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

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Abstract

This study was performed in order to acquire key market information and information on raw material usage for the wood pallet and container industry in 2016. Historical trends in the wood pallet market were also analyzed between 1991-2016 using the results of previous Virginia Tech and U.S. Forest Service pallet surveys. Paper mail questionnaires and online questionnaires were sent to 2,520 companies that manufactured or wholesaled wood pallets and crates in the United States to obtain these data.

The wooden pallet and container industry produced an estimated 508 million new wood pallets in 2016, which is a 22% increase since 2011. Approximately 35% of this was 48" x 40" pallets, which continues to be the dominant standardized pallet size. Approximately 39% of new wood pallets were custom sizes which is a significant decrease from the 60% share found in 2011. Stringer class pallets remained the dominant pallet class with 76% share while block pallets and skids only accounted for 21% and 3% of the market, respectively. Approximately, 38% of these new wood pallets were heat treated.

Furthermore, an estimated 341 million pallets were recovered and sold as recycled/repaired or remanufactured pallets in 2016. The most common size of the recycled or remanufactured pallets was 48" x 40", accounting for 69% of the recycled market. Ninety-one percent of recycled or remanufactured pallets were stringer class pallets while block class pallets made up the remaining 9%.

Wood byproduct usage has changed since 2011. The conversion of broken pallets and wood waste to landscape mulch (37.5%) and animal bedding (4.2%) have declined with a proportional increase in other uses (28.3%). Biofuel conversion has remained steady since 2006 at 30%.

General Audience Abstract

This study was performed in order to acquire key market information and information on raw material usage for the wood pallet and container industry in 2016. Historical trends in the wood pallet market were also analyzed between 1991-2016 using the results of previous Virginia Tech and U.S. Forest Service pallet surveys. Paper mail questionnaires and online questionnaires were sent to 2,520 companies that manufactured or wholesaled wood pallets and crates in the United States to obtain this data.

As a whole, the wooden pallet and container industry has shown growth. The industry produced an estimated 508 million new wood pallets in 2016, which is a 22% increase since 2011. Furthermore, an estimated 341 million pallets were recovered and sold as recycled/repaired or remanufactured pallets in 2016. This is a small increase in the recycled/repaired or remanufactured pallet market.

Wood byproduct usage has changed since 2011. The conversion of broken pallets and wood waste to landscape mulch (37.5%) and animal bedding (4.2%) have declined with a proportional increase in other uses (28.3%). Biofuel conversion has remained steady at 30%.

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Introduction

The first official pallet was patented in 1932 by Bill House and George Raymond, Sr. (Raymond 2007). However, the use of pallets only started to grow in the 1940s, as they became valuable tools to ease the demand for increased material handling speed during the Second World War (LeBlanc 2011). Since World War II, the use of pallets has expanded into other industrial applications outside of the military. Today, wooden pallets are used by 93% of material handling companies (McCrea 2016), thus the wooden pallet industry is a key part of the United States economy (Freedonia 2017).

Pallets utilize low-grade lumber that would not readily be used otherwise (Bejune 2001). In 1995, it was estimated that the pallet industry consumed 38% of hardwood lumber produced in the U.S. (Reddy et al. 1997) and 5.6% of U.S.-produced softwood lumber (Bush et al. 1998). In 2006, pallet production accounted for between 30% and 33% of hardwood lumber produced in the U.S. (Bumgardner 2016).

The majority of wooden pallets are newly constructed from new lumber. In 2011, it was estimated that 416 million new wood pallets were produced, accounting for 56.1% of pallets produced. (Bush 2013). This was a 5.7% decrease from the 441 million new wood pallets produced in 2006, which accounted for 57.9% of the pallets produced that year (Bush Araman 2008).

A large proportion of pallets are recovered, repaired, or downcycled as other products. In 2011, it was estimated that 474 million pallet cores were recovered (Bush 2013). Of that amount, approximately 326 million pallet cores were either reused without repair or repaired and then put back into use (Bush 2013). Pallets that cannot be repaired and broken pallet parts can instead be converted into colored and uncolored landscape mulch, animal bedding, biofuel, furnishing for fiber-based products, or other uses (Bush 2014). Less than 1 million cores were sent to landfill from pallet recyclers and remanufacturers.

Due to the volume of new and recovered wood used by the pallet industry, the tracking of historical wood usage and pallet production is important to gauge the current state of the industry. This study provides the wood pallet and container industry with current information on trends in

new and used wood pallet production, wood volumes, heat treatment, and byproduct production. Companies in the industry can adopt business strategies to take advantage of current developments in these trends.

Research Objectives

The main goal of this study was to ascertain the use of new and recovered wood in the wooden pallet and container industry for 2016. A paper survey was administered in conjunction to an equivalent online survey to gather data for the entire industry. With the analysis of the responses, this study accomplished its main objective, which was to determine the status of the wooden pallet and container industry, focusing on the following sub-objectives:

1. Determine the types, volumes, and usage trends of new wood used in the U.S. pallet and container industry
2. Determine the volumes, uses, and trends of used or recovered wood by firms in the U.S. pallet and container industry
3. Determine wood material usage trends for the U.S. pallet and container industry on a national and regional level.

Literature Review

Pallets are portable platforms built for the transportation, storage, and handling of goods (MH1 Committee, 2016). Pallets are often described by "class, use, type, style, bottom deck, size, and design" (MH1 Committee, 2016). Roughly 2 billion pallets are in use in the United States and carry roughly 80% of US commerce (Curran, 2016).

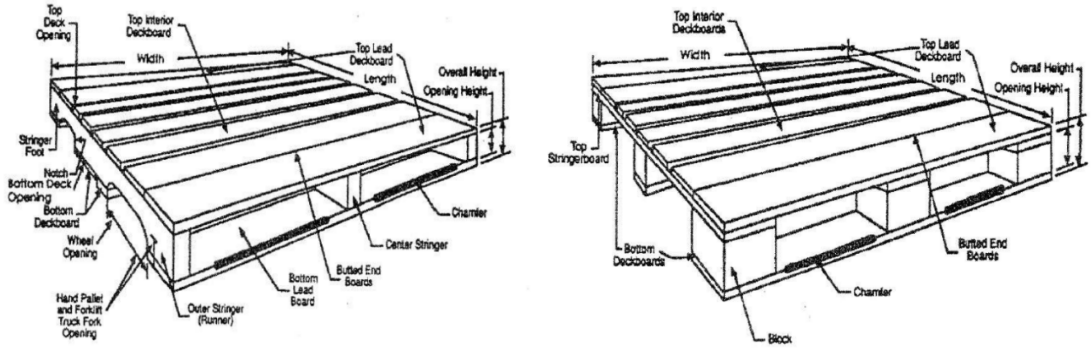
Pallet production is a multibillion dollar industry worldwide and is expected to continue growing (Freedonia 2017). The U.S. is a large part of the global industry, and it was responsible for 28.5% of pallets produced worldwide in 2012 (Freedonia 2017). The largest demand for pallets in North America is from the manufacturing industry, followed by warehousing, then the food and beverage manufacturing industry, and the construction industry (Freedonia 2017). Freedonia estimates that U.S. pallet demand will increase to 2.6 billion units by 2016 (Freedonia 2017).

Pallet Classifications

Pallets are classified into block class pallets and stringer class pallets (MH1 Committee 2016). A stringer pallet is a pallet that has stringers running along the pallet's length (Figure 1). A stringer is a solid or notched beam that supports the pallet decks (MH1 Committee 2016). Stringers are referred to by their location: outer or middle stringer. (MH1 Committee 2016).

Block pallets are pallets where the top and the bottom decks are separated by blocks (Figure 1). The number of blocks commonly ranges between six and nine. A pallet block is a spacer that is often rectangular or cylindrical (MH1 Committee 2016).

Figure 1: A stringer pallet (left) and a block pallet (right) (NWPCA 2014)



Pallets are also classified by use categories. Reusable pallets are built to carry more than one unit load on multiple trips (NWPCA 2014). Single-use pallets are built for one unit load and are not intended to be used for more than one trip (NWPCA 2014).

Pallets have 3 different entry types. Two-way entry pallets only accessible to material handling equipment from either end of the pallet. These pallets are typically unnotched stringer pallets (NWPCA 2014). Partial four-way entry pallets have openings at both ends and both sides but have limited accessibility to material handling equipment on the sides (NWPCA 2014). These are typically notched stringer pallets. Full 4-way entry pallets are fully accessible to material handling equipment from all four sides and are typically block pallets (NWPCA 2014).

Pallet have 3 distinct styles. Single-face pallets have only one deck (NPWCA 2014). Double-face non-reversible pallets have two decks but only one deck can be used as the top deck (NWPCA 2014). Double-face reversible pallets have two decks that can both be used as either the top deck or the bottom deck (NWPCA 2014).

Pallets can be classified based on their top deck constructions. These classifications take into account the number of deckboards or if the top deck is a panel (NWPCA 2014). Pallets can also be classified based on bottom deck constructions. A pallet's bottom deck can have unidirectional deckboards oriented towards either the width or length of the pallet, overlapping deckboards going in both length and width directions, perimeter deckboards that go around the perimeter of the pallet, or cruciform deckboards that are oriented in both the length and width of the pallet as well as along the perimeter (NWPCA 2014).

Pallet Sizes

The size of a pallet is often stated as the length by width by height of the pallet. (MH1 Committee 2016). The length of a stringer pallet is the dimension of the side of a pallet that is parallel to the stringers. The length of a block pallet is the dimension of the side of a pallet that is parallel to the stringerboards (MH1 Committee 2016). For pallets without stringers or stringerboards, the length is the longest side of the pallet. The width of a pallet is the non-vertical dimension perpendicular to the length (MH1 Committee 2016). The height of a pallet is the vertical distance between the bottom of the bottom deck boards to the top of the top deck boards. (MH1 Committee 2016). Pallet sizes are often listed with a tolerance of ± ¼ of an inch (MH1 Committee 2016).

There are approximately two hundred pallet sizes used in industry (MH1 Committee 2016). The most common sizes (listed as length x width) are 48 inches x 40 inches, 40 inches x 48 inches, 42 inches x 42 inches, 48 inches by 48 inches, 48 inches x 42 inches, 48 inches x 45 inches, 37 inches x 37 inches, and 48 inches x 36 inches. Historically, other pallet sizes have made up approximately 50% of pallet production (Redy et al. 1995, Bejune et al. 2002, Bush 2008, Bush 2013).

Common pallet sizes differ from country to country. In Australia, 1165 mm x 1165 mm pallets are common, while 1100 mm x 1100 mm are popular in Asia and 800 mm x 1200 mm pallets are popular in Europe (Tranpak 2018). This variability of pallet size by region makes it difficult to standardize pallet sizes, since there is no true common size worldwide.

Pallet Materials

Common materials for pallet production are wood, corrugated paperboard, metal, and plastic (Millwood Inc.). Wood pallets can be produced from a variety of species from both hardwoods and softwood species, such as pine or oak. These lumber must be, at a minimum, economy grade or better. Paper pallets are manufactured from corrugated paperboard or honeycomb (LeBlanc 2018). Metal pallets are typically steel or aluminum (MH1 Committee 2016). Plastic pallets are made of HDPE or PP (Tranpack).

Pallet Fasteners

A fastener is a nail, screw, bolt, wood screw, lag screw, or staple that is used to connect the components of pallets together. The types of nails used include plain shank, helically threaded, annularly threaded, fluted, or twisted squared wire nails. The types of staples are round wire or square wire. In general, all fasteners should be long enough to penetrate the stringer or block at least 1 ¼ inches when the deckboards are more than ½ inch thick or penetrate at least 1 inch when the deckboards are less than ½ inch thick (NWPCA 2014).

Nail and staple fasteners are specified by one or both of the following characteristics. One of these identifying characteristics is the measurement of physical or mechanical characteristics such as length, wire diameter, thread length, thread-crest diameter, crown length or width, number of rings or helixes, number of flutes, and Morgan Impact Bend-Angle Nail Tester (MIBANT) angle (MH1 Committee, 2016). MIBANT angle is the angle the fastener shank deforms when subjected to a MIBANT test, which is performed when the shank is held in a vice and impacted on the head. The length of a fastener is the measurement from the head or crown of the fastener to the point at the other end (NWPCA 2014). The wire diameter is the diameter of the non-threaded part of the fastener, whereas the thread crest diameter is diameter of the fastener at the widest point of the threads the threads (NWPCA 2014). The thread length is the distance of the fastener's length that

contains a thread (NWPCA 2014). Crown length is the length of the top part of a staple, much like the head diameter is the diameter of a nail's head (NWPCA 2014). The number of flutes refers to the amount of threads in a fastener (NWPCA 2014). The number of helixes is the number of times the flutes ridge up from the fastener along one side of its length (NWPCA 2014). The MIBANT angle the angle the fastener bends when subjected to impacts and is used as an indication of its resistance to bending (NWPCA 2014). The allowable MIBANT angle is larger in single use pallets than in multiple use pallets or repair pallets (MHI Committee 2016). The other identifying characteristic is the "specification of connection design properties" (NWPCA 2014).

Nails and staples are assessed using the Fastener Withdrawal Index, or FWI, which represents the expected effect of deformations to the shank as the nail resists withdrawal (NWPCA 2014). These types of fasteners are also assessed using the Fastener Shear Index, or FSI, a measure of the fastener's resistance to shear relative to a specified quality of nail (NWPCA 2014).

Third Party Management

Third party pallet management is a business model that creates a closed loop system that can help to eliminate pallet waste by allowing pallet production companies to take back their pallets and by using higher quality pallets for multiple uses (ADEQ 2014). This business model allows a company to use a pallet but not own it. The pallet producer still owns the pallet, which will be returned after a specified time. When the pallet is managed by the user this way, it is referred to as pallet rental. Pallet rental encourages the use of higher quality pallets that will deliver goods without breaking apart (Trebilcock 2010).

Third party management also often includes pallet pooling where a group of pallets are "shared amongst participants in the system." (LeBlanc 2017) Pooling systems require heavy use of reverse logistics and pallet repair so the manufacturer can collect the pallets downstream in the supply chain and cycle them back upstream (Debjit et al. 2016). Pallet pooling companies are a large part of the U.S. pallet market. CHEP USA, which is the largest pallet pooling company in

the US, accounted for 20% of pallet usage that year (Trebilcock 2010). The second and third largest pallet pooling companies in the US are PECO Pallet and iGPS (LeBlanc 2017). While PECO Pallet pools wooden pallets, iGPS pools plastic pallets and tracks all of their pallets with radio frequency identification (RFID) (LeBlanc 2017). Currently, approximately 13% of wood pallet users participate in a pooling system (McCrea 2016).

In some cases, third party management is not handled by a specific company, but a trade organization or association. In Europe, the European Pallet Association (EPAL) produces and repairs pallets that are based on their specified design. In 2014, EPAL produced 63.5 million pallets and repaired 21.5 million pallets under their license (EPAL Updates on Production of Euro Pallets 2014). Overall, EPAL has been successful and has been in business since 1991 (Engels 2017). Canada used to have a similar system with the Canadian Pallet Council (CPC), which started in 1977 and ended operations in 2015 (LeBlanc 2016). The CPC offered various benefits to its members, including "entitlement to use CPC pallets," free access "to proprietary, pallet costing software," and overall lower costs of pallets (LeBlanc 2016). An organization similar to EPAL and CPC called 9BLOC, was established in the US in 2011. 9BLOCK aims to "network an industry of exceptional proven resources, while maintaining the entrepreneurial benefits of the pallet industry." (MMH Staff 2012).

Repairing and Recycling/Landfilling of Wooden Pallets

When a pallet has been damaged to the point that its strength of functionality is compromised then the pallet is collected and sent to a pallet repair facility. Damages that would prompt repair include missing or broken deckboards, stringers, or blocks. The exact damages modes are outlined in the Uniform Standard of Wood Pallets by the National Wooden Pallet and Container Association (NWPCA 2014).

Broken pallets (often called cores) are collected from the users by pallet repair companies. When the cores arrive at the pallet repair company, the cores are inspected and split into three categories: does not need repair, needs repair, cannot be repaired.

Pallets that do not need repair have no damages, splits, missing wood, or block twists. They can be resold without repairs of any kind. Pallets that need repair have damages that can range from minor to extreme, but can be repaired with plugs, companion stringers, metal connector plates, replacement blocks, or new fasteners (NWPCA 2014). Pallets that cannot be repaired are those with damages that cannot be remedied by the aforementioned methods, typically cross-grain splits (NWPCA 2014).

The method of pallet repair depends on the damage incurred. For splits in the stringers, metal plates that are a minimum of 2 ¾ inches long and wide can be applied to hold together the split (NWPCA 2014). Metal plates have metal teeth across one face in order to adhere to the wood surface. These plates must be applied to both ends of the split (NWPCA 2014).

Pallets with broken stringers are repaired with companion stringers, which are blocks of wood that act as stringers for the broken part of the stringer (NWPCA 2014). In order of size, they can be full length stringers (spanning the full length of the pallet), half stringers (spanning half the length of the pallet), notched blocks (blocks with a 9” notch and at least 4” on each side), C-blocks (blocks with a 9” half-notch cut into one side), and plugs (a block ranging from 6” – 16” (NWPCA 2014).

Repaired pallets are categorized into three classes. Class 1 or Class A pallets have repaired top and bottom deckboards and one or more stringers can be repaired using metal plates but none of the stringers are repaired using companion stringers. Class 2 or Class B pallets contain one or two repaired stringers using different types of companion stringers. Class 3 or Class C pallets have such extensive damages that they do not meet the criteria for Class 1 or 2 repaired pallets (MH1 Committee 2016. When unbroken wood from broken pallets is used to construct an entirely new pallet, it is called a remanufactured pallet. Some companies, such as Nazareth Pallet Co, claim that this can save them 20%-40% when compared to the cost of new pallets, but it is still less than the

70% cost savings when using recycled pallets (Nazareth Pallet Company 2015). The use of remanufactured pallets grew from 9 million in 1992 to 48 million in 1999 (Bejune et al. 2002).

Pallets that cannot be repaired can be dismantled and converted into other products. Pallet dismantling uses a bandsaw-type machine to separate deckboards from stringers or blocks (Piland 2004). These pallet pieces are either used to remanufacture pallets or are ground or chipped into other products (Staff 2016). These other products include colored and non-colored landscape mulch, animal bedding, biofuels, or as fiber for engineered wood products (Staff 2016).

The recovery and recycling or remanufacturing of wooden pallets has been one of the leading sectors of growth in the pallet industry (Bejune et al. 2002). In 1995, 171 million pallets were recovered and recycled back into the supply stream, which grew to 299 million pallets in 1999 (Bejune et al. 2002). In 2011, 474 million pallets were received by pallet repair companies. Out of these, 326 million recovered pallets were repaired and sent back to the supply stream and 141 million pallets were recycled into other products (LeBlanc 2015). These gains "can be attributed to developments… such as increased profitability, environmental concerns, reduction in users' costs, and low barriers to entry" (Bejune et al. 2002). Pallets that have not been collected by a pallet repair company are typically sent to municipal solid waste landfills for disposal. In 1995, it was estimated that 181 million wood pallets went to landfill (Redy et al. 1995). From those, only 17% were recovered that year.

Alternative Pallet Materials

Although wooden pallets are used by 91% of all companies (McCrea 2016), not all pallets used in the U.S. are made of wood. The most common alternative materials for pallet construction are plastic, corrugated paperboard, and metal. Each of these materials has its own properties that determine the particular use of the pallet.

Plastic pallets entered the packaging and transportation industry in the 1960s (LeBlanc 2011). While wood is the dominant material used in the pallet industry, plastic pallets are used for applications that require greater sanitation (LeBlanc 2011). "Plastic pallets are relatively light,

durable, and resistant to moisture" (Lee, 2004). This makes them ideal for transporting unit loads through areas that are likely to be high in ambient moisture. They are most commonly made of high-density polyethylene (HDPE) or polypropylene (PP). As they are not made of woody materials, they are not subject to the phytosanitary regulations that are mentioned in ISPM-15 (ISPM 2015). One major issue with plastic pallets is that, due to the low modulus of elasticity of plastic materials, they are more flexible and exhibit high levels of creep. Plastic pallets typically also cost more than wood pallets. Due to their high initial cost, they are often used for closed loop applications, where they will not be lost in transit. Plastic pallets make up the 2nd largest share of the market after wood pallets, with 37% of companies in the U.S. using plastic pallets (McCrea 2016). The plastic pallet market generated $1.2 billion in the U.S. in 2016 (Freedonia 2017).

Corrugated board pallets (referred to in the industry as corrugated) first entered the market in the 1970s (Nelson, 2006). They are often made of double or triple wall corrugated boards, yet they are the lightest pallets in the industry, weighing in at only around 12 pounds (Triwall 2004). This helps reduce costs during shipping, especially in airfreight. They are also easily recycled which reduces their impact to the environment (UPS 2005). The major downside is that they degrade with contact to moisture, making them unsuitable for use in many of the current methods of product transportation (FedEx 2016). Corrugated paper pallets do not make up a large portion of the market. There are only 41.1 million corrugated pallets in use which makes up 3% of the worldwide market (Freedonia 2017).

Metal pallets were introduced after the Second World War (Lee 2004). Originally, they were made from rolled and welded steel, but aluminum pallets have come into the market as well. Regardless of the type used, metal pallets are the most durable and sanitary pallets that can be purchased. However, they are expensive. In addition, they tend to weigh more than other pallets which significantly increases the shipping costs. They are mostly used in closed loop systems where high load capacity is required. The military uses metal pallets to carry ammunition and supplies (MIL-STD-1660). Metal pallets make up a small share of the market, with only 5% of companies in the U.S. using metal pallets. (McCrea 2016).

There are other materials that can be used to make pallets, but these are materials make up a lower percentage of the market. Examples are wood composite pallets and wood-plastic hybrid

pallets. Wood composite pallets are made of engineered wood, such as oriented strand board (OSB) and plywood. Hybrid pallets are made of a combination of wood and other materials, such as plastic blocks (Millwood Inc. 2017).

Economic Factors

The wooden pallet market is closely tied to the lumber market, as lumber is the main raw material used in pallet production. In 2012, the boom in exploration for natural gas and associated pipelines increased the demand for hardwood to produce temporary board roads and crane mats (Johnson 2016). This increase in demand for hardwood lumber left little supply for others, such as the pallet industry. Hardwood pallet production fell, and softwood pallet production dominated the market (Johnson 2016). The natural gas boom is mostly over, returning the hardwood to related markets (Johnson 2016). Hardwoods have come back to dominate the pallet market again, but it is still to a lesser degree than before the natural gas boom (Johnson 2016).

Due to its reliance on the lumber industry, the pallet industry was also heavily affected by the housing market (McBee 2008). During the housing crash starting in 2006, several hundred smaller sawmills went out of business, reducing supply for both the high-quality lumber used for housing and the low-quality lumber used for pallet production (Guy Lumber Floor Service Inc 2014). During this time, pallet production fell significantly, practically mirroring the housing industry (McGinley 2017). The pallet industry has recovered from the recession in 2009 and is expected to grow at a rate of 2.6% annually (McGinley 2017).

The Softwood Lumber Agreement, an agreement between the US and Canadian governments, seeks to remedy price discrepancies on the stumpage of softwood lumber between Canada and the US governments (Parajuli et al. 2015). Canada subsidizes its softwood lumber, allowing Canadian softwood lumber producers to sell at prices that US-based companies believe are unfairly low (Parajuli et al. 2015). These US-based companies have lobbied the US government to intervene, causing high tariffs on lumber imported into the US from Canada. The US and Canadian governments have come up with temporary solutions to this trade war, known as the

Softwood Lumber Agreement. The most recent Softwood Lumber Agreement was enacted in 2006 and significantly reduces tariffs on US imports from Canada and gives Canadian companies 2 options: export to the US with a higher tariff or export to the US with a lower tariff but a size restriction (SLA 2006). These higher tariffs have not significantly impacted the flow of Canadian-sourced softwood into the US (Parajuli et al. 2015). However, the tariffs have cost US consumers of softwood $2.3 billion and have produced a $1.6 billion gain for US softwood lumber producers (Parajuli et al. 2016). The Softwood Lumber Agreement of 2006 expired in 2015 (SLA 2006) and the US has no intention of reinstating it with the current administration, instead intending to increase tariffs to 20% (Lee 2017). It is estimated that doing so will reduce wages for American workers by $500 million (Lee 2017).

Transportation

The type of transportation methods the pallet will experience determines the size and type of pallet used. For example, air freight requires partial or full four-way entry pallets, whereas truck freight does not require full four-way pallets (UPS 2005) Pallet size can affect space efficiency in the transportation method; some companies use this factor to help determine the transportation method for their unit loads when they have the luxury of choosing (White 2018).

The rail transportation system relies on trains to move products from place to place. Railways are preferred in the U.S. for moving bulk loads of products more than 750 miles (Railroad Transportation 2001). In the U.S., there are seven main rail systems that determine the movement of products (Federal Rail Administration 2016). In 1999, rail transportation was the 2nd largest transportation industry sector, accounting for approximately 25% of intercity freight (Railroad Transportation 2001). In 2010, railroads were the largest freight industry sector in the U.S. making up almost 40% of ton-miles (miles traveled multiplied by tons carried) transported (Federal Rail Administration 2016). Currently, the railroads are a $60 billion industry.

Truck freight is often relied on for transportation below 750 miles (Railroad Transportation 2001). Below that threshold, trucks dominate the market. Truck delivery is faster than rail delivery and is even used for transportation over 750 miles when time is a critical factor (Railroad Transportation 2001). Trucks can ship either as TL (Truck Load) or LTL (Less than Truck Load)

(Freightquote 2015). Shipping TL uses the full space or weight capacity of the truck and is often used when shipping enough items to fill the truck and/or when delivery is time sensitive. Shipping LTL uses less than the entire space or weight capacity of the truck, and it is often used for shipping loads of less than 15,000 pounds (Freightquote 2015). In 1999, truck transportation was the largest transportation industry sector (Railroad Transportation 2001). Truck freight comprises 28% of the ton-miles moved in the freight industry (Federal Rail Administration 2016). This industry is responsible for more than 50% of tonnage moved between cities and more than 70% of small package shipments (Truck Transportation 2001).

Water freight is mainly used for transporting bulk goods (Water Transportation 2001). The water freight industry uses four main modes of transportation: coastwise, lakewise, internal, and intra-port (Water Transportation 2001). The most-used of these four modes is internal, which accounts for more than 50% of tonnage moved. Use of water freight has declined from 1989 to 2016 (Federal Rail Administration 2016). In 1989, this industry sector accounted for 1,017 million tons, or 16% of intercity tonnage, which fell to 1,006 million tons, or 12.5% of intercity tonnage in 1998 (Water Transportation 2001). Water freight accounted for 12% of ton-miles shipped in the U.S. in 2016 (Federal Rail Administration 2016).

Air freight has historically had low use in domestic transportation, but it remains the biggest competitor of water freight in international cargo transportation (Air Transportation 2001). In 1999, air freight accounted for 12 billion ton-miles of international trade, which is less than 1 percent of ton-miles in the U.S. freight transportation industry (Air Transportation 2001). Air freight's place in the transportation market has remained fairly stable over the last 20 years and accounted for less than 1 percent of ton-miles in the U.S. transportation industry in 2016 (Federal Rail Administration 2016).

Wood Properties

Wood is a complex and variable material that can make engineering a consistent product difficult. It is anisotropic, with three axis that all have different physical and mechanical properties from each other. The longitudinal axis is in-line with the grain of the wood. The radial axis cuts

through the grain and goes through the center of the tree. The tangential axis cuts through the grain. It does not go through the center of the tree, but instead, it lies tangential to growth rings (Hoadley 1990).

There are two differentiated wood species categories: hardwood and softwood. Softwoods have a cellular structure that is more uniform than hardwoods. Softwoods are composed of tracheids and sometimes resin canals surrounded by epithelial cells (Hoadley 1990). Hardwoods are composed of pores, fibers, ray cells, and fewer tracheids than softwoods (Hoadley 1990). Geographical regions have different naturally growing prevalent species, so the materials available for pallet construction change by region. For example, longleaf pine grows mainly in Florida and Georgia but does not grow in the Northeastern, Midwestern, or Western states. A change in species of lumber has a major effect on various pallet properties, including the compressive strength, tensile strength, specific gravity, shrinkage and swelling rates, and modulus of elasticity. This change in properties can affect the whole design of the pallet, as a higher-density wood will have thinner pallet deckboards to support the same weight.

Wood characteristics such as knots and grain slope can alter the strength of the wood. Wood pallets are categorized into different grades based on the quality of the lumber. Common pallet grades include: select, premium, standard, utility, and economy (Ulrich et al. 2012). Being a natural material, wood can harbor a variety of insects such as the emerald ash borer beetle. Some of these insects are regulated by ISPM 15 because they can cause severe damage to naturally growing forests if they end up traveling to countries where they have no natural predators. Therefore, all solid wood pallets need to be either heat treated or Methyl-bromide fumigated to kill the insects harboring inside the pallet components. Due to the high moisture content of the wood components used in pallet construction, wood pallets often have mold growth which can lead to health risks and product damage if improperly managed.

Wood is the most “abundant, cost competitive, and environmentally friendly” resource (BAMF 2004 pg 1). Wood’s abundance has given rise to a variety of uses. Wood lumber can be used structurally for buildings. Trees can be chipped into mulch. Wood fibers can be made into paper. The U.S. lumber industry generates more than $3 billion annually (US Lumber Coalition

2016). Despite its challenges, wood is a cheap and plentiful resource. Wood pallets make up between 90 and 95 percent of the U.S. pallet industry (Bush 2013).

Previous Surveys

Surveys have catalogued the trends of the wooden pallet and container industry for the past 20 years (1992, 1995, 1999, 2006, 2011).

In 1992, Virginia Tech conducted a survey of the U.S. pallet and container industry to catalogue wood use in the industry (Cristoforo et al. 1993). The study found that approximately 4.6 billion board feet of hardwood was used for pallet and container production in the U.S. in 1991 while softwood use was at 2.1 billion board feet. The most used hardwood species was oak. The most used softwood species group was southern pine. The survey was administered to approximately 3,000 firms and had a 36% adjusted response rate.

The survey conducted in 1995 found that U.S. hardwood use had grown to 4.7 billion board feet (Reddy et al. 1995). The same study found that softwood use had fallen to 1.8 billion board feet. The most used hardwood species was mixed hardwoods (with no species separation), oak was still the most used single species. The most used softwood species was again southern pine.

Prior to the 1999 survey (Bejune et al. 2002), the U.S. Census switched from using Standard Identification Classification (SIC) codes to the North American Industry Classification System (NAICS). Thus, the survey study drew parallels between SIC 2441 (wood boxes and shook), 2448 (wood pallets), and 2449 (wood containers not classified anywhere else) and NAICS 321920 (wooden pallets and containers). This survey found that hardwood had fallen to 4.4 billion board feet while softwood had grown to 2.1 billion board feet. The most used hardwood species was mixed hardwoods, followed by oak as the most used single species. The most used softwood species was southern pine. The study found that around 48 million pallets were recovered and un-nailed, either to be used to repair other pallets or to be ground or chipped and sold as another product. This survey's adjusted response rate was 26%.

The 2006 survey (Bush 2008) was the first to ask about phytosanitary treatment, and they found that 21.4% of all wood in the pallet and container industry was heat-treated. It was found

that 6 million board feet of hardwood was used by the industry while softwoods accounted for 1.26 million board feet in the industry. The highest use of hardwood was mixed hardwood, followed by oak. The most used softwood species group was southern pine. 460 million used pallets were purchased, of which 311 million were either repaired or un-nailed and used to repair other pallets.

The most recent survey of the industry was conducted in 2011 (Bush 2013). It found that 37.6% of all new wood pallets were heat-treated, and 12.2% of used pallets were heat-treated. The industry used 2.56 billion board feet of hardwood and 4.31 billion board feet of softwood. The largest use of hardwood was mixed hardwood, followed by oak. The most used species of softwood was southern pine. It was found that only 3.8% of new wood used in pallet and container production was environmentally certified. Around 474 million used pallets were purchased for reuse, repair, or disassembly.

Freedonia, Inc. conducted several surveys about the worldwide pallet industry in 2002, 2007, and 2012 (Freedonia 2017). Questions were asked about pallet materials, pricing, and location. Growth rates were forecast for 2017 and 2020. The report found that the pallet market in North America was 1,290 million pallets in 2012 and expected to rise to 1,540 million pallets in 2017. The study found that wood was, globally, the most highly used material to make pallets, and worldwide, wood pallets are a $13.4 billion industry. This is the largest segment of the global pallet industry, and the 2nd largest is plastics at $1.2 billion. The study also found that average global pallet prices are expected to rise between 1 and 2 percent from 2014 and 2019, depending on the material used.

Regional Trends

Pallet and container surveys of the U.S. have been looking at wood use and pallet production rates on both the national scale and on the scale of geographical regions. The US Census Bureau has divided the US into four geographical regions: Northeast, South, Midwest, and West.

Pallet and container companies in the West have a historically large consumption of softwoods. In 1991, the West consumed over 800 million board feet of softwood parts and 47% of all softwood lumber and cants produced in the U.S. (Christoforo et al. 1993). In 1999, the West consumed the 2nd largest amount of softwoods, at 758 million board feet and the lowest amount of hardwoods at 109.4 million board feet (Bejune et al. 2002). In 1991, the most used hardwood species in the West was Alder (Christoforo et al. 1993). This remained unchanged through 1999 (Bejune et al. 2002). This trend could not be recorded further because, in 2006, alder was combined with other wood species into mixed hardwoods, which became the most used wood category in the West (Bush 2008). In 1999, the most used softwood in the West was spruce-pine-fir, which continued to be the most used softwood in the West in 2011 (Bush 2008, Bush 2013). In 1999, the West produced the fewest new pallets, at 33.7 million pallets (Bejune et al. 2002). This grew to 311 million new wood pallets in 2006, causing it to be the 2nd largest producing region of new wood pallets in the U.S (Bush 2008). The West also produced the fewest recovered pallets in 1999 at 33.7 million (Bejune et al. 2002). In 2006, the West maintained the lowest recovery of used wood pallets, reclaiming 63.8 million (Bush 2008). In 2011, the West became the region with the 2nd lowest recovery of used wood pallets, taking in 74 million (Bush 2013).

Hardwood historically dominates the Midwest pallet markets. The pallet and container companies in the Midwest consumed less than 1,500 million board feet of hardwood in 1991 (Christoforo et al. 1993), 1,527.9 million board feet in 1999 (Bejune et al. 2002), and 1,451 million board feet in 2006 (Bush 2008). This fell to 935 million board feet in 2011 (Bush 2013). In 1999, the most used hardwood species category in the Midwest was mixed hardwoods (Bejune et al. 2002), which continued into 2011 (Bush 2013). The Midwest consumed less than 400 million board feet in 1991 (Christoforo et al. 1993), 460.5 million board feet in 1999 (Bejune et al. 2002), 421 million board feet in 2006 (Bush 2008), and 791 million board feet in 2011 (Bush 2013). In 1999, the most commonly used softwood species was southern pine, followed closely by spruce-pine-fir (Bejune et al. 2002). In 2006, spruce-pine-fir dominated the softwood market and continued to do so in 2011 (Bush 2008, Bush 2013). The Midwest recovered the 2nd highest amount of used pallets in 1999 (Bejune et al. 2002), and continued as the region to recover the 2nd largest amount of used pallets through 2011 (Bush 2013).

Pallet companies in the Northeast consumed more than 600 million board feet of hardwood in 1991 (Christoforo et al. 1993), 781 million board feet in 1999 (Bejune et al. 2002), 858 million board feet in 2006 (Bush 2008), and only 573 million board feet in 2011 (Bush 2013). The Northeast also consumed less than 200 million board feet of softwood in 1991 (Christoforo et al. 1993), 119.5 million board feet in 1999 (Bejune et al. 2002), 114 million board feet in 2006 (Bush 2008) and 276 million board feet in 2011 (Bush 2013). The most used hardwood category was mixed hardwood in 1999 (Bejune et al. 2002), which continued to dominate the hardwood market in 2011 (Bush 2013). The most used softwood species was southern pine in 1999 (Bejune et al. 2002), which changed to imported softwood species in 2006 (Bush 2008). In 2011, southern pine once again became the most used softwood species (Bush 2013). The Northeast had one of the smallest pallet recovery markets, since it was the region with the 2nd lowest recovery rate in 1999 (Bejune et al. 2002) through 2006 and became the region with the lowest used pallet recovery market in 2011, recovering only 61 million (Bush 2008, Bush 2013).

Pallet companies in the South historically have used a large amount of hardwood. They consumed 1.500 million board feet of hardwood in 1991 (Christoforo et al. 1993). They consumed 1,993.1 million board feet of hardwood in 1999(Bejune et al. 2002). The South consumed 2,290 million board feet in 2006 (Bush 2008) and 873 million board feet in 2011 (Bush 2013). The South consumed more than 400 million board feet of softwood in 1991 (Christoforo et al. 1993), 791 million board feet in 1999 (Bejune et al. 2002), 709 million board feet in 2006 (Bush 2008), and 1,195 million board feet in 2011 (Bush 2013). The most used hardwood category in 1999 was mixed hardwood (Bejune et al. 2002), which continued to be the most used hardwood type in 2011 (Bush 2013). The most used softwood species in 1999 was southern pine (Bejune et al. 2002), which continued to be the most used softwood in the south through 2011 (Bush 2013). The South has had the largest wood pallet recovery market, recovering 156.4 million in 1999 (Bejune et al. 2002), 180.4 million in 2006 (Bush 2008), and 204 million in 2011 (Bush 2013).

Chapter 3: Methods

Survey

A database of companies in the wooden container and pallet manufacturing industry (NAICS 321920) was purchased from the NAICS Association (Rockaway, NJ) and was then combined with a list of companies from the National Wooden Pallet and Container Association (NWPCA) to create the list of companies used for this study. Adding the NWPCA database may have biased results towards larger production numbers. The addresses were run through the Virginia Tech mailing service (Blacksburg, VA) for to ensure they were valid addresses. Duplicates and invalid addresses were removed, leaving 2,520 companies in the industry to survey. To ensure survey reliability, the first question of the survey asked for those that were not in the industry to not answer questions but to return the survey with a pre-paid postage envelop. Each company was contacted and asked to provide information on raw material usage in their pallet and container production operations, production numbers for different sizes and classes of pallets, and non-confidential business information among other questions. The business information asked about included data on the distribution of sales between goods and services, employee numbers, days in operation, and average number of shifts for the calendar year 2016. Some questions were asked in a way to allow for differentiation within four geographical regions. The regions used were the U.S. geographical regions as defined by the U.S. Census Bureau: Northeast, Midwest, South, West (U.S. Census Bureau).

Data were collected through the use of a mailed questionnaire based on previous Virginia Polytechnic Institute and State University surveys **(**Bejune 2002, Cristoforo et al. 1993, Reddy et al. 1995, Bush and Araman, 2008**)**. An IRB exemption was obtained to allow this survey. Many questions in the questionnaire were changed from the previous surveys in order to refine the type of data collected, but the questions were kept similar enough to allow for historical comparisons. All questions were reviewed for validity by the Science and Technology Committee of the National Wooden Pallet and Container Association (Alexandria, VA) as well as Virginia Tech's Laboratory for Interdisciplinary Statistical Analysis (Blacksburg, VA). The questionnaire was created as a paper version and an identical online version using Qualtrics (Provo, Utah). The online version was made accessible through the use of a unique ID that was provided to the companies with the paper survey when it was sent out. Duplicate responses were identified using the unique ID and were treated as one response. Three mailings were

performed between late May and July of 2017. Any more than three mailings of the survey could have been considered harassment (Institutional Review Board 2010).

The first mailing was the paper questionnaire, the second mailing was a reminder postcard, and the third mailing was another copy of the paper questionnaire. The third mailing was sent only to companies that had not yet responded. Each mailing was sent out two weeks after the previous mailing.

Data

After finishing the collection of the questionnaires, the data was checked for validity. Outliers were investigated to obtain rational reasons for their existence. Data was screened for duplicates, which were then removed. Data checking is covered further in the Data Cleaning subsection. Data from late responses was compared to data from early responses in order to determine if there were any systematic differences between late and early responders, which is further discussed in the Late Response Bias subsection.

The received responses were analyzed based on the question type. If the question indicated a percentage response, the responses were averaged to give an average reported percentage. The results of percentage-based questions were also multiplied with relevant reported statistics from other questions on a by-company-basis in order to give weight to the responses that had larger reported statistics. These new statistics were added together to get the industry parameters. This gives weight to companies that produce more of the relevant unit and therefore gives a better representation of the industry.

For industry totals, such as total pallets produced, the data collected on a regional level was then added together to show the national total. Totals were calculated by scaling up the answers given in the survey responses. This scaling was performed by using the number of employees reported as a percentage of the total number of employees in the industry as a whole as reported by the US Census Bureau's employment numbers of NAICS 321920 in 2016 (Bejune 2000). This percentage was then used as a representation of the percentage of the industry that was recorded. For example, if companies representing 20% of total employees responded that they produced 100 pallets, the scale-up factor would be 5 (20% * 5 = 100%). So the industry would be responsible for producing 500 pallets. This per-employee basis assumes that all work is being done at the same level of automation, so this method may lead to inflated production numbers.

Some of the data was analyzed on a regional basis. This was to allow comparisons between the regions. Regional comparisons were conducted using nonparametric tests, since the data was not normally distributed. Spearman's Correlation and Kruskal-Wallis Test were utilized to determine if any one region

was significantly different from the other regions in respect to the analyzed question at the $\alpha = 0.05$ level (Laerd Statistics 2018). When questions asked for percentages instead of units, regional comparisons were conducted with chi-squared tests at the $\alpha = 0.05$ level.

Late Response Bias

It is important to determine if the firms that responded were systematically different from those that did not. This potential bias, called nonresponse bias, was simulated by late response bias by considering late respondents as a proxy for non-respondents (Armstrong et al. 1977). Respondent companies were separated into 2 groups: early respondents and late respondents. Early respondents were those that responded before July 21st, 2017, which is around the time that the companies would be receiving the second mailing of the questionnaire so these respondents would be responding to the first mailing. Late respondents were those that responded on June 21st, 2017, or later, so they were responding to the second mailing of the questionnaire. Companies were further broken down into 3 categories: small (20 or fewer employees), medium (21 to 75 employees), and large (76 or more employees). Early and Late respondents were compared based on being small, medium, or large companies. They were further compared based on their responses to the questions regarding the production of new, recycled/recovered, and remanufactured pallets, as well as the collection of pallet cores. No significant difference was found using Wilcoxon tests.

Data Cleaning

In order to ensure the quality of the data received, responses were screened for accuracy. Firms with responses that did not make sense in the context of the questions asked were contacted and asked for clarification. If the firm did not respond, their responses were evaluated based on type of question. Responses to percentage-based questions that did not add up to 100% were removed in order to avoid unfairly biasing one category over another. Outliers were evaluated based on company size and employee count, and they were removed if they were unrealistically high or low. Reported lumber volume per pallet produced was evaluated. Realistic values were expected to be between 0.5 board feet and 30 board feet per pallet. If a response was above this range by a factor of 1,000, it was assumed that the respondent likely reported by the board feet instead of by the requested thousand board feet, and their response was adjusted accordingly. If the response was outside of the normal range, and the company did not respond

to contact, their response for reported board feet was removed.

Chapter 4: Results

Respondents

Out of the original pool of 2,520 companies, 86 were no longer in the industry. Of the remaining 2,414 valid companies within the wooden pallet and container industry, 179 responded. This gave an adjusted response rate of 7.4%.

The response rate varied per question due to question contents that may not be relevant to each respondent (Appendix A). Question 1 was answered by all valid respondents since it was a yes-or-no question about whether or not the respondent was in the pallet and container industry. Question 2 had 179 usable responses. Question 3 had 164 usable responses. Question 4 had 147 usable responses. Question 5 had 129 usable responses. Question 6 had 119 usable responses. Question 7 had 98 usable responses. Question 8 had 125 responses. Question 9 had 124 usable responses. Question 10 had 22 usable responses. Question 11 had 77 responses. Question 12 had 102 responses. Question 13 had 69 responses. Question 14 had 59 usable responses. Question 15 had 55 usable responses. Question 16 had 64 usable responses. Question 17 had 42 usable responses.

These responses accounted for 248 facilities in the United States. Respondents reported their primary source of income in 2016 as one of five options: new wood pallet manufacturing (51.9%), recycled/repaired/remanufactured wood pallet production (24.0%), brokering or wholesaling pallets (11.7%), wood crate manufacturing (6.7%), and other uses (5.7%), as seen in Table 1. The percentage of companies that reported selling new wood pallets as their primary source of income decreased approximately the same amount as the percentage of companies that reported that brokering or wholesaling pallets as their primary source of income increased. This implies a trend towards brokering or wholesaling pallets, possibly as a form of third party management. While reported company performances varied, overall respondents indicated that their sales volume has increased an average 10%. This may imply that wood prices are cheaper for the same volume or that there has been a growth in the pallet industry.

Table 1. Products accounting for the estimated largest sales dollars for companies in the wooden pallet and container industry (historical perspective).

Year [a]	New Pallets	Recycling, Repair, Remanufacturing Wood Pallets	Brokering or Wholesaling Pallets	Crate Manufacturing	Other
2011	58.9%	25.1%	1.3%	---*	14.7%
2016	51.9%	24.0%	11.7%	6.7%	5.7%

Note: *This value was not collected in 2011 and is included in Other.

Most respondents indicated that they only had one production facility (76%). Most multi-facility responders indicated that they had 2 facilities (14%). The rest of the responses indicated 3 facilities (4%), 4 facilities (2%), 5 facilities (3%), 7 facilities (<1%), and 10 facilities (<1%).

The survey respondents employed a total of about 9,906 employees, which accounts for 19% of the total 51,345 employees in the industry (US Census Bureau, 2015). The South had the most reported employees at 4,614. The Midwest had the second highest number of reported employees at 2,604. The Northeast had the second lowest reported number of employees at 1,484, and the West had the lowest reported number of employees at 1,204.

New Wood Material Use

Approximately 508 million new wood pallets were produced in 2016 as seen in **Table 2**. This is a 22% increase from the pallets produced in 2011. Approximately 341 million recycled or remanufactured wood pallets were produced in 2016. This is 5% more than the amount produced in 2011. These estimates were obtained using the calculations shown in Appendix B.

Table 2. Estimated wooden pallet production in the U.S.: 1995 - 2016.

Year [a]	1995	1999	2006	2011	2016
New Pallets (millions)	411	429	441	416	508
Recycled/Recovered/Remanufactured Pallets (millions)	143	223	321	326	341

The South produced the largest number of new pallets with 23% of total new pallets being manufactured here. The South also repaired the largest number of pallets with 15% of total repaired pallets. The West produced the fewest new pallets. Only 8% of total new pallets manufactured came from the West. The Northeast produced the fewest recycled pallets with only 5% of total recycled pallets as seen in **Table 3**.

Table 3. [b] Estimated wooden pallet production in the U.S. as a percent of total production from companies in the wooden pallet and container industry in 2016 by region.

Pallet Type	Northeast	Midwest	South	West
New	13%	15%	23%	8%
Recycled	4%	9%	12%	9%
Remanufactured	1%	2%	3%	1%
Total Pallets	18%	26%	38%	18%

Spearman's Correlation, which assumes the data is not normal, found no statistically significant differences in mean regional pallet production per company for new, recycled, or remanufactured pallets. This means that the differences in pallet production are likely due to a difference in the facilities of that region.

Of the total produced, 38% of new wood pallets were heat-treated according to phytosanitary regulations, which is higher than the 21% reported in 2006. Twenty-eight percent of recycled pallets were heat-treated. Heat-treatment is regulated by International Standards for Phytosanitary Sanitation 15 (ISPM 15), which was adopted in the U.S. in late 2005 (Haack et al 2014). The proportional increase in heat-treated pallets may be because of the time it takes to implement heat-treatment policies. The South produced the highest percentage of heat treated new wood pallets at 51%. The Midwest produced the highest reported percentage of heat-treated recycled or remanufactured wood pallets at 24%. Using chi-squared tests, it was found that there is no statistical difference between regions for the heat-treatment of new or used pallets.

Responses indicated that 9.16 billion board feet of new lumber was consumed to produce both new and repaired wood pallets. This accounts for 21.5% of the 42 billion board feet of total new lumber produced in the U.S. in 2016 (Madison's Lumber Reporter 2017). Approximately 8.56 billion board feet of new lumber, or 20.1% of wood produced in the U.S. (Madison's Lumber Reporter 2017), was consumed for the production of new wood pallets.

It was estimated that 0.60 billion board feet of new lumber, or 1.4% of U.S. lumber production (Madison's Lumber Reporter 2017), went into the repair and remanufacturing of wood pallets. Pallet repair used an estimated 0.44 billion board feet of new lumber. Pallet remanufacturing used an estimated 0.16 billion board feet of new lumber.

The West consumed the largest amount with 53% of total lumber in the U.S. being consumed for pallet production. This was mostly comprised of spruce, pine, and fir which made up 27% of the lumber consumed for pallet production. The South consumed the second largest amount of softwood with 39% of total lumber consumed for pallet production. This was mostly southern pine which comprised 38% of total lumber consumed for pallet production. This is in line with wood species maps of the U.S. that show high growth rates of spruce, pine, and fir in the West and high growth rates of southern pine in the South (U.S. Forest Service 2001). The largest consumer of hardwood was the South which used 16% of total lumber consumed for pallet production. This was mostly in the form of high density hardwoods which made up 10% of total lumber consumed for pallet production, as seen in **Table 4.** This is in accordance with forestry maps of the U.S. which show that most high-density hardwoods are grown in the Midwest and South (U.S. Forest Service 2001).

It is generally assumed that pallet and container companies use locally sourced wood, and these results back up this assumption. Roughly 6% of new wood that was used to manufacture or repair wood pallets was imported from outside of the United States. Most of this imported wood was sourced from Canada (94%), and the rest came from South America (2%) or other countries (4%). No wood was sourced from Mexico or Central America.

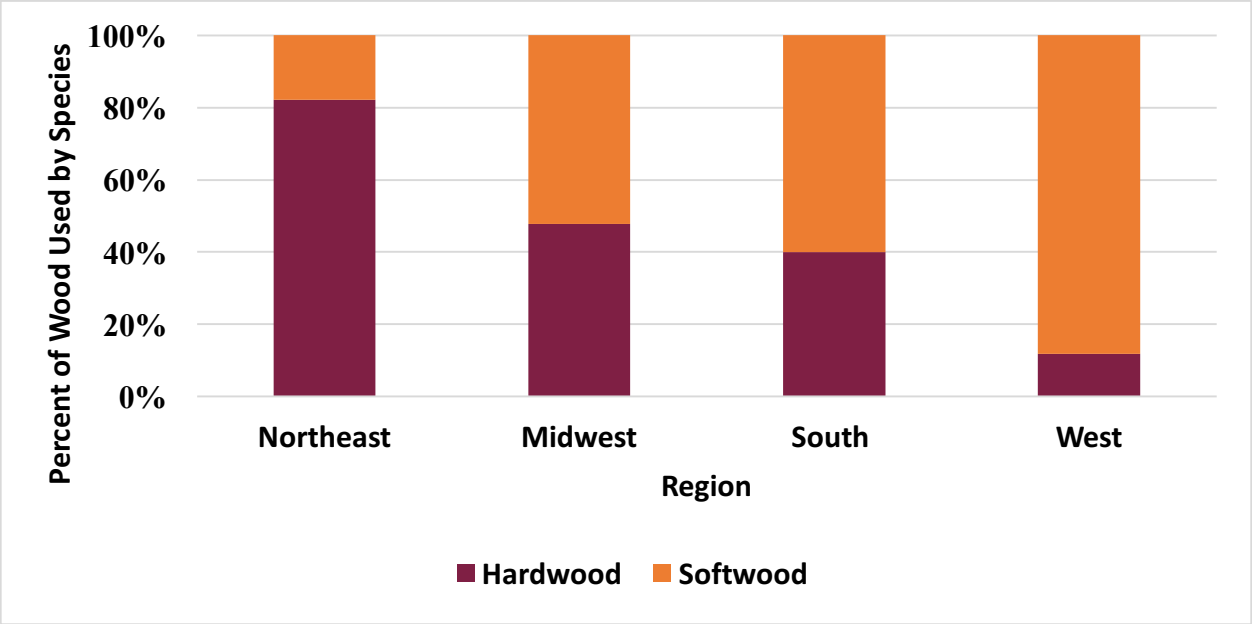
The type of wood consumed in the four regions differed, as seen in Figure 2. The wood consumed for pallet production in the West was 88% softwood and 12% hardwood. Meanwhile, an opposite trend was observed in the Northeast where 82% of the wood consumed was hardwood while 18% was softwood. In the South, wood consumed was 60% softwood and 40% hardwood, and in the Midwest, 48% of wood consumed was hardwood and 52% was softwood. Using the chi squared test, it was found regional proportional consumption of hardwood and softwood consumption are significantly different.

Spearman's Correlation did not find significantly different mean softwood consumption per company per region. Therefore, any differences seen in softwood consumption among the different regions could be due to a difference in the number of companies per region. However, the West had 9 responses, and so may have had too small of a sample size for this analysis.

Table 4. [b] Estimated wood species consumption as a percentage of total wood consumption for wooden pallet production in 2016 by region.

	Species Groups	Northeast	Midwest	South	West
Hardwood	Low Density Hardwood	2%	1%	4%	1%
	Medium Density Hardwood	2%	1%	3%	0%
	High Density Hardwoods	7%	4%	10%	0%
Softwood	SPF	<1%	4%	<1%	27%
	Southern Pine	<1%	<1%	23%	0%
	Douglas-Fir	<1%	<1%	<1%	5%
	Other North American Softwoods	<1%	<1%	<1%	<1%
Imported Wood	Canada Import	2%	3%	0%	1%
	Mexico Import	0%	0%	0%	0%
	South American Import	0%	0%	<1%	0%
	Central American Import	0%	0%	0%	0%
	Other Imports	0%	<1%	<1%	0%
Total Wood Consumption		13%	14%	40%	33%

Figure 2. A Regional Analysis of Wood Used for Pallet Production.



Hardwood

Responses indicated that 4.13 billion board feet of hardwood, which is 45% of wood used to produce pallets, was consumed in the production or repair/remanufacturing of wood pallets. Of this, 4.07 billion board feet of hardwood were used to produce new pallets in 2016, as seen in **Table 5**. This puts hardwood use near pre-2011 levels, as shown in Table 5. The hardwood consumption for all pallets accounts for 43% of the 9.5 billion board feet of hardwood lumber produced in the U.S. in 2016 (Madison's Lumber Reporter, 2017). This is approximately 8% higher than the amount of hardwood used in producing pallets in 1999 (35.4%) and 2015 (34.9%) (Bumgardner 2016). However, the Madison Lumber Reporter survey doesn't cover pulpwood that is used to make parts, as companies don't often keep track of this, so the percentage of hardwood might be lower than reported. It should be reasoned that this 43% is the upper limit of the percentage of pallet wood in the lumber industry. The increase in hardwood use since 2011 is likely due to the recovery of the market from the Great Recession, which caused a decline in lumber production in the U.S. Out of the total 4.13 billion board feet used in pallet production, 2.25 billion board feet was used for hardwood lumber and cants, while 1.88 billion board feet was used for hardwood parts. For new wood pallet production, an estimated 4.07 billion board feet was used, while 0.04 billion board feet was used for recycled pallet production and 0.01 billion board feet was

used for remanufactured pallet production . Most of the hardwood used was high-density hardwood (63%). Low density (21%) and medium density (16%) hardwoods make up the remaining 45% of hardwood used.

Table 5. [b] Estimated volume of new wood used in new pallet production by region

Year [a]	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	4.5	8.6

Softwood

Responses indicated that 5.01 billion board feet of softwood, which is 55% of total wood used, was consumed to produce or repair/remanufacture wood pallets. Of this, 4.48 billion board feet of softwood were used to produce new pallets in 2016. This is a lower proportion than the softwoods consumed in 2011 (Table 5). An estimated 0.40 billion board feet was used to produce recycled pallets. An estimated 0.15 billion board feet were used to produce remanufactured wood pallets. The softwood consumed to produce all pallets accounts for approximately 15% of U.S. softwood lumber production in 2016 (Madison's Lumber Reporter, 2017). Approximately 2.79 billion board feet was consumed to form softwood lumber or cants, and 2.24 billion board feet was consumed to form other softwood parts. The most-used softwood species were spruce, pine, and fir (51%), followed by southern pine (39%), douglas-fir (8%) and other North American softwoods (1%), as shown in Table 6. Historically, softwood pallets were primarily made of southern pine, which has now traded places in market dominance with spruce, pine, and fir. The decrease in other wood, when compared to 2011, is likely due to the inclusion of douglas-fir with other species in the 2011 survey, whereas it was asked about separately in the 2016 survey.

Table 6. [b] Estimated percent use of softwood species for wood pallets :1991 - 2016

Year [a]	SPF	Southern Pine	Douglas-Fir	Other
1991	---	40%	29%	32%
1993	---	34%	24%	42%
1995	31%	41%	11%	17%
1999	25%	48%	10%	16%
2006	36%	54%	4%	7%
2011	32%	41%	---	26%
2016	51%	39%	8%	1%

New Pallet Production

Of the estimated 513 million new pallets produced (Appendix B), 56% were produced using non-certified wood, 16% using SFI certified wood, 8% using FSC certified wood, and 9% using wood with other certifications. The question involving environmental certifications received a very low response rate (only 22 usable responses), so these percentage estimates of certification are in question. Especially since this level of certification (32%) is much higher than the level of certification in 2011 (3.8%). Environmentally certified wood had yet to penetrate pallet markets in 2011, but sources have grown substantially since then. From 2011 to 2015, SFI certified forests increased from approximately 200 million acres in North America to approximately 300 million acres (Sustainable Forest Initiative, 2016).

It was reported that 76% of new wood pallets were stringer pallets, 21% were block pallets, and 2% were skids or other types of pallets. The proportion of block pallets has increased narrowly since 2011 (Figure 3). The proportion of stringer pallets has declined significantly since 2011 and is at the lowest proportion seen since 1999. The most common standardized size of new pallets is 48” x 40” (35%), followed by 48” x 48” (6%). The other sizes asked about in the survey were 40” x 48” (4%), 48” x 45”

(5%), 48” x 42” (3%), 48” x 36” (1%), 42” x 42” (5%), 37” x 37” (<1%), and 800 mm x 1200 mm (1%). The remaining 39% of pallets were reported as other sizes. These sizes were asked for because they are used for, respectively, the grocery industry, drums, military, the automotive industry, the chemical industry, the beverage and packaged paper industries, paints, the beverage industry, and international trade (Tranpak 2018). The historical comparison for pallet sizes can be seen in Table 7. The proportion of new pallets being 48” x 40” pallets is at the highest seen in the last 10 years. This may be due to the fact that industry consolidation is eliminating smaller pallet companies that focused on producing custom sizes, the natural variation of survey statistics, or an increase in clarity of the pallet sizes as more explanation of the different sizes was included with the questionnaire.

Figure 3. New wood pallet classes as a percentage of new wood pallet production: 1999 – 2016

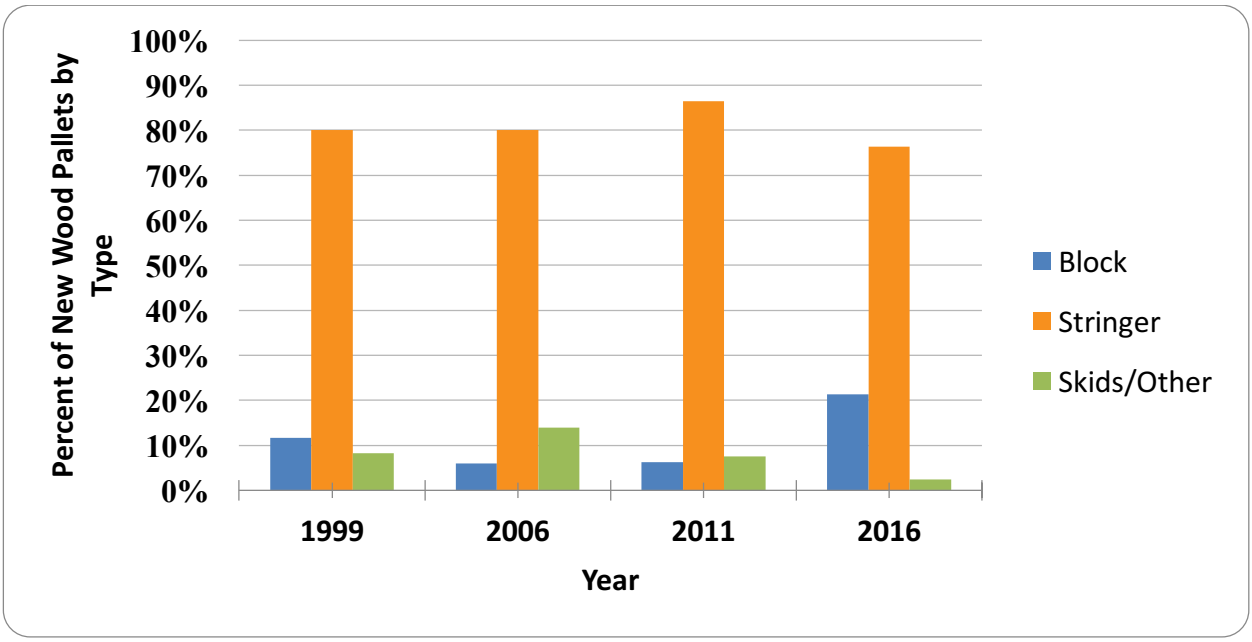


Table 7. [b] Estimated percentages of new wood pallet sizes produced in the U.S.: 2006 - 2016.

Year [a]	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 mm	Other
2006	27%	5%	4%	2%	4%	2%	5%	2%	---	50%
2011	24%	3%	4%	---	---	2%	5%	2%	1%	60%
2016	35%	4%	7%	5%	3%	1%	5%	<1%	1%	39%

Wood waste from new pallet manufacturing was used for colored landscape mulch (9.5%), other landscape mulch (24.7%), animal bedding (17.3%), pellets and other compressed wood fuel (1.8%), non-compressed wood fuel (44.8%), and other uses (1.9%). No wood waste from new wood pallet manufacturing was sent to the landfill.

Pallet Repair, Recycling, and Remanufacturing

Pallet Recovery

It was estimated that 551 million pallets were recovered for further use in 2016. Of these recovered pallets, 91% were stringer pallets and 9% were block pallets. It was estimated that, of all pallets recovered, 65% were 48” x 40” stringer pallets; meanwhile, 7% were 48” x 40” block pallets. This proportion of 48” x 40” block pallets is higher than the 3% recovered in 2011.

Respondents indicated that the sizes of pallets they recovered were 48” x 40” (69% of recovered pallets), 40” x 48” (3% of recovered pallets), 48” x 48” (3% of recovered pallets), 48” x 45” (3% of recovered pallets), 48” x 42” (2% of recovered pallets), 48” x 36” (2% of recovered pallets), 42” x 42” (3% of recovered pallets), 37” x 37” (4% of recovered pallets), 800 mm x 1200 mm (<1% of recovered pallets), and other sizes (11% of recovered pallets). This is similar to the sizes of recovered pallets in 2012, when 48” x 40” pallets were 81% of recovered pallets (Park et al. 2016).

Utilization of Recovered Pallets

It was estimated that 341 million recovered pallets were repaired and sold as used pallets (Appendix B), accounting for 69.9% of recovered pallet cores. This is roughly the same proportion as in previous years. Approximately 157 million of the recovered pallets were dismantled and used for other purposes or landfilled. The second-highest use of recovered pallets was to dismantle them for other uses (19.5%). The remaining uses for recovered pallets includes those sold without repair (5.9%), those that are ground or chipped (11.5%), those sent to the landfill (0.3%), as well as other uses (1.0%). The historical perspective can be seen in Table 8. Selling pallets without repair has decreased 6% since 2011, and this is at its lowest proportion of utilization seen since 1992. Pallet dismantling has increased 2% since 2011, and this is the highest proportion seen since 1995. Grinding and chipping operations have remained the same since 2011. Pallet repair for 48" x 40" stringer pallets is estimated to generate 0.19 kg of CO_2 equivalents per pallet (Park, 2015). Using this as a baseline, there were more than 100 million kg of CO_2 equivalents produced during pallet repair and remanufacturing.

In 2016, approximately than 25 million pallets were sent to landfills (Shiner et al., 2018). This means that only 3% of all new pallets produced in the US are being sent to landfills. Relatively few pallets are sent to the landfill. This is mostly because of the expenses associated with landfilling (Shiner et al., 2018) and because taking actions that add value to the product further enhances relationships along the supply chain (Sanchez et al. 2011).

Table 8. [b] Estimated percentage of processes of used pallets received at U.S. landfills: 1991 - 2016

Year [a]	Reused without repair	Repaired	Disassembled	Ground or Chipped	Landfilled	Other
1991	15%	62%	14%	8%	---	1%
1993	13%	61%	15%	8%	---	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%

Utilization of Ground or Chipped Pallets

It was estimated that 4.3 million tons of used pallets were ground or chipped. Most of this wood waste was sold as colored landscape mulch (921 thousand tons) or converted into non-compressed wood fuel (1.44 million tons). The rest of the ground or chipped wood waste was used for other landscape mulch (335 thousand tons), animal bedding (208 thousand tons), or for other uses (1.40 million tons). Animal bedding is a popular end of life utilization for broken wood pallets; they do not have any contamination that would inhibit their use around animals (White and McLeod 1989). None of the ground or chipped wood waste was used for compressed wood fuel, such as pellets, nor was it landfilled, which would have been consistent with past historical trends, as seen in Table 9.

Table 9. [b] Estimated percent use of ground or chipped pallets: 1991 - 2016

Year [a]	Landscape Mulch	Animal Bedding	Fuel	Other Uses
1991	12.3%	5.8%	53.1%	28.8%
1993	18.5%	17.1%	41.6%	22.9%
1995	18.7%	7.4%	43.2%	30.7%
1999	54.3%	7.7%	22.8%	15.2%
2006	62.1%	4.4%	29.2%	4.3%
2011	54.3%	10.0%	30.0%	5.7%
2016	37.5%	4.2%	30.0%	28.3%

Chapter 5: Conclusion

New wood pallet manufacturing dominates the pallet industry. It is the primary source of income for 51.9% of responding firms. The production of used, recycled, remanufactured, or repaired pallets was the primary source of income for 24.0% of responding firms. Brokering and wholesaling pallets was the primary source of income for 11.7% of responding firms. Wood crate production was the primary source of income for 6.7% of respondent firms, and other uses accounted for the remaining 5.7% of responding firms.

The results show that the wooden pallet and container industry is performing strongly and continuing to grow. Overall, pallet production has increased to 849 million pallets, which is a 14% increase compared to 2011. New pallet production has increased approximately 22% to 508 million pallets, and used pallet production has increased approximately 5% since 2011 bringing it to approximately 341 million pallets.

New wood pallets were reported as predominantly stringer pallets (72%). Block pallets and skids only accounted for 21% and 2% of the industry, respectively. This is an increase in block pallet production and the lowest proportion of stringer pallet production since 1999.

The most common size for new wood pallets remains the standard 48” x 40” pallet, which accounts for 35% of all new wood pallets produced. This is a 35% increase from 2006. Meanwhile, non-standard pallet sizes accounted for 39% of new wood pallets produced. This is a 46% decrease from 2006.

The results show that the U.S. pallet industry consumed 9.16 billion board feet of new wood for the production of new and used wood pallets. This means that the pallet industry utilizes 21.5% of lumber produced in the United States (Madison Lumber Reporter 2017). Hardwood accounts for 4.13 billion board feet, or 43%, of reported U.S. hardwood production (Madison Lumber Reporter 2017). Softwood accounts for 5.01 billion board feet, or 5%, of U.S. softwood production (Madison Lumber Reporter 2017). Softwood consumption by the pallet industry has increased significantly, and softwood pallets have continued to dominate the pallet market since they first outweighed hardwood pallets in 2011. Only a small portion of wood consumed by the

pallet industry was imported (4% of total volume), coming mostly from Canada (94% of imported wood volume).

Roughly 341 million recovered pallets were repaired or remanufactured and then sold as used pallets, accounting for 65% of recovered pallet cores. The use of recycled and remanufactured pallets remained at nearly the same 40% proportion of the industry that it has been since 2006. This means that recycled pallets have reached a stable proportion of the industry. Unless there is a paradigm shift or external market shock, it will be unlikely to see the use of recovered pallets change much over the next few years.

Wood waste use from recovered pallets has changed since 2011. The proportional use of landscape mulch has declined, which coincides with the percentage increase in other uses. Animal bedding production fell in proportion since 2011, and it now has returned to 2006 levels.

Simple linear regressions were run to compare historical pallet production with Gross Domestic Product or GDP. Six bivariate analyses were run, comparing new, used, and total pallet production to U.S. manufacturing GDP as reported by the U.S. Bureau of Economic Analysis (Bureau of Economic Analysis 2018) and U.S. nominal GDP as reported by the World Bank (World Bank 2018). Strong linear correlations (R squared values above 0.80) were found between used pallet production and both forms of GDP, as well as total pallet production and both forms of GDP (Appendix C). This strong correlation shows that there might be a connection between pallet production and economic performance. It is likely because manufacturing production growth means that more products must be transported and are put on pallets to do so. This could be a topic for future research.

Recommendations for Future Research

This study is a snapshot of the wooden pallet and container industry. In order to see if these trends continue, a similar study should be performed in the future.

While a lot of good data was collected, there were issues with the survey's response rate. In order to enhance the response rates in the future, it is imperative that a better database is constructed.

"Other" uses for wood pallet waste has risen in proportion to the other waste use categories, so further studies should ask for examples of what the "other" uses are. This would give us a better idea of the developing industry trends.

This study's questionnaire asked about the use of certified wood in pallet production, but it did not consider the limitations of chain-of-custody certification within the supply chain. A question regarding chain-of-custody would be beneficial in determining the use of certified wood.

End Notes

a. Data from 1992 and 1993 is Christoforo 1993. Data from 1995 is from Redy et al. 1995. Data from 1999 is from Bejune 2001. Data from 2006 is from Bush, Araman 2008. Data from 2011 is from Bush, Araman 2013. Data from 2016 is from the current study.

b. Percentages may not add up to exactly 100% due to rounding.

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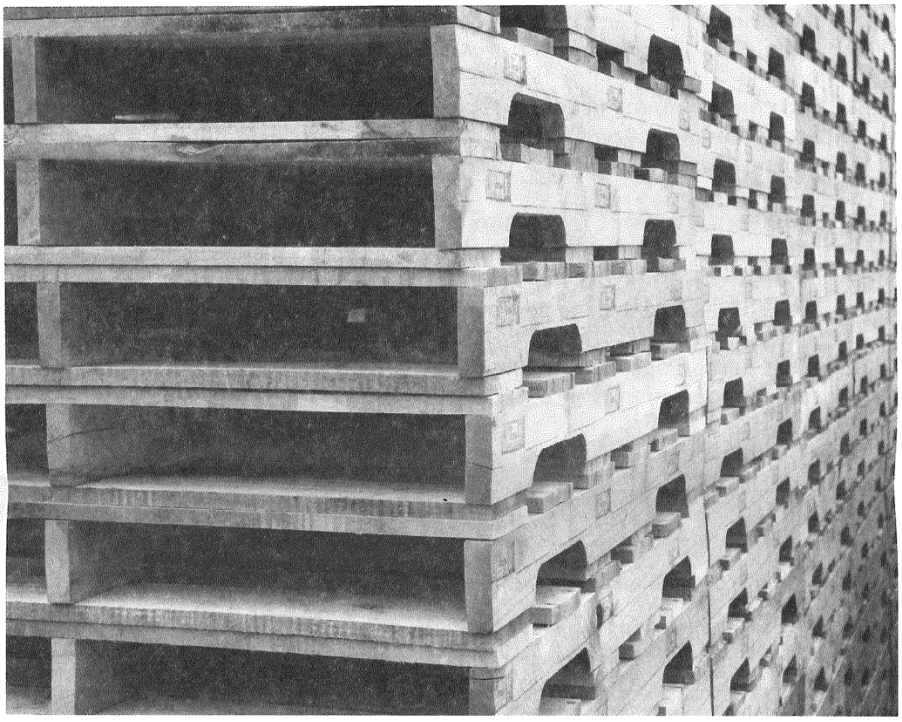
Appendix A: Survey Instrument

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



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Invent the Future

If you have any questions or concerns about this study, please contact:
Nathan Gerber at (336) 404-1428 or gnathan8@vt.edu

This questionnaire asks about your company's manufacturing, repairing, remanufacturing, and/or recycling of pallets and containers. When answering, please include all of your company's production facilities.

1. **Did your company produce, repair, recover/recycle, remanufacture or broker any wood packaging (pallets, skids, crates/containers, etc.) during 2016?**

   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 next question

2. **What percentage of your company's sales dollars did each product category account for in 2016?**

   ____% New wood pallets produced

   ____% Wood pallets repaired, recovered/recycled, or remanufactured

   ____% Crates and containers

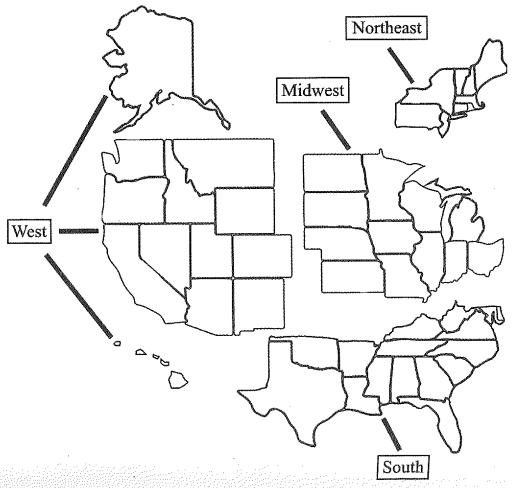
   ____% Wood pallets brokered or wholesaled

   ____% Other products (please list)_____

Total: 100%

If you brokered 100%, thank you for your time. Please return the survey. Postage is prepaid. Thank you.

Many questions in this survey will ask for data from specific geographical regions of the United States. These regions are: Northeast, South, Midwest, and West. Please consult the following image to identify the region(s) you operate in.



3. **Please provide the following demographic information for the calendar year 2016.**

	Northeast	Midwest	South	West
# of facilities				
# of shifts (1, 2, or 3) per weekday				
# of days in operation in 2016 (average per facility)				
# Production employees				
% Turnover production employees				
# Non-Production employees				

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

4. **Did your sales volume increase or decrease in 2016 compared to 2015? By what percent?**

   ____% Increase

   ____% Decrease

   ☐ Stayed the same

5. **How many units of the following did your company produce in 2016?**

	Northeast	Midwest	South	West
New pallets				
Recycled/recovered, or repaired pallets				
Remanufactured pallets*				
Crates/containers				

* complete reassembly using used or new components.

6. **In 2016, what percentage of the total wood pallets your company sold was heat-treated?**

	Northeast	Midwest	South	West
% of New wood pallets by region that was heat-treated (please check here ☐ if your company did not sell new pallets in 2016)				
% of Used/Repaired/Remanufactured wood pallets by region was heat-treated (please check here ☐ if your company did not sell used pallets in 2016)				

____ We do not heat treat

____ We do not have the data

The following five questions ask about the use of new wood in wood pallets. If your company did not use any new wood materials in 2016, please skip to Question 13.

7. **How much of the following new wood did your company use in 2016 for the production, recycling/recovery, and/or remanufacturing of wood pallets? (If your company purchases logs or bolts, please report the amounts used for wood packaging as an equivalent volume in the appropriate Lumber/cants category)**

	Materials	Volume used in 2016 (In Thousand Board Feet)			
		Northeast	Midwest	South	West
New wood used in new pallets	Hardwood parts				
	Hardwood Lumber/cants				
	Softwood parts				
	Softwood Lumber/cants				
New wood used in recycled/ recovered pallets	Hardwood parts				
	Hardwood Lumber/cants				
	Softwood parts				
	Softwood Lumber/cants				
New wood used in remanufactured pallets	Hardwood parts				
	Hardwood Lumber/cants				
	Softwood parts				
	Softwood Lumber/cants				

8. **What species group of <u>new wood</u> did your company use in the production, repair, and/or remanufacturing of wood packaging during 2016? (Please indicate the percentage of total board feet in each species group.)**

	Percentage of total board feet of new wood			
	Northeast	Midwest	South	West
Hardwoods from the US				
Softwoods from the US				
Wood imported from outside the US				
Total	100%	100%	100%	Total

9. **What species of <u>new wood</u> did your company use in the production, repair, and/or remanufacturing of wood packaging during 2016? (Please indicate the percentage of total board feet in each species group.)**

Hardwoods from the US

	Percentage of total board feet of hardwoods			
	Northeast	Midwest	South	West
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%	100%	100%	100%

Softwoods from the US

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

Wood imported from outside of the United States

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

10. What percentage of the <u>new wood</u> your company used in 2016 was environmentally certified by the following groups?

____% Forest Stewardship Council certified

____% Sustainable Forest Initiative certified

____% Other Certification

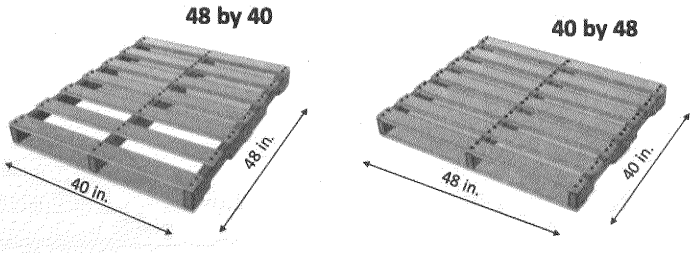
____% Non-certified

Total: 100%

____ We do not have this data

The following <u>two</u> questions ask about the production of <u>new</u> wood pallets. If your company did not produce new wood pallets in 2016, please skip to Question 13.

11. What percentage of the total <u>new wood pallets</u> (both block and stringer) your company produced in 2016 was each of the following sizes? Please look at the following two pictures before you fill out the table below.



Length by width	% Total new wood pallets in each region			
	Northeast	Midwest	South	West
% 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%	100%	100%	100%

____ We do not have this data

12. What percentage of the total new wood pallets your company produced in 2016 was each of the following types?

	Northeast	Midwest	South	West
% Stringer pallets				
% Block pallets				
% Skids and other types of pallets				
Total	100%	100%	100%	100%

___We do not have this data

The following questions ask about the recycling, repair, and remanufacturing of wood pallets. If your company was not involved in any of these activities in 2016, please skip to Question 17.

13. How many used, broken, or scrap pallets did your company purchase or receive in 2016?

	Northeast	Midwest	South	West
Pallets				

14. What percentage of the total used pallets your company received in 2016 was each of the following types?

	Northeast	Midwest	South	West
% 48 by 40 inches block pallets (including rentals)				
% Other block pallets				
% 48 by 40 inches stringer pallets				
% Other stringer pallets				
Total	100%	100%	100%	100%

____We do not have this data

15. What percentage of the total recovered/recycled/ remanufactured wood pallets your company produced in 2016 was each of the following sizes (Refer to Question 12 for pallet dimension drawings)?

	Northeast	Midwest	South	West
% 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%	100%	100%	100%

____We do not have this data

16. What was done with the used pallets your company received in 2016? (Exclude rental pallets)

	Northeast	Midwest	South	West
% Sold without repair				
% Repaired				
% Dis-assembled				
% Ground or chipped				
% Sent to a landfill				
% Other				
Total	100%	100%	100%	100%

____We do not have this data

17. If your company collected wood waste, ground or chipped pallets or pallet parts in 2016, how was this material used (in weight in US tons)?

	Weight in US tons	
	New	Used
Colored landscape mulch		
Other landscape mulch		
Animal bedding		
Pellets or compressed fuel		
Non-compressed wood fuel		
Sent to landfill		
Other uses		

____ We do not have a grinding or chipping operation

____ We do not have this data

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:_____

1893

VirginiaTech
College of Natural Resources and Environment

Center for Packaging and Unit Load Design
Virginia Tech
1650 Research Center Dr.
Blacksburg, Virginia 24061
540-231-7107 Fax: 540-231-8868
email: unitload@vt.edu
www.unitload.vt.edu

Dear Sir/Madam,

This is a survey conducted by the Center for Packaging and Unit Load Design at Virginia Tech in partnership with the National Wooden Pallet and Container Association.

The wood pallet and container industry is vital to the modern supply chain. Because of this, Virginia Tech and pallet industry leadership are collecting data about the use of wood and other pallet industry information. Our survey will add to our previous bodies of research to help us identify historical trends that are occurring. With this information and knowledge, we will be able to better serve the industry by focusing on its current needs.

The survey results will also allow you to compare your company to the general pallet industry, and to your region, to help you benchmark your organization for strategic decision-making.

Furthermore, by filling out your survey, you will have immediate access to the aggregated results upon their publication.

You can either take the survey either on paper or online. You can access the survey online at
www.palletsurvey.com
Your ID is

I would like to assure you that all survey responses are confidential. Only trends in data, such as total wood usage, will be released. No data from specific companies will be reported.

I realize this is not a short survey and hope you will take the time to assist the industry. Thank you for your time and cooperation.

If you have questions about this survey, please contact me by phone at (336) 404-1428 or by email at gnathan8@vt.edu.

Sincerely,

Nathan S. Gerber
Graduate Research Assistant

)620

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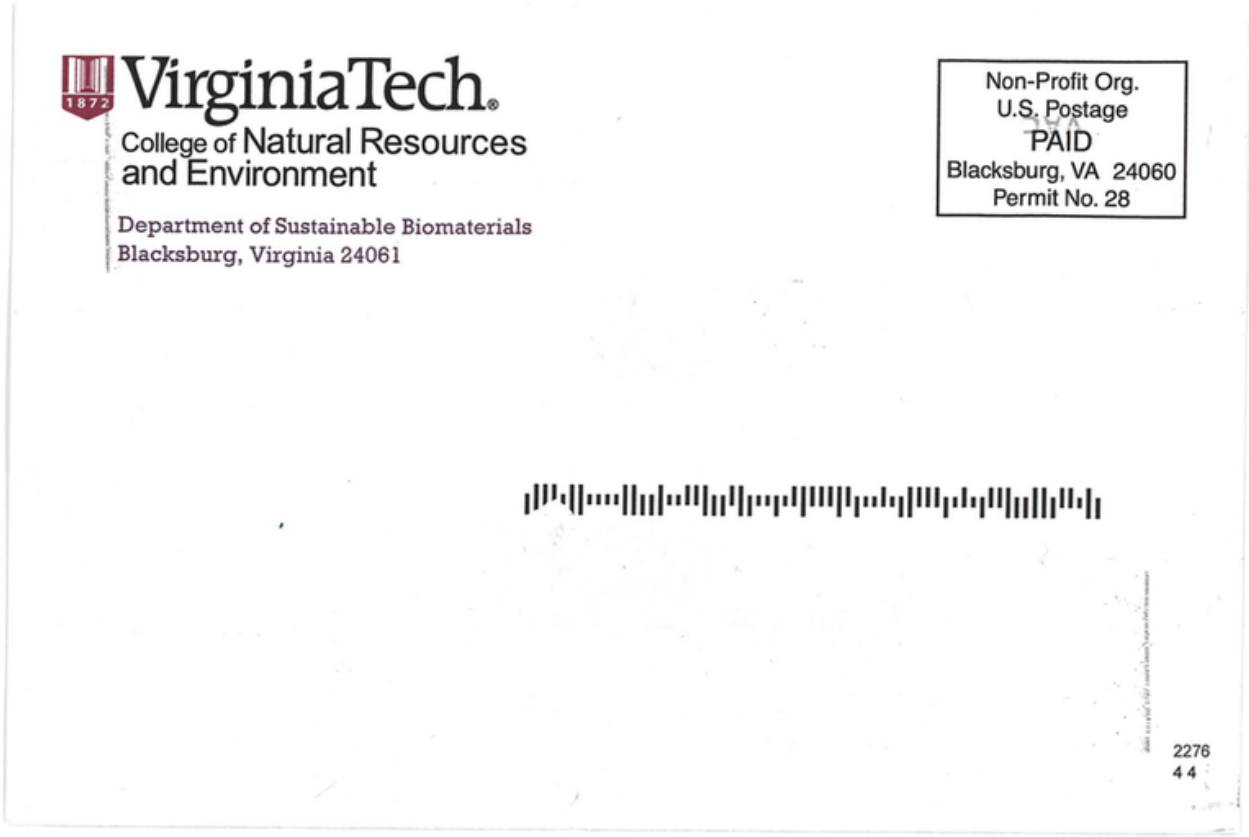
PO BOX 850
BLACKSBURG VA 24063-9959


VirginiaTech
College of Natural Resources and Environment
Department of Sustainable Biomaterials
Blacksburg, Virginia 24061
Non-Profit Org.
U.S. Postage
PAID
Blacksburg, VA 24060
Permit No. 28
2276
4 4

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 by 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.palletsurvey.com. Your ID is

Your participation is critical to the success of this study. The information you provide is strictly confidential. If you have any questions, pleas do not hesitate to contact me at by email gnathan8@vt.edu or by phone at (336) 404-1428.

Thank you in advance for your help,

Nathan Gerber

Nathan Gerber
Department of Sustainable Biomaterials
Virginia Tech

2276

Appendix B: Data Manipulation

General:

- If responses to questions that asked for percentages did not add up to 100%, they were excluded from the analysis.
- Responses to Question 5 were divided by responses to Question 7 to get board feet per pallet. The results were assessed using the assumed "reasonable" estimate of 0.5 to 30 board feet per pallet. If a response was off by a factor of 1,000 from what was assumed reasonable, it was assumed that the respondent had given their answer in board feet even though the question specifically asked for their answer in thousand board feet. In these cases, the respondents' board feet estimate was divided by 1,000.
- The raw data can be found at http://ezid.cdlib.org/id/doi:10.7294/W43N21KM

Total Pallet Production
Questions used: 3 & 5

Step 1: For each response, check to see if a value was given for number of pallets produced and employees. Remove all responses that did not provide both.

Step 2: Sum the employee numbers and compare to the U.S. Census Bureau's industrywide employee numbers to determine the scale up factor.

Scale up factor = (U.S. Census Bureau employee numbers) / (employees accounted for in the reported pallet production).

Step 3: Sum pallet production numbers.

Step 4: Multiply the sum calculated in Step 3 by the scale up factor determined in Step 2 to acquire the national estimate.

Lumber Consumed
Questions used: 3 & 7

Step 1: On each questionnaire check to see if a value was given for employee numbers and for Question 7. Remove questionnaires that did not have both.

Step 2: Sum the employee numbers and compare to the U.S. Census Bureau's industrywide employee numbers to determine the scale up factor.

Scale up factor = (U.S. Census Bureau employee numbers) / (employees accounted for in the reported pallet production)

Step 3: Sum together lumber numbers and multiply the total by 1,000 to convert MBF to BF.

Step 4: Multiply scale up factor by the sum calculated in Step 3 to acquire national estimate.

Average Reported Sales Growth
Question Used: 4

Step 1: Average all reported growths (including negatives) to get the estimated mean sales growth.

Proportions of Wood Species Consumed to Produce New Pallets
Questions used: 7, 8, & 9

Step 1: On each questionnaire, check to ensure that all three questions were answered. Remove responses that did not answer all three questions.

Step 2: For each of the remaining questionnaires, sum the board feet used for new pallets as reported in Question 7.

Step 3: Multiply this summed board feet with the percentages reported in Question 8. This will reveal the volume of wood in each category: hardwood from the U.S., softwood from the U.S., and wood imported from outside the U.S.

Step 4: For each response, multiply the volumes calculated in step 3 by the percentage pertaining to them from Question 9. Multiply the "hardwood from the U.S." volume by the percentage of high, medium, or low density hardwood. Multiply the "softwood from the U.S." volume by the percentage for SPF, southern pine, douglas-fir, or other North American softwoods. Multiply the volume of "wood imported into the U.S." by the percentages for the countries listed in Question 9.

Step 5: Sum the response for each species to calculate total reported volumes for each species.

Step 6: Divide the volume for each species by the summed total volume of all species to get the proportion that each species is of the total. Multiply by 100% to convert to a percentage of total wood consumed to produce new pallets.

Proportion of Pallet Sizes for New Pallets
Questions used: 5 & 11

Step 1: On each questionnaire, check to ensure that both questions were answered. Remove responses that did not answer both questions.

Step 2: For each response, multiply the reported new pallets from Question 5 with the percentages for each size (from Question 11) to calculate each respondent's reported number of pallets of each size

Step 3: Sum the pallet amounts for each size.

Step 4: Divide the total number of pallets of each size by the sum of all sizes to get the proportion of total new pallets by size. Multiply by 100% to convert to a percentage of new wood pallets.

Proportion of Pallet Sizes for Recovered Pallets
Questions used: 13 & 14

Step 1: On each questionnaire, check to ensure that both questions were answered. Remove responses that did not answer both questions.

Step 2: For each response, multiply the reported number of recovered pallets from Question 13 with the percentage for each size of pallet as reported in Question 14 to calculate the reported number of pallets for each size.

Step 3: Sum the total pallets per each size.

Step 4: Divide the total pallets for each size by the sum of all sizes to get the proportion of total recovered pallets by size. Multiply by 100% to convert to a percentage of recovered wood pallets.

Proportion of Wood Consumed that was Imported from Outside the U.S.
Questions used: 7 & 8

Step 1: On each questionnaire, check to ensure that both questions were answered. Remove responses that did not answer both questions.

Step 2: For each remaining response, sum the amount of board feet reported in Question 7 for new pallets.

Step 3: Multiply the summed amount of board feet for each response with that responses percentages reported in Question 8. This will reveal how much volume of wood is in each category: hardwood from the U.S., softwood from the U.S., and wood imported from outside the U.S.

Step 4: Sum the wood imported from outside the U.S. to get the total reported wood.

Step 5: Divide the total reported wood imported from outside the U.S. by the summed total wood from Question 8. Multiply by 100% to convert to a percentage of new wood consumed to produce new pallets.

Proportion of New Wood Pallets that were Block or Stringer Pallets or Skids

Questions used: 5, 12

Step 1: For each response, check if both questions were answered. Remove responses that did not answer both questions.

Step 2: For each response, multiply the new pallets recorded in Question 5 by the percentages for block, stringer, and skid pallets from Question 12.

Step 3: Sum up the pallet amounts for each category of Question 12 to get the total reported value for each category.

Step 4: Divide the totals of each category (block, stringer, or skid) by the sum of all categories from Question 12. Multiply each result by 100% to get the proportion of each category for new pallets.

Proportion of Recovered Wood Pallets that were Block or Stringer Pallets or Skids

Questions used: 5, 15

Step 1: For each response, check if both questions were answered. Remove responses that did not answer both questions.

Step 2: For each response, multiply the recovered pallets recorded in Question 5 by the percentages for block, stringer, and skid pallets from Question 15.

Step 3: Sum up the pallet amounts for each category of Question 12 to get the total reported value for each category.

Step 4: Divide the totals of each category (block, stringer, or skid) by the sum of all categories from Question 12. Multiply each result by 100% to get the proportion of each category for recovered pallets.

Proportions of Uses for Wood Cores

Questions used: 13, 16

Step 1: For each response, check if both questions were answered. Remove responses that did not answer both questions

Step 2: For each remaining response, multiply the reported amount of cores received from Question 13 with the percentages reported in Question 16.

Step 3: Sum up the amounts of pallets that went into each use, as given in Step 2.

Step 4: Divide the total pallets used for each use by the total pallets from all uses. Multiply these results by 100% to get the total reported percentage from each category.

Wood Waste Tonnage and Proportions

Questions used: 17

Step 1: Sum all responses for the total tonnage of wood waste produced.

Step 2: Sum wood waste tonnage for each byproduct.

Step 3: Divide wood waste tonnage for each byproduct by the total tonnage of wood waste. Multiply each of these results by 100% to acquire the percentage of wood waste that went into making each byproduct.

Appendix C: Advanced Statistical Analysis

Wilcoxon Test for New Pallet Production by Mailing Type for Small Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	9	58.000	76.500	6.4444	-1.907
Second	7	78.000	59.500	11.1429	1.907

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
78	1.90672	0.0566

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
3.8404	1	0.0500

Missing Rows 17

Wilcoxon Test for Recycled Pallet Production by Mailing Type for Small Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	9	71.000	72.000	7.88889	-0.059
Second	6	49.000	48.000	8.16667	0.059

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
49	0.05893	0.9530

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0139	1	0.9062

Missing Rows 18

Wilcoxon Test for Remanufactured Pallet Production by Mailing Type for Small Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	6	34.000	36.000	5.66667	-0.317
Second	5	32.000	30.000	6.40000	0.317

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
32	0.31719	0.7511

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1789	1	0.6724

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Missing Rows 22

Wilcoxon Test for Pallet Cores Collected by Mailing Type for Small Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	6	28.000	33.000	4.66667	-0.962
Second	4	27.000	22.000	6.75000	0.962

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
27	0.96232	0.3359

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.1433	1	0.2850

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Missing Rows 23

Wilcoxon Test for New Pallet Production by Mailing Type for Medium Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	10	98.000	90.000	9.80000	0.732
Second	7	55.000	63.000	7.85714	-0.732

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
55	-0.73237	0.4639

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.6103	1	0.4347

Missing Rows 15

Wilcoxon Test for Recycled Pallet Production by Mailing Type for Medium Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	8	56.500	60.000	7.06250	-0.388
Second	6	48.500	45.000	8.08333	0.388

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
48.5	0.38772	0.6982

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.2046	1	0.6510

Missing Rows 18

Wilcoxon Test for Remanufactured Pallet Production by Mailing Type for Medium Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	7	42.500	49.000	6.07143	-0.869
Second	6	48.500	42.000	8.08333	0.869

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
48.5	0.86917	0.3848

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.8866	1	0.3464

Missing Rows 19

Wilcoxon Test for Pallet Cores Collected by Mailing Type for Medium Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	7	34.000	42.000	4.85714	-1.430
Second	4	32.000	24.000	8.00000	1.430

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
32	1.43043	0.1526

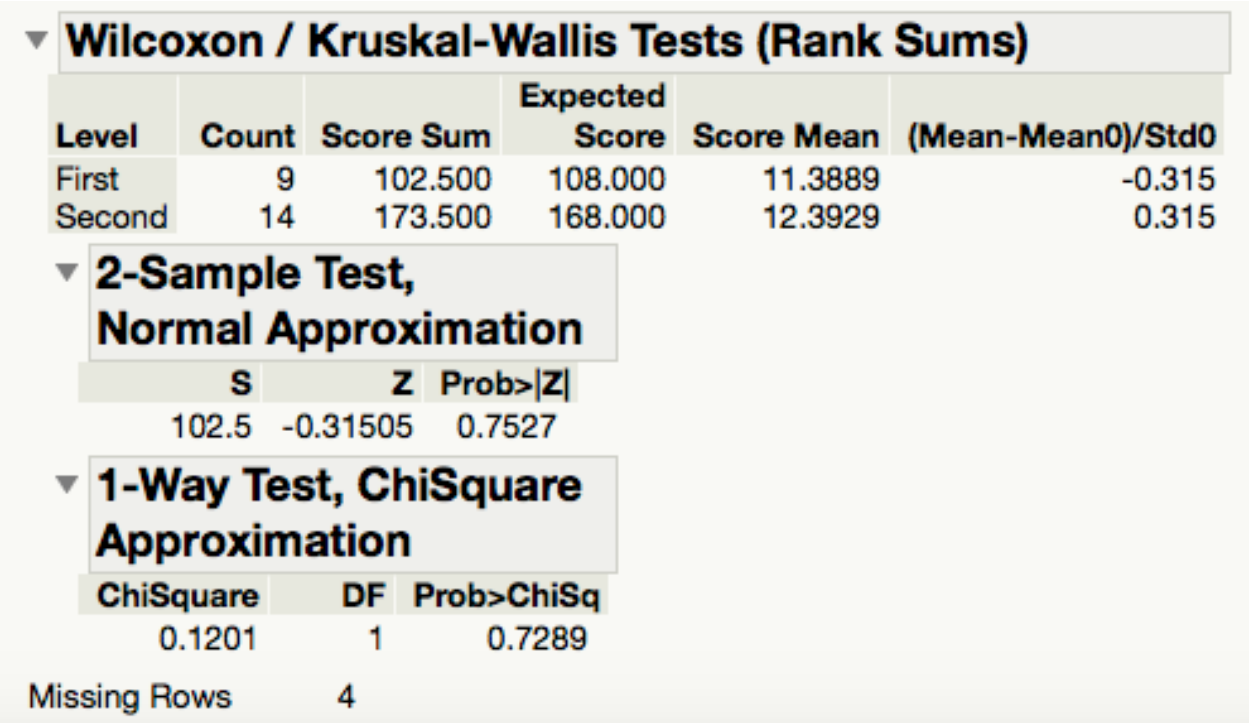
1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.3280	1	0.1271

Small sample sizes. Refer to statistical tables for tests, rather than large-sample approximations.

Missing Rows 21

Wilcoxon Test for New Pallet Production by Mailing Type for Large Companies



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	9	102.500	108.000	11.3889	-0.315
Second	14	173.500	168.000	12.3929	0.315

2-Sample Test, Normal Approximation

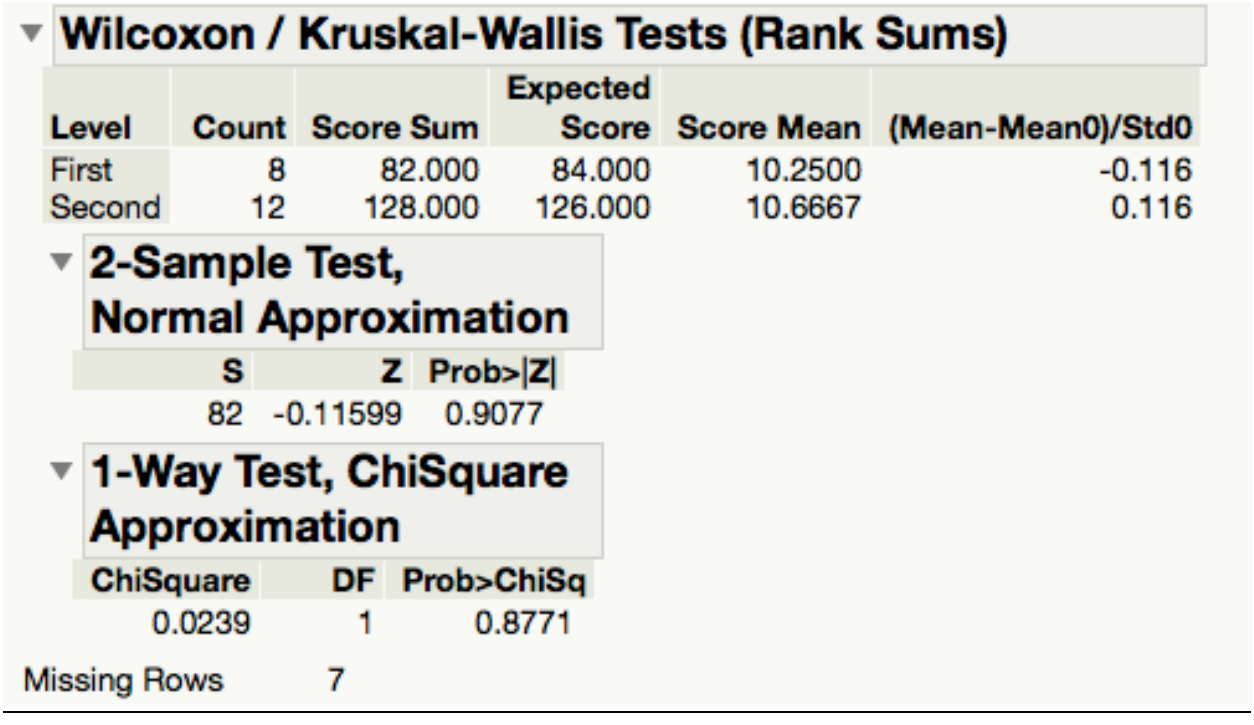
S	Z	Prob>|Z|
102.5	-0.31505	0.7527

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1201	1	0.7289

Missing Rows 4

Wilcoxon Test for Recycled Pallet Production by Mailing Type for Large Companies



Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	8	82.000	84.000	10.2500	-0.116
Second	12	128.000	126.000	10.6667	0.116

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
82	-0.11599	0.9077

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.0239	1	0.8771

Missing Rows 7

Wilcoxon Test for Remanufactured Pallet Production by Mailing Type for Large Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	7	70.500	66.500	10.0714	0.332
Second	11	100.500	104.500	9.1364	-0.332

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
70.5	0.33169	0.7401

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1437	1	0.7046

Missing Rows 9

Wilcoxon Test for Pallet Cores Collected by Mailing Type for Large Companies

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
First	5	26.000	37.500	5.20000	-1.468
Second	9	79.000	67.500	8.77778	1.468

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
26	-1.46828	0.1420

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.3563	1	0.1248

Missing Rows 13

Spearman's Correlation for New Pallets per Company by Region

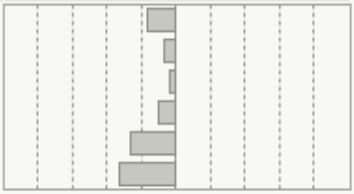
Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|
Midwest New Pallets	Northeast New Pallets	-0.2656	0.2205
South New Pallets	Northeast New Pallets	-0.0973	0.6586
South New Pallets	Midwest New Pallets	0.0112	0.9433
West New Pallets	Northeast New Pallets	0.5394	0.0703
West New Pallets	Midwest New Pallets	-0.2907	0.3593
West New Pallets	South New Pallets	-0.1761	0.5841

Spearman's Correlation for Recycled/Recovered Pallets per Company by Region

Nonparametric: Spearman's ρ

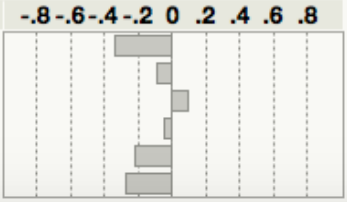
Variable	by Variable	Spearman ρ	Prob>|ρ|
Midwest Recycled/Recovered	Northeast Recycled/Recovered	-0.1586	0.4699
South Recycled/Recovered	Northeast Recycled/Recovered	-0.0702	0.7502
South Recycled/Recovered	Midwest Recycled/Recovered	-0.0287	0.8552
West Recycled/Recovered	Northeast Recycled/Recovered	-0.0943	0.7707
West Recycled/Recovered	Midwest Recycled/Recovered	-0.2573	0.4194
West Recycled/Recovered	South Recycled/Recovered	-0.3257	0.3015



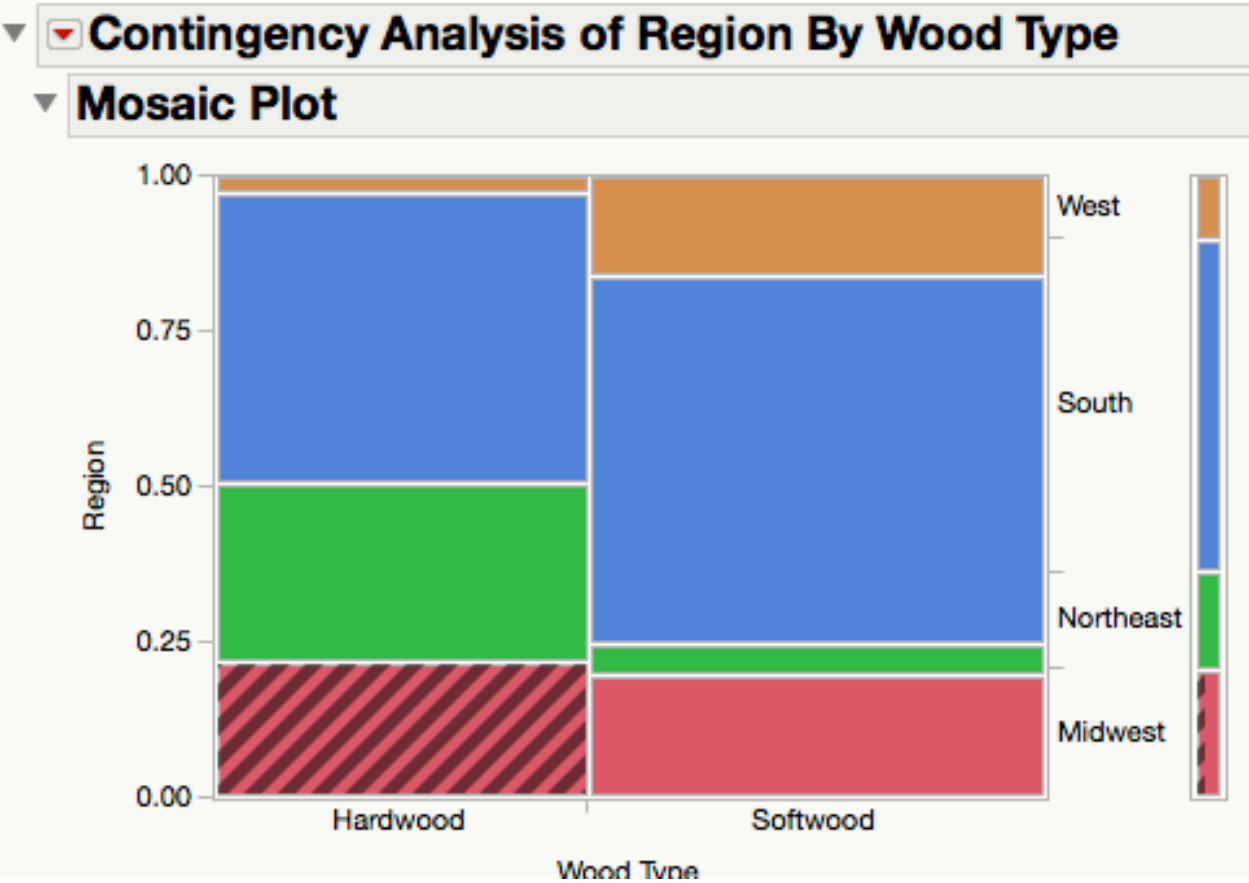
Spearman's Correlation for Remanufactured Pallets per Company by Region

Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|
Midwest Remanufactured Pallets	Northeast Remanufactured Pallets	-0.3380	0.1147
South Remanufactured Pallets	Northeast Remanufactured Pallets	-0.0815	0.7116
South Remanufactured Pallets	Midwest Remanufactured Pallets	0.1023	0.5141
West Remanufactured Pallets	Northeast Remanufactured Pallets	-0.0388	0.9046
West Remanufactured Pallets	Midwest Remanufactured Pallets	-0.2189	0.4942
West Remanufactured Pallets	South Remanufactured Pallets	-0.2718	0.3928



Chi Square Contingency Table Mosaic Plot for Hardwood and Softwood Proportional Comparison



Chi Square for Hardwood and Softwood Proportional Comparison

Tests

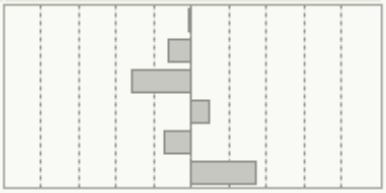
N	DF	-LogLike	RSquare (U)
919165	3	69755.452	0.0642

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	139510.9	<.0001*
Pearson	128461.9	<.0001*

Spearman's Correlation for Softwood Consumption per Company by Region

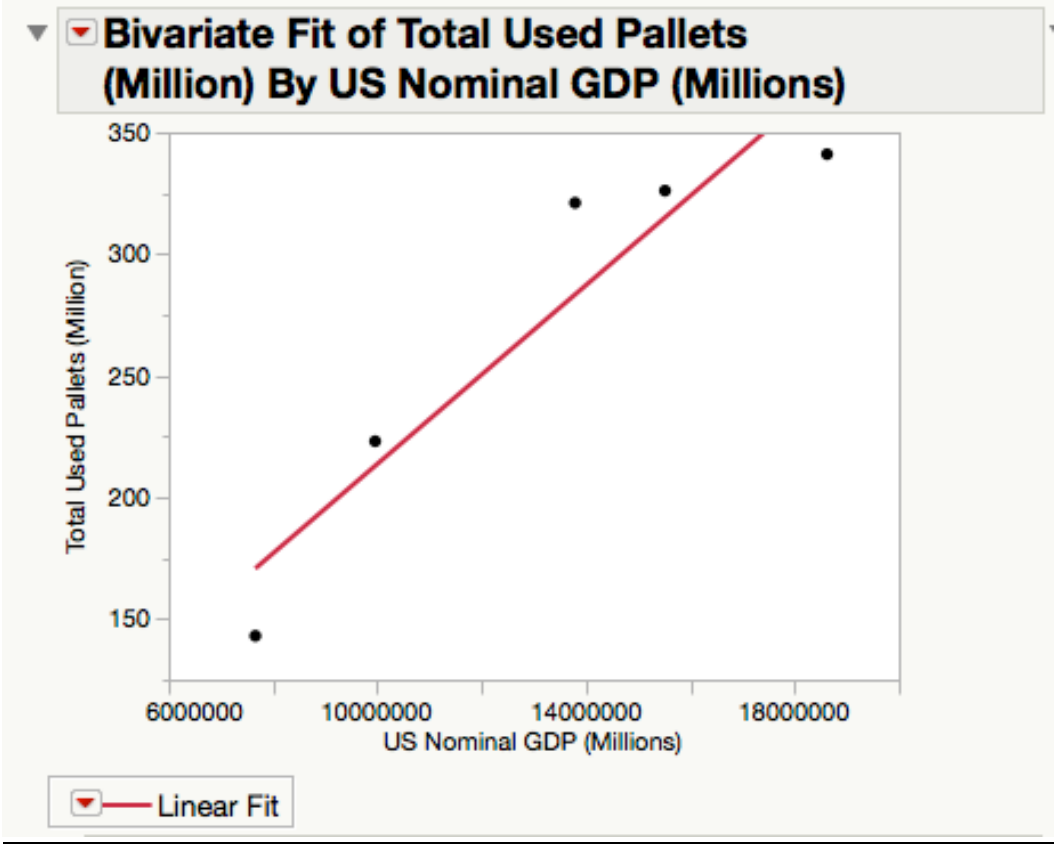
Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|
Midwest Softwoods	Northeast Softwoods	-0.0117	0.9632
South Softwoods	Northeast Softwoods	-0.1216	0.6308
South Softwoods	Midwest Softwoods	-0.3132	0.1046
West Softwoods	Northeast Softwoods	0.0974	0.8032
West Softwoods	Midwest Softwoods	-0.1447	0.7103
West Softwoods	South Softwoods	0.3448	0.3635



Warning: sample size of 9 is too small, P value suspect.

Simple Linear Regression for Used Pallet Production by U.S. Nominal GDP



Simple Linear Regression Summary of Fit for Used Pallet Production by U.S. Nominal GDP

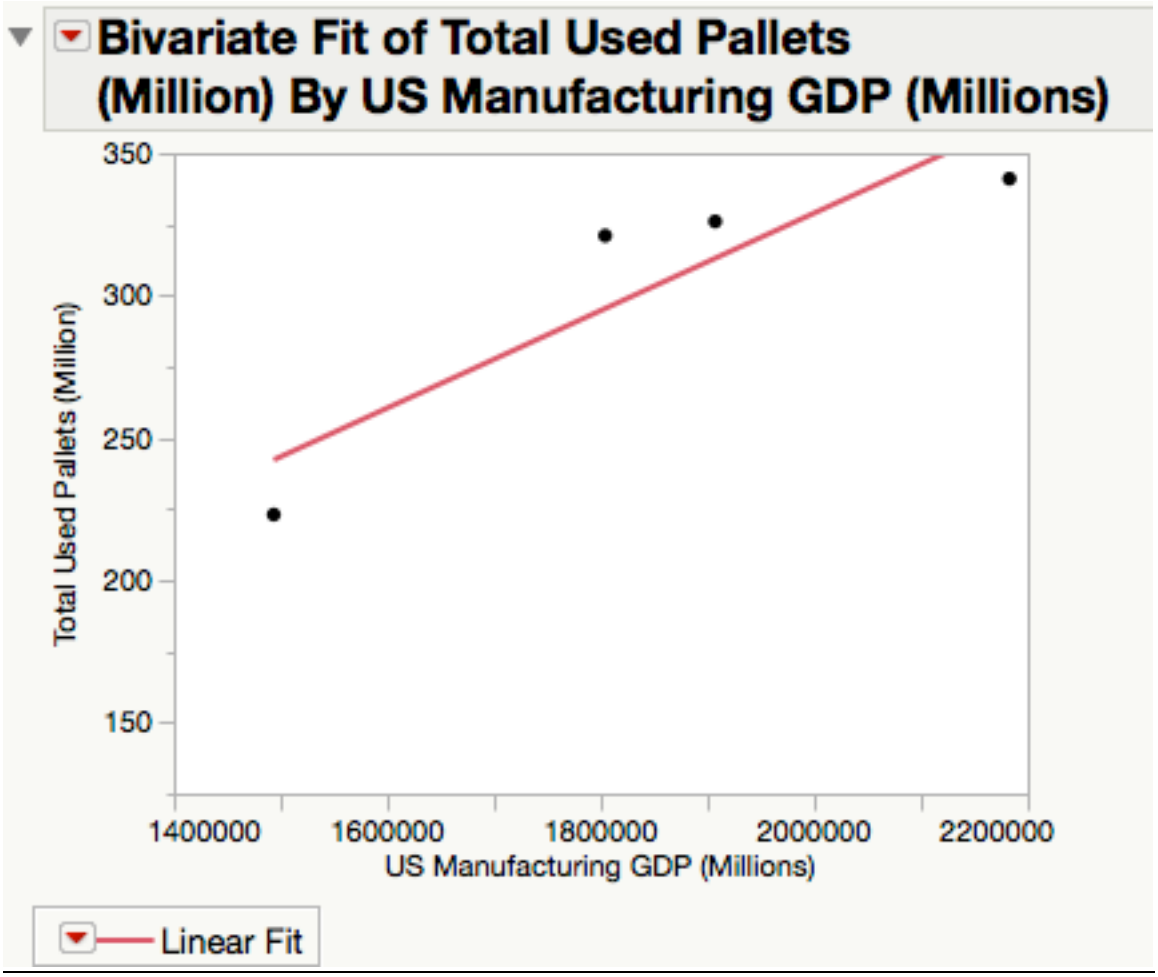
Linear Fit

Total Used Pallets (Million) = 29.905319 + 1.8372e-5*US Nominal GDP (Millions)

Summary of Fit

RSquare	0.884041
RSquare Adj	0.845388
Root Mean Square Error	33.5454
Mean of Response	270.8
Observations (or Sum Wgts)	5

Simple Linear Regression for Used Pallet Production by U.S. Manufacturing GDP



Simple Linear Regression Summary of Fit for Used Pallet Production by U.S. Manufacturing GDP

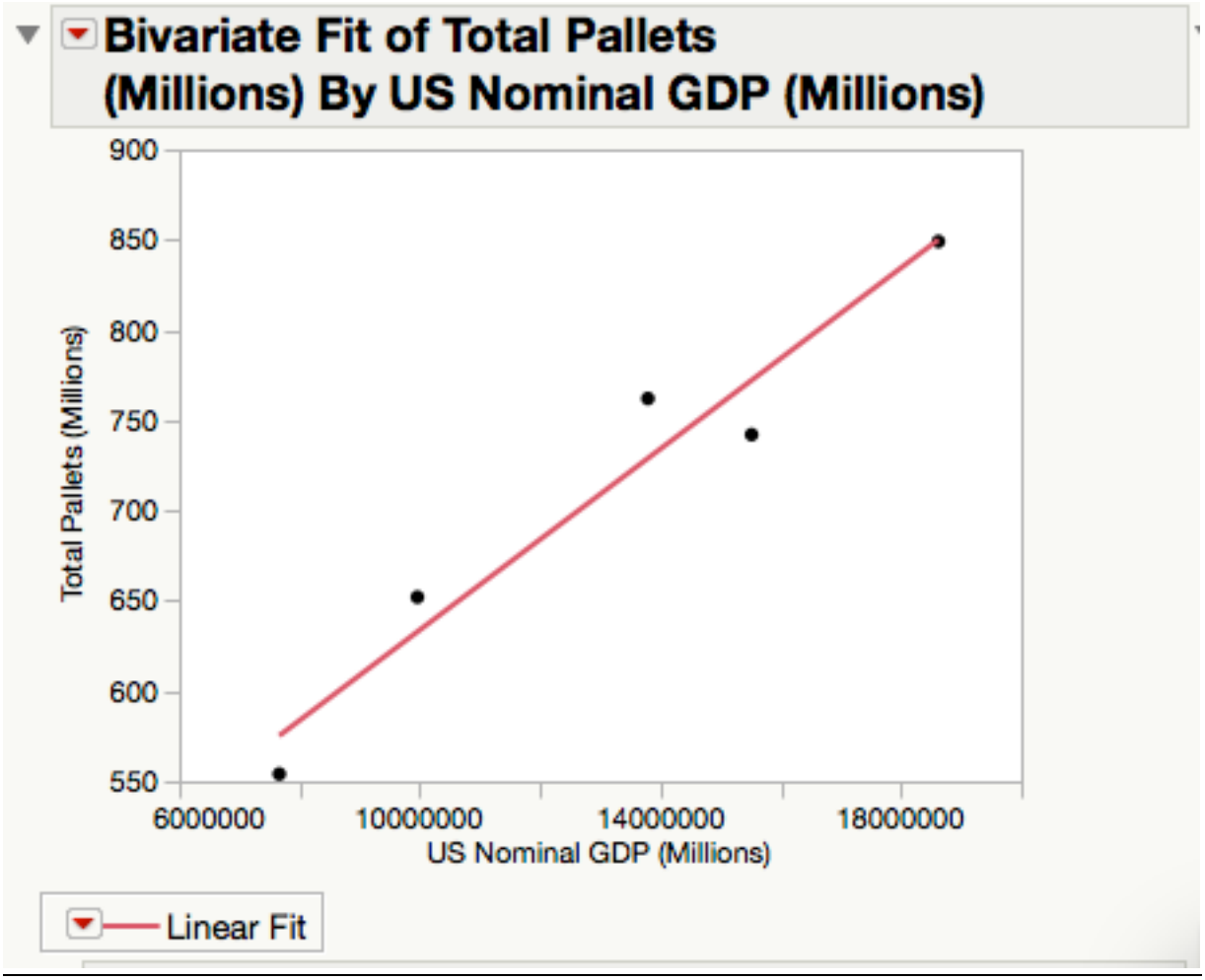
Linear Fit

Total Used Pallets (Million) = -13.58125 + 0.0001713*US Manufacturing GDP (Millions)

Summary of Fit

RSquare	0.820175
RSquare Adj	0.730262
Root Mean Square Error	27.96333
Mean of Response	302.75
Observations (or Sum Wgts)	4

Simple Linear Regression for Total Pallet Production by U.S. Nominal GDP



Simple Linear Regression Summary of Fit for Total Pallet Production by U.S. Nominal GDP

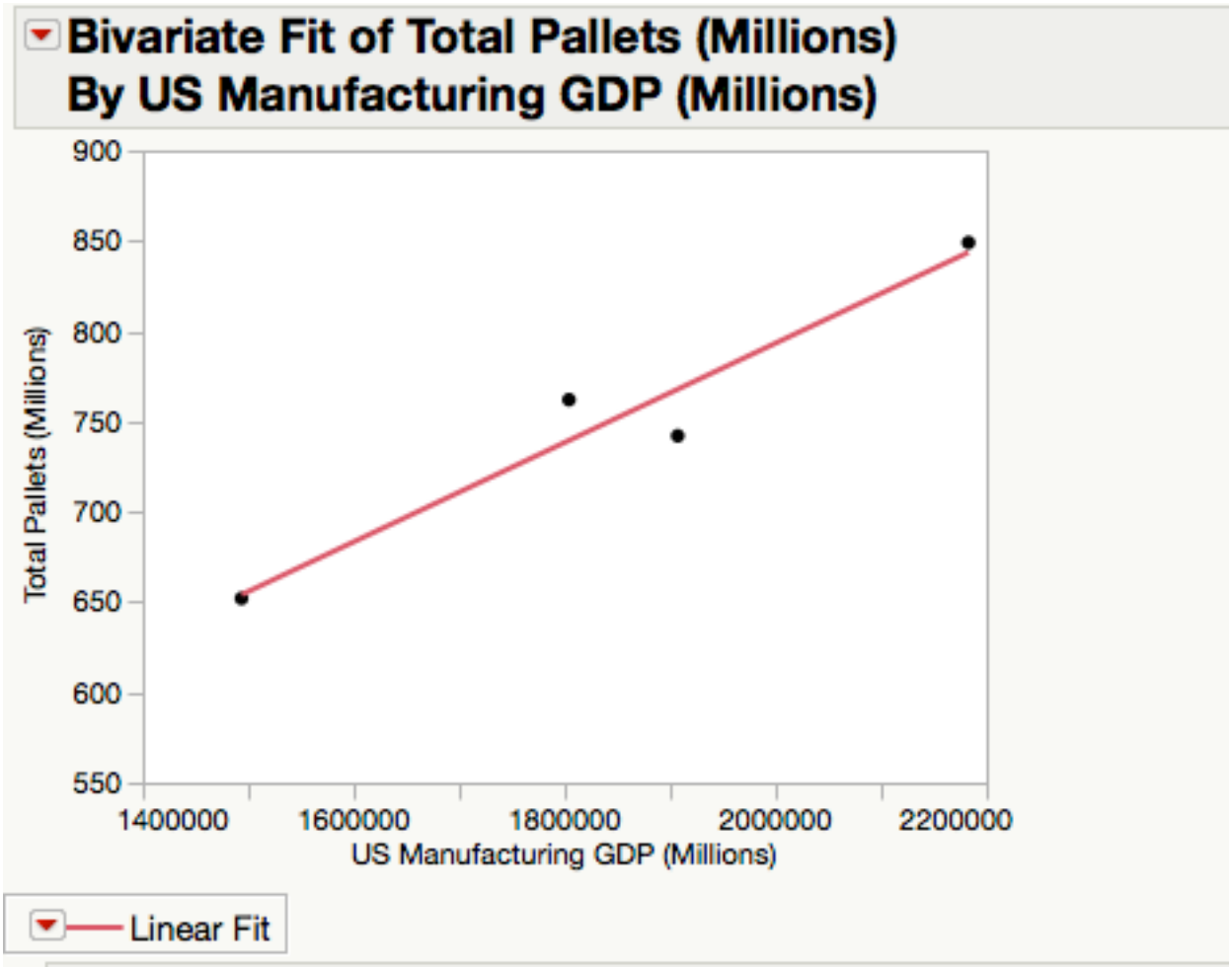
Linear Fit

Total Pallets (Millions) = 383.13039 + 2.5066e-5*US Nominal GDP (Millions)

Summary of Fit

RSquare	0.944349
RSquare Adj	0.925798
Root Mean Square Error	30.6776
Mean of Response	711.8
Observations (or Sum Wgts)	5

Simple Linear Regression for Total Pallet Production by U.S. Manufacturing GDP



Simple Linear Regression Summary of Fit for Total Pallet Production by U.S. Manufacturing GDP