

The Investigation of the Plastic Pallet Industry in the United States in 2018

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

Master of Science

In

Forest Products

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December 5th, 2019

Blacksburg, VA

Keywords: plastic pallets, market trends, pallet production, pallet sizes

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Academic Abstract

Pallets are abundant throughout the supply chain with 2.6 billion pallets in circulation in the United States (Freedonia, 2015). In 2005 it is estimated that more than 93% of goods are transported in the form of a palletized unit load (White and Hamner, 2005). Plastics are the second most commonly used material to manufacture these shipping platforms (Bond, 2018), yet there is a lack of information to be found about the plastic pallet industry's characteristics. Therefore, the main objective of this research was to investigate the status of the plastic pallet industry in the United States in 2018.

To gather information, an online survey was conducted. It was sent out electronically to twenty-six plastic pallet manufacturers with response rate of 54%. The results have shown that almost 16 million plastic pallets were manufactured in the United States by respondents in 2018. Of these, over 80% were multiple use pallets and about 80% were standard size (48 in. x 40 in., 45 in. x48 in.). Most plastic pallets manufactured by the respondents were made with high pressure injection molding (63%) using high density polyethylene (HDPE) resin (68%). Close to 50% of the pallets had reinforcement beams and 12% had fiberglass reinforcement. Although most plastic pallets were manufactured using virgin resin, 34% were manufactured from recycled resin which reduces the cost and increases the sustainability of the plastic pallet. In addition, this study has shown that most of the plastic pallets manufactured in 2018 had no flame-retardant additives since only 20% from the respondents indicated that their pallets were Underwriter Laboratories (UL) or Factory Mutual (FM) certified. Based on these results, a new survey format and framework is designed with a recommendation to conduct it in every five years in order to further explore the state and market trends of the plastic pallet industry.

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General Abstract

Pallets are abundant throughout the supply chain with 2.6 billion pallets in circulation in the United States (Freedonia, 2015). More than 93% of goods are transported in the form of a palletized unit load (White and Hamner, 2005). Plastics are the second most commonly used material to manufacture these shipping platforms (Bond, 2018), yet there is a lack of information to be found about the plastic pallet industry's characteristics. Therefore, the main objective of this research was to investigate the status of the plastic pallet industry in the United States in 2018.

To gather information, an online survey was conducted. It was sent out electronically to twenty-six plastic pallet manufacturers with response rate of 54%. The results have shown that almost 16 million plastic pallets were manufactured in the United States by the survey respondents in 2018. Of these, over 80% were multiple use pallets and about 80% were standard size. Most plastic pallets that were manufactured by the respondents were made with high pressure injection molding (63%) using high density polyethylene (HDPE) resin (68%). Close to 50% of the pallets had reinforcement beams and 12% had fiberglass reinforcement. Although most plastic pallets were manufactured using virgin resin, 34% were manufactured from recycled resin which reduces the cost and increases the sustainability of the plastic pallet. In addition, this study has shown that most of the plastic pallets manufactured in 2018 had no flame-retardant additives since only 20% from the respondents indicated that their pallets were Underwriter Laboratories (UL) or Factory Mutual (FM) certified. Based on these results, a new survey format and framework is designed with a recommendation to conduct it in every five years in order to further explore the state and market trends of the plastic pallet industry.

Acknowledgements

I would like to thank you for this opportunity to Dr. Laszlo Horvath whose guidance and patience were essential to pursue my Master's degree at Virginia Tech.

My thanks to Dr. Robert Smith and Dr. Marshall White for their help and support they provided as my committee members.

My time at Virginia Tech was more pleasurable with the friends that became a part of my life. I am glad for the time I was able to spend with them and made cherished memories with Eszter Sendula, Anthony Page Clayton, Paula Fallas, Alina Mejias- Rojas, Eduardo Molina, Steven Morrissette, Nicolas Navarro, Leah Johnson, Chandler Quesenberry and Zack Shiner.

Special thank you to Nathan Gerber and Gloria Alvarez for their unwavering support and love that helped me through the struggles of graduate school. I cannot be grateful enough for them.

Lastly, I would like to thank my family for all their love and encouragement thought this period of my life. Words cannot express my gratitude for them.

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1 Introduction

Currently, there are more than 2.6 billion pallets circulating in the United States (Freedonia, 2015). These shipping platforms carry 93% to 95% of the distributed goods in a form of a unit load (White and Hamner 2005). A pallet is a “portable, horizontal, rigid, composite platform” which purpose is to help store and distribute products (MH1, 2016). Pallets are classified into two categories: block and stringer. Pallets can also be grouped based on their accessibility (entry types), bottom deck structure, usage categories and styles. They can be manufactured from several different materials, such as wood, plastic, composites, metal, and paper-based material.

Although, the majority of companies (93%) are using wooden pallets in their supply chain, plastic is the second most commonly used material for pallet manufacturing with more than 33% of them using plastic some pallets (Bond, 2018). Plastic pallets classification is similar to the classification of wood pallets. Plastic pallets are designed for reuse or single use (MH1, 2016). They can be either reusable, which means they can be used multiple times, or single use pallets, which were manufactured for one-way use. Similar to wooden pallets, they can be classified as two-way entry, partial four-way entry and full four-way entry (MH1, 2016). Based on their stackability, plastic pallets can be nestable and stackable.

Beswick and Dunn (2002) states that plastic pallets have many advantages including their greater durability compared to wood pallets, however, they are more expensive. Therefore, they are commonly used in closed loop systems where reusability of the pallet is required. Plastic pallets are also recyclable, which creates a favorable end of life scenario. In addition, plastic pallets are easier to sanitize, therefore, they are commonly used in the food and pharmaceutical industries. (Freedonia, 2015).

Although, plastic pallets have an important role in the supply chain, there is a lack of published information on the U.S. plastic pallet industry. Most information is published by the Freedonia group that has been reporting on the industry since 2002. The Freedonia Report (2015) predicts that the demand for plastic pallets will be increasing with 4.6% from 2014 to 2019. According to their survey conducted in 2009, estimated pallet demand in the United States will reach 1.4 billion units by 2019 and will increase to 1.515 billion units (8.21%) by 2024. From the overall demand, 43.4 million (3.1%) will be plastic pallets in 2019 and 53 million (3.5%) will be plastic pallets in 2024.

However, in order to aid business decisions, foster investment in the industry, and allow the comparison of the plastic pallet industry to the wood pallet industry, a more in-depth characterization of the plastic pallet market is needed.

2 Objectives

The main objective of the research is to investigate the status of the plastic pallet market in the United States in 2018.

The specific objectives of the research are the following:

- Examine the material use of the industry such as percentage of recycled plastic in pallets, percent of plastic pallets with fire retardants, and usage of additives and reinforcements.
- Investigate design characteristics of plastic pallets such as common sizes, manufacturing methods, styles, and reusability.
- Develop a format for a repeatable survey to investigate long term trends in the industry.

3 Literature Review

3.1 Pallet Classification

MH1 (2016) describes a pallet as a “portable, horizontal, rigid, platform” the purpose of which is to help store and distribute products (Figure 1). They can be classified into two classes: stringer and block class pallets.

A stringer class pallet has several longitudinal pieces of wood with or without notches running the length of the pallet. Stringers are fastened together by deckboards (MH1, 2016).

A block class pallet is commonly constructed of nine blocks which are connected by stringer boards. The top deckboards are fastened to the stringer boards while the bottom deckboards are fastened directly to the blocks.



Figure 1 Stringer and block pallet (All Pallet Sizes, 2019).

Pallets also can be classified based on usage, top deck structure, accessibility, and size. Based on their usage, pallets are classified: reusable, meaning they can be handled more than once and single-use, which are designed to be used only once. (MH1, 2016). Some multiple use pallets are called pool pallets, which are produced and circulated by dedicated pooling companies such as CHEP USA , PECO Pallet or iGPS. Users can rent these pallets for a period of time but they never obtain ownership of the pallet.

Based on the top and bottom deckboard orientation, pallets are classified as single-deck, double-deck reversible, double-deck nonreversible, flush, single or double-winged, and single or double-cantilever (MH1, 2016).

Single-deck pallets are pallets without deckboards on the bottom. Double-deck, reversible pallets have identical top and bottom deckboard structure; thus, either side of the pallet can be used as the

top. Due to the location of the bottom deckboards, this pallet design cannot be handled by a pallet jack. Double-deck nonreversible pallets have different top and bottom deckboards; thus, they only can be used in one orientation. The double-deck nonreversible pallet design can be handled using a pallet jack (Figure 2.).

A flush pallet has top and bottom deckboards that do not extend beyond the spacers (blocks or stringers). The pallet is called single-winged if only the top deckboards extend beyond the spacers, and it's called double-winged if both the top and bottom deckboards extend beyond the spacers (MH1, 2016).

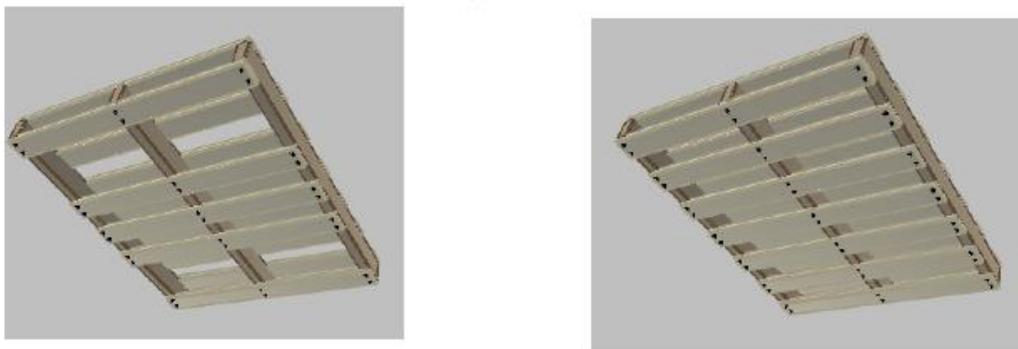


Figure 2 Non-reversible (1st picture) and reversible (2nd picture) pallets (NWPCA, 2018).

Based on their accessibility, pallets are classified as two-way, partial four-way, or full four-way pallets. Two-way entry pallets allow forklift tines and pallet hand jack handling from two ends only (ISO 6780:2003). Partial four-way entry pallets have full accessibility at the two ends, but the pallet only can be handled from the two sides using a forklift due to the restricted accessibility caused by the size of the notch (MH1, 2016). Full four-way entry pallets are open on all four sides allowing both forklifts and pallet jacks to enter them without any trouble (MH1, 2016).

Based on bottom deckboard orientation, pallets can be classified as unidirectional, overlapping, perimeter, or cruciform (Figure 3). Overlapping means that parts of the pallets are overlapping each other. Perimeter pallets are pallets “which in the bottom deck has the outer bottom components arranged as a complete frame with one or two centre bottom components” (ISO 445:2008). In the case of unidirectional pallets, all bottom deckboards are oriented either parallel to the length or parallel to the width of the pallet (MH1, 2016). Cruciform pallets have two middle bottom deckboards that are perpendicular to each other (ISO 445:2008).

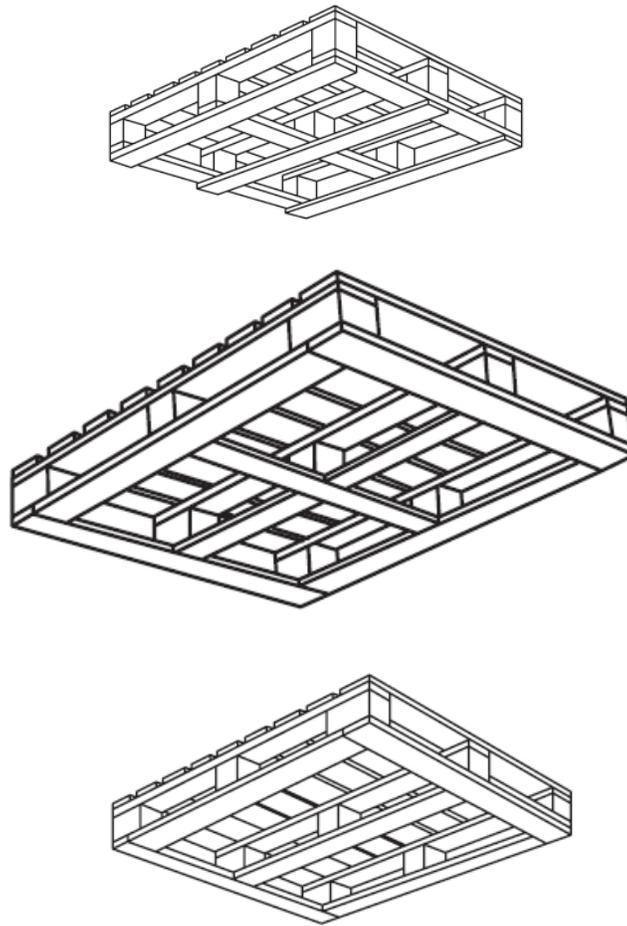


Figure 3 (Top to bottom) Overlap pallet, cruciform pallet, & perimeter base pallet (ISO 445:2008).

Some variations of plastic pallets can be stacked but not nested. The picture frame stringer pallet, perimeter stringer pallet, leg pallet, double deck pallet and runner pallet belong to this category (MH1, 2016).

3.2 Pallet Sizes

The size of a pallet is determined by length and width. The length of the pallet is determined by the length of the stringer boards or stringers for wooden pallets, the direction of the strong axis for plywood top deck pallets (ISO 6780:2003), or the dimension of the longer side for plastic pallets. The width is to the length of the top deckboards for wooden pallets and as the shorter side for plastic pallets. The most common size in the US is the 48 in. x 40 in. which is mainly used by the US grocery industry (Gerber, 2018). Other industries also have their own common pallet sizes (Bush and Araman, 2008) such as chemical companies prefer 42 in. x 42 in., drums are distributed

on 48 in. x 48 in., and the automotive industry uses 48 in. x 45 in. (Figure 4). However, according to the recent wood pallet survey conducted by Virginia Tech (Gerber, 2018), 39% of all wooden pallets are non-standard sizes.

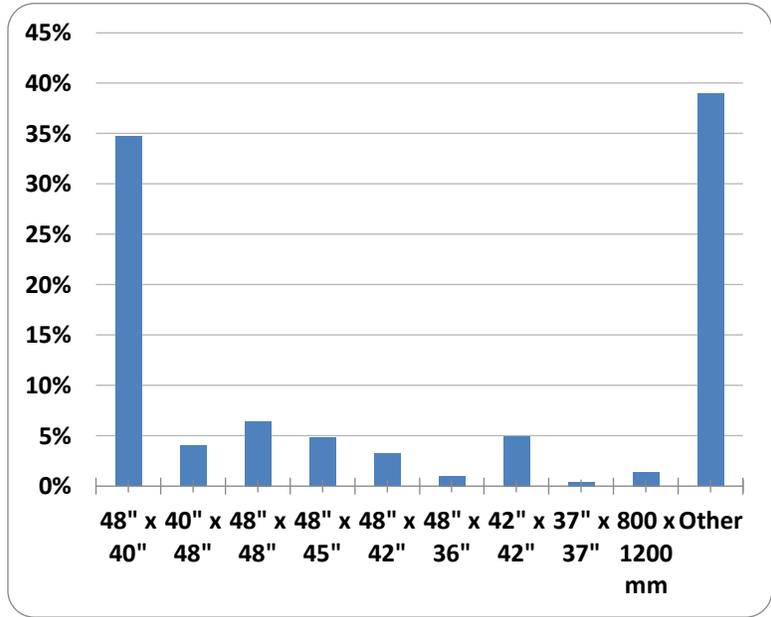


Figure 4 Most Common Pallet Sizes in the US. (Gerber, 2018)

Other than the different pallet sizes commonly used by U.S. industries, there are several other common pallet sizes used across the globe (Table 1). The mostly commonly used pallet size in Europe is 800 mm x 1200 mm (31.50 in. x 47.24 in.); Australia uses 1165 mm x 1165 mm pallets; and the Asia Pacific area uses 1100 mm X 1100 mm pallets.

Table 1 Pallet dimensions on different continents.

Dimensions (W x L) millimeters	Dimensions (W x L) inches	Region most used in
1016 x 1219	40.00 x 48.00	North America
1000 x 1200	39.37 x 47.24	Europe, Asia
1165 x 1165	45.9 x 45.9	Australia
1067 x 1067	42.00 x 42.00	North America, Europe, Asia
1100 x 1100	43.30 x 43.30	Asia
800 x 1200	31.50 x 47.24	Europe

3.3 Material

3.3.1 Wood

Wood is the most commonly used pallet manufacturing material and wood is considered as one of the most “cost competitive, and environmentally friendly” materials (BAMF, 2004). In 2018, 93% of pallet users used wooden pallets (Bond, 2018); meanwhile, wood was responsible for 93% of the material demand estimate in 2019 (Freedonia, 2015). Wood species can be categorized into different lumber qualities, called grades (Ulrich et al., 2012) and divided into hardwood or softwood. Hardwoods are deciduous; their leaves are broad (Rae, 2005). The most common hardwoods are oaks, maples, and birches. Softwoods are evergreen, meaning they do not drop their leaves at the end of the season (Rae, 2005). The most common softwoods are pines, spruces, firs, and hemlocks. In the United States, hardwoods are mostly used in the Northeast (82%). As the region changes from the Northeast to the Midwest (48%), the South (40%) and the West (12%), the hardwood consumption decreases and changes over to softwood. In the West U.S. pallet manufactures use mostly softwood (Gerber, 2018).

3.3.2 Plastic

Plastic is the second most commonly used pallet material in the U.S. (Bond, 2018). More than 30% of pallet users use some plastic pallets (Bond, 2018). Plastic makes up 3.4% of pallet demand (Freedonia, 2015). The market demand for plastic pallets is projected to grow by 22%. They are washable, light, and commonly more durable than wood pallets (Freedonia Report, 2015). Plastic pallets are preferred by companies that desire a high level of sanitation, greater durability, or need pallets that are exempt from the ISPM 15 phytosanitary regulations (FAO, 2017). They also can be manufactured in different colors which can increase the appeal of store displays. Some of the disadvantages include the high purchase price, low friction and stiffness, slower production, and the fact that some plastic pallets cannot be repaired.

Plastic pallets can be made of thermoset resin, thermoplastic resin, or composite plastic materials. Thermoset resins are often defined as petrochemicals, and they are not common for plastic pallets because at room temperature, prior to applying catalyst, they are liquids (Johnson, 2019).

Thermoplastic resins are less expensive than thermoset resins, and their properties vary with temperatures. Under this classification there are two commonly used resin types: High Density

Polyethylene (HDPE) and Poly Propylene (PP). In the U.S. HDPE is the most common, making up 86% of material demand (Freedonia, 2015). This resin can be virgin resin or recycled resin. Virgin resin is more frequently used (84%) because the length of the polymer chains degrades during the recycling process which reduces stiffness, strength, and the impact resistance of the pallet.

Besides resin, different fillers or fiber reinforcements are added to these plastic materials in order to improve their properties. Pallets with a significant amount of added materials are classified as composite pallets. The most common fibers added to the resin are glass and wood fibers.

Moreover, plastic pallets often include additives such as UV inhibitors, fire or flame retardants, pigments, blowing agents, nitrogen gas, and cold temperature additives to improve the performance of the pallet (Maine Department of Environmental Protection, 2011).

UV inhibitors are additives that reduce the effects of ultraviolet radiation on its properties. Fire retardants reduce the burning temperature of the plastic pallet during a fire in order to allow a sprinkler system time to extinguish the fire. The most commonly used chemicals are ammonium polyphosphate, magnesium hydroxide, and zinc borate (Ayrilmis, 2011). It has been shown that using fire retardant chemicals can affect the surface of the plastic; the smoothness decreases while the roughness increases. Pigments can add color to the plastic pallet. To reduce the raw material in a plastic pallet, the manufacturer may use nitrogen gas blowing. To save the pallets' mechanical properties during cold temperatures, cold temperature additives can be added.

3.3.3 Corrugated

Corrugated pallets are used 8% by the responding companies in the United States (McCrea, 2018). The world's demand for these type of shipping platforms was 161 million in 2017 (Freedonia, 2015).

Pallets can be made of paper-based materials such as corrugated boards or honeycomb sheets. Due to their light weight, paper pallets are more ergonomic and can lower freight costs. They also have a smooth deck surface. On the other hand, paper pallets tend to be less durable than wood or plastic pallets, and they are more susceptible to moisture.

3.3.4 Metal

Metal pallets including steel, stainless steel, and aluminum are used by approximately 6% of the industry (Bond, 2018) and are responsible for only 0.7% of the pallet demand (Freedonia, 2015). Due to their exceptional strength and stiffness, metal pallets are mostly used in the military or in industries where pallets are either exposed to extreme environmental conditions or need to carry heavy weights. Metal pallets are also reusable, recyclable, sanitary, and resistant to fire. However, the high purchase price, heavy weight, and low top deck friction limits their usability.

3.3.5 Composite

In 2017, 18% of the surveyed industries were using some wood composite pallets. This was a 3% increase in their usage from 2016 and 2015 (McCrea, 2017).

Composite pallets are favored by some companies due to their smooth top deck surface, and the fact that they are exempt from ISPM 15 phytosanitary regulations. However, they have a high purchase price and they are expensive to repair. Other factors include the facts that composite pallets are less recyclable than solid wood pallets, less water resistant than plastic or metal pallets, and fasteners can damage the products/unit load.

3.4 Manufacturing Methods

3.4.1 Wood

Around the mid 1900s, manual assembly was the main operation for pallet assembly (LeBlanc and Richardson, 2003). All wood shipping platforms were nailed together with hammer by manual labor. Later, to increase efficiency, assembly machines were invented; the nailing of the deckboards to the stringers could now be performed by machine, but the lumber still needed to be placed into the machine by workers. In the following years, the level of automation was further increased so that automatically feeding and positioning the pallet components into the machines could now be performed automatically (LeBlanc and Richardson, 2003). The quality requirements for board dimensions and placement are listed in the Uniform Standard for Wood Pallets by the National Wooden Pallet and Container Association (NWPCA, 2014).

The components of the pallet can be fastened with nails, staples, bolts, screws, or lag screws (NWPCA, 2014). The minimum number of fasteners per connection are specified in the Uniform

Standard for Wood Pallet standard published by the National Wooded Pallet and Container Association (NWPCA, 2014) and presented in Table 2.

Table 2 Minimum Numbers of Fasteners Per Connection (NWPCA, 2014)

Deckboard Width	Minimum Number of Fasteners per Connection of Single-Use or Reusable Pallets
Up to 5-1/4 in. (133 mm)	2
5-1/4 up to 7 in. (133-179 mm)	3
7 to 8 in. (179-203 mm)	4
Corner block	3
Interior block	2

3.4.2 Plastic

There are several different ways to manufacture plastic pallets including high pressure injection molding, low pressure molding, thermoforming, rotational molding, compression molding, blow molding, and profile extrusion (MH1, 2016).

During high pressure injection molding, the plastic resin is injected to a closed mold, and then, after a pressuring the plastic product can be removed from the machine. Almost the same manufacturing process is followed for low-pressure molding with the exception that the plastic resin has gas added by the injection machine. The thermoforming method takes one or two soft plastic sheets and forms them into a mold using vacuum or positive pressure. Rotational molding is a slower process than injection molding or thermoforming because the plastic resin is heated first than is slowly rotated around inside the mold to form its final shape then slowly cooled down (Figure 5).

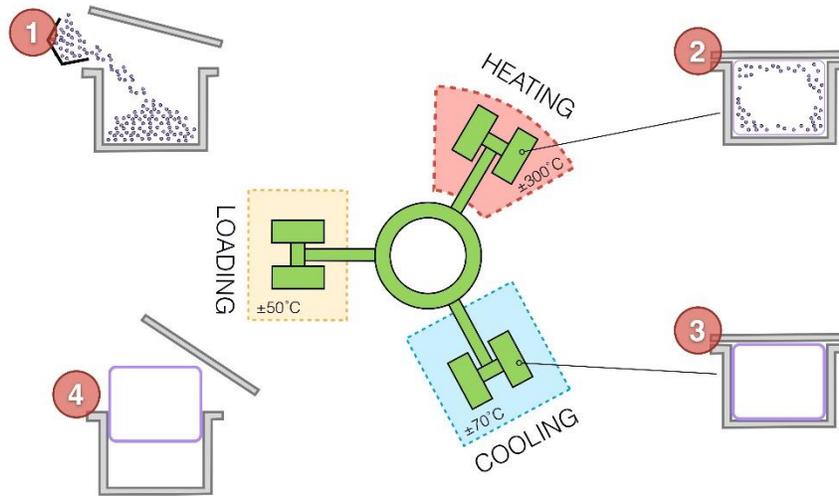


Figure 5 Process of rotational molding (Pentas Moulding, 2019).

During compression molding the melted plastic resin is placed into the machine, and then using compression, the final product is created (Figure 6).

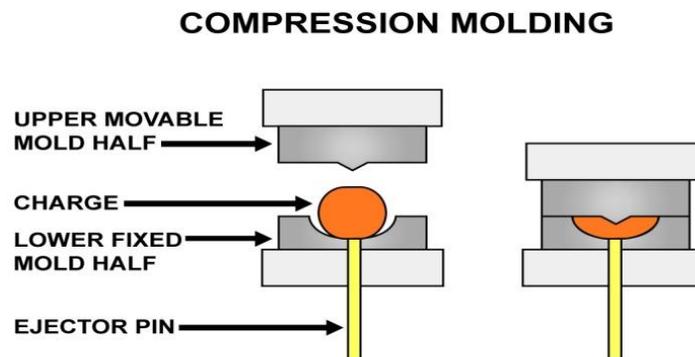


Figure 6 Process of compression molding (MoldEx3D, 2019).

Blow molding forces liquid plastic into the required mold by air-pressure (MH1, 2016). During profile extrusion (Figure 7), the moldable plastic resin is extruded through a die into continuous profiles. After cooling down, these profiles will be cut to length and then assembled into a pallet.

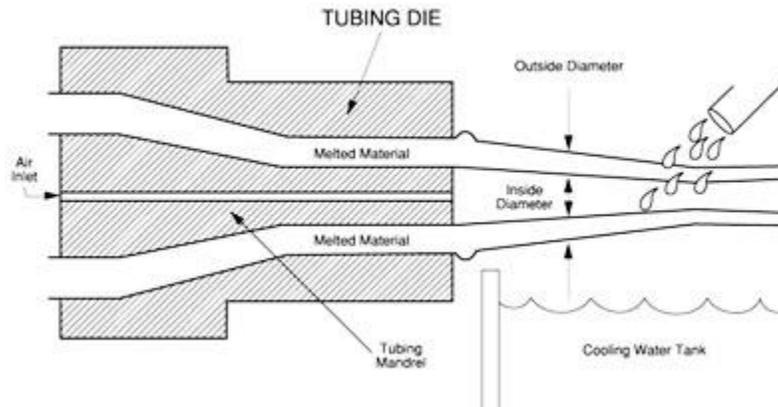


Figure 7 Profile extrusion process (Industrial Extrusion Machinery, 2019).

There are several different ways to fasten the components of a plastic pallet together. One option is snap fits; these are connections made by two interlocking clips compressed together. Another way is welding, where the plastic pallet parts are linked by melting the components together. Plastic pallet components also can be secured together using adhesives or mechanical connections including bolts, screws, and nails.

3.5 Market Studies

3.5.1 U.S. Market for Wood Pallets

Globally a significant 82.6% of the pallet market share is wood pallets (Persistence Market Research, 2017). This dominance also shows in the U.S. market where wood pallet production reached 849 million (Gerber, 2018), and 72% of those were stringer pallets. Results have shown that new wood pallet production has grown significantly (22%), and the most common size manufactured is 48 in. x 40 in. (35%) (Gerber, 2018).

3.5.2 U.S. Market for Plastic Pallets

In the U.S., more than 30% of companies are using plastic pallets (Bond, 2018), and the market share of plastic pallets based on material demands is 3.4% (Freedonia, 2015). It is estimated that the demand for plastic pallets will increase from 43.4 million in 2019 to 53.0 million in 2024. Since plastic pallets are manufactured from resin, Freedonia (2015) predicted how many pounds of resin will be needed to fulfill the demand of plastic pallet manufacturers. According to their data, demand for resin will reach 125 million pounds by 2024. From this total, 84.5% will be HDPE and 15.5% will be other resins. It was estimated that most of the resin used in 2019 was virgin resin (84%) while the rest was reclaimed (16%). The average cost of a plastic pallet in 2019 was \$35.50; however, plastic pallets had a wide price range from \$20.00 for export pallets to \$80.00 for multiple use pallets. Although the Freedonia Report (2015) published market demands by region and sector, the demand for wood, plastic, and other materials were combined.

4 Methodology

4.1 Survey Design and Collection

The survey used the Total Design Method (Dillman et al., 2009) to collect the data for this study. The emailed questionnaire consisted 15 questions; 3 questions about general company information such as employee and facility numbers, 3 questions about production numbers for plastic pallets, 9 questions about manufacturing methods and raw material usage for the calendar year 2018. The questions included open and closed- ended inquiries including an “other” option. Some questions required answers on numerical (ratio scale) levels.

The database for the plastic pallet and reusable packaging companies was collected using the addresses provided from the NAISC code 326199 - All Other Plastics Product Manufacturing (total number of businesses: 9427). The survey was also distributed with the help of the Reusable Packaging Association (Tampa, FL) by reaching out to their members to support the data collection and help gather more information about the industry.

The first draft of the questionnaire was sent out to three selected company leaders for clarity and quality checking (Rea and Parker, 2014). The finalized survey was created using Qualtrics (Provo, UT). The questions were available on an online platform.

The final version of the survey was sent out in June 2019. Each addressee received an introduction letter and an ID number to keep the answers anonymous but trackable for clarity check if necessary. There were two follow-up mailings via email: two weeks and four weeks after the initial mailing. The survey was closed eight weeks after the original mailing (Rea and Parker, 2014).

4.2 Data Analysis

After the questionnaire was closed, the data was checked for validity. If any unusual data is found, it was investigated by contacting the company for clarification. Answers received after the closure were not be counted into the survey to exclude late response bias.

A descriptive analysis was conducted on the collected data using Microsoft Excel (Microsoft Cooperation, Redmond, WA) and JMP (Cary, NC) in order to gain information about the plastic pallet industry.

4.3 Limitations

The limitation of this study includes the following: There is a lack of information on the number of plastic pallets manufactures and employee numbers in the plastic pallet industry. Therefore, the results of the survey cannot be scaled up using company number or employee numbers. Thus, the number of pallets manufactured by the respondents were compared to the results published by the Freedonia report in order to identify whether the majority of production was captured by the survey.

5 Results and discussion

After closing the survey, the data needed cleaning and clarification. Out of the 26 companies that were contacted, 14 replied resulting in a 54% response rate.

5.1 Number of plastic pallets

The number of plastic pallets produced by the respondents in the United States in 2018 was 15,952,042. This is only 37% of the expected plastic pallet demand (43.4 million plastic pallets) that was predicted by the Freedonia report (2015) for the United States for 2019. However, it needs to be pointed out that the current survey estimated the actual number of plastic pallets manufactured in the United States, while the Freedonia report (2015) estimated only the demand for plastic pallets. In other words, the estimated pallet demand could include pallets manufactured outside of the United States and imported into the country. The demand could also be fulfilled by multiple use plastic pallets that are already in circulation.

The survey also revealed that the 14 responding company employed an estimated 5298 employees. Other studies that surveyed the wooden pallet industry (Bejune et al., 2002; Bush and Araman, 2008; Bush and Araman, 2014; & Gerber, 2018) used the employee numbers to estimate the total number of wooden pallets manufactured in the United States. However, contrary to the Wooden Container and Pallet Manufacturing (NAICS 321920), there is not an NAICS code that would include only the manufacturers of plastic pallets. Therefore, the employee number could not be used to scale the numbers obtained from the survey and estimate the national totals for plastic pallets.

5.2 Usage

Out of the almost 16 million plastic pallets manufactured by the respondents to this survey, 81% were manufactured as multiple use and 19% were manufactured as single use (export) pallets. In general, single use pallets are utilized when the design of the supply chain does not allow for cost-effective return and reuse of the pallets. Most single use pallets, in the United States, are used for import/export shipments (Bengtsson, 2015).

The majority of plastic pallets produced by the responding companies were multiple use pallets with favorable material properties, design flexibility, and durability. Multiple-use plastic pallets also help companies save money and be more environmentally responsible (Bengtsson, 2015). The majority of plastic pallets exists in closed-loop systems which means that they are used in a captive environment where they do not leave the warehouse. The food industry is a major participant in this type of closed-loop pallet-rental system because it helps them reduce the risk of contamination as the plastic pallets are cleaned more regularly and more effectively than in the case of wooden pallets (Go Plastic Pallets, 2007).

5.3 Size

The 48 in. x 40 in. pallet is the most commonly used size of pallet by the grocery industry and it is the most manufactured pallet size (55%) by the respondents of this survey (Figure 8). The most common sizes are the 48 in. x 45 in. (29%) used by the automotive industry and the 56 in. x 44 in. (5%) pallet used most often in the transportation of cans, glass, and PET containers. A small percentage of the remaining standard pallet sizes are the 48 in. x 48 in. (2%) which is used for 55-gal drum storage and the 37 in. x 37 in. (1.4%) which is most often used by the beverage industry. Seven percent of the respondents choose the “Other” option, which could be 29 in. x 42 in., 37 in. x 43 in., 36 in. x 48 in. or 32 in. x 37 in. pallets.

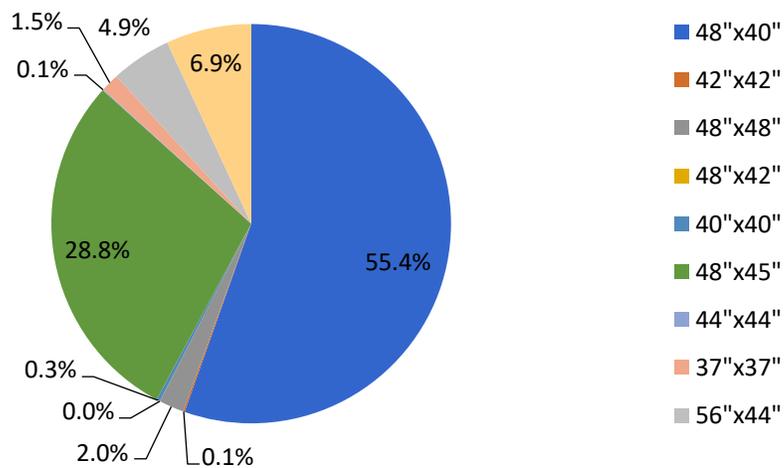


Figure 8 Proportion of the sizes of plastic pallets manufactured in the U.S. in 2018.

Regarding the standardization of pallets, this survey shows a higher level of standardization in the plastic pallet industry compared in the wood pallet industry. This survey indicates that the 48 in. x 40 in. is 55% of the production of the respondents whereas in the wood pallet industry this percentage is only 35% (Gerber, 2018). Furthermore, more than 39% of new wooden pallets were custom sized for specialized applications (Gerber, 2018); while, this survey showed that only 7% of plastic pallets produced by the respondents were custom sizes.

5.4 Manufacturing

The main reported manufacturing methods of plastic pallets were: high pressure injection molding (63%), compression molding (17%), and low-pressure injection molding (15%) (Figure 9). Only a small percent of the responding companies used rotational molding (4%) or thermoforming (1%) to manufacture plastic pallets.

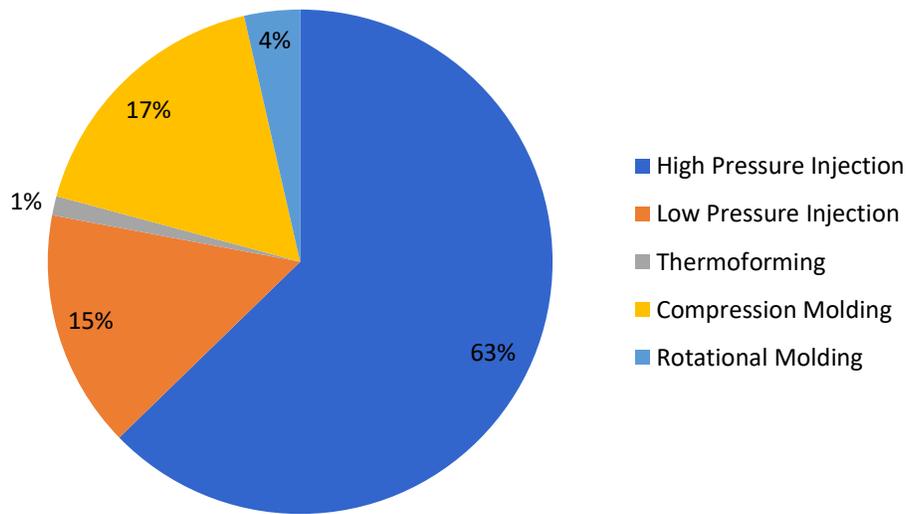


Figure 9 Proportion of manufacturing methods of plastic pallets in the U.S. in 2018.

The advantages of the high-pressure injection process are usually the faster cycle times and the lower pallet weight. However, the disadvantage of high-pressure injection molding is the cost of tooling. In order to make a pallet with this process, a high pressure is required. It takes more than 3000 tons of pressure to create a one-piece pallet or 1500-1800 tons of pressure to create a two-piece pallet. On the other hand, low pressure foam molding offers much larger platen sizes (wider

and taller than high pressure injection molding machines), larger shot sizes, and it requires less tonnage of pressure (500-750 tons) to create one pallet. One major disadvantage of low-pressure foam molding is heavier parts and longer manufacturing time (Yam, 2009). In addition, pallets manufactured using high pressure injection molding tend to crack; whereas, foam-molded pallets tend to break off in chunks.

5.5 Plastic Material and Recycling

The survey respondents used 271,451 U.S. tons of plastic resin to manufacture the nearly 16 million plastic pallets. This gives us an average plastic pallet weight of 34 lbs. which is higher than the average plastic pallet weight of 25 lbs. reported by the Freedonia Report (2015). The most commonly used plastic resin types were high-density polyethylene (HDPE) with 68% of the total and polypropylene (PP) with 9% of the total (Figure 10.).

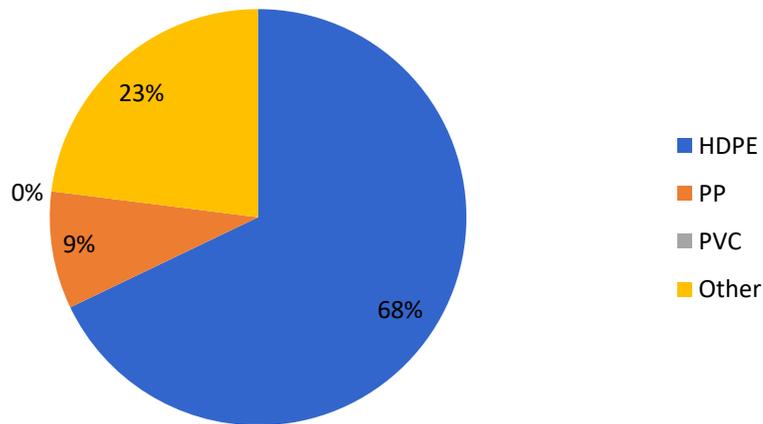


Figure 10 Proportional distribution of virgin resin used to manufacture plastic pallets.

The HDPE usage by the respondent was about 20 % lower than the 85.7% predicted by the Freedonia Report (2015). Nonetheless, HDPE is one of the most widely used resin types in the industrial sector (Mordor Intelligence, 2019). In North America, HDPE production is expected to reach 21 million mega tons. From the 21 million mega tons of HDPE, Freedonia (2015) predicts a demand of 823 million lbs. (0.37 mega ton) for plastic pallets industry by 2019. One of the main advantages of HDPE is that it can resist extreme weather and drastic temperature changes as it has a high temperature tolerance (125 °C) (Wei et al., 2010). Furthermore, it can handle impacts from

rough handling as it has higher density, modulus of elasticity, and tensile strength than other resin types (Meran et al., 2008). In addition, HDPE is cheaper than PP which would explain its wider use among pallet manufacturers. The remaining plastic pallets were manufactured with resin types of the “Other” category (23%).

Even though, plastic resins can be easily recycled, this survey found that manufacturers used 178,470 tons (66%) of virgin resin and 92,981 tons (34%) of recycled resin. During manufacturing procedures, resin experiences heat and pressure. When recycled, the resin becomes weaker each time it goes through the heat and pressure of the manufacturing process (i.e. each time it is recycled) (Diff, 2019). Therefore, the mechanical properties of recycled resins are lower than the mechanical properties of virgin resins. However, the potential cost savings still make recycled resin a popular choice for pallet manufacturers. To compensate for the lower mechanical properties, pallet manufacturers mix virgin and recycled resin to obtain the desired properties. To ensure that a pallet performs as intended, each plastic pallet design has a maximum recycled resin content.

This study has shown that 44.4% of the manufacturers who responded use recycled plastic resin content of between 25-50% in their plastic pallets (Figure 11). This is followed closely by 42.7% of respondents stated that they used 75-100% recycled resin content in their plastic pallets indicating, that respondents may consider cost over performance or manufacturing pallets with lower mechanical properties.

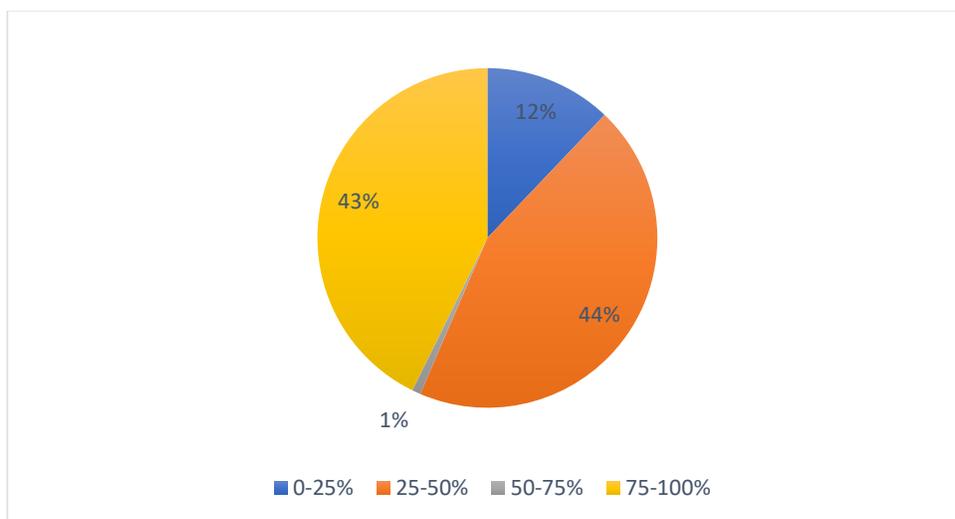


Figure 11 Proportion of recycled resin content in plastic pallets.

Reground/recycled plastic materials are cheaper to purchase but they are weaker as described before since the substance has been modified after several recycling cycles. On the other hand, 12.1% of the pallets produced by the respondents are made of high percent of virgin materials (0-25% recycled plastic). Pallets made of 100% virgin resin have better mechanical properties and virgin resin is also required in industries that require high level of sanitation such as the food and pharmaceutical industry or want to avoid cross contamination such as some of the chemical companies (Singh et al., 2016). Because pallets with recycled resins content have better environmental footprint, pallets manufactured for non-regulated industries might contain a higher percentage of recycled resin because it generally does not affect the pallets' performance just makes them more sustainable.

5.6 Additives and Fire Performance

Early Suppression Fast Response (ESFR) systems has been a major change in warehouse sprinkler systems. Research programs measuring the effectiveness of this advanced sprinkler technology started in 1983, and within two years, the new ESFR sprinkler system was developed. The main purpose of the study was to develop a sprinkler system that could perform better during large warehouse fires where the interior height of the warehouses reached 30+ ft. The previous warehouse sprinkler systems, which used large drop-hoses and in-rack sprinklers, did not have the capacity to deal with large fires (Yao, 1988).

The types of warehouse sprinkler systems depend on which packaging commodity classes are stored in the warehouse. There are four commodity classes based on the type/size of unit load and the type of pallet (NFPA 13, 2013). The higher the commodity class of unit loads stored in the warehouse, the higher density of sprinkler systems is required. When the goods are stored on wooden pallets, the commodity class is predominantly determined by the type of products and packages. However, when unit loads stored on unreinforced HDPE and PP plastic pallets the classification of the commodity unit can be increased one class. On the other hand, when reinforced HDPE and PP plastic pallet are used, the classification of commodity unit can be increased two classes expect for class IV commodity (NFPA 13, 2013). If EFSR systems are not used, plastic pallets used certain flame-retardant additives to reduce their burn temperature and consequently, to reduce their commodity class to match their wood pallet counterparts.

Due to the wide variety of available flame-retardant additives, the fire performance of these pallets needs to be certified by an accredited agency. There are only two available certifications in the United States: Underwriter Laboratories (UL 2335) and Factory Mutual (FM 4996) certified (Maine Department of Environmental Protection, 2011). Underwriter Laboratories is a third-party firm certified from 2001 that performs fire retardancy tests in order to ensure plastic pallets meet NFPA 13 regulations (Gardner Publications, 2001). Meanwhile, Factory Mutual is an insurance company that also insures a large number of warehouses in the United States (Factory Mutual Files Suit, 2010).

The majority of the pallets produced by the respondents were not listed. Only 4 companies indicated that they have listed plastic pallets, three companies FM listed and one company UL listed. Meanwhile, 16.8% of the pallets were FM 4996 listed and only 3.6% were UL 2335 listed (Figure 12). One reason for the low percent of listed pallets could be the high cost of certification and also that most modern warehouses are already equipped with advanced EFSR sprinkler systems which can more effectively mitigate the fire. Since adding flame-retardant additives weaken pallet performance and raise their costs, manufacturers only add flame-retardant additives when it is required by NFPA or the customer based on personal communication with survey participants in 2019.

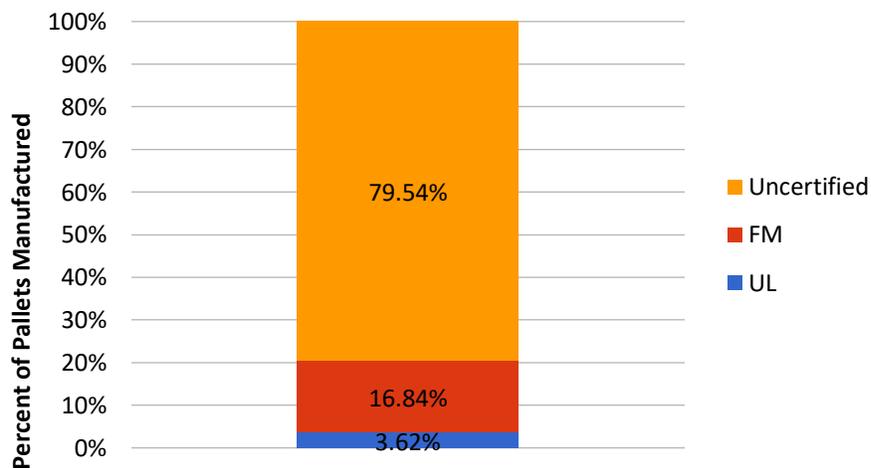


Figure 12 Level of fire-performance certification of the plastic pallets in the United States in 2018 (FM: Factory Mutual, UL: Underwriter Laboratories).

The most-used flame-retardant additives used by the responding companies is phosphate (15.3%), which became popular when the industry turned away from halogenated additives due to their harmful effects on human health and the environment (Figure 13). At present, only 3.3% of the pallets have halogenated additive. Metal hydroxide is used by 6.6% of respondents as this chemical can reduce flammability, smoke, and has low toxicity (Fu et al., 2017). Most of the respondents (74.7%) claimed to use “Other” flame-retardant or “None”. One possible explanation for the high percent of the “Other” responses that the companies are not allowed to use brominated flame-retardant additives (Axelrad, 2009), therefore, they may keep research and development related to flame retardant chemicals confidential.

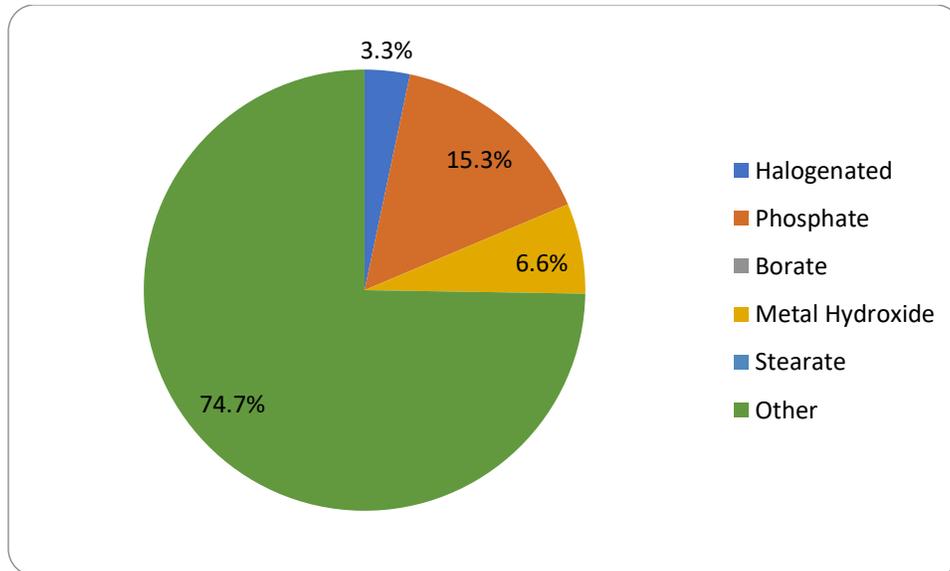


Figure 13 Proportion of fire-retardant additives in plastic pallets in the U.S. in 2018.

5.7 Reinforcements

To increase the strength properties of plastic pallets, some manufacturers are using fiber reinforcement. The results of this survey indicate that 13% of the plastic pallets produced by the respondents were reinforced with glass fibers due to the fact that glass fibers are three times denser than PP resin (Figure 14). Glass fibers increase stiffness and impact resistance of plastic pallets, even though they also increase the weight (Corbière-Nicollier et al., 2001). The disadvantage of putting fiber reinforcements into the pallet is that the fibers cause extra wear on the manufacturing equipment and make recycling of the plastic pallets more difficult (Soury et al., 2009).

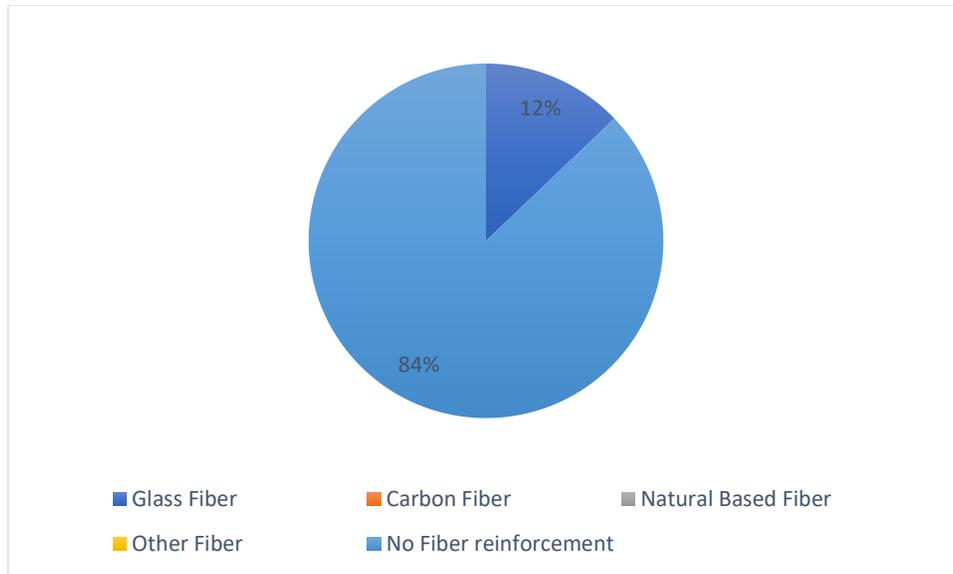


Figure 14 Proportions of fiber reinforcement types used in plastic pallets.

Another way to increase the strength properties of plastic pallets is to add reinforcement parts to them. For this question only 13 companies responded with the following ratio: 5 companies indicated that they were using predominantly steel reinforcement, 3 companies preferred aluminum reinforcement, 1 company indicated that they are using poltrution and 4 companies claimed that they are using other or do not know.

5.8 Format for a repeatable survey

Although, the survey revealed important industry characteristics, observing the change in the investigated factors over time would help our understanding of the ongoing trends in the plastic pallet sector. Therefore, based on observations made during the current survey, the survey instrument was modified in order to be used to analyze long term trends.

In order to reach a larger audience and create a representative data set for the U.S., closer cooperation between these companies, Reusable Packaging Association (RPA) and Virginia Tech, is required. In the future, the survey instrument could also be distributed by major industry magazines, such as Material Handling Industry (MHI), in order to reach companies who might not be part of the Reusable Packaging Association (RPA).

The method of delivery for the survey should also be revised. Based on the greater number of responses received during the wooden pallet survey conducted by Gerber in 2018 and the feedback

received during this survey distribution, future surveys should be distributed in both a digital and a paper form.

To repeat this study with improved questions the following steps are recommended:

Step 1. Check the database for validity and contact the Reusable Packaging Association (RPA) to find new contacts.

Step 2. Setup a survey in Qualtrics or any equivalent software based on the template in Appendix A.

Step 3. Setup an email delivery software (Mailchimp, Atlanta GA) for the initial email and all reminders based on Appendix B, C, and D. Attach the survey and an introduction letter (found in Appendix E) as Word documents that are downloadable content in the email.

Step 4. Upload the updated database into Mailchimp. Make sure each company has an individual company code in order to keep the survey anonymous.

Step 5. Send out the initial email (6 weeks before closing the survey).

Step 6. Remove people who respond from the MailChimp database.

Step 7. Send a reminder email (4 weeks before closing the survey).

Step 8. Remove people who respond from the MailChimp database.

Step 9. Send a second reminder email (2 weeks before closing the survey).

Step 10. Close the survey.

Step 11. Review the collected data and contact any companies whose responses require clarification.

Step 12. Use the method/template to analyze the results.

Step 13. Publish the results.

6 Conclusion

Based on this study surveying 26 companies with 54% response rate, the plastic pallet industry manufactured almost 16 million plastic pallets in the United States in 2018.

The results indicate that there is a higher level of standardization in the plastic pallet industry than in the wood pallet industry. Two sizes, 48 in. x 40 in. and 48 in. x 45 in., dominated the plastic pallet market in 2018 with an 84% market share. All other plastic pallet sizes only made up a small percentage of the market (2-7%). In comparison, the sizes of wood pallets varied more. The most frequently produced size of wooden pallets was 48 in. x 40 in. (35%) and 39% of the market was made up of non-standard sizes (Gerber, 2018). The high level of standardization for plastic pallets can be explained by their more expensive manufacturing costs which makes customers to standardize their processes before making a larger investment to manufacture plastic pallets.

Most plastic pallets manufactured by the respondents were made with high pressure injection molding (63%), and the most used resin type was HDPE (68%). Although 66% of the materials used to produce plastic pallets were virgin resins, the industry also used a high percentage of recycled resin content (34%) as well, which reduces the cost of the pallet and reduces its environmental footprint.

This study has shown that most of the plastic pallets manufactured in 2018 did not contain flame-retardant additives; only 20% of the respondents indicated that their pallets were UL or FM certified. Phosphate was the mostly commonly applied flame-retardant additive (8%). The low percentage of pallets produced with flame-retardant additives could be explained by the prevalence of Early Suppression Fast Response (ESFR) systems in the industry. After 1990, most warehouses were built with these high efficiency sprinkler systems which are very effective in putting out fires. Therefore, these warehouses do not require their pallets to be treated with flame retardant additives.

To improve stiffness, plastic pallets can be reinforced with short fibers infused into the plastic resin, or reinforcement beams can be added into the plastic pallets' structure. In 2018, only 13% of the pallets produced by our survey respondents had any fiber reinforcement and this 13% all reported using glass fibers. On the other hand, 47% of the plastic pallets manufactured by respondents used reinforcement beams in order to increase strength and stiffness.

Although this study obtained essential information about the current state of the plastic pallet market, observing long term trends in the industry could reveal more information the industry. Therefore, this survey has been revised and the framework of a study is proposed that would allow researchers to investigate long-term trends in the plastic pallet industry. We propose that in collaboration with relevant associations and government agencies, this survey/study should be conducted every five years, in order to ensure the efficient data collection and yield high response rates.

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Appendix

Appendix A: Plastic pallet survey questions from Qualtrics.

Q1

First time ever, Virginia Tech in collaboration with the Reusable Packaging Association is conducting a comprehensive market study of the US plastic pallet industry.

To begin the survey, please provide the company code that was included in the invitation letter.

Q2 How many facilities did your company have in the United States in calendar year 2018?

Q3 How many production employees did your company have in calendar year 2018?

Q4 How many NEW plastic pallets were produced by your company in calendar year 2018?

Q5 What percentage of the plastic pallets produced by your company was intended for single or multiple use in 2018?

Single Use (Export) : _____ (1)

Multiple Use : _____ (2)

Total : _____

Q6 What percentage of the total plastic pallets produced by your company in 2018 was each of the following sizes?

% 48" x 40" : _____ (1)

% 42" x 42" : _____ (2)

% 48" x 48" : _____ (3)

% 48" x 42" : _____ (4)

% 40" x 40" : _____ (5)

% 48" x 45" : _____ (6)

% 44" x 44" : _____ (7)

% 37" x 37" : _____ (8)

% 56" x 44" : _____ (10)

Other : _____ (11)

Total : _____

Q7 What percentage of the plastic pallets were manufactured by your company using the following methods in 2018?

High pressure injection : _____ (1)

Low pressure injection : _____ (2)

Thermoforming : _____ (3)

Compression molding : _____ (4)

Rotational molding : _____ (5)

Total : _____

Q8 What percentage of the following virgin resin types your company used to produce plastic pallets during 2018?

HDPE : _____ (1)

PP : _____ (2)

PVC : _____ (3)

Other : _____ (4)

Total : _____

Q9 What amount of the plastic resin in US tons did you use to produce plastic pallets in 2018 from the following categories?

virgin resin (US tons) (1) _____

recovered resin (US tons) (2) _____

Q10

What percentage of the plastic pallets produced by your company in 2018 has approved maximum recycled resin content that fits into the following categories?

0-25% max recycled content : _____ (1)

25-50% max recycled content : _____ (2)

50-75% max recycled content : _____ (3)

75-100% max recycled content : _____ (4)

Total : _____

Q11 What percentage of the plastic pallets produced by your company in 2018 were tested and certified by the following groups ?

Underwriters Laboratories (UL) : _____ (1)

Factory Mutual (FM) : _____ (2)

Non- Certified : _____ (3)

Total : _____

Q12 What percentage of the fire retardant additives used by your company in 2018 were made of the following materials?

Halogenated : _____ (1)

Phosphate : _____ (2)

Borates : _____ (3)

Metal Hydroxide : _____ (4)

Stearate : _____ (5)

Other : _____ (6)

Total : _____

Q13 What percentage of the following fiber reinforcements were used in plastic pallets produced by your company in 2018?

Glass Fiber : _____ (1)

Carbon Fiber : _____ (2)

Natural Plant Based Fiber : _____ (3)

Other Fiber : _____ (4)

Without Fiber Reinforcement : _____ (5)

Total : _____

Q14 What percentage of the following beam reinforcements were used in plastic pallets produced by your company in 2018?

Aluminum : _____ (1)

Steel : _____ (2)

Poltrution : _____ (3)

Other : _____ (4)

None : _____ (5)

Total : _____

Q15

Thank you very much for filling out the survey.

Appendix B: Initial email sent via Mailchimp.



Market Study of the Plastic Pallet Industry in the United States in 2018

The first time ever, Virginia Tech in collaboration with the [Reusable Packaging Association](#) is conducting a comprehensive [market survey of the US plastic pallet industry](#). The survey will collect key industry characteristics including number of plastic pallets, level of standardization, common manufacturing processes, among other essential market information.

This data has never been collected before; therefore, this survey will provide essential information to plastic pallet and container manufacturers to make decisions that will increase the competitiveness of the industry. The provided information will also help the Reusable Packaging Association to represent the industry better.

By filling out this survey your company will benefit by:

- Having priority access to the aggregated results upon their publication
- Improving your competitiveness by comparing key characteristics of your business of industry averages
- Improving strategic planning based on key market trends

To begin the survey, please provide the company code listed below:

|CODE|

[Take the Survey](#)

Individual survey answers will be confidential and no data from specific companies will be published. The results will only be presented in an aggregate format.

Your time and cooperation will be highly appreciated.

If you have any questions about the survey, please contact Dorina Bugledits (email: dorina93@vt.edu.)



CENTER FOR PACKAGING AND UNIT LOAD DESIGN

Appendix C and D: First and second reminder emails sent via Mailchimp.



Market Study of the Plastic Pallet Industry in the United States in 2018

We need your help! Recently, you were invited to help collect data for the [FIRST plastic pallet market study in the United States](#). I am contacting you to ask for your help by completing an online survey.

By filling out this survey your company will benefit by:

- Having priority access to the aggregated results upon their publication
- Improving your competitiveness by comparing key characteristics of your business of industry averages
- Improving strategic planning based on key market trends

To begin the survey, please provide the company code listed below:

|CODE|

Take the Survey

For your convenience you may download the survey by clicking the button below.
However, please enter the final information in the **online survey**.

[Download Survey Questions](#)

Individual survey answers will be confidential and no data from specific companies will be published. The results will only be presented in an aggregate format.

Your time and cooperation will be highly appreciated.

If you have any questions about the survey, please contact Dorina Bugledits (email: dorina93@vt.edu.)



CENTER FOR PACKAGING AND UNIT LOAD DESIGN

Appendix E: Introduction letter



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

Dear Sir/ Madame,

The first time ever, **Virginia Tech** in collaboration with the **Reusable Packaging Association** is conducting a comprehensive **market survey of the US plastic pallet industry**. The survey will collect key industry characteristics including number of plastic pallets, level of standardization, common manufacturing processes, among other essential market information.

This data has never been collected before; therefore, this survey will provide essential information to plastic pallet and container manufacturers to make decisions that will increase the competitiveness of the industry. The provided information will also help the Reusable Packaging Association to represent the industry better.

Furthermore, by filling out this survey your company will benefit by:

- **Having priority access** to the aggregated results upon their publication
- **Improving your competitiveness** by comparing key characteristics of your business of industry averages
- **Improving strategic planning** based on key market trends

I would like to assure you that the responses are confidential. No specific data of companies will be reported, they will be only used in trends.

Your time and cooperation will be highly appreciated.

If you have any questions about the survey, please contact Dorina Bugledits (email: dorina93@vt.edu.)

Sincerely,

Dorina Bugledits
Graduate Research Assistant

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

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Appendix F: Data Manipulation

Total Usage (Question 5):

Step 1: Number of pallets manufactured by the respondent * percentage of single or multiple usage = Total number of single and multiple used pallet

Step 2: Add up the number of each category

Step 3: Total number of single/ multiple used pallets / total number of pallets manufactured = percentage of single/ multiple used pallets

Total Sizes (Question 6):

Step 1: Number of pallets manufactured by the respondent * percentage of the size = Total number of sizes

Step 2: Add up the number of each category

Step 3: Total number of sizes / total number of pallets manufactured = percentage of sizes

Total Manufacturing Methods (Question 7):

Step 1: Number of pallets manufactured by the respondent * percentage of the manufacturing method = Total number of manufacturing methods

Step 2: Add up the number of each category

Step 3: Total number of manufacturing methods / total number of pallets manufactured = percentage of manufacturing methods

Total Plastic Material (Question 8):

Step 1: Number of pallets manufactured by the respondent * percentage of the plastic material = Total number of pallets made with one material

Step 2: Add up the number of each category

Step 3: Total number of made with one material / total number of pallets manufactured = percentage of pallets made with one material

Total Recycled Resin content (Question 10):

Step 1: Number of pallets manufactured by the respondent * percentage of the maximum approved resin content = Total number of pallets with maximum approved resin content

Step 2: Add up the number of each category

Step 3: Total number of pallets with maximum approved resin content / total number of pallets manufactured = percentage of pallets with maximum approved resin content material

Total Certified Pallets (Question 11):

Step 1: Number of pallets manufactured by the respondent * percentage of certified pallets = Total number of certified pallets

Step 2: Add up the number of each category

Step 3: Total number of certified pallets / total number of pallets manufactured = percentage of certified pallets

Total number of Fire-retardant additives (Question 12):

Step 1: Remove the responses that did not respond with any certification in the previous question

Step 2: Number of pallets manufactured by the respondent * percentage of fire-retardant additives = Total number of pallets with fire retardant additives

Step 3: Add up the number of each category

Step 4: Total number of pallets with fire- retardant additive / total number of pallets manufactured = percentage of pallets with fire- retardant additive

Total number of Fiber-Reinforcement (Question 13 & 14)

Step 1: Number of pallets manufactured by the respondent * percentage of fiber reinforcement = Total number of pallets with fiber reinforcement

Step 2: Add up the number of each category

Step 3: Total number of pallets with fiber reinforcement / total number of pallets manufactured = percentage of pallets with fiber reinforcement