishes to purchase. Therefore, the industry generally categorizes this value chain into four broad groups based on the type of raw material used; 1) Forestry; 2) Logging; 3) Primary Manufacturing; 4) Secondary Manufacturing. Each is briefly discussed below.

2.2.1.1 Forestry Description

Forestry is the science, art, and management of natural resources (American Heritage Dictionary 2000). Most often forestry's main focus is on the management of timber because of the economic impact of wood and wood products (The Columbia Electronic Encyclopedia 2003). Two important goals of forestry include developing methods of removing timber for the promotion of healthy growth for a new forest crop and ensuring that optimal conditions exist for the germination and survival of desirable species at sustainable levels (The Columbia Electronic Encyclopedia 2003).

In the forestry sector, harvestable, standing timber is purchased by primary processors, independent loggers, or timber speculators (Luppold and Bumgardner 2004). Loggers and speculators are basically middlemen and purchase timber based on their own perception of the quality of a stand. Their view is based on the need of the localized market (primary processors) where prices are constrained to what those producers will pay (Luppold and Bumgardner 2004). Once the timber is purchased it is most often harvested through logging.

2.2.1.2 Logging Description

The North American Industrial Classification System (NAICS) describes logging as the engagement of cutting timber to produce "rough, round, hewn, or riven" forest raw materials, or producing wood chips in the field (U.S. Census Bureau 2003). The resulting products from logging include roundwood, chips and waste. Roundwood and chips are marketable products generating revenue for this industry, whereas waste is often left in the forest for natural decomposition. The Food and Agricultural Organization of the United Nations (FAO) (2003) defines roundwood for statistical purposes as "wood in the rough," that has been harvested; basically any consumable part of a felled tree removed from a forest as well as trees outside the forest. It is traded in many forms including with or without bark, round, semi-round, or slightly square.

Roundwood is sold as a raw material in the form of logs (saw or veneer), pulpwood, or industrial roundwood (wood composites and pallets raw material) to primary manufacturers. It is also sold as fuelwood to a variety of end users including industrial manufacturers and the general public. Roundwood markets can be broadly defined based on the end use of the material. Two typical roundwood markets exist for hardwood resources; fiber markets or solid wood markets (Hansen et al. 1999). Fiber markets mainly consist of manufacturers of composites and paper products. Such roundwood purchases are based on price, density and other general characteristics. These industries consume a large portion of the low quality roundwood available today.

The solid markets buy their material based on species, diameter, number of clear faces, end use, physical attributes and/or other characteristics (Luppold and Bumgardner

2004). Luppold and Bumgardner (2004) label these characteristics as merchandising criteria. The solid market can be further segmented into aesthetic (veneer, lumber) or industrial products (pallets, crossties, composites etc.). The aesthetic markets demand high quality materials whereas the industrial sector consumes large amounts of low-grade roundwood. Table 2.1 explains the breakdown of the hardwood roundwood markets, the desired quality of the incoming raw material and the value resulting from manufacturing products (Luppold and Bumgardner 2004).

Table 2.1 Primary hardwood industries, principal products manufactured, value range of roundwood purchased (Luppold and Bumgardner 2004).

Industry	Category of roundwood product consumed	Timber product category	Quality of category of wood commonly consumed	Value range of roundwood primarily consumed
Face veneer mills (Slicer)	Aesthetic	Veneer logs	Veneer logs	High to very high
Face veneer mills (rotary)	Aesthetic	Veneer logs	Veneer or sawlogs	Medium to high
Large sawmill (grade mill)	Aesthetic or industrial	Sawlogs	Sawlogs	Medium to high
Large sawmill (industrial)	Industrial or aesthetic	Sawlogs	Sawlogs or bolts	Low to medium
Medium sawmill	Aesthetic or industrial	Sawlogs	Sawlogs or bolts	Low to high
Plywood mill	Aesthetic or industrial	Veneer logs	Sawlogs or bolts	Low to medium
Pulp mill	Fiber	Pulpwood	Cull logs, bolts, tree-length logs, chips, and mill residue	Very low to low
Engineered products mills	Fiber	Composites	Cull logs, bolts, tree-length logs, and roundwood residue	Low to high

Market prices for roundwood are functions of supply and demand trends, thus prices are constantly fluctuating (Thomson 2004). Thomson (2004) describes the supply and demand short- and long-term elements that most affect the markets. Factors controlling the long-term supply of material are growing stock, growth rates and accessibility to timber. The main long-term demand element is economic growth. Long-term trends are also influenced by changes in consumer preferences for species as well as for nonwood substitutes such as plastics, steel, concrete, etc. In the short-term, demand follows changes in consumer and government spending as well as business investments. The main short-term supply element is harvesting decisions (Thomson 2004). Perhaps the key influence in the demand of hardwood raw material is the economic activity of consumers at the end of the value chain (Thomson 2004). The preferences and purchases by the end-users dictate what secondary wood users will manufacture. This indicates the demand for lumber and consequently roundwood.

Hardwood roundwood is sold based on volume and grades to primary manufacturers. The prices associated with roundwood greatly depend on a number of different variables. Species, grades, quality, diameter, frequency of defects, and growth characteristics (ring count, color, roundness, etc.) are just a few parameters that determine the value for a particular log. Those variables also determine how that log will be used. Higher quality roundwood is in high demand due to its versatility. For example high quality logs are easily processed by sawmills and veneer mills at high yields and high margins. Depending on the logs' destination, the resulting product is high quality lumber or veneer with both products assuming high prices in their respective markets. Therefore, the value placed on these logs is generally higher than that of lesser quality logs. Veneer logs are perhaps the most valuable logs in the hardwood roundwood market returning up to 1.5 to 6 times the price of the highest grade sawlogs (Wiedenbeck 2004b).

2.2.1.3 Primary Manufacturing Description

Primary manufacturers of the forest products industry include all manufacturers using roundwood or some direct byproduct as the basic incoming raw material. Primary manufacturers convert roundwood to a higher value product. Lumber, veneer, pulp and engineered wood composites are example products of primary manufacturers. Primary manufacturers strategically locate themselves near the raw material resource base, as shown in Figure 2.1. Eastern U.S. Hardwood and Softwood Sawmill Locations in 1999 (USDA Forest Service 1999). Comparing the forest cover depicted in Figure 2.2 with the sawmill location in Figure 2.1, it is noticeable that there is a high concentration of sawmills loacated along the Appalachian region and in northern Michigan and Wisconsin.

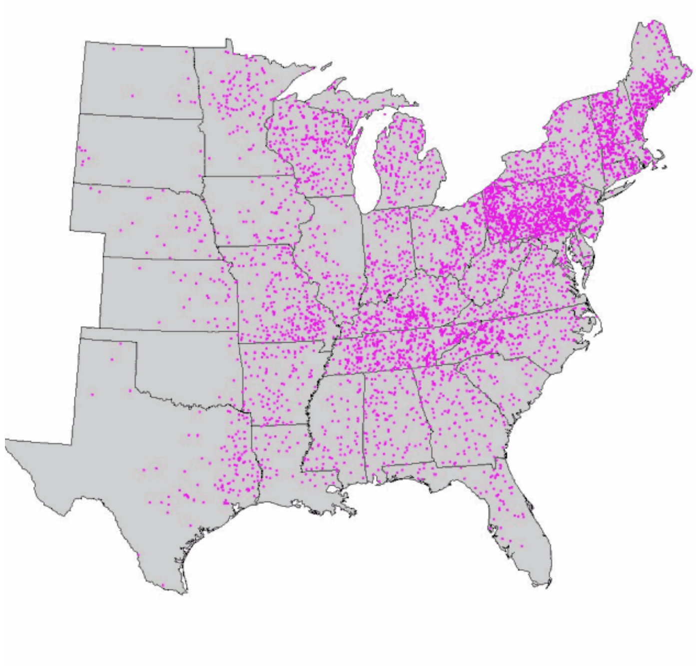

Figure 2.1 Eastern U.S. hardwood and softwood sawmill locations in 1999 (USDA Forest Service 99).

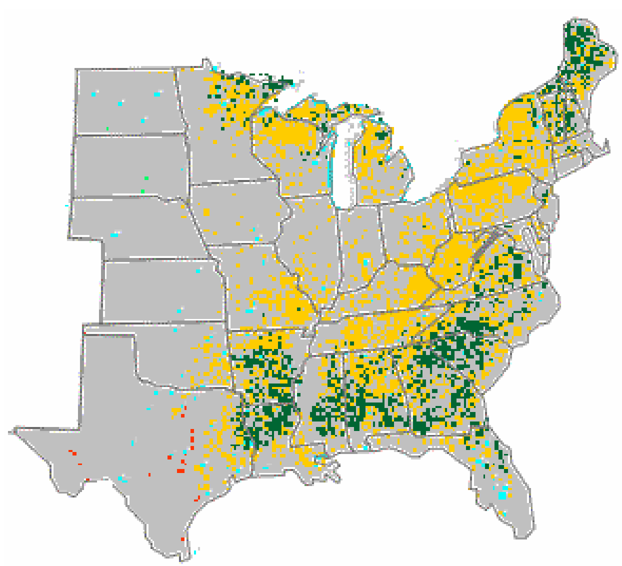

Figure 2.2 Eastern US hardwood (Yellow) and softwood (Green) forest cover (Wood Resources Institute 05).

Hardwood lumber is another primary wood product sold based on volume and grade. The value of hardwood lumber is benchmarked by the prices reported in industry trade publications such as *Hardwood Review* (2005) or the *Hardwood Market Report* (2002). As with roundwood, lumber prices are mainly functions of supply and demand but other variables such as grades, species and production capabilities influence the prices. Actual prices are based on the conditions of the local market and the relationship between the entities involved in the transaction (Bond 1999). Hardwood lumber prices have historically followed an oscillating and slowly upward trend (Luppold 1982).

2.2.1.4 Secondary Manufacturing Description

Secondary manufacturers continue adding value to the raw material obtained from primary manufacturers. Primary manufactured products are generally remanufactured by secondary manufacturers into consumer goods such as furniture, cabinetry, pallets, flooring, and paper, or are directly used in millwork, paneling, moulding, and hardwood dimension stock (Forest Products Laboratory 1999).

2.2.2 Hardwood Production and Consumption Data

2.2.2.1 Roundwood Consumption

As stated, the manufacturing of wood and paper products requires the production and consumption of roundwood. As consumer demand for such products increases, more pressures are placed on the forests to produce this resource. This is evident in the statistics that state that the U.S.'s consumption of roundwood (including firewood) has increased roughly 1.0 percent a year from 13.3 in 1965 to 19.7 billion ft^3 in 2002 (Howard 2003). Roundwood production also increased 1.0 percent a year from 1965 to 1997, from 12.3 to 17.6 billion ft^3. However, the harvesting of roundwood has slightly declined since 1997 to a level of 16.5 billion ft^3 in 2002. Howard (2003) explains this decline may be a result of decreases in the production of pulpwood. This decline in pulpwood production indicates a potential increase in the supply of low-value material.

2.2.2.2 Hardwood Lumber – Production and Imports

The U.S. is the global number one purchaser for furniture, kitchen cabinets and various other solid wood products. U.S. consumers demand species they have been accustomed to purchasing and using in their homes or workplace. Oak (White and Red) and yellow poplar are the most widely used native hardwood species for such products (Shepley 2002). The remaining indigenous species include ash, basswood, yellow birch, cedar, cherry, cypress, hickory, hard and soft maple, various oaks, and walnut (Howard 2003). Therefore, many of the domestically grown and processed species are those demanded in the consumer markets, making the production of hardwood lumber an important part of the forest industry in the U.S. This is especially true in the South, where roughly 80 percent of the nation's hardwood lumber is produced. Total U.S. hardwood lumber production for 2002 was estimated at 11.8 billion board feet (BF) (Howard 2003). This production continues to drop from the levels achieved in the late 1990's. Domestic production is not the only source of hardwood lumber available to the secondary manufacturing industry. Hardwood lumber imports tallied 700 million BF in 2002, with Canada being the main source, accounting for 73 percent of the imported hardwood lumber (Howard 2003).

Production and import volumes combined total roughly 12.5 billion BF of hardwood lumber for 2002. U.S. manufacturers consumed 11.3 billion BF of this hardwood lumber in 2002 (Howard 2003). This lumber is used as a raw material for several different secondary manufacturing processes. Hansen and West (1998 as cited in Hansen et al. 1999) reported estimates (1997) for hardwood lumber consumption by sectors; 4.5 billion BF for pallets, 3.0 billion BF for furniture, 2.5 billion BF for dimension parts, 1.3 billion BF for moulding and millwork, 1.2 billion BF for cabinets and 1.1 billion BF for flooring. A discrepancy is noticed between the reported volumes of lumber consumed by both papers. Accurately estimating consumption numbers is extremely difficult. The products produced by dimension manufacturers are actually consumed and included in the wood usage of furniture, moulding, millworks, and cabinet sectors of the industry. Therefore, certain volumes are actually accounted for twice (Hansen et al. 1999). Nonetheless, a large portion of hardwood lumber is produced and consumed by domestic manufacturers.

The remaining 1.2 billion BF was exported to major hardwood markets such as Canada, the European Union and Asia (Howard 2003). The emergence of these global manufacturers will continue to have a significant impact on the demand for domestically grown hardwood lumber in the future. The Chinese furniture industry, where demand for wood raw materials has grown rapidly since the economic reforms of the early 1980s is expected to play an important role in the future of the hardwood industry. Sun and Hammett (1999) foresee China's need for wood raw material will increase 5 to 10 percent annually over the next few years. China's dependence on wood is important to U.S. manufacturers of hardwood lumber because their gap between domestic (China's) production and consumption is growing (Sun et al. 1999). Changes in Chinese forestry policies have limited their domestic timber production and Chinese manufacturers are spending large amounts of money to import commercial species (Sun et al. 1999). Red oak from the U.S. is the most popular imported temperate hardwood species. To satisfy the demand, increases in high-quality U.S. hardwood lumber, dimension stock and veneer exports are expected (Sun et al. 1999).

2.3 An Industry Struggling

The positive outlook for exporting lumber is promising but the domestic value-added wood industry faces several threats as it moves into the 21st century. Overcapacity, nonwood alternatives, low priced imports, environmental pressures, and changing consumer attitudes are major factors affecting the survival of U.S. forest products industries (Blackman, 1998). Poisson et al. (2002) further explains several factors including: a highly fragmented competitor base where there is no production or price discipline; capital intensive manufacturing processes; "*production-focused operating philosophies*" contributing to overcapacity and a lack of inventory control; weak commodity-type markets; and a historically strong dollar making low cost imports more viable. Other authors, such as Buehlmann and Schuler (2002) note that domestic industries lose market shares because: they no longer control a national market through trade protection due to globalization; improvements in containerized shipping have further reduced costs of international trade; a strong U.S. economy attracts foreign products; and high U.S. wages. Other commonly cited reasons include lack of industry innovation and reductions in the quality of incoming raw material.

These factors are both internal and external to U.S. manufacturers. While some of the blame is on the industry itself, the emergence of low-cost manufacturers from overseas negatively affects several U.S. wood companies' competitiveness. World furniture production experienced its sixth straight year of growth during 2004 and even though the U.S. furniture industry's sales peaked in 2000 with $13.3 billion (USITC 04) the domestic industry has continuously lost market shares since that peak. Analysis shows that following the peak in 2000 and ending in 2003, the domestic industry had suffered a sales volume loss of 36 percent. Many look at the free trade treaties that have opened our borders to low-cost imports. Bumgardner et al. (2004) state that 40 percent of all wood household furniture sold in the United States during 2001 was imported and the trend is expected to continue for some time. More recently, US Department of Commerce's (2006) figures show that during 2005, U.S. imports for wood and upholstered furniture and wood furniture components rose to $17.72 billion while exports increased only to $1.4 billion that same year. The result is a $16.3 billion trade deficit for the industry.

Furniture is not the only forest products industry suffering from cost competitive imports. The construction boom has created attractive opportunities for the kitchen cabinet and countertop industry and while the domestic manufacturers have benefited from this market growth, it has also created an alternative market for low-cost importers to exploit. During the time period from 2000 to 2004 the U.S. International Trade Commission reports increases in kitchen cabinet and countertop imports as such: China experienced a 709 percent increase ($11.4 to $89.0 million), Italy a 500 percent increase ($5.0 to $30 million), Malaysia a 1000 percent increase ($297,000 to $3.295 million) and Vietnam a 3,085.8 percent increase ($4,000 to $703,000) (USITC 2004).

Many global manufacturers are succeeding in the U.S. market because, generally, their products are lower in price compared to domestically made products. Therefore, if domestic manufacturers are to maintain market share they are forced into a price war with these low-cost importers. Lowering prices reduces profits unless manufactures can figure out ways to reduce costs. Controlling such costs as labor, material, operating, and overhead becomes important since it makes the difference in survival. Since, the U.S. forest products industry cannot compete on wages, it is forced to look for other opportunities to reduce costs. These cost reducing opportunities can be in the form of innovation and investments in technology, specifically automation, continuous improvements to processes and finding low-cost alternatives for their raw materials.

2.3.1 Hardwood Sawmill (Primary) Operations

Sawmills have difficulty selling low-grade lumber because of the unwanted additional costs secondary manufacturers often incur while processing this material. On the other hand sawmills have little trouble selling their high-grade hardwood lumber to secondary manufacturers (Smith et al. 2002). Strong markets exist, nationally and internationally, for the high-grade commercial species that are demanded by the end-users of wood products. However as the resource declines, so will the yield of higher-grade boards (Smith et al. 2002). Sawmills are now faced with an optimization issue of finding the most value from a sawlog. This often includes utilizing the log in an effort to produce the most high-grade lumber (highest value) with the least amount of residuals. Sawmill residuals include sawdust, edgings, and sawmill slabs and can account for 14 percent (by weight) of a log in a typical sawmill (Serrano and Cassens 2001 as cited by Buehlmann and Wiedenbeck 2002).

Slabs result from "squaring" timber and are often considered a wasteful by-product at sawmills. The value for slabs is significantly less than other portions of the log even though slabs are removed from the best part of that log. Different sawing techniques exist to reduce slab production, but the slabs that are produced are chipped or further processed to recover the usable portions. Chipping compromises the potential value of the material because chips are low in value with weak and volatile markets. Recovery efforts are costly and the material is difficult to value because the small sizes do not meet minimum requirements for accepted grading standards.

A major industry concern is developing for primary manufacturers because market options for sawmill residuals are weak and the Forest Service has predicted an abundance of low-grade material for the future (Bumgarner et al. 2001). The presence of low-grade material coupled with a high volume of sawmill slabs will begin to affect a sawmill's profitability and eventually its survival. This forces managers into finding creative ways to market and sell this material in a profitable manner to maintain margins. It also increases the pressure on sawmills to optimize yields and find more desirable options that will add value to their low-grade lumber and sawmill residues (Smith et al. 2002).

2.3.2 Secondary Operations

Lumber has traditionally been the raw material of choice for secondary manufacturers who produce such products as furniture, cabinets, wood components, and doors. Lumber is a heterogeneous raw material that contains unusable portions (Brunner et al. 1990 as cited in Buehlmann 1998). Processing lumber is unique in the way that the usable portion of the board must be separated from the unusable portions known as defects. The process of removing these defects occurs in what is known as a rough mill. "*Rough mills consist of a series of machines and allied equipment intended to convert kiln dried lumber into dimension stock*" (Buehlmann 1998). The efficiency and costs of rough mills greatly depend on the grade of material being processed. Lumber grade is based on physical attributes such as size and the proportional area of usable wood. Lumber is estimated to account for 50 – 70 percent of the total costs (material and processing) associated with a rough mill (WCMA 1999, Wengert and Lamb 1994 as cited in Buehlmann 1998). Controlling material costs in the rough mill is a major concern to manufacturers who convert lumber to usable parts. Therefore, due to the high material costs compared to processing costs, secondary manufacturers typically use intermediate quality and priced lumber (Luppold and Baumgras 1996).

In recent years, the demand for intermediate quality lumber has increased along with its price despite a decrease in the quality. Processing this material in a traditional rough mill becomes a costly process. Lower yields are recognized and more lumber must be bought and processed to achieve the manufacturer's cutting bill (list of necessary parts). Furthermore, more cuts are required to remove the usable portions from this material, adding to processing costs. Unfortunately, these clearings are often too small to satisfy the long and wide pieces required in manufacturers' cutting bills. However, methods exist to alleviate this shortcoming. Finger-jointing is a process that creates longer lengths from several short pieces. Finger-jointing can utilize pieces of random lengths but requires uniform widths and thicknesses. On the other hand, edge-gluing is a process that creates wider widths from several narrow pieces. Combining the two techniques allows manufacturers to make solid panels of any width and length within the constraints of today's technology. However, the additional processes also create additional costs. This increased pressure of rising lumber costs and processing costs are beginning to push manufacturing costs to unprofitable levels (Buehlmann 1995).

2.4 Improving Efficiency

In order for US forest products manufacturers to remain competitive, companies must find ways to improve efficiency. Efficiency in this aspect has three components; material, processing and economic. Utilization of the material, in terms of yields, has been a concern for a number of years. A considerable amount of research is available that investigates improving yields in rough mills using state of the art technology and innovative processes. The industry has also been very successful in introducing products such as engineered wood composites that have increased the amount of usable wood from trees. What was once considered waste is chipped and formed into composite panels. These panels are then overlaid with a hardwood veneer (another innovative usage of wood) or some other decorative cover to give consumers the appearance of solid wood. Composites have found innovative uses for wood byproducts and wastes, but the value of the wood has been significantly sacrificed. As a result, the industry has developed several processes through the years that were attempts to salvage or even add value to the low-grade resource.

2.4.1 Green Dimensioning

Green dimensioning was first used in the United States in the 1920's. The drive towards such a concept was much the same as today's; the decline in raw material quality (Gephart et al. 1995). Green dimensioning manufactures defect free dimension parts straight from the sawlog without the intermediate steps of lumber manufacturing, grading, trading, shipping, drying, and storage (Lin et al. 1994, Lin et al. 1995 and Gephart et al. 1995). Gephart et al. (1995) stated that benefits from green dimensioning included: "*1) enhance resource utilization by using low-grade logs; and 2) reduce drying and transportation costs since only usable wood sections are dried and shipped*" (Gephart et al. 1995). Green dimensioning is also a proven method for using low-grade material to economically produce high-value dimension products (Lin et al. 1994). Green dimension stock is commonly referred to as small dimension stock, ready-cut stock, and ready-dimension lumber (Gephart et al. 1995).

A literature review by Gephart et al. (1995) stated that sources of raw materials for the production of hardwood stock through green dimensioning included sawmill residues, pallet stock, lumber, cants, flitches, and logs. They noted that several authors were aware of the use of sawmill residues for green dimensioned material. Using these residues greatly impacted log yield as normally the material would be treated as a wasteful byproduct (Upson and Benson 1923 as cited in Gephart et al. 1995). Logging residues such as tops and large limbs were also investigated as a source for green dimensioned material (Dunmire et al. 1972 as cited in Gephart et al. 1995). Several of the studies involving the use of low-grade lumber and logs are discussed below.

In a study conducted by Lin et al. (1994) green dimensioning Grade 2 and Grade 3 red oak logs was found to be a "*promising method for converting low-grade timber resources into high-value solid wood products*." Their study showed yields for rough green dimensioning parts, based on the average scaling, were 57.8 to 78.5 percent for Grade 2 red oak logs and 52.3 to 76.7 percent for Grade 3 red oak logs. The recovered value for directly processing dimension parts from logs ranged from \$1.34 to \$1.65 for Grade 2 logs and \$1.06 to \$1.37 for Grade 3 logs. The value obtained from processing \$1 of log input into green dimension parts ranged from \$3.62 to \$4.45 of parts output for Grade 2 logs and \$8.82 to \$11.39 of parts output for Grade 3 logs. The ranges reported in Lin et al. (1994) study were results of testing different processes including: live sawing vs. cant sawing and rip first vs. crosscut first rough mills.

The same authors (Lin et al. 1995) used simulation to investigate the impacts of changes in mill configurations, log grade input, and cutting bills. The focus was on the overall production rate (volume of dimension produced) of four different mill layouts: 1) live sawing and gang-rip first, 2) live sawing and crosscut first, 3) five-part (cant) sawing and gang-rip first, and 4) cant sawing and crosscut first. For each mill design the authors simulated 2 log grades (Grade 2 and Grade 3) and 3 cutting bills. Their findings showed that a one headrig mill can produce 12.1 to 22.0 MBF of rough green dimension stock from Grade 2 red oak logs and 9.4 to 14.9 MBF rough green dimension stock from Grade 3 red oak logs in a typical 8-hour shift. Live-sawing mills produced on average 22 percent more than cant sawing mills, however due to bottlenecks in the cant sawing process, increases in capacity for certain machines in the cant sawing rough mill would be needed to produce similar volumes as the live-sawing mills (Lin et al. 1995).

Similarly, Bratkovich et al. (2000) studied a real world example of using green dimensioning on low-grade/low-value lumber otherwise utilized in the production of pallets or sold as firewood. They studied the ability of a pallet stock sawmill to manufacture dimension stock through green dimensioning. The desired part lengths were 12, 18 and 20 to 43 inches at 1-inch increments. The desired part widths were 1-3/4, 2-3/4, and 3-1/2 inches all with a thickness of 1-1/8 inches. The dimension parts were used to manufacture countertops (butcher block style) for recreational vehicles. The scaling yield, "defined as board footage of total product output to board footage of log input" was calculated at 78 percent. Of the 1,876 BF obtained, 1,148 BF or 61 percent was clear dimension parts in 12 to 43 inch lengths and 1-3/4, 2-3/4 and 3-1/2 inch widths. Nearly 30 percent or 344 BF of the dimension output were in lengths of 38 to 43 inches. On a per cord basis, 197 BF of clear dimension parts was realized (Bratkovich et al. 2000).

To successfully implement green dimensioning, manufacturers must develop ways to efficiently handle and dry the stock and markets must change their perception of traditional sawmills (Gephart et al. 1995). Green dimensioning produces numerous random length and width parts, many of them are small and difficult to handle. Drying poses another challenge to the feasible implementation of green dimensioning as sticker alignment and proper stacking techniques need to be further developed.

2.4.2 3-Sided Cant System

Reynolds and Schroeder (1978) investigated the three-sided cant system as a means of producing furniture cuttings from logging residues. In their system, the identification of "good quality residue" consisted of three screening stages. Stage 1 occurred before the sawmill, when bolts were bucked at lengths of 4, 5, 6, 7, and 8 feet with a 2-inch trim allowance. The low-quality or questionable bolts were deemed pulpwood. In the sawmill, bolts were quickly checked for one clear face. The bolts were placed on the sawing carriage with the best face towards the saw and a "light slabbing cut" exposed roughly 3 inches of wood. If the exposed area was poor in quality the bolt was sawn into pallet cants, otherwise, the bolts were sawed into three-sided cants.

The cants were then sawn into boards using a three-saw, single arbor circular gang resaw. This saw was chosen because of its minimal kerf and accurate sawing. All of the boards were sawn parallel to the first cut face from the sawmill process with a 1 1/32 inch thickness. The variation of thickness within-board did not exceed .005 (3/64) inch, while the variation between any 2 boards did not exceed .085 (5/64) inch. No board grading was completed after sawing the cants; however there was a minimal dimension criteria the boards had to meet. If there was not at least a 1-1/2 inch wide by 12-inch long cutting in the board, it was rejected. The study resulted in 1,335 BF of boards sawn from 1,750 BF of cants or a yield of 76 percent.

At the time of the study, sawn boards were too narrow and short to have been processed by the available technology, so a "gang rip first" rough mill was developed from commercially available equipment. The kiln-dried boards were first planed to 7/8 inch thickness using an abrasive planer. After the boards were planed to a designated thickness they were fed through the ripsaw. This particular ripsaw had a 24 inch opening with 8 saws, each with a kerf of 1/8 inch, spaced at (from left to right); 4 inches, 3 inches, 2 ½ inches, 2 inches, 2 inches, 2 inches, 1 ½ inches 1 ½ inches with 4 inches leftover. This set-up resulted in cuttings of 1.5, 2.0, 2.5 and 3.0 inch wide strips. The defects were then marked and removed by a "mark-sensing chopsaw." All cuttings were random lengths with the restriction of a 1 by 12 inch minimum clearing. Yields ranged from 47 – 66 percent. Processing the 4 foot boards resulted in the lowest yield while the 8 foot boards resulted in the highest.

2.4.3 Low-Grade Hardwood Marketing Method

Reynolds and Gatchell (1979) introduced a marketing method that they believed enhanced low-grade hardwood's appeal to manufacturers. Their idea consisted of using the better quality low-grade logs to create valuable dimension parts for furniture and cabinet manufacturers. The remaining low-grade logs were utilized as pallets, pulp chips, and for energy. Loggers harvested the low-grade resources as bolts and the bolts were processed into cants. Cants were sawn into rough dimension parts (Reynolds and Gatchell 1979).

At the stumpage (fee paid for timber) trading point, the low-grade material had a maximum diameter of 12 inches. The idea was to remove enough small-diameter material to improve the timber stand based on the current forest management technology. The price assumed for the stumpage was equal to or slightly above the costs of the logger to remove this material plus the costs of the remaining work required for Timber Stand Improvement (TSI). This offered loggers and land owners the incentive to remove the more valuable small-diameter material while improving the health of the forests. Once the timber was cut, the best 6-foot portion with a diameter between 7.5 and 12 inches was removed from the log. This greatly compromised the potential yield from the log but minimized the crook, sweep and various growing defects that hindered efficient processing. Also, because a majority of the furniture and kitchen cabinet dimension parts were less than 6 feet in length, manufacturing demands were not sacrificed.

At the time of this study it was difficult for traditional sawmills to break-even when processing low-grade logs into lumber. Taking note from previous work (Reynolds and Shroeder 1978), Reynolds and Gatchell (1979) suggested converting these small-diameter bolts into cants in an effort to market a low-cost product and generate profits for sawmills. The idea for reducing costs existed because, at the time, cants could be efficiently produced from bolts using Scragg-type sawmills. Once the cant was produced, the sawmiller was done with processing. In traditional lumber manufacturing, the cant required further processing to extract boards. Furthermore, these boards needed to be graded, dried, graded again and sorted. Reynolds and Gatchell (1979) believed eliminating these additional processes could potentially save costs for the sawmill, enabling them to sell the cants (versus sawn lumber) at a lower price per board foot while maintaining profits.

The cant was to be sold to a newly designed dimension manufacturer. The dimension manufacturer incurred the costs of sawing the cants for boards and drying. Kiln-dried boards were further processed by edging, crosscutting, and planing. Defects were removed unless too much manual processing was required, in such a case the part was discarded for fuel. The resulting product was rough dimension stock that was believed to be competitive with that cut from standard hardwood lumber using traditional methods. At the time, the costs associated with this stage of processing were comparable to conventional practices. The reduced cost in the raw material was intended to offset the additional processing costs of the dimension manufacturer.

Profit margins were generated in the pricing strategy proposed by Reynolds and Gatchell's (1979) research. They realized the success of this method depended on the perceived benefits for each member in the value chain. They reasoned that at each trading point; the resulting product must carry the costs (raw material and processing) and provide a profit for the manufacturer while providing a low-cost raw material alternative for the next link in the chain.

2.4.4 Standard-size Blanks

The "standard blank" concept was studied by Araman et al. (1982). Their focus was to produce a value-added product from low-grade lumber. In their analysis, thousands of individual parts produced by furniture and cabinet manufacturers were studied and grouped according to length, width, thickness, and quality. This information spawned the "standard blank," defined as kiln-dried, "*pieces of solid wood (which may be of edge-glued construction) of a predetermined size and quality*" (Araman et al. 1982). Secondary manufacturers used these blanks to cut the individual parts for their own products resulting in minimal losses of less than 10 percent through end trim (Araman et al. 1982 and Reynolds and Araman 1983). Reynolds (1984) noted that only a rip saw and trim saw were necessary to make parts from blanks. Therefore, for secondary manufacturers who traditionally buy green lumber to produce parts, blanks had the potential to essentially eliminate the need of a large storage areas, air and kiln drying, rough mills and edge-gluing equipment (Reynolds 1984).

The continuing research of Araman et al. (1982) eventually led to 148 different blank quality/width/thickness/length combinations (Reynolds 1984). The proposed qualities were clear, frame, core, or interior at widths of 20- or 26-inches. Available thicknesses varied with quality but blanks are offered in 5/8-, 3/4-, 4/4-, 5/4-, 6/4-, and 8/4- inches. Several studies by the Northeastern Forest Experimentation Station revolved around the use of blanks in furniture and kitchen cabinet products (Reynolds and Araman 1983, Reynolds et al. 1983, and Reynolds and Hansen 1986). These studies focused on blanks manufactured from low-grade lumber and small diameter low-grade logs harvested from the National Forests. Species included red oak, white oak, and black cherry. In each paper it was realized that the contingency of these panels depended on the blanks' width, length, and thickness and their value rested in manufacturers' ability to efficiently produce the necessary parts from these panels.

A market study by Araman and Reynolds (1983) reported the potential for such products offered to craftsmen. A survey booth set up at two popular woodworking trade shows revealed that roughly 92 percent of those surveyed would buy this type of product. Clear-one-face and clear-two-face panels were the preferred quality at thicknesses of 3/4 inch and 1 inch. The research also stated "price, quality, species, and other marketing factors affected the demand for standard-size panels." Specific requirements included: accepted commercial species; panels free of drying stresses and defects; material at 6 to 8 percent moisture content; proper color matching; quality in gluing; and individually wrapped blanks for retailers (Araman and Reynolds 1983).

Araman and Hansen (1983) completed a simulation study for a conventional facility (crosscut-rip-salvage rough mill) to estimate the economics of producing standard blanks. In their study, they assumed the incoming raw material to be green sawn lumber of 70 percent 4/4 and 30 percent 5/4 red oak lumber. Using a previous study (Vaughn et al. 1966), they estimated this green sawn lumber to contain 9 percent FAS, 5 percent Select, 45 percent No. 1 Common, and 41 percent No. 2 Common. Lumber costs were $333 MBF; consisting of a weighted average price (1981) of $293 per MBF with a $40 delivery charge. The results from their simulation showed that with an initial investment of $3 million, blanks sold at an average weighted price of $1.80 (1983 dollars) per square foot would have an after-tax internal rate of return (IRR) of 26 percent for one shift production and 40 percent for a two shift production. The calculated net present value (NPV) at a 15 percent discount was $1,667,075 for one operating shift and $4,985,732 for two operating shifts. The internal cost for manufacturers was estimated at $0.89 to $1.07 per square foot, based on the amount of investment required. Each shift would produce 9.6 MBF of edge-glued blanks (Araman and Hansen 1983).

A follow up study by Hansen and Araman (1985) studied the concept of producing blanks using four different species while scaling down production. This study followed a one shift production schedule with an output of 300 MBF per year of red oak, black cherry, or hard maple blanks or 325 MBF of yellow poplar blanks annually. Assuming a tax rate of 46 percent the estimated after-tax IRR was lowest for hard maple blanks at 31 percent and highest for yellow poplar blanks at 38 percent. The NPV at a 15 percent discount was $213,000 for hard maple blanks and $298,000 for yellow poplar blanks. The initial investment for such a facility was calculated at $204,050. All values are in 1985 dollars (Hansen and Araman 1985).

2.4.5 Past Research on Lean Processing

Today, the more notable research on processing efficiency focuses on the concept of lean manufacturing. Lean manufacturing, borrowed from the Japanese, is a philosophy that reduces or eliminates waste (Cardenas et al. 2005). Waste in this aspect refers to non-value added activities performed during the manufacturing process. Several forest products industries are starting to adopt the practices of lean manufacturing but are finding that certain teachings are creating conflicts in their processes, mainly due to the concepts of inventory control (Ray et al. 2003). Ray et al. (2003) continue their explanation by stating secondary manufacturers with rough mills attempt to control raw material costs by investing in optimization equipment because lumber tends to be their major cost. Increasing the amount of usable wood obtained from lumber reduces raw material costs and increases the potential value for a particular board. Therefore, during optimization of the material, unnecessary parts are often produced and inventoried in an effort to maximize raw material yields. In lean manufacturing controlling inventory is a primary concern. This is usually accomplished in a pull-type manufacturing system where each work station only produces the necessary parts for the next work station. This idea compromises the issue of yields and controlling raw material costs because manufacturers would be discarding usable wood quite often (Ray et al. 2003).

Ray et al. (2003) argued the previously mentioned conflict is less pronounced in industries processing a homogeneous raw material. In such cases, the uniform raw material allows manufacturers the ability to remove the required portions in the most efficient way, because they are not faced with defects or variable sizes that restrict the product and the process. They simply remove the desired piece from the stock whenever necessary. As explained earlier, this becomes extremely difficult when processing heterogeneous raw materials such as lumber. However, there are several wood products in today's markets that better serve important lean manufacturing concepts. Wood fiber based composite panels significantly reduce the space required for storage, act in the same manner as a homogeneous raw material and often give the appearance of solid wood. Several different companies produce and sell such panels and they are readily available in the market. There are no defects to cut around and these panels are available in standard sizes. Therefore, manufactures are able to control inventory through "lean" philosophies. They are better able to calculate costs and yields when processing parts by knowing the size of the panel, size of their parts and the expected losses due to saw kerfs and end trim. Another benefit is realized when the complexity of processing lumber is reduced to simply removing the needed parts without having to cut around defective material. Unfortunately, wood products manufactured out of wood composites are conceived as lower quality than solid wood products in the marketplace. Therefore, such products are not as valuable to the consumer as solid wood products are.

2.4.6 Past Research on Value

The focus is now shifting towards realizing the potential value of hardwood raw materials (Mendoza et al. 1991). Economic efficiency, in this sense, consists of maximizing the value from a particular raw material. Several methods have been developed over the history of the forest products industry. Hardwood face veneer may be one of the best examples of a product that most utilizes value from a hardwood resource. Using a high-quality hardwood log, thin sheets of wood are sliced using different techniques that minimize wasteful byproducts. Even though hardwood veneer is a high-priced product, it requires high priced and high quality logs; a diminishing resource.

One attempt into improving the potential value for low-grade hardwood resources revolves around developing standards to measure quality and establishing values for such materials. Hardwood lumber grades do not account for boards smaller than 4 feet by 3 inches (NHLA 1998). Without standards, values are hard to determine. However, the emergence of the wood components industry has raised awareness to this issue. The wood components industry provides secondary manufacturers with cut-to-size dimension parts and standard-size edge-glued blanks (Lawser 1997). A majority of the parts traded in this industry have dimensions smaller than National Hardwood Lumber Association lumber grade minimums. Therefore, the Wood Components Manufacturers Association has developed a list of rules and specifications that act as guidelines for this industry.

This organization also conducts research and provides publications on buying and selling such products.

Wengert et al. (1987) went a step further by researching a grading system for short-length lumber. For the purpose of their study, they defined short-length lumber as pieces ranging 4- to 8-inches in width and 4- to 8-feet in length. The justification for their research revolved around current grading rules which are not good predictors for the lumber's true value. They conclude that the system was feasible but due to the industry's unwillingness to adopt new standards, the system most likely would not succeed (Wenger et al. 1987).

2.5 Solid Hardwood Panels

If the domestic forest products industry wants to stay competitive in today's global economy, it must develop and market products that utilize low-grade material in the most efficient way. Knowing that consumers demand solid wood products for which premium prices are paid, one suggested option is solid hardwood panels. Solid hardwood panels are standard-size, finger-jointed, edge-glued blanks manufactured from a deciduous tree. Panels provide an excellent opportunity for the value-added wood industry to compete internationally through innovation and cost competitiveness (Tabarsi et al. 2003). This solution offers a lower cost alternative to the conventional rough mill and an opportunity to utilize species and grades of lumber that have traditionally caused problems for secondary manufacturers (Araman and Lamb 1990). Solid hardwood panels have the potential to (1) better utilize the raw material, (2) offer primary manufacturers a value-added product for low-grade lumber and sawmill residuals and (3) reduce the manufacturing costs for secondary wood processors. Evidence shows it to be a viable business in the U.S. as edge-glued panels account for roughly 13 percent ($650 million - U.S.) of the $5 billion (U.S.) wood components market (WCMA 2001 as cited in McDaniel 2003). Furthermore, there are over 80 manufacturers producing panels and marketing them towards a broadly defined group of industrial manufacturers who produce furniture, doors and various other solid wood products (WCMA 2004 and Tabarsi et al. 2003).

2.5.1 Past Research on Solid Hardwood Panels from Underutilized Material

The realization of the potential of using low-grade material for solid hardwood panels began in the late 70s at the USDA's Forestry Service's Northeastern Experiment Station. Several researchers started investigating the dynamics of a business that produces panels from small-diameter timber. Their comprehensive research consists of studying parts manufactured by secondary producers to develop a standard-size panel program. They created a series of 148 different size and quality panels that allowed furniture and kitchen cabinet manufactures to cut their parts from these panels with less than 10 percent trim losses (Araman et al. 1982 and Reynolds and Araman 1983). To manufacture these panels they developed System 6.

2.5.1.1 System 6

System 6 was an innovative processing technique that utilized short and small in diameter logs. System 6 was an integrated system designed to add value to these low-grade, small-diameter logs by manufacturing dimension parts and standardized panels for furniture and cabinet manufacturers (Bumgardner et al. 2001). The idea behind System 6 was actually a culmination of a number of studies completed by the Forest Service. Reynolds and Gatchell's (1979) three sided cant system and Araman's (1982) standard blanks were the backbone studies to the System 6 technology. Reynolds and Gatchell (1982), the lead authors of the system 6 idea, reported four concepts that differentiated System 6 technology from traditional methods of converting hardwood logs into furniture and cabinet components. These included: (1) standard-size blanks represent the end product instead of lumber; (2) highly automated techniques process logs into blanks; (3) every board with a minimum-size cutting is processed; and (4) minimal human decisions with limited choices. Unfortunately, major challenges to System 6 at the time included the lack in technology that allowed manufacturers to properly handle and dry small random size pieces as well as the inability to efficiently match slats to produce panels of a uniform color. These deficiencies made it difficult to satisfy consumer preferences in an economically competitive way. Figure 2.3 shows a material flowchart for System 6.

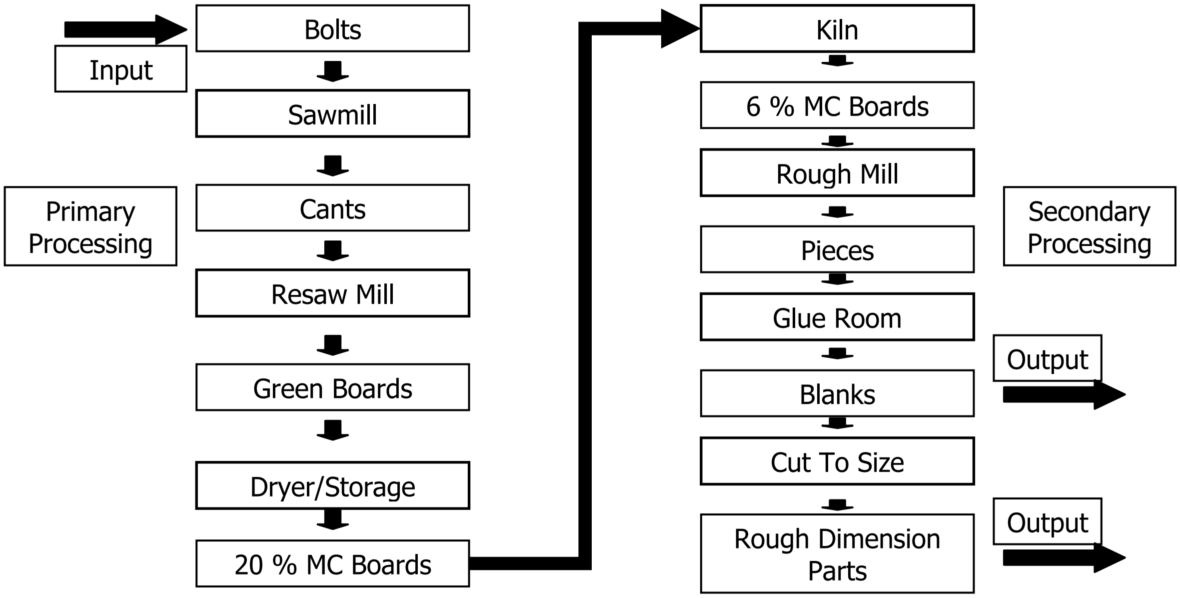

Figure 2.3 Flowchart of System 6 (Reynolds and Gatchell 1982 and Reynolds 1984).

2.5.1.1.1 System 6 Logging

The system started with loggers bucking stems to 6 feet (75 inches actual) or 8 feet (99 inches actual) with no more than 1 ½ inch of sweep and diameters between 7.5 to 12.5 inches. Each bolt was sound and solid. The logger made the decision on a System 6 bolt or a pallet bolt, pulpwood, or firewood. Sweep and crook were difficult characteristics to deal with at the time due to technology. To limit the effect of sweep and crook, past studies showed a log bucked to 6 feet best reduced sweep while allowing for an acceptable yield (Reynolds and Schroeder 1978). Diameter restrictions resulted from the bolt being sawn into two cants. The minimum thickness on a cant was set at 3-1/4 inch and a log diameter of 7.6 inches was the smallest size that will yield two 3-1/4 inch cants. The upper diameter limit was set at 12 inches because traditional sawing equipment made better use of logs with diameters above 12 inches, than System 6. Cants of 4 inches were expected from bolts near the upper limits.

2.5.1.1.2 System 6 Primary Manufacturing

Sawmills manufacturing under System 6 produced two-sided cants instead of lumber. Reynolds and Gatchell (1979) suggested that technology existed that would allow sawmills to operate profitably while producing 2-sided cants. The procedure was: (1) the bolt was loaded on the carriage and a light 3-inch slab reveals a face for inspection; (2) the bolt was rotated 180º; (3) a second cut was made leaving the bolt at a thickness equal to two 3-1/4 inch cants or two 4 inch cants plus the kerf; (4) the last cut produced the two cants. Figure 2.4 shows how the different size logs will be processed and the resulting 2-sided cants.

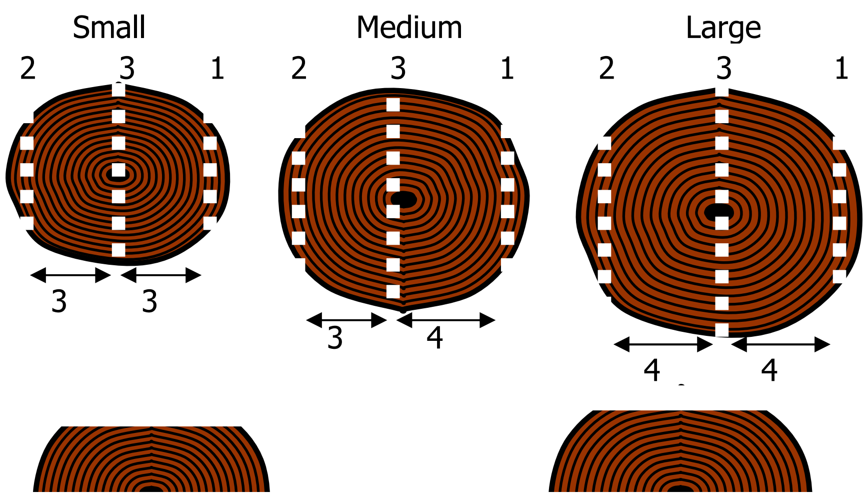

Figure 2.4 System 6 log processing resulting in 2-sided cants (Reynolds and Gatchell 1982).

The two-sided cants were processed using automated cant sawing equipment. Automation was feasible in this situation because the lack of higher quality material reduced the necessary human decisions and processes to produce high-grade lumber (Reynolds and Gatchell 1982). Circular gang resaws were the equipment of choice because they were relatively inexpensive but accurate. They were also proven by years of use in pallet manufacturing plants operating under the same techniques.

The entire cant must be sawn in one pass to minimize the effects of growing stresses in the small-diameter cants. In traditional sawing, boards were cut one at a time. For this situation, the time between cuts may have been long enough for the growth stresses to be relieved and the cant may have experienced crook, bow or twist. The next cut would have resulted in lumber with a thickness variation. To offset this phenomena the whole cant was sawn at once (Reynolds and Gatchell 1982).

Saws were placed on the arbor at uniform distances because under System 6 to ensure proper stacking techniques for drying, all boards needed to be the same thickness. The boards were immediately stacked for drying after the cant saw. All the boards not containing a 1-1/2 inches wide by 15 inch long cutting were discarded.

After sawing, a majority of the boards were 3 ¼ inches or 4 inches wide by 6 feet or 8 feet long with a uniform thickness. Boards towards the edges of the cants were less wide due to the curvature of the log. The stresses associated with this material made drying one of the more critical steps in System 6 (Reynolds and Gatchell 1982). During the study, boards were immediately stacked for drying after the cant saw in 4 x 4 x 6-foot packages. Smooth ½ inch-thick stickers were placed between layers on 2-foot centers. The thinner stickers prevented the surfaces of the boards from drying too fast in the initial stages of drying, while their smoothness promoted mobility and allowed the boards' drying stresses to be relieved during drying (Reynolds and Gatchell 1982). The packages were banded using a polypropylene strapping and allowed to air dry or subjected to forced-air predrying. Once in the kilns, a schedule of liberal equalizing and conditioning times should have produced flat, stress-free boards.

2.5.1.1.3 System 6 Rough Mill

As with any rough mill the object is to process kiln-dried lumber through a series of machines into high quality dimension stock in the cheapest way possible (Buehlmann 1998). Traditional rough mills process various species, grades, and thicknesses of lumber to satisfy a parts list, known as a cutting bill. Often, the incoming raw material is of intermediate quality that requires extensive processing to remove the clear parts. This requires complicated decisions by operators and/or computers and consequently the effectiveness of the rough mill is dependent on operators' skill/experience and the amount of capital investment manufacturers have spent on technology. The end product is defect free stock that has been cut to a variety of specified lengths, widths and thicknesses. Figure 2.5 represents the material flow through the System 6 rough mill.

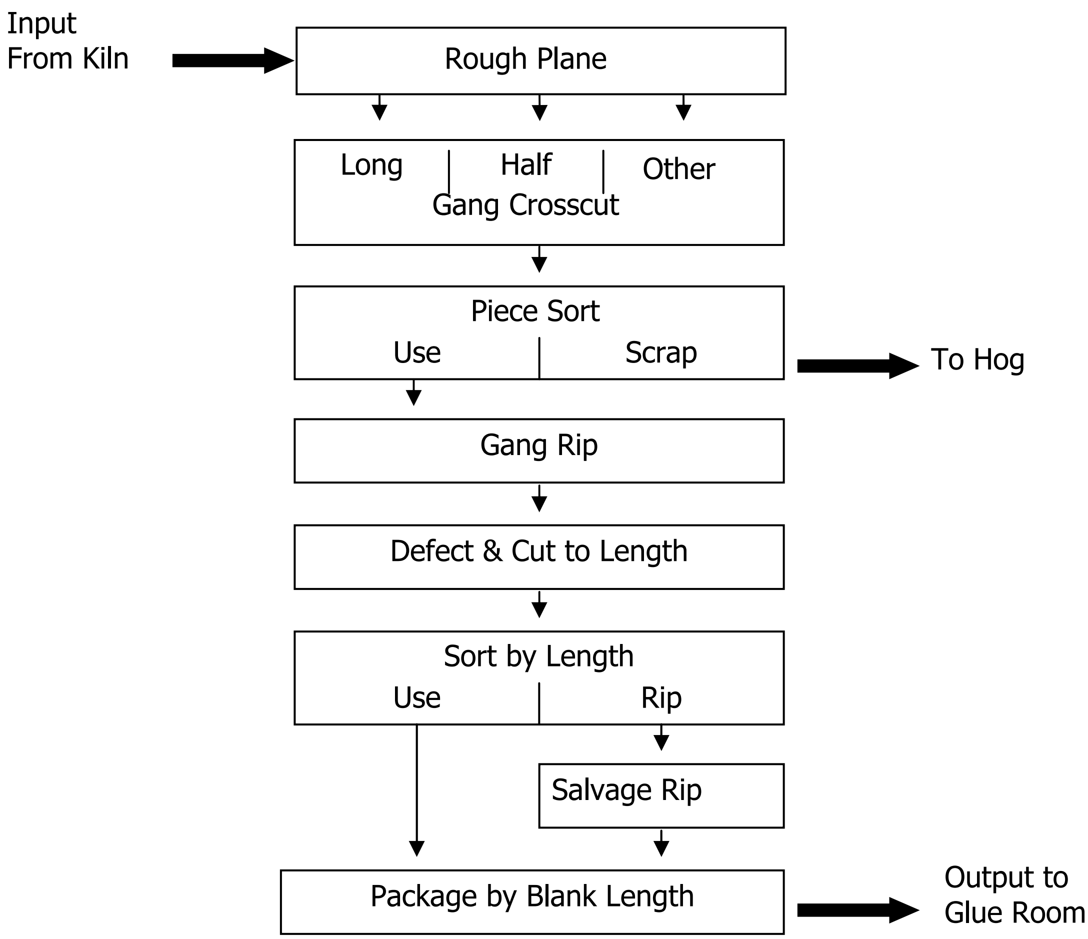

Figure 2.5 Flowchart of System 6 rough mill (Reynolds 1984).

In the System 6 rough mill, the designers attempted to create an efficient and practical manner to utilize the low-grade material (Reynolds 1984). System 6 produced blanks in four qualities, two widths, and six thicknesses, but not all width and thickness combinations were produced. The results were standard-size blanks offered in 13 different quality/width/thickness combinations. In the System 6 rough mill, only 1 of these 13 different blank combinations in all of the standard lengths was produced during a run.

In System 6, kiln-dried boards were of extremely low grade because of the nature of the raw material. Past studies showed that 1/2 to 2/3 of all boards were below 3A Common standards. Reynolds and Gatchell (1982) developed techniques to remove the defects from these boards in a rapid and efficient manner. Operators chose the best of a limited number of cutting options for a particular board and the board was automatically processed. Each board entered a gang crosscutting saw that produced 1 to 4 pieces from each board. Spacing in between the saw blades on the gang crosscutter was set in intervals to produce blanks of the lengths most needed. An estimated 10 percent of the boards (Board Quality 1, Figure 2.6) would have a clear cutting that was roughly the full length of the board. This board was only trimmed on the end by the outside saws. This action is represented in Figure 2.6. In some instances (approximately 20 percent), boards would have defective areas towards the end of the board (Board Quality 2 in Figure 2.6). In this case a full length cutting was not feasible. The operator chose which direction to run the board through the gang crosscutter to optimize the clear area in that board. All other boards (approximately 70 percent) would have contained small clear areas scattered throughout the board (Board Quality 3 in Figure 2.6). In this instance, the operator chose which direction to run the board through the saw to optimize clear areas. The only decision the operator made was whether to turn the board from end to end to minimize defects and maximize lengths.

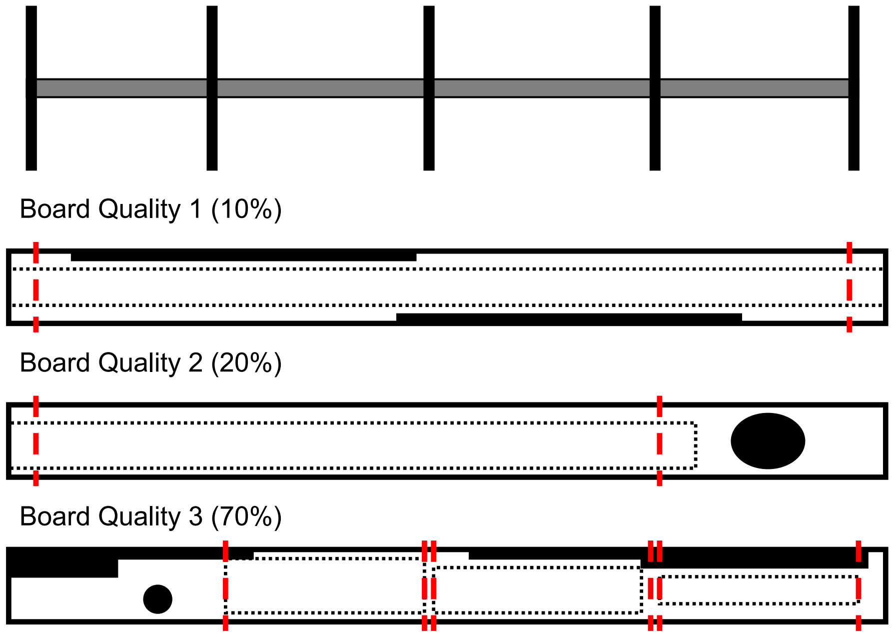

Figure 2.6 Gang crosscutting System 6 boards (Reynolds 1984).

Once the boards were cut to length, each piece was inspected for a minimal size cutting and further processed using a gang ripsaw. Saws were placed on the arbor at ½ inch increments resulting in standardized widths of 1-1/2, 2, 2-1/2, 3, and 3-1/2 inches. The incoming boards were either 3-1/4 inches or 4 inches wide. In an effort to speed processing and reduce the number of decisions made by the operator, only one pass was allowed for each board. The inspected boards were placed in one of the five pockets and cut to the specified width with ¼ inch edge trim allowance. At this point it was estimated that 80 percent of the defects have been removed. The boards were again sent through a crosscut machine to finalize defect removal and a glue-joint ripsaw if necessary. Both of these processes were operated manually. "*System 6 secondary processing was designed to run without interruption until all the boards to be cut by the given GCL (Gang Crosscut Lengths) have been used* (Reynolds et al. 1983)."

The end products were cuttings of limited widths, lengths, and thicknesses. These "standardized blanks" were marketed towards furniture or kitchen cabinet manufacturers as rough dimension stock. The blanks in 1-1/2 inch to 3-1/2 inches increments worked well for small narrow parts, whereas larger parts could be made from edge-gluing these standardized-blanks together into panels. In addition there were byproducts which were marketed as well. These included slabs from sawmills; discarded boards and cants from processing; edgings and trimmings; and green and dry sawdust.

2.5.1.2 System 6 Feasibility Studies

The system's capabilities were studied in three published reports from the USDA's Forest Service's Northeastern Forest Experiment Station. Reynolds and Araman (1983) tested System 6 while making frame-quality blanks from white oak thinnings. Their results showed they obtained approximately 850 BF per acre of 6-foot white oak sawbolts (using International ¼-inch rule) (Reynolds and Araman 1983). They noted that the quality of the incoming sawbolts was very poor, 72 percent were 9-1/2 inches in diameter or less. From the total production of 3,233 BF, only 32 percent of the boards made at least a grade of 3A Common. The study showed a 58 percent yield of incoming board footage for secondary manufacturing using all of the System 6 boards regardless of grade. This yield was high because of the number and type of defects that were allowed in frames versus exterior parts. The authors suggested that System 6 was an effective technology for producing frame-quality blanks (Reynolds and Araman 1983).

In another study, Reynolds et al. (1983) investigated the economics behind producing Clear 2 Face (C2F) dimension stock for kitchen cabinet manufacturers. They estimated, in 1982 dollars, an investment of $1.8 million could produce 16 MBF (thousand board feet) of blanks from cants in one 8-hour shift. Their study included all the necessary primary, secondary, drying, and energy equipment along with the buildings and land. They used low-grade red oak cants with a derived value of $180 per MBF. Primary processing yielded 960 BF of boards for every MBF of cants. Boards meeting a grade of 3A Common or better accounted for 40 percent of the total output. The other 60 percent graded below 3A Common. After kiln-drying, pieces followed the System 6 process. However, in an effort to increase yields, an extra process known as serpentine end matching (sem) was used for scrap pieces to make 25-inch long blanks. In this process short scrap pieces were matched by width, grain and color and joined end to end through "sem" to the desired length.

Two manufacturing options were discussed in Reynolds et al.'s (1983) paper. "Option 1" used lengths cut from all the boards using two different gang crosscut setups and the manufactured sem strips. This option yielded C2F blanks at 35% of the raw material input. At the time “Option 1” showed a 21.3 percent rate of return after taxes with an investment of $2.1 million (Reynolds et al. 1983).

“Option 4” used only lengths cut from the 3A Common and Better boards during the 2 gang crosscutting setups. Sem strips were not included in “Option 4”. This option yielded C2F blanks at 41.7 percent of the raw material input. The capital investment in this option was $100,000 less because no sem equipment was required. At the time, “Option 4” returned 20.9 percent after taxes for a $2 million investment. Yields were much lower than the previous experiment because in this experiment blanks required two clear faces (Reynolds et al. 1983).

2.6 Literature Review Summary

The wood products industry is an integral part of the American economy because of its creation of capital and employment opportunities. This is particularly true for many small towns throughout the U.S. whose local economy is supported by such manufacturers. Current day threats such as global competition and a decline in the quality of the raw material has forced the industry to research new products and processes in an effort to stay competitive. One industry initiative is innovative products manufactured from underutilized resources. This push is extremely important to the future of the wood products industry because it not only better utilizes the limited resource but will also offer landowners the economic incentive to remove problematic resources such as small-diameter material and non-commercial species from their forests. Such acts will improve the health of timber stands and ensure a high-quality timber resource for future generations.

Past research suggests that one viable product to satisfy today’s concerns is the solid hardwood panel. Solid hardwood panels consist of several smaller sized clear cuttings finger-jointed for length and edge-glued for width. Underutilized resources such as sawmill slabs, small-diameter timber and low-grade lumber are potential sources of raw materials for solid hardwood panels. Several concepts such as green dimensioning, System 6 and the 3-sided cant system have suggested the potential of low-grade resources while changes in the industry such as lean manufacturing and a focus on being efficient have expressed the need for panel products.

2.7 Research Problem Statement and Goal

Unfortunately, the past research on System 6 was never implemented in the industry. Several factors are given as reasons: System 6 required secondary producers to modify their operations at a time when such changes may not have been necessary (Reynolds and Gatchell 1982); the need for utilizing such material was not as evident as it is today; the technology reached a limited number of manufacturers; and the industry has historically been labeled as one that is not receptive to change. However, the aforementioned conditions of today's industry suggest a reevaluation of such a project. In the last 25 years, the industry has seen major changes. Little research on solid hardwood panels is available since the System 6 project; and if this is to become a viable manufacturing option, an update is needed. This up-to-date research will provide the industry a better understanding of one option available for manufacturing, marketing, and selling their products produced from low grade resources. Therefore, the goal of this research is to demonstrate through a business model concept, that underutilized forest resources such as sawmill slabs, low-grade lumber and small-diameter roundwood can be used as a raw material to manufacture solid hardwood panels in an economically viable way.

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Chapter 3

3 Raw Materials

3.1 Introduction

One goal of this research is resolving the issues associated with profitably manufacturing solid hardwood panels from underutilized resources. The underutilized resources considered for this study are small-diameter roundwood, low-grade lumber and sawmill slabs. Small-diameter roundwood is a low-grade resource in the forests. Sawmill slabs are a necessary byproduct when sawing roundwood into grade lumber.

Small-diameter roundwood, low-grade lumber and sawmill slabs are considered underutilized because their full potential is not realized in today's markets and manufacturing processes. Low-grade material is identified by excessive knots, lack of straightness, and is small in size compared to other available wood resources. In each case, the material under investigation contains clear usable wood, however processing and removing these portions is difficult, costly, and often results in low yields of short, narrow clearings that have limited applications. Therefore, sawmills and secondary manufacturers wish not to process such raw materials because of high costs associated with its low quality. This material begins to accumulate in the forests as well as the markets resulting in excess inventories that exceed the demand.

The purpose of this chapter is to identify and quantify the amount of underutilized material available for manufacturing solid hardwood panels. The literature review begins the discussion of the terms, values and grades, and their correlation to one another. Next, the underutilized resources of interest are listed, defined and discussed as well as the grading standards that allow buyers and sellers to evaluate each resource. An understanding of grades and value gives a better insight into exactly why this material is considered underutilized. Reviewing past research on utilizing low-grade resources, more specifically lumber, provides the basis for the research design for a computer simulation that quantifies the amount of usable material obtainable from such underutilized resources. Finally, the results of the computer simulation are discussed.

This knowledge is important to an entrepreneur or facility investigating the feasibility of a solid hardwood manufacturing enterprise. Raw material costs for component manufacturers often reach 50 percent of the total product costs (Lawser 2004). Knowing the availability, costs, and resulting yields of this type of material provides a sound starting point in investigating and evaluating the economic feasibility for such a business venture.

3.2 Literature Review

3.2.1 Low-Grade/Low-Value Material

The terms low-value and low-grade are strongly related but most often do not mean the same thing. Luppold and Bumgardner (2003) defined the factors that are associated with these terms. They stated that value is an economic characteristic that is decided by markets. A number of factors can affect value, including but not limited to; supply, end-users demand and processing capabilities. The value of a particular material will change with corresponding changes in factors affecting value. Grade, however, is a physical characteristic decided by standards. Associations set standards on the quality of material that manufacturers produce. Although grading standards vary according to organizations and disciplines they are very similar and remain constant over a period of time. (Luppold and Bumgardner 2003)

Low-value refers to a product's price that is relatively lower than similar products (Luppold and Bumgardner 2003). In the hardwood market, value is correlated to supply, demand and processing capabilities. Supply and demand is affected by time, consumer preferences and innovation (Luppold and Bumgardner 2003). The supply of hardwood material is controlled by the growth in the forests. The price for a particular species may become lower as the supply of that species becomes more available and vice versa (Luppold and Bumgardner 2003). A species' value can also change as market preferences change. If a species becomes more desirable, its price will go up (Luppold and Bumgardner 2003). Processing capabilities, technology and product innovation also affect the value of a particular resource. Several factors affect a raw materials' value but generally, a common hardwood resource that is difficult to process and yields little usable portions of wood is considered low-value. On the other hand, this material may increase in value if technology or innovative uses are developed to utilize the low-value resource.

This inadvertently would increase demand as well as prices (Luppold and Bumgardner 2003).

Low-grade refers to a product's physical attributes that restricts its production efficiency and product serviceability when compared to similar products (Luppold and Bumgardner 2003). Low-grade is a direct reference to the quality of the raw material. The quality of the raw material greatly affects the efficiency and profitability of forest product companies' manufacturing processes. For manufacturers producing solid hardwood products, a low-grade raw material generally results in small useable portions requiring extra processes at low yields and higher costs.

Grades were established to give "*buyers and sellers a uniform basis for assessing the quality of the product being exchanged*" (Cassens and Fischer 1992). Grades also help manufacturers determine the cost and waste expected from each purchase (AHEC 1992). Different grading standards exist based on the form of the raw material and its intended use. Trees, logs and lumber are graded under different standards in the U.S. hardwood industry. Growing trees are covered under the United State's Department of Agriculture's Forest Service (USDA Forest Service) tree grades, logs are covered under the USDA Forest Service's log grades, and lumber is covered under the National Hardwood Lumber Association's (NHLA) lumber grades.

3.2.2 USDA's Forest Service Timber Grading

Standing trees in today's forest are the resources that will serve the future needs of the forest products industry. Judging the quality and potential of a growing tree is a difficult but necessary task for properly managing forests. Therefore, grading standards exist that specify a growing tree's potential at maturity (Boyce and Carpenter 1968). Most live standing trees (and in some instances dead standing trees) are considered growing stock by the USDA's Forestry Service. Trees not considered growing stock include non-commercial species and those unsuitable for sell, i.e. rotten or excessive defects, crook, or sweep. To judge the maturity of growing stock, this class is further divided into two overlapping groups based on tree diameter because trees growing in favorable conditions increase their diameter as they mature. Hardwood growing stock over 5 in. in diameter at breast height (DBH) is deemed pole timber. Growing stock over 11 in. at DBH is considered sawtimber, if the butt logs contain one 12 foot sawlog or two

8 foot sawlogs (Luppold and Bumgardner 2003, Bumgardner et al. 2001, and Araman and Lamb, 1990). As the name implies sawtimber is mature and harvestable.

3.2.2.1 Small-Diameter Roundwood

Small-diameter roundwood (SDR) results from harvesting growing stock trees that have a DBH between 5 and 11 inches (Bumgardner et al. 2001). SDR presents many problems throughout the supply chain. At the forest level, overpopulated ecosystems suffer from the amount of small-diameter trees (Wolfe 2000). Research on SDR stands suggests that heavily populated areas have a higher tendency to succumb to drought, disease, and/or damaging wildfires (Wolfe 2000, LeVan-Green and Livingston 2001, Cantrell et al. 2004). Traditional forest management practices would call for mechanical thinning and prescribed burning to enhance the health of the stand and hopefully the quality of the remaining trees (Paun and Jackson 2000, LeVan-Green and Livingston 2001, Paun and Wright 2001). Thinning is particularly important for eastern hardwoods, where low quality timber is removed to allocate additional growing space for the higher quality, more desirable trees (Baumgras 1992, Cumbo et al. 2004). For this reason, it is believed future government interaction and proper forest management practices will insist on land owners removing this material (Cantrell et al. 2004). Unfortunately, once removed from the forests, small-diameter roundwood becomes a major source of the low-grade/low-value material traded in today's hardwood markets.

Removing this material is not economical because costs exceed the perceived value assumed in the different markets where it is sold. In 2000, Wolfe (2000) stated the average value for this material was \$26 to \$60/green ton. Levan-Green and Livingston (2001) believed the average cost for the Forest Service to properly thin a timber stand is \$70/dry ton while the return is only about half of that cost at \$25 to \$35/dry ton in the energy and chip markets. Therefore an economic barrier for timber stand improvements exists because the cost of removing, transporting, and processing this material from the forest is higher than the market value (Wolfe 2000). An increase in market value for this material through innovative processes and products will help recover the cost of thinning and improve the overall health of our nation's forest.

A census study from the USDA Forestry Service (1983-1998) revealed that 32 to 42 percent of the United States forest volume consists of growing stock considered poletimber, but these trees account for 93 to 95 percent of the total number of growing trees (Bumgardner et al. 2001). This study backs up the assumption of the nation's forest being stagnant and overstocked. The result is a decrease in the supply of high quality, large diameter roundwood. To alleviate this problem, proper forest management techniques include the identification, classification and removal of a large portion of small-diameter material from the forests. This would improve the growing conditions for traditional commercial species.

In the short run, the industry can expect an abundance of small-diameter material in the market. A thinning study of two Virginia oak-hickory stands by Craft and Baumgras (1979) resulted in roundwood products as follows: 20 percent sawlogs (10 inch diameter by 8 feet length, minimum Factory Grade 2); 4 percent poles (6 inch diameter by 8 feet long); 27 percent 6-foot sawlogs (8- to 12-inch diameter by 75 inches long, sound, with a minimum of 1-1/2 inch of sweep; 14 percent 4-foot sawbolts (6-inch diameter minimum); 32 percent pulpwood (5-foot length minimum); and 3 percent firewood (Craft and Baumgras 1979 as cited in Reynolds and Araman 1983). Craft and Baumgras' (1979) research concluded that there was a considerable amount of material from a thinning that was underutilized, specifically the 6-foot sawlogs (27 percent) and the 4-foot sawbolts (14 percent) because grading standards classified it as low-grade.

Small diameter material is low-grade and low-value for many reasons. "*Lower grade logs yield primarily lower grade lumber*" (Cumbo et al. 2004). A study by Holtzscher and Lanford (1997 as cited in Cumbo 2004) suggested that as tree diameter increased, the cost of producing lumber decreased. The width of the lumber processed from any log is restricted by log diameter. By definition, SDR has a DBH between 5 and 11 inches. NHLA lumber rules (Table 3.2) state that the minimum width of a Select and FAS board is 4 and 6 inches respectively (NHLA 1998). A study by Cumbo et al. (2004) revealed that board widths were largely concentrated in the 4 inch range for logs with diameters less than 8 inches. It was only when 9 and 10 inch diameter logs were sawn that they started to obtain widths of 6 inches or wider. Their study revealed Factory Grade 2 logs primarily produce lumber with NHLA grades of 2A, 2B, and 3A, and Factory Grade 3 logs primarily produce 3B or lower.

Other characteristics of small-diameter roundwood contributing to its low-grade and low-value are its high concentrations of knots, sapwood, and juvenile wood when compared to older, more mature trees. The presence of knots restricts grades and requires more processing to get clear pieces. Furthermore, a smaller portion of the small-diameter log is heartwood. In most domestic hardwood species, the heartwood contains extractives that give the species its distinctive color. Often the sapwood is lighter in color and results in discoloration or unwanted shades of the finished product. Color uniformity is another desired characteristic by end users particularly in situations where the part is exposed (Cumbo et al. 2004). Also, this smaller portion of heartwood my contain pith. Pith is a problem because as it dries it tends to disintegrate and leave a hollow opening. Pith is restricted in FAS, Selects, and 1 Common boards under the NHLA grading standards (Table 3.2). The larger proportions of juvenile wood are also a concern. Juvenile wood is structurally different than mature wood and physically and mechanically unstable. Processing juvenile wood presents problems with warpage, shrinking and swelling, and unpredictable mechanical properties (Patterson and Xie 1998).

3.2.3 USDA's Forestry Service Log grading

Roundwood to be used for the manufacturing of lumber must be cut into shorter lengths before the sawing process. These shorter lengths are referred to as sawlogs and generally exist at even number lengths such as 6, 8, 10 or 12-feet. Just in the same manner as standing timber, the potential for a sawlog is evaluated through the United States Forestry Service's log grades. Log grades allow foresters, timber sellers and timber buyers a method of differentiating logs into distinguished classes based on how suitable the log is for manufacturing a class of products (Rast et al. 1973). Standards provide a static set of parameters that separate cut logs into two or more different grade classes based on the expected output from that log. In the Forest Service's system, four grades classes exist based on end use. These classes include; veneer class, factory class, construction class, and local-use classes.

Logs classified under the factory class are marketed and sold to sawmills for the production of factory lumber. These logs are labeled sawlogs. Sawlogs are cut from the stems (lower portion of the tree) and must meet an 8 ft length requirement. All logs shorter than 8 ft are considered bolts. Bolts are not considered factory class material regardless of the quality of the wood but can be considered under other classes. The factory class is divided into three grades; grade 1 (F1), grade 2 (F2), and grade 3 (F3). The grades were developed to represent a total lumber tally for each lumber grade class defined by the NHLA, with the requirement of "*significant differences in unit value or in end product yield between the log grades*" (Hanks et al. 1980). This classification allows markets to derive a value for logs using grades (expected yield), manufacturing costs, and the current price of lumber (Hanks et al. 1980).

Bond (1999) listed the expected NHLA lumber yields based on log grade. Over 60 percent of lumber should grade better than No. 1C for grade 1 logs, 40-60 percent for grade 2 logs, and less than 40 percent for grade 3 logs. However, the true expected yield for each NHLA lumber grade actually removed from the sawlog is dependent on species and measurable characteristics (Rast et al. 1973). Sawlogs are further separated within each species into distinct categories based on their characteristics. Log diameter, log length, log position, clear cuttings, sweep and crook, scalable defects and sound end defects are the measurable variables that allow graders to properly classify logs. Log diameter is measured inside the bark at the small end of the log. Log length is important for grade 1 logs, where a 10 ft. minimum is required. Grade 2 and 3 logs must be at least 8 ft. long. Log position refers to its position in the stem. Butt logs are the logs removed from the lower part of the stem and must be greater than 13 inches in diameter to register as a grade 1 sawlog. Logs removed from the top potion of the stem are referred to as uppers and must measure 16 inches in diameter to register as grade 1 sawlogs. Sweep and crook is measured to estimate the potential volume lost during sawing.

During the sawing process, the sawyer removes a small portion of the outside wood and bark in an attempt to judge the true quality of the wood inside the log. The portion of material removed is referred to as a slab. The exposed area is referred to as a face. Clear cuttings are measured on the three best faces of the log. Clear cutting rules for logs are based on those imposed by NHLA lumber grading rules (Table 3.2) but basically represent defect free zones. Defects have been defined by The Society of American Foresters as "*any irregularity or imperfection in a tree, log, piece, product, or lumber that reduces the volume of sound wood or lowers its durability, strength, or* *utility*" (Rast et al. 1973). Scalable defects are rot, shake and sweep and crook. Sound end defects include defects that do not cause a loss of mechanical properties. These include gum spots, bird pecks, bark pockets, and stain. Table 3.1 describes the grades based on the discussed variables.

Table 3.1 United States Department of Agriculture Forestry Service standard grades for hardwood factory lumber logs (Rast et al. 1973).

Grading Factors		Log grades							
		F1			F2				F3
Position in Tree		Butts only	Butts & Uppers		Butts & uppers				Butts & uppers
Scaling diameter, inches		13-15	16-19	20+	11+	12+			8+
Length without trim, feet		10+			10+	8-9	10-11	12+	8+
Required clear cuttings on each of 3 best faces	Min. length, feet	7	5	3	3	3	3	3	2
	Max. number	2	2	2	2	2	2	3	No limit
	Min. proportion of log length required in clear cutting	5/6	5/6	5/6	2/3	¾	2/3	2/3	½
Maximum sweep & crook allowance	For logs with less than ¼ of end in sound defects	15%			30%				50%
	For logs with more than ¼ of end in sound defects	10%			20%				35%
Maximum scaling deduction		40%			50%				50%

3.2.3.1 Slabs

Slabs are byproducts from squaring timber at sawmills. During sawmilling a round log produces solid rectangular products (lumber). In order to begin the extraction of these rectangular pieces, a portion of the round log must be removed to expose an open face. The open face allows the sawyer to evaluate the quality of the log and the best suitable sawing technique for maximizing yield and value from the log. Eventually, this exposed face will become the face of a board. Since log grades are based on an expected yield of NHLA grades, the size of the slab (and open face) is dictated by the grade of log being processed. For example, based on NHLA standards the minimum size width for Common boards is 3 inches. Therefore, when sawing for Common board grades a light slabbing of 3-½ inches is recommend to maximize scale (Malcolm 2000). This 3-½ inch measurement is the width of the face (exposed wood) after the slabbing. If sawing for FAS, a heavy slabbing of 6-½ inches is recommended (Malcolm 2000).

Diameter, taper and sweep are other factors affecting the amount of wood removed during slabbing. Large diameter logs yield more lumber. They also require a less shallow slabbing cut to reveal a face. Taper or truncated cone effect is a condition associated with having one end of cylindrical shaped object significantly larger in diameter than the other, as is the case with most logs. The amount of taper is a function of log length and species. Generally, on long sawlogs, there is a large difference in the diameters on the opposing ends. Some species are genetically prone to taper more than others. The geometry of a tapered log makes it extremely difficult to efficiently generate the rectangular shapes of lumber (Steele 1984). The same is true for sweep. Sweep is defined as a bow in the log. Heavy slab loses are expected in logs with significant taper and sweep.

Unfortunately, slab cuts are removed from the clear, high quality portion of the logs. However, because the usable portions of wood contained in slabs are short and narrow, NHLA lumber grades (Table 3.2) do not consider this material in their standards (NHLA 2003, Smith et al. 2002). Without a way to classify the material's quality (e.g. grades) it becomes difficult to market and value the stock cut from slabs. Furthermore, the additional processing required to remove the usable portions of wood from slabs is costly. Most manufacturers are unwilling to conquer the tasks of processing, marketing, and selling the smaller usable portions removed from slabs. Therefore, the potential usable material contained in these slabs is often chipped into a low-value product.

3.2.4 National Hardwood Lumber Association Lumber Grading

Standards for lumber were developed by the NHLA at its inception in 1897 and are universally accepted (Cumbo 2000 as cited in Shepley 2002). Occasionally, the

NHLA will submit changes to the lumber standard based on the supply of timber and the industry's needs (NHLA 2003). Lumber is used in many different ways to manufacturer consumer products. Often times it is used to produce goods such as furniture, cabinets, doors, and flooring were buyers wish for an aesthetic appeal. For this reason manufacturers need large amounts of clear lumber to competitively produce such products. Therefore, NHLA grades are based on the size and number of clear cuttings or its usable portions aside from undesirable characteristics considered defects. A clear cutting is defined by the NHLA as a "*portion of a board or plank obtained by cross-cutting or ripping, or by both, having one clear face and the reverse side sound, or free from rot, pith, shake and wane*" (NHLA 2003). Lumber defects include knots, wane, crook, decay, and splits. Grades are based on percentage of clear wood regardless of overall appearance (AHEC 1992).

Table 3.2 describes the NHLA grades and the necessary minimum requirements for a board. Grades are determined by the ability of the board to produce the minimum amount of required clear cutting area based on a minimum size and a maximum number of cuts. The number of cuttings allowed is determined by surface measure. Surface measure is the area of the board in inches.

Table 3.2 Standard hardwood lumber grades and their minimum requirements (NHLA 1998).

Lumber Grade	FAS	Selects	#1 Common	#2A	#3A	#3B
Min. Width	6"+	4"+	3"+	3"+	3"+	3"+
Min. Length	8'-16'	6'-16'	4'-16'	4'-16'	4'-16'	4'-16'
No. of cuttings allowed	SM*/4 Not over 4	SM*/4 FAS Side (SM* + 1)/3 #1 C Side	(SM* + 1)/3 Not over 5	SM*/2 Not over 7	No Limit	No Limit
Minimum size of cuttings	4"x5' 3"x7'	4"x5' or 3"x7' FAS side 4"x2' or 3"x3' #1 C Side	4"x2'	3"x2'	3"x2'	Minimum 1 ½" wide containing at least 36 square inches
Yield amount req. in clear face cuttings	10/12	10/12 FAS side 8/12 #1 C Side	8/12	6/12	4/12	3/12

Yield from each grade will ultimately depend on the particular cutting bill a manufacturer is operating under. The upper grades, FAS and Selects, are best suited for manufacturers who require long clear parts because the boards must yield at least 83 1/3 percent of clear wood in large sizes. On the other hand, the common grades are generally best utilized by manufacturers who are capable of using shorter and narrower cuttings.

Although these previously mentioned grading standards provide a basis for the trade of specific hardwood resources, they fail to include certain groups of materials that are capable of being used by primary and secondary manufacturers. These underutilized resources include, logging bolts (logs less than 8ft), lumber shorter than 4 feet or narrower than 3 inches and byproducts from processes such as sawmill slabs. These underutilized resources contain a considerable amount of usable wood and the industry is beginning to realize its potential.

Currently, research is being done on different processes and products "*that could significantly impact the development and acceptance of value-added products from a resource that currently has limited appeal*" (Wolfe 2000). However, Wolfe (2000) believed the industry's marketing philosophy must change in an effort for markets to begin accepting new products from the changing forests for these technologies to prove their value. In his literature review he agreed with Barbour et al. (1995) and stated the industry should focus less on product orientation and more on marketing orientation. This is backed up by a reference to several products and processes that were technically feasible ideas but never made it to market due to the industry's failure to modify or improve their product lines.

> *"Today, availability of the timber resource has become a serious issue. Escalating lumber prices, lower log quality, and environmental constraints are forcing the industry to consider nontraditional wood sources and processing methods. One possible solution is to use the lower quality logs, lower grade lumber, and residues such as slabs, which were either previously left in the woods, used in lower valued products, or land-filled. However, recovery of the usable wood from low quality raw material may*

necessitate a change in processing, handling, drying and marketing procedures (Gephart et al. 1995).”

A paradigm shift that focuses on end-user’s needs as well as satisfying the processing issues at each link of the supply chain is necessary. It is believed the proposed business model for manufacturing solid hardwood panels from underutilized resources meet these criteria. The end-user is satisfied with a high-quality solid wood product, the secondary manufacturer’s processes are simplified, primary manufacturers have new markets for byproducts and low-grade lumber, and the health of the forest is improved.

With clear definitions of small-diameter roundwood and sawmill slabs, the focus turns towards defining the industry’s term; “low-grade lumber.” Cumbo et al. (2003) attempted to define low-grade lumber based on the forest products industry’s perception. Their research made use of an industry survey that revealed 37 percent of the respondents think No. 2 Common and below is low-grade, 34 percent state No. 3A Common is low-grade and 21 percent believe No. 3B Common is low-grade. Cumbo et al.’s (2003) study revealed that more than 51 percent of their respondents believed lumber classified as No. 3A Common and lower as low-grade. These definitions will be used throughout the project and provide the foundation for the objective of the raw materials portion of this research.

3.2.5 Raw Materials Objective

“Identify, define, and quantify potential low-value sources of raw materials for the production of solid hardwood panels based on existing literature and computer simulation.”

3.2.6 Simulation

To estimate the amount of usable wood obtained from these low-grade resources, the ROMI 3 rough mill simulator is used. Simulation is “*the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system*” (Wiedenbeck 1992). With advances in technology, simulation models have evolved from complex mathematical equations only understood by a select few to user-friendly computer programs designed to process numerous variables in short periods of time. This allows users the benefits of analyzing different scenarios for a process without the time constraints and costs of executing the actual process (Thomas and Buehlmann 2002).

In the forest products industry, the oldest use of simulation has been to analyze the cut-up and flow of raw materials and has since become a valuable decision support tool (Thomas and Buehlmann 2002). In 1962 R.J. Thomas realized the importance of lumber yield on a dimension producers' profitability and developed the first computer-based simulation tool (Buehlmann 1998). He used punch cards to map the geometry and defects of approximately 35,000 board feet of oak, yellow poplar, and hard maple in an effort to estimate yield. Years of refinement and technological advances eventually led to the introduction of Steele and Harding's RIP-X software (Steele and Harding 1997) and R. Edward Thomas' ROugh MIll Rip-first simulator (ROMI-RIP) (Thomas 1995). Today these are the two most widely used lumber cut-up simulation tools in the forest products industry.

Thomas' ROMI-RIP (1995) was developed as a rip-first rough mill analysis tool for the USDA's Forest Service. A sister program ROMI-CROSS (Thomas 1997) was also developed by Thomas to analyze cross cut-first rough mills. Eventually the two programs were combined and renamed ROMI. The latest edition ROMI 3 (Thomas and Weiss 2005) is capable of analyzing rip-first and cross cut-first rough mills and contains a variety of options that enable users to best replicate their rough mill manufacturing process.

3.2.7 ROMI-RIP Rough Mill Simulator Validation

The popularity of the ROMI simulation programs by researchers and industry decision makers as a decision support tool leads to the question about its validity. Thomas and Buehlmann (2002) validated the results of ROMI-RIP 2.0 by comparing the results obtained from a simulation to those obtained from actual tests at a state-of-the-art rough mill. Their study used a lumber sample of 930 BF. The digitized representations of the lumber were tested in ROMI-RIP and compared to the actual yields resulting from processing the lumber in a rough mill. Statistical analysis at the 95 percent level of significance $(\alpha = 0.05)$ showed ROMI-RIP 2.0 accurately simulates the process of an actual rough mill when using No. 1 Common lumber.

3.2.8 ROMI Assisted Studies on Low-Grade Utilization

The ROMI family of simulation programs is an invaluable tool in understanding and estimating the effects of lumber quality and cutting bills on yields for rough mills. Several researchers have uses ROMI to show how to improve the utilization of low-grade raw materials.

3.2.8.1 Size of Character Marks vs. Lumber Yield in Rip-First Mill

Buehlmann et al. (1998), in an effort to improve raw material utilization, used ROMI-RIP to investigate the effects on yield by allowing different sized character-marks in dimension parts from a rip-first rough mill. Other objectives of this research included: 1) studying the interaction between lumber grade mix and character-mark on yield; 2) studying the interaction of character-mark size and cutting bills on yield. The researchers noted that the four variables in question (part quality, cutting bill, grade mix, and character-mark sizes) significantly affected yield. Results relevant to the objectives of the hardwood panel research showed yields improved the most when allowing 2-inch character-marks. By processing 2A Common lumber (based on NHLA grades), the researchers determined furniture part yield increased 13.8 percent (50.9% to 64.7%) when 2-inch character-marks are allowed on both sides. Yield increased 6.5 percent (50.9% to 57.4%) when character-marks were only allowed on one face (C1F parts). For 1 Common lumber, yields increased 6.1 percent (65.2% to 71.3%) by allowing 2-inch character-marks on both sides and 3.2 percent (65.2% to 68.4%) for character-marks on one side. The authors noted that 2-inch character-marks were a little "ambitious" for US market acceptance because consumers are not used to seeing character marks of such sizes in their purchased products. A 1-inch character-mark seemed more feasible. The yield increase for processing 1 Common and 2A Common lumber into dimension parts with 1-inch character-marks on both sides was 3.3 percent (65.2% to 68.5%) and 7.8 percent (51.0% to 58.8%) respectively. Manufacturing dimension parts with 1-inch character-marks on one side from 1 Common and 2A Common lumber increased the yield 1.9 percent (66.3% to 67.2%) and 3.9 percent (50.8% to 54.7%) respectively.

3.2.8.2 Size of Character Marks vs. Lumber Yield in Crosscut-First Mill

In a follow up study Buehlmann et al. (1999) used ROMI-CROSS to investigate the effects on yield by allowing character marks in dimension parts from a cross cut first rough mill. Other objectives of this research included: 1) studying the interaction of factors such as grade mix and cutting bill geometry on yield; 2) comparing the performance of rip-first and crosscut-first systems by their response to the size of character-marks. As in the previous study, they found all four variables (part quality, cutting bill, grade mix, and character-mark size) in question significantly affected yield. Results relevant to the objectives of the hardwood panel research showed yield increased most when allowing 2-inch character-marks. When processing 2A Common lumber (based on NHLA grades), the researchers determined furniture part yield increased 11.0 percent (52.7% to 63.7%) by allowing 2-inch character-marks on both sides. Yield increased 5.5 percent (52.7% to 58.2%) when character-marks were only allowed on one face (C1F parts). For 1 Common lumber, yields increased 5.1 percent (63.8% to 68.9%) for 2-inch character-marks on both sides and 2.2 percent (63.8% to 66.0%) for character-marks on one side. The yield increase for processing 1 Common and 2A Common lumber into dimension parts with 1-inch character-marks on both sides was 2.8 percent (63.8% to 66.6%) and 6.4 percent (52.7% to 59.1%) respectively. Manufacturing dimension parts with 1-inch character-marks on one side from 1 Common and 2A Common lumber increased the yield 1.4 percent (63.8% to 65.2%) and 3.7 percent (52.7% to 56.4%), respectively. This research also allowed the researchers to study the difference in crosscut-first rough mills and rip-first rough mills. Rip-first rough mills showed higher yield improvements versus crosscut-first mills when allowing character-marks of less than 1 inch.

3.2.8.3 Lumber Length Effects on Yield in Gang-Rip-First Rough Mills

Hamner et al. (2002) used ROMI-RIP 2.0 to analyze the effects of board lengths on rough mill yield based on two cutting bills ("easy" and "hard") and three part-prioritization strategies. The easy cutting bill was described as having 15 part lengths, 5 part widths, and 5 panel parts. The average part width and length was 2.94 and 30.36 inches, respectively (weighted based on need). The three part-prioritization strategies were: 1) Static strategy with emphasis on longer parts - $priority = L^2 xW$; 2) Basic dynamic strategy incorporating part quantity - $priority = L^2 xWxN$; and 3) Complex dynamic exponent strategy emphasizing long wide parts - $priority = L^{WFlength} xW^{WFwidth}$. A more thorough description of part-prioritization strategies is available in the ROMI-3: Rough Mill Simulator 3.0 User's Guide (Weiss and Thomas 2004).

Hamner et al. (2002) objectives were to determine if the same volume of lumber and grade mix of short boards (7 to 8 ft.), medium-length boards (11 to 12ft.) and long boards (15 to 16 ft.) produce the same clear part yield for a gang-rip-first rough mill. The results relevant to the solid hardwood panel research showed significant differences in dimension part yields when comparing the three classes of lumber length for both cutting bills and each part-prioritization strategies. Yields increased as the length of the boards tested increased. For the easy cutting bills using the static part prioritization strategy ($priority = L^2 xW$), the average part yields for 7- to 8- foot boards were 59.6 percent, 3.8 percent lower than the average for 11- to 12- foot boards (63.4%) and 6.4 percent lower than the average for 15- to 16- foot boards (66.0%).

3.2.8.4 Optimal Part Yield for No. 3A Common Lumber

Shepley (2002) used ROMI-RIP 2.0 and ROMI-CROSS to determine specific conditions for the optimal processing of No. 3A Common, 4/4 thickness, kiln-dried, red oak lumber. The production performance of No. 3A Common lumber was investigated by analyzing how part sizes and cutting bill parameters affect efficiency measurements such as yield and machine productivity. Research objectives included identifying two feasible "low-grade" cutting bills for comparing yield differences in using either; all No. 2A Common, all No. 3A Common, or a 50/50 mix of No. 2A and No. 3A Common lumber.

Shepley (2002) used total part yield, a ratio of output volume to input volume, and sawing efficiency, total number of rip cuts and crosscuts divided by board feet of parts produced, to identify two feasible "low-grade" cutting bills. From the simulation, Shepley (2002) determined that cutting bills characteristic of narrow part widths of 3 inches or less, and short part lengths of 40 inches or less were the best cutting bills in terms of part yields and sawing efficiencies. He stated, "*cutting bills designed to achieve optimal part yield from No. 3A Common red oak lumber should not have part widths in* *excess of 3 inches and there should be at least 10 different part length definitions less than 40 inches for every part width in the cutting bill*" (Shepley 2002). Furthermore, he determines part yields and sawing efficiencies for such cutting bills improved when lumber quality improved.

3.2.8.5 Relationships of Lumber and Cutting Bill Requirements

Buehlmann (1998) used ROMI-RIP to examine the relationship of cutting bill geometries and yields. Using No. 1 Common, 4/4 thickness, kiln-dried red oak lumber from the board databank, he described the effect of part length, width, and quantity on yields using statistical analysis. He concluded parts 2.5 inches wide and 17.5 inches long contributed the most towards high yields. On the other hand, parts 4.25 inches wide and 72.50 inches long were found to have the most negative impacts on yields. Further analysis showed that due to the variability of lumber and its characteristic of having clear areas of differing sizes, cutting bills consisting of many different sizes were the most advantageous for higher yields. He also concluded that adding several small parts to cutting bills requiring larger parts improved yield.

3.3 Defining the Solid Hardwood Panel Product

The past research using ROMI simulations provides an understanding on how different cutting bill parameters, part qualities, part prioritization strategies, incoming raw material quality, length, and grade mix affect yield. Combining this past research with the common knowledge that low-grade resources yield short, narrow, clear cuttings has spawned the idea of solid hardwood panels in an effort to find higher-value-added uses for underutilized material. This idea calls for these short and narrow clear cuttings to be finger-jointed for length and edge-glued for width to obtain larger, more applicable sizes. The manufacturing of solid hardwood panels allow managers of rough mills the ability to design cutting bills with optimal part sizes to best utilize the resource. The parameters of the proposed cutting bill are a culmination of the aforementioned research. Each panel will measure 4 feet by 8 feet and consist of uniform sized clearings (slats).

3.3.1 Panel Grades

Panels grades are designed using a derivation of the A/B grade standards set forth by the Wood Components Manufacturers Association (WCMA 2004). The "A" face is acceptable for noticeable surfaces for an aesthetic appeal such as tops, doors and drawer fronts. Small, sound knot specks; dark mineral streak or pitch pockets less than 1/16 inch wide and l inch long; and light discolorations are allowed. “A” face slats must be between 1 and 5 inches wide. The “B” face is acceptable for surfaces that are not as noticeable as tops, doors, and drawer fronts but still require an aesthetic appeal, such as end panels, shelves, and inside drawer fronts. Occasional pin knots and small sound knots; mineral streak less than l/4 inch by 2 ½ inch; moderate discoloration; and the occasional birdseye is allowed. “B” face slats must be between 3/4 and 5 inches wide. A slight modification to the “B” face concerning knot size is made for the purpose of this research. Because yield improves for low-grade lumber as accepted knot size increases, 1/4 inch sound knots will be allowed for the “B” face.

3.3.2 Slat Sizes

Shepley’s (2002) research suggests that for optimal cutting bill yields, sizes should be evenly distributed between 5 widths and 10 lengths. Buehlmann’s (1998) research suggests a 2.5 by 17.50 inch part contributed the most towards higher yields for #1 Common lumber. It is general knowledge that higher yields are obtained from low-grade lumber using cutting bills that consists of short, narrow parts. Therefore, the cutting bill of the proposed solid hardwood manufacturing facility will contain 5 widths and 10 lengths for a total of 50 different slat sizes. The slat lengths will range from 5 to 40 inches. Average part length is 21.7 inches. The slat widths range from 1 to 5 inches. Average part width is 2.75 inches. Table 3.3 lists the 5 widths and 10 lengths accepted for the manufacturing of solid hardwood panels.

Table 3.3 Proposed part widths and lengths for solid hardwood panels.

Widths	Lengths	
1”	5”	23”
1.75”	11”	26”
2.5”	14”	29”
3.5”	17”	32”
5.0”	20”	40”

3.4 Raw Materials Methodology

ROMI 3.0 is used as an analytical tool to estimate the amount of clear useable wood that can be obtained from a typical supply of underutilized resources as defined by this research. The incoming supply will consist of sawmill slabs and log runs of small-diameter trees removed from the forest and processed by a sawmill under contract for the specific use of this manufacturing facility. The purpose of the simulation is to give the entrepreneur a rough estimate on expected raw material costs to run a manufacturing facility producing approximately 15 MBF of solid hardwood panels per shift or about 470 panels per shift.

3.4.1 Part Grades

The proposed panel grades are a modification of the WCMA's A/B grade. The modification comes from a change in the accepted knot size allowed on the "B" side. WCMA calls for knots of less than 1/8 of an inch. The "B" grade for this setup will allow 1/4 of an inch. This change is made for several reasons: 1) ROMI 3.0 does not offer knot sizes smaller than 1/4 of an inch, 2) the jump in knot size for WCMA's "B" grade to "C" is from 1/8 of an inch to 1/2 of an inch, and 3) initial market research shows 1/4 of an inch as an acceptable character mark size for side panels and interior applications[2].

The part grade setup allows for several different character marks for one side of the slat. These character marks include, sound knots sized 1/4 of an inch or smaller (ROMI 3.0 Defect Code 1501), sap and mineral streak (22), pin worm hole less than 1/16 on an inch (211) and bird peck (23). Each part grade is allowed to be re-ripped to salvage usable pieces to maximize yield. The resulting part grade window looks similar to Table 3.4 Part Grade Set-up for Manufacturing Solid Hardwood Panels.

[2] Several cabinet manufacturers, including one where the author is currently employed, allow sound knots on highly visible surfaces such as doors and drawer fronts. The specs allow 1 sound knot less than 1 inch in diameter or 2 sound knots if their combined diameters are less than 1 inch.

Table 3.4 Part grade set-up for manufacturing solid hardwood panels.

Grade Code	Side	Face	Description	Re-Rip
0	Face	0	Scrap, All Defects	
1	Face	999	Clear, No Defect	
2	Back	1501	Sound knots <= .25 inch area	
3	Face	1501	Sound knots <= .25 inch area	
2	Back	22	Sap stain/mineral streak	
3	Face	22	Sap stain/mineral streak	
2	Back	211	Pin worm hole (<1/16)" area	
3	Face	211	Pin worm hole (<1/16)" area	
2	Back	23	Bird Peck	
3	Face	23	Bird Peck	
4	Face	999	Clear, No Defect	Yes
5	Back	999	Clear, No Defect	Yes
6	Back	1501	Sound knots <= .25 inch area	Yes
7	Face	1501	Sound knots <= .25 inch area	Yes
6	Back	22	Sap stain/mineral streak	Yes
7	Face	22	Sap stain/mineral streak	Yes
6	Back	211	Pin worm hole (<1/16)" area	Yes
7	Face	211	Pin worm hole (<1/16)" area	Yes
6	Back	23	Bird Peck	Yes
7	Face	23	Bird Peck	Yes

3.4.2 Cutting Bill

The cutting bill defined in this ROMI 3.0 simulation uses the 5 widths and 10 lengths defined in ***Section 3.3.2 Slat Sizes***. There are a total of 50 different part combinations. Each slat size requires a fixed length with a primary part grade of 2 and a secondary part grade of 3. The part grades refer to the Grade Code defined in ***Section 3.4.1 Part Grades.*** Because the simulation only calls for a rough estimate of the yield, an arbitrary quantity of 100 pieces per size is used.

3.4.3 Rip Saw Setup

The "RipSaw Arbor Optimizer" is used to set up the rip-saw. The set-up calls for a 24 inch wide arbor with a saw kerf of 3/16 of an inch during optimization for cutting bill widths. Using the lumber data file later explained in ***Section 3.4.5 Grade Mix***, running the optimizer results in the following set-up at a 93.3 percent yield. Arbor saw spacing set-up is set at 5.0 in. – 1.75 in. – 1.0 in. – 1.0 in. – 2.5 in. – 3.5 in. – 1.75 in. –

2.5 in. – and 2.5 inch. Arbor width totals 23.0 inches with 9 saw blades. Left and right edging kerfs are 1/8 of an inch.

3.4.4 Mill Control Setup

All units are in inches and part priorities are updated periodically at 200 BF intervals. Primary operations are to avoid orphan parts. Salvage cuts to cutting bill requirements are allowed.

3.4.5 Grade Mix

Red oak lumber is used for this study. Red oak lumber is the most important wood species used by the wood components industry accounting for 28.9% of all wood used (Lawser 2004). The simulation uses lumber attained from the USDA Forest Service's 1998 data bank for kiln-dried red oak lumber (Gatchell et al. 1998). The grade mix is developed based on the assumption that this company will receive lumber cut straight from the log runs of small-diameter thinnings and sawmill slabs. Logs will be bucked at 6 and 8 feet. Log diameters mainly range from 8 inches to 11 inches with an occasional larger diameter of 12 or 13 inches. Therefore it is assumed that all incoming sawlogs will be log grades 2 or 3. Hanks et al. (1980) reported the NHLA grade distribution based on log diameter and this distribution is listed in Table 3.5. Note that percentages do not add up to 100 because the authors do not report the material grading below NHLA's #3 Common grade.

Table 3.5 Lumber grade recovery percentages based on log grades and diameters (number of logs examined in parenthesis) (Hanks et al. 1980).

NHLA Board Grades	Grade 2 Logs 10 in (2)	Grade 2 Logs 11 in (35)	Grade 3 Logs 8 in (7)	Grade 3 Logs 9 in (10)	Grade 3 Logs 10 in (20)	Grade 3 Logs 11 in (15)
Uppers	7.9%	10.7 %	-	3.2%	2.4%	1.5%
1 Common	33.1%	27.8%	19.7%	14.1%	21.4%	12.6%
2 Common	15.7%	23.4%	8.4%	20.4%	20.7%	32.9%
3 Common	43.3%	27.2%	48.6%	40.5%	41.9%	50.4%

A presentation by Wiedenbeck (2004) revealed before and after drying lumber recovery for small-diameter red oak logs (Table 3.6).

Table 3.6 Before and after drying lumber recovery for small-diameter red oak logs (Wiedenbeck 2004).

NHLA Board Grades	Green	Dry
Uppers	8%	4%
1 Common	15%	7%
2 Common	26%	22%
3 Common	50%	60%

Cumbo et al. (2004) used a board width and grade distribution based on the diameter of the log processed. Their efforts proposed a different grading system by grouping the traditional NHLA lumber grades into 3 categories (Table 3.7). Grade 1 represented FAS, FAS 1 Face, and 1 Common. Grade 2 represented #2A Common, #2B Common, and #3A Common. Grade 3 represented all lumber grades of #3B Common and lower. The grade distribution Table 3.7 is as follows:

Table 3.7 Grade distribution based on log diameter (number of logs examined in parenthesis) (Cumbo et al. 2004).

	Log Diameter				
Board Grade	6 in (3)	7 in (38)	8 in (73)	9 in (63)	10 in (47)
1	-	3%	-	4%	10%
2	15%	14%	35%	44%	42%
3	85%	83%	65%	52%	48%

The width distribution Table 3.8 is as follows:

Table 3.8 Board width distribution based on log diameter (number of logs examined in parenthesis) (Cumbo et al. 2004).

	Log Diameter				
Board Width	6 in (3)	7 in (38)	8 in (73)	9 in (63)	10 in (47)
4 in	70%	90%	62%	35%	25%
6 in	30%	10%	38%	65%	72%
8 in	-	-	-	-	3%

Using these previous studies it is noticed that in each case 40 percent or more of the boards are #3 Common or lower. Generally, 20 – 30 percent of the boards grade #2 Common. Ten to 20 percent grade #1 Common and less than 10 percent grade in the upper NHLA grades. However, because a significant percentage of the grades in the Hanks et al. (1980) report are below #3 Common or lower, this project will assume enough usable material from these logs and consider them in the research. This project also utilizes sawmill slabs which are removed from the best portion of the log and contain a significant amount of clear usable wood.

Therefore, the grade mix developed for this simulation consists of 5 percent Selects, 10 percent #1 Common, 25 percent #2 Common, and 60 percent #3 Common. In determining minimum and maximum widths, Cumbo et al. (2004) stated that a majority of the lumber removed from small-diameter logs is in the 4 and 6 inch range. Because the research calls for logs greater than 10 inches in diameter and sawmill slabs, it is assumed some boards will be wider than 6 inches and narrower than 4. Unfortunately a limitation in the data bank will only allow ROMI 3 to include lumber 3.5 inches and wider. Therefore, our sample will have a minimum width of 4 inches (data bank limitation) and a maximum of 10 inches. Since the incoming logs are bucked to 6 and 8 feet, and sawmill slabs, which are generally smaller than 6 feet, the board length minimum is set at 40 inches (essentially 4 feet) whereas the maximum is set at 104 inches (essentially 8 feet). Due to the measurement of digitized boards, ROMI 3 advises widening the desired length range 6 – 8 inches on both ends of the spec to improve the selection of available boards. Therefore a grade mix that closely resembles Wiedenbeck's (2004) presentation is used for the simulation, with the board dimensions derived from the Cumbo et al. (2004) study.

The grade mix is used a total of 7 times in the simulation which results in a total board footage of 5,853.7 BF. 1,603 boards are processed. The actual breakdown of grades and board count are shown in Table 3.9.

Table 3.9 Actual lumber grade mix in board count, board feet and percentage of total for ROMI 3.0 simulation run.

	Lumber Grade Mix (Widths 4-10 in.) (Lengths 40-104 in.)				
	Selects	1 Common	2 Common	3A Common	Totals
Count	119	170	378	936	1603
BF	364.7	665.3	1,507.3	3,316.4	5,853.7
Percentage	6.23%	11.37%	25.75%	56.65%	100.00%

3.5 Raw Materials Results and Discussion

The feasibility of using underutilized wood resources to produce high quality solid hardwood panels is based on part yield and sawing efficiency. Part yield is the ratio of output volume (usable parts) to input volume (raw materials). Yield is calculated by totaling the BF of Primary, Excess Primary, Salvage and Excess Salvage parts and dividing that sum by the total BF of incoming raw material. Yield is generally expressed in terms of percentages and therefore multiplied by 100. Sawing efficiency is a measurement to determine the average number of cuts to produce one BF of lumber. Sawing efficiency is calculated by totaling the number of rip cuts and cross cuts by the total BF of parts produced. Yield and sawing efficiency is important to a potential entrepreneur because an estimated yield allows them to calculate the amount of raw material needed to satisfy a production quota and sawing efficiency indicates a starting point in determining the associated costs of manufacturing solid hardwood panels from underutilized resources.

The simulation imitates a production run of 7 log runs of small-diameter timber and sawmill slabs. This type of raw material supply represents a contractual agreement with a sawmill to process small-diameter timber and provide the manufacturing facility with the resulting lumber and sawmill slabs. The sawmill slabs in this case would also accumulate from the processing of higher grade logs which the sawmill processes as part of their daily activity. The actual results from this simulation are located in Section 7.2 Appendix B. Table 3.10 lists the part areas, part yields and sawing efficiencies for primary and salvage parts in each lumber grade and in total.

Table 3.10 Usable part areas and resulting yields with sawing efficiencies for each lumber grade and as a total.

	Lumber Processing Statistics Based on Lumber Grade		
	Part Areas	Part Yields	Sawing Efficiency
	Selects		
Primary	238.7	65.44%	3.21
Salvage	49.9	13.68%	6.34
Totals	288.5	79.12%	3.75
	1 Common		
Primary	341.5	51.33%	4.81
Salvage	128.1	19.25%	9.66
Totals	469.6	70.58%	6.13
	2A Common		
Primary	691.8	45.90%	5.92
Salvage	277.6	18.42%	12.77
Totals	969.4	64.32%	7.88
	3A Common		
Primary	1,148.5	34.64%	7.67
Salvage	715.8	21.58%	14.74
Totals	1,864.3	56.22%	10.38
	Total Lumber Process Statistics		
Primary	2,420.6	41.35%	6.33
Salvage	1,171.4	20.01%	13.36
Total	3,591.9	61.36%	8.62

3.5.1 Yields

The results of the simulation show that processing 5,835.7 BF produces 3,591.9 BF of usable slats at a 61.36 percent yield. The 364.7 BF of Select lumber produce 288.5

BF of usable slats at a 79.12 percent yield. The 665.3 BF of #1 Common lumber produce 469.6 BF of usable slats at a 70.58 percent yield. The 1507.3 BF of #2 Common lumber produce 969.4 BF of usable slats at a 64.32 percent yield. The 3,316.4 BF of #3A Common lumber produce 1,864.4 BF of usable slats at a 56.22 percent yield.

The allowance of salvage parts significantly increases overall yield as well as the yields for each individual lumber grade simulated. For the cutting bill specified, allowing salvage cuts increases yield for this simulation of 7-1,000 BF log runs 20.01 percent or 1,171.4 BF. An increase in 1,171.4 BF represents about 36 finished panels. The largest increase in yield through the allowance of salvage parts occurs in 3A Common lumber where 21.58 percent or 715.8 BF of lumber is reclaimed. The Select lumber realizes an increase of 13.68 percent or 49.9 BF of usable parts. The 1 Common lumber realizes a 19.25 percent yield increase or 128.1 BF. The 2A Common lumber realizes an 18.42 percent yield increase or 277.6 BF.

3.5.2 Sawing Efficiency

A total of 30,965 cuts were required to process the 5,835.7 BF of lumber into 3,591.9 BF of usable panel parts with a sawing efficiency of 8.62. The total breakdown consisted of 12,173 rip cuts and 18,792 crosscuts. As expected, the sawing for small useable portions of clear wood becomes less efficient as the grades decrease. Sawing efficiency factors for Select, 1 Common, 2A Common and 3A Common lumber were 3.75, 6.13, 7.88 and 10.38 cuts respectively. Table 3.11 lists the part areas, part counts, number of rip- and cross-cuts required and the sawing efficiency for primary and salvage parts for each lumber grade and as a whole.

The allowance of salvage parts greatly increases yields (roughly 20 percent) but also requires a significant number of extra processes. In terms of cuts, the retrieval of salvage parts requires 15,650 extra rip and cross cuts. This accounts for 50.5 percent of the total number of cuts required. In each grade a considerable increase in cross cuts is noticed. Furthermore, the sawing efficiency factors for each lumber grade nearly double when simulating for recovery efforts.

Table 3.11 Usable part areas, part counts and resulting processing cuts necessary with sawing efficiencies for each lumber grade and as a total.

	Lumber Processing Statistics Based on Lumber Grade					
	Part Areas	Part Counts	Rip cuts	Crosscuts	Total Cuts	Sawing Efficiency
			Selects			
Primary	238.7	319	371	394	765	3.21
Salvage	49.9	155	136	180	316	6.34
Totals	288.5	474	507	574	1,081	3.75
			1 Common			
Primary	341.5	686	688	956	1,644	4.81
Salvage	128.1	536	490	747	1,237	9.66
Totals	469.6	1,222	1,178	1,703	2,881	6.13
			2A Common			
Primary	691.8	1,643	1,582	2,515	4,097	5.92
Salvage	277.6	1,497	1,337	2,209	3,546	12.77
Totals	969.4	3,140	2,919	4,724	7,643	7.88
			3A Common			
Primary	1,148.5	3,054	3,733	5,076	8,809	7.67
Salvage	715.8	4,264	3,836	6,715	10,551	14.74
Totals	1,864.3	7,318	7,569	11,791	19,360	10.38
			Total Lumber Process Statistics			
Primary	2,420.6	5,702	6,374	8,941	15,315	6.33
Salvage	1,171.4	6,452	5,799	9,851	15,650	13.36
Total	3,591.9	12,154	12,173	18,792	30,965	8.62

3.6 Raw Materials Conclusions

The simulation confirmed that underutilized raw materials such as small diameter roundwood, low-grade lumber and sawmill slabs are viable sources of raw materials for a solid hardwood panel manufacturing enterprise. A satisfactory yield of 61.36 percent is obtained with the grade mix satisfying all quantities (100 for each size combination) specified by the cutting bill. The high yield for this grade mix is attributed to the cutting bill designed; which consisted of small part sizes, the inclusion of Select lumber in the grade mix and the allowance of salvage parts.

Unfortunately this high yield comes at a cost. The number of cuts necessary to process the lumber into usable pieces is relatively high. This is a result of small sizes in the cutting bill and the allowance of salvage parts. This increase in processes, both sawing and material handling, will no doubt cause an increase in processing costs.

However, in a process where raw materials generally account for 50 percent of processing costs the low cost raw material and high yields should offset this concern.

One issue that may arise in manufacturing derives from the product definition. Panels are manufactured using a uniform sized slat. Initial market research indicates that demand will be for those panels consisting of wide and long slats. However, the raw material used tends to produce short and narrow slats. This concern is easily overcome with increases in the higher grades such as Selects and 1 Common to the grade mix. This will cause an increase in raw material costs but should cut down on the effect of salvage parts and sawing efficiencies.

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Chapter 4

4 Business Plan

4.1 Executive Summary

Practical Wood Solutions, Inc. is a new venture firm manufacturing solid hardwood panels from underutilized wood resources. Our new, innovative product properly named the Adaptive Panel solves a number of problems faced by the domestic hardwood value-added industry such as stagnant forest growth, excess supply relative to market demand for low-grade material and global competitiveness by using wood resources that have traditionally been underutilized. With an initial capital investment of $7,554,624, Practical Wood Solutions, Inc. manufactures solid finger-jointed, edge-glued red oak panels from small-diameter timber, low-grade lumber, and sawmill slabs.

Adaptive Panels will compete in the $5 billion (U.S.) wood components market. Specifically the company will compete in the solid wood panels segment, which accounts for 13 percent ($650 million U.S. dollars) of the total wood components market. Such panels are marketed towards a broadly defined group of industrial manufacturers who produce furniture, doors, kitchen and bath cabinets as well as various other solid wood products (Tabarsi et al. 2003). This market segment is expected to grow as secondary wood manufacturers continue to realize the value in purchasing semi-finished components. Furthermore, in today's global economy, the opportunities to export domestically manufactured forest products continue to expand.

Our company, Practical Wood Solutions, Inc., will be located in the Piedmont Triad region of North Carolina. This area is close to the resource as well as a number of secondary wood product manufacturers. We will purchase low-value resources such as small-diameter timber, low-grade logs, and sawmill slabs. Through contracts with local sawmills this material will be processed into lumber and sold to the company. The incoming lumber will be processed in our state-of-the-art facilities. Panels will be produced in a standard size of 4 x 8 feet and each panel contains a uniformed size slat.

Our Adaptive Panels will be marketed through certain forest product industry associations, publications, and trade shows. Trade associations include the American

Furniture Manufacturers Association, The Kitchen Cabinets Manufacturers Association, National Hardwood Lumber Association, National Kitchen and Bath Association, Wood Components Manufacturers Association, and Wood Products Manufacturers Association. Industry trade journals include Custom Woodworking Business, Wood and Wood Products, Wood Digest, and Woodshop News. Industry trade shows are generally regionally based but larger shows such as The International Woodworking Fair, The Association of Woodworking & Furnishings Suppliers show, and the NHLA Annual symposium occur on yearly or every two year intervals.

Two salespeople will contact potential customers in the eastern U.S. Products will be delivered to the customer using two basic methods. Local customers will benefit from direct delivery from Practical Wood Solutions, Inc. Larger orders and customers outside of the region will receive their Adaptive Panels through contracted shipping services.

The plant will operate one 8-hour shift a day, 235 days a year. At capacity, we will be capable of producing 469 Adaptive Panels a day. Yearly revenues, at capacity, are estimated to exceed $15.5 million a year. Panels range in price from $128.21 to 148.96 per 8' x 4' panel. Operating margins are expected to reach 40 percent on our higher end products with an overall operating margin averaging 26 percent for the full product line. The company expects the project to break-even between April and July of the second year (2008).

4.2 Introduction

Practical Wood Solutions, Inc. is a firm dedicated to supplying solid hardwood panels for wood furniture, wood components, and door and cabinet manufacturers in the Eastern U.S. Our innovative product, the Adaptive Panel, is a high-quality, solid wood panel manufactured from underutilized wood resources such as small-diameter roundwood, low-grade lumber, and sawmill slabs. Using such materials to manufacture Adaptive Panels offers a higher value-added alternative than the traditional uses of these raw materials in products such as composites, pallets and fuel wood. Furthermore, Adaptive Panels provide a low-cost alternative to conventional rough-mill because potential customers can essentially eliminate rough mill processing and expensive lumber costs by purchasing semi-machined panels. Adaptive Panels also provide an opportunity to utilize grades of lumber that have traditionally caused problems for secondary manufacturers. Adaptive Panels are marketed to a broadly defined group of industrial manufacturers who produce furniture, kitchen and bathroom cabinets, doors, and various other solid wood products where the end users of these products perceive solid wood products to be superior to those manufactured from wood composites (Tabarsi et al. 2003). Practical Wood Solutions, Inc., through the introduction of Adaptive Panels, hopes to improve the competitiveness of our customers by offering a low cost alternative to the traditionally used raw material, expensive, high-grade lumber. Not only does the use of Adaptive Panels improve the solid wood industry's value chain downstream from the forest resource, it also has the potential to improve the health of timber stands by better utilizing small-diameter resources and offering primary manufacturers a value-added product for low-grade lumber and sawmill residuals.

Adaptive Panels will compete in the edge-glued panel segment of the wood components market. The wood components industry is composed of an estimated 1,300 companies producing a variety of parts for furniture, cabinet, and related wood product manufacturers (Lawser 2004). Annually, the wood components industry produces $5 billion (U.S.) worth of products (Lawser 2004). The edge-glued panel segment is the fifth largest segment accounting for 13 percent ($650 million – U.S.) of the wood components market (WCMA 2001 as cited in McDaniel 2003). The Wood Components Manufacturers Association (WCMA) lists 79 member companies that produce edge-glued panels (WCMA 2004). These panels are marketed to a broadly defined group of industrial manufacturers who produce furniture, doors, kitchen and bath cabinets, and various other solid wood products (Tabarsi et al. 2003).

The company will require an initial investment of $7,554,624 (U.S. Dollars) at startup. The project expects to break-even by the 19th month after startup using a net income approach. Practical Wood Solutions, Inc. anticipates funding to be raised through equity funding, debt, and government grants and incentives. Practical Wood Solutions, Inc. will first look for industry support for investments. Potential investors include landowners, logging companies, and sawmills; e.g. entities who would benefit significantly from the market's acceptance of Adaptive Panels.

4.3 Problem / Solution

The domestic value-added wood industry has several concerns as it moves into the 21st century. Poisson et al. (2002) point to a "*production-focused operating philosophy*" that contributes to overcapacity and a lack of inventory control as a major concern. While, Buehlmann and Schuler (2002) note the U.S.'s attraction of foreign products, especially low priced imports, due to a traditionally robust economy backed by a historically strong dollar as another. Other commonly cited concerns include lack of industry innovation and reductions in the quality of incoming raw material.

Processing a heterogeneous raw material such as lumber is unique in the way that the unusable portions of the board known as defects must be removed to create clear usable areas of predetermined sizes. The process of removing these defects occurs in a rough mill. "*Rough mills consist of a series of machines and allied equipment intended to convert kiln dried lumber into dimension stock*" (Buehlmann 1998). The efficiency and costs of rough mills greatly depend on the grade of material being processed. Lumber grade is based on physical attributes such as size and the proportional area of usable wood (NHLA 1998). The processing of lumber is estimated to account for 70 percent of the total costs (material and processing) associated with a rough mill (Lawser 2004). It is for this reason that controlling material costs in the rough mill is a major concern to manufacturers who convert lumber to usable parts.

Due to the high material costs compared to processing costs, secondary manufacturers typically use intermediate quality and priced lumber (Luppold and Baumgras 1996). Traditionally, the nation's forests have supplied the forest products industry with sufficient quality logs. However, due to years of heavy deforestation and forest mismanagement several decades ago, the quality of today's raw materials has been declining. Many of today's timber stands are stagnant and characterized by being overpopulated with small-diameter timber and non-commercial species (Irland 1988). As a result, there is an abundance of low-grade hardwood timber inhabiting the forests (LeVan-Green and Livingston 2001). This material is considered low-grade because of excessive knots, crookedness, or small diameter. Bumgardner et al. (2001) estimate such material accounts for approximately 93 percent of the total number of trees or 40 percent of the forest volume. This low-grade resource, in general, cannot be profitably harvested and processed into lumber using conventional techniques. Therefore, it is left in the forests while the higher quality timber is removed. This selective harvesting technique further accentuates the dominance of low-grade timber.

To improve the conditions of today's standing hardwood timber, proper forest management techniques would call for the removal of small-diameter and low-grade timber as well as non-commercial species. This would reduce overstocking and stagnation while promoting healthy growth (Irland 1988). However, traditional markets for such material are slowing for several reasons; pallet manufacturers have figured out how to recycle/reuse their pallets reducing their demand for low quality lumber, and the domestic paper industry, due to an increase in paper recycling and pulp and paper imports is demanding less and less fiber. Finding cost effective processes and products for higher value markets would offer the economic incentives to landowners to begin and continue removing this material when necessary. Eventually, selective harvesting techniques would decline to acceptable levels and the volume and quality of hardwood timber would return to that enjoyed by past generations.

Unfortunately, in the short run, the industry will be faced with an abundance of low-grade, small diameter material in the market. Such material is characterized by low yields and high processing costs. Likely, sawmills are concerned with the profitability associated with processing, marketing, and selling this low-grade material. The June 10, 2005 Hardwood Review reports that 4/4 (1 in.) red oak prices, based on kiln-dried gross tally, average $300 less for #3 Common lumber and $200 less for #2 Common lumber versus #1 Common (Hardwood Review 2005). Secondary manufacturers also are concerned with using low-grade lumber in their manufacturing processes. Processing inferior quality material in traditional rough mills becomes a costly operation. Lower yields are obtained from such materials and therefore more lumber must be bought and processed to achieve the manufacturer's parts needs. For example, in a typical rough mill processing #1 Common lumber at 53 percent yield, a 1 percent decrease in yield would increase the raw material cost roughly $45 for every 1000 BF of parts required[3] (Mitchell 2001). Furthermore, more cuts are required to remove the usable portions from

[3] Based on processing 4/4 #1 Common red oak lumber and June 10, 2005 Kiln-Dried Net Tally Prices. 1000 BF Parts / 53% x $980/MBF = $1850/MBF of parts – 1000 BF Parts / 52% x $980/MBF = $1885/MBF of parts.

this material, adding to processing costs. The clear cuttings removed from low-grade wood resources are often too small to satisfy the long and wide piece counts required in manufacturers' cutting bills. The increased pressures of rising lumber and processing costs are pushing manufacturing costs to unprofitable levels (Buehlmann 1995). Therefore, industry prefers not to buy, process, or sell this type of material.

Realizing that consumers demand solid wood products for which premium prices are paid (Buehlmann and Wiedenbeck 2002), one suggested option to solve current industry concerns is our product, the Adaptive Panel. Adaptive Panels are standard-size, finger-jointed, edge-glued blanks manufactured from deciduous trees. Such panels provide an excellent opportunity for the value-added wood industry to compete internationally through innovation and cost competitiveness (Tabarsi et al. 2003). This solution offers a lower cost alternative to the conventional rough mill and an opportunity to utilize grades of lumber that have traditionally caused problems for secondary manufacturers while reducing the manufacturing costs associated with these grades (Lamb and Araman 1990). In the U.S., edge-glued panels account for roughly 13 percent ($650 Million) of the $5 Billion (U.S.) wood components market (Lawser 2004 and McDaniel 2003). These panels are marketed towards a broadly defined group of industrial manufacturers who produce furniture, doors and various other solid wood products (Tabarsi et al. 2003).

4.4 Technology Description/Products Services

4.4.1 Technology Description

The Adaptive Panel is an innovative idea of producing standard-size, solid red oak panels from underutilized wood resources such as small-diameter roundwood, low-grade lumber and sawmill slabs. This material is considered underutilized because when processed in traditional rough mills it produces short and narrow cuttings at low yields and therefore is neglected by manufacturers because of the high costs. The idea of the Adaptive Panel calls for the clear cuttings from this underutilized red oak resource to be finger-jointed for length and edge-glued for width to obtain larger, more applicable sizes. Each panel will be offered in one thickness, 4/4 (1 inch), and measure 4 feet by 8 feet and consist of uniform sized clearings (slats). Panels will be cut to size using state-of-the-art trim saws leaving glue quality edges. The faces of the panels will be sanded to the desired final thickness using a 120 grit sand paper.

The red oak Adaptive Panels will be offered in one grade which is a derivation of the high-quality A/B grade standards set forth by the Wood Components Manufacturers Association. The A/B grade represents one clear face (A) acceptable for highly noticeable surfaces such as tops, doors and drawer fronts and a face (B) acceptable for other noticeable surfaces such as end panels, shelves, and inside drawer fronts (WCMA 2004). The derivation in the grading standards occurs on the "B" face where a slightly larger size sound knot is allowed in an effort to improve yields.

4.4.2 Product Services

Manufacturers purchasing Adaptive Panels will enjoy a high-quality, low-cost alternative to processing lumber in the traditional rough mill. The idea of the Adaptive Panel allows manufacturers to design cutting bills that best represent the needs of their end products instead of the characteristics of their raw materials. By knowing the size of the panel, the parameters of the cutting bill and the expected waste from end trim and saw kerf; manufacturers can accurately and consistently calculate expected yields, raw material costs and processing costs. This knowledge will help managers control raw material inventories and costs and allow them to practice lean manufacturing techniques.

Adaptive Panels have several specific benefits for our customers. Perhaps the most beneficial aspect of using Adaptive Panels is the cost savings of processing panels compared to processing lumber. A reduction in costs should be first noticed when the delivery truck arrives at the customer's loading dock. Since our product, the Adaptive Panel, has already been processed into a high quality, defect free blank; customers are essentially paying less on freight because they are receiving only usable portions of wood. Another cost savings is recognized while storing the Adaptive Panels. Semi-machined panels stack easier and require less storage space than rough lumber. Furthermore, Adaptive Panels can be processed into usable parts using only one machine (a panel saw or CNC router) versus rough lumber, which requires at least 4 machines (a chopsaw, planer, ripsaw, and moulder). Customers will save on capital investments for such machines while reducing their processing costs. They are also able to run the one required machine at or near capacity, which is an efficient use of capital. Another unique advantage is the benefits in processing defect free panels versus rough lumber. As mentioned earlier, lumber is a heterogeneous raw material requiring extensive processing versus the defect-free and essentially homogenous Adaptive Panel. With panels, manufacturers process parts with minimal cuts. There are no defects to cut around, no re-rips to remove salvageable pieces, and the yields and raw material costs are known before the operator's first cut.

4.4.3 Product Life Cycle

This unique product will enter the panel market, which is believed to be in the later stages of market growth, possibly early market maturity. This assumption derives from the notion that the market is beginning to saturate with products combined with the fact that the lack of innovation has yet to create new market opportunities for these manufactures and their products.

Several factors can change the anticipated life cycle of the Adaptive Panel such as market acceptance (both manufacturers and end users), stricter government regulations on forest management, and improvements in panel manufacturing technology. Improvements in certain technologies might lengthen the life cycle. Developments, such as; the ability to match color and grain in slats; improvements in finger-jointing and edge-gluing; or improvements in drying capabilities for small slats; have the potential to draw out or even increase the demand for this product. However, technology also has the possibility to have a negative effect on the Adaptive Panels' life cycle. Improvements in timber and lumber processing technology could make lumber a more viable option. Other topics of concern that might shorten the Adaptive Panel's product life cycle are: industry innovation for better suited products, improvements in forest health, and the continued trend toward closure of domestic secondary wood manufacturers.

4.5 Market Analysis

4.5.1 Industry Description

Solid hardwood lumber, hardwood plywood, and other decorative laminated panels have traditionally been used as primary raw materials by the manufacturers of furniture, wood flooring, cabinets and several other fashion oriented products (Figure 4.1). These materials allow manufacturers to produce strong, durable and aesthetically pleasing consumer goods. In the U.S., manufacturers consume over 11 billion BF (26 million m^3) of hardwood lumber, 4.7 million m^3 of hardwood plywood, and roughly 8 million m^3 of particleboard and 4.3 million m^3 of medium density fiberboard a year (Howard 2003). Each material serves a unique purpose in the market but in general, manufacturers prefer solid hardwood lumber because end users of their products perceive solid wood products to be superior to those manufactured from wood composites.

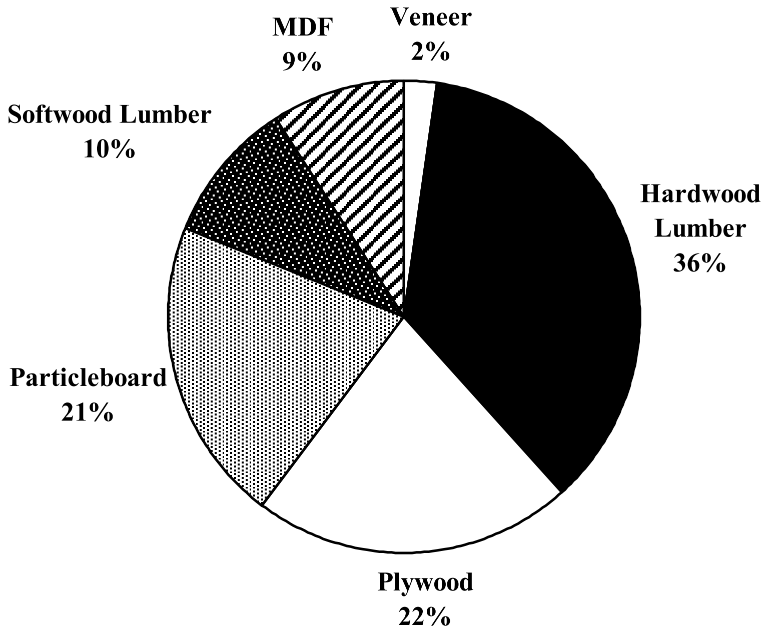

Figure 4.1 Percentage of 1997 total raw material usage for southern U.S. manufactures of home and office furniture (upholstered and nonupholstered), kitchen cabinets, and office/store fixtures (Wu and Vlosky 2000).

Manufacturers who purchase these types of materials manufacture parts in what is known as a rough mill. However, due to increases in processing and raw material costs, there has been a change in the way of doing business for a majority of the secondary wood products manufacturers. Over the last 20, years the cost of raw materials for rough mills has increased significantly while the quality has declined (Lawser 2004). Today, raw material costs account for roughly 50 percent (Figure 4.2) of the total production costs of a rough mill (WCMA 1999 as cited by Mitchell 2001). Managers are now realizing that it costs less to buy semi- or fully-machined parts than it does to make them (Lawser 2004). This is especially true for larger secondary manufacturers who produce dimension parts used in their end products in rough mills.

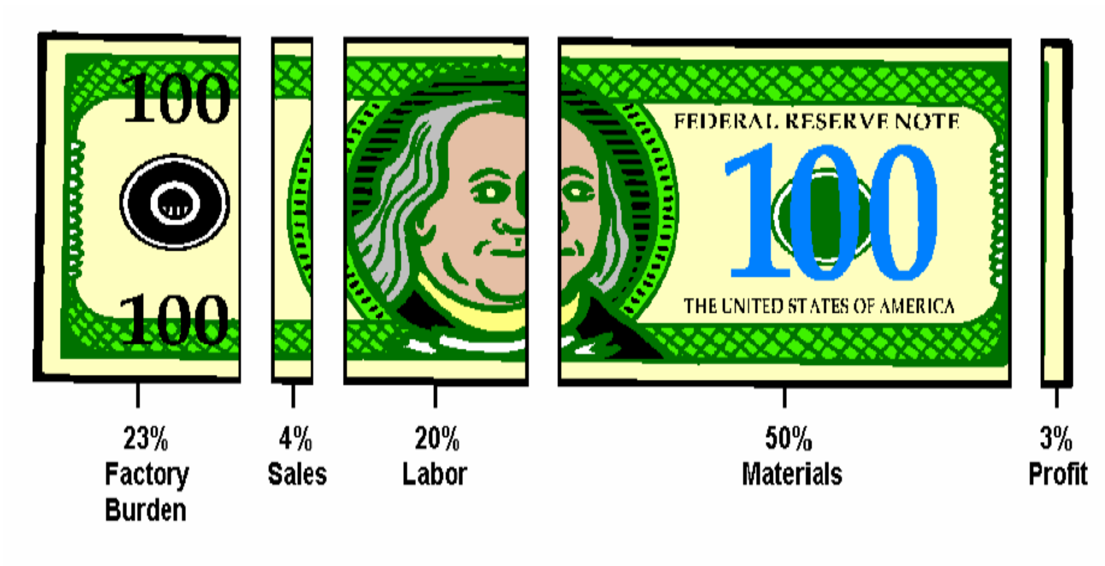

Figure 4.2 Percentage of costs and profit in the typical rough mill (Mitchell 2001).

The emergence of the wood components industry can be attributed to the changing business model previously mentioned. The wood components market provides kiln-dried, fully or semi-machined, hardwood parts "*which have been processed to a point where the maximum waste is left at the dimension mill, and the maximum utility delivered to the user*" (WCMA 2004). Wood component companies, on average, consume 6.5 MMBF of lumber annually (Lawser 2004). Red oak (28.9 %), hard maple (19.4 %), cherry (10.6%), poplar (7.7%), and soft maple (7.1%) are the five most used species in the wood components industry (Lawser 2004). The wood components market is divided into several major segments: wood mouldings, wood cabinet parts, millwork, stair parts, furniture components, turning squares, flooring blanks, and edge-glued blanks. Each segment produces a variety of products that serve certain needs of secondary wood processors.

Today the wood components industry is highly fragmented with the Wood Components Manufacturers Association (WCMA) listing 1,300 manufacturers who participate in their association. Annual sales are expected to reach over $5 billion (U.S.) for 2005 (Lawser 2004). Component manufacturers produce a variety of products and generally compete on price, quality, lead times, on-time delivery, and customer service (Lawser 2004). Figure 4.3 represents a breakdown of wood component customers.

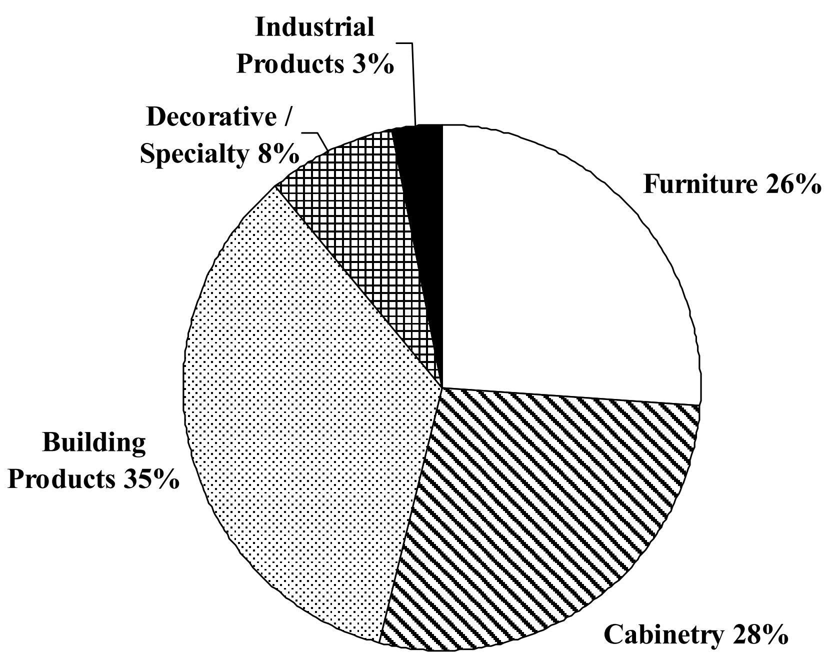

Figure 4.3 Wood components sales by industry in 2004 (Lawser 2004).

4.5.2 Target Market

Practical Wood Solutions, Inc. plans on targeting the solid edge-glued panel segment of the wood components market. This segment accounts for 13 percent (U.S. $650 million) of the wood components market (WCMA 2001 as cited in McDaniel 2003). Panels are marketed towards a broadly defined group of industrial manufacturers who produce furniture, doors, kitchen and bath cabinets, and various other solid wood products (Tabarsi et al. 2003). Export markets are also of interest for Practical Wood Solutions, Inc. U.S. hardwood manufacturers have enjoyed a significant increase in exports since 1985 (Lawser 1997). Edge-glued panel manufacturers also are enjoying this push towards exporting as edge-glued panels are the second most exported product in the wood components market (Lawser 1997).

4.5.3 Competitive Analysis

The WCMA lists 79 companies who produce solid edge-glued panels in their annual wood components source guide (WCMA 2004). It is safe to assume several other manufacturers produce solid hardwood panels that are not WCMA members. Manufacturers produce and market several different panel sizes. Prices are generally based on grade, size of slats (also known as strips), and the square footage of the board. Competitive advantages are associated with manufacturers' closeness to raw material supply and customers. Other advantages are in the form of technology investments, well managed supplier/customer relationships, an appropriate marketing strategy, and the size of a company (Lawser 2004).

Not only are manufacturers of edge-glued panels competing with one another, they also compete with a variety of decorative laminated composites in the panel form. Our target customers generally manufacture products for consumers who make purchases based on aesthetic appeal. In this fashion oriented market, several alternative products exist that will compete against the Adaptive Panels within the targeted markets. Hardwood plywood is a widely used product consisting of thin sheets of lower valued wood with a decorative hardwood veneer used on the face and the back. The wood layers are laminated in a fashion to improve the stability and durability of the panel. Fortunately, for Practical Wood Solutions, Inc., many industry experts believe plywood has reached the maturity stage of the product life cycle (Wood Markets 2000 as cited by Tabarsi et al. 2003).

Another popular group of products among secondary industry manufacturers are decorative laminates. Although hardwood plywood is by definition a laminate, these groups of products are considered separately. Decorative laminates are manufactured by gluing decorative laminates to a substrate. The decorative laminates exist in the forms of real wood veneer, printed paper intended to mimic real wood, a Formica (melamine) sheet as well as several other alternatives. The substrates are generally a medium density fiber board, edge-glued panels, plywood, particleboard, or oriented strand board. Practical Wood Solutions Inc. believes these types of products may be gaining market acceptance for several reasons. One example includes improvements in manufacturing technology. Manufacturers are able to produce higher quality substrates with smoother faces for improved laminating. The laminates have improved as well. Printing quality has reached the point where it's becoming harder to separate real wood from the fake print. These panel products are now made cheaper and faster, better serving the manufacturers wishing to practice lean manufacturing techniques. Table 4.1 gives a brief description of the alternative products available to our target customers.

The Adaptive Panel has several advantages over the alternative products available to our targeted customers. Mainly, secondary manufacturers producing consumer goods in this segment demand solid wood over composite products because solid wood has better finishing characteristics than particle based boards and demanded by end users (Vlosky and Wu 2001). Practical Wood Solutions, Inc. also believes the Adaptive Panel has several advantages over traditional edge-glued panels within our immediate competitive environment. Traditionally, edge-glued panels are manufactured from intermediate quality and priced lumber. The Adaptive Panel will be manufactured from a low-quality, low-cost raw material. Furthermore, we will employ the latest technology in panel manufacturing. In conclusion, we perceive a price point advantage over our competitors while maintaining a competitive profit margin because of these factors.

Table 4.1 Competing types of raw materials with descriptions, strengths and weaknesses.

Raw Material	Description	Strengths	Weaknesses
Traditional Solid Edge-glued Panel[4]	Solid wood pieces edge-glued to obtain desired widths	Consumer demanded, Dimensionally stable, Aesthetically appealing, durable	Uneconomical to manufacture, raw material is becoming more difficult to secure
Hardwood Plywood	Decorative hardwood veneer cross-laminated over a variety of cores (mainly cheaper hardwood veneers)	Consumer demanded, Dimensionally stable, Aesthetically appealing, durable, slightly cheaper than solid wood	Exposed edges must be edge-banded, damaged face veneer is difficult to hide or repair
High Pressure Laminate	Decorative printed paper laminated over a several layers of glue impregnated papers pressed at high pressures	Extremely durable, cheap to manufacture, cheap for customers, consistent quality	Not a popular product for furniture, door, or component applications, difficult to machine and process, consumers perceive as cheap and low in quality
Melamine Laminated Substrate	Decorative printed resin laminated over a variety of cores (most often PB or MDF)	Surface is extremely durable, cheap to manufacture, cheap for customers, consistent quality, offered in a variety of colors and designs	Not engineered for moist environments, exposed edges must be edge-banded, consumers perceive as cheap and low in quality
Paper Laminated Substrate	Decorative printed paper laminated over a variety of cores (most often PB or MDF)	Cheap to manufacture, cheap for customers, consistent quality, perception of real wood veneer, capable of being finished like wood	Not engineered for moist environments, exposed edges must be edge-banded, consumers perceive as cheap and low in quality
Veneer Laminated Substrate	Decorative hardwood veneer laminated over a variety of cores (most often PB or MDF)	Real wood appearance, cheaper for customers than solid wood, consistent quality	Not engineered for moist environments, exposed edges must be edge-banded, consumers perceive as cheap and low in quality

4.5.4 Socio-Political Environment

The need to find innovative products and new markets for underutilized forest resources is the number one research priority among the forest products industry and its research community (Shepley et al. 2004). Practical Wood Solutions, Inc. foresees a push from government officials to better utilize such resources. This push may be in the form of regulation and/or tax incentives for manufacturers. Furthermore, there has been a

[4] Traditional in the sense where manufacturers are designing a cutting bill to cut slats to manufacturer edge-glued blanks.

change in consumers' perception of environmentally friendly forest products. The demand for such products manufactured from resources obtained from certified forests should increase as conscientious end users become more aware of the problems faced by the forest products industry concerning the raw material supply.

This drive may be necessary for the Adaptive Panel to be successful in this market. The acceptance of new products by manufacturers has traditionally been a slow process and is often dictated by the acceptance of these products by the end users (Vlosky and Wu 2001). Several other barriers to entry exist for Practical Wood Solutions, Inc. A limited availability to the resource is of concern, whether it is location, a finite supply of hardwoods or seasonal factors. Such an organization also requires a large capital investment.[5] The cost of establishing lumber yards and obtaining manufacturing equipment may prohibit entrepreneurs from entering this market. Furthermore, the level of competition in this industry is fierce. Companies compete on prices and often will cut their price and profits to gain market shares.

4.6 Marketing and Sales Plan

4.6.1 Marketing Penetration Strategy

Practical Wood Solutions, Inc. will begin its penetration into the target markets by focusing on those market segments that have historically shown a willingness to purchase edge-glued panels. We have identified these segments as office furniture and door manufacturers. Figures 4.4 and 4.5 show the importance of edge-glue panels in our target markets.

[5] However, due to the number of recent plant closures, used equipment may be readily available for the manufacture of Adaptive Panels.

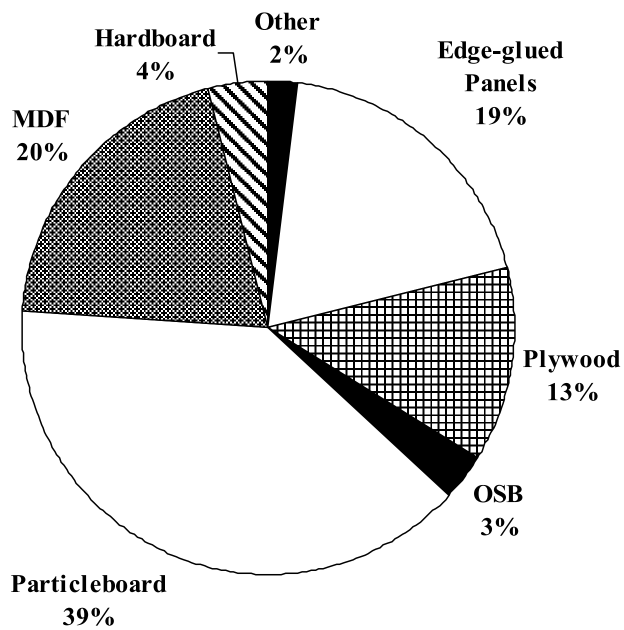

Figure 4.4 Wood-based panels used in office furniture manufacturing in 2000 (Tabarsi et al. 2003).

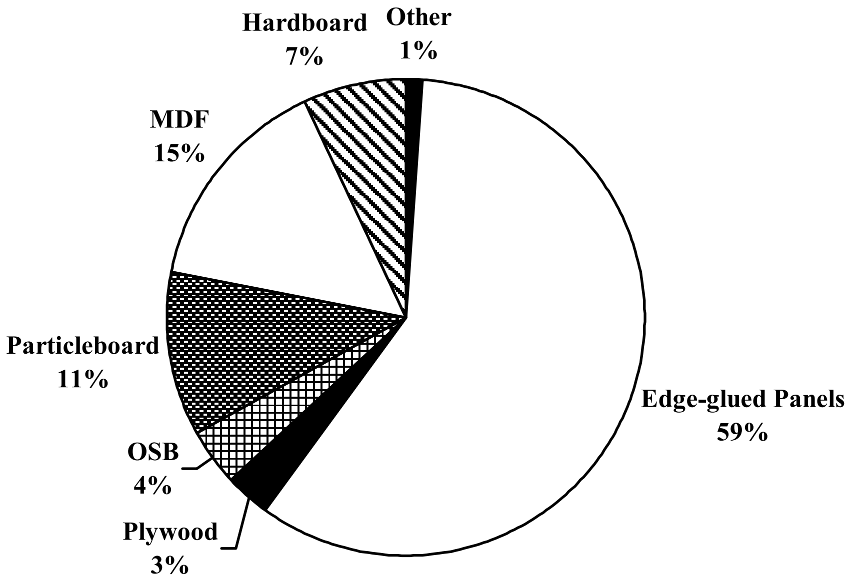

Figure 4.5 Wood-based panels used in door manufacturing in 2000 (Tabarsi et al. 2003).

Practical Wood Solutions, Inc. will offer the Adaptive Panel in a number of different product variations. These variations will exist in the size (width and length) of the slat (clear cutting) that will make up the board. To optimize the yield of our raw material, Practical Wood Solutions, Inc., through research and computer simulation, has designed a cutting bill of 5 standard widths and 10 standard lengths. The combination of lengths and widths results in 50 different part sizes being produced in the milling department. Since Practical Wood Solutions, Inc. will only offer panels of uniform sized slats, 50 different product variations of the Adaptive Panel will be manufactured.

The pricing strategy for the Adaptive Panel will be based on a cost-plus pricing strategy with the target profit margin based on the perceived demand for each product variation. Research suggests that Practical Wood Solutions, Inc. should expect the costs of producing a panel with average size slats (2.5 x 23 inches) to be in the $3.325[6] per BF range (Lawser 2004, Zaech 2001, WCMA 1999 as cited by Mitchell 2001, and Smith et al. 2002). A 25 percent profit margin will result in a price of $4.156 per BF or $133.00 per panel entry price point. Knowing that demand will vary according to the size of the slat in each panel, we will adjust our profit margin based on the perceived need for each product variation relative to the average price $3.325 of producing one BF of panel.

We perceive the strongest demand for the Adaptive Panel will be in the product with the largest size slat, 5 by 40 inches. Unfortunately, we realize the larger size slats will be the most difficult to obtain from the desired raw material. This variation will be our highest earning product with a target margin of 40 percent. The price point for this product is $4.655 per BF leading to a panel price of $148.96. Prices and target margins fluctuate throughout the product line and are listed in Table 4.12 in the Business Plan Appendix.

4.6.2 Growth Strategy

Practical Wood Solutions, Inc. has already developed several strategies to initiate growth for the future.[7] To reach customers in other market segments, Practical Wood Solutions, Inc. will look into expanding the product line which will include different thicknesses, custom sizes and offering panels in a variety of species. Furthermore, products such as a "butcher-block style" panel or tri-ply panels are also viable options for the future. Vertical growth options include the acquisition of land and sawmills as well as an opportunity to offer the product directly to consumers through the internet or retail centers. Research on new markets and future sources of raw materials will provide the direction for accomplishing these strategies.

4.6.3 Distribution channels

Orders specifying quantity and size of slats desired will be processed and shipped with a 1 week lead time. Initially, orders for Adaptive Panels will be distributed directly to our customers, e.g., the manufacturers of a variety of wood products. The product will

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[6] Estimates – Per BF (percentage of total costs) - **direct materials** - $0.770 (23.16%), **variable MFG OH** - $1.765 (53.08%), **direct labor** - $0.160 (4.81%), **variable S&A** - $0.045 (1.35**%), fixed MFG OH** - $0.415 (12.48%), **fixed S&A** - $0.170 (5.11%).

[7] These are future strategies that will most likely be investigated outside of the 5-year plan presented in this model.

be pulled from inventory, wrapped in moisture inhibiting plastic wrap, banded and shipped. Shipping will be handled by two different methods. For smaller orders within the area, we will deliver using a company owned delivery truck. A shipping company will be contracted for larger orders.

4.6.4 Communication

Marketing promotion will be performed through trade journal articles, and trade journal advertisements, trade shows/conferences, and a company website. Typical trade journals include “Custom Woodworking Business,” “Wood and Wood Products,” “Wood Digest,” and “Woodshop News.” Several trade shows and conferences take place throughout the year that will provide opportunities to showcase this unique product. These shows are often regionally based but larger shows such as The International Woodworking Fair (IWF), The Association of Woodworking & Furnishings Suppliers (AWFS) show, and the NHLA Annual Meeting are great opportunities to showcase the product because these shows are attended by international manufacturing and industry participants. Color brochures will be available to interested show participants. These brochures will provide background information on the product, specs, pictures, contact information, and the address to the company website.

A company website will be set up to provide information on the company and products offered. This website will consist of a number of links that include specifics about the products such as specifications, qualities, sizes, species offered, and a pricing list. This website will also have contact information for key company personnel.

4.6.5 Sales strategies

Initially, Practical Wood Solutions, Inc. will employ two salespersons to handle the Eastern half of the U.S. Each salesperson will be responsible for a region. The North Region will cover all states north of the Virginia – Maryland border. This region will reach as far west as Wisconsin. The South Region will cover all states south of the Virginia – Maryland border. This region will reach as far west as Texas. Contacts will be made through cold calling, customer inquiries, and references. Interested customers will be visited and presented with the product. Prior to each visit, research will be conducted on the potential customer. Needed information that is important to each visit will include customer demographics, processing techniques, current raw material consumption, and future manufacturing plans. During the visit, the salesperson will present a cost analysis of using our product, Adaptive Panels, versus lumber or alternative panel products.

Practical Wood Solutions, Inc. realizes the small size of the company will be a disadvantage when it comes to sales activities. We plan on overcoming this shortcoming by hiring dedicated salespersons capable of handling the job. We also will employ support staffers who will contribute to the research efforts. Paralleling the growth of the company will be growth of the sales force. Potential options include adding a representative to the Asian and European markets as well as adding to the U.S. sales force.

4.7 Operations

The internal value chain for Practical Wood Solutions, Inc. is listed in Figure 4.6.

Human Resources **- (See Management & Organization Section 4.8)**				
Research & Development **– Semi-critical – Market research with continuous process and product improvements**				
Procurement **– Handled by COO with assistance from M&S support staffers.**				
Infrastructure **– (See Operations Section 4.7.2)**				
Inbound: **Outsourced - Low-grade lumber from small diameter timber as well as other sources and sawmill slabs**	***Operations:*** **In-house - Competitive advantage through designed cutting bill and highly automated process**	***Outbound:*** **High-quality solid hardwood panel in a 4’x8’ standard size**	***Sales & Marketing:*** **In-house – Critical. Another potential point for competitive advantage**	***Customer Service:*** **In-house. Critical. Lab technicians, sales managers, and executives**

Figure 4.6 Practical Wood Solutions, Inc. internal value chain for the production of Adaptive Panels.

4.7.1 Location

Practical Wood Solutions, Inc. will operate out of North Carolina's Piedmont Triad Area (Greensboro, High Point, and Winston Salem). This business friendly area is appropriate for several reasons. The area is ideally located close to several furniture manufacturers. Cities with high concentrations of furniture and wood product supporting industries such as High Point, Thomasville, Danville, and Martinsville are all located within an hour and a half drive. Furthermore, the area is relatively close to the resource (Figure 4.7) and several area hardwood sawmills (Figure 4.8). There is a highly skilled workforce available in this area as well as several higher education institutions, most notably wood education programs such as those at N.C. State and Virginia Tech as well as several area community colleges.

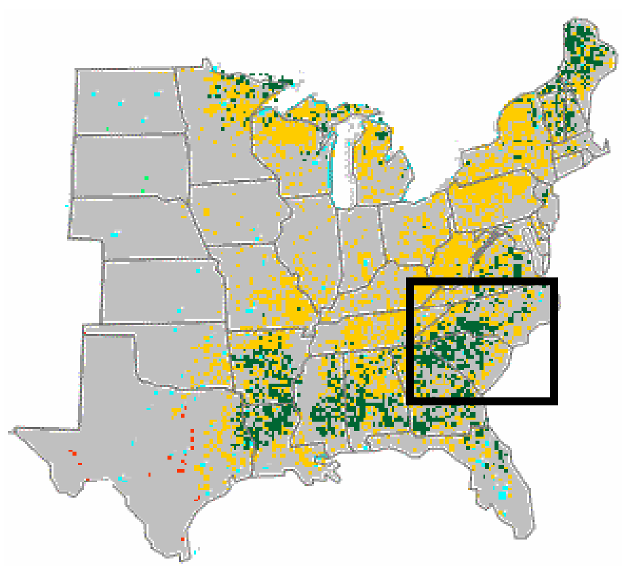

Figure 4.7 Eastern US hardwood (yellow) and softwood (green) forest cover (Wood Resources Institute 05).

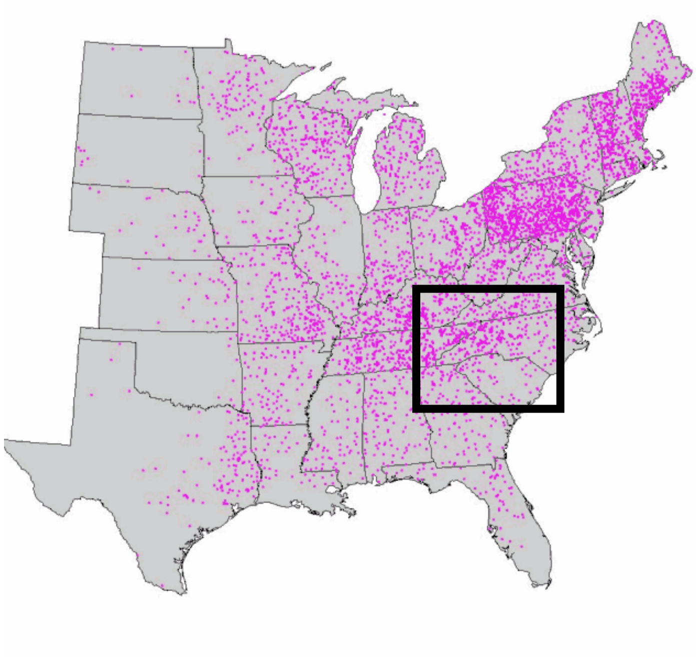

Figure 4.8 Eastern U.S. hardwood and softwood sawmill locations in 1999 (USDA Forest Service 99).

4.7.2 Infrastructure

The Triad area is accessible through many different forms of transportation. Piedmont Triad International Airport (PTI) is the region's main airport offering non-stop flights to a number of major East Coast cities. In 2007, PTI will become FedEx's Mid-Atlantic Hub (High Point Chamber of Commerce 2005). CSX and Norfolk Southern serve the Triad area's major railway freight needs as well as several smaller lines that connect many of the area's industrial sites to the railroad infrastructure. Amtrack serves the Triad area's railway passenger needs (High Point Chamber of Commerce 2005). The Triad area offers easy access to a number of the major highways that serve as arteries for the nation's transportation needs. Interstates I-40 and I-85 run through the area, while several other interstates are easily accessed through I-40 or I-85 including I-95, I-77, I-81, and I-74. North Carolina is home to two major deep water ports located in Wilmington and Morehead City. The Wilmington port is a 3-½ hour drive via I-40 East. An intermodal port terminal is located in Greensboro that offers inland container staging and storage for each of the state's ports.

4.7.3 Materials and Procurement

Practical Wood Solutions, Inc. will operate one 8-hour shift a day for 235 days a year. Once the company is up and running, the estimated daily output will be 469 Adaptive Panels or roughly 15 thousand board feet (MBF) of finished product. This equates to a total of 3.5 million board feet (MMBF) of panels a year. Practical Wood Solutions, Inc., through research and the aid of computer simulation, has designed a cutting bill that optimizes yield for the grade mix of lumber that is anticipated by the company. From this simulation, Practical Wood Solutions, Inc. believes we will experience about a 60 percent yield (rough mill) for this particular cutting bill. Total plant yield is estimated at 48 percent[8]. At a 48 percent yield, it will be necessary to process about 31.25 MBF of raw wood material a day or a little more than 7.4 MMBF a year.

All manufacturing will be done in-house. Practical Wood Solutions, Inc. will develop supplier relationships with regional landowners, logging companies, and sawmills. The goal is to buy the higher quality small-diameter timber removed during forest improvement projects. Contracts will exist with sawmills who will process this material and sell the resulting lumber to Practical Wood Solutions, Inc. We also anticipate purchasing sawmill slabs from several local area sawmills. Restrictions will be placed on the minimum size of slabs accepted.

4.7.4 Production and service delivery procedures

Practical Wood Solutions, Inc. will be subdivided into three departments: Production, Marketing and Sales, and Engineering and Finance. All three departments will work closely together in the team oriented environment.

The Production Department is responsible for procuring and receiving raw material, processing raw material, and shipping final product; the main aspects of the day-to-day operations. A production manager will be in charge of this department which is subdivided into 4 groups based on specific tasks. The four groups are the ‘green end’, ‘milling’, ‘panel’, and ‘shipping’. The green end is responsible for receiving the raw material, ripping the material into the five standard widths, stacking and drying. Milling

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[8] Total plant yield equals 40% loss in rough mill, 8% loss in dry-kiln, 2% loss through finger-jointing and moulding, and 2% loss in edge trimming.

is responsible for unstacking the strips, processing the rough material into defect-free blanks, and sorting the blanks based on size and color. Once sorted, a full bin of same size blanks within an accepted color range will be delivered to the panel group. In paneling the blanks are finger-jointed for length, moulded to uniform thickness and width, and edge-glued into the full-size width. A final sizing process will take place and panels are sanded to a specified thickness and smoothness. The finished panels are sent to shipping where they are stacked, packaged, stored, and shipped. The proposed process will be highly automated and require fewer skilled laborers than is common in traditional panel manufacturing processes.

The Marketing and Sales Department is responsible for marketing and selling the product. This department will be managed by the Marketing and Sales manager. Salespeople will be in constant contact with current and potential customers. The information and knowledge gained from contacts and market research will be used to strategically plan for the future. Staff supporters will handle sales documentation, support marketing research, and other general duties of the department.

The Engineering and Finance Department is responsible for managerial accounting, financial reporting, concurrent engineering and evaluating projects such as capital investments and process and product improvements. The Engineering and Finance Department manager will serve as the Chief Financial Officer (CFO). Engineers and accountants make up this department.

Increases in capacity will be evaluated by the Engineering and Finance Department and discussed among the executives and then the Board. When projects are approved, the principal owners will be contacted and given the necessary information to make a decision on the project. Increases in capacity can be handled with capital investments, increases in the supply of raw material, and possibly the addition of employees. Foreseeable changes are customized sizing for customers, customer-defined color matching, and just-in-time (JIT) deliveries.

4.7.4.1 Operating competitive advantages

Practical Wood Solutions, Inc. will operate using a number of competitive advantages. Through extensive research and simulation, we have designed our cutting bill and product in a way that uses a low-cost raw material and efficiently processes this material for maximum yield. Furthermore, the cutting bill calls for 5 standard widths and 10 standard lengths; this reduces operational complexities and lowers processing costs. Our low-cost inputs, a unique process, and state-of-the-art manufacturing facility will produce a high-quality product with minimal costs, enabling us to price our product slightly below the market's price point for this particular grade and enjoy high margins. We also believe our 8' x 4' standard-size will allow us to capture a small portion of the wood composites' market because companies can easily convert to the Adaptive Panel without changes to their manufacturing process and offer their customers a higher-value product. Once the company has production running smoothly, Practical Wood Solutions, Inc. will begin to accumulate a finished goods inventory enabling the company to almost immediately satisfy specific customer panel needs. Practical Wood Solutions, Inc.'s main competitive advantage is the ability to operate under a customer focused philosophy, engineering products for the market.

4.7.4.2 Suppliers

Practical Wood Solutions, Inc. will receive two forms of raw material, lumber and sawmill slabs, for the manufacturing of Adaptive Panels. Small-diameter timber from thinning practices will be purchased from regional landowners. Current prices for small-diameter hardwood stumpage average $19.60/ton (Wiedenbeck 2004). . Daniels (2005) estimates 9-11 tons of hardwood logs are necessary to produce 1,000 BF of lumber, resulting in an average cost of $196/MBF[9]. Practical Wood Solutions, Inc. believes such material can be delivered to area sawmills who will be contracted to cut the logs into lumber for $336/MBF[10]. The lumber processed from the log runs will be delivered to the manufacturing facility at a final cost of roughly $370/MBF[11].

[9] 10 tons @ $19.60/ton

[10] Logging estimated at $100/MBF, trucking estimated at $40/MBF

[11] 10% markup from sawmill

Slabs will also be purchased from a number of different sawmills at a cost of $10/ton. In a recent study by N.C. State University researchers, it is estimated that 15% of the sawmill slab is capable of producing a blank measuring at least 1 inch thick by 2 inches wide by 1 foot long (Buehlmann et al. 2005). This estimate is conservative when measured to our efforts, because the actual minimum size allowed in the Adaptive Panel is half as wide and less than half the length (5"). We expect a significant increase in the percentage of useful material from slabs for our process and consider slabs a viable source of usable material.

Practical Wood Solutions, Inc. will have enough storage space to make large purchases when market prices are low and after the initial stages of production, enough excess to sustain production when market prices are high. At startup, procuring raw material will be extremely important. Unfortunately, drying lumber is an extremely difficult and long process and at any given time there must be enough kiln-dried material to support 4-5 days of production. Therefore, it will be necessary to build raw material inventories as quickly as possible in order to set-up drying (air, shed and kiln) schedules for future production demands.

At times, Practical Wood Solutions, Inc. may find it necessary to purchase kiln-dried red oak material. These purchases will be of varying grades and volumes. This may be especially true in the initial stages of production, when the kiln-dried material inventory is low and fluctuating. Prices for kiln-dried, 4/4 red oak lumber (based on net tally) vary according to region but generally range from $650 for #3 Common to $1,000 for #1 Common for 1,000 BF (Hardwood Review 2005).

Practical Wood Solutions, Inc. will need to select a mix of lumber grades for several reasons. The large clear cuttings available in #1 Common lumber will serve as the primary source for the larger size slats. Also, utilizing high grade lumber such as #1 Common will help rough mill yields. However, as the percentage of #3 Common of lumber is increased in the grade mix, the yields are expected to decrease.

4.8 Management and Organization

Practical Wood Solutions, Inc. incorporates as an "S-Corporation" in the Piedmont Triad area of North Carolina. Filing for Subchapter S allows Practical Wood Solutions, Inc. several benefits including; limited liability, recognition as a legal entity, favorable tax treatment, relative ease of transferability of interests, and continuity (Pepke 1988). S-Corporations are not double taxed and treated more like a partnership meaning taxes are not calculated at the corporate level, instead, profits and losses are passed down to the shareholders and taxed once on their income statements.

4.8.1 Management Structure

The management team and the structure of our organization will be vital to the success of Practical Wood Solutions, Inc. There are four levels of management in this company; Board of Directors, high level managers (CEO and COO), department managers, and operations supervisors. At startup, Practical Wood Solutions, Inc. anticipates a total of 41 employees. The organization's management structure at inception is represented by Figure 4.9.

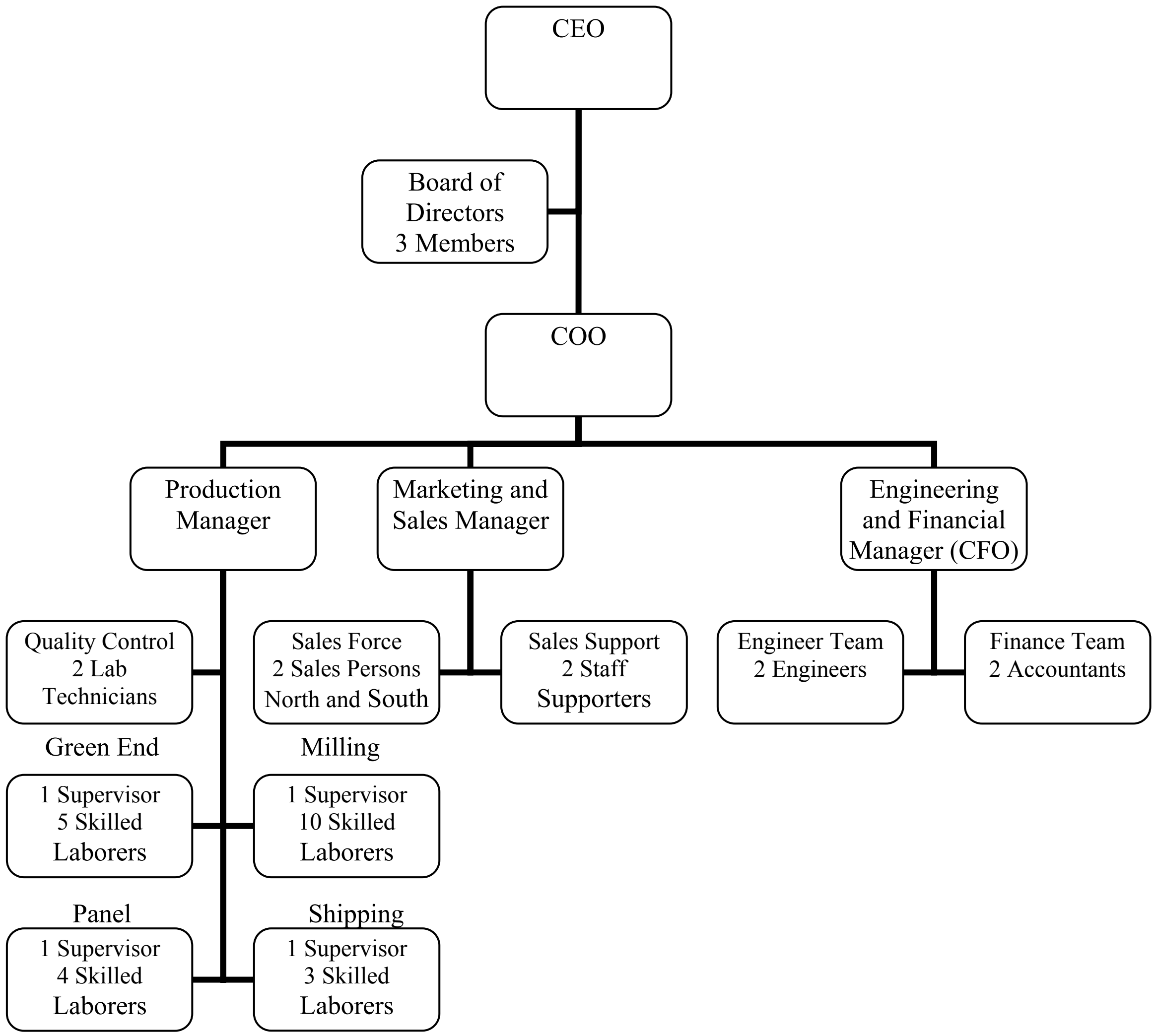

Figure 4.9 Practical Wood Solutions, Inc. management structure at startup.

The Chief Executive Officer will be the highest ranking manager in the organization. He/she is responsible for developing and carrying out short and long-term strategies. The CEO will act as Chairman of the Board of Directors and will incorporate their thoughts and input into the company's operational plan. The CEO will also work closely with the Chief Operation Officer (COO). The COO is in charge of manufacturing and daily operations. His/hers' main responsibility is meeting production schedules and producing a high quality product suitable for our customers.

Practical Wood Solutions, Inc. will be subdivided into three departments: Production, Marketing and Sales, and Engineering and Financial. Each department will have a manager with the Engineering and Financial Manager acting as the Chief Financial Office (CFO). The production manager reports to the CEO and the COO and will be responsible for managing twenty-eight people and five operations. One operation, quality control, will require two lab technicians to perform quality assurance tests on various stages of the process. This operation will also be in charge of customer service, because of their knowledge of the product and process. The other four operations will require a number of skilled workers to complete specific tasks in the manufacturing process. Therefore, each of these four operations will have an operation supervisor who will report to the production manager.

The marketing and sales manager also reports to the CEO and the COO and is in charge of four people. Practical Wood Solutions, Inc.'s focus is on supplying high-quality solid panels to our customers. The marketing and sales manager will manage two sales persons and two support staffers. The sales persons will be responsible for two regions. The North Region will cover all states north of the Virginia – Maryland border. This region will reach as far west as Wisconsin. The South Region will cover all states south of the Virginia – Maryland border. This region will reach as far west as Texas. Two support staffers are required to handle sales receipts and various other day to day duties. It is important that this department work closely with the Engineering and Finance Department.

The engineering and financial manager is also in charge of four people and will act as Practical Wood Solutions, Inc.'s Chief Financial Officer (CFO). The CFO's main responsibility is assuring the financial health of Practical Wood Solutions, Inc. and evaluating manufacturing improvements and potential investments in machinery. This department will be subdivided into two teams, engineering and accounting, each with two people. The company will follow an activity-based costing method. In activity-based costing, cost information is determined by measuring the cost of activities that are specific to producing the product. This accounting method presents the true cost of fulfilling the customer's needs and will allow Practical Wood Solutions, Inc. to continue investigating, engineering, evaluating, and improving the process and the finished product as efficiently as possible while minimizing costs.

4.8.1.1 Key Management Descriptions

The management positions have not yet been filled by Practical Wood Solutions, Inc. However, the company is using a set of ideal characteristics while searching for potential candidates for each role. The Board of Directors will consist of three members. The CEO will serve as the Chairman of the Board. The search for other members of the board will include active and retired industry executives and experts, preferably from academia or the furniture, kitchen and bath cabinet, or sawmill sectors. Compensation for the two outside board members will be determined through negotiations and will most likely include stock options and a salary that is based on a percentage of the profit.

The executives for Practical Wood Solutions, Inc. play an important role in the success of the company. Candidates should have experience in company startups with excellent leadership skills. It is important for the COO to be knowledgeable in manufacturing processes and the wood material. The candidate we seek should have a Masters of Science degree in a wood science curriculum with an industrial engineering background. The CEO must be knowledgeable in marketing and everyday business operations as well as the current conditions of the wood industry. The candidate we seek for this job should have a Bachelors of Science in marketing or wood science with more than 10 years of industry experience. Ideally, this candidate would also have a Masters of Business Administration. The engineer and financial manager (CFO) should be knowledgeable in engineering economics as well as industrial practices. An interest in financial accounting is also recommended. The candidate we seek for this job should have a Bachelors of Science in accounting, be a CPA (Certified Public Accountant) and have a strong manufacturing background. Compensation for the top executives will range from $100,000 to 175,000 a year, based on experience and performance. The CEO, serving on the board, will receive a larger base salary and also be rewarded with stock options and a percentage of revenue to be determined during negotiations. Potential candidates for the manager and supervisor positions are expected to have experience in leadership and wood product manufacturing. Managers' pay will range from $75,000 to 100,000 a year while supervisors pay will range from $35,000 to 50,000 a year based on experience and performance.

4.9 Financial Plan

4.9.1 Capital Requirements

The total capital required for Practical Wood Solutions, Inc. at startup is $7,554,624 (U.S.). Included in this total is capital for constructing the manufacturing facility, capital for purchasing machinery, extra cash for operating expenses, and a 20 percent safety mark-up for unforeseen expenses. Funding will come in the form of owner's equity (approximately 10 percent)[12], debt, and government grants. Construction of the facility will begin immediately upon receipt of the first $2.5 million. Construction is expected to last six months. During construction, Practical Wood Solutions, Inc. will seek sources of raw materials and begin preparing this material for production. Also, during the six months of construction, Practical Wood Solutions, Inc. will continue to seek investments for the purchasing of manufacturing equipment. Production is expected to begin during the ninth month.

4.9.2 Revenue Generation

Practical Wood Solutions, Inc. hopes to reach $15.5 million in annual sales when operating at full capacity. We are not expected to reach full capacity until September 2008 (month 21) of operation which is actually month 12 of production. All revenue will be generated through the sales of the Adaptive Panel. Prices for the Adaptive Panel will range from $128.21 to 148.96 per panel. Gross margins for the Adaptive Panel range from 20.5 percent to 40 percent per panel.

4.9.3 Financial Statements

Practical Wood Solutions, Inc. has projected two pro forma income statements, a pro forma statement of cash flows, and a pro forma balance sheet for the next five years. One income statement details the monthly projections during the production startup phase, years one and two. The other gives annual income projections for years 1 through 5. The purpose of these statements is to evaluate the profitability of introducing the Adaptive Panel in our target markets. Throughout the financial statements, several assumptions are used to develop the necessary line items. In each case, the assumptions for the particular statement are followed by the actual statement itself.

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[12] Seeking investments from venture capitalist, private investors and established businesses.

4.9.3.1 Pro Forma Income Statements and Assumptions

1) Production begins during month 9.
2) Production will increase 800 panels a month until capacity.
3) Average cost of producing 1 BF of the Adaptive Panel is $3.325. The breakdown is listed in Table 4.2.

Table 4.2 Average manufacturing cost per BF of Adaptive Panel.

Cost Type	Cost per BF	Percentage of Total Costs
Direct Materials	$0.770	23.16%
Variable MFG Overhead	$1.765	53.08%
Direct Labor	$0.160	4.81%
Variable S&A	$0.045	1.35%
Fixed MFG Overhead	$0.415	12.48%
Fixed S&A	$0.170	5.11%
Total Cost / BF	$3.325	

4) Net sales based on the average price of $133.00 per panel.
5) Assume total market consumption of capacity.
6) Building the raw material inventory - treated as an operating expense:
    a) Year 1 – add 200 MBF at an average cost of $370 / MBF
    b) Year 2 – increasing to 1 MMBF at an average cost of $370 / MBF
7) Insurance is treated as an operating expense and is estimated to cost $100,000 a year.
8) S-Type Corporation is treated as a “pass through entity” meaning taxes are passed down to the shareholders.
    a) $2,000,000 S-corporation distribution is paid to owners starting at year three
9) Years 3, 4, and 5 experience inflation at a rate of 2 percent per year.

Table 4.3 Practical Wood Solutions, Inc.'s Income Statement during year 1.

Revenues	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Panels Sold	0	0	0	0	0	0	0	0	0	385	1,185	1,985
Price / Panel	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133
Net Sales	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$51,205**	**$157,605**	**$264,005**
COGS												
Direct Materials	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,486	$29,198	$48,910
Direct Labor	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,971	$6,067	$10,163
Variable MFG OH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$21,745	$66,929	$112,113
Fixed MFG OH	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211
Total	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$151,413	$220,405	$289,397
Gross Margin	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($118,211)**	**($100,208)**	**($62,800)**	**($25,392)**
Expenses												
Operating Expenses												
Variable S&A	$0	$0	$0	$0	$0	$0	$0	$0	$0	$554	$1,706	$2,858
Fixed S&A	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333
Total S&A	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,888	$51,040	$52,192
Operating Income	($167,544)	($167,544)	($167,544)	($167,544)	($167,544)	($167,544)	($167,544)	($167,544)	($167,544)	($150,096)	($113,840)	($77,584)
Income/Expense	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)	($14,500)
EBIT	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($164,596)**	**($128,340)**	**($92,084)**
Income Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Income	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($182,044)**	**($164,596)**	**($128,340)**	**($92,084)**

Table 4.4 Practical Wood Solutions, Inc.'s Income Statement during year 2.

Revenues	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08
Panels Sold	2,785	3,585	4,385	5,185	5,985	6,785	7,585	8,385	9,185	9,185	9,185	9,185
Price / Panel	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133	$133
Net Sales	**$370,405**	**$476,805**	**$583,205**	**$689,605**	**$796,005**	**$902,405**	**$1,008,805**	**$1,115,205**	**$1,221,605**	**$1,221,605**	**$1,221,605**	**$1,221,605**
COGS												
Direct Materials	$68,622	$88,334	$108,046	$127,758	$147,470	$167,182	$186,894	$206,606	$226,318	$226,318	$226,318	$226,318
Direct Labor	$14,259	$18,355	$22,451	$26,547	$30,643	$34,739	$38,835	$42,931	$47,027	$47,027	$47,027	$47,027
Variable MFG OH	$157,297	$202,481	$247,665	$292,849	$338,033	$383,217	$428,401	$473,585	$518,769	$518,769	$518,769	$518,769
Fixed MFG OH	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,211	$118,212	$118,213	$118,214
Total	$358,389	$427,381	$496,373	$565,365	$634,357	$703,349	$772,341	$841,333	$910,325	$910,326	$910,327	$910,328
Gross Margin	**$12,016**	**$49,424**	**$86,832**	**$124,240**	**$161,648**	**$199,056**	**$236,464**	**$273,872**	**$311,280**	**$311,279**	**$311,278**	**$311,277**
Expenses												
Operating Expenses												
Variable S&A	$4,010	$5,162	$6,314	$7,466	$8,618	$9,770	$10,922	$12,074	$13,226	$13,226	$13,226	$13,226
Fixed S&A	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333	$49,333
Total S&A	$53,344	$54,496	$55,648	$56,800	$57,952	$59,104	$60,256	$61,408	$62,560	$62,560	$62,560	$62,560
Operating Income	($41,328)	($5,072)	$31,184	$67,440	$103,696	$139,952	$176,208	$212,464	$248,720	$248,719	$248,718	$248,717
Income/Expense	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)	($33,000)
EBIT	**($74,328)**	**($38,072)**	**($1,816)**	**$34,440**	**$70,696**	**$106,952**	**$143,208**	**$179,464**	**$215,720**	**$215,719**	**$215,718**	**$215,717**
Income Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Income	**($74,328)**	**($38,072)**	**($1,816)**	**$34,440**	**$70,696**	**$106,952**	**$143,208**	**$179,464**	**$215,720**	**$215,719**	**$215,718**	**$215,717**

Table 4.5 Practical Wood Solutions, Inc.'s Income Statement for first five years of operation.

	Year				
Revenues	2007	2008	2009	2010	2011
Panels Sold	3,555	81,420	110,215	110,215	110,215
Price / Panel	$133	$133	$135.66	$138.37	$141.14
Net Sales	**$472,815**	**$10,828,860**	**$14,951,767**	**$15,250,802**	**$15,555,818**
COGS					
Direct Materials	$87,595	$2,006,189	$2,770,012	$2,825,412	$2,881,920
Direct Labor	$18,202	$416,870	$575,587	$587,099	$598,841
Variable MFG OH	$200,786	$4,598,602	$6,349,442	$6,476,431	$6,605,960
Fixed MFG OH	$1,418,531	$1,418,531	$1,446,902	$1,475,840	$1,505,356
Total	$1,725,114	$8,440,192	$11,141,942	$11,364,781	$11,592,077
Gross Margin	**($1,252,299)**	**$2,388,668**	**$3,809,825**	**$3,886,021**	**$3,963,742**
Expenses					
Operating Expenses					
Variable S&A	$5,119	$117,245	$161,884	$165,121	$168,424
Fixed S&A	$592,000	$592,000	$603,840	$615,917	$628,235
Total S&A	$597,119	$709,245	$765,724	$781,038	$796,659
Operating Income (Loss)	($1,849,418)	$1,679,423	$3,044,101	$3,104,983	$3,167,083
Operating Expenses	$174,000	$396,000	$102,000	$104,040	$106,121
EBIT (Loss)	**($2,023,418)**	**$1,283,423**	**$2,942,101**	**$3,000,943**	**$3,060,962**
Income Taxes	$0	$0	$0	$0	$0
Net Income (Loss)	**($2,023,418)**	**$1,283,423**	**$2,942,101**	**$3,000,943**	**$3,060,962**
Retained Earnings					
Beginning (Loss)		($2,023,418)	($739,995)	$202,106	$1,203,049
S-Corp Distribution			($2,000,000)	($2,000,000)	($2,000,000)
Ending (Loss)	**($2,023,418)**	**($739,995)**	**$202,106**	**$1,203,049**	**$2,264,011**

4.9.3.2 Pro Forma Statement of Cash Flows and Assumptions

1) Salaries are paid weekly.
2) Practical Wood Solutions, Inc. assumes 30 day revolving accounts for suppliers as well as customers.
3) Depreciation ($223,526) is calculated using the straight line method over 20 years. Salvage value is $0.
    a. Total plant value equals $431,500 depreciating at $21,575 a year
    b. Total equipment value equals $4,039,020 depreciating at $201,951 a year
4) Accrual expenses refer to prior week's owed salary and the future month's payable interest[13] with 2 percent inflation for years 3, 4, and 5.
5) Accounts payable refer to the prior month's cost for raw materials purchased on credit with 2 percent inflation for years 3, 4, and 5.
6) Inventory adjustments are made during years 1 and 2, while changes in years 3, 4, and 5 represent inflation.
7) Accounts receivable are derived from owed revenue from December sales.
8) Prepaid assets include future month's cost of insurance.
9) $550,000 is the cost of the property, $431,500 is the cost of the buildings, and $4,039,020 is the cost of the machinery.
10) Startup costs total $7,554,624 – 90 percent ($6,799,162) through financing and 10 percent ($755,462) through the issuance of stock (owner's equity).
11) Payments towards long-term borrowing are calculated from the annual $747,255 payment minus total interest paid for the year.
    a. $6,799,162, 20-year loan at a fixed 9.25%[14] interest rate
12) S-Corporation distributions in the amount of $2,000,000 are paid after years 1 and 2.

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[13] Amortization table located in Table 4.27 Amortization table for $6,799,162 on Jan. 1, 2007.
[14] Actual loan would include 3 separate loans with such structures: "*1) A real estate loan amortized over 15 years with a 5 year rate call at prime (7.25%) plus 1-2%; 2) An equipment loan amortized over 5 years at prime plus 1-2%; 3) A working capital loan or an operating line of credit for whatever the cash needs of the company are, this loan will be based on a cash budget as the company ramps up. This loan would also be at the prime rate plus 1-2%. Most likely there would be a portion of a line of credit that would become frozen and have to be termed out as permanent working capital. This loan would be cross collateralized with the assets of the company including accounts receivables*" (White 2005).

Table 4.6 Practical Wood Solutions, Inc.'s Statement of Cash Flows for first five years of operation.

	Year				
	2007	2008	2009	2010	2011
Beginning Cash	**$0**	**$274,537**	**$150,170**	**$1,128,581**	**$2,150,592**
Net Cash Flow					
Operating Activities					
Net Income (Loss)	($2,023,418)	$1,283,423	$2,942,101	$3,000,943	$3,060,962
Depreciation	$223,526	$223,526	$223,526	$223,526	$223,526
Increase (Decrease) in Accruals	$98,419	$3,873	($106)	($197)	($297)
Accounts Payable	$48,910	$177,408	$4,516	$4,617	$4,709
Increase in Inventory	($211,185)	($719,598)	($18,615)	($18,988)	($19,367)
Increase in A/R	($264,005)	($957,600)	($24,376)	($24,920)	($25,418)
Increase in Prepaid	($8,333)	$0	($167)	($170)	($173)
Total Operating Activites (Loss)	**($2,136,086)**	**$11,032**	**$3,126,880**	**$3,184,811**	**$3,243,942**
Financing Activities					
Purchase of Land	($550,000)				
Purchase of Buildings	($431,500)				
Purchase of Equipments	($4,039,020)				
Total Financing Activities (Loss)	**($5,020,520)**	**$0**	**$0**	**$0**	**$0**
Investing Activites					
Borrowings from Bank	$6,799,162	$0	$0	$0	$0
Payments on LT borrowing	($123,481)	($135,400)	($148,469)	($162,800)	($178,514)
Proceeds from Issuance of Stock	$755,462				
S-Corp Distributions	$0	$0	($2,000,000)	($2,000,000)	($2,000,000)
Total Investing Activities	**$7,431,143**	**($135,400)**	**($2,148,469)**	**($2,162,800)**	**($2,178,514)**
Ending Cash	**$274,537**	**$150,170**	**$1,128,581**	**$2,150,592**	**$3,216,020**

4.9.3.3 Pro Forma Balance Sheet and Assumptions

1. Salaries are paid weekly.
2. Practical Wood Solutions, Inc. assumes 30 day revolving accounts for suppliers as well as customers.
3. Accounts receivable are derived from owed revenue from December sales.
4. Inventory estimates:
    a. Finished goods inventory – 2 weeks worth of production with inflation in years 3, 4, and 5
    b. Work-in-process inventory – 1 week worth of production with inflation in years 3, 4, and 5
    c. Raw material inventory – $370 / MBF with inflation in years 3, 4, and 5
5. Prepaid assets include future month's cost of insurance.
6. Land valued at $550,000 and does not depreciate.
7. Total plant valued at $431,500 depreciating at $21,575 a year.
8. Total equipment value equals $4,039,020 depreciating at $201,951 a year.
9. Notes payable:
    a. Principle – Future month's principal owed[15]
10. Accounts payable refer to the prior month's cost for raw materials purchased on credit with 2 percent inflation for years 3, 4, and 5.
11. Accrual expenses:
    a. Prior week's owed salary with 2 percent inflation for years 3, 4, and 5
    b. Future month's payable interest[15] with 2 percent inflation for years 3, 4, and 5
12. Notes payable refer to the amount of remaining debt.[15]
13. Capital stock refers to stocked issued to initial investors.

[15] Amortization table located in Table 4.27 Amortization table for $6,799,162 on Jan. 1, 2007.

Table 4.7 Practical Wood Solutions, Inc. projected balance sheet for first 5 years of production.

	Year				
Assets	2007	2008	2009	2010	2011
Current					
Cash	$274,537	$150,170	$1,128,581	$2,150,592	$3,216,020
Accounts Receivable	$264,005	$1,221,605	$1,245,981	$1,270,900	$1,296,318
Inventory					
Finished Goods	$91,457	$423,189	$431,652	$440,285	$449,090
WIP	$45,728	$211,594	$215,826	$220,143	$224,545
Raw Materials	$74,000	$296,000	$301,920	$307,958	$314,118
Prepaid Assets	$8,333	$8,333	$8,500	$8,670	$8,843
NonCurrent					
Net Property	$550,000	$550,000	$550,000	$550,000	$550,000
Net Plant (minus depreciation)	$409,925	$388,350	$366,775	$345,200	$323,625
Equipment (minus depreciation)	$3,837,069	$3,635,118	$3,433,167	$3,231,216	$3,029,265
Total Assets	***$5,555,055***	***$6,884,360***	***$7,682,401***	***$8,524,964***	***$9,411,824***
Liabilities					
Current					
Notes Payable					
Principal	$10,813	$11,857	$13,001	$14,256	$15,632
Accounts Payable	$48,910	$226,318	$230,834	$235,451	$240,160
Accrued Expenses					
Salaries Payable	$46,961	$51,878	$52,916	$53,974	$55,053
Interest Payable	$51,458	$50,415	$49,270	$48,015	$46,639
Long-Term					
Bonds Payable					
Notes Payable	$6,664,868	$6,528,425	$6,378,812	$6,214,757	$6,034,867
Total Liabilities	**$6,823,011**	**$6,868,893**	**$6,724,833**	**$6,566,453**	**$6,392,351**
Stockholders' Equity					
Capital					
Stock	$755,462	$755,462	$755,462	$755,462	$755,462
Excess					
Retained Earnings(Loss)	($2,023,418)	($739,995)	$202,106	$1,203,049	$2,264,011
Total SE	**($1,267,956)**	**$15,467**	**$957,568**	**$1,958,511**	**$3,019,473**
Total L and SE	***$5,555,055***	***$6,884,360***	***$7,682,401***	***$8,524,964***	***$9,411,824***

4.9.4 Economic Analysis

4.9.4.1 Net Present Value

Net present value (NPV) is a popular and appropriate metric used to measure the value added or lost through an investment. NPV is calculated by comparing the present value of future cash flows to the cost of the initial investment. The projected cash flows for Practical Wood Solutions, Inc. are listed in Table 4.8. These values represent best estimates in income, expenses, and salvage value over the initial 5-year planning period. Salvage value ($8,106,663) includes depreciated equipment ($3,352,890), land value ($550,000), and estimated inventory on hand (finished, work-in-process, and finished – $987,753). The net present value (NPV) estimates for an investment in the manufacturing of Adaptive Panels were calculated using the net cash flows (Table 4.8) over a range of discount rates (3 to 20 percent, Table 4.9).

Table 4.8 Projected cash flows for Practical Wood Solutions, Inc. based on net cash flow, and salvage value over 5 years.

	Year					
	0	1	2	3	4	5
Initial Cost	($7,554,624)					
Cash Inflow		$274,537	$150,170	$1,128,581	$2,150,592	$3,216,020
Equipment Salvage						$3,352,890
Land Value Salvage						$550,000
Inventory Salvage						$987,753
Net Cash Flow	**($7,554,624)**	**$274,537**	**$150,170**	**$1,128,581**	**$2,150,592**	**$8,106,663**

Table 4.9 The net present value for an investment in Practical Wood Solutions, Inc. with estimated sash flows.

Year	Net Cash Flow	Discount Rate	NPV	Discount Rate	NPV	Discount Rate	NPV
0	($7,554,624)	3%	**$2,789,930**	9%	**$487,420**	15%	**($1,200,233)**
1	$274,537	4%	**$2,352,920**	10%	**$169,466**	16%	**($1,435,879)**
2	$150,170	5%	**$1,939,039**	11%	**($132,632)**	17%	**($1,660,420)**
3	$1,128,581	6%	**$1,546,843**	12%	**($419,807)**	18%	**($1,874,478)**
4	$2,150,592	7%	**$1,174,990**	13%	**($692,932)**	19%	**($2,078,633)**
5	$8,106,663	8%	**$822,236**	14%	**($952,821)**	20%	**($2,273,429)**

4.9.4.2 Return on Investment

The return of an investment (ROI) measures the benefits of the project as a function of the total assets required. Benefits in this context refer to net income and are taken from the 5 year income statement. Total assets are a measure of the total dollar value of the assets and taken from the 5 year balance sheet. There are several ways to measure ROI, the formula used to calculate ROI for this proposal:

$$ROI = Return\ of\ Investment\ /\ Assets\ Invested$$

Table 4.10 Return on Investment based on net income, payable interest, tax rate and the book value of assets for years one through five.

	Year 2007	2008	2009	2010	2011
Net Income	($2,023,418)	$1,283,423	$2,942,101	$3,000,943	$3,060,962
Total Assets	$5,555,055	$6,884,360	$7,682,401	$8,524,964	$9,411,824
ROI	**-36.42%**	**18.64%**	**38.30%**	**35.20%**	**32.52%**

4.9.4.3 Break-even Analysis

A break-even analysis is conducted using yearly net income over the first five projected years of the project. The project is expected to break even between April and July of the second year (2008).

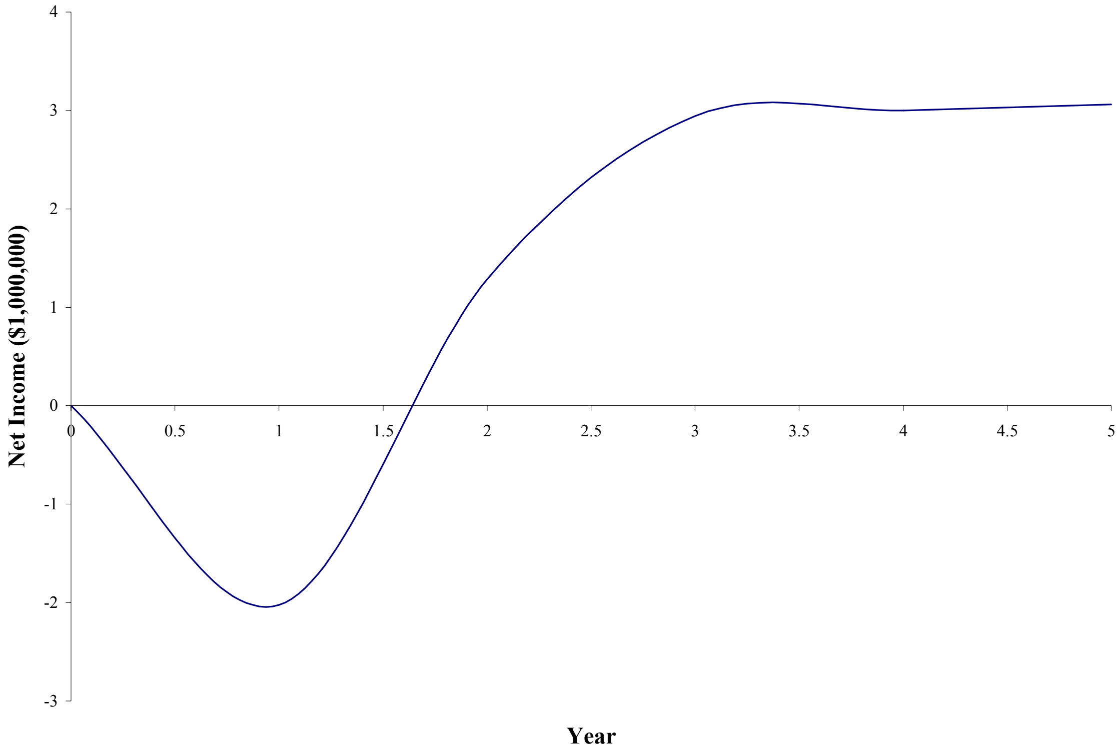

Figure 4.10 Break-even analysis for Practical Wood Solutions, Inc. over the first five projected years.

4.9.4.4 Contribution Margin and Break-even in Unit Sales

The financial statements assume that all panels produced throughout the year will be sold. This is a bold assumption and in reality may not prove to be true. Therefore, to better understand the relationship between costs and profits, the contribution margin for producing the average panel is calculated. Contribution margin is defined as the difference between total revenues and total variable costs. This value better illustrates the portion of the sales that goes towards covering fixed costs and providing a profit (Morse et al. 2002). This metric works well when planning for a particular profit or determining a sales volume to break-even. Using the previously mention average costs and average price for one panel, the contribution margin for an Adaptive Panel is $45.32 or approximately 34 percent of the cost of the panel.

Table 4.11 Contribution margin and ratio to sales for the Adaptive Panel under the average cost and price assumption.

	Per Unit	Ratio To Sales
Avg. Sales Price	$133.00	1.000
Variable Costs	($87.68)	(0.659)
Contribution Margin	**$45.32**	**0.341**

To determine the break-even point based on unit sales the following formula is used:

$$\textit{Break-even unit sales volume} = \frac{\textit{Fixed Costs}}{\textit{Unit Contribution Margin}}$$

Fixed costs for the purpose of this calculation refer to the total fixed costs at full capacity minus any inflation. This value is $2,010,531. To break-even, Practical Wood Solutions, Inc. needs to sell 44,363 Adaptive panels a year. This is about 40 percent of the capacity for the proposed facility. A cost-volume-profit graph (Figure 4.11) illustrates the concept of Practical Wood Solution, Inc.'s contribution towards covering fixed costs.

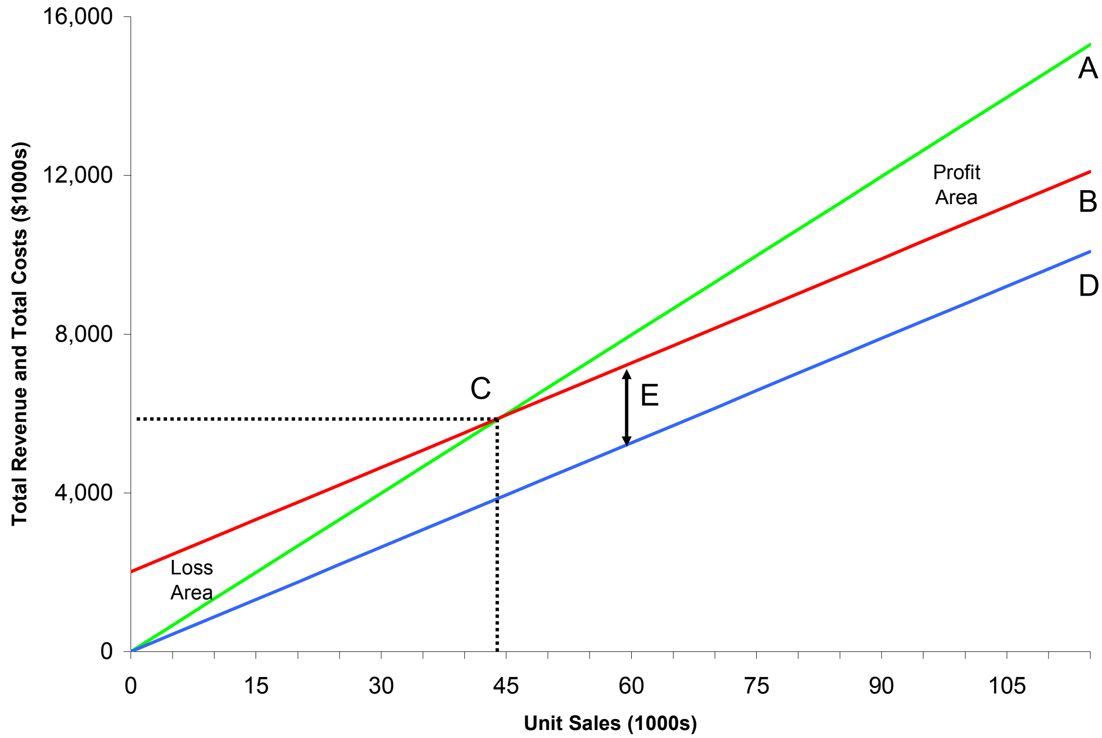

Figure 4.11 Cost-volume-profit graph for break-even for Practical Wood Solutions, Inc.

Description of plotted lines

A. Total revenues at an average price of $133 per panel.
B. Total costs of $2,010,531 in fixed costs plus a unit variable cost of $87.68 per panel.
C. Break-even point of 44,363 panels a year.
D. Total variable costs at $87.68 per panel.
E. Total fixed costs at $2,010,531.

4.10 Appendices or Exhibits

4.10.1 The Adaptive Panel

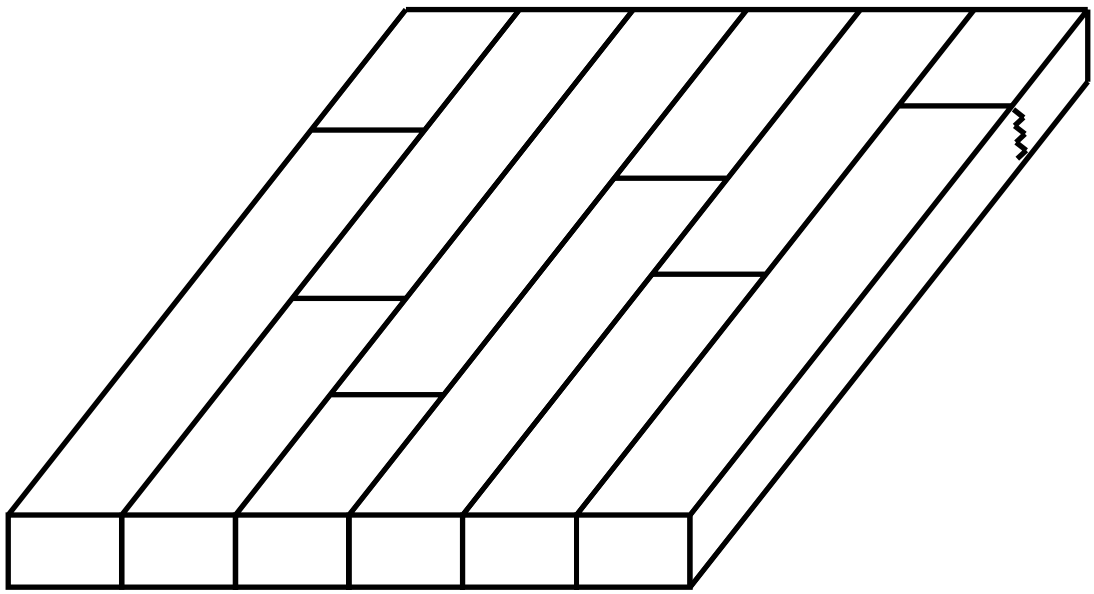

Figure 4.12 The Adaptive Panel product description. Clear pieces are edge-glued for width and finger-jointed for length to product panels 4 ft. wide, 8 ft. Long, and 1 in. thick.

4.10.2 Practical Wood Solutions in the Value Chain

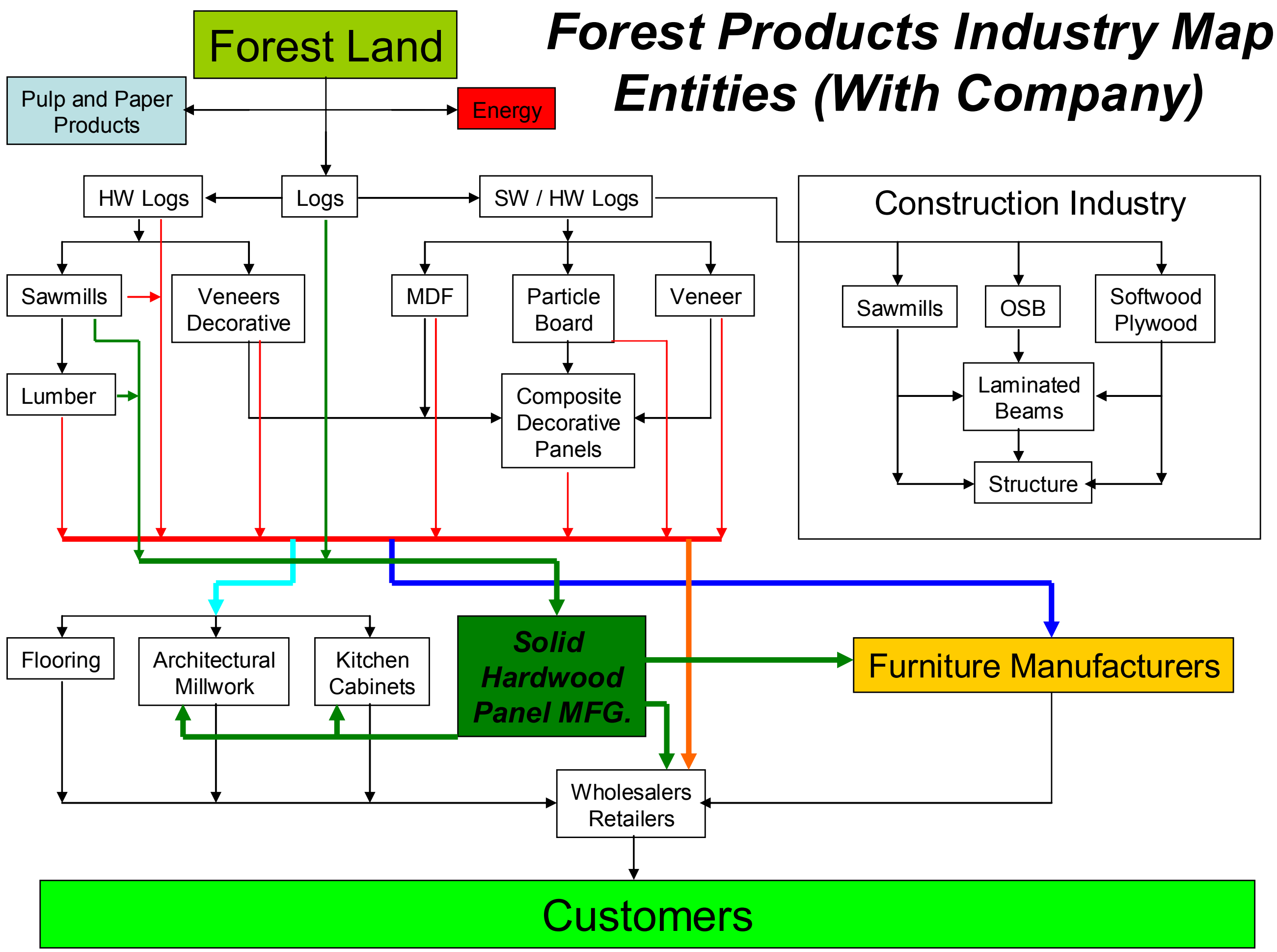

Figure 4.13 Practical Wood Solution, Inc.'s position in today's forest products value chain.

4.10.3 Material Flow Diagram

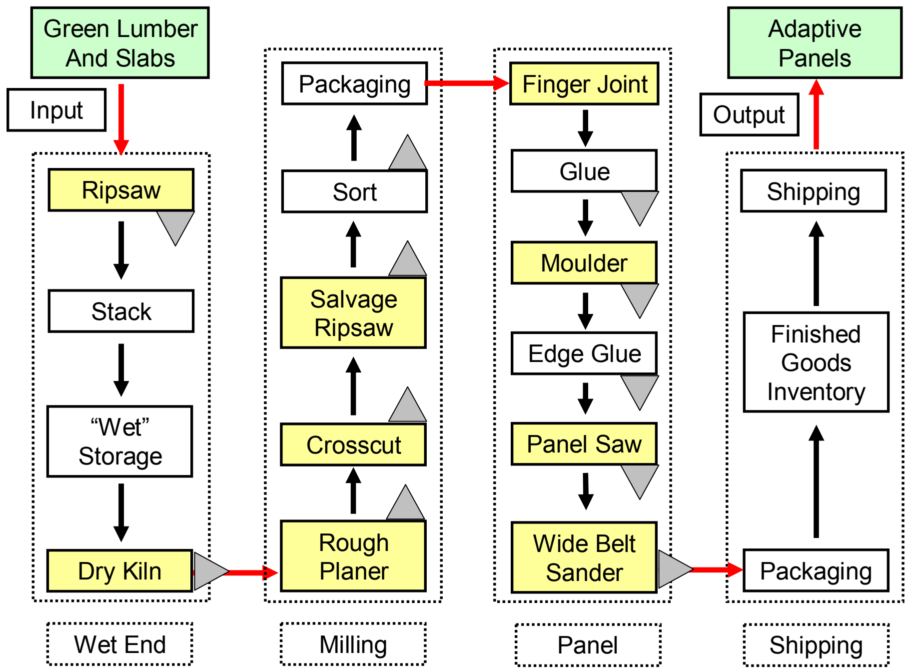

Figure 4.14 Material flow diagram for the production of Adaptive Panels.

The material flow diagram above represents the manufacturing process of the Adaptive Panel. Green boxes represent raw materials and finished goods. Yellow boxes represent areas where material is lost due to processing. Material losses occur from saw kerfs, drying defects, material sizing, defect removal, waste, normal processing, and sanding. In each case improvements in technology represent areas to improve yields. Red arrows represent an exchange of components between departments during manufacturing. The gray triangles represent processes that add a significant amount of value to the components.

4.10.4 Gang-Ripsaw Set-up

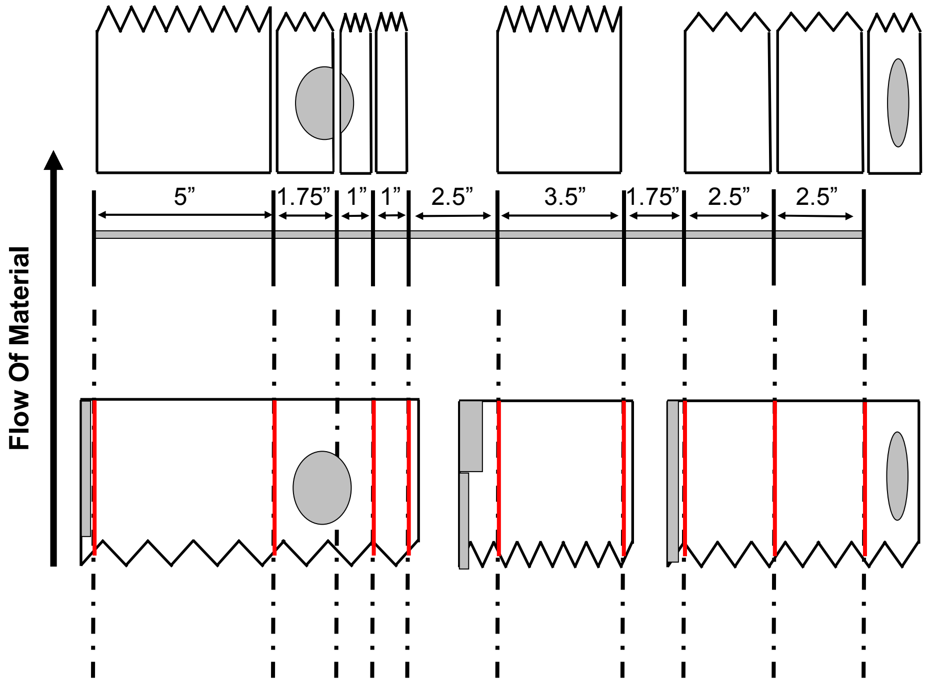

Figure 4.15 Gang-ripsaw set-up for the manufacturing of the Adaptive Panel.

Practical Wood Solutions, Inc. will incorporate a rip-first rough mill. The proper set-up of the gang-ripsaw's arbor is necessary to efficiently process low-grade lumber. ROMI's "RipSaw Arbor Optimizer" is used to set-up the arbor (Weiss and Thomas 2004). The results are shown in Figure 4.15 *Gang-Ripsaw Set-up for the Manufacturing of the Adaptive Panel*. Green lumber arrives in widths ranging from 4 to 10 inches with lengths ranging from 4 to 8 feet. Scanning technology reviews each board and the computer makes the decision on how to process the board. Boards and slabs are processed through the position on the arbor in a manner that maximizes the amount of useable material based on the defects within the board while minimizing the loss due to trim and kerf. After boards are ripped they are stacked and dried.

4.10.5 Panel Prices

Table 4.12 Panel price relative to size of individual slat with profit margins based on perceived demand.[16]

Width	Length	Margin	SQFT Price	Panel Price
5	40	40.0%	$4.655	$148.96
	32	38.0%	$4.589	$146.83
	29	36.0%	$4.522	$144.70
	26	34.0%	$4.456	$142.58
	23	32.0%	$4.389	$140.45
	20	30.0%	$4.323	$138.32
	17	28.0%	$4.256	$136.19
	14	26.0%	$4.190	$134.06
	11	24.0%	$4.123	$131.94
3.5	40	35.0%	$4.489	$143.64
	32	34.0%	$4.456	$142.58
	29	33.0%	$4.422	$141.51
	26	31.0%	$4.356	$139.38
	23	29.0%	$4.289	$137.26
	20	27.0%	$4.223	$135.13
	17	25.0%	$4.156	$133.00
	14	23.0%	$4.090	$130.87
	11	21.0%	$4.023	$128.74
	5	20.5%	$4.007	$128.21
2.5	40	30.0%	$4.323	$138.32
	32	28.0%	$4.256	$136.19
	29	27.0%	$4.223	$135.13
	26	26.0%	$4.190	$134.06
	23	25.0%	$4.156	$133.00
	20	23.0%	$4.090	$130.87
	17	22.0%	$4.057	$129.81
	14	21.5%	$4.040	$129.28
	11	21.0%	$4.023	$128.74
	5	20.5%	$4.007	$128.21

[16] Cost-Plus Pricing Strategy where the base price is the average cost for producing 1 square foot of panel which is estimated to be $3.325

Table 4.12 (Continued.) [17]

Width	Length	Margin	SQFT Price	Panel Price
1.75	40	27.0%	$4.223	$135.13
	32	26.0%	$4.190	$134.06
	29	25.0%	$4.156	$133.00
	26	24.0%	$4.123	$131.94
	23	23.0%	$4.090	$130.87
	20	22.5%	$4.073	$130.34
	17	22.0%	$4.057	$129.81
	14	21.5%	$4.040	$129.28
	11	21.0%	$4.023	$128.74
	5	20.0%	$3.990	$127.68
1	40	25.0%	$4.156	$133.00
	32	24.5%	$4.140	$132.47
	29	24.0%	$4.123	$131.94
	26	23.5%	$4.106	$131.40
	23	23.0%	$4.090	$130.87
	20	22.5%	$4.073	$130.34
	17	22.0%	$4.057	$129.81
	14	21.5%	$4.040	$129.28
	11	21.0%	$4.023	$128.74
	5	20.5%	$4.007	$128.21

[17] Cost-Plus Pricing Strategy where the base price is the average cost for producing 1 square foot of panel which is estimated to be $3.325

4.10.6 Capital Expenditures at Startup

Table 4.13 Estimated building and equipment costs for Practical Wood Solutions, Inc.[18]

	Item and Description	Manufacturer / Model	Total
Building and Infrastructure Capital Costs			
1	Land (10 Acres) ($55,000 / Acre)	Triad NC	$550,000
2	Site Prep (10 Acres) ($10,000 / Acre)	Triad NC	$100,000
3	Main Manufacture and Office Building (31,000 sqft) ($9.00/sqft)	General Steel Corp	$279,000
4	Boiler and Dry Storage Building (15,000 sqft) ($8.00/sqft)	General Steel Corp	$120,000
5	Predrier Covered Storage Area (5,000 sqft) ($6.50/sqft)	General Steel Corp	$32,500
6	Boiler (400 HP) (Wood Fired)		$400,000
7	4 Dry Kilns (43,000 BF capacity Each) ($2.86/BF)		$491,920
	Building and Infrastructure Subtotal		**$1,973,420**
Manufacturing Equipment Capital Costs			
8	Rip-saw	Raiman KR-310	$215,000
9	Lumber Stacker (Automatic)[19]		$350,000
10	Rough Planer	Whitney S-290	$70,000
11	Chop Saw	Dimter Opti-cut 350	$200,000
12	Salvage Rip	Diehl ESL-35-30	$30,000
13	Pallet Wrapper	Lantech S-65-L	$5,000
14	Finger-jointer w/ Press	Grecon/Dimter HK 800 K-170/1200, PN 10/SHL	$650,000
15	Moulder	Weinig H23C	$232,700
16	Edge-glue and Press	Dimter ProfiPress	$350,000
17	Sizing Panel Saw	Holz-her Beam Panel Saw	$85,000
18	Wide Belt Sander	Cemco	$175,000
19	Panel Stacker (Manless)		$75,000
	Manufacturing Equipment Subtotal		**$2,437,700**

Assumptions

Building and Infrastructure Costs

1) Land and site preparation costs (Araman and Hansen 1983[20] and Davis 2001).
2) All buildings and covered space (Araman and Hansen 1983[21] and GSC 2004).
3) Boiler and kiln space (Ex-Factory 2005).

Manufacturing Equipment Costs

4) All manufacturing costs (Ex-Factory 2005).

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[18] Prices Current as of September 2005
[19] Machine needs to be customized to handle short lengths and narrow widths
[20] Referencing the projected acreage of the site
[21] Referencing the projected square footage of the manufacturing facility

Table 4.13 (Contnued)[22]

	Item and Description	Manufacturer / Model	Total
Misc. Equipment Capital Costs			
20	Conveyor System (200 Feet) (Belt @ $5 per lineal ft)		$1,000
21	Rollers (200 Feet) ($2 per lineal ft)		$400
22	Company Box Truck	Ford F-450 Box Truck	$60,000
23	Company Work Truck	Ford F-250	$30,000
24	Forklifts (2 Rated @ 15,500 lbs)	Hyster	$120,000
25	Dust Extraction System and Equipment		$100,000
26	Dust Collector Bag House System (60,000 CFM)	Torit 376-RFW-10	$143,000
27	Wood Waste Hog (60 HP)		$45,000
28	Compressed Air System (100 HP Rotary Screw)	Champion RCS100	$30,000
29	Electrical Installation		$125,000
30	Plumbing / Dust Installation		$50,000
31	Heating System w/ Humidity Control		$100,000
32	Fire Protection Equipment		$50,000
33	Office Furnishings		$30,000
34	Operating Cash (Raw Material, Salaries, etc)		$1,000,000
	Misc. Equipment Subtotal		**$1,884,400**
	Subtotal		**$6,295,520**
	Total Initial Investment (Cost + 20%)		**$7,554,624**

Assumptions

Misc. Equipment Costs

1) Conveyor and roller system needs estimated.
2) Box and work truck estimated.
3) Forklifts (Machine Trader 2005).
4) Dust extraction rough estimated (Araman and Hansen 1983).
5) Dust collector bag house system (Araman and Hansen 1983 and Ex-Factory 2005).
6) Electrical and plumbing installation costs rough estimated (Araman and Hansen 1983).
7) Heating system, fire protection and office furnishings rough estimated (Araman and Hansen 1983).

[22] Prices Current as of September 2005

4.10.7 Salaries

Table 4.14 Yearly wages in U.S. dollars.

Salaries

		Base Salary	
		Minimum	Maximum
Executives and Managers			
1	CEO	$100,000	$175,000
2	CFO	$100,000	$175,000
3	COO	$100,000	$175,000
4	Production Manager	$75,000	$100,000
5	Marketing and Sales Manager	$75,000	$90,000
	Manager Total		**$715,000**
Support Staff			
5	Lab Tech	$30,000	$45,000
6	Lab Tech 2	$23,000	$35,000
7	Green Supervisor	$35,000	$50,000
8	Mill Supervisor	$35,000	$50,000
9	Panel Supervisor	$35,000	$50,000
10	Ship Supervisor	$35,000	$50,000
11	Sale Persons	$30,000	$70,000
12	Sale Persons	$30,000	$70,000
13	Support Staff	$25,000	$30,000
14	Support Staff 2	$25,000	$30,000
15	Engineer	$45,000	$70,000
16	Engineer 2	$45,000	$70,000
17	Accountant	$37,000	$60,000
18	Accountant 2	$37,000	$60,000
	Support Staff Total		**$740,000**
Hourly Workers			
19	Skilled Laborers (22)	$18,800	$31,960
	1,880 hours per year	$10/hr	$17/hr
	Hourly Workers Total		**$703,120**
	Subtotal		**$2,158,120**
	Total Payroll + 25% in Benefits		**$2,697,650**

Assumptions

1) Totals are determined based on highest available salary to the individual.
2) Sales persons' salaries are based on a base salary plus compensation with a cap at $70,000.
3) Skilled laborers salaries are based on a 235 day work year with a minimum $10 / hour and a maximum $17 / hour pay scale.
4) Benefits are a rough estimate and include medical insurance, social security and 401K investment options.
5) Wages and benefits are believed to be in line with industry standards.

4.10.8 Estimated Yield Losses

It is important to realize the yield losses associated with manufacturing adaptive panels. This estimation is used to plan for the ordering of raw materials. Rough mill losses are calculated from the simulation and are expected to reach 40 percent. Drying losses are estimated at 8 percent. Finger-joint, moulder, and trimming losses are assumed to reach 4%. Total plant loss is expected to reach 52 percent.

Table 4.15 Estimated total plant yield losses during the manufacturing of Adaptive Panels.

Yield Losses	
Rip, Salvage, Cross	40.00%
Drying	8.00%
Finger-joint and Mould	2.00%
Final Trim	2.00%
Total Plant Loss	**52.00%**

4.10.9 Estimated Cost Structure

The pricing strategy used by Practical Wood Solutions, Inc. is a cost plus pricing strategy where all costs of producing the product along with a desired margin determine the price point. Manufacturing costs are separated by cost drivers and behavior. These prices are presented in tables as ranges with references as footnotes. The actual price used throughout the business plan was an average of the total price range. Table 4.16 reflects variable raw material costs (excluding glue) and range from \$0.6563 to 0.8837 per BF. Table 4.17 lists the variable manufacturing overhead costs. These costs are based on the average size Adaptive Panel (2.5 x 23 inch slat) and total \$1.765 per BF. Table 4.18 lists the required direct labor. Costs are variable and estimated to range from \$0.12 to 0.20 per BF. Table 4.19 lists the variable sales and administration costs associated with selling the Adaptive Panel. This costs range from \$0.03 to \$0.06 per BF. Table 4.20 shows the fixed costs associated with manufacturing overhead. On yearly basis this cost ranges from \$1,337,531 to \$1,499,531. This value is divided by the proposed total BF (3.5 MMBF) produced and sold in a full capacity year. Per BF this cost ranges from \$0.38 to 0.43. Table 4.21 shows Practical Wood Solutions, Inc. fixed cost associated with selling and marketing the Adaptive Panel. This cost ranges from $449,000 to 735,000 a year or $0.13 to 0.21 per BF.

Table 4.16 Estimated wood raw material cost range.

Description	Wood Raw Materials Low Estimate	High Estimate	Unit
Stumpage[23]	$19.60		Ton
Tons Necessary for MBF of Lumber[24]	9	11	Ton - MBF
Total	**$176.40**	**$215.60**	**MBF**
Logging[25]	$80.00	$120.00	MBF
Trucking[25]	$30.00	$50.00	MBF
Total	**$286.40**	**$385.60**	MBF
%Sawmill[26]	10%	10%	
Total Cost Delivered To Mill	**$315.04**	**$424.16**	**MBF**
Cost @ 48% Yield	**$656.33**	**$883.67**	**MBF**
Cost @ 48% Yield	**$0.6563**	**$0.8837**	**BF**

[23] Wiedenbeck 2004
[24] Daniels 2005
[25] Smith et al. 2002
[26] Estimate

Table 4.17 Estimated variable manufacturing overhead cost range.

Variable MFG Overhead - Processing Costs			
Description	Low Estimate	High Estimate	Unit
Rip[27]	$0.069	$0.069	BF
Drying[28]	$0.300	$0.300	BF
Planer[28]	$0.100	$0.100	BF
X-cut[27]	$0.159	$0.159	BF
Salvage Rip[27]	$0.028	$0.028	BF
Finger-joint[27]	$0.428	$0.428	BF
Moulding[27]	$0.100	$0.100	BF
Edge-Gluing[27]	$0.152	$0.152	BF
Triming[27]	$0.048	$0.048	BF
Sanding[27]	$0.041	$0.041	BF
Glue[29]	$0.240	$0.240	BF
Miscellaneous MFG Materials[29]	$0.100	$0.100	BF
Total Processing Costs	**$1.765**	**$1.765**	**BF**

Table 4.18 Estimated direct labor cost range.

	Direct Labor		
Description	Low Estimate	High Estimate	Unit
Skilled Laborers (22)	$413,600	$703,120	Year
Total Direct Labor	**$413,600**	**$703,120**	**Year**
Total Direct Labor / BF	**$0.118**	**$0.201**	**BF**

Table 4.19 Estimated variable sales and administration cost range.

	Variable S&A		
Description	Low Estimate	High Estimate	Unit
Sale Persons	$30,000	$70,000	Year
Sale Persons	$30,000	$70,000	Year
Support Staff	$25,000	$30,000	Year
Support Staff 2	$25,000	$30,000	Year
Total Variable S&A	**$110,000**	**$200,000**	**Year**
Variable S&A / BF	**$0.031**	**$0.057**	**BF**

[27] Zaech 2001
[28] Smith et al. 2002
[29] Estimate

Table 4.20 Estimated fixed manufacturing overhead cost range.

Description	Fixed MFG Overhead Low Estimate	High Estimate	Unit
Depreciation	$232,276	$232,276	Year
Notes Payable	$747,255	$747,255	Year
Production Manager	$75,000	$100,000	Year
Lab Tech	$30,000	$45,000	Year
Lab Tech 2	$23,000	$35,000	Year
Green Supervisor	$35,000	$50,000	Year
Mill Supervisor	$35,000	$50,000	Year
Panel Supervisor	$35,000	$50,000	Year
Ship Supervisor	$35,000	$50,000	Year
Engineer	$45,000	$70,000	Year
Engineer 2	$45,000	$70,000	Year
Total Fixed MFG Overhead	**$1,337,531**	**$1,499,531**	**Year**
Fixed MFG Overhead / BF	**$0.382**	**$0.428**	**BF**

Table 4.21 Estimated variable manufacturing costs range.

Description	Fixed S&A Low Estimate	High Estimate	Unit
CEO	$100,000	$175,000	Year
CFO	$100,000	$175,000	Year
COO	$100,000	$175,000	Year
Marketing and Sales Manager	$75,000	$90,000	Year
Accountant	$37,000	$60,000	Year
Accountant 2	$37,000	$60,000	Year
Total Fixed S&A	**$449,000**	**$735,000**	**Year**
Total Fixed S&A / BF	**$0.128**	**$0.210**	**BF**

Table 4.22 Breakdown of estimated cost range.

Breakdown of Costs and Percentages				
Description	Low Estimate	High Estimate	Low Estimate Percentage	High Estimate Percentage
Direct Materials	$0.6563	$0.8837	21.30%	24.93%
Variable MFG Overhead	$1.765	$1.765	57.28%	49.79%
Direct Labor	$0.12	$0.20	3.84%	5.67%
Variable S&A	$0.03	$0.06	1.02%	1.61%
Fixed MFG Overhead	$0.38	$0.43	12.40%	12.09%
Fixed S&A / BF	$0.13	$0.21	4.16%	5.92%
Total Cost / BF	**$3.0814**	**$3.5451**	100%	100%

4.10.10 Sensitivity Analysis for Changes to Raw Materials Percentages Using Contribution Margin Method

A sensitivity analysis is carried out to determine how increases in the price of wood raw materials affect the total cost of producing 1 BF of parts. The contribution margin approach is used in this sensitivity analysis. Table 4.23 shows the relative cost of direct materials per BF at several different percentages of total costs.

Table 4.23 Impact on total cost per BF from percentage changes to variable manufacturing overhead costs.

Category	20%	23.16%	25%	30%	35%	40%
Direct Materials	$0.639	$0.770	$0.852	$1.095	$1.375	$1.703
Variable MFG Overhead		$1.765				
Direct Labor		$0.160				
Variable S&A		$0.045				
Fixed MFG Overhead		$0.415				
Fixed S&A		$0.170				
Total Cost / BF	$3.194	$3.325	$3.407	$3.650	$3.930	$4.258

Table 4.24 lists the contribution margin and break-even sales volume considering the changes to variable costs from fluctuations in wood raw material costs. At $1.703 per BF of raw material the company will not have capacity to break-even.

Table 4.24 Impact on the unit contribution margin from percentage changes to material costs.

	20%	23.16%	25%	30%	35%	40%
Avg. Sales Price	$133.00	$133.00	$133.00	$133.00	$133.00	$133.00
Variable Costs	($83.49)	($87.68)	($90.29)	($98.08)	($107.05)	($117.54)
Contribution Margin	$49.51	$45.32	$42.71	$34.92	$25.95	$15.46
Break-even Unit Sales Volume	40,610	44,363	47,076	57,572	77,468	**130,078**

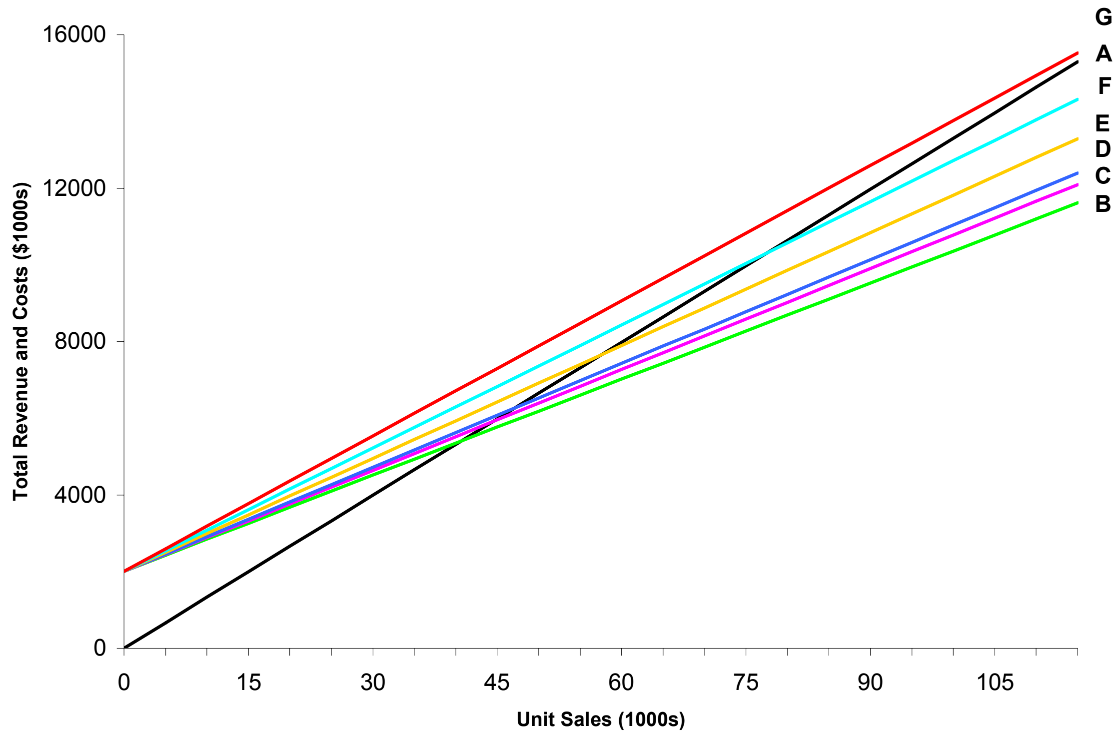

Figure 4.16 Contribution margin's sensitivity towards changes in the percentage of raw material costs.

Description of plotted lines

A. Total Revenues
B. Raw material costs as 20 percent of total costs
C. Raw material costs as 23.16 percent of total costs
D. Raw material costs as 25 percent of total costs
E. Raw material costs as 30 percent of total costs
F. Raw material costs as 35 percent of total costs
G. Raw material costs as 40 percent of total costs

4.10.11 Sensitivity Analysis for Changes to Variable Manufacturing Overhead Percentages Using Contribution Margin Method

A sensitivity analysis is carried out to determine how increases in the price of variable manufacturing overhead (processing costs) affect the total cost of producing 1 BF of parts. The contribution margin approach is used in this sensitivity analysis. Table 4.25 shows the relative cost of variable manufacturing overhead per BF at several different percentages of total costs.

Table 4.25 Impact on total cost per BF from percentage changes to variable manufacturing overhead costs.

Category	50%	53.08%	55%	60%	65%	70%
Direct Materials		$0.770				
Variable MFG Overhead	$1.562	$1.765	$1.906	$2.347	$2.895	$3.630
Direct Labor		$0.160				
Variable S&A		$0.045				
Fixed MFG Overhead		$0.415				
Fixed S&A		$0.170				
Total Cost / BF	$3.122	$3.325	$3.466	$3.907	$4.455	$5.190

Table 4.26 lists the contribution margin and break-even sales volume considering the changes to variable manufacturing overhead costs. At variable manufacturing overhead costs of $2.895 and $3.630 per BF the company will not have capacity to break-even.

Table 4.26 Impact on the unit contribution margin from percentage changes to variable manufacturing overhead costs.

	50%	53.08%	55%	60%	65%	70%
Avg. Sales Price	$133.00	$133.00	$133.00	$133.00	$133.00	$133.00
Variable Costs	($81.18)	($87.68)	($92.20)	($106.32)	($123.83)	($147.35)
Contribution Margin	$51.82	$45.32	$40.80	$26.68	$9.17	-
Break-even Unit Sales Volume	38,802	44,363	49,276	75,353	**219,184**	**-**

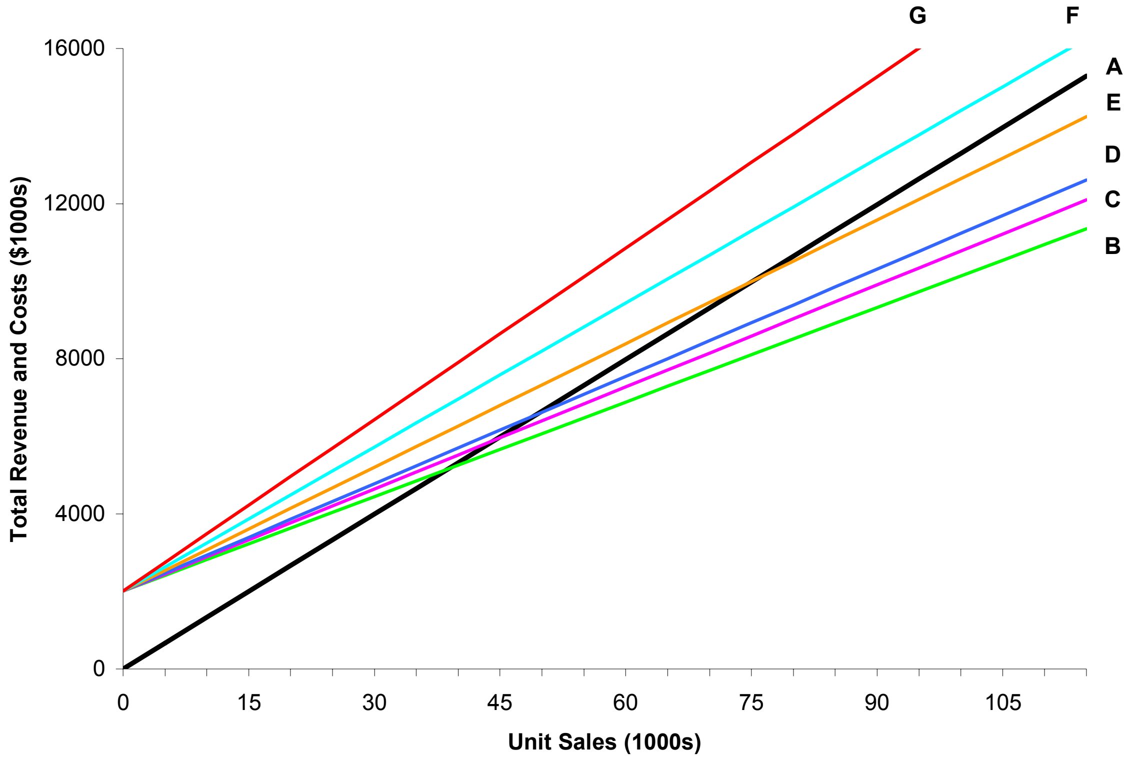

Figure 4.17 Contribution margin's sensitivity towards changes in the percentage of variable manufacturing overhead costs.

Description of plotted lines

A. Total Revenues
B. Variable manufacturing overhead as 50 percent of total costs
C. Variable manufacturing overhead as 53.08 percent of total costs
D. Variable manufacturing overhead as 55 percent of total costs
E. Variable manufacturing overhead as 60 percent of total costs
F. Variable manufacturing overhead as 65 percent of total costs
G. Variable manufacturing overhead as 70 percent of total costs

4.10.12 Amortization Table

Table 4.27 Amortization table for $6,799,162 borrowed on Jan 1, 2007.

Month	**Jan-07**	**Feb-07**	**Mar-07**	**Apr-07**	**May-07**	**Jun-07**	**Jul-07**	**Aug-07**	**Sep-07**	**Oct-07**	**Nov-07**	**Dec-07**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$9,861	$9,937	$10,014	$10,091	$10,169	$10,247	$10,326	$10,406	$10,486	$10,567	$10,648	$10,730
Interest Paid	$52,410	$52,334	$52,258	$52,180	$52,103	$52,024	$51,945	$51,866	$51,785	$51,705	$51,623	$51,541
Total Interest	$52,410	$104,744	$157,002	$209,182	$261,285	$313,309	$365,255	$417,120	$468,906	$520,610	$572,233	$623,775
Balance	$6,789,301	$6,779,364	$6,769,350	$6,759,259	$6,749,091	$6,738,844	$6,728,518	$6,718,112	$6,707,626	$6,697,060	$6,686,411	$6,675,681
Month	**Jan-08**	**Feb-08**	**Mar-08**	**Apr-08**	**May-08**	**Jun-08**	**Jul-08**	**Aug-08**	**Sep-08**	**Oct-08**	**Nov-08**	**Dec-08**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$10,813	$10,896	$10,980	$11,065	$11,150	$11,236	$11,323	$11,410	$11,498	$11,587	$11,676	$11,766
Interest Paid	$51,458	$51,375	$51,291	$51,206	$51,121	$51,035	$50,949	$50,861	$50,773	$50,685	$50,595	$50,505
Total Interest	$675,233	$726,608	$777,899	$829,105	$880,226	$931,262	$982,210	$1,033,071	$1,083,845	$1,134,529	$1,185,125	$1,235,630
Balance	$6,664,868	$6,653,972	$6,642,992	$6,631,927	$6,620,777	$6,609,541	$6,598,218	$6,586,808	$6,575,310	$6,563,723	$6,552,048	$6,540,282
Month	**Jan-09**	**Feb-09**	**Mar-09**	**Apr-09**	**May-09**	**Jun-09**	**Jul-09**	**Aug-09**	**Sep-09**	**Oct-09**	**Nov-09**	**Dec-09**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$11,857	$11,948	$12,040	$12,133	$12,226	$12,321	$12,416	$12,511	$12,608	$12,705	$12,803	$12,902
Interest Paid	$50,415	$50,323	$50,231	$50,138	$50,045	$49,951	$49,856	$49,760	$49,663	$49,566	$49,468	$49,370
Total Interest	$1,286,045	$1,336,368	$1,386,599	$1,436,738	$1,486,782	$1,536,733	$1,586,589	$1,636,349	$1,686,012	$1,735,578	$1,785,047	$1,834,416
Balance	$6,528,425	$6,516,477	$6,504,437	$6,492,304	$6,480,078	$6,467,757	$6,455,341	$6,442,830	$6,430,222	$6,417,517	$6,404,714	$6,391,813

Table 4.27 (Continued).

Month	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$13,001	$13,101	$13,202	$13,304	$13,407	$13,510	$13,614	$13,719	$13,825	$13,931	$14,039	$14,147
Interest Paid	$49,270	$49,170	$49,069	$48,967	$48,865	$48,761	$48,657	$48,552	$48,447	$48,340	$48,233	$48,124
Total Interest	$1,883,687	$1,932,857	$1,981,926	$2,030,893	$2,079,758	$2,128,519	$2,177,176	$2,225,728	$2,274,175	$2,322,515	$2,370,748	$2,418,872
Balance	$6,378,812	$6,365,710	$6,352,508	$6,339,204	$6,325,798	$6,312,288	$6,298,674	$6,284,955	$6,271,130	$6,257,199	$6,243,160	$6,229,013
Month	**Jan-11**	**Feb-11**	**Mar-11**	**Apr-11**	**May-11**	**Jun-11**	**Jul-11**	**Aug-11**	**Sep-11**	**Oct-11**	**Nov-11**	**Dec-11**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$14,256	$14,366	$14,477	$14,588	$14,701	$14,814	$14,928	$15,043	$15,159	$15,276	$15,394	$15,512
Interest Paid	$48,015	$47,905	$47,795	$47,683	$47,571	$47,457	$47,343	$47,228	$47,112	$46,995	$46,878	$46,759
Total Interest	$2,466,887	$2,514,793	$2,562,587	$2,610,270	$2,657,841	$2,705,298	$2,752,641	$2,799,870	$2,846,982	$2,893,977	$2,940,854	$2,987,613
Balance	$6,214,757	$6,200,391	$6,185,915	$6,171,326	$6,156,626	$6,141,812	$6,126,884	$6,111,840	$6,096,681	$6,081,405	$6,066,011	$6,050,499
Month	**Jan-12**	**Feb-12**	**Mar-12**	**Apr-12**	**May-12**	**Jun-12**	**Jul-12**	**Aug-12**	**Sep-12**	**Oct-12**	**Nov-12**	**Dec-12**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$15,632	$15,753	$15,874	$15,996	$16,120	$16,244	$16,369	$16,495	$16,622	$16,751	$16,880	$17,010
Interest Paid	$46,639	$46,519	$46,397	$46,275	$46,152	$46,027	$45,902	$45,776	$45,649	$45,521	$45,392	$45,262
Total Interest	$3,034,253	$3,080,771	$3,127,169	$3,173,444	$3,219,595	$3,265,623	$3,311,525	$3,357,301	$3,402,950	$3,448,471	$3,493,862	$3,539,124
Balance	$6,034,867	$6,019,115	$6,003,241	$5,987,244	$5,971,125	$5,954,881	$5,938,512	$5,922,017	$5,905,394	$5,888,644	$5,871,764	$5,854,754

Table 4.27 (Continued).

Month	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$17,141	$17,273	$17,406	$17,540	$17,676	$17,812	$17,949	$18,087	$18,227	$18,367	$18,509	$18,652
Interest Paid	$45,130	$44,998	$44,865	$44,731	$44,596	$44,460	$44,322	$44,184	$44,044	$43,904	$43,762	$43,620
Total Interest	$3,584,254	$3,629,252	$3,674,117	$3,718,848	$3,763,444	$3,807,904	$3,852,226	$3,896,410	$3,940,454	$3,984,358	$4,028,120	$4,071,740
Balance	$5,837,613	$5,820,340	$5,802,934	$5,785,394	$5,767,718	$5,749,907	$5,731,958	$5,713,870	$5,695,643	$5,677,276	$5,658,767	$5,640,115
Month	**Jan-14**	**Feb-14**	**Mar-14**	**Apr-14**	**May-14**	**Jun-14**	**Jul-14**	**Aug-14**	**Sep-14**	**Oct-14**	**Nov-14**	**Dec-14**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$18,795	$18,940	$19,086	$19,233	$19,382	$19,531	$19,682	$19,833	$19,986	$20,140	$20,295	$20,452
Interest Paid	$43,476	$43,331	$43,185	$43,038	$42,890	$42,740	$42,590	$42,438	$42,285	$42,131	$41,976	$41,819
Total Interest	$4,115,216	$4,158,547	$4,201,732	$4,244,770	$4,287,659	$4,330,400	$4,372,989	$4,415,427	$4,457,712	$4,499,843	$4,541,819	$4,583,639
Balance	$5,621,320	$5,602,380	$5,583,293	$5,564,060	$5,544,678	$5,525,147	$5,505,466	$5,485,633	$5,465,646	$5,445,506	$5,425,211	$5,404,759
Month	**Jan-15**	**Feb-15**	**Mar-15**	**Apr-15**	**May-15**	**Jun-15**	**Jul-15**	**Aug-15**	**Sep-15**	**Oct-15**	**Nov-15**	**Dec-15**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$20,610	$20,768	$20,929	$21,090	$21,252	$21,416	$21,581	$21,748	$21,915	$22,084	$22,255	$22,426
Interest Paid	$41,662	$41,503	$41,343	$41,181	$41,019	$40,855	$40,690	$40,524	$40,356	$40,187	$40,017	$39,845
Total Interest	$4,625,300	$4,666,803	$4,708,146	$4,749,327	$4,790,346	$4,831,201	$4,871,891	$4,912,415	$4,952,770	$4,992,957	$5,032,974	$5,072,819
Balance	$5,384,149	$5,363,381	$5,342,452	$5,321,362	$5,300,110	$5,278,694	$5,257,112	$5,235,364	$5,213,449	$5,191,365	$5,169,110	$5,146,684

Table 4.27 (Continued).

Month	**Jan-16**	**Feb-16**	**Mar-16**	**Apr-16**	**May-16**	**Jun-16**	**Jul-16**	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$22,599	$22,773	$22,949	$23,126	$23,304	$23,483	$23,664	$23,847	$24,031	$24,216	$24,403	$24,591
Interest Paid	$39,672	$39,498	$39,323	$39,146	$38,967	$38,788	$38,607	$38,424	$38,241	$38,055	$37,869	$37,681
Total Interest	$5,112,492	$5,151,990	$5,191,313	$5,230,458	$5,269,426	$5,308,214	$5,346,820	$5,385,245	$5,423,485	$5,461,541	$5,499,409	$5,537,090
Balance	$5,124,085	$5,101,312	$5,078,364	$5,055,238	$5,031,934	$5,008,451	$4,984,786	$4,960,940	$4,936,909	$4,912,693	$4,888,290	$4,863,700
Month	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**	**Dec-17**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$24,780	$24,971	$25,164	$25,358	$25,553	$25,750	$25,949	$26,149	$26,350	$26,553	$26,758	$26,964
Interest Paid	$37,491	$37,300	$37,108	$36,914	$36,718	$36,521	$36,323	$36,123	$35,921	$35,718	$35,513	$35,307
Total Interest	$5,574,581	$5,611,881	$5,648,989	$5,685,902	$5,722,620	$5,759,141	$5,795,464	$5,831,586	$5,867,507	$5,903,225	$5,938,739	$5,974,046
Balance	$4,838,919	$4,813,948	$4,788,784	$4,763,427	$4,737,873	$4,712,123	$4,686,175	$4,660,026	$4,633,676	$4,607,122	$4,580,364	$4,553,400
Month	**Jan-18**	**Feb-18**	**Mar-18**	**Apr-18**	**May-18**	**Jun-18**	**Jul-18**	**Aug-18**	**Sep-18**	**Oct-18**	**Nov-18**	**Dec-18**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$27,172	$27,382	$27,593	$27,805	$28,020	$28,236	$28,453	$28,673	$28,894	$29,116	$29,341	$29,567
Interest Paid	$35,099	$34,890	$34,679	$34,466	$34,252	$34,036	$33,818	$33,599	$33,378	$33,155	$32,930	$32,704
Total Interest	$6,009,145	$6,044,034	$6,078,713	$6,113,179	$6,147,431	$6,181,466	$6,215,284	$6,248,883	$6,282,260	$6,315,415	$6,348,346	$6,381,050
Balance	$4,526,228	$4,498,846	$4,471,254	$4,443,448	$4,415,429	$4,387,193	$4,358,740	$4,330,067	$4,301,173	$4,272,057	$4,242,716	$4,213,149

Table 4.27 (Continued).

Month	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$29,795	$30,025	$30,256	$30,489	$30,724	$30,961	$31,200	$31,440	$31,683	$31,927	$32,173	$32,421
Interest Paid	$32,476	$32,247	$32,015	$31,782	$31,547	$31,310	$31,072	$30,831	$30,589	$30,344	$30,098	$29,850
Total Interest	$6,413,526	$6,445,773	$6,477,788	$6,509,570	$6,541,117	$6,572,427	$6,603,499	$6,634,330	$6,664,919	$6,695,263	$6,725,361	$6,755,212
Balance	$4,183,354	$4,153,330	$4,123,073	$4,092,584	$4,061,860	$4,030,899	$3,999,699	$3,968,259	$3,936,576	$3,904,649	$3,872,476	$3,840,056
Month	**Jan-20**	**Feb-20**	**Mar-20**	**Apr-20**	**May-20**	**Jun-20**	**Jul-20**	**Aug-20**	**Sep-20**	**Oct-20**	**Nov-20**	**Dec-20**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$32,671	$32,923	$33,176	$33,432	$33,690	$33,950	$34,211	$34,475	$34,741	$35,009	$35,278	$35,550
Interest Paid	$29,600	$29,349	$29,095	$28,839	$28,581	$28,322	$28,060	$27,796	$27,531	$27,263	$26,993	$26,721
Total Interest	$6,784,812	$6,814,161	$6,843,255	$6,872,095	$6,900,676	$6,928,998	$6,957,058	$6,984,854	$7,012,384	$7,039,647	$7,066,640	$7,093,361
Balance	$3,807,385	$3,774,462	$3,741,286	$3,707,853	$3,674,163	$3,640,214	$3,606,003	$3,571,528	$3,536,787	$3,501,778	$3,466,500	$3,430,950
Month	**Jan-21**	**Feb-21**	**Mar-21**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$35,824	$36,101	$36,379	$36,659	$36,942	$37,227	$37,514	$37,803	$38,094	$38,388	$38,684	$38,982
Interest Paid	$26,447	$26,171	$25,892	$25,612	$25,329	$25,045	$24,758	$24,469	$24,177	$23,884	$23,588	$23,289
Total Interest	$7,119,808	$7,145,979	$7,171,871	$7,197,483	$7,222,813	$7,247,857	$7,272,615	$7,297,084	$7,321,261	$7,345,144	$7,368,732	$7,392,022
Balance	$3,395,125	$3,359,025	$3,322,646	$3,285,987	$3,249,045	$3,211,818	$3,174,305	$3,136,502	$3,098,408	$3,060,020	$3,021,337	$2,982,355

Table 4.27 (Continued).

Month	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$39,282	$39,585	$39,890	$40,198	$40,508	$40,820	$41,134	$41,452	$41,771	$42,093	$42,418	$42,744
Interest Paid	$22,989	$22,686	$22,381	$22,074	$21,764	$21,451	$21,137	$20,820	$20,500	$20,178	$19,854	$19,527
Total Interest	$7,415,011	$7,437,697	$7,460,078	$7,482,151	$7,503,915	$7,525,367	$7,546,503	$7,567,323	$7,587,823	$7,608,002	$7,627,855	$7,647,382
Balance	$2,943,073	$2,903,488	$2,863,597	$2,823,400	$2,782,892	$2,742,072	$2,700,938	$2,659,486	$2,617,715	$2,575,622	$2,533,205	$2,490,460
Month	**Jan-23**	**Feb-23**	**Mar-23**	**Apr-23**	**May-23**	**Jun-23**	**Jul-23**	**Aug-23**	**Sep-23**	**Oct-23**	**Nov-23**	**Dec-23**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$43,074	$43,406	$43,741	$44,078	$44,418	$44,760	$45,105	$45,453	$45,803	$46,156	$46,512	$46,870
Interest Paid	$19,197	$18,865	$18,531	$18,194	$17,854	$17,511	$17,166	$16,819	$16,468	$16,115	$15,759	$15,401
Total Interest	$7,666,579	$7,685,445	$7,703,975	$7,722,169	$7,740,023	$7,757,534	$7,774,700	$7,791,519	$7,807,987	$7,824,102	$7,839,862	$7,855,263
Balance	$2,447,386	$2,403,980	$2,360,240	$2,316,162	$2,271,744	$2,226,985	$2,181,880	$2,136,427	$2,090,624	$2,044,468	$1,997,956	$1,951,086
Month	**Jan-24**	**Feb-24**	**Mar-24**	**Apr-24**	**May-24**	**Jun-24**	**Jul-24**	**Aug-24**	**Sep-24**	**Oct-24**	**Nov-24**	**Dec-24**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$47,232	$47,596	$47,963	$48,332	$48,705	$49,080	$49,459	$49,840	$50,224	$50,611	$51,001	$51,394
Interest Paid	$15,040	$14,676	$14,309	$13,939	$13,566	$13,191	$12,813	$12,431	$12,047	$11,660	$11,270	$10,877
Total Interest	$7,870,302	$7,884,978	$7,899,287	$7,913,226	$7,926,792	$7,939,983	$7,952,796	$7,965,227	$7,977,274	$7,988,934	$8,000,204	$8,011,081
Balance	$1,903,854	$1,856,258	$1,808,296	$1,759,963	$1,711,259	$1,662,178	$1,612,720	$1,562,880	$1,512,656	$1,462,044	$1,411,043	$1,359,649

Table 4.27 (Continued).

Month	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$51,791	$52,190	$52,592	$52,998	$53,406	$53,818	$54,233	$54,651	$55,072	$55,496	$55,924	$56,355
Interest Paid	$10,481	$10,081	$9,679	$9,274	$8,865	$8,454	$8,039	$7,621	$7,199	$6,775	$6,347	$5,916
Total Interest	$8,021,561	$8,031,643	$8,041,322	$8,050,596	$8,059,461	$8,067,914	$8,075,953	$8,083,574	$8,090,773	$8,097,548	$8,103,895	$8,109,811
Balance	$1,307,858	$1,255,668	$1,203,076	$1,150,078	$1,096,672	$1,042,855	$988,622	$933,971	$878,899	$823,403	$767,479	$711,123
Month	**Jan-26**	**Feb-26**	**Mar-26**	**Apr-26**	**May-26**	**Jun-26**	**Jul-26**	**Aug-26**	**Sep-26**	**Oct-26**	**Nov-26**	**Dec-26**
Payment	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271	$62,271
Principal Paid	$56,790	$57,227	$57,669	$58,113	$58,561	$59,012	$59,467	$59,926	$60,388	$60,853	$61,322	$61,795
Interest Paid	$5,482	$5,044	$4,603	$4,158	$3,710	$3,259	$2,804	$2,346	$1,884	$1,418	$949	$476
Total Interest	$8,115,293	$8,120,336	$8,124,939	$8,129,097	$8,132,807	$8,136,066	$8,138,870	$8,141,216	$8,143,099	$8,144,517	$8,145,466	$8,145,943
Balance	$654,334	$597,106	$539,438	$481,325	$422,764	$363,751	$304,284	$244,358	$183,970	$123,117	$61,795	$0

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Chapter 5

5 Conclusions

5.1 Research Perspective

There has been a considerable amount of research concerning various innovative products and processes for underutilized hardwood resources over the past 25 years. Generally, this research focused on the availability of different underutilized resources and how suitable various processes such as System 6, 3-sided cant sawing, and green dimensioning might be for converting these inputs into products. This past research mainly presented quantitative data on yields and availability but often neglected the economic consequences of using these underutilized resources in the manufacturing process.

The research presented in this thesis is intended to investigate the economic feasibility of manufacturing solid hardwood panels from underutilized resources. The science portion focused on using yield calculations obtained from a computer simulation to estimate the amount of usable material available from underutilized slabs and low-grade boards. The yields estimated by the simulation provided the starting point for creating a basic cost structure for the proposed venture. Through these estimates, a preliminary business plan was developed to demonstrate the opportunities. This business plan included the necessary capital investments for manufacturing solid hardwood panels from underutilized hardwood resources. The business plan also acknowledged several potential markets where solid hardwood panels are viable as well as a marketing strategy to capitalize on the opportunity. The business plan concludes by disclosing the venture's profitability under the assumed financial conditions.

5.2 Summary

Today's forest products industries face a challenging predicament with the decline in availability of high quality wood resources because of the depletion of major forest ecosystems and a history of poor forest management. Due to this, primary and secondary manufacturers of hardwood products are forced to use lower-grade resources or pay higher prices for their raw material. This problem, coupled with globalization, which has opened the attractive American market to the world, has significantly affected the domestic industry's competitiveness in today's global economy.

However, the lack of high quality material does not indicate a shortage of resources as there is a significant amount of useful material available through underutilized resources. Underutilized resources examined in this research include sawmill slabs, small-diameter roundwood, and low-grade lumber. Slabs are a sawmill byproduct resulting from sawing lumber (rectangular) from roundwood (truncated cone). Small-diameter roundwood is defined as logs having a diameter between 5 and 11 inches. Lumber grades below 2A Common is generally perceived as low-grade lumber by the secondary wood industry (Cumbo et al. 2003). These sources of raw material are considered underutilized because usable portions are often difficult and costly to remove. Therefore, industry tends to shy away from this material while making use of intermediate quality wood resources. It is for this reason that developing innovative products for the efficient use of underutilized materials is a top research priority among the forest products industries. Finding economically feasible products will create more value for such materials compared to their traditional "low-value" uses as fuel and as a source of raw materials for wood composites. This in turn should improve profits for landowners and manufacturers utilizing low-grade materials while creating more capital for reinvestments. In addition, this will give landowners the incentive to remove this material from their forest, improving forest health and ensuring for future a steady supply of high quality wood material.

Solid hardwood panels were presented in this research as a potential product to satisfy tomorrow's demand for solid hardwood components as well as the manufacturing needs of raw materials processing efficiency. Solid hardwood panels are standard-size, finger-jointed, edge-glued blanks, manufactured from such underutilized resources. Solid hardwood panels provide an opportunity as a value-added product for several reasons. They can be manufactured from low-grade/low-value resources. Solid hardwood panels also have the potential to improve the processes of manufacturers of wood components, cabinets, and furniture because they are essentially receiving defect free lumber. These customers receive a material that allows them to better calculate material costs and yields because they know their only loss of material during processing is due to measurable variables such as saw kerf and end trim. Solid panels can also save customers money by reducing shipping and storage costs because no space is wasted on unusable portions of wood. Most importantly, solid hardwood panels allow the raw material to stay in its natural solid form, preserving its beauty and offering end users a product they deem as highly desirable.

Literature shows that panels can be manufactured efficiently from underutilized wood resources such as sawmill slabs, small-diameter roundwood, and low-grade lumber. One particularly noteworthy research project, System 6, completed by the U.S. Forestry Service utilized short and small diameter logs by manufacturing dimension parts and standardized panels for furniture and cabinet manufacturers (Reynolds and Gatchell 1982). The System 6 research presented a promising and feasible process for solid hardwood panel manufacturing with satisfactory results. Even today, the System 6 process, with a little tweaking, proves to be an ideal process to manufacture solid hardwood panels from underutilized resources.

An objective of the research was to calculate the potential yields obtained from processing underutilized resources such as sawmill slabs, small diameter roundwood and low-grade lumber. The yields were used to estimate the required volumes of raw material to satisfy production demands. Since this is a preliminary evaluation of a startup manufacturing facility, a computer simulation provides a quick and efficient tool for making a decision. ROMI 3 is the computer simulation of choice. Before the simulation was conducted, an effective cutting bill was designed using past research on cutting bills and their effects on yields. The cutting bill presented and used in this simulation consisted of a total of 50 parts generated from 5 desired widths combined with 10 desired lengths. Slat widths range from 1 to 5 inches and lengths ranged from 5 to 40 inches. The average part size in this cutting bill measured 2.75 by 21.7 inches. The results of the simulation revealed an average of 8.62 cuts were necessary to produce 1 board foot of lumber with yields in excess of 61 percent. The yields obtained from simulation provide an optimistic result considering the quality of the resource used; however, removing the usable material requires many cuts and will be costly.

Manufacturing solid hardwood panels out of underutilized wood resources is a feasible idea from a process standpoint. An initial investment of $7,554,624 (U.S.

Dollars) is required to build a manufacturing plant from the ground up. A plant of this size has the capacity to produce 469 solid hardwood panels (approximately 15 MBF) a day while operating one 8-hour shift. Yearly production for 235 days totals 110,215 panels equaling 3.5 MMBF. This would require a raw material input of 31.25 MBF of lumber a day and 7.4 MMBF of lumber a year with the estimated plant yield of 48 percent.

Panel prices are developed using a cost-plus strategy. Preliminary estimates indicate an average cost of $3.325 (U.S. Dollars) per board foot of panel produced. Profit margins range from 40 percent for premium panels down to 20 percent for the bargain boards. This results in a price range of $128.21 to 148.96 per board. A company manufacturing solid hardwood panels under the circumstance presented in this research should expect total sales to exceed $15.5 million a year while incurring $12.5 million a year in expenses. A breakdown in manufacturing costs are as follows; direct material costs account for 23.16 percent, variable manufacturing overhead costs account for 53.08 percent, variable manufacturing overhead costs account for 12.48 percent, direct labor costs account for 4.81 percent, variable sales and administration costs account for 1.35 percent, fixed sales and administration costs account for 5.11 percent.

The wood components industry currently ships $5 billion (U.S. Dollars) worth of products a year (Lawser 2004). Solid hardwood panels make up $650 million or 13 percent of this market (WCMA 2001 as cited in McDaniel 2003). Several markets that are willing to accept solid hardwood panels include office furniture and solid wood door manufacturers. As of 2003, edge-glued panels accounted for 59 and 19 percent of the raw materials used by the door and office furniture manufacturing segments respectively. These markets have shown an acceptance for solid wood panels and provide the ideal situation for the introduction of solid hardwood panels to secondary wood processors.

5.3 Future Research

The purpose and objectives of this research limit the true evaluation of such an enterprise. Initial results are unpromising but future research may reveal more information and opportunities for the manufacturing of solid hardwood panels. The next few sections suggest areas of research that should be conducted. Extending this research will reveal more detailed information that may change the research assumptions and improve the economic feasibility of a startup enterprise.

5.3.1 Market Research

One major shortcoming of this research was the availability of quality market research. The available literature containing market information is considered outdated (older than 5 years) by marketing research standards. The assumptions presented in this research are generated from this literature meaning the pricing, cost structures and demands presented may not accurately portray today's market conditions. In particular the prices for this research are derived from a cost-plus strategy and changes in the price structure of the panels will significantly affect the project's profitability. It is believed these prices are significantly lower than the panel's actual market value. Therefore, the first suggested step for continuing the investigation of such a project is conducting an extensive market survey.

5.3.1.1 Market Survey

A market survey will give entrepreneurs a better look at what is available in the target market and what prices potential customers are willing to pay. Additional relevant information is needed in respect to current cost structures of solid wood panel manufacturers as well as raw material data such as species, grades and quantities consumed. Beyond the manufacturing of panels, researchers should investigate the concerns and conditions in today's rough mills. Detailed information on the current cost to manufacture defect-free blanks may provide the opportunity to showcase the value for manufacturers to purchase semi-machined panels versus internal manufacturing. Another area of attention revolves around consumer's insert in "green products." The results of the market survey often provide enough information for all parties involved to make the "go" or "no go" decision for the project.

5.3.1.2 Export Opportunities

After a domestic market survey, an investigation into several different export opportunities will further quantify the potential for solid hardwood panels. Europe and China are just two of the many countries who may be willing to purchase solid hardwood panels manufactured from our underutilized domestic wood resources. This project idea was conceived by a European who actually derived the proposed product from a current European product. The rapid growth of the Chinese wood products industry will force manufacturers to evaluate alternative sources of raw material and solid hardwood panels may prove to be one solution.

5.3.2 Technology Research

Several processes for the production of solid hardwood panels are presented in this research. These processes are feasible, but may not provide the most economical or efficient means for processing underutilized resources into solid panels. Areas needing immediate research and improvements include drying and material handling. These two processes may prove to be the biggest barrier for the manufacturing of solid panels. A majority of the material researched during this project can be characterized by having large amounts of juvenile wood when compared to larger, mature timber. Defects generated during drying such as crook, bow, twist and splits, tend to be more pronounced in juvenile wood. Bow, crook and twist make processing difficult while splits are unacceptable in the final product. As a result, boards containing such defects reduce yields and increase costs. Reducing stresses through drying by developing new techniques or equipment is the goal.

Small, clear, usable portions of wood are generated during the cut-up of lumber. Handling, sorting, and storing these pieces will be difficult. The cutting bill calls for 50 different parts coming out of the rough mill. Furthermore, the markets demand color matched products. This equates to hundreds of different SKUs based on size and color. Moving these pieces efficiently from the rough mill through a sorting station and finally to storage while keeping track of the “A” side requires a complex system. Finding capable yet efficient machines or even combining machine functions while improving the plant layout may reduce processing costs and improve the profitability of the enterprise.

5.3.3 Refining the Rough End Research

Reviewing the available literature and running a simulator provides a quick and inexpensive method to justify further investigation into the proposal. However, for a true evaluation of the project, one must reach deeper into the question at hand. This will eventually require running live experiments in sawmills and rough ends to quantify the amount of material obtainable from the desired resource. During this experiment, variables such as rip-first vs. crosscut-first should be analyzed along with variations to part sizes in the cutting bill. Continuous improvements in research and technology at the rough end of the process have the potential to further reduce costs and increase profits for manufacturers.

5.3.4 Fixed Lengths vs. Random Lengths

A decision was made early in the research to keep slat sizes fixed in the width and length dimensions. This decision was based on a similar product in the European and Asian markets. The idea was that product marketing would be considerably easier by utilizing the available information from those markets.

The problem with fixed slat sizes is they reduce rough mill yields by restricting the flexibility of the raw material. Unfortunately, character marks naturally occur in wood at random locations. Under a fixed dimension cutting bill strategy, as the board is scanned, a computer calculates the distance between character marks, makes the best decision on what part will fit in that space, and proceeds with cutting that part. Quite often, the area of the clear cuttings does not equal the area of the desired parts and usable material is wasted. By not specifying a dimension the saw is able to cut as close to the character mark as possible. This practice maximizes the amount of raw material and ultimately saves costs.

For the product proposed, it is necessary to have fixed widths. This is due to the fact that the finger-jointed material needs to be the same width. However, the lengths of these slats are not critical. Investigating the feasibility of manufacturing panels under a random length strategy is recommended as another research interest. Utilizing random lengths should increase rough mill yields as well as end trim losses from sizing panels. A suggestive manufacturing process could be to rip the lumber at desired widths, chop out defects where they occur, finger-joint matching widths in continuous streams and chop once again to create blanks slightly longer than the desired length of the panel.

5.3.5 Expanding the Product Line

During this research, a tri-ply hardwood panel was mentioned as a potential product. The idea behind a tri-ply panel increases the utilization of the material while improving the dimensional and mechanical stability of the panel. This type of panel is capable of using cores of plywood, MDF, particleboard, or even low-quality edge-glued panels. Using edge-glued panels as the core allows the manufacturer to make use of slats that would normally be scrapped because of the presence of sound knots, sap stains, mineral streaks or any other defect that does not compromise the strength of the board. The challenge to a company that wishes to offer the tri-ply panel is developing an efficient process to manufacture such panels.

Beyond the tri-ply panel, a manufacturer already producing solid hardwood panels is capable of producing several other product variations. These variations may come in the form of custom-sized panels, panels offered in different thicknesses, panels made from other species, or even made from non-commercial species. Expanding the product line through slight modifications is easily done with changes to the process and/or capital investments in machinery. Developing these types of products offers customers a larger variety of products to choose from that best suit their manufacturing initiatives.

5.3.6 Non-commercial Species

The research presented focuses on red oak, the most widely used species in the wood components market. Red oak is popular among manufacturers because it is widely available in the market at a favorable price. Red oak is also easy to machine and finishes well providing the end user an aesthetically pleasing product at an affordable price. However, it has not always been the popular species and its use is beginning to decline.

The market can only speculate on the next “big wood” and the potential of using non-commercial species is becoming more apparent as other forest and wood quality issues arise. McDaniel (2003) researched the idea of using non-commercialized species and found that their full potential has yet to be realized. His market survey reveals that several smaller companies are more likely to accept the “non-traditional” species as a source for raw materials. Developing this potential will require more comprehensive research on the needs of the industry. Manufacturers will be challenged with creating clever marketing plans that will help secondary manufacturers and consumers realize the need for such products and hopefully, as a result, develop a strong enough demand to sustain a business.

5.3.7 The Green Initiative

The push towards a “green” forest products marketplace becomes more evident as time passes. Several associations have begun to research consumer markets, trying to discover the thoughts and demands for products produced with environmentally friendly components. Several third party organizations are now offering certification for products that are derived from forests that are properly managed. In a commoditized industry, often times these certifications may prove the difference in a company’s product being purchased versus that of a competitor, which may not be certified. Researching the requirements for products to be labeled as green is a logical objective of an entrepreneur wishing to manufacture solid hardwood panels in the manner presented in the project. The green initiative is no doubt the future of the forest products industry and joining the efforts early may mean big profits.

5.3.8 Government Interaction

As with most government policies, the need for regulation derives from public awareness/opinion, research and desperation. Forest fires have become a major concern in today’s society. Not only are they destroying land, homes and businesses, they are believed to be critical factor in global warming. Stands with heavy concentrations of small diameter timber are more susceptible to forest fire than properly managed lands (LeVan-Green and Livingston 2001). As better research becomes available, more government regulation is expected. Therefore, it is expected that the supply of small-diameter timber available in the market will exceed demand. These factors offer several opportunities to expand the research knowledge in and effort to improve the sanctions imposed by the government as well as the industry itself.

5.3.9 Business Model Changes

Several opportunities for future research are more specific to the business model. The profitability of the proposed business plan is not promising due to the large capital investment and high manufacturing costs. Under the assumptions, building a completely new factory and purchasing new equipment is not ideal for this particular business model. Leasing the building and equipment may prove to be a better option.

The lease vs. buy decision is often debated and basically depends on the situation of the individual company. Each scenario has benefits and drawbacks. Often times, and in the case of this proposal, buying equipment requires a loan. Companies financing purchases through a loan incur the costs of a principal payment and interest payment to the creditor. The magnitude of these payments is determined by the length of the loan. A short loan term results in a larger payment and less cash flow for the company. Purchasing equipment and infrastructure gives companies instant ownership meaning they also incur the cost of depreciation. However, these costs are often offset in the balance sheet because the purchased equipment is an asset. Buying is a better option when companies have the capital and cash flow to handle the payments, need ownership of equipment for proprietary reasons or due to a competitive advantage, or the company is concerned with increasing their asset value (U.K. Business Link 2006).

In a startup company, adequate cash flow is one of the most important contributors to survival. Having cash allows startup companies to purchase raw materials, pay the bills and its employees, and handle any unforeseen situations that may arise during production ramp-up. Therefore, leasing may be a better option for startup companies. Through a lease the company still incurs the costs of principal, interest and depreciation, but leases are normally drawn out over a longer period of time than loans. In the short run lease payments are generally less than loan payments. This means more cash available for operations and potential growth. Leasing equipment also gives the company flexibility to change with industrial technology improvements. Leasing is a better option for companies concerned with cash flow and changing technologies.

Improvements to the business model can also be made by figuring ways to reduce manufacturing overhead and direct labor costs. The model proposed is heavily dependent on labor both management and skilled workers. Due to the lack of manufacturing experience it is difficult for the author to determine what level of labor is necessary to successfully sustain operations. Suggestions have come in the form of eliminating a senior management position and reducing the staff by 10 employees. This has the potential to save $688,000[30] a year in costs. Other options include outsourcing labor or investments in automation. Outsourcing labor can include hiring outside sales professionals, engineering firms, accountants, or making use of a temp agency for skilled laborers. Automation may be in the form of material handling systems, color matching technology or machines designed to carry out two or more processes at once.

5.4 Author's Opinion

The economic analysis shows slight signs of profitability under the proposed conditions but there are several concerns about its true viability. Therefore, the author has mixed feelings about the potential of the project proposed. These doubts result from the product definition, several bold assumptions, and the uncertainty of how to properly dry the material in question.

Several issues exist with the product defined. These issues include manufacturing panels from uniformly sized slats and the costs involved with processing panels with the smaller sized slats. Stating uniformly sized slats greatly reduces the flexibility of the raw material. Random lengths are preferred because of the potential cost savings. These cost savings exist in improvements to rough mill yields and through less complicated processes.

The focus of this research is on materials that produce short and narrow portions of usable wood. In reality, the cost of wood raw materials is roughly half of the total manufacturing costs. Therefore, most manufacturers are concerned with maximizing the amount of clear usable portions from their raw material. By considering the researched raw material and operating under this "maximize yield philosophy," the cutting bill allows for short, narrow portions of wood. The simulation proved the designed cutting bill would satisfy yield concerns. But by satisfying one cost concern the proposed cutting bill creates another - processing. An estimated 8.62 cuts are required to produce 1 BF of

[30] 1 senior manager - $137,500, 8 skilled workers - $25,380 each, 1 quality technician - $30,000, 1 sales person - $70,000, 1 engineer - $60,000, 1 accountant - $50,000, in addition 25% for benefits – totaling roughly $600,000

edge-glued panels, furthermore, to edge-glue this board foot back together it will require 7 to 8 glue lines. Expand this out over 32 BF of panel and it is quickly realized that processing costs are now the major cost concern.

Assumptions are used throughout this research because the objectives did not cover the topic or because relevant information is not readily available. The author realizes these assumptions and highlights the concerns by including a future research section. However, under the scope of this research, several bold and possibly unlikely assumptions had to be made. In particular the assumptions that the market will accept the product proposed and accept it in a manner of consuming 100 percent of the manufacturing facility's capacity. Furthermore, the number of glue lines in the proposed product may not satisfy today's U.S. consumers' wants. It is also unclear without more market research that there is a large enough price difference to create a demand for the lower end products (smaller slat sizes).

The last major concern from the author deals with properly drying the raw material in question. Small diameter timber contains large portions of juvenile wood, which tends to react very differently than mature wood during dimensional changes. It is expected that large portions of wood will be lost during drying under today's conventional drying techniques. Several technologies exist that may reduce the drying stresses but no relevant research is found that studies the technology and low-grade material together. Perhaps this proves to be the ultimate challenge to a successful business utilizing small diameter and low-grade wood resources.

Although several major obstacles are present, the research still shows promising opportunities. Under the assumptions presented in this research, the investment in a start-up company producing solid hardwood panels seems uneconomical by the economical analysis presented. However, there may be opportunities for an outside entity to set up the installation as a turnkey project to a current wood component or sawmill operation or even the wood component producer or sawmill undertaking this project as an intrepreneurial opportunity. This seems more logical from a cost standpoint because the land, building, a majority of the equipment, and management structure already exists. This strategy also allows the organization to continue the necessary research to launch the product while maintaining a revenue stream from their existing operations.

Improving today's forests to the ideal ecological conditions for growing quality hardwood calls for the removal of large portions of small-diameter timber with limited economic value (Keegan et al. 2005). The industry as well as the research community's responsibility will be finding efficient methods of using this material while satisfying consumer demands. Solid hardwood panels are just one of the many opportunities available to the industry that improves the value and utilization of the resource from the forests to the consumer. Future research and ideas are necessary to develop the opportunities that will provide the cornerstone for tomorrow's industry. All stakeholders of the forest products industry will depend on past, present, and future knowledge to ensure the competitiveness of the domestic forest products industry into the future.

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Chapter 6

6 Appendices

6.1 Appendix A

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Tue Jul 26 19:55:21 2005

                         ROMI-RIP VER 3.0 beta
                   USDA Forestry Sciences Laboratory
                        Princeton, West Virginia

Data file processed:
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+
C:\Program Files\Romi 3.0 beta\dat_files\Lumber Grade Mix Panels+

Cutting bill output in:  C:\Program Files\Romi 3.0 beta\Simulation Run
7 Board Files.out

Part grade definition file used:  Slat Part Grades.def

ALL part measurements are in INCHES!

Panel Specifications: Min. part width: 1.50  Max. part width:   4.00

Random width edging strips are not acceptable for use in panel
production

Arbor type is  FIXED-BLADE-BEST-FEED
Order of saw spacings from left edge of arbor
5.0000-|||-1.7500-|||-1.0000-|||-1.0000-|||-2.5000-|||-3.5000-|||-
1.7500-|||-2.5000-|||-2.5000

Fixed Arbor Spacing:  -|||- Movable Arbor Spacing:  <-|->

Width Ranges:
0.90   1.60   2.10   2.30   2.80   3.10   3.60   4.10
1.60   2.10   2.30   2.80   3.10   3.60   4.10   6.50

Rough mill central controller priorities updated every   200 Bdft.

Primary operations avoid orphan parts.

Board placement with respect to arbor optimized in 2/16-inch steps

3/16-inch ripsaw kerf
3/16-inch chopsaw kerf
```

Left edger set to edge 0.1250 inch
Right edger set to edge 0.1250 inch
Boards will NOT be end trimmed.

Salvage uses primary widths. Salvage uses primary lengths.

Tue Jul 26 19:55:21 2005

ROMI-RIP VER 3.0 beta
Grade-Based Yield and Processing Statistics

Selects Process Statistics
Board Count: 119 Bdft: 364.7 Pct. of Total Grade Mix: 6.23

	Strip Area	Strip Yield	Part Area	Part Yield	Strip Count	Part Count	Rip Count	X-Cut Count
Primary	278.155	76.27	212.398	58.24	128	286	371	394
Exc-Pri			26.264	7.20		33		
Salvage	56.245	15.42	3.078	0.84	55	18	26	21
Exc-Sal			46.799	12.83		137	110	159
Total	334.400	91.69	288.538	79.12	183	474	507	574

1 Common Process Statistics
Board Count: 170 Bdft: 665.3 Pct. of Total Grade Mix: 11.37

	Strip Area	Strip Yield	Part Area	Part Yield	Strip Count	Part Count	Rip Count	X-Cut Count
Primary	478.078	71.86	289.495	43.51	272	602	688	956
Exc-Pri			52.031	7.82		84		
Salvage	133.322	20.04	10.531	1.58	160	54	63	75
Exc-Sal			117.564	17.67		482	427	672
Total	611.401	91.90	469.622	70.59	432	1222	1178	1703

2A Common Process Statistics
Board Count: 378 Bdft: 1507.3 Pct. of Total Grade Mix: 25.75

	Strip Area	Strip Yield	Part Area	Part Yield	Strip Count	Part Count	Rip Count	X-Cut Count
Primary	1080.446	71.68	559.589	37.12	620	1352	1582	2515
Exc-Pri			132.248	8.77		291		
Salvage	304.779	20.22	19.609	1.30	380	140	166	203
Exc-Sal			257.991	17.12		1357	1171	2006
Total	1385.225	91.90	969.438	64.32	1000	3140	2919	4724

3A Common Process Statistics

Board Count: 936 Bdft: 3316.4 Pct. of Total Grade Mix: 56.65

	Strip Area	Strip Yield	Part Area	Part Yield	Strip Count	Part Count	Rip Count	X-Cut Count
Primary	2205.914	66.52	956.286	28.84	1371	2526	3733	5076
Exc-Pri			192.253	5.80		528		
Salvage	855.354	25.79	47.786	1.44	957	254	278	384
Exc-Sal			668.024	20.14		4010	3558	6331
Total	3061.268	92.31	1864.351	56.22	2328	7318	7569	11791

Lumber Yield and Processing Statistics for all lumber grades

Boards processed: 1603 Board feet: 5853.7

	Strip Area	Strip Yield	Part Area	Part Yield	Strip Count	Part Count	Rip Count	X-Cut Count
PRIMARY	4042.594	69.06	2017.767	34.47	2391	4766	6374	8941
Exc-Pri			402.797	6.88		936		
Salvage	1349.701	23.06	81.005	1.38	1552	466	533	683
Exc-Sal			1090.378	18.63		5986	5266	9168
Total	5392.295	92.12	3591.948	61.36	3943	12154	12173	18792

Overall Strip Yield Statistics

Strip Width	Strip Count	Before Defecting Length	Before Defecting Area	After Defecting Length	After Defecting Area
1.0000	618	4367.96	364.00	2139.92	178.33
1.7500	681	4756.40	693.64	2278.58	332.29
2.5000	426	3017.62	628.67	2094.25	436.30
3.5000	446	3109.48	906.93	2169.75	632.84
5.0000	758	5255.94	2189.97	2017.92	840.80

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Sequence Part Requirements Were Met

Part Width		Part Length	Board Footage Processed	Number of Boards Processed
5.0000	x	40.0000	3436.1	936
5.0000	x	32.0000	4247.4	1156
5.0000	x	29.0000	5051.1	1379
5.0000	x	26.0000	5853.7	1603
5.0000	x	23.0000	5051.1	1379
5.0000	x	20.0000	5251.6	1430
5.0000	x	17.0000	5653.0	1545
5.0000	x	14.0000	4449.8	1213
5.0000	x	11.0000	4449.8	1213
5.0000	x	5.0000	3233.2	879
3.5000	x	40.0000	1217.3	331
3.5000	x	32.0000	2019.9	555
3.5000	x	29.0000	2423.0	658
3.5000	x	26.0000	2830.4	774
3.5000	x	23.0000	3032.7	830
3.5000	x	20.0000	3233.2	879
3.5000	x	17.0000	3436.1	936
3.5000	x	14.0000	3032.7	830
3.5000	x	11.0000	3032.7	830
3.5000	x	5.0000	1417.7	382
2.5000	x	40.0000	810.9	222
2.5000	x	32.0000	1417.7	382
2.5000	x	29.0000	1819.2	497
2.5000	x	26.0000	2222.7	604
2.5000	x	23.0000	2628.4	717
2.5000	x	20.0000	2830.4	774
2.5000	x	17.0000	3032.7	830
2.5000	x	14.0000	2222.7	604
2.5000	x	11.0000	2423.0	658
2.5000	x	5.0000	810.9	222
1.7500	x	40.0000	607.4	163
1.7500	x	32.0000	1217.3	331
1.7500	x	29.0000	1617.9	440
1.7500	x	26.0000	2019.9	555
1.7500	x	23.0000	2222.7	604
1.7500	x	20.0000	2423.0	658
1.7500	x	17.0000	2628.4	717
1.7500	x	14.0000	1819.2	497
1.7500	x	11.0000	2019.9	555
1.7500	x	5.0000	607.4	163

Part Width		Part Length	Board Footage Processed	Number of Boards Processed
1.0000	x	40.0000	405.7	106
1.0000	x	32.0000	607.4	163
1.0000	x	29.0000	810.9	222
1.0000	x	26.0000	1014.0	280
1.0000	x	23.0000	1217.3	331
1.0000	x	20.0000	1417.7	382
1.0000	x	17.0000	1617.9	440
1.0000	x	14.0000	1014.0	280
1.0000	x	11.0000	1014.0	280
1.0000	x	5.0000	405.7	106

A 0 in the Board Footage Processed and Number of Boards Processed columns indicated that the part requirements for that part were not met.

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Cutting Bill Overall Part Quantity Obtained Report

Cutting Bill Processed: C:\Program Files\Romi 3.0 beta\cutting_bills\Slat Sizes

Weighting Method: L**2 W
Glue-Up parts prioritized at 0.0 percent of solid parts

Width x Length	Level	Glue Up	Required Quantity	Obtained Quantity	Salvage Quantity
5.0000 x 40.0000	1	-	100	102	0
5.0000 x 32.0000	1	-	100	101	0
5.0000 x 29.0000	1	-	100	117	0
5.0000 x 26.0000	1	-	100	141	0
5.0000 x 23.0000	1	-	100	106	0
5.0000 x 20.0000	1	-	100	106	5
5.0000 x 17.0000	1	-	100	131	1
5.0000 x 14.0000	1	-	100	102	0
5.0000 x 11.0000	1	-	100	113	5
5.0000 x 5.0000	1	-	100	124	12
3.5000 x 40.0000	1	-	100	113	0
3.5000 x 32.0000	1	-	100	118	0
3.5000 x 29.0000	1	-	100	122	0
3.5000 x 26.0000	1	-	100	123	1
3.5000 x 23.0000	1	-	100	128	3
3.5000 x 20.0000	1	-	100	142	7
3.5000 x 17.0000	1	-	100	162	17
3.5000 x 14.0000	1	-	100	109	5
3.5000 x 11.0000	1	-	100	102	7
3.5000 x 5.0000	1	-	100	120	22
2.5000 x 40.0000	1	-	100	117	0
2.5000 x 32.0000	1	-	100	126	0
2.5000 x 29.0000	1	-	100	118	0
2.5000 x 26.0000	1	-	100	122	2
2.5000 x 23.0000	1	-	100	137	3
2.5000 x 20.0000	1	-	100	111	10
2.5000 x 17.0000	1	-	100	133	18
2.5000 x 14.0000	1	-	100	104	12
2.5000 x 11.0000	1	-	100	111	24
2.5000 x 5.0000	1	-	100	140	25

Width	Length	Level	Glue Up	Required Quantity	Obtained Quantity	Salvage Quantity
1.7500 x	40.0000	1	-	100	117	0
1.7500 x	32.0000	1	-	100	148	0
1.7500 x	29.0000	1	-	100	129	1
1.7500 x	26.0000	1	-	100	139	1
1.7500 x	23.0000	1	-	100	149	3
1.7500 x	20.0000	1	-	100	117	5
1.7500 x	17.0000	1	-	100	177	27
1.7500 x	14.0000	1	-	100	109	22
1.7500 x	11.0000	1	-	100	109	33
1.7500 x	5.0000	1	-	100	130	45
1.0000 x	40.0000	1	-	100	148	1
1.0000 x	32.0000	1	-	100	135	3
1.0000 x	29.0000	1	-	100	116	2
1.0000 x	26.0000	1	-	100	107	1
1.0000 x	23.0000	1	-	100	116	14
1.0000 x	20.0000	1	-	100	134	23
1.0000 x	17.0000	1	-	100	163	17
1.0000 x	14.0000	1	-	100	104	18
1.0000 x	11.0000	1	-	100	111	25
1.0000 x	5.0000	1	-	100	109	46

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Cutting Bill Quantity Report by Lumber Grade

Width		Length	Glue Up	FAS	F1F	Selects	1 Common	2A Common	3A Common
5.0000	x	40.0000		0	0	49	15	25	13
5.0000	x	32.0000		0	0	26	21	34	20
5.0000	x	29.0000		0	0	25	24	22	46
5.0000	x	26.0000		0	0	27	27	34	53
5.0000	x	23.0000		0	0	11	8	14	73
5.0000	x	20.0000		0	0	6	8	37	55
5.0000	x	17.0000		0	0	2	5	13	111
5.0000	x	14.0000		0	0	4	9	33	56
5.0000	x	11.0000		0	0	4	10	27	72
5.0000	x	5.0000		0	0	8	15	50	51
3.5000	x	40.0000		0	0	16	40	31	26
3.5000	x	32.0000		0	0	13	23	31	51
3.5000	x	29.0000		0	0	1	18	72	31
3.5000	x	26.0000		0	0	3	5	11	104
3.5000	x	23.0000		0	0	20	52	20	36
3.5000	x	20.0000		0	0	2	6	96	38
3.5000	x	17.0000		0	0	5	2	32	123
3.5000	x	14.0000		0	0	5	13	24	67
3.5000	x	11.0000		0	0	3	7	29	63
3.5000	x	5.0000		0	0	5	10	50	55
2.5000	x	40.0000		0	0	6	21	48	42
2.5000	x	32.0000		0	0	3	21	60	42
2.5000	x	29.0000		0	0	2	4	13	99
2.5000	x	26.0000		0	0	1	23	47	51
2.5000	x	23.0000		0	0	2	1	37	97
2.5000	x	20.0000		0	0	1	7	23	80
2.5000	x	17.0000		0	0	2	31	22	78
2.5000	x	14.0000		0	0	1	7	23	73
2.5000	x	11.0000		0	0	5	8	34	64
2.5000	x	5.0000		0	0	3	10	38	89
1.7500	x	40.0000		0	0	12	23	45	37
1.7500	x	32.0000		0	0	10	23	42	73
1.7500	x	29.0000		0	0	1	7	47	74
1.7500	x	26.0000		0	0	5	18	9	107
1.7500	x	23.0000		0	0	2	24	67	56
1.7500	x	20.0000		0	0	1	3	56	57
1.7500	x	17.0000		0	0	0	11	23	143
1.7500	x	14.0000		0	0	1	7	21	80
1.7500	x	11.0000		0	0	1	8	18	82
1.7500	x	5.0000		0	0	4	17	44	65

Width	Length	Glue Up	FAS	F1F	Selects	1 Common	2A Common	3A Common
1.0000	x 40.0000		0	0	15	39	94	0
1.0000	x 32.0000		0	0	4	15	33	83
1.0000	x 29.0000		0	0	0	4	10	102
1.0000	x 26.0000		0	0	2	2	15	88
1.0000	x 23.0000		0	0	6	33	25	52
1.0000	x 20.0000		0	0	0	9	46	79
1.0000	x 17.0000		0	0	0	4	28	131
1.0000	x 14.0000		0	0	4	12	26	62
1.0000	x 11.0000		0	0	3	4	26	78
1.0000	x 5.0000		0	0	5	26	78	0

6.2 Appendix B

Table 6.1 Summary of the requirements of solid hardwood panel manufacturing based on cutting bill results.

Width	Length	Quantity Obtained	Panel Width	Panel Length	Theoretical Required Slats (Width)	Actual Required Slats (Width)	Theorectical Required Slats (Length)	Actual Required Slats (Length)	Actual Required Slats per Panel	Theorectical Panels Produced	Panels Produced	Loss To Width Trim	Loss To Length Trim
5	40	102	48	96	9.60	10	2.40	3	30	3.40	3	2	24
5	32	101	48	96	9.60	10	3.00	4	40	2.53	2	2	32
5	29	117	48	96	9.60	10	3.31	4	40	2.93	2	2	20
5	26	141	48	96	9.60	10	3.69	4	40	3.53	3	2	8
5	23	106	48	96	9.60	10	4.17	5	50	2.12	2	2	19
5	20	106	48	96	9.60	10	4.80	5	50	2.12	2	2	4
5	17	131	48	96	9.60	10	5.65	6	60	2.18	2	2	6
5	14	102	48	96	9.60	10	6.86	7	70	1.46	1	2	2
5	11	113	48	96	9.60	10	8.73	9	90	1.26	1	2	3
5	5	124	48	96	9.60	10	19.20	20	200	0.62		2	4
3.5	40	113	48	96	13.71	14	2.40	3	42	2.69	2	1	24
3.5	32	118	48	96	13.71	14	3.00	4	56	2.11	2	1	32
3.5	29	122	48	96	13.71	14	3.31	4	56	2.18	2	1	20
3.5	26	123	48	96	13.71	14	3.69	4	56	2.20	2	1	8
3.5	23	128	48	96	13.71	14	4.17	5	70	1.83	1	1	19
3.5	20	142	48	96	13.71	14	4.80	5	70	2.03	2	1	4
3.5	17	162	48	96	13.71	14	5.65	6	84	1.93	2	1	6
3.5	14	109	48	96	13.71	14	6.86	7	98	1.11	1	1	2
3.5	11	102	48	96	13.71	14	8.73	9	126	0.81		1	3
3.5	5	120	48	96	13.71	14	19.20	20	280	0.43		1	4
2.5	40	117	48	96	19.20	20	2.40	3	60	1.95	1	2	24
2.5	32	126	48	96	19.20	20	3.00	4	80	1.58	1	2	32
2.5	29	118	48	96	19.20	20	3.31	4	80	1.48	1	2	20
2.5	26	122	48	96	19.20	20	3.69	4	80	1.53	1	2	8
2.5	23	137	48	96	19.20	20	4.17	5	100	1.37	1	2	19
2.5	20	111	48	96	19.20	20	4.80	5	100	1.11	1	2	4

Table 6.1 (Continued)

Width	Length	Quantity Obtained	Panel Width	Panel Length	Theoretical Required Slats (Width)	Actual Required Slats (Width)	Theorectical Required Slats (Length)	Actual Required Slats (Length)	Actual Required Slats per Panel	Theorectical Panels Produced	Panels Produced	Loss To Width Trim	Loss To Length Trim
2.5	17	133	48	96	19.20	20	5.65	6	120	1.11	1	2	6
2.5	14	104	48	96	19.20	20	6.86	7	140	0.74		2	2
2.5	11	111	48	96	19.20	20	8.73	9	180	0.62		2	3
2.5	5	140	48	96	19.20	20	19.20	20	400	0.35		2	4
1.75	40	117	48	96	27.43	28	2.40	3	84	1.39	1	1	24
1.75	32	148	48	96	27.43	28	3.00	4	112	1.32	1	1	32
1.75	29	129	48	96	27.43	28	3.31	4	112	1.15	1	1	20
1.75	26	139	48	96	27.43	28	3.69	4	112	1.24	1	1	8
1.75	23	149	48	96	27.43	28	4.17	5	140	1.06	1	1	19
1.75	20	117	48	96	27.43	28	4.80	5	140	0.84		1	4
1.75	17	177	48	96	27.43	28	5.65	6	168	1.05	1	1	6
1.75	14	109	48	96	27.43	28	6.86	7	196	0.56		1	2
1.75	11	109	48	96	27.43	28	8.73	9	252	0.43		1	3
1.75	5	130	48	96	27.43	28	19.20	20	560	0.23		1	4
1	40	148	48	96	48.00	49	2.40	3	147	1.01	1	1	24
1	32	135	48	96	48.00	49	3.00	4	196	0.69		1	32
1	29	116	48	96	48.00	49	3.31	4	196	0.59		1	20
1	26	107	48	96	48.00	49	3.69	4	196	0.55		1	8
1	23	116	48	96	48.00	49	4.17	5	245	0.47		1	19
1	20	134	48	96	48.00	49	4.80	5	245	0.55		1	4
1	17	163	48	96	48.00	49	5.65	6	294	0.55		1	6
1	14	104	48	96	48.00	49	6.86	7	343	0.30		1	2
1	11	111	48	96	48.00	49	8.73	9	441	0.25		1	3
1	5	109	48	96	48.00	49	19.20	20	980	0.11		1	4