

Investigation of New and Recovered Wood Shipping Platforms in the United States

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ABSTRACT

It is estimated that there are 2.6 billion pallets in circulation in the United States and the majority of these pallets are made of wood. Wooden pallets are essential part of the supply chain carrying approximately 80% of all products shipped domestically. The production of pallets is also strongly correlated (85%) of G.D.P that came from manufacturing. This research was conducted to obtain important information on the market and raw material usage trends in the wooden pallet and container industry from 2019 through 2021. These trends have been compared to historical data that has been collected by Virginia Tech and U.S. Forest Service pallet surveys from 1991-2016. This study was conducted by sending out physical and online surveys to 2319 companies who produce and broker wooden pallets and crates. The results revealed that the wooden pallet and container industry produced and estimated 919 million new pallets in 2021 which is an estimated 75% increase since 2016. The 48"x40" pallet size continues to be the dominant new pallet size with a 29% market share. The share of softwood lumber used in the industry steadily increased since 2016 and accounted for 81% of the lumber used in pallet production. The industry used an estimated 38.6% percent of the total sawn softwood and 37.6% of the total sawn hardwood lumber produced in the U.S. The industry also produced 280 million repaired and remanufactured pallets that is 16.4% decrease compared to 2016. In 2021, approximately 89% of all recovered wooden pallets are converted to repaired or remanufactured pallets. Approximately 22% of respondents stated that they were not affected by the pandemic. A majority of 51% of respondents stated that they exceeded their 2019 sales, with 12% seeing no change in sales in 2020 compared to 2019.

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GENERAL AUDIENCE ABSTRACT

Wooden pallets are an essential part of the supply chain, especially because 80 percent of the products produced in the US are transported on wooden pallets. The number of new wooden pallets produced annually also has a strong correlation to the U.S. G.D.P from manufacturing that further highlights the importance of pallets. This study was conducted to obtain key information about the market trends in the wooden pallet industry from 2019-2021. This data was compared to historical trends researched by Virginia Tech and the U. S. Forest service from 1991-2016. This study was conducted by sending out physical and online surveys to 2319 companies who produce and broker wooden pallets and crates. The wooden pallet industry continued to trend upward from previous surveys conducted. In 2021, total pallet production increased 40% from 2016 increasing to 1.18 billion. As pallet production increased so did material usage. In 2021 the wooden pallet industry used an estimated 17.9 billion board feet of lumber which is a 95% increase from 2016. As for repaired and recycled pallets there were an estimated 280 million produced in 2021. This is a 16.4% decrease from the previous survey conducted. Though with this decrease approximately 89% of all received pallet cores were either repaired or used during the remanufacturing process. This study also delved into the impacts of the Covid-19 pandemic on the wooden pallet and container industry. The results of the covid section implied that the industry was stable throughout the pandemic. Approximately 22% of respondents stated that they were not affected by the pandemic. A majority of 51% of respondents stated that they exceeded their 2019 sales, with 12% seeing no change in sales in 2020 compared to 2019. This data is important so that companies can use it to make better descension by looking at the important modern trends in the industry.

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INTRODUCTION

The United States (U.S.) is covered with roughly 33.9% forested land which translates to approximately 3.1 million square kilometers. It is estimated that there were 37.3 billion board feet of sawn softwood and 9.3 billion board feet of sawn hardwood harvested (Alderman et al., 2022). The forest product industry contributes to approximately 4% of the nation's Gross Domestic Product (GDP) which translates to approximately \$930 billion (Global Forest Resources Assessment 2020, 2020).

Different quality lumber is used for different hardwood and softwood products. Lumber is typically graded based on its imperfections, strength properties, and visual appearance. Higher quality lumber is used for structural members in housing, molding, furniture, decorative pieces, and other high value products (*A Study Guide to Lumber Grades in Manufacturing* | *Conner Industries*, n.d.). The domestic furniture industry uses less than 5% of all hardwood produced in the U.S. (Barford, 2013). Lower quality lumber is used in applications where appearance is not critical such as railroad ties, gas exploration mats, fence posts, and pallets (Lumber Zeeland Lumber & Supply, 2020).

Pallets were invented in the early 1900s in conjunction with the invention of the forklift. They began to gain popularity when their true potential was seen during the rise of World War II. They were used heavily in shipping supplies and equipment across the European and Pacific fronts. Their heavy use showed how effective they were; this quickly made them the backbone of the U.S. and world's supply chain (Pallet Management, 2017a). In the U.S., 80% of all products sold are unitized on pallets (Aldaz-Carroll & Raballand, 2005).

Pallets allow for shorter lead times for larger shipments making the supply chain more efficient. Without pallets, the supply chain would get bogged down with the manual labor of loading and unloading products (Leise, 2021). The reliance of the U.S supply chain on wooden pallets causes an 80% correlation between pallet production and the U.S. manufacturing GDP

(Gerber et al., 2018). Due to the importance of pallets in the supply chain, many researchers have investigated the pallet market over the years (Bush & Araman, 1992; Gerber et al., 2018).

In 2016, it was estimated that the pallet industry used 4.13 billion board feet of hardwood and 5.03 billion board feet of softwood. The lumber usage by the pallet industry accounted for approximately 43% of all hardwood and 15% of all softwood lumber harvested in the U. S. (N. S. Gerber et al., 2018). The majority of wooden pallets produced (61%) were new pallets constructed from new lumber. In 2016, it was estimated that there were 513 million new pallets produced (Gerber et al., 2020). This was a 23% increase from the previous survey conducted in 2011 (Araman and Bush, 2015). Historically, lumber usage and pallet production have been on a steady incline from 1995 to 2016. The only disruption came on the 2011 survey and was due to the economic impact of the great recession and housing crisis.

Of the new pallets produced, approximately 76% were stringer class pallets in 2016. This was unique to the U.S.; in Europe, the block class pallet is the most predominant (Pallet Management, 2017). The 48" x 40" is the specific size that is most used and makes up an estimated 35% of new pallet production. These pallets are used for many different industries; although, mainly retail and groceries. Other pallet sizes are specifically created for different industries due to their compatibility with the products that are most-often moved by these industries. Some other common sizes are 48" x 48" (used by the chemical industry) and 48" x 45" (used by the automotive industry)(Hasanovic, 2020). The majority of pallets produced are "other" sizes, meaning they are customized for their intended payloads. This is made possible due to the existence of simple-to-use pallet design softwares.

Often, when a pallet reaches the end of its life cycle, it is collected and repaired or remanufactured to be used again. In 2016, there was an estimated 390 million pallets that were recovered by the industry. Out of these recovered pallets, approximately 326 million were repaired and sold as used pallets. The remaining 84 million were dismantled to either be used in remanufacturing other pallets or for other uses (Gerber et al., 2020). The parts of the recovered pallet that can no longer be used in the remanufacturing process are typically chipped or ground for landscape mulch, biofuel, animal bedding, fiber-based products, and other uses (Araman and

Bush, 2015). From of the 513 million new pallets produced in 2016, only 3.5% of them ended up in landfills. And, after the pallet recovery process, only 1.6% remained landfilled(Z. Shiner et al., 2021).

Due to the volume of lumber used by the wooden pallet industry, there have been LCAs and sustainability investigations into their usage. Some research into the sustainability of wooden pallet usage has been about the effect of pallet design and durability on the sustainability of the GMA 48" x 40" stringer class pallet (Wallen, 2008). There have also been tools put in place by the National Wooden Pallet and Container Association (NWPCA), such as an environmental product declaration (EPD), which can help consumers understand the environmental impacts of wooden pallets.

Due to the sheer volume of lumber used and pallets produced, it is important to track the trends in the wooden pallet and container industry. By comparing modern trends to historic trends, companies can adopt competitive strategies as the industry changes throughout the years. This study provides essential current trends of the industry, such as new and used pallet production, lumber usage, heat treatment, sizes, etc. This study also delves into how the Covid-19 pandemic affected this industry and how what was learned can be used to prepare for any future pandemic situations. The pandemic put strain on the global supply chain, including sourcing raw materials for pallet production (Riddle, 2021).

RESEARCH OBJECTIVES

The primary goal of this study was to investigate the trends in the wooden pallet and container industry in the United States from 2019 through 2021. To achieve this a paper and online survey were administered to gather data from the entire industry. With analyzing the responses this study accomplished its primary goal while focusing on the following sub-objectives:

1. Determine the trends, usage, and types of new wood used in the U.S. wooden pallet industry.
2. Determine the trends in the production, recovery, and recycling of wooden pallets in the U.S.

3. Determine the effects of Covid-19 on the wooden pallet industry.

LITERATURE REVIEW

1.1 FORESTATION

The United States has forests stretching coast to coast covering roughly 33.9% of its land. This translates to around 3.1 million kilometers squared in 2020. Forest products from the United States were roughly 4% of the nation's GDP in 2021. From 2010 to 2020, forests have steadily increased around 0.03% per year (Global Forest Resources Assessment 2020, 2020). Forests greatly differ in species depending on where they are located. Some of the forests that are located in the U.S. are as follows: boreal forests in Alaska, deciduous forests in the eastern U.S., pine plantations in the southern U.S., and coniferous forests in the western U.S. Location is what drives which species of wood is used in pallet manufacturing around the country. Lumber mills tend to sell the wood species that are the most readily available to them. In respect to lumber distribution, according to the latest pallet survey done in 2016, the Northeast produced roughly 82% hardwood pallets, whereas the western U.S. produced roughly 90% softwood pallets. The South produced around 60% softwood and 40% hardwood pallets (Gerber et al., 2018)

Western and eastern forests are also differentiated by who owns them. As of 2021, 69% of U.S. forests are privately owned, and 31% are federally owned. In eastern forests, roughly 350 million acres are privately owned, whereas approximately 50 million acres are federally owned. As for western forests, roughly 200 million acres are federally owned compared to 125 million acres privately owned (U.S. Forest Ownership and Management, 2021). Non-federally owned forests are either privately owned, or state owned. The trends on the distribution of federal and non-federal forests historically come from the pattern of land settlement of the U.S. Federal forests are managed, at the federal level, by the Forest Service (FS) and the Bureau of Land Management (BLM). These forests have stricter regulations and are maintained for livestock grazing, recreation, timber production, and wildlife. Non-federal forests are classified as private

corporate, private noncorporate, and other public. Forest regulation varies greatly depending on the location, ownership, and local government. Private corporate and noncorporate forests are maintained as seen fit by their owners, whereas other public forests are managed in accordance with local laws.

Old growth forests have been defined since the 1940s, but they underwent a significant definition change in the 1980s. They are now defined as forests that contain old, mature trees with certain, specific attributes. These attributes consist of tree size, amount of canopy layers, species composition, and the amount of large, deadfall, woody tree composition. Since the 1980s, this definition has differed in each of the nine Forest Service regions across the U.S. Currently, old growth forests are defined by their unique biophysical characteristics dependent on the region in which they are located. Some of these characteristics are species, soil productivity, climate, and disturbance history. Recently, the definition has been expanded to include the addition of another stage of forest which proceeds old growth forests called mature forests(Forest Service, 2023). Forest plantations are those which are human grown with the intention of harvesting the lumber for wood products. These forests are intended to give relief to natural forests, so they do not become depleted. These forests can be used for environmental purposes as well. This includes the protection of soil and water, carbon sequestration, and to replenish natural forests(Zhang & Stanturf, 2008).

One trend in recent years that has affected forests are wildfires which predominantly take place in the Western U.S. Wildfires are fires that were not purposely set, have grown out of control, and cause mass destruction. On average, 89% wildfires from 2017-2021 were caused by humans; however, the most forest damage was caused by lightning strikes. Lightning caused 52% of wildfire damage during those years. From 2007-2020, the yearly average damage increased 790 thousand acres for a total of 10.12 million acres burned in 2020. In 2021, 73% of damage was to federal forests while only 27% was to non-federal lands.

1.2 PALLET MARKET

Pallets are platforms that are designed to store, transport, and protect goods. In 2017, the U.S. shipped 12.5 billion tons of goods, which were worth approximately \$14.5 trillion (Census Bureau, 2020). Eighty percent of commerce is shipped on pallets which means that, in 2017, \$11.6 trillion worth of goods and materials were shipped on pallets. As of 2018, there were roughly 2 billion pallets in circulation with 1.5 billion being rebuilt and 500 million being new pallets (Handfield, 2018).

Modern Materials Handling and Peerless Research Group conducted a survey in 2022. This survey collected data from 161 pallet users such as warehouses and fulfilment centers. During that time frame, 95% of the respondents used wooden pallets. In 2022, 51% of surveyed pallet users reported an increase in the usage of wooden pallets. Out of these respondents, 72% of pallets were purchased whereas only 8% were pooled. This is a 10% decrease from the previous year (McCrea, 2022).

The pallet and container industry has been surveyed regularly since 1992. These surveys have recorded data on wood usage, taking into consideration the species used, for the production of pallets and wooden containers. The 1992 survey performed by Virginia Tech found that 4.6 billion board feet of hardwoods were used in the production of pallets and containers while 2.1 billion board feet of softwoods were used. The main hardwood species was oak whereas the main softwood species was southern pine (Cristoforo et al., 1993). In 1995, the survey conducted showed that hardwood usage increased to 4.7 billion board feet whereas the softwood fell to 1.8 billion board feet. However, the main species usage remained the same (Reddy et al., 1995). This lumber usage allowed for 411 million new pallets to be produced and 143 million pallets to be repaired/remanufactured. The 1999 survey showed that hardwood usage fell to 4.4 billion board feet while softwood usage rose to 2.1 billion. While the hardwood usage decreased on this survey, the creation of new pallets increased to 429 million and repaired pallets also increased to 223 million (Bejune et al., 2002). The 2006 survey was the first to ask about the amount of heat treatment used in the pallet industry (Bush, 2008). The respondents reported that 21.4% of pallets were heat-treated that year. Hardwood saw a huge spike to 6 billion board feet while softwood fell to 1.26 billion. This accounts for the increase in new pallet production which

reached 441 million pallets and repaired/remanufactured pallets also increased to 321 million which was a 44% increase from the previous survey.

The 2011 survey found that the production of new pallets had decreased to 416 million pallets, while repaired/remanufactured pallets increased again to 326 million. On the latest survey conducted in 2016, the production of new pallets increased 22.1% to 508 million pallets. Repaired/remanufactured pallets also increased 4.6% to 341 million. A Freedonia Report survey, conducted in 2017, speculated pallet trends for 2019 and 2024. They speculated that the wood pallet demand in 2019 would increase to a total of 1.3 billion pallets. This is projected to increase another 8.2% in 2024 to 1.515 billion total wood pallets (Freedonia, 2017).

As reported by the Madison Lumber Report, there were roughly 42.9 billion board feet of lumber harvested in the United States in 2016. From this harvested lumber, 9.5 billion board feet were hardwoods while 33.4 billion board feet were softwoods (Madison's Lumber Reporter, 2017). The pallet industry consumed roughly 9.14 billion board feet or 21.3% of the total lumber produced in 2016. Hardwoods that were used in the production of new/repaired pallets accounted for 45% of the total hardwood produced, around 4.13 billion board feet. The use of softwood in the production of pallets accounts for 15% of the total softwood harvested, around 5.01 billion board feet. Out of the hardwood consumed, 63% was high-density, 21% low density, and 16% medium-density. Of the softwood species, SPF accounted for 51%, southern pine 39%, Douglas-Fir 8%, and lastly North American softwoods at 1%.

Different regions across the U.S. produce pallets utilizing different wood species (Gerber et al., 2018). The regions are split into the Northeast, Midwest, South, and West. This is due to the local lumber mills utilizing the species that is most readily available to them. According to the latest survey in 2016, the Northeast used 11% of the total hardwood used in pallet production (Gerber et al., 2018). Comparing that to the other regions, the Midwest used 6%, the South used 17%, while the West used only 1% of hardwoods. For softwoods, the Northeast used less than 1%, the Midwest used 4% of SPF, the South used 23%, and the West used roughly 32% of the total softwood used for the production of pallets. In terms of the total production of new pallets, the Northeast produced 13%, the Midwest 15%, the South 23%, and the West produced

8% of total new pallets in the U.S. As for the total recycled/repaired pallets, the Northeast accounted for 5%, the Midwest 11%, the South 15%, and the West 10%. This brings the total pallets from the Northeast at 18%, the Midwest at 26%, the South at 38%, and the West at 18%.

There are two main styles of wood pallets that are produced and used. These main types are stringer and block class pallets (MH1 Committee, 2016). Stringer class pallets have beams “stringers” that run parallel to their length while having top and bottom deck boards. Block pallets have their top and bottom deck boards separated by blocks. The latest survey from 2016 reported that stringer class pallets accounted for 76% of the wood pallet market while block class pallets accounted for 21% of the demand (Gerber et al., 2018). Block class pallet usage had increased by roughly 15% as it had been reported as only 6% of total wood pallet usage in the 2011 survey.

When a pallet reaches the end of its lifecycle, and/or its strength/functionality is compromised, the pallet core often still has value in repair/recyclability. In 2016, it was reported that around 551 million used pallets were recovered to be repaired, disassembled for parts, chipped, or sent to landfills. It reported that 65% of recovered pallets were repaired for reuse, 18% were disassembled for parts, 11% were chipped, and less than 1% were sent to landfills. Compared to the 2011 survey, repaired pallets were down 4%, disassembled pallets were up 2%, ground pallets were up 8%, and pallets sent to the landfill remained the same (Gerber et al., 2018).

When pallets reach the end of their life span and cannot be repaired any further, they are mostly chipped for other uses rather than sent to a landfill. Once chipped, the remains are used for landscape mulch, animal bedding, fuel, and other uses (Gerber et al., 2018). According to the 2016 survey, 4.3 million tons of used pallets were chipped. The two main uses for chipped pallets are landscape mulch and fuel at 37.5% and 30%, respectively. This accounted for 1.6 and 1.29 million tons of chipped pallets respectively. Animal bedding accounted for 4.2% while “Other uses” as indicated by respondents accounted for 28.3%. Compared to the 2011 survey, the production of landscape mulch decreased by 16.8% in 2016. Animal bedding also decreased by 5.8%; fuel remained the same, while other uses increased by 22.6%. If pallets are not chipped, they may make their way to landfills. In a 2016 study about landfilled pallets, roughly 1.8% (267

tons) of wood waste in landfills was wooden pallets. This meant approximately 13 million pallets were landfilled. Comparing 2016 to the previous study done in 1998, there were 125 million fewer pallets landfilled(Z. Shiner et al., 2021).

A LCA (life cycle analysis) is a tool that gives information about the environmental impact of a product. One angle that is studied is the impact of the resources required to produce the product and all the way to disposing of the product. This is commonly referred to as “cradle to grave.” This angle considers the energy consumption and impacts of harvesting and cutting the raw materials, material transportation, heat treatment, fastener manufacturing, pallet repair, and recycling. The main contributor to the global warming impact was the manufacturing and raw material supply stages. One of the least impactful processes is the pallet repair process which only contributes 7% towards global warming. Transportation impact varies depending on the distance traveled, with every 1000 km. distance resulting in a 35% increase in the global warming impact. Just the raw material transportation results in 23% of the global warming impact (Alanya-Rosenbaum et al., 2021).

1.3 PALLET CLASSIFICATION

Pallets are placed into two main classifications which are the stringer and block class pallets as seen in Figure 1(MH1 Committee, 2016). Stringer pallets are identified by the stringers that run along the length of the pallet. Stringers are beams that can be notched, and they support the top and bottom deck boards. Stringers usually number from three to four and are labeled as inner, outer, or middle stringers based on their location.

Block pallets are identified by the wooden blocks that separate the top and bottom deck boards (MH1 Committee, 2016). These blocks range usually from six to nine depending on the pallet design. Block pallets also have stringer boards that run the length of the pallet, and the top deckboards are typically connected directly to the stringer boards.

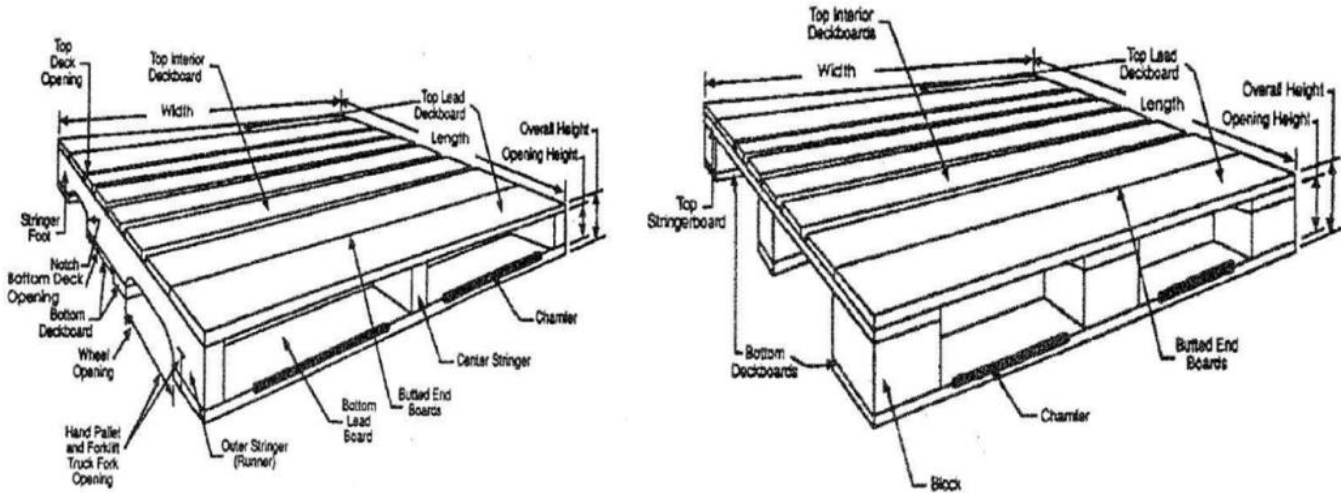


Figure 1. Stringer Class (left) Block Class (right) (ANSI, 2016)

Pallets can also be split into use categories. These categories are single-use or reusable. Single-use pallets are only intended to be used once in the supply chain and then disposed of, whereas reusable pallets are intended to be used multiple times before being repaired or discarded (MH1 Committee, 2016).

Pallets have three different entry types: two-way, partial four-way, and full four-way. Two-way pallets are stringer pallets that are not notched which only allows them to be carried from two sides of the pallet. Partial four-way pallets are notched, stringer pallets that allow forklift entry on all four sides of the pallet, but they limit pallet jack entry to only two sides of the pallets. Full four-way pallets are those that allow all pallet handling tools to enter the pallet from all four sides. These are block pallets that do not have overlapping stringer and deck boards (MH1 Committee, 2016).

Pallets can also be classified into three decking styles: single-face, double-face nonreversible, and double-face reversible. Single-face pallets only have deck boards on one side of the pallet. Double-face nonreversible pallets have deck boards on the top and the bottom; however, the deck board placements differ on each side, so there is a designated top and bottom

of the pallet. Double-face reversible pallets have deck boards on the top and bottom that are arranged the same, so either side can be used as the top or bottom.

Top and bottom deck board configurations are used to help classify pallets as well. Top deck boards are classified by the number, position, and whether a panel is used. Bottom deck boards have more classifications. Unidirectional bottom deck boards are oriented only in the direction of the pallet's length or the pallet's width. Perimeter bottom deck boards are those that run the length and the width of the pallet, with butted end boards. Cruciform bottom deck boards are like perimeter bottom deck boards but include connector boards. Similarly, the placement of stringers and blocks can also change the classification of the pallet. If the placement of the outer stringers or blocks are moved inward so they are not flush along the length of the pallet, it is classified as a double-winged pallet (MH1 Committee, 2016).

1.4 PALLET SIZES

The dimensions of a pallet are classified by the length, width, and height. The length of a stringer class pallet is determined parallel to the stringers. For block class pallets, the length is parallel to the stringer boards. The length of pallets that do not fall into these cases is determined by the longest side of the pallet. Then the width of the pallet is always perpendicular to the length. The height of the pallet is determined by measuring the distance between the outside of the top and bottom deck boards (MH1 Committee, 2016). The tolerance in measuring pallets is $\pm \frac{1}{4}$ in.

Pallets come in many sizes, with there being roughly 200 different sizes commonly used in the U.S. as of 2016. The most popular pallet size in use is the 48" x 40" (length x width) which makes up around 27% of the total wooden pallet market. Other popular sizes are 40" x 48", 42" x 42", 48" x 48", 48" x 42", and 48" x 45". Combined these pallets make up roughly 20.2% of the total market. In 2016, 39% of pallets used were classified under "other sizes" (N. S. Gerber et al., 2018). Other countries use the metric system for their pallet measurement and commonly measure them in millimeters. The most common pallets in Asia are 1100 mm x 1100

mm, and in Europe, they are 800 mm x 1200 mm (Pallets, Slip Sheets, and Other Bases for Unit Loads, 2016).

1.5 SPECIES DISTRIBUTION

Wooden pallets are made from many different species depending on where they are produced. Pallets tend to be made from the species that is the most easily accessible and usually native to the location where the pallet is being produced. Tree species are scattered across the U.S. and are dependent on climate and geographical location. The Northeast region of the U.S. has large, deciduous forests. These forests are comprised of hardwoods such as Sugar Maple, American Beech, Aspen, Oak, and Hickory which make up roughly 71% of the total forest land in this region (Juzwik et al., 2006). The forests in the Southern U.S. are more diverse though are still comprised of roughly 55% hardwoods. Southern hardwoods are composed mainly of Oak, Hickory, and Gum. Although hardwoods are predominant, softwoods make up roughly 34% of the Southern forests. Southern pine accounts for most of the southern softwoods, and it both grows naturally and on plantations. The other 11% of Southern forests are a combination of both (Finco & Wilson, 2022). Looking at the Midwest U.S., most of its forests are located in the northern parts of this region. These forests are comprised of mostly hardwoods such as Birch, Maple, Oak, and Poplar. The softwood composition is Hemlock, Cedar, and Pine. The last notable region of forests is the American West. The West is mainly dominated by softwoods with much of these coniferous forests being composed of Spruce, Pine, and Fir (Finco & Wilson, 2022).

1.6 MARKET SEGMENTS FOR LUMBER

Every tree, even in the same species, will grow differently. Differences will be in the number of knots, reaction wood, and other unique properties. When lumber is harvested and sawn, it is split into different grades depending on the clarity and any imperfections in the wood. For softwoods, the grades are split into four, with one being the highest quality. The first grade is known for its reduced imperfections, and it only allows some small, tight knots. This grade of lumber is used for high-quality products like furniture due to it being mostly defect-free and able to be painted easily making it the most visually appealing for high-quality products. The second grade is known as “standard grade,” and it has slightly more and/or larger knots. It is still able to

be painted semi-easily allowing it to be used in some higher quality applications. The third grade is known as “utility” and contains some splits and knotholes. This grade is best utilized in lower-grade and structural applications where its imperfections will not be seen. The fourth grade is known as “economy” grade, and it has the most imperfections. This lumber is used by manufacturers and remanufacturers for industrial products. The third and fourth grades are the ones primarily used by the pallet and crate industry (Conner Industries, n.d.).

Similar to softwoods, hardwoods go through grading after harvesting and processing, to determine the quality of lumber that was produced. Hardwoods tend to be used more for high-quality products like furniture due to their visually appealing nature. The highest-grade that hardwood lumber can get is called First and Seconds (FAS) which is used typically for furniture and other high-quality products that should not have imperfections showing. The next two categories are Select Grade and FAS One Face. Select grade is also premium lumber, though slightly lower quality than FAS. FAS One Face can be used when only one side of the lumber will be showing (*Wood Handbook Wood as an Engineering Material*, n.d.). These two lumber grades are also used for furniture, decorative pieces, and other high-value products. The middle grades are known as No. 1 Common, No. 2A Common, and No. 2B Common. No. 1 is also called shop grade and is still fairly good quality, whereas No. 2A and No. 2B are used for utility products. The final two grades are 3A and 3B common which are sold and used by manufacturers. This lumber is used by the wooden pallet and crating industry (Zeeland Lumber & Supply, n.d.).

1.7 FOREST CERTIFICATION

Forest certification began in the early 1990s in order to try to protect and preserve forests from deforestation and degradation. Certifications were established to help inform consumers whether the lumber they are purchasing falls within certain standards (Chizmar et al., n.d.). These aim to preserve wildlife, plant life, soil health, clean water, and many other aspects of the forests. They also aim to help ensure that forests remain healthy, and that deforestation does not devastate them. These certifications are conducted by third-party organizations who evaluate the management of each forest by a set of standards. Benefits that come from these certifications include improved forest health, a price premium in certain markets, increased access to markets,

and less waste(Chizmar et al., 2020). By certifying these forests, the lumber can be sold at a premium price due to people knowing it was harvested in an environmentally friendly manner (Chizmar et al., n.d.). In the U.S., there are three main forest certifications: The American Tree Farm System (ATFS); the Forest Stewardship Council (FSC); and the Sustainable Forestry Initiative (SFI). Roughly 20% of forests in the U.S. are certified; 36.4 million acres are certified by FSC (*Facts & Figures*, n.d.); 63 million acres are certified by SFI; and 24 million acres are certified by ATFS (International Paper, n.d.).

1.8 WOOD SPECIES

Wood is a natural product which is complex and full of inconsistencies. Its structure can be considered orthotropic; the properties of wood are different in each of the three main directions (longitudinal, radial, and tangential). The longitudinal direction is always parallel to a tree's growth. The tangential direction is the one that makes a tangential cut on the cylindrical portion of the tree. Finally, the radial direction is a cut that goes in the direction of the center of the tree. Compression and tension properties are the highest and dimension changes during drying are the lowest in the longitudinal direction. This is due to the cell structure acting like columns in this direction (Wood Handbook Wood as an Engineering Material, 2010).

There are two, main wood species categories, hardwoods, and softwoods. These two differ anatomically and physically. Hardwoods are typically deciduous which means they lose their leaves in the colder months; whereas softwoods are ever green which means they keep their foliage all year round. Anatomically, softwoods tend to be more uniform in structure. They are comprised of mostly long vertical cells, called longitudinal tracheid, which act like columns and give support to the tree. They also have radial parenchyma which act as storage for the tree. Resinous softwoods contain resin canals which allow for the movement of resin throughout the tree. The pattern and structure of these cells are uniform throughout the tree. In contrast, hardwoods consist of the same cells, but with the addition of fibers and vessels, and hardwoods contain more hemicellulose. This leads to hardwoods having a more complex structure and being typically denser(Wood Handbook Wood as an Engineering Material, 2010).

One of the most important of wood's characteristics, which affects the strength properties of all wood species, is specific gravity. Specific gravity is how heavy a material is compared to water. The higher the specific gravity the stronger the material will be. For comparison, in wood species that are largely used for pallet construction, mixed southern pine (softwood) has a specific gravity of roughly 0.51; whereas, mixed oak (hardwood) is around 0.68 (Wood Handbook Wood as an Engineering Material, 2010). This indicates that the hardwood material is stronger.

Another property that influences performance is the moisture content. The lower the moisture content in the wood, the higher its performance will be. There are two forms of water that are within and between wood cells. These types are free and bound water. Free water is that which is within the cell lumina (the free space of the cell) or is between cells. Bound water is that which is trapped within the cell wall bound by intermolecular forces. The point at which water influences the properties of lumber is called the fiber saturation point. This is the point at which the bound water is saturated, but there is no free water in the lumina, which gives the lumber around a 19% moisture content. Anything above 19% is called green lumber. Adding additional water increases the lumber's weight. Under a 19% moisture content is where properties of the lumber begin to change. The lower the moisture content is under that fiber saturation point; the stronger lumber becomes. Also, dimensions begin to change as the wood shrinks. Removing the moisture from lumber is easy above the fiber saturation point (19%) due to the fact that free water is able to be removed easily. Removing the bound water (getting a moisture content of less than 19%) becomes more difficult due to the need of kiln drying. This costs more due to the energy needed by the ovens to heat the lumber for long enough to remove bound water (Wood Handbook Wood as an Engineering Material, 2010).

Lumber can have imperfections like knots and reaction wood. Knots are branches embedded into the trunk of the tree. Knots are weak points in lumber making it unable to handle loads that clear lumber could handle. Reaction wood is similar because the strength properties of this type of lumber are also decreased. Reaction wood forms when the tree must grow in an unnatural way. For example, if it's growing at an angle on the side of a mountain, a tree will

begin to curve into a vertical position (Wood Handbook Wood as an Engineering Material, 2010).

1.9 PALLET MANAGEMENT

Pallets are created with many purposes and use is a main consideration when they are produced. There are two main types: single-use and multi-trip pallets. Single-use pallets are those that are intended to be used once and not returned to the initial user (One-Way Wooden Pallets - Can They Be Used More than Once?, 2021). These pallets can be used more than once, but they are only used once by the initial user. Once the pallet is used, it can either be reused by the destination company, purchased by a recycler, or ground down for other woody products. These pallets can be dismantled or repaired and sold again. In this case, the initial user does not bare any responsibility for the pallet (One-Way Wooden Pallets - Can They Be Used More than Once?, 2021). Multi use pallets are those that, once sent to their destination, are reused, and returned to the initial user. The burden of transportation and repair falls completely on the user of the pallet. These pallets are intended to stay in a closed loop within the company, so more pallets do not have to be purchased.

Rather than purchasing pallets, pooling is another viable method in gaining pallet stock. Pooling refers to renting pallets from a pooling company; the two largest pooling companies are Chep and PECO. These companies rent pallets to users, then retrieve them after use, and rent them out again to another user (Chep, 2022). The main advantage of using these companies is that they do all the tedious work. Once the pallet is used, the user does not have to retrieve or repair them. All liability falls on the pooling company. Once the pallets are retrieved by the pooler, they will either be rented back out to different users or repaired back to their original specification and then rented out again. Pallet pooling also removes any hidden costs. Costs such as transporting and storage are mitigated using this method (Carroll, 2022). The pallets are typically oversized meaning they can carry most products, and they are dropped off/picked up by the pooling company. Another advantage is that once the pallets are damaged, they are repaired and reused, giving them more sustainability. This allows them to have a long lifespan and to stay in the field as long as possible. According to the 2022 Pallet Report, the use of pooled pallets has decreased since 2018(McCrea, 2022). This type of system is called a “closed pallet

pool” because one company rents out, maintains, and recovers the pallets. They are the property of that company. Another similar pooling method is an open pool system. This system works by having specific pallet specifications that can only be made and repaired by specific, licensed pallet manufacturers/repairers. Once a user gets said pallet, they can return it for money back or a repaired pallet. The main difference between closed and open pallet pools is that in closed pallet pools, the pallet company is responsible for collecting the pallets after use and repairing them. In open pallet pools, the end user is responsible for returning the pallets. Also, other pallet companies can produce and repair the specific pallets, if permitted. One of the largest uses of the open pallet pool system is in Europe with EPAL (Thompson, 2022)

Other than pooling, pallet exchange is also another option for maintaining a steady number of pallets. This method deals with two parties: the pallet shippers and the pallet receivers. Once the shippers bring the loaded pallets to their destination, the receivers return an equal number of pallets. One challenge is that there has to be exceptional coordination between these two parties (iGPS, 2020), so there is not a buildup or diminishment of pallets on either side. The pallets also have to be/stay in good condition, so they can be reused.

1.10 REPAIRING AND RECYCLING/LANDFILLING OF WOODEN PALLETS

Once a new pallet is used for its intended purpose, it is often picked up by a pallet recycler. If possible, it is repaired and reintroduced to the supply chain. In 2016, there were roughly 341 million repaired pallets produced, which made up around 40% of pallet production that year (Gerber et al., 2018). Pallets received by pallet repair companies are classified into the following categories: pallet that do not require repair, damaged pallets that can be repaired, damaged pallets that will be dismantled for components, and odd size pallets that will be converted into byproducts such as mulch and animal bedding.

Pallets are considered damaged when the damage to individual components or connections exceeds the maximum amount of allowable damage as specified by the Uniform Standard for Wooden Pallets (NWPCA, 2014). Damaged pallets are repaired by either reconnecting loose components, replacing broken deckboards, or repairing broken stringers. Stringers can be repaired using companion stringers placed next to the broken stringer and secured to the deckboards with pallet fasteners. Companion stringers can be full companion

stringers, half stringers, c-blocks or a stringer plug. Metal connector plates can also be used over the break to bridge the two sides of the broken stringer (NWPCA, 2014).

Once a pallet goes through the repair process, it will be given a specific classification which explains what type of repairs were done to it. These classifications go from A (1) to C (3) which represent least to most repaired. The class A (1) pallet indicates that deck boards may have been replaced, and metal plates may have been used to repair stringers, but no companion stringer parts were used. Class B (2) indicates that deck boards may have been replaced and up to two companion stringers may have been inserted. Class C (3) simply means that the repairs done do not meet class 1 or 2 (NWPCA, 2014).

If a pallet cannot be repaired due to the damage being too severe, it can be dismantled, and its parts used in the repair process for other pallets or to build remanufactured pallets. If a newly designed pallet is made from parts of dismantled pallets, it is considered a remanufactured pallet. Remanufactured pallets are often made with new stringers. When a remanufactured pallet is constructed, new fasteners are positioned to avoid the existing fastener holes (NWPCA, 2014)

Instead of being repaired, some pallets are ground down at the end of their life cycle. The wood in pallets is clean wood so the ground wood chips can be used for various products such as landscape mulch, biofuel, and animal bedding (ANSI, 2016). In 2016, there were roughly 4.3 million tons of ground pallets produced. From this total, 37.5% (1.6 million tons) was used for landscape mulch. Roughly 30% (1.3 million tons) was used as fuel or biofuel. Only 4.2% (180 thousand tons) was used for animal bedding (Gerber et al., 2018)

Some of the pallets cannot be collected at the end of a trip/use because the distance from the nearest pallet recycler is too far to be economical. These pallets often end up going to landfills. Some of these pallets are damaged beyond repair and could not be used any further. Other pallets that are landfilled could still be used and many are recovered. In 2016, there were roughly 12 million pallets landfilled which stayed landfilled. This was down from the 40 million pallets landfilled in 1998 (Shiner et al., 2018). In 2016, there was 15.8 million pallets recovered versus roughly 22 million pallets recovered in 1998. This shows that more pallets recovered for secondary uses than landfilled in 2016; whereas, in 1998 more pallets were landfilled than recovered (Shiner et al., 2018).

1.11 ECONOMIC FACTORS

The wooden pallet industry is closely connected to the lumber industry due to them sharing the same raw material. Looking at the recession and housing crisis of 2008, in the Western U.S., there was a major decline in lumber production. From 2006 to 2009, forest products output fell 31% from \$49 billion to \$34 billion (Keegan et al., 2012). A similar trend occurred in the Southern U.S. where lumber production also decreased greatly. From 2005 to 2009, Southern Pine production decreased from 19 to 11.8 billion board feet: hardwood production took an even harder hit decreasing from 12.6 to 5.7 billion board feet. Nationwide from 2005 to 2009, housing production fell roughly 75% which created less demand for lumber and lumber products (Hodges et al., n.d.). This large decline in lumber production directly impacted the wooden pallet industry. During the recession, there was less demand for products leading to a lower demand for pallets to ship those products.

With the emergence of the pandemic in 2020, the lumber industry was greatly affected. Due to the diversity of the lumber industry, some aspects were more affected than others. Some sectors saw shortages, price fluctuations, and closures while other sectors prospered. The pandemic caused lumber prices, supply, and demand to fluctuate more than in previous years. The Bureau of Labor Statistics (BLS) reported that in the year prior to the pandemic, from March 2019 to April 2020, lumber prices changed by around 1%. However, in May of 2020, prices decreased 2.6%, and by September, lumber usage was down 6.7%. Between October 2020 and March 2021, prices began to increase, and they became 3% higher than before the pandemic. This became a trend of increasing prices through May of 2021; they rose to 7% higher than prices in May 2019. In some regions of the U.S., prices increased to over 15% higher than pre-pandemic. In conjunction with this, the supply of lumber shrunk during this time as well. House remodeling fell 22.3% in March of 2020. This caused lumber mills to curb lumber production in response to the shrinking demand. In the ensuing months, a steady rise in construction caused a lumber shortage due to the idled lumber mills. By March of 2021, there was more home construction than any period since 2006. Even once lumber mills began ramping up production, there was much more demand than available lumber. From the 2nd quarter of 2020 to the 2nd quarter of 2021, prices more than doubled for Southern Yellow pine going from \$442/MBF to

\$1041/MBF. Prices did start to decline and fell to \$689/MBF in July of 2021 (Anne A. Riddle, 2021).

In 2016, as reported by the NWPCA, wooden pallets and containers were worth \$10.7 billion dollars. In total, the wooden packaging industry was worth \$30.7 billion dollars. This industry has approximately 67,000 employees and affects approximately 105,000 employees of companies who work and rely heavily on the wooden pallet industry (NWPCA, 2016).

MATERIALS AND METHODS

1.12 SURVEY

To try and gain the most accurate representation of the pallet industry, a database was purchased using the NAICS 321920 code. This NAICS code represents the wooden pallet and container industry and contained 2,603 companies from across the U.S. Another database was provided by the National Wooden Pallet and Container Association (NWPCA) and contained the contact information for 398 companies. After the removal of duplicates, the databases were combined. Then an initial screening was conducted to see if these companies were still in business and if they had an online presence. Once these initial cleaning processes were completed, a final database was produced.

The survey was designed to collect information about raw production numbers, pallet classes, sizes, new versus repaired production, and other non-confidential questions. Questions were similar to the ones used in historical pallet market surveys in order to be able to analyze long-term trends. However, some of the questions were modified to improve clarity and increase response rates. The questions relating to regional distributions were removed. New questions were added relating to the COVID-19 pandemic. Most questions were focused on pallet market characteristics during 2021, but some of the questions also collected information for 2019 and 2020. Both surveys had initial questions asking people to skip the survey if they did not produce any wooden pallets, or if they only brokered wooden pallets, in order to help minimize any bias.

The online version of the survey was designed with mostly the same questions as the physical version. The online version could not be restarted once begun, so a link to a pdf was

also be provided. This was so participants could download the survey and see all the questions prior to beginning the online version. This allowed them to take their time and/or fill out the survey in multiple sessions before submitting it via email. The online version of the survey also asked companies who were not assigned a code to fill out their company name and location as they were not in the original database. To help with bias, additional questions were asked that directed respondents to appropriate sections. For example, if respondents selected “No” to the question of “Does your company produce new wood pallets?” They would be directed to skip the new pallet section and go to the repaired pallet section. The online version of the survey also had validation on specific questions. So, if a certain question requires responses that add up to 100%, respondents would not be able to move on until their answers add up to the proper amount.

To increase the response rate, the survey was sent out in both electronic and paper formats. The first set of physical surveys was sent in January 2023 followed by a reminder postcard in February 2023. After the postcard, a second round of paper surveys was sent out to just non-responders in June 2023. The online version of the survey was sent to those companies whose emails were included in the database. The online survey was also promoted by the Pallet Enterprise Magazine and the National Wooden Pallet and Container Association. To make sure that the survey was not filled out twice by the same company, each company was assigned a specific code that they had to enter to access the survey.

Once physical copies were returned, they were entered into the online survey site so all of the data could be compiled electronically. They were entered with a double zero in front of the ID code to identify it as a physical copy. If any bounce backs were received, they were removed from the master database as they were technically not surveyed since the survey never reached them. Companies were also be removed if they responded that they were not a pallet or crate-producing company, or if they responded that they were no longer in business.

1.13 DATA CLEANING

Once responses were submitted, they were examined for any inconsistencies or in case any of the questions were filled out wrong. If data looked questionable, the respondent was contacted to clarify the response. Simple calculations were used to determine if the responses were realistic. This was done for the total board feet used and pallets produced. If the board foot per pallet listed was anywhere from 5 bd ft to 30 bd ft, it was deemed reasonable. Calculations were also used for the number of cores received per year and the number of repaired pallets, as well. Responses were also removed when the answers did not add up to 100%, in order to minimize bias.

1.14 ANALYSIS

Percent questions were analyzed by comparing them to previously recorded years to determine what has changed in the industry. Some questions were treated with a scale-up factor to obtain an industry total. To calculate the total pallet and wood usage, a ratio was created based on the employee numbers reported by the respondent of the particular question and the total number of employees in the industry at the time. This ratio was then multiplied by the response given to specific questions to estimate the total numbers produced by the industry. This numerical data was then compared back to previous surveys to see the % change. More advanced statistics such as a simple linear regression was used to compare pallet production in the U.S. to its GDP for the corresponding year. Advanced statistics such as the Wilcoxon/Kruskal Wallis tests were used to compare small, medium, and large companies that reported numerical values which could be statistically analyzed. Some of these comparisons were cores received, new, and repaired / remanufactured pallet production.

1.15 LATE RESPONDER BIAS:

When conducting data collection in the form of a survey, there are certain aspects that should be examined to determine if any bias is present. One form of bias that should be accounted for is nonresponse bias. This occurs when participants who were given the survey drop out early / do not complete the survey at all / or are significantly and systematically different than others who have filled out the data (Prince, 2012). To simulate this bias, an

investigation into late responses was used. Participants who filled out the survey late (after the second mailing) were used as non-responses for comparing their data to those who filled it out before the second round of surveys were sent. The early respondents were those who filled out the survey before June 2023. The late responders were those who filled the survey out after this time. These respondents were compared by their new, repaired, and remanufactured pallet production, as well as the number of pallet cores received.

RESULTS

1.16 RESPONDENTS

The purchased database initially contained 2,625 companies from across the U.S. After sending out the first round of surveys, 305 companies were removed from the database because they either had gone out of business or had been sold to a larger company. Out of the remaining 2,320 companies, 98 responses were received giving a total response rate of 4.2%. One factor that could lead to a low response rate is survey fatigue. Though this survey is not sent out every year, it has been conducted since 1995. The more a survey is conducted, the less likely people are to fill it out due to survey fatigue (Porter et al., 2004). The increased levels of consolidation might have also affected the response rate. Large, publicly-traded companies are less likely to fill out the survey to avoid issues of insider trading.

The response rate throughout the survey varied per question as seen in Figure 2. Questions 1-3 were filled out completely as they were simple questions such as confirming that they were a pallet manufacturer, giving the number of facilities, and how much of their sales dollars came from what percent of their business. The response rate decreased for questions 4 through 10. These questions focused on wood species usage which can be difficult for a smaller company to estimate. The response rate increased on questions 11 through 15 that focused on trends in new pallet production. Questions 16 through 20 focused on recycled pallet production. Not all companies have recycling operations; thus, these questions had a lower response rate. Question 20 had the lowest response rate. This question asked about the uses of ground/chipped pallets – the results show that not many respondents had these operations available to them. Response rate again increased for questions 21 through 24. These questions inquired about trends that may have occurred during the pandemic.

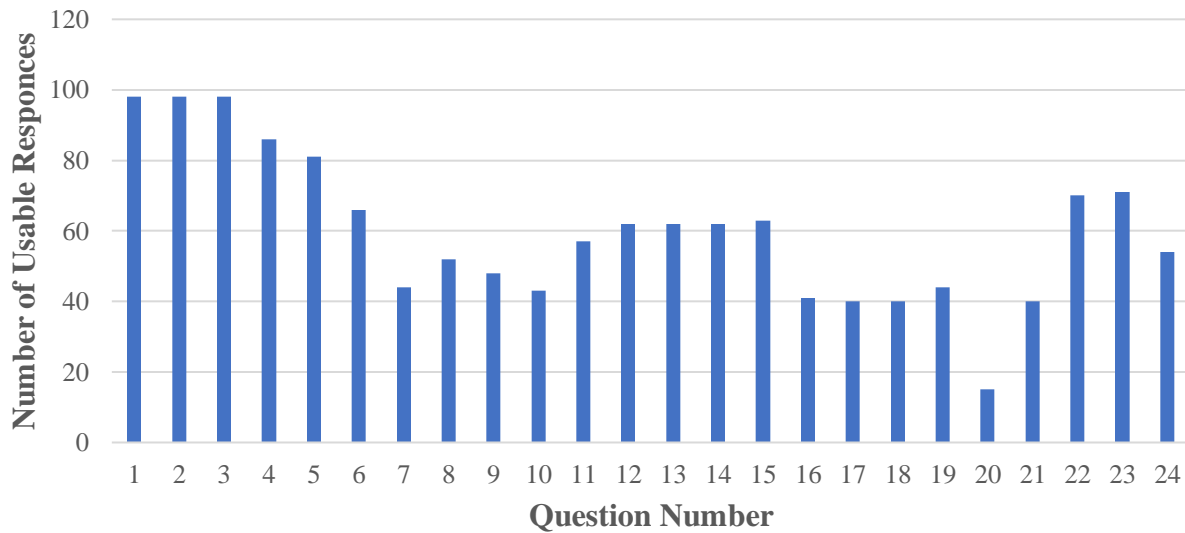


Figure 2. Bar chart of the cleaned and used responses per question asked. Responses that were deemed to be impractical were removed during the data cleaning process.

According to the 98 responses, the collected data accounted for 212 facilities across the U.S. Respondents were asked about what percentage of their sales dollars in 2021 came from five different categories: new pallet production (55.44%), repaired and remanufactured pallets (26.99%), brokering or wholesaling pallets (3.69%), crate manufacturing (3.82%), and other (10.07%). Compared to historical data, as seen on Table 1, the share of new pallet manufacturing as a percent of sales dollars decreased by 3.46 percentage points while repaired and remanufactured pallets slightly increased by 1.89 percentage points (since 2011). The largest change seen was in brokering pallets, which increased by 11.7 percentage points from 2011 to 2016, then decreased by 8.01 percentage points from 2016 to 2021. The share of crate manufacturing also decreased by 2.88 percentage points in 2021, and the share of the other category increased by 4.37 percentage points.

Table 1. Products Accounting for the Estimated Largest Sales Dollars for Companies in the Wooden Pallet and Container Industry Between 2011-2021.

Year	New Pallets (%)	Recycling, Repair, Remanufacturing Wood Pallets (%)	Brokering or Wholesaling Pallets (%)	Crate Manufacturing (%)	Other (%)
2011	58.9	25.1	1.3	0	14.7
2016	51.9	24.0	11.7	6.7	5.7
2021	55.4	26.9	3.7	3.8	10.2

*Data from surveys conducted in 2011, 2016, 2021.

The number of facilities that pallet companies operate have been increasing since 2016. In 2016, most of the respondents of the survey (76%) only had a single facility operating while a small percent of the respondents had two (14%) or three or more (9%) facilities. By 2021, the share of single facility operations stayed unchanged at 75% while the percent of companies with three or more facilities increased to 15%, causing a corresponding decline in the percentage (10%) of companies with only two facilities. This showed that companies were beginning to grow by purchasing more facilities to expand their operations. The number of facilities operated by the respondents decreased from 248 in 2016 to 186 in 2019. This could be due to the different respondents who filled out the 2019 survey. However, it appears that, from 2019 to 2021, the responding companies acquired more facilities; thus, the number of facilities operated by the respondents increased by 25 going to 211 total in 2021. This further indicates the rapid consolidation that is being experienced by the industry.

In 2019, respondents indicated that they employed 4,437 people. This represented 8% of the total wooden pallet and container industry which employed a total of 53,380 people in 2019 (Census Bureau, 2021). The number of employees slightly decreased to 4,346 in 2020, but this was followed by a rapid increase to 4,604 in 2021. The decrease in employee numbers in 2020 could be related to the COVID-19 pandemic. However, many companies during this time frame indicated that, not only did they not lay off employees, but for many of the employees who did leave, replacements could not be found. The trend of increasing employees in 2021 could be directly related to rebounding after the pandemic and the increase in demand of products from

the spike in e-commerce during the pandemic (Young, n.d.). As more goods were being shipped, the need for pallets also increased.

1.17 PALLET PRODUCTION

The production numbers reported by the respondents for new and recycled pallets are presented in

Table 2. It was estimated that the wooden pallet industry produced an estimated 748 million pallets in 2019. This was a 45% increase compared to the last survey that was conducted in 2016. The number of new pallets further increased to 880 million, and 919 million pallets in 2020 and 2021, respectively. Repaired/Remanufactured pallet production was estimated to be around 223 million in 2019 which represented a 31.5% decrease in recycled pallets since 2016. The recycled pallet production recovered slightly to 280 million pallets by 2021, but it did not get close to the peak of 326 million observed in 2016. When the total number of new pallets produced per responding companies was investigated (

Figure 3 and

Figure 4), it was observed that in 2021 a higher number of large facilities filled out the survey compared to 2016.

When the number of new pallets produced, per employee, per 8-hour shift, was calculated (Figure 5 and 6), it was observed that greater number of responding companies had much higher production efficiency than in 2016. This shift to a higher production output per employee can be attributed to many factors, mainly stemming from automation. Due to the pandemic and the lack of labor force that came back to work, companies had to acquire more automation to compensate

for the rise in demand for pallets that also came during this period (Pérez, 2023). We also saw much consolidation; larger companies with more resources and higher demand purchased smaller companies leading to higher output of pallets per employee.

Table 2. Estimated Annual Production Number for New and Repaired/ Remanufactured Pallets Between 2016 and 2021.

Year	New Pallets (Millions)	Repaired/Remanufactured Pallets (Millions)
2016	513	326
2019	748	223
2020	880	237
2021	919	280

*Data from surveys conducted in 2016 and 2021.

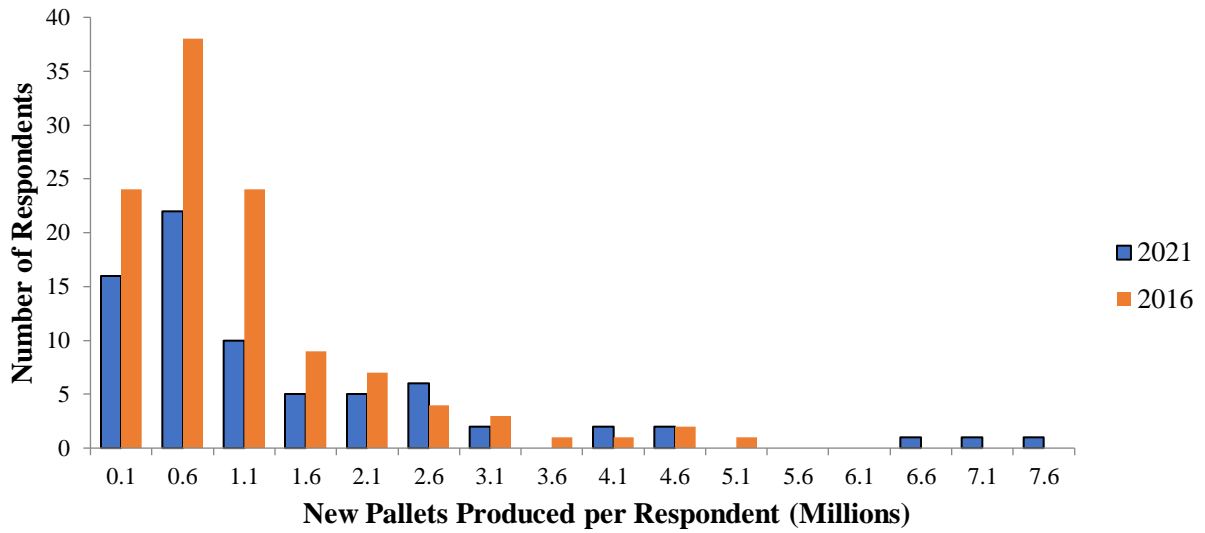


Figure 3. Total Estimated New Pallet Production per Respondent in 2006 and 2021.

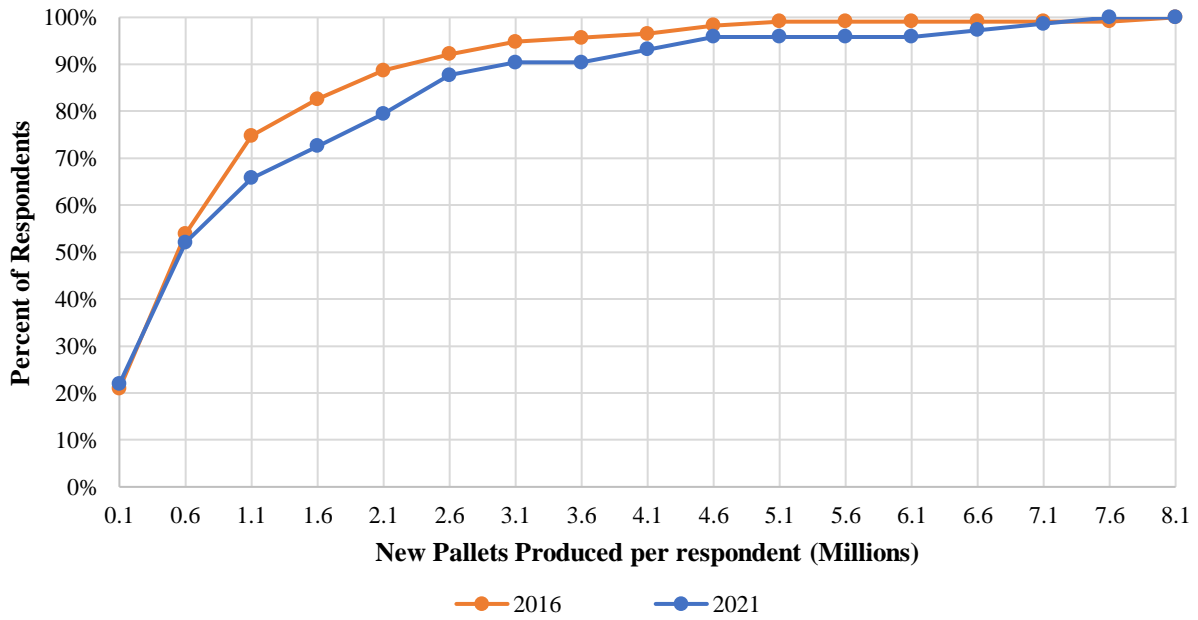


Figure 4. Cumulative Distribution Plot of Total New Pallet Production per Respondent in 2016 and 2021.

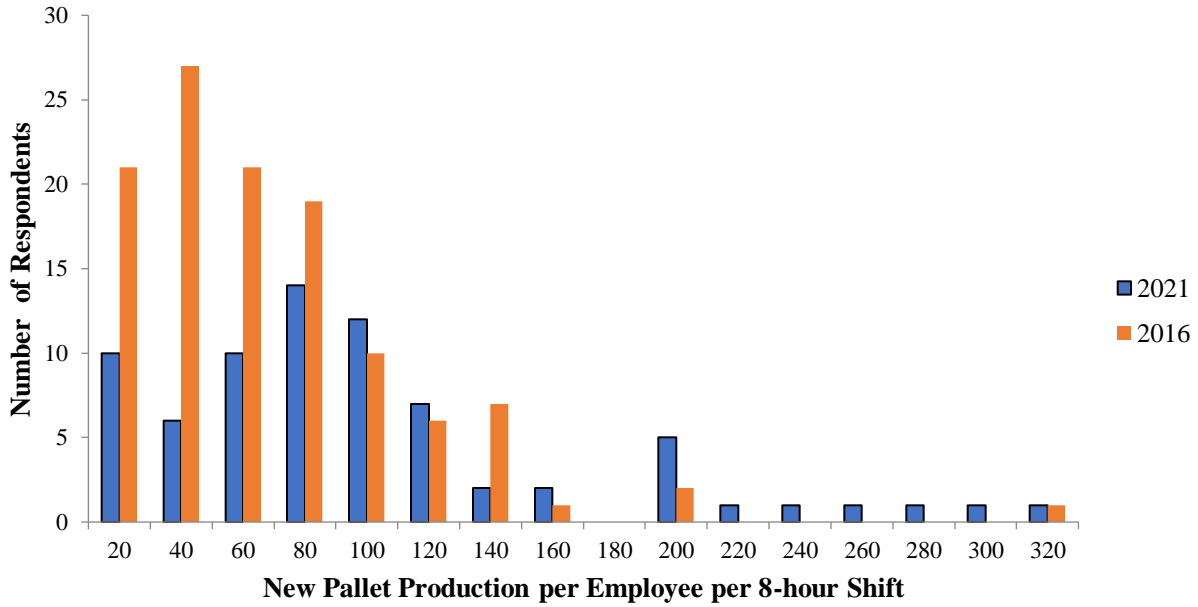


Figure 5. Total new Pallet Production per Employee per 8-Hour Shift in 2016 and 2021.

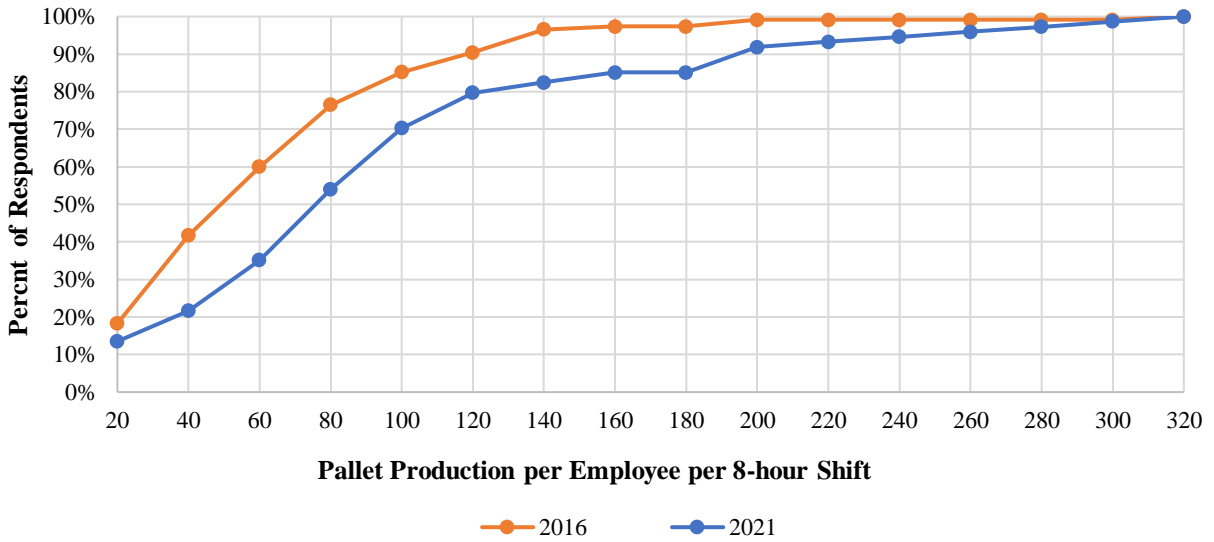


Figure 6. Cumulative Distribution Plot of New Pallet Production per Employee per 8-Hour Shift in 2016 and 2021.

1.18 NEW PALLET TRENDS

The changes in the market share of new pallet sizes are presented in Table 3. In 2021, 48” x 40” pallets were still the predominant pallet size produced (29%) showing a 6 percentage point decrease since 2016. This could be due to the large increase in ecommerce sales in comparison to that of typical retailers. During the pandemic, ecommerce sales grew nearly 30% meaning fewer 48” x 40” pallets were needed (Young, 2022). This is because products did not have to be repalletized and shipped to retail stores. Within the 48” x 40” pallet size, companies were asked the number of variations they produced. A variation is any difference in the design such as deck board placement, number of deck boards/stringers, notch placement and size, and so forth. A majority (65%) of companies responded that they produced less than 10 variations. And, 31% of respondents reported they produced 10-50 variations, 3% produced 50-100 variations, and 2% produced 100-500 variations. The market share of the 40”x 48” and 48” x 48” pallet sizes increased since 2016. The market share of the 40” x 48” pallet size, which is typically used by the Department of Defense (DoD), doubled from 4% to 8% compared to 2016. This trend in an increasing demand for military pallets was due to the increased need to ship supplies around the world during the pandemic. During health emergencies, the logistics network is often used to distribute critical supplies to both the military and the public (Lopez, 2020). These supplies included vaccinations, tests, and other related supplies that were in high demand. Also, the military has strict specifications for pallets; thus, when the ordered pallets deviate from the required specifications, the pallets must be reproduced, leading to even more orders (Personal Communication with the Department of Logistics Agency). Other pallet sizes remained relatively the stable at 40% showing that custom pallet sizes are still the most-used in the wooden pallet industry.

Table 3. Percent of New Wood Pallet Sizes Produced Between 2006 and 2021.

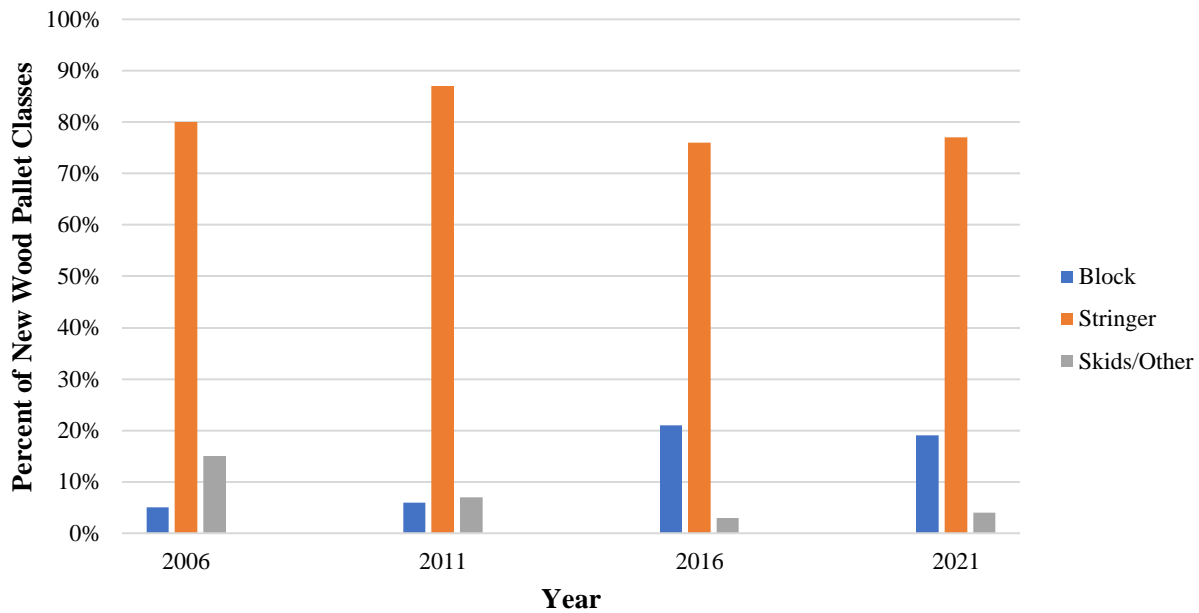
	New Pallet Dimensions									
Year	48” x 40” (%)	40” x 48” (%)	48” x 48” (%)	48” x 45” (%)	48” x 42” (%)	48” x 36” (%)	42” x 42” (%)	37” x 37” (%)	800 x 1200 (%)	Other (%)

2006	27	5	4	2	4	2	5	2	0	50%
2011	24	3	4	0	0	2	5	2	1	60%
2016	35	4	7	5	3	1	5	<1	1	39%
2021	29	8	7	3	4	2	6	<1	<1	40%

*Data from surveys conducted in 2006, 2011,2016 and 2021.

Stringer pallets remained the predominant pallet produced at 77% (*Data from surveys conducted in 2006, 2011, 2016 and 2021).

Figure 7). This is only a 1 percentage point increase from the previous survey in 2016. Block pallets were reported at 19% in 2021 which was a 2 percentage points decrease from 2016, while skids/other increased from 1% to 4%. The increased production of block pallets stayed consistent with the spike in 2016 due to the rise of pallet pooling (LeBlanc, 2021). Skids/other remain the lowest type of pallet used since 2016. By definition, a skid is a pallet that lacks bottom deck boards or deck(ANSI, 2016). Skids not having bottom deck boards lead them to be less structurally sound, stable, and durable than traditional pallets. Skids also have limited capacity for racking situations due to the lack of bottom deck boards. These limitations lead them to be typically used less than the traditional wooden pallet.

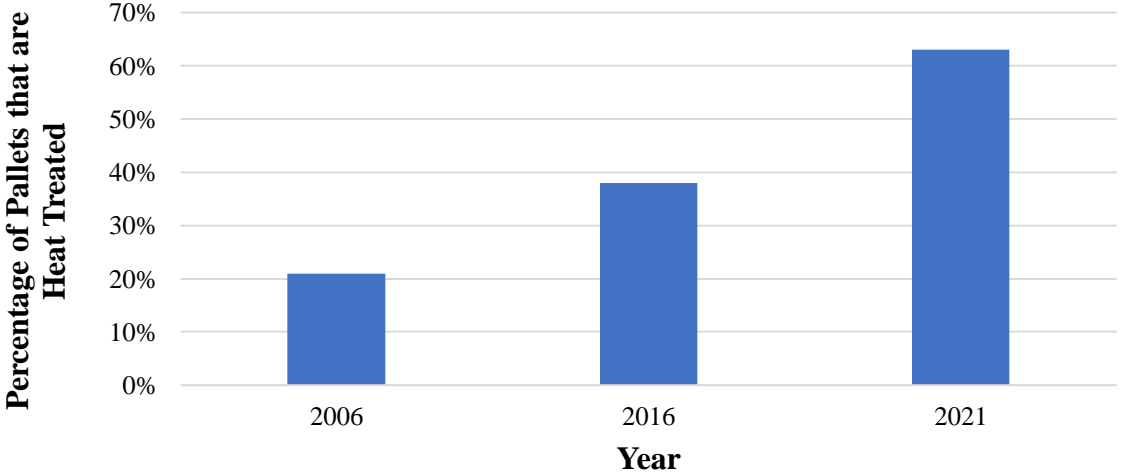


*Data from surveys conducted in 2006, 2011, 2016 and 2021.

Figure 7. Percent of New Wood Pallet Classes Between 2006 and 2021.

Respondents indicated that 63% of new wood pallets were heat treated (**Error! Not a valid bookmark self-reference.**). This is a 25 percentage points increase from 2016 and 42% from 2006. Heat treatment is used to kill insects and larva in pallets. It is one of the most frequently used methods recommended by the ISPM 15 standard to reduce the amount of invasive species being transported during international trade. The observed increase in heat treated pallets is in line with the increase in exports from the U.S. In 2021, the U.S. exported approximately 2.53 trillion dollars' worth of goods which was a 74% increase over the 1.45-billion-dollar U.S. export in 2016(WITS, 2021).This showed that the need for heat treatment increased as the upward trend of exporting globally increased. Another driving factor was the growth in the food industry since 2016. Due to contamination potential and the harm that can cause the food industry, pallets are required to be as hygienic as possible to reduce the risk of any possible contamination (Boersig & Cliver, 2010). From 2016 to 2021, the food industry in the U.S. has grown 14.5% (Statista, 2023). This helps explain the growth in heat-treated pallets as they are more sterile than non-heat-treated pallets. Additionally, 80% of all products sold domestically are shipped unitized on pallets (Aldaz-Carroll & Raballand, 2005). Along with the

percentage of heat-treated pallets, the location of the heat-treated pallets was investigated. Respondents indicated that 67% of pallets were heat-treated on site; whereas, only 33% of pallets were manufactured with purchased heat-treated lumber. Often, when a pallet company purchases precut lumber (parts), they then put them through the kiln drying process to help strengthen the wood and keep it from warping. Kiln dried lumber often meets the ISPM-15 heat treatment standard which calls for the lumber to be heated to 56 degrees Celsius for 30 minutes (*Regulation of Wood Packaging Material in International Trade*, 2018). So, many of the of the wooden pallet and container companies who purchase kiln dried lumber parts, are already purchasing heat treated lumber.



*Data from surveys conducted in 2006, 2016 and 2021.

Figure 8. Estimated Percent of New Pallets That Were Heat-Treated Between 2006 and 2021.

1.19 REPAIRED AND REMANUFACTURED PALLET TRENDS

Respondents reported that 74% of pallet cores received were 48” x 40” stringer pallets while 14% were 48” x 40” block class pallets (Figure 9). Block pallets are repaired at lower rates due to the difficulty of the repair/dismantling process. It can take up to 50% longer to dismantle a block class pallet in comparison to a stringer class pallet (Kirkaldy, 2011). Additionally, in the case of pallet poolers, the recyclers are not allowed to re-sell these pallets because they do not

own them. These pallets can sit at the recycling facility, taking up space, until the pooler retrieves them, sometimes with little to no compensation (E. Brindley, 2019). The remaining responses accounted for 11% of other stringer pallet sizes and 2% other block pallet sizes.

Most of the incoming cores and scraps (78%) are repaired and sold (Table 4). This was a 12 percentage point increase compared to 2016 and the highest value seen in 30 years. This increase in pallet repairs can be attributed to the increase in pallet demand as e-commerce continues to increase and to help support omni-channel distribution (C. Brindley, 2022). Additionally, as lumber prices reached record highs during this time period, repaired pallets were a cheaper alternative for distributors that could utilize used pallets (Riddle, 2021). Disassembling is the second highest case with 11% of pallet cores being disassembled for the remanufacturing process. Reused without repair consisted of only 5%, ground or chipped 5%, landfilled 1%, and other 1% in 2021. The reused without repair percentage did not increase, due to the declining quality of pallet cores in the field. This means that pallets cores needing to be repaired are more often dismantled so the parts can be used in the repair process (C. Brindley, 2022). Some notable changes from 2016 are that disassembled cores decreased 7 percentage points and ground or chipped cores decreased 6 percentage points.

Table 4. Percent What was Done with Received Pallet Cores and Scraps Between 1993 and 2021

Year	Reused Without Repair (%)	Repaired (%)	Disassembled (%)	Ground or Chipped (%)	Landfilled (%)	Other (%)
1993 ¹	13	61	15	8	0	2
1995 ²	10	63	18	8	1	1
1999 ³	8	70	16	5	1	<
2006 ⁴	10	67	16	6	<1	1
2011 ⁵	11	69	16	3	<1	<1
2016 ⁶	5	65	18	11	<1	1
2021	5	78	11	5	<1	1

*Data from surveys conducted in 1993, 1995, 1999, 2006, 2011, 2016 and 2021. (¹Christoforo, 1993; ²Redy et al., 1995 ;³Bejune et al., 2002; ⁴Bush 2008; ⁵Bush 2013; ⁶Gerber et al., 2018;)

In 2021, 80% of repaired and remanufactured pallets were 48” x 40” (Figure 10). This is a 11 percentage points increase from the previous survey in 2016. The remaining sizes took up a fraction of the repaired and remanufactured pallet sizes at 1% for 40” x 48”, 1% for 48” x 48”, 2% for 48” x 45”, <1% for 48” x 42”, 1% 48” x 36”, 1% for 42” x 42”, 1% for 42” x 42”, 0% for 800mm x 1200mm, and 13% for other sizes. These percentages are sizes of repaired pallets that were sold; this means that some pallet cores that were received were not reported. A portion of the block pallets received are from poolers, so they are not eligible to be repaired or sold. Also, pallets cores that are not fit for repair are ground up for other products; they are not represented in this data. Other size pallets, larger than 48” x 40”, are often dismantled and cut down to create good parts for the repair process of other 48” x 40” pallets. This leads to a difference in the sizes of incoming pallet cores to the outgoing repaired pallets sold. Repairing 48” x 40” pallets remain the vast majority of pallet size being repaired due to it being the most abundant specific pallet size used by the most industries.

The final repaired/remanufactured pallet trend investigated was the percent of heat treatment as seen in **Error! Not a valid bookmark self-reference.** In 2021, respondents indicated that approximately 23% of repaired and remanufactured pallets were heat treated. This was a 15 percentage points decrease from 2016, though it is similar to what was reported in 2006, increasing 2 percentage points from that year. Heat-treated pallets are mainly used in export shipping due to the laws and regulations surrounding the potential of accidentally transporting invasive species(WITS, 2021). From this, it is assumed that fewer companies are using repaired pallets in the export process compared to previous years. This trend could also be explained by the fact that exporters need to use pallets of known load capacities; repaired pallets do not qualify. Respondents were also asked to indicate what was done with the ground up pallets once they reached the end of their life and could no longer be repaired or used for parts in the repair process. This question yielded a lower response rate compared to the rest of the survey; in 2021, the highest percentage of grounds were used for biofuel at 54%. The remaining uses were landscape mulch (35%), animal bedding (5%), and other (6%). Comparing this to the previous survey conducted, the largest changes were that biofuel increased 24 percentage points and ‘other’ decreased 22.3 percentage points from 2016. Landscape mulch and animal bedding remained similar with them being 37.5% and 4.2%, respectively (Gerber et al., 2018). However, it is important to acknowledge that the difference between the 2021 and 2016 results could just be due to the lower response rate.

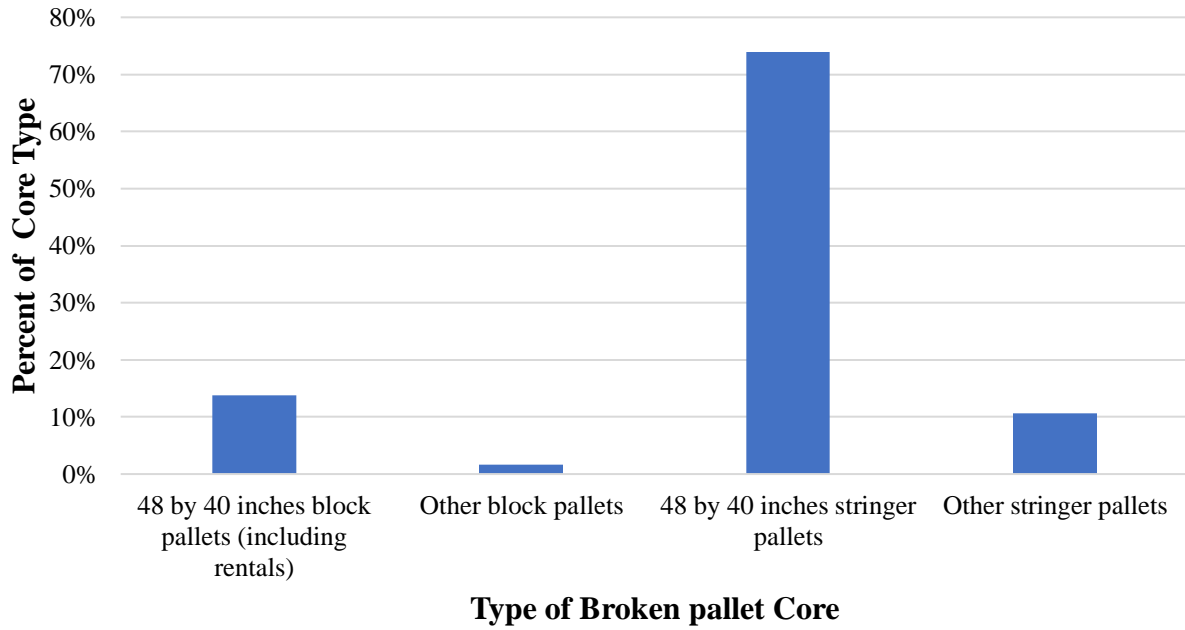


Figure 9. Type and Size of Received Pallet Cores.

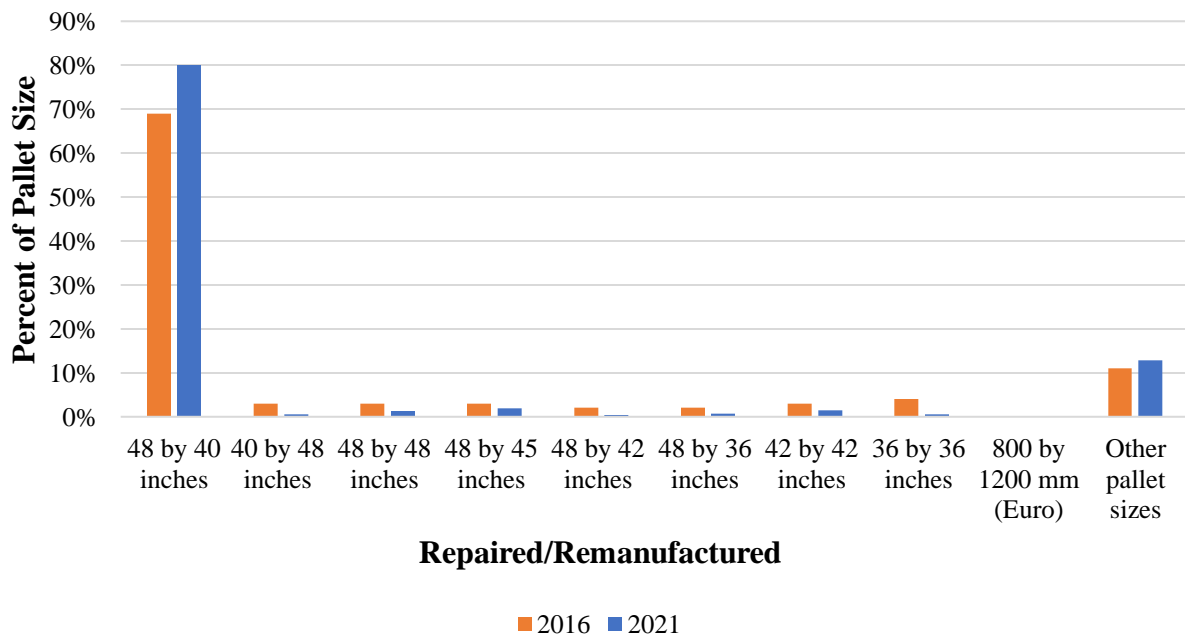
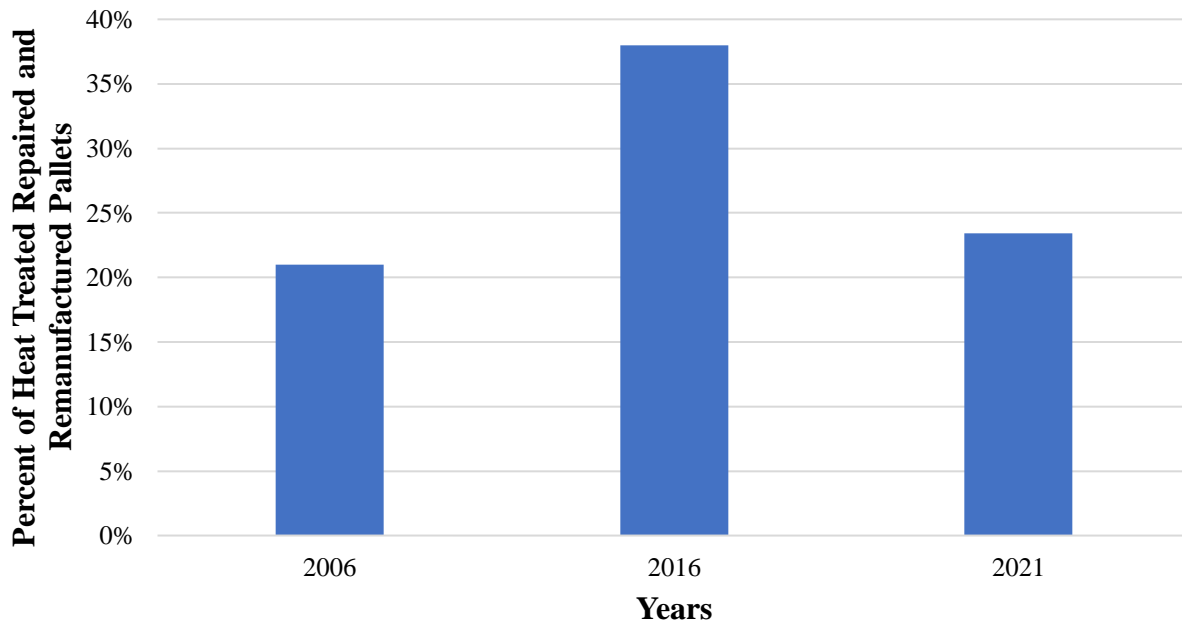


Figure 10. Percent of Different Repaired and Remanufactured Pallet Sizes in 2016 and 2021.



*Data from surveys conducted in 2006, 2016 and 2021.

Figure 11. Percent of Heat-Treated Repaired and Remanufactured Pallets Between 2006 and 2021.

1.20 WOOD USAGE TRENDS

Another important aspect that was investigated in this survey was the trend in wood and raw material used for pallet production. Respondents indicated how much of their lumber usage came from certified forests. In 2021, respondents answered that 23% of lumber used was knowingly certified (*Data from surveys conducted in 2011, 2016, and 2021.

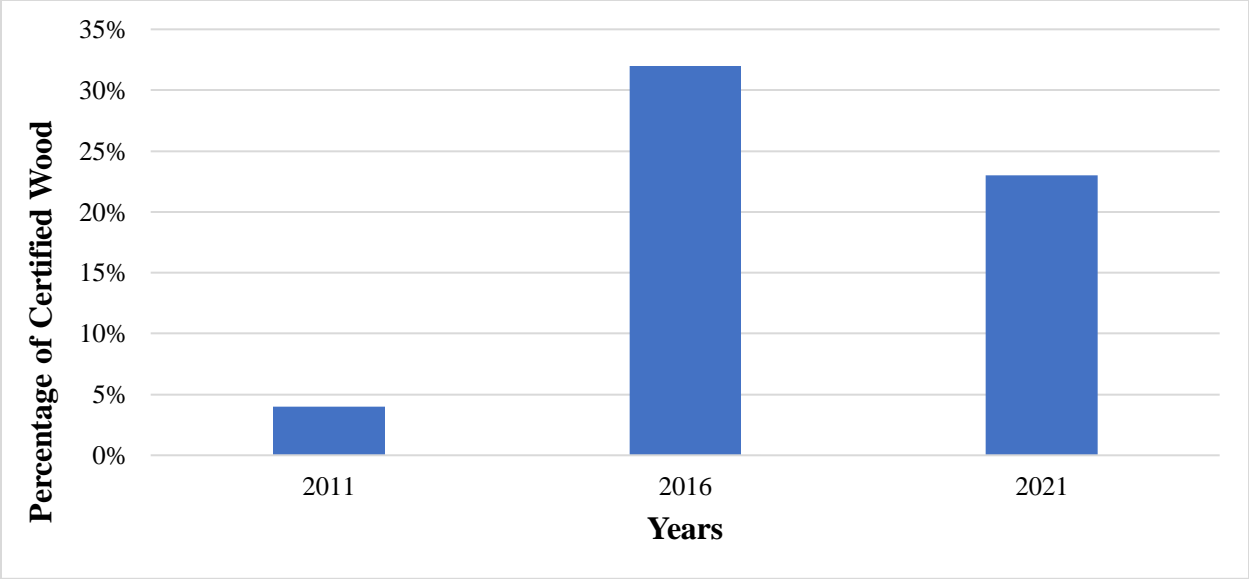
Figure 12). However, 48% of respondents indicated that they did not know if their company used certified lumber or not. Comparing this data to previous research shows a 9 percentage points decrease since 2016. This is due to the previous survey not having an option for ‘not known,’ so it was calculated by just the respondents who truly knew if they used certified lumber or not. The data in 2021 was calculated by all respondents, using those who checked ‘not known’ as non-certified lumber users. Comparing this to the earliest data point from 2006, there was a 28 percentage points increase. This could be attributed to forest certification growing 88% from

2009 to 2010 (United Nations, 2010). Out of the certified lumber used, 22% was from the Forest Stewardship Council (FSC), 76% was from the Sustainable Forest Initiative (SFI), and the remaining 2% came from other certifications (Figure 13)

Another trend investigated was where imported lumber was coming from. In 2021, approximately 69% of all imported lumber came from South America, 25% from Canada, and 6% from other countries. In comparison to the previous survey, there was a major shift from imported lumber; it used to be imported from mainly from Canada but changed to more being imported from South America. Imports from South America increased 67 percentage points while imports from Canada decreased 69 percentage points (Figure 14). Though a vast majority of South American lumber came from one respondent. Without this one response, Canadian lumber would remain the most-imported for pallet production, though it has still decreased since the previous research. Without the one respondent, Canadian lumber decreased to 65% from 2016; whereas, South American lumber increased from 2% to 27% (from 2016 to 2021). This shows that the trend of decreasing Canadian lumber and increasing in South American lumber is still prevalent though not as strong. In the last four quarters, lumber imports from Canada have been on the decline. A reduction in the annual allowable harvesting has reduced lumber by one third in the province of British Columbia over the last five years (Wood Resources International, 2021). Canadian lumber also had record high prices in May 2021 (Robuck, 2021). This could have forced the U.S. pallet industry import lumber from another source. Respondents indicated that the total lumber used from softwoods and hardwoods was approximately 17.9 billion bdft in 2021. This is a 95% increase from 2016. This increase coincides with the major increase in pallet production seen during the same time frame. As seen in *In the more category for 2021 ranges from 100 to 162 million board feet. Data from surveys conducted in 2016 and 2021.

Figure 15 and

Figure 16, respondents in 2021 reported higher lumber usage on average then in 2016.



*Data from surveys conducted in 2011, 2016, and 2021.

Figure 12. Percent of Certified New Lumber Used in Pallet Production Between 2011-2021.

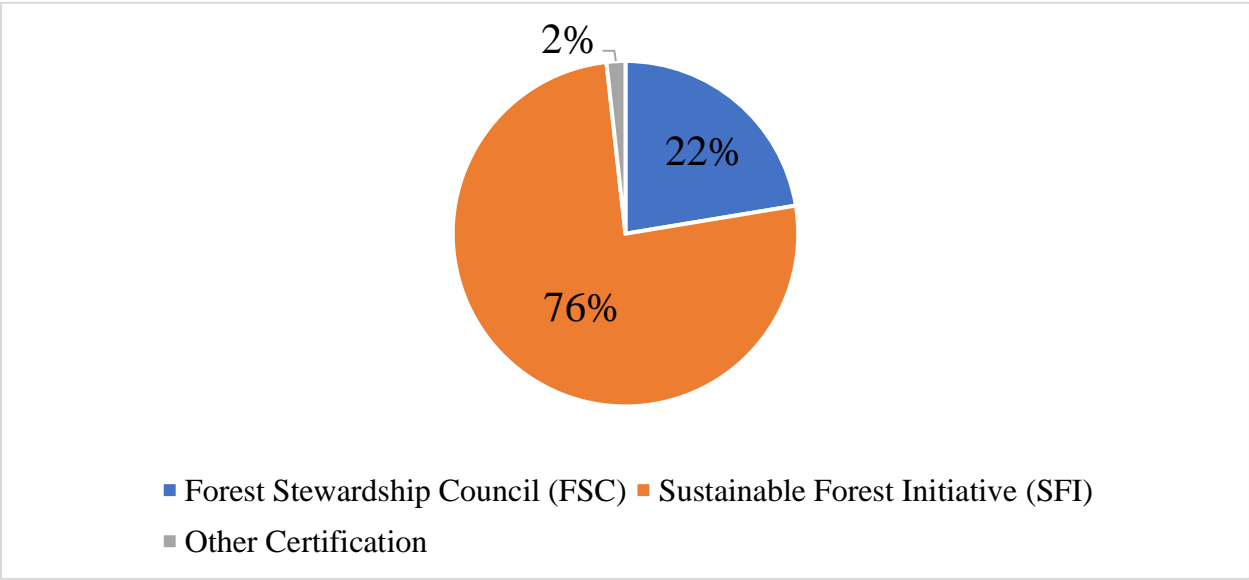


Figure 13. Percent Forest Certification for Harvested New Lumber in 2021.

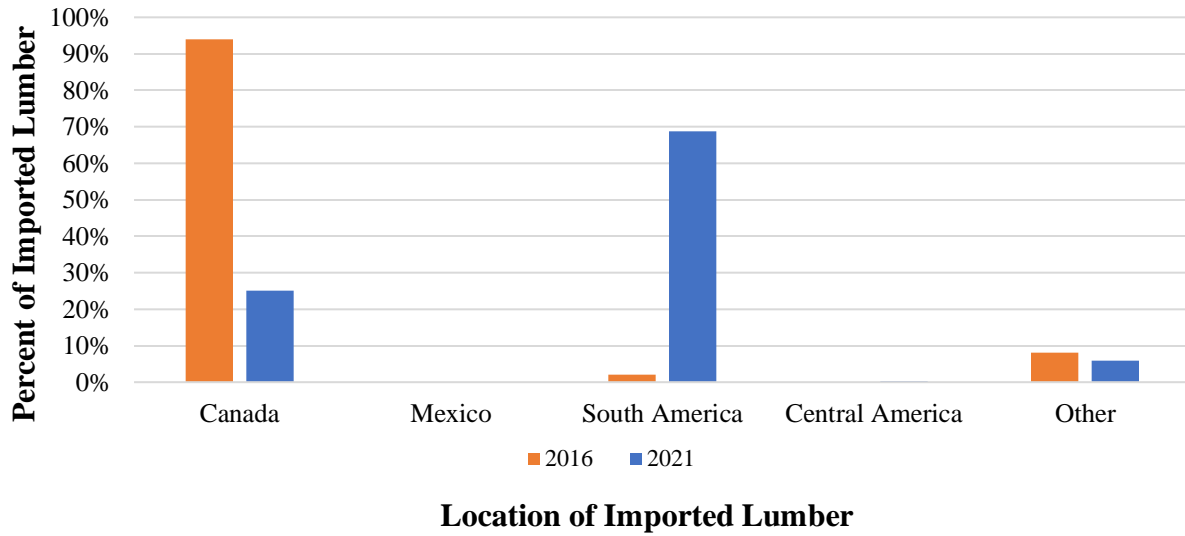
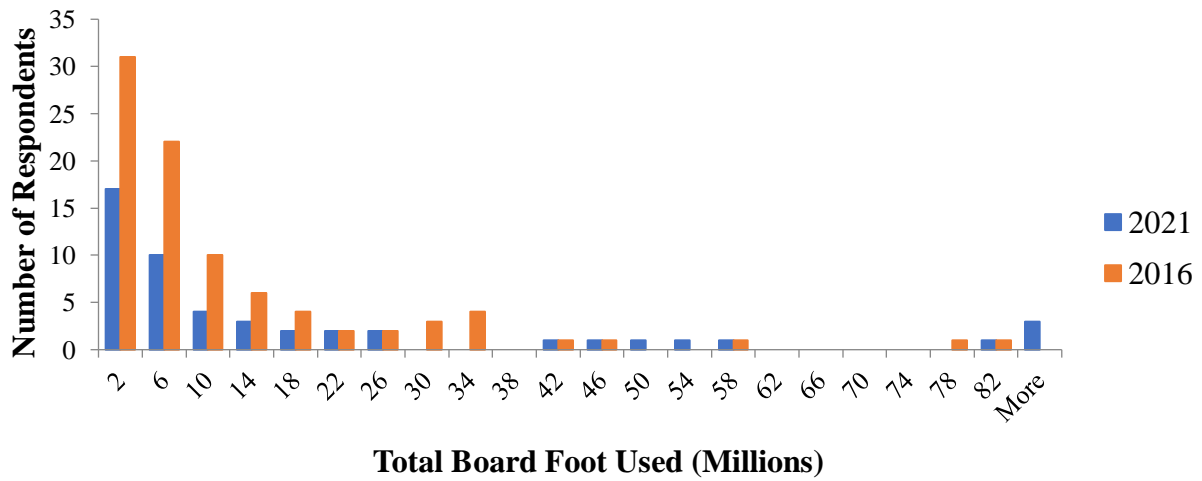


Figure 14. Percent Location Distribution of Imported Lumber in 2016 and 2021.



*In the more category for 2021 ranges from 100 to 162 million board feet. Data from surveys conducted in 2016 and 2021.

Figure 15. Distribution Plot of Total Board Foot Used in Pallet Production in 2016 and 2021.

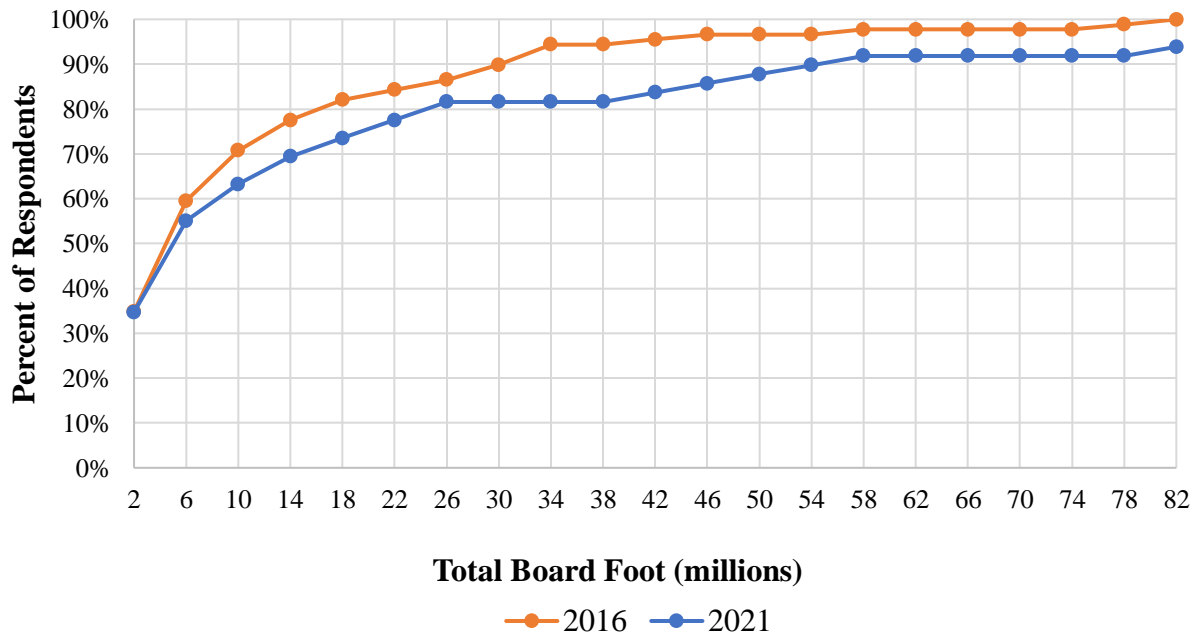


Figure 16. Cumulative Distribution Plot of Total Board Foot Used by Respondents in 2016 and 2021.

1.21 SOFTWOOD USAGE TRENDS

Respondents reported the amount of softwoods used between the years 2019 and 2021. There was approximately 13.0 billion bdft used in 2019, 14.1 billion in 2020, and 14.4 in 2021. In 2021, this lumber usage consisted of 38.6% of sawn softwood produced in the U.S. Comparing this to historical data there was an 8.74 billion bdft increase from 2016 to 2021. Softwood consisted of roughly 81% of the total bdft used in wooden pallet manufacturing in 2021. This is a major shift from the results of previous surveys (*Data from surveys conducted in 2006, 2016 and 2021).

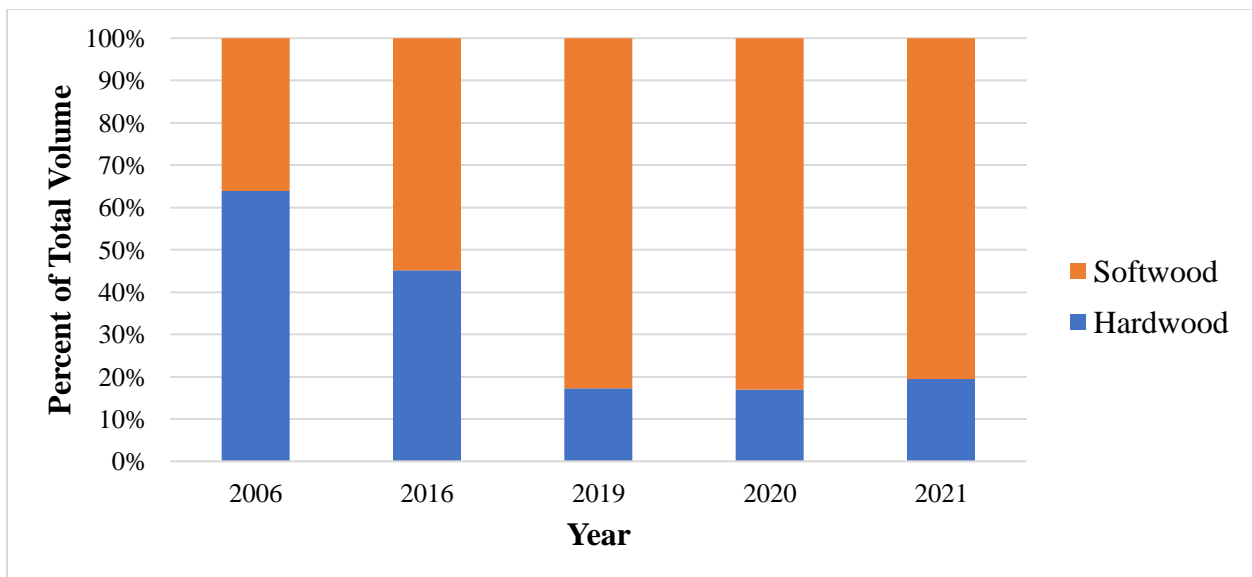
Figure 17. Percent Softwood to Hardwood Usage Between 2006 and 2021

). Looking at historical trends, it can be seen that there has been a shift from using more hardwoods, to now using predominantly softwoods. In the earliest data collected in 2006, it was reported that 64% of the pallets were made of hardwood and only 36% from softwood. This changed in 2016 to 45% hardwood / 55% softwood ratio and this shift continued from 2019 to 2021. Respondents also indicated the species used within their softwood trends. In 2021, the

main two species used were Southern Pine (42%) and Douglas-Fir (40%). The remaining species was Spruce-Pine-Fir (SPF) (14%) and other softwood (3%) as seen in

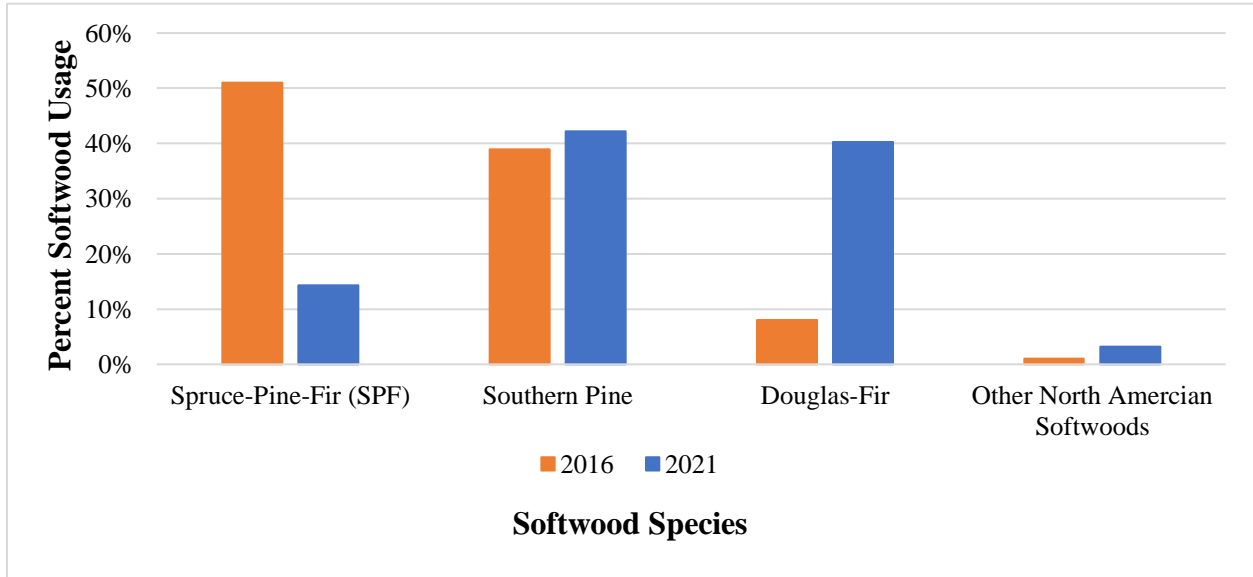
*Data from surveys conducted in 2016 and 2021.

Figure 17. Compared to the previous data from 2016, there was a switch in usage between Douglas-Fir and SPF. In 2016, SPF was responsible for over half of the softwood usage but dipped to only 14% of the market in 2021, while Douglas-Fir went from only 8% to 40%. It also needs to be mentioned that in 2021, one respondent consisted of almost half of the Douglas-fir usage. If this one respondent is removed, the share of Douglas-fir and SPF is still greatly increased from previous surveys, while the share of SPF is still greatly decreased. With this one point removed, Southern pine would consist of 54%, Douglas-fir 27%, (SPF) 17%, and other softwoods 2%. Meanwhile, the market share of Southern Pine would also increase becoming over half of the softwood species used. This could be due to declining SPF populations from wildfires and infestations of bark beetles which have caused major shortages (Fastmarkets, 2023). In 2021, approximately 34% of softwood lumber was received as lumber parts; whereas, 66% was received as lumber cants. Compared to the previous survey conducted in 2016, lumber cants increased 10.5 percentage points and lumber parts decreased by 10.5 percentage points (Gerber et al., 2018).



*Data from surveys conducted in 2006, 2016 and 2021.

Figure 17. Percent Softwood to Hardwood Usage Between 2006 and 2021



*Data from surveys conducted in 2016 and 2021.

Figure 17. Percent Softwood Species Usage in 2016 and 2021.

1.22 HARDWOOD USAGE TRENDS

In 2019, there were approximately 2.7 billion bdft of hardwood used, 2.9 billion bdft in 2020, and 3.5 billion bdft in 2021. In 2021, this lumber usage made up 37.6% of all of the sawn hardwood produced in the U.S. In comparison to the previous survey conducted, hardwood bdft usage decreased 650 million bdft from 2016 to 2021. Hardwood usage was at its lowest point in 2011, when the industry used approximately 2.6 billion bdft, as seen in Table 5. In 2021, the respondents indicated that 43% of new hardwood lumber was high-density, 20% was medium density, and 37% was low density hardwoods. Compared to the 2016 survey, high-density hardwood usage decreased approximately 20%; low-density hardwoods increased 16%, and medium density increased 4% (

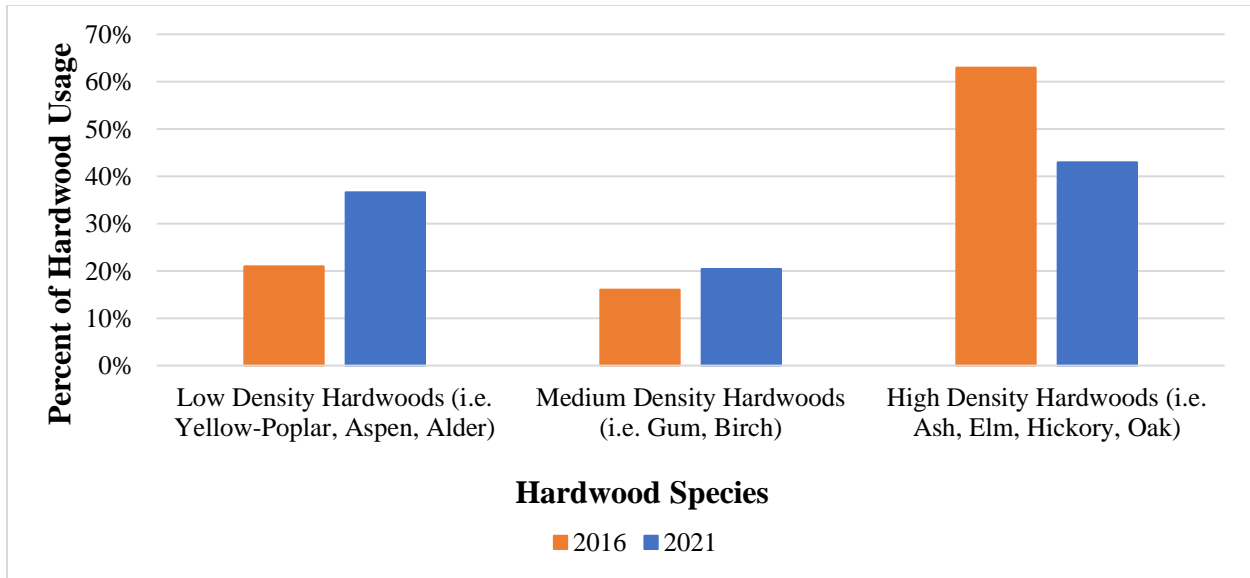
*Data from surveys conducted in 2016 and 2021.

Figure 18). This could be due to the declining number of oak forests, forcing the industry to use more common hardwoods in lower density classes (*Oak Decline (U.S. National Park Service)*, n.d.). In 2021, 71% of raw material came as lumber cants while the remaining 29% came as lumber parts. Compared to the previous survey conducted, the use of lumber cants increased 16.5 percentage points while the use of lumber parts decreased 16.5 percentage points (Gerber et al., 2018).

Table 5. Estimated Volume of New Wood Used to Produce New, Recycled, and Remanufactured Pallets Between 1999 and 2021.

Year	Billion Board Feet of Hardwood	Billion Board Feet of Softwood	Total Board Feet (Billion)
1999	4.5	2.1	6.6
2006	4.6	2.6	7.2
2011	2.6	4.3	6.9
2016	4.13	5.03	9.16
2019	2.69	12.96	15.56
2020	2.77	14.10	16.87
2021	3.48	14.40	17.88

*Data from surveys conducted in 1999, 2006, 2011, 2016 and 2021.



*Data from surveys conducted in 2016 and 2021.

Figure 18. Percent Hardwood Species Usage by Density Between 2016 and 2021.

1.23 COVID QUESTIONS

Due to the unique timing of when this survey was conducted, companies were also asked questions about how they fared during the pandemic. The first question pertained to employment and production numbers during the time period from March to July of 2020. Approximately 33% of companies indicated that they did not have to lay off employees, 16% had to temporarily lay off employees, 7% had to temporarily furlough employees, and only 4% had to permanently lay off employees. As for production, 31% had to shut down for less than four weeks, 2% had to shut down for more than four weeks but less than three months, and 7% had to permanently shut down.

The second question inquired about how their sales were affected in 2020 compared to 2019. Approximately 29% of companies responded that their 2020 sales exceeded their 2019 sales. Around 22% of respondents said their sales were not affected by the pandemic, and 22% responded that their sales initially dipped around March and April but then exceeded their sales numbers from 2019. Roughly 12% of respondents indicated that their sales dipped below 2019

sales in March and April of 2020 but then recovered to similar numbers as before the pandemic; only 14% of respondents indicated that their sales were constantly lower than pre-Covid sales.

The final pandemic related question was about the procurement of raw materials. Approximately 32% of respondents reported that they had no challenges procuring raw material throughout the pandemic. Around 22% of respondents reported that they had some challenges though they stabled out through the year with 46% reporting that they had constant challenges throughout the pandemic in acquiring raw materials.

The Covid-19 pandemic shed light on the importance of pallets in the supply chain. Due to the high demand of essential products like food and health care items, pallets were also in high demand to ensure that supply chains were able to handle these product demands. Due to the rising demand of pallets and labor shortages due to the pandemic, many companies were afraid that pallet companies could not keep up with the increasing demand (Brindley, 2021).

1.24 LATE RESPONSE BIAS

The final group of data analyzed was the late response bias. Companies who filled out the survey before June 2023 were considered early responders, and they were compared to those who filled out the survey after this time period. These companies were compared by their production of new pallets, repaired pallets, remanufactured pallets, and revived pallet cores. Using the Wilcoxon test, no significant differences were found with the p-values of all tests being over 0.05. This shows that there was no bias in response time for this data set.

1.25 VARIABILITY

Some simple statistics were run to determine the variability in some data sets. The data sets used were new pallet production, repaired pallet production, hardwood lumber usage, and softwood lumber usage. These tests were run to see how stable the data would be if there was a change in the data set. These data sets were tested by taking a random 10% of the data set out five times and recalculating the data with the adjusted scale up factor. The coefficient of variance from each data set is seen in Table 6. Both new pallet and repaired pallet production had a

coefficient of variation under 5% which is considered a low variation in the data set. As for hardwood usage, the percentages were around the 5% mark, though higher than the pallet production variation. Finally, the softwood lumber usage saw the most variability ranging from 8.38% to 11.62% showing the highest variability of the data sets.

Table 6. Coefficient of Variation in Selected Data Sets Between 2019-2021.

Year	Coefficient of Variation			
	New Pallet	Repaired	Harwood	Softwood
2019	1.39%	4.63%	5.87%	8.38%
2020	2.13%	4.71%	7.07%	9.62%
2021	2.53%	4.14%	5.75%	11.62%

*Data from surveys conducted in 2021.

CONCLUSION

New wooden pallet production remains dominate in the industry. At 56% it is the main source of income according to respondents. Used, repaired, and remanufactured pallets are the second highest source of income at 26.5% according to respondents. The production of other wood products contributed to 10.2% of revenue. Manufacturing crates and containers attributed to 3.9% of total revenue and lastly brokering pallets contributed to 3.4% of revenue according to respondents.

The respondents indicated that the state of the wooden pallet and container industry is healthy and has continued to grow throughout the pandemic. Overall, the industry produced approximately 1.18 billion total pallets in 2021 which is a 40% increase from 2016. Out of these produced pallets in 2021, 919 million produced were new pallets and 280 million were repaired or remanufactured pallets. This is a 75% increase in new pallet production and a 16.4% decrease in repaired and remanufactured pallet production compared to 2016.

New pallet production trends have stringer class pallets remaining dominate in the industry at 77% of production. Block class and skids/other accounted for 19% and 4% respectively. The percent of block pallets remained similar to the spike in production that occurred in 2016. For pallet sizes the 48”x40” pallet remains the most used specific pallet size at 29%. This was a 6% decrease from 2016. Other pallet sizes which are custom take up 40% of the pallet size market which is only a 1% increase from 2016. The most variation that came from another pallet size was the double in production of 40”x48” pallets up to 8% of the new pallet market.

The wooden pallet industry used 17.9 billion board feet of lumber for the production of pallets in 2021. This is a 95% increase from 2016 where 9.16 billion board feet was used. Out of the total board feet used softwood accounted for 14.42 billion board feet which was 38.6% of all sawn softwood produced in the United States(Alderman, 2021). Softwood usage increased 286% from 2016 where 5.01 billion board feet was used. As for hardwood the wood pallet industry used 3.48 billion board feet which consisted of 37.6% of all sawn hardwood produced in the United States(Alderman, 2021). This hardwood usage was a 18% decrease from 2016 where 4.13 billion board feet was used. This high usage of softwood continues the trend the industry has seen of going from using predominantly hardwood to softwood. Additionally, 10.6% of all lumber used was imported lumber. This is a 6.6% increase from 2016.

Approximately 280 million repaired or remanufactured pallets were produced in 2021. An estimated 78% of received pallet cores were repaired which is a 13% increase from 2016. As for used pallet sizes the predominate size produced was 48”x40”. This size took up an estimated 80% of the market share. This was a 11% increase from 2016. Additionally, 89% of recovered wood pallets were converted to repaired or remanufactured pallets.

The Covid-19 pandemic sent shock waves around the world affecting most aspects of daily life and all industries. The wooden pallet industry stayed steady through the pandemic and saw healthy growth. Approximately 22% of respondents indicated that they were not affected by the pandemic. An estimated 51% of respondents indicated that they exceeded their 2019 pre covid sales in 2020 with 12% of respondents seeing similar sales to 2019. As for employment only 16% of respondents had to temporarily lay off employees where only 4% had to permanent

layoffs. Finally, 54% of respondents indicated that they had no problems procuring material or had initial problems but were able to sort them out with the remaining 46% having constant problems throughout the pandemic. Another large issue that the industry saw throughout the pandemic was employment related. In the open response question 43% of respondents indicated that they could not keep enough employees on staff throughout the pandemic. Many of these responses also indicated that even if they could get new hires they often did not stay long and had hire turnover rates than in previous years.

RECOMMENDATIONS FOR FUTURE RESEARCH

This research is only accounting for a short period of time of the wooden pallet and container industry. To continue to find trends similar research should be conducted in the future it helps accumulate more knowledge.

While this survey gathered good information there were constant challenges with the response rate. To help increase response rates it is important that a better database is created to help reach more active respondents. Also, there should be more outreach and reminders sent to make sure a higher response rate is met.

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APPENDIX A: SURVEY INSTRUMENT

2775

Investigation of New and Recovered Wood Shipping Containers in the United States



COLLEGE OF NATURAL
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VIRGINIA TECH.

*If you have any questions or concerns about this study, please contact:
Sean Hobbs at (516) 355-8861 or hsean99@vt.edu*

2775

This questionnaire asks about your company's manufacturing, repairing, remanufacturing, and/or recycling of pallets and containers.

1. Did your company produce, repair, recover/recycle, remanufacture or broker any wood packaging (pallets, skids, crates/containers, etc.) during 2021?

No → Please stop here and return the questionnaire by following the directions provided on the last page. Postage is prepaid. Thank you.

Yes → Please continue to the next question

2. Please indicate whether you are completing this survey for a specific facility or your entire organization.

Specific facility

Entire organization

3. What percentage of your company's sales dollars did each product category account for in 2021?

	Percentage of Sales Dollars
New wood pallets produced	%
Wood pallets repaired, recovered/recycled, or remanufactured	%
Wood pallets brokered or wholesaled	%
Other wood packaging products (please specify below)	%
Total	100%

Other products (please list): _____

If 100% of sales dollars come from brokered or wholesaled pallets produced by other companies, thank you for your time. Please return the survey. Postage is prepaid. Thank you.

2775

4. Did your sales volume change in 2021 compared to 2020? (Please use negative percentages to indicate a decrease and positive percentages to indicate an increase)

___%

The following three questions will ask data for 2019, 2020, and 2021.

5. Please provide the following information for calendar years 2019, 2020, and 2021.

	2019	2020	2021
# of facilities			
average # of shifts (1, 2, or 3) per weekday			
# of days in operation in the respective year (average per facility)			
# Production employees			
# Non-Production employees			
% Turnover production employees			

If you broker pallets from other firms, please do not include those volumes when completing the remainder of the survey.

6. How many units of the following did your company receive/ produce in 2019,2020, and 2021?

	Number of units produced/received		
	2019	2020	2021
Used or broken cores received			
New pallets produced			
Recycled/recovered, or repaired pallets produced			
Remanufactured pallets produced*			
Crates/containers produced			

* complete reassembly using used or new components.

7. How much new wood of the following species groups of did your company use in the production, repair, and/or remanufacturing of wood packaging during 2019, 2020, and 2021?

	Volume used (In Thousand Board Feet)		
	2019	2020	2021
Hardwoods from the US			
Softwoods from the US			
Wood imported from outside the US			

The remaining questions will focus on the calendar year 2021 only.

8. What percent of the following **new wood** raw materials did your company use in 2021 for the production, recycling/recovery, and/or remanufacturing of wood pallets? (If your company purchases logs or bolts, please report them in the lumber/cants category)

Materials		Percentage of total board feet of new wood
Hardwood	Parts	%
	Lumber/cants	%
Softwood	Parts	%
	Lumber/cants	%
Total		100%

9. What species categories of **new wood** did your company use in the production, repair, and/or remanufacturing of wood packaging during 2021? (Please indicate the percentage of total board feet in each species group.)

Hardwoods from the US

	Percent of total board feet of hardwoods
Low-Density Hardwoods (i.e. Yellow-Poplar, Aspen, Alder)	%
Medium Density Hardwoods (i.e. Gum, Birch)	%
High-Density Hardwoods (i.e. Ash, Elm, Hickory, Oak)	%
Total	100%

Softwoods from the US

	Percentage of total board feet of softwood
Spruce-pine-fir (SPF)	%
Southern pine	%
Douglas-Fir	%
Other North American softwoods	%
Total	100%

Wood imported from outside of the United States

	Percent of total board feet imported wood
Canada	%
Mexico	%
South America	%
Central America	%
Other	%
Total	100%

10. What percentage of the **new wood** your company used in 2021 was environmentally certified by the following groups?

	Percentage of total board feet of new wood
Forest Stewardship Council certified	%
Sustainable Forest Initiative certified	%
Other Certification	%
Non-certified	%
Total	100%

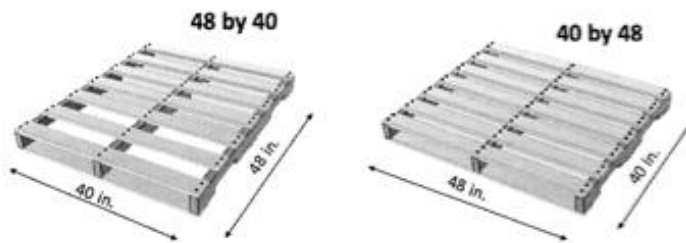
___ We do not have this data

11. Of your heat-treated pallets, what percentage of the pallets were made from purchased heat-treated wood versus pallets that were heat-treated on site in 2021?

	Percentage of total board feet of new wood
Purchased heat-treated	%
Heat-treated on site	%
Total	100%

The following questions ask about the new wood pallets. If your company did not produce new wood pallets in 2021 please skip to Question 14.

12. What percentage of the total new wood pallets (both block and stringer) your company produced in 2021 was each of the following sizes? Please look at the following two pictures before you fill out the table below.



	Percentage of total new wood pallets
48 by 40 inches	%
40 by 48 inches	%
48 by 48 inches	%
48 by 45 inches	%
48 by 42 inches	%
48 by 36 inches	%
42 by 42 inches	%
37 by 37 inches	%
800 by 1200 mm (Euro)	%
Other pallet sizes	%
Total	100%

13. How many different versions of a 48 in. x 40 in. pallet design does your company manufacture? (Separate pallet designs by variation in component dimensions, number of components, placement of components, and wood species)

- ___ Less than 10
- ___ 10-50
- ___ 50-100
- ___ 100-500
- ___ 500-1,000
- ___ More than 1,000

14. What percentage of the total new wood pallets your company produced in 2021 was each of the following types?

	Percentage of total new wood pallets
Stringer pallets	%
Block pallets	%
Skids and other types of pallets	%
Total	100%

15. In 2021, what percentage of the total NEW wood pallets your company sold was heat-treated? (Please specify 0% if your company did not sell heat-treated new pallets)

___ %

The following questions ask about the **recycling, repair, and remanufacturing** of wood pallets. If your company did not recycle, repair or remanufacture wood pallets in 2021, please skip to Question 19.

16. What percentage of the total **recovered/recycled/remanufactured** wood pallets your company produced in 2021 was each of the following sizes (Refer to Question 11 for pallet dimension drawings)?

	Percentage of total repaired wood pallets
48 by 40 inches	%
40 by 48 inches	%
48 by 48 inches	%
48 by 45 inches	%
48 by 42 inches	%
48 by 36 inches	%
42 by 42 inches	%
36 by 36 inches	%
800 by 1200 mm (Euro)	%
Other pallet sizes	%
Total	100%

17. What percentage of the total **broken or used cores** your company received in 2021 was each of the following types?

	Percentage of total repaired wood pallets
48 by 40 inches block pallets (including rentals)	%
Other block pallets	%
48 by 40 inches stringer pallets	%
Other stringer pallets	%
Total	100%

18. In 2021, what percentage of the total **recovered/recycled/remanufactured** wood pallets your company sold was heat-treated? (Please specify 0% if your company did not sell heat-treated recycled pallets)

___ %

19. What was done with the used pallets your company received in 2021? (Exclude rental pallets)

	Percentage of total repaired wood pallets
Sold without repair	%
Repaired	%
Dis-assembled	%
Ground or chipped	%
Sent to a landfill	%
Other	%
Total	100%

___ We do not have this data

20. If your company collected wood waste, ground, or chipped pallets or pallet parts in 2021, how was this material used (in weight in US tons)?

	Weight in US tons		
	From New Pallets	From Repaired Pallets	Collected Wood Waste
Colored landscape mulch			
Other landscape mulch			
Animal bedding			
Pellets or compressed fuel			
Non-compressed wood fuel			
Sent to landfill			
Other uses (Please specify below)			

We do not have a grinding or chipping operation

We do not have this data

If you selected the "Other uses" option please provide more details below

The following questions asks about the impacts of Covid-19 on your company during the pandemic.

21. Please indicate how the COVID-19 pandemic affected your company in 2020 between March and July. (Indicate all that apply)

- Had to temporary lay off employees
- Had to permanently lay off employees
- Had to temporary furlough employees
- Had to shut down production for less than 4 weeks

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Had to shut down production for more than 4 weeks but less than 3 months

Had to permanently close the company

22. Please select one of the following options that best describe how your sales and production were affected by the COVID-19 pandemic. (please, select only one option)

Pallet sales and production numbers continuously exceeded the 2019 levels throughout 2020

Pallet sales and production numbers were not affected by the COVID-19 restrictions

Pallet sales and production numbers temporary decreased in March/April, but they exceeded the 2019 levels by the end of the year

Pallet sales and production temporary decreased in March/April but recovered to the 2019 levels by the end of the year

Pallet sales and production temporary decreased in March/April, and they were still below the 2019 levels by the end of the year

Other (Please specify _____)

23. Please select one of the following options that best describe how your company's access to raw materials was affected by the COVID-19 pandemic. (please, select only one option)

Procuring raw materials was stable throughout the pandemic

Procuring raw materials posed a constant challenge at the beginning of the pandemic but the raw material supply stabilized by the end of the year

Procuring raw materials posed a constant challenge throughout the pandemic

Other (Please specify _____)

24. Please describe the challenges related to the COVID-19 pandemic that your company experienced in 2020.

2775

_____ My company did not have any challenges related to the COVID-19 pandemic

**Thank you for your help.
Please fold the questionnaire in half and send it back in the included
return envelope.**

RETURN POSTAGE IS PREPAID.

**As a participant, you can view a summary of the study results. Please
list your email address below, and we will send you the URL and
password.**

Email: _____



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Dear Sir/Madam,

I need your help! Recently, I mailed you a copy of a questionnaire titled **"Investigation of New and Recovered Wood Shipping Containers in the United States."** I am contacting you now to ask for your help completing and returning the questionnaire.

The information generated by this study will inform leaders of the industry, including yourself, on the trends and needs of the industry. You can take the survey online at www.palletsurvey2022.com. **Your ID is 2180**

Your participation is critical to the success of this study. The information you provide is strictly confidential. If you have any questions, please do not hesitate to contact me by email at hjean99@vt.edu or by phone at (516) 355-8861.

Thank you in advance for your help,



Sean Hobbs
Department of Sustainable Biomaterials
Virginia Tech

APPENDIX B: DATA MANIPULATION

General:

Average Percent Sales Dollars Per Category Sold

Question Used: 3

Step 1: Average each category answered by respondents to get approximated percent of income received from each category.

Average Reported Sales Growth

Questions Used: 4

Step 1: Average each reported percent (including negative values) to get an approximated sales growth.

Total Pallet Production

Questions Used: 5 and 6

Step 1: For every response check to see if both questions were answered. Remove all responses that did not complete both questions.

Step 2: Create a scale up factor by summing up all employee numbers reported by respondents and comparing them to the industry employees provided by the U.S. Census Bureau.

Scale up factor = (U.S. Census Bureau employee numbers) / (summed up employee numbers provided by respondents)

Step 3: Sum up pallet production numbers

Step 4: Multiply the summed-up pallet numbers in step 3 by the created scale up factor in step 2 to get the approximated total pallet numbers in the United States.

Total Lumber Consumed

Questions Used: 5 and 7

Step 1: For every response check to see if both questions were answered. Remove all responses that did not complete both questions.

Step 2: Create a scale up factor by summing up all employee numbers reported by respondents and comparing them to the industry employees provided by the U.S. Census Bureau.

Scale up factor = (U.S. Census Bureau employee numbers) / (summed up employee numbers provided by respondents)

Step 3: Sum up reported lumber used by respondents.

Step 4: Multiply the summed-up lumber board foot reported in step 3 by the created scale up factor in step 2 to get the approximated total pallet numbers in the United States.

Proportion of Wood Species Used for New Pallet Production

Questions Used: 7 and 9

Step 1: Check each respondent to make sure they have answered both questions. If not remove those that have not.

Step 2: Add up all of the hardwood and softwood used by respondents separately.

Step 3: Multiply the reported hardwood used by each respondent to their reported percentage of hardwood species to get the board foot of each species used by that company (High, Medium, and Low density).

Step 4: Repeat step 3 with softwood to acquire the split of softwood species usage per respondent (SPF, Southern pine, Douglas-Fir, Other).

Step 5: Add each of the same species usage reported by each respondent for both hardwood and softwood.

Step 6: Divide the total species usage by its respective total lumber added in step 2 to get the approximated percent of lumber species used.

Proportion of Imported Lumber Used

Questions used: 7 and 9

Step 1: Check each respondent to make sure they have answered both questions. If not remove those that have not.

Step 2: Add up all of the reported imported lumber used by respondents.

Step 3: Multiply the individual reported imported lumber used value by the corresponding region percentage to get the lumber used from each region.

Step 4: Sum up all of the calculated regions from step 3 separately

Step 5: Divide each region summed in step 4 into the total summed up in step 2 to get the percent of imported lumber used from each region.

Proportion of Environmental Certification

Questions used: 7 and 10

Step 1: Check each respondent to make sure they have answered both questions. If not remove those that have not.

Step 2: Add hardwood and softwood lumber usage for each individual company.

Step 3: Multiply the reported percentage of certification for each respondent by the total lumber used for each respondent in step 2.

Step 4: Add up all of the respective certification lumber usage separately to get a total for each category.

Step 5: Sum up all of the lumber usage reported by respondents to get total lumber used.

Step 6: Divide the number calculated in step 4 of each respective category by the total calculated in step 4 to get the percent usage of each category.

Proportion of New and Used Pallet Sizes

New Pallets

Questions used: 6 and 12 (New)

Step 1: Check each respondent to make sure they have answered both questions. If not remove those that have not.

Step 2: Multiply out new pallet production through reported pallet sized used for each respondent.

Step 3: Add up all corresponding pallet sizes through each respondent to get a total of each pallet size used.

Step 4: Add all pallet sizes from each respondent to get total new pallets produced.

Step 5: Divide each pallet size from step 3 with the total number of produced new pallets from step 4 to get the percentage usage of each pallet size used in new pallet production.

Used Pallets

Questions used: 6 and 16 (Used)

Step 1: Add repaired and remanufactured pallet production for each respondent individually.

Step 2: follow the same remaining steps as for new pallets though with question 16 used pallet size data instead of question 12.

Proportion of New Pallet Classes

Questions used: 6 and 14

Step 1: Check each respondent to make sure they have answered both questions. If not remove those that have not.

Step 2: Multiply each respondents new pallet production with the reported class type percentage to get the amount produced by class.

Step 3: Add up all pallet classes individually to get the total number of each class used by the respondents.

Step 4: Add separately to step 3 all of the new pallets produced by each respondent to get total new pallets produced.

Step 5: Divide each pallet class from step 3 by the total number of new pallets in step 4 to get the percent usage of each pallet class.

Percentage of Pallet Heat Treatment

Questions used: 6 and 15

Step 1: Make sure each respondent has answered both questions.

Step 2: If both questions were not answered remove those respondents.

Step 3: Multiply each respondents new pallet production by their reported pallet heat treatment percentage to get the amount of pallets heat treated.

Step 4: Add up all of the recalculated heat-treated pallets from step 3.

Step 5: Add all of the new pallets produced by each respondent to get the total amount of new pallets produced.

Step 6: Divide the sum calculated in step 4 by the total number of new pallets calculated in step 5 to get the percentage of new produced heat treated pallets.

Proportion of Received Used or Broken Cores Types and Size

Questions used: 6 and 17

Step 1: Make sure each respondent has answered both questions.

Step 2: If both questions were not answered remove those respondents.

Step 3: Multiply each respondents received pallet cores by the percentage reported individually by the respondents to get the amount of each pallet core size and type.

Step 4: Add up all of the respective core size and type to get a total of each response.

Step 5: Add up all of the total pallet cores used by each respondent.

Step 6: Divide the respective size and type acquired from step 4 with the total pallet cores received from step 5 to get the percent received.

Proportion of What Was Done With Received Pallet Cores

Questions used: 6 and 19

Step 1: Make sure each respondent has answered both questions.

Step 2: If both questions were not answered remove those respondents.

Step 3: Multiply received pallet cores by each percent possibility in question 19 for each respondent.

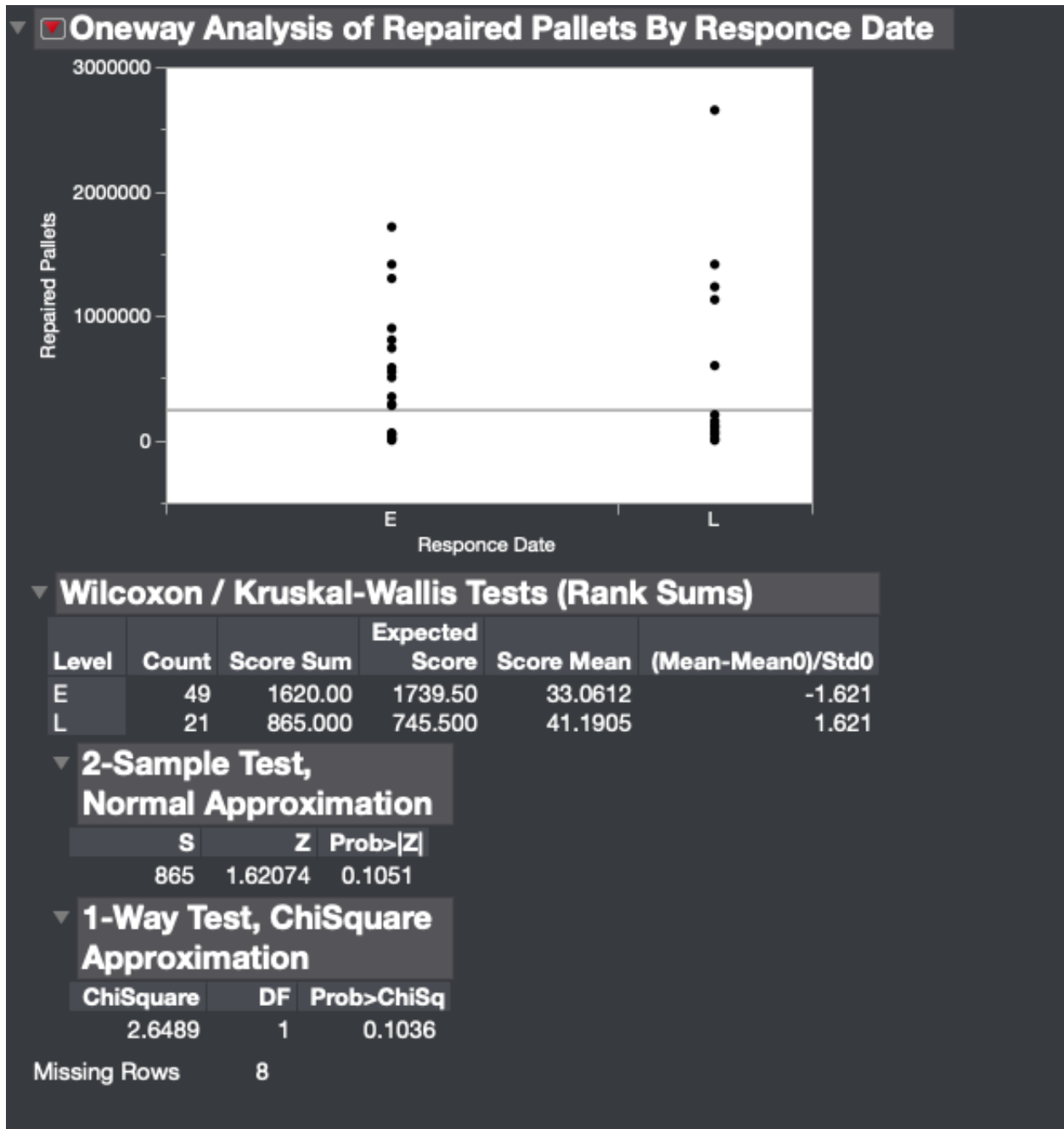
Step 4: Add up each of the respective uses to get a total for all of the respondents.

Step 5: Add up all of the received pallet cores for each respondent to get total received pallet cores.

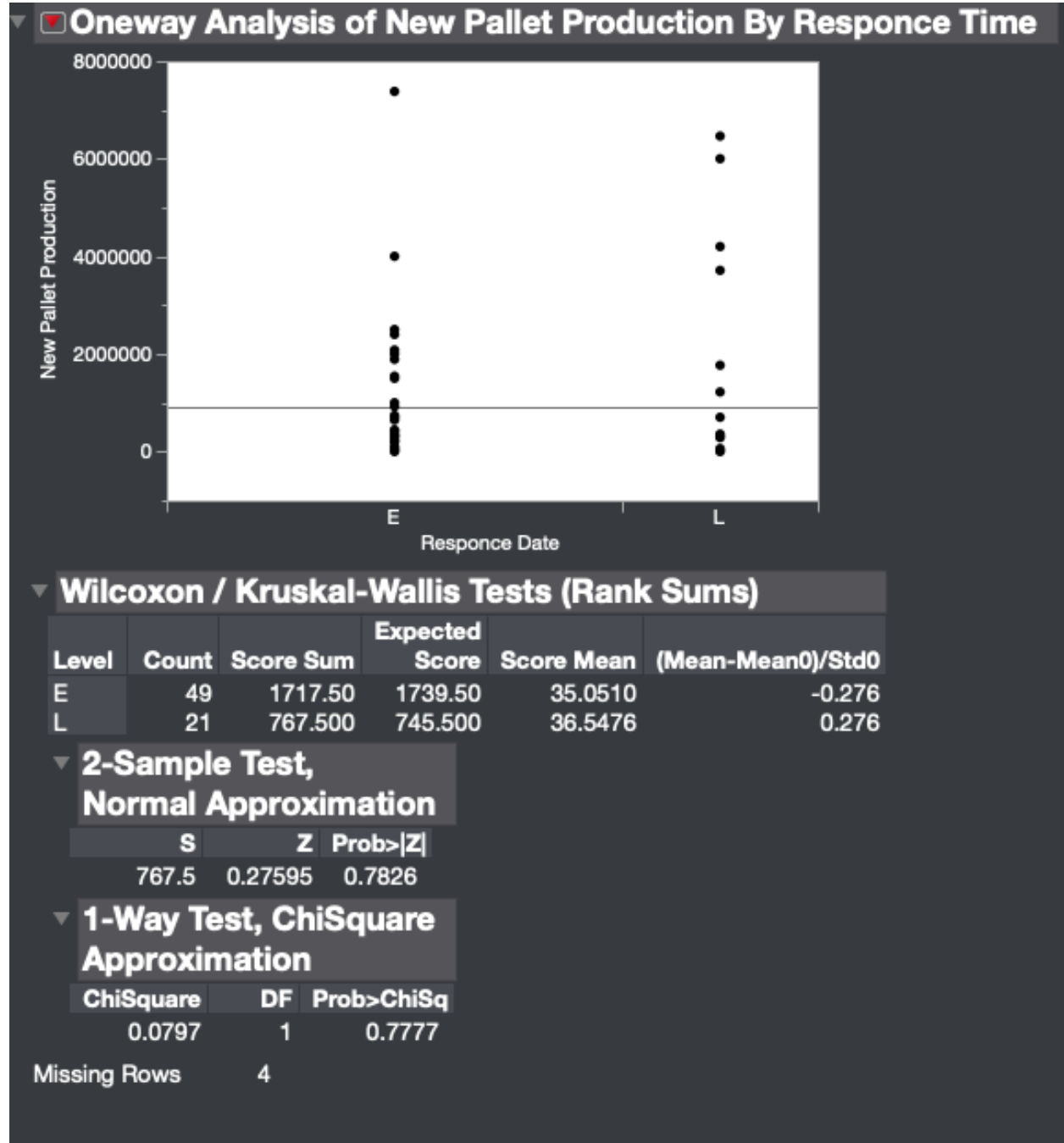
Step 6: Divide each use calculated from step 4 by the total pallet cores from step 5 to get the total percent of each use case.

APPENDIX C: ADVANCED STATISTICAL ANALYSIS

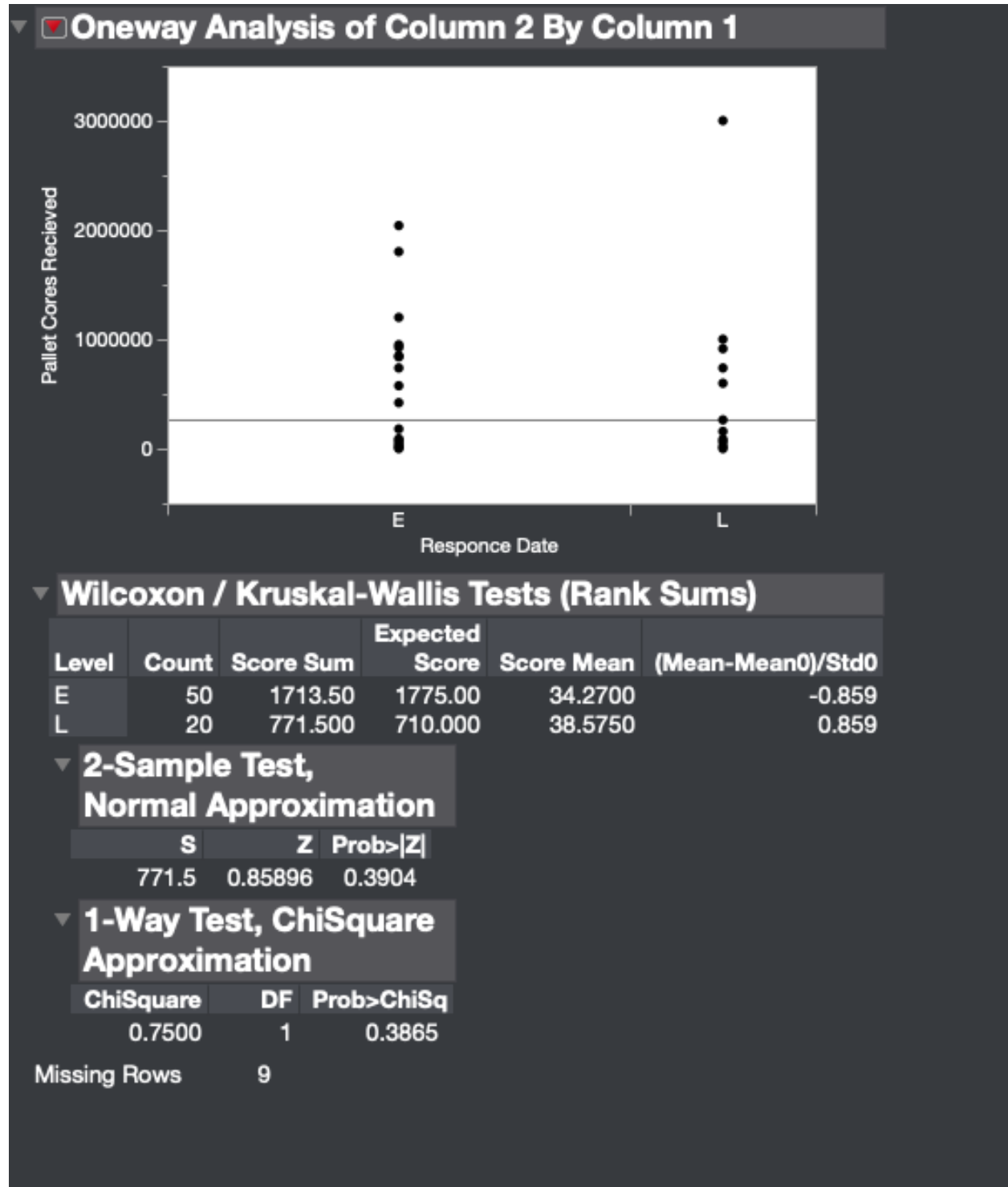
Repaired Pallet Production Wilcoxon Test for Late Response Bias



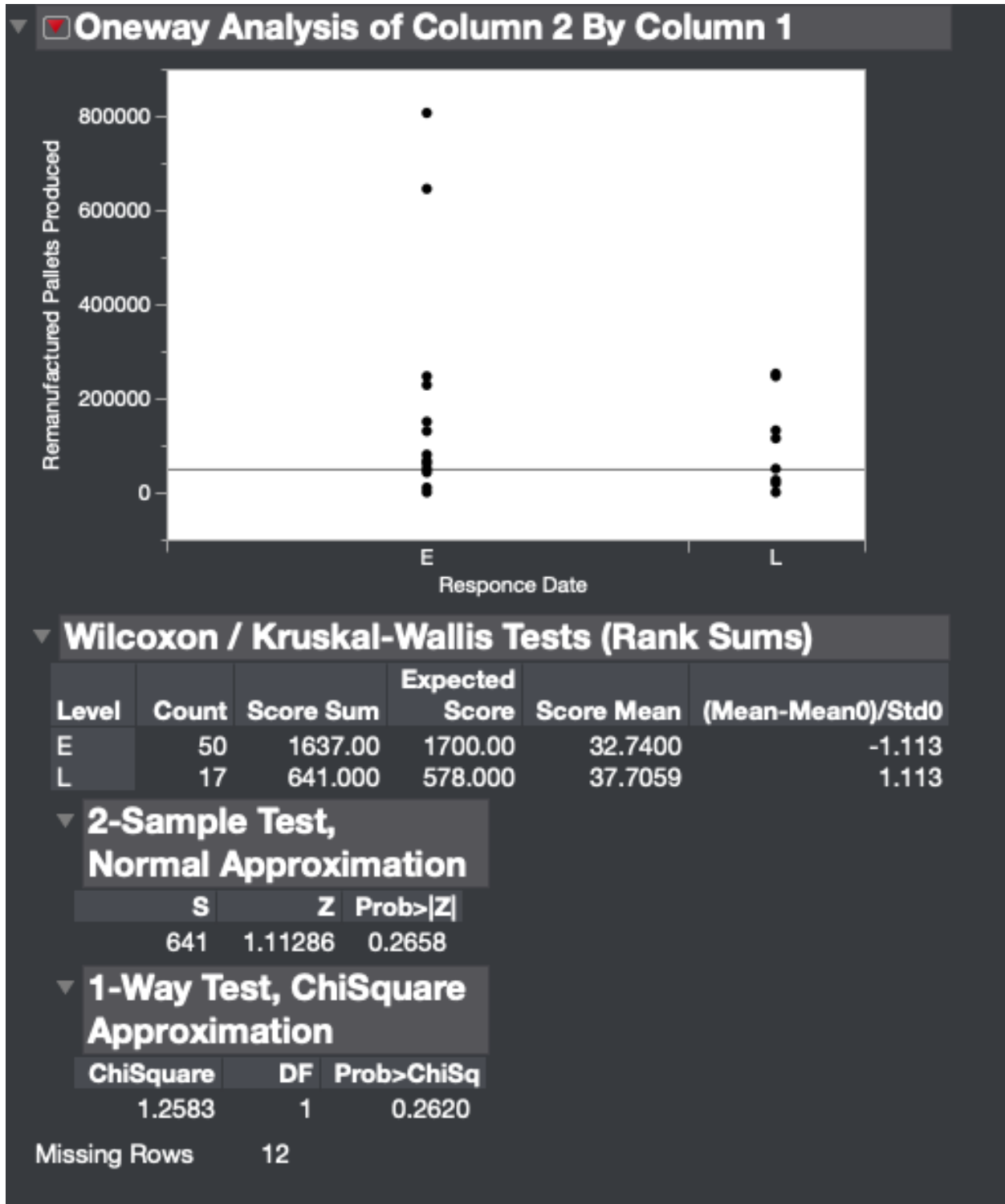
New Pallet Production Wilcoxon Test for Late Response Bias



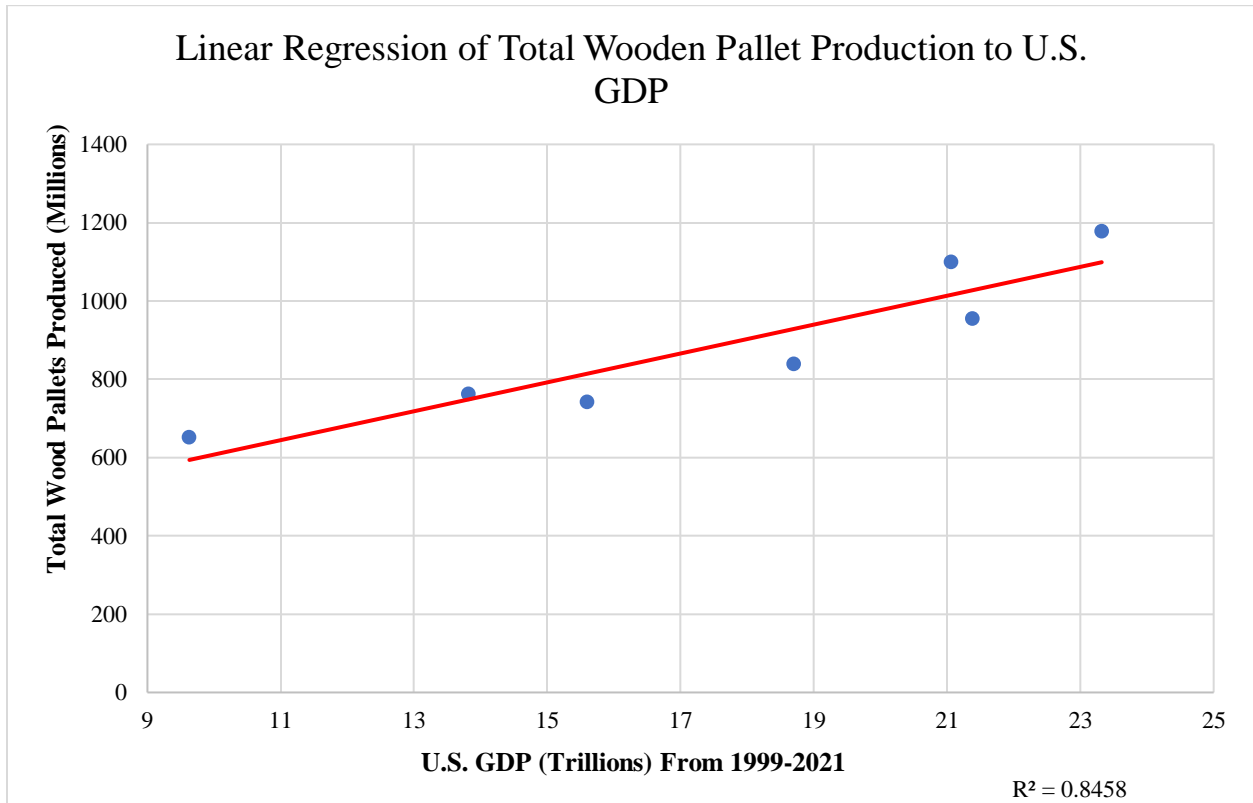
Received Pallet Cores Wilcoxon Test for Late Response Bias



Remanufactured Pallet Production Wilcoxon Test for Late Response Bias



Linear Regression for U.S. GDP



Linear Regression for G.D.P That Manufacturing Accounted for in the U.S Compared to Total Pallet Production

