Investigation of the Status of the Wooden Pallet Market during the COVD-19 Pandemic

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GRAPHICAL ABSTRACT
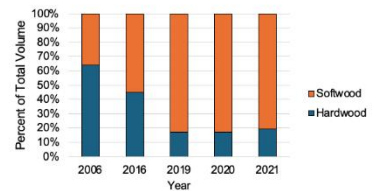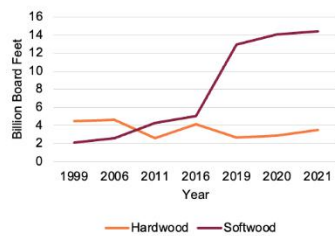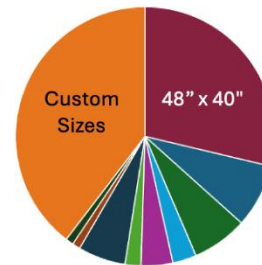
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Sean Hobbs,[a] Laszlo Horvath [ID],[a,*] and Brad Gething [b]

It is estimated that there are 3.1 billion pallets in circulation in the United States, and the majority of these pallets are made of wood. This research was conducted to obtain important information about the market and raw material usage trends in the wooden pallet and container industry from 2019 through 2021. The results revealed that the wooden pallet and container industry produced an estimated 919 million new pallets in 2021, which is an estimated 75% increase over 2016. The 48" x 40" pallet size continued to be the dominant new pallet size with a 29% market share. The share of softwood lumber used in the industry has steadily increased since 2016, and it accounted for 81% of the lumber used in pallet production in 2021. The industry used 38% of the total sawn softwood and hardwood lumber produced in the U.S. The industry also produced 280 million repaired and remanufactured pallets; this is a 16.4% decrease compared to 2016. Approximately 22% of respondents stated that they were not affected by the pandemic. A majority of respondents (51%) stated that they exceeded their 2019 sales, and only 12% saw no change in sales in 2020 compared to 2019.

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INTRODUCTION

The United States (U.S.) is covered with roughly 33.9% of forested land, which translates to approximately 766 million acres. In 2019, 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 and Brandeis 2022). The forest products industry contributes to approximately 4% of the nation's Gross Domestic Product (GDP), which translates to approximately $930 billion (USDA 2022). The amount of forest land area in the United States has continuously increased for a decade (McGinley *et al.* 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 (Conner Industries 2024). Lower quality lumber is used in applications where appearance is not critical, such as railroad ties, gas exploration mats, fence posts, and wood packaging, including pallets (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

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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 at some point transported on pallets (Aldaz-Carroll and Raballand 2007).

Pallets allow for shorter lead times for larger shipments, making the supply chain more efficient. Without pallets, loading and unloading products would require a significant amount of manual labor that would reduce the efficiency of the supply chain (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.* 2020). In 2019, the pallet stock in the United States was 3.1 billion units (Freedonia 2020). Due to the importance of pallets in the supply chain, many researchers have investigated the pallet market over the years: 1991 survey (Christoforo 1993), 1995 survey (Reddy *et al.* 1997), 2006 survey (Bush *et al.* 2011), 2011 survey (Bush *et al.* 2014), and 2016 survey (Gerber *et al.* 2020).

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. (Gerber *et al.* 2020). The majority of wooden pallets produced (61%) were new pallets constructed from new lumber. In 2016, it was estimated that 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 sole interruption occurred during the 2011 survey, which can be attributed to the economic repercussions of the Great Recession and the 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 2017b). The 48" x 40" pallet 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 grocery. Other pallet sizes are specifically created for different industries due to their compatibility with the products that are most-often moved by those 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 software.

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 were an estimated 390 million pallets 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). A study conducted by Shiner *et al.* (2021) revealed that, of the 513 million new pallets produced in 2016, only 13% were disposed of in landfills. Following the pallet recovery process, this figure was further reduced to just 5% (Shiner *et al.* 2021).

Due to the volume of lumber used by the wooden pallet industry, quantifying the environmental impact of wooden pallets has been the focus of multiple research projects

(Bilbao *et al.* 2011; Carrano *et al.* 2014, 2015; Niero *et al.* 2014; Park and Horvath 2018; Deviatkin *et al.* 2019; Koci 2019; Alanya-Rosenbaum *et al.* 2021; Khan *et al.* 2021). There have also been tools put in place by the National Wooden Pallet and Container Association (NWPCA), such as a life cycle assessment (LCA) and subsequent environmental product declaration (EPD), which can help consumers understand the environmental impacts of wooden pallets (Alanya-Rosenbaum *et al.* 2021).

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. Through comparing modern trends to historic trends, companies can adopt competitive strategies as the industry changes throughout the years. This study provides essential information on the current trends of the industry, such as new and used pallet production, lumber usage, heat treatment, pallet 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).

The primary goal of this study was to investigate the usage trends of wood in the wooden pallet and container industry in the U.S. from 2019 through 2021. The following are the objectives of the study: 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 challenges to the U.S. wooden pallet industry during the Covid-19 pandemic.

EXPERIMENTAL METHODS

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 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 those used in VT's 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 from 2021, but questions 5 to 7, which focused on detailed company information, pallet production number, and lumber usage, also collected information for 2019 and 2020. Both surveys had an initial section asking people to skip the survey if they did not produce any wooden pallets, or if they only brokered wooden pallets, 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 provided. This was so that participants could download the survey and see

all of 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. 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 were 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 required responses that add up to 100%, respondents would not be able to move forward until their answers added 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 NWPCA. 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 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 because the survey never reached them. Companies were also 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.

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, then 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%, to minimize bias.

Analysis

Once the data were cleaned and ready to be analyzed, the questions were separated to analyze them for the response rate per question. Percent questions were analyzed by comparing them to previously recorded years to determine what had 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 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 find the % change. More advanced statistics, such as simple linear regressions, were used to compare pallet production in the U.S. to its GDP for the corresponding year. Advanced statistics, such as the Wilcoxson/Kruskal Wallis

tests, were used to compare small, medium, and large companies that reported numerical values that could be statistically analyzed. Some of these comparisons were cores received, and new or repaired/remanufactured pallet production. More details on the data analysis are included in the Appendix.

Late responder bias

When conducting data collection in the form of a survey, there are certain aspects that should be examined to determine whether 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 conducted. Participants who filled out the survey later (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 numbers, as well as the number of pallet cores received.

More survey instruments and all applicable documentations can be found in the Masters Thesis of Sean Hobbs (Hobbs 2024).

RESULTS AND DISCUSSION

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%. The response rate of the current survey was lower than the surveys conducted in previous years (17.4% in 2006, 7.4% in 2016). 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 a survey to avoid issues of insider trading.

The response rate throughout the survey varied per question, as can be seen in Fig. 1. Questions 1 to 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 also 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.
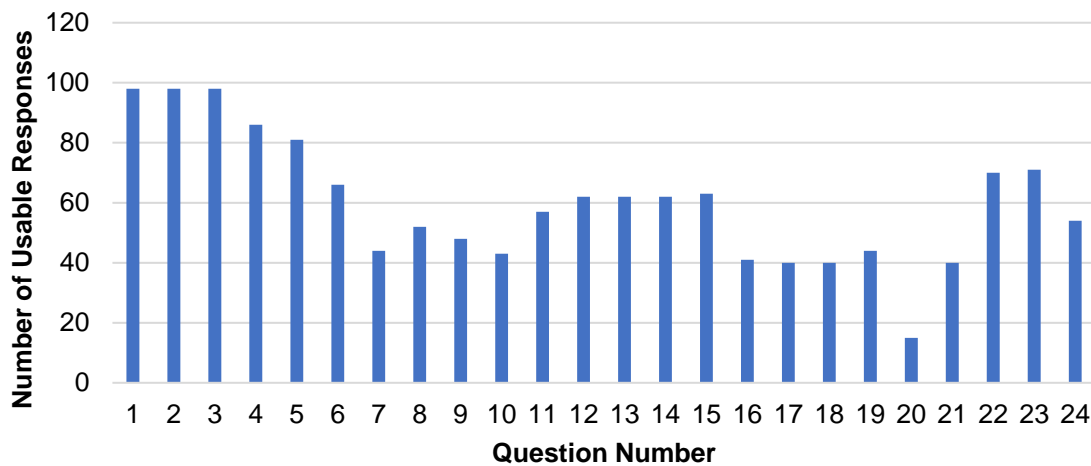

Fig. 1. Bar chart of the cleaned and used responses per question asked. Responses that were deemed to be impractical were removed during the data cleaning process.

According to the 98 responses, the collected data accounted for 212 facilities across the U.S. Respondents were asked what percentages of their sales dollars in 2021 came from five different categories: new pallet production (55.4%), repaired and remanufactured pallets (27.0%), brokering or wholesaling pallets (3.7%), crate manufacturing (3.8 %), and other (10.1%). Compared to historical data, as listed in Table 1, the share of new pallet manufacturing as a percent of sales dollars decreased 3.5% points while repaired and remanufactured pallets increased slightly 1.9% points (since 2011). The largest change seen was in brokering pallets, which increased 11.7% points from 2011 to 2016, then decreased 8.0% points from 2016 to 2021. The share of crate manufacturing also decreased by 2.9% points in 2021, and the share of the other category increased 4.8% points.

Table 1. Products Accounting for the Estimated Largest Sales Dollars for Companies in the Wooden Pallet and Container Industry Between 2011 and 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	27.0	3.7	3.8	10.1

*Data from surveys conducted in 2011, 2016, and 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 26, giving a total of 212 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 (U.S. 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 for products from the spike in e-commerce during the pandemic (Young 2022). As more goods were being shipped, the need for pallets also increased.

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. Although, the total number of recycled pallets decreased compared to the data reported in 2016, the percent of sales dollars from recycled pallets still showed an increase (Table 1). This trend could be caused by the significant increase in recycled pallet cost during the 2019 to 2021 timeframe. When the total number of new pallets produced per responding companies was investigated (Fig. 2), it was observed that in 2021 a higher number of large facilities filled out the survey compared to 2016.

The calculation of new pallets produced per employee per 8-hour shift (Fig. 3) showed that many companies had significantly higher production output per employee 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 (Clevertech 2022). The rise in pallet demand resulted a significant increase in new pallet numbers but in recycled pallet due to the companies using their pallets longer and not sending it to recyclers, which causes broken core availability issues. There was also 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

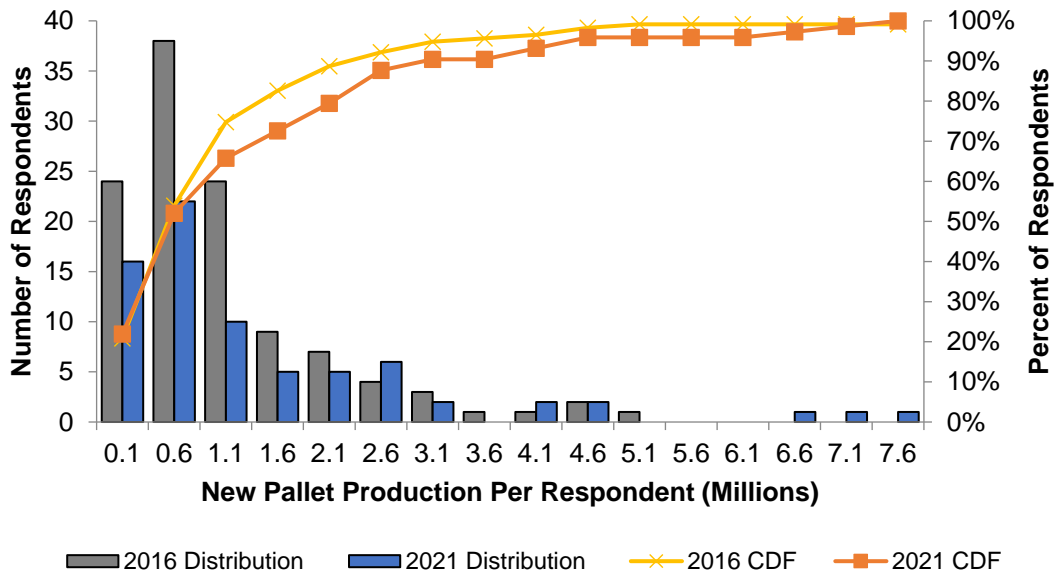*Data from surveys conducted in 2016 and 2021

Fig. 2. Distribution and Cumulative Distribution Function plot of total new pallet production per respondent in 2016 and 2021
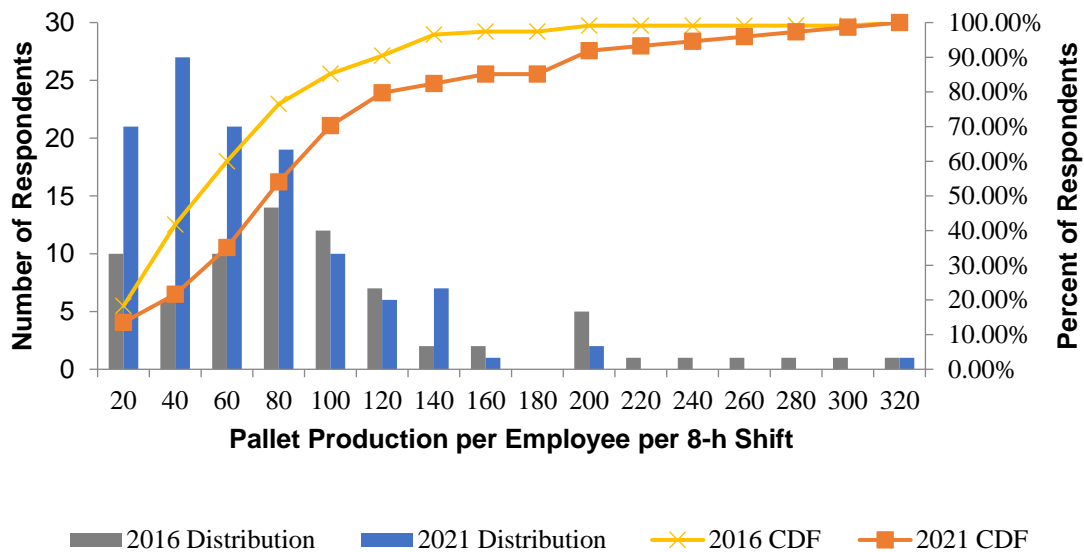

Fig. 3. Distribution and Cumulative Distribution Function plot of total new pallet production per employee per 8-h shift in 2016 and 2021

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% 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 that 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; 31% of respondents reported they produced 10 to 50 variations, 3% produced 50 to 100 variations, and 2% produced 100 to 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 may be 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. Additionally, 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 2023). 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

Year	New Pallet Dimensions (in)									
	48 x 40 (%)	40 x 48 (%)	48 x 48 (%)	48 x 45 (%)	48 x 42 (%)	48 x 36 (%)	42 x 42 (%)	37 x 37 (%)	31.5 x 47.25[1] (%)	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%

[1] 800 mm x 1200 mm Euro pallet
*Data from surveys conducted in 2006, 2011,2016, and 2021

Stringer pallets remained the predominant pallet produced at 77% (Fig. 4). This was only a 1% point increase from the previous survey in 2016. Thus, from the practical point of view, the share of stringer pallets was unchanged since 2016. Block pallets were reported at 19% in 2021, which was a 2% point 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 MH1 2016). Not having bottom deck boards leads skids to be less structurally sound, stable, and durable than traditional pallets. Such 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.
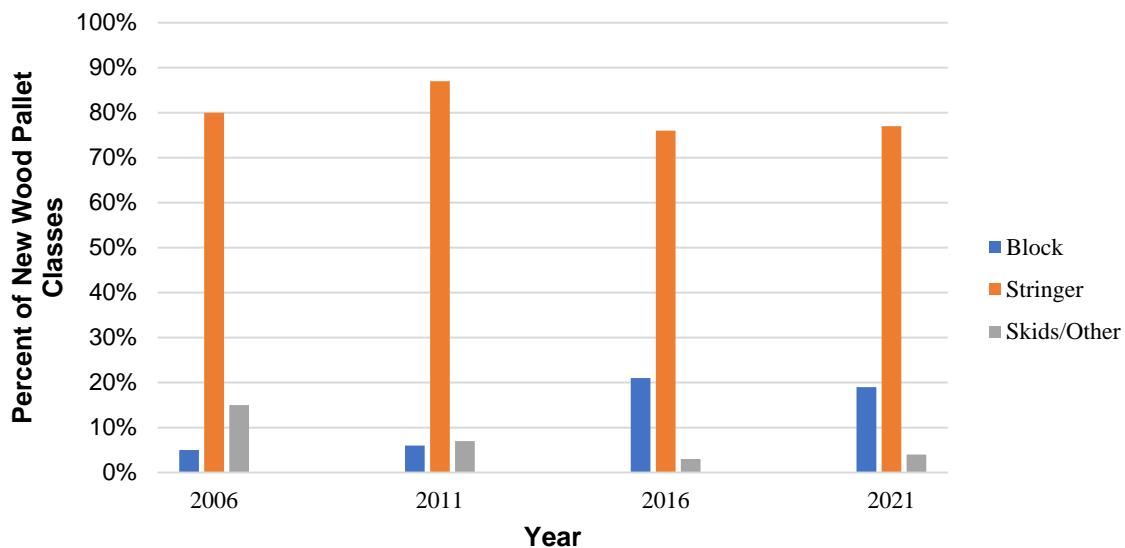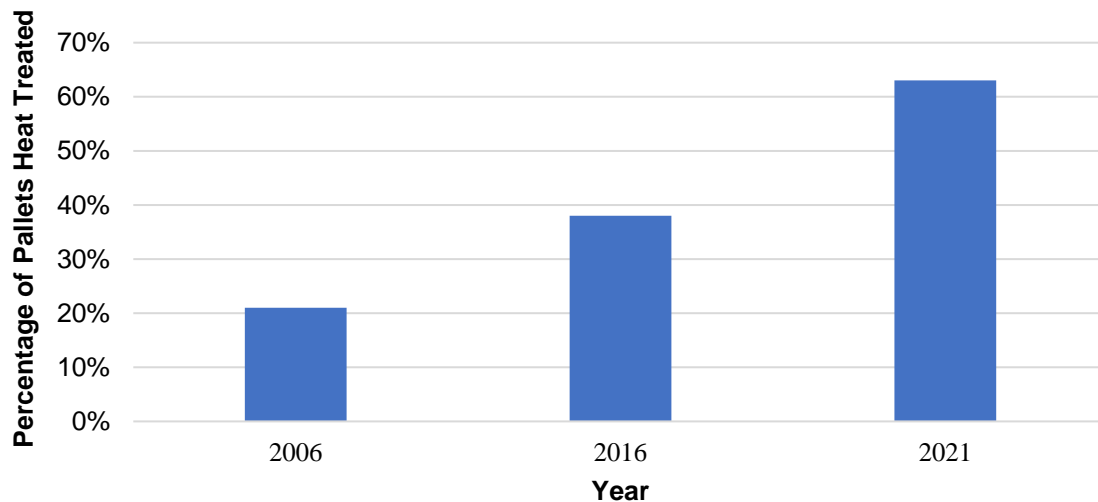

*Data from surveys conducted in 2006, 2011, 2016, and 2021

Fig. 4. Percent of new wood pallet classes between 2006 and 2021

Respondents indicated that 63% of new wood pallets were heat treated (Fig. 5). This is a 25% point increase from 2016 and 42% from 2006. Heat treatment is the most widely used approach to comply with the ISPM 15 (2016) Standard to phytosanitize wood pallets for international trade. Moreover, heat treatment is used in the food and pharmaceutical industry for improved sanitation purposes. 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 1.75 trillion dollars' worth of goods, which was a 20% increase over the 1.45-trillion-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 contamination can cause the food industry, their pallets are required to be as hygienic as possible to reduce the risk of any possible contamination (Boersig and 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 sanitary than non-heat-treated pallets. Additionally, 80% of all products sold domestically are shipped unitized on pallets (Aldaz-Carroll and Raballand 2007).

Along with the percentage of heat-treated pallets, the location of the heat-treatment to 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 °C for 30 min (FAO 2019). Therefore, many of the of the wooden pallet and container companies who purchase kiln-dried lumber parts are already purchasing heat-treated lumber. The rise in heated-treated lumber may also be attributed to the increased

usage of softwood (described later). Softwood is much easier to kiln dry, and kiln-dried wood is less susceptible to other issues such as mold, and thus the increase in heat treatment may occur by association.

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

Fig. 5. Estimated percent of new pallets that were heat-treated between 2006 and 2021

Repaired and Remanufactured Pallet Trends

Respondents reported that 74% of pallet cores received were 48" x 40" stringer pallets while 13% were 48" x 40" block class pallets (Fig. 6). 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 (Brindley 2019). The remaining responses accounted for 11% of other stringer pallet sizes and 2% of other block pallet sizes.

Most of the incoming broken or used cores (78%) were repaired and sold (Table 4). This was a 12% 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. It also can be attributed to the decline in core quality (Brindley 2022). Additionally, as lumber prices reached record highs during this time period, repaired pallets were a cheaper alternative for distributers 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 accounted for only 5%, ground or chipped 5%, landfilled < 1%, and other 1% in 2021. Some notable changes from 2016 are that disassembled cores decreased 7% points and ground or chipped cores decreased 6% points.

Table 4. What Was Done with Received Pallet Broken or Used Cores between 1993 and 2021

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

In 2021, 80% of repaired and remanufactured pallets were 48" x 40" (Fig. 7). This is an 11% point 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% for 48" x 36", 1% for 42" x 42", 1% for 42" x 42", 0% for 800 mm x 1200 mm, and 13% for other sizes. These percentages are of the 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 were from poolers, so they were not eligible to be repaired or sold. Moreover, pallet cores that were not fit for repair were 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. The 48" x 40" pallets remain the vast majority pallet size being repaired due to it being the most abundant specific pallet size used by the most industries.
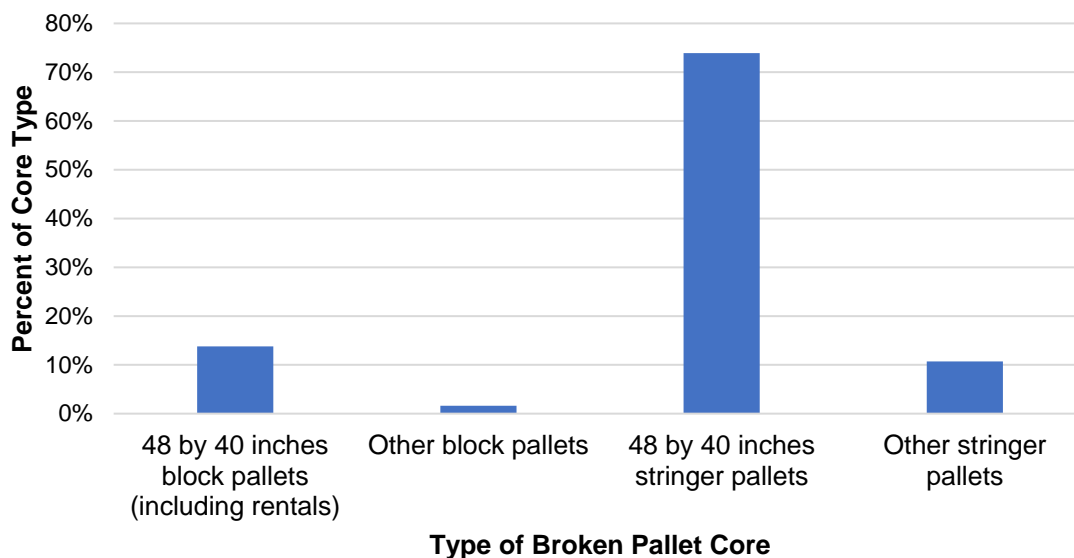

Fig. 6. Types and sizes of received pallet cores

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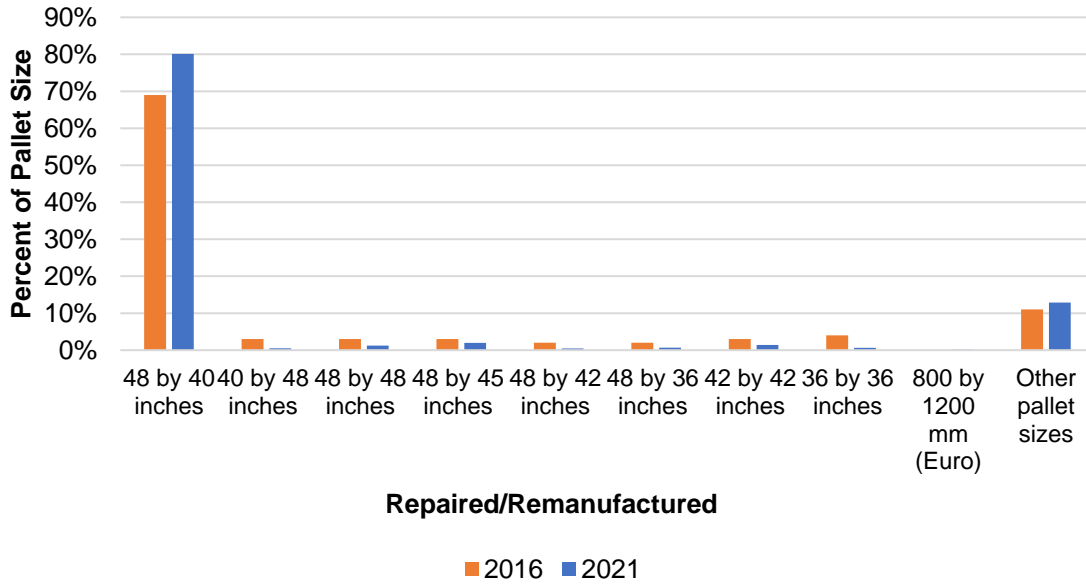
*Data from surveys conducted in 2016

Fig. 7. Percent of different repaired and remanufactured pallet sizes in 2016 and 2021

The final repaired / remanufactured pallet trend investigated was the percent of heat treatment, as shown in Fig. 8. In 2021, respondents indicated that approximately 23% of repaired and remanufactured pallets were heat treated. This was a 15% point decrease from 2016, though it is similar to what was reported in 2006, increasing 2% 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. 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. In addition, export pallets are not as widely used by the food and pharmaceutical industries where pallets are often heat treated to provide increased sanitation.
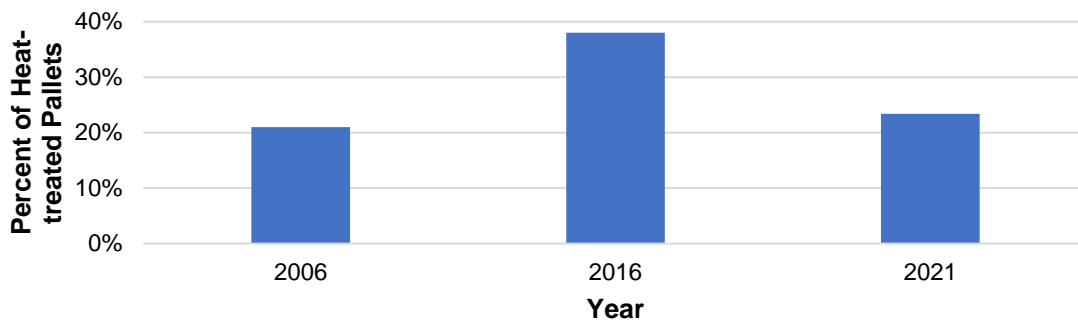
*Data from surveys conducted in 2006, 2016, and 2021

Fig. 8. Percent of heat-treated repaired and remanufactured pallets between 2006 and 2021

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 (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% points and 'other' decreased 22.3% points from 2016. Landscape mulch and animal bedding remained similar with them, being 37.5% and 4.2%, respectively (Gerber *et al.* 2020). However, it is important to acknowledge that the difference between the 2021 and 2016 results could also be due to the lower response rate.

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 (Fig. 9). Comparing this data to the previous research conducted shows a 10% point increase since 2016. However, 48% of respondents indicated that they did not know whether their company used certified lumber. Therefore, the data for 2021 was recalculated, using those who checked 'not known' as non-certified lumber users. This resulted in a decrease in the percentage of certified lumber from 42% to 23%. Comparing this to the data from 2016, there was a 10% point decrease. However, it needs to be mentioned that in the 2016 survey, there was no option for the respondents to select 'not known'; thus, using the current methodology, the 2016 data might have been different. This could be attributed to forest certification growing 88% from 2009 to 2010 (UNECE 2010). Out of the certified lumber used, 22% was from the Forest Stewardship Council (FSC), 76% was from the Sustainable Forest Initiate (SFI), and the remaining 2% came from other certifications (Fig. 10).

Another trend investigated was determining from where imported lumber was coming. 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 in imported lumber; it used to be imported mainly from Canada, but it changed to mainly being imported from South America. Imports from South America increased 67% points while imports from Canada decreased 69% points between 2016 and 2021 (Fig. 11). However, a vast majority of the imported South American lumber total came from one respondent. Without this one response, Canadian lumber would remain the most-imported for pallet production (65%); however, it has still decreased since the previous research. In addition, the share of South American lumber imported 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, without that one respondent. In the last four quarters, lumber imports from Canada have been on the decline. A reduction in the annual allowable harvesting has reduced lumber harvested 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 to 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 Fig. 12, respondents in 2021 reported higher lumber usage on average than in 2016.
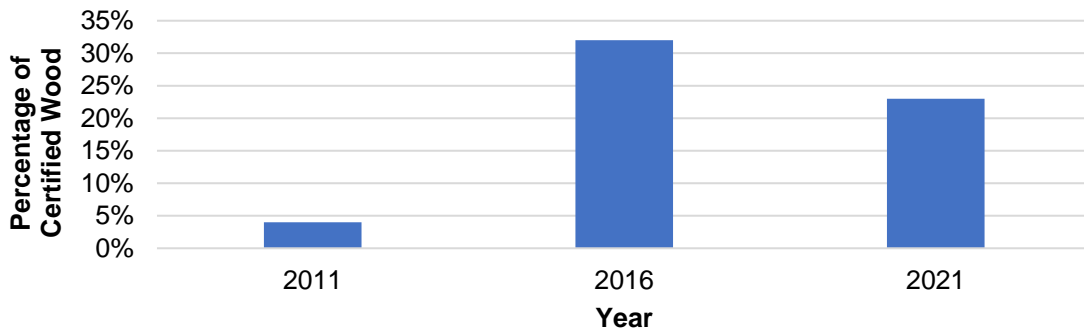
*Data from surveys conducted in 2011, 2016, and 2021

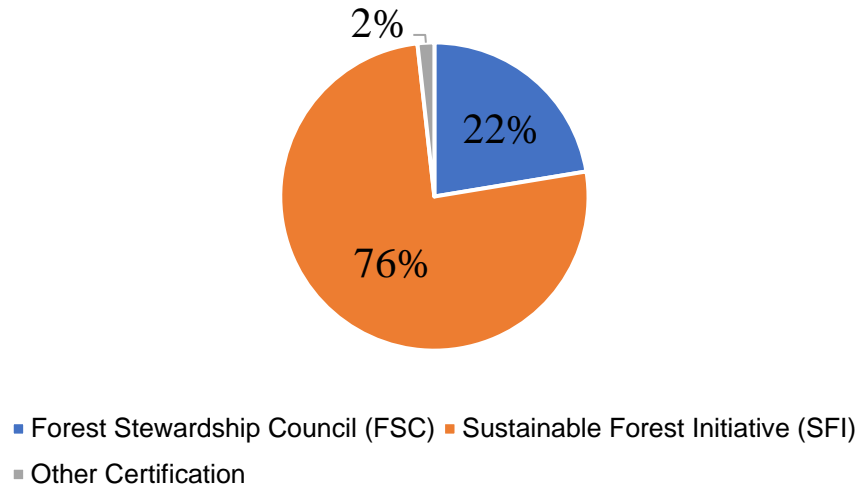**Fig. 9.** Percent of certified new lumber used in pallet production between 2011 and 2021

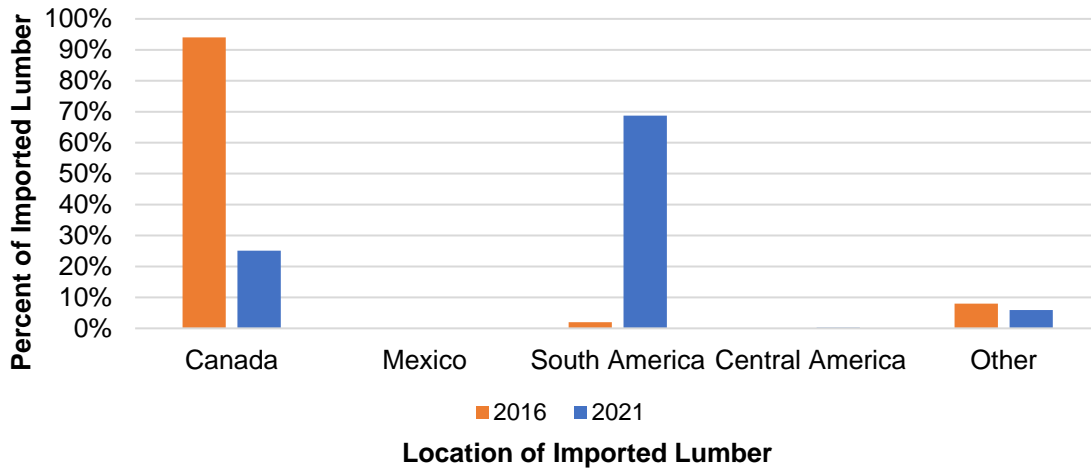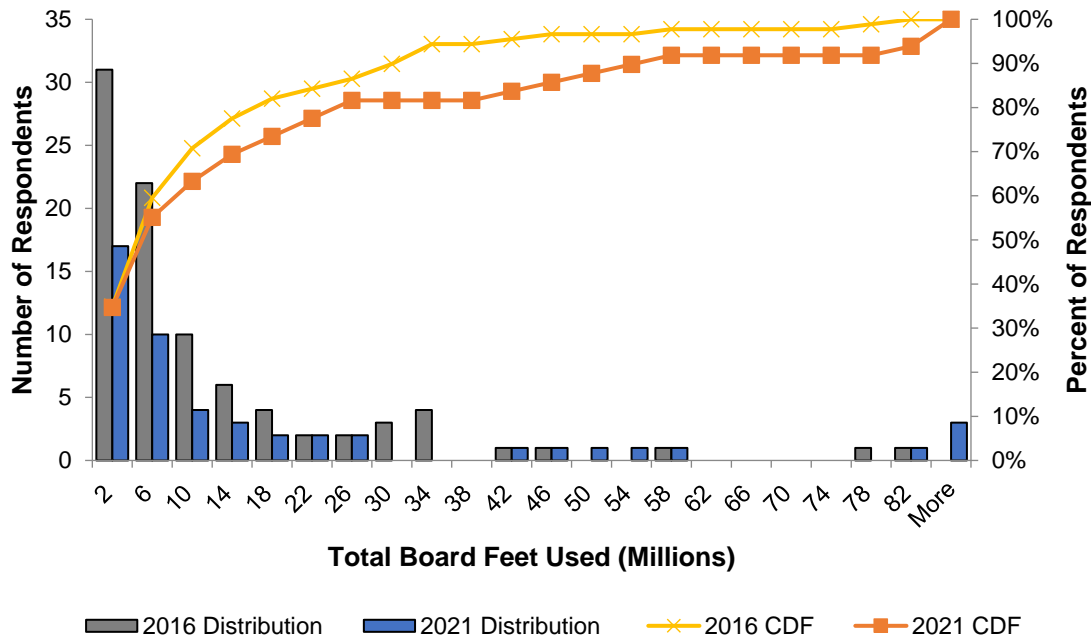**Fig. 10.** Percent forest certification for harvested new lumber in 2021

Fig. 11. Percent location distribution of imported lumber in 2016 to 2021

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

Fig. 12. Distribution and CDF plot of total board feet used in pallet production in 2016 and 2021
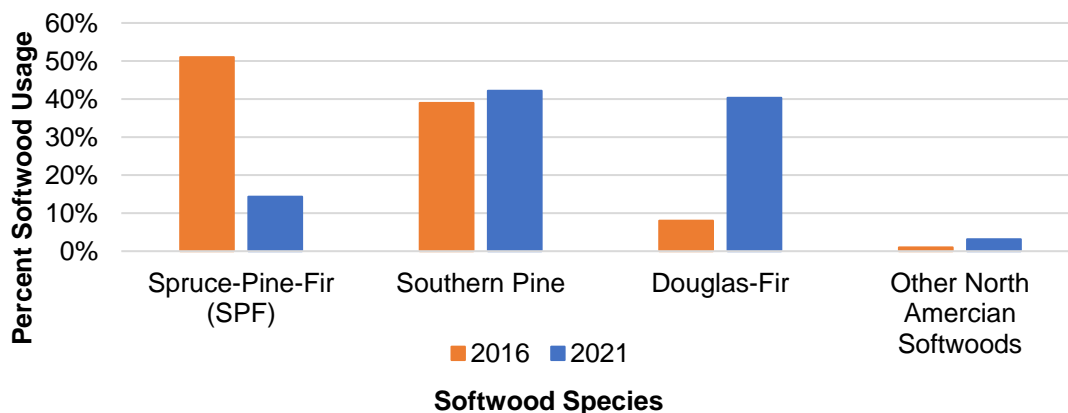
Softwood Usage Trends

Respondents reported the amount of softwoods used between the years 2019 and 2021. There was approximately 13 billion bdft used in 2019, 14.1 billion in 2020, and 14.4 billion in 2021. In 2021, this lumber usage consisted of 38.6% of the sawn softwood produced in the U.S (Alderman and Brandeis 2022). 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 (Fig. 13). Looking at historical trends, 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 pallets were made from hardwoods and only 36% from softwoods. 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 this softwood trend. 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 softwoods (3%) as shown in Fig. 14. Compared to 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 accounted of almost half of the Douglas-Fir usage. If this one respondent is removed, the share of Douglas-Fir (27%) is still greatly increased from previous survey results (8%), while the share of SPF (17%) is still greatly decreased. Meanwhile, the market share of Southern Pine slightly increased, becoming over half of the softwood used. This could be due to declining SPF populations; wildfires and infestations of bark beetles 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% points and lumber parts decreased 10.5% points (Gerber *et al.* 2020).
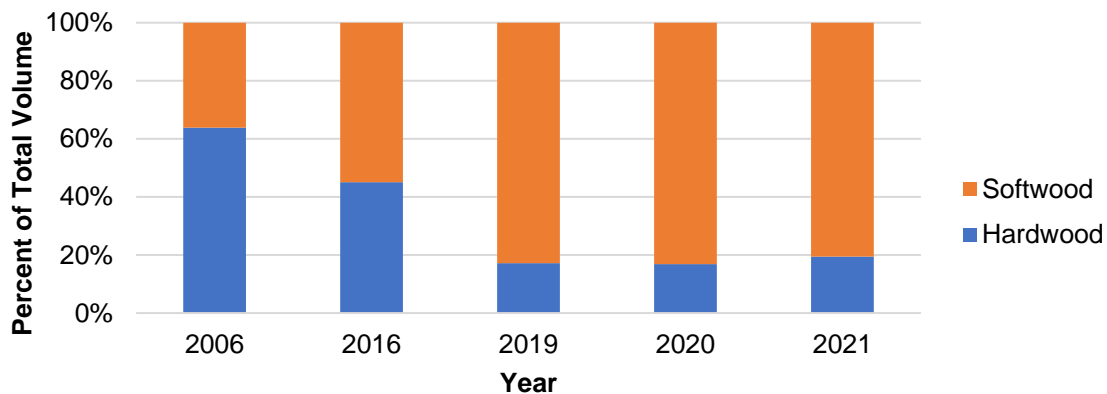
*Data from surveys conducted in 2006, 2016, and 2021

Fig. 13. Percent softwood to hardwood usage between 2006 and 2021

*Data from surveys conducted in 2016 and 2021

Fig. 14. Percent softwood species usage in 2016 and 2021

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 the sawn hardwood produced in the U.S. (Alderman and Brandeis 2022). 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. Compared to the 2016 survey, high-density hardwood usage decreased approximately 20%; low-density hardwoods increased 16%, and medium density increased 4% (Fig. 15). This could be due to the declining number of oak forests, forcing the industry to use more common hardwoods in lower density classes (U.S. National Park Service 2019). 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% points while the use of lumber parts decreased 16.5% points (Gerber *et al.* 2020).

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	4.1	5.0	9.1
2019	2.7	13.0	15.6
2020	2.8	14.1	16.9
2021	3.5	14.4	17.9

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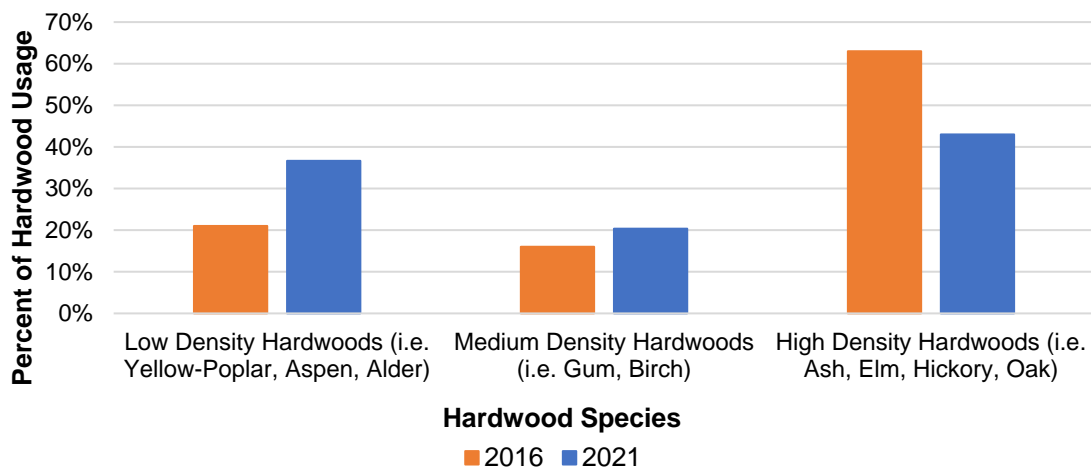
*Data from surveys conducted in 2016 and 2021

Fig. 15. Percent hardwood species usage by density between 2016 and 2021

Covid Questions

Due to the unique timing of this survey, companies were also asked questions about how they fared during the Covid-19 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 after-Covid 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 materials throughout the pandemic. Around 22% of respondents reported that they had some challenges initially but they stabilized throughout the year; 46% reported 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 for 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 for pallets and the labor shortages due to the pandemic, many companies were afraid that pallet manufacturers could not keep up with the increasing demand (Brindley 2021).

Late Response Bias

The final group of data analyzed was the late response bias. Companies who filled out the survey before June 2023 where 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 received pallet cores. Using the Wilcoxon test, no significant differences were found with the p-values of all tests being over 0.05. The statistical analysis was conducted using SAS JMP 16 (SAS Institute, Cary, NC, USA). This shows that there was no bias in response time for this data set.

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. For hardwood usage, the percentages were also around the 5% mark, though higher than the pallet production variation. Finally, the softwood lumber usage saw 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 and 2021

Year	New Pallet Production	Repaired Pallet Production	Harwood Lumber Usage	Softwood Lumber Usage
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

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SUMMARY AND CONCLUSIONS

1. The total production of wooden pallets in the U.S. has increased to 1.18 billion in 2021, which is a 40% increase from 2016. Of the total pallets produced, an estimated 919 million were new pallets and 280 million were repaired/remanufactured pallets.

2. Stringer-class pallets were the predominant class, at an estimated 77%; block pallets accounted for 19%; skids and other accounted for 4%. This remained in line with historical trends of new, stringer-class pallets dominating the industry.

3. The most common size of new pallet produced remained the 48" x 40" (29%). This was a 6% point decrease from 2016; the 40" x 48" pallet increased 8% points due to military needs during the pandemic. Other sized (custom) pallets accounted for 40% of new pallets produced showing the industry's need for customized pallets.

4. The wooden pallet industry consumed approximately 17.9 billion board feet of lumber in 2021. Softwoods accounted for 14.4 billion board feet, which is an estimated 38.6% of all sawn softwood produced in the U.S. Hardwood usage accounted for the other 3.5 billion board feet of lumber used, which was approximately 37.6% of all sawn hardwood produced in the U.S. in 2021.

5. For repaired/remanufactured pallets, an estimated 78% of received pallet cores were directly repaired. This is a 13% point increase from the previous research conducted in 2016. Disassembling pallet cores and grinding them both decreased from 2016 to 11% and 5%, respectively. Approximately 94% of recovered wood pallets were reused or converted to repaired or remanufactured pallets.

6. An estimated 74% of received pallet cores were 48" x 40" stringer-class pallets in 2021. From the repaired/remanufactured pallets produced, 80% were 48" x 40". This was a 11% point increase from 2016.

7. A total of 22% of respondents reported that they were not affected by the pandemic. An estimated 51% of respondents indicated that they exceeded their 2019 pre-Covid sales in 2020, and 12% of respondents saw similar sales post-Covid as they did in 2019. As for employment, only 16% of respondents had to temporarily lay off employees, whereas and only 4% had to conduct permanent layoffs.

8. In regard to procuring raw materials, 54% of respondents indicated that they had no problems procuring materials or had initial problems, but they were able to quickly sort them out; the remaining 46% reported constant problems throughout the pandemic.

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APPENDIX : 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 Burau.
Scale-up factor = (U.S. Census Burau 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 Burau.
Scale-up factor = (U.S. Census Burau 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 reaming 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.

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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.