Process Methods and Levels of Automation of Wood Pallet Repair in the United States

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This study documented the current status of wood pallet repair in the United States by identifying the types of processing and equipment usage in repair operations from an automation perspective. The wood pallet repair firms included in the study received an average of approximately 1.28 million cores (*i.e.*, used pallets) for recovery in 2012. A majority of the cores received were stringer-style pallets. The most common pallet size received and repaired was 48 x 40 inch. The most commonly used stringer repair method was the application of companion stringers. It was found that most firms utilized high levels of manual labor, with limited machinery support. The board trimming and pallet sorting/stacking processes had the highest level of automation, while the inspection, nailing, and painting processes utilized manual labor.

Keywords: Wood pallet; Recycling; Repair; Automation

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INTRODUCTION

Wood pallets are popular, important components in modern material handling and distribution systems. Pallets enable the efficient transportation and storage of goods in a unitized form while reducing transaction costs. There are an estimated 2 billion pallets in circulation in the United States (Buehlmann *et al.* 2009). While pallets can be made from several materials, including rigid plastics, metal, wood composites, and corrugated fiberboard, the majority of pallets (92%) made in the U.S. are constructed using solid wood (Trebilcock 2013) because it yields a favorable balance between price and performance (Clarke 2002).

The repair of cores (*i.e.*, used pallets) is a growing trend in the United States. Bush *et al.* (2012) found that the production of recovered, repaired, and remanufactured pallets grew from 143 million units in 1995 to 326 million units in 2011. Newly manufactured wood pallets are supplied to pallet users such as product manufacturers, retailers, and pallet pooling companies. When pallets break or become damaged while circulating through the supply chain, they are often sent to wood pallet repair firms. The most common damage types that lead to pallet recycling are missing top deckboards and split stringer notches (Frost *et al.* 1975). After damaged pallets are repaired, they are resupplied to pallet users. According to Bush and Araman (2009), repair for reuse was the most frequent end-of-life option for used pallets received by repair firms. Repaired pallet production has more than doubled between 1995 and 2006, while new pallet production grew modestly (7%) during the same period (Bush and Araman 2009). If damaged pallets cannot be repaired, they may be transformed into products such as boiler fuel and mulch. Figure 1 provides an example of the wood pallet repair process.

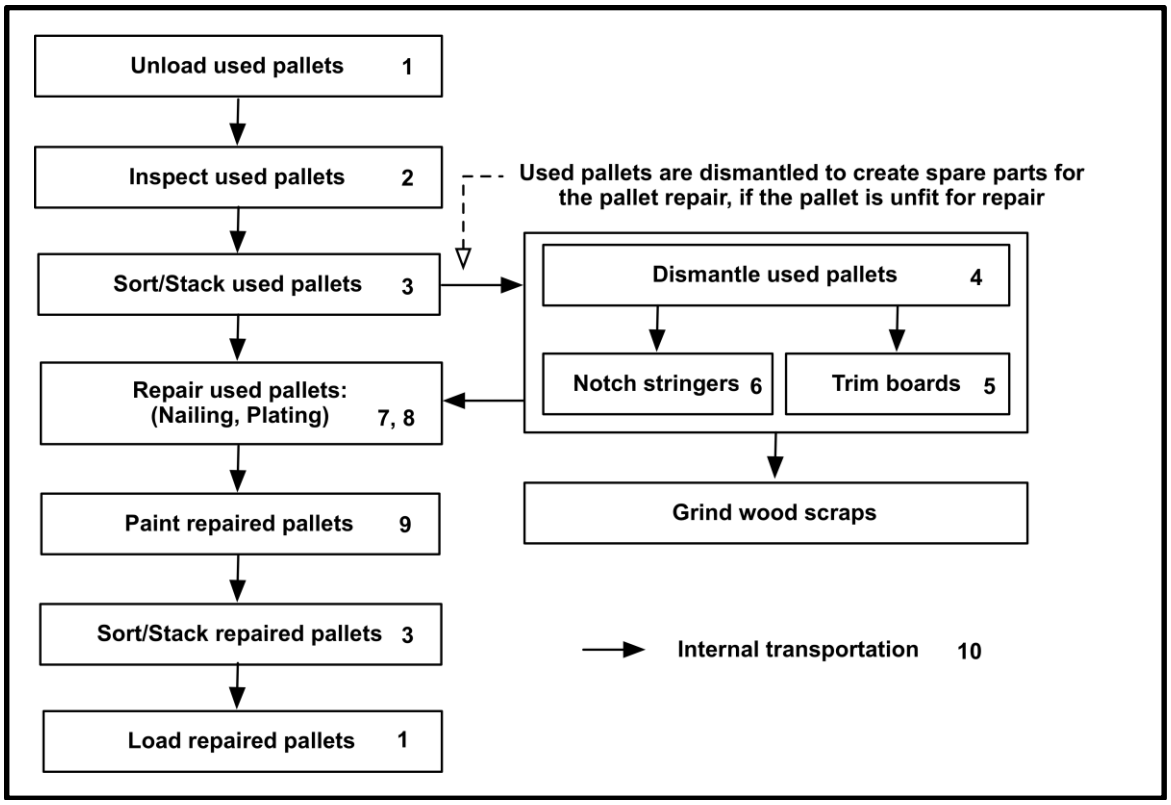

Fig. 1. Schematic representation of the pallet repair process and activities used by pallet repair operations in the United States. The numbered activities were investigated in this study.

The increased production and demand for repaired pallets can be ascribed to numerous factors, including a lower selling price and recycling mandates. Price benefits may be the primary reason for the increased use of repaired wood pallets. Pallet users can purchase repaired pallets at lower prices and avoid landfill tipping fees by providing used pallets to repair facilities. The typical price for a used Grocery Manufacturer's Association (GMA) 48 × 40 inch pallet is four to six dollars, while the price of a new GMA 48 × 40 inch wood pallet is nine to eleven dollars (Ray *et al*. 2006). The average landfill tipping fee for hardwood pallets is $36.69 per ton (USEPA 2012). The durability of repaired pallets is also an important factor. Clarke *et al.* (2001 and 2005) found that new and repaired wood pallets have similar resistance to rough handling, resulting in comparable service lives in some supply chains. Clark *et al.* (1993) also found that repairing pallets using a metal connector plate can restore the strength of the stringer to the orginal level. Recycling mandates due to growing environmental concerns can also affect pallet repair. For example, North Carolina House Bill 1465, passed in 2005 (NCGA 2005), banned wood pallets from landfill disposal starting October 1st, 2009.

Even though production and demand have increased, there is no standardized process for repairing wood pallets. Damaged wood pallets are typically repaired by adding additional components such as companion stringers or metal plates to cracked stringers and/or by replacing broken deckboards. Processes and equipment vary since pallet repair firms use different methods depending on their capabilities. Manual repair methods using hand-held tools are still common, while robotic systems for pallet repair that require minimal manual labor have recently been introduced to the industry.

Pallet repair can be an economically and environmentally beneficial end-of-life option that can increase the sustainability of wood pallets (Buehlmann *et al.* 2009). In addition, the standardization of repair methods can improve the physical performance of repaired wood pallets (Clarke *et al.* 2005). Despite the use and potential value of repaired pallets, few studies have investigated the wood pallet repair industry.

The purpose of this study was to document the current status of wood pallet repair in the United States by identifying process types and equipment usage in repair operations from an automation perspective. This study provides information concerning the level of automation used to repair pallets in the United States. The results identify opportunities to improve the efficiency of pallet repair.

EXPERIMENTAL

A 25-item questionnaire was created to collect information regarding firm characteristics, pallet repair procedures, and other information relevant to the pallet repair business. The questionnaire consisted of two parts: 10 questions focusing on the pallet repair processes and on automation levels, followed by 15 general information questions regarding company demographics, materials for stringer repair, wood scrap usage, and typical core procurement distances. Question types included close-ended inquiries, partially closed-ended inquiries with an "Other" option, and open-ended inquiries asking for short, sentence-based answers. The questionnaire was reviewed by three experts in the wood pallet industry prior to use and changes were made based on their recommendations. In addition, the questionnaire was pre-tested with ten firms to verify its validity. Respondents reported data for the 2012 calendar year.

The pallet repair/recovery firms included in the initial sample frame for the study were drawn from those listed on the National Wood Pallet and Container Association's (NWPCA) member list (NWPCA 2013). The NWPCA is the largest trade organization representing U.S. wood pallet and container manufacturers. After removing duplicates and listings with invalid contact information, the sample frame included 343 firms. All of these firms were included in the sample.

The questionnaire was initially distributed in May 2013 using the online survey software Qualtrics (Provo, UT, USA). The first e-mail reminder was sent to all non-respondents two weeks after the initial distribution of the questionnaire. The second and third (final) e-mail reminders were sent to non-respondents four and six weeks after the initial questionnaire distribution, respectively. In an effort to increase the response rate, additional paper versions of the survey questionnaire were distributed to non-respondents at the NWPCA Annual Leadership Meeting held in Fort Lauderdale, Florida, between March 1, 2014 and March 3, 2014. The survey closed on March 20, 2014.

The automation levels of the wood pallet repair firms were analyzed based on two assumptions in this study. The first assumption was that the 10 processes used during pallet repair (Fig. 1) contributed equally to a firm's overall automation level. The second assumption was that the difference between the three levels of automation within each process (three choice options) was the same. The choice options were categorized into three levels that were assigned numerical values of one, two, or three. Level 1 (numerically coded as 1) corresponded to repair completed with hand tools (*e.g.*, hammers and dismantling bars). Level 2 (numerically coded as 2) corresponded to semi-automated repair using some electric or pneumatic equipment but still requiring manual labor (*e.g.*, bandsaw

dismantlers with manual feeds). Level 3 (numerically coded as 3) corresponded to fully automated repair using integrated equipment with only a minimal amount of manual labor (*e.g.*, machine-controlled infeed/outfeed dismantling bandsaw systems). The assigned values for the ten unit-processes were averaged to calculate the automation level of each responding firm. The statistical software package SAS® Jmp® (version 10; Cary, NC, USA) was used to perform statistical analyses

RESULTS AND DISCUSSION

Of the 343 firms in the sample, 52 responded. Among the 52 respondents, 13 firms did not operate pallet repair operations in 2012. Therefore, the adjusted sample included 330 firms. Of the 39 valid responses that were received, 35 were *via* the email survey and 4 were from the paper survey. This resulted in an overall response rate of 11.8%.

Respondent Characteristics

Most respondents (82%) operated both new pallet manufacturing and pallet repair businesses, while seven (18%) engaged solely in pallet repair. The respondents were categorized into nine geographical regions corresponding to regions used by the U.S. Census Bureau (Fig. 2). The majority of responses were obtained from firms located in the South Atlantic region (29%), followed by the East North Central (16%), the West North Central (16%), the East South Central (13%), the Mid-Atlantic (8%), the Pacific (5%), the Mountain (5%), the West South Central (5%), and the New England regions (3%).

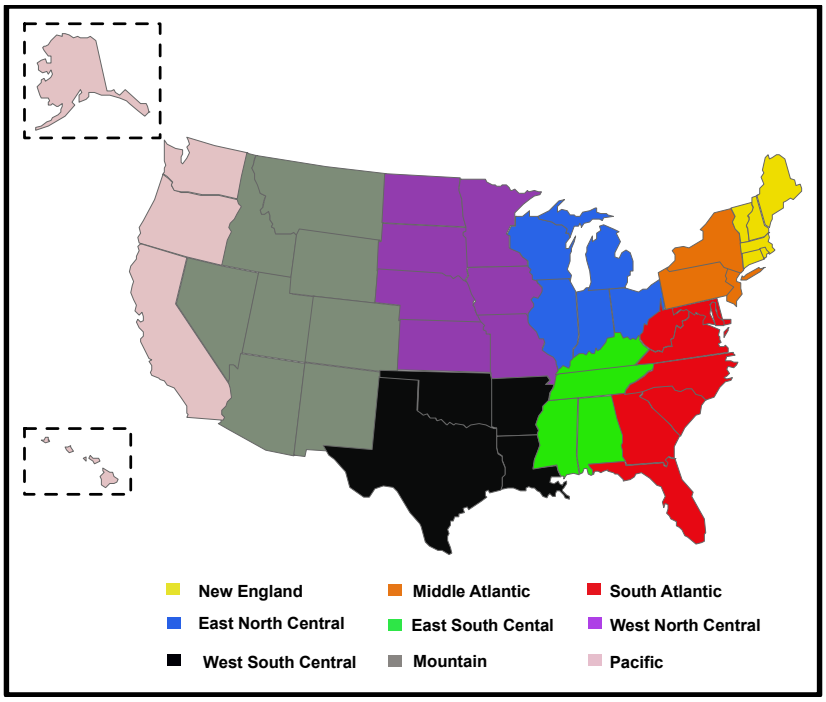

Fig. 2. Geographical region classifications used in this study

Most respondents (33%) reported 1 to 5 million dollars in annual sales in 2012. Thirty-one percent of firms reported 5.1 to 10 million dollars, while 22% reported sales of 10.1 to 20 million dollars. Eight percent of firms reported over 30 million dollars, and 6% reported less than 1 million dollars in annual sales in 2012.

The responding pallet repair firms employed an average of 60 people (including both production and non-production employees) in 2012. The average number of full-time production employees was approximately 48. The average number of full-time non-production employees was approximately 10. Some pallet repair firms hired part-time employees for production or non-production positions; however, most firms (78%) employed only full-time employees.

Based on the total number of employees, responding repair firm sizes were distributed as follows: small firms (1 to 20 employees; 25%), medium-sized firms (21 to 100 employees; 58%), and large firms (more than 100 employees; 17%).

The responding pallet repair firms received an average of approximately 1.28 million cores (median: 725,000 cores) in 2012. The results indicated a significantly higher number of cores received compared with a previous study conducted in 2006 (Bush and Araman 2009), which reported an average of 394,160 cores received. The different samples used in each study could explain the different results regarding the received-core numbers. While the sample used in Bush and Araman (2009) included all pallet manufacturers and recyclers in the United States, the sample used in this study included only U.S. pallet recycling firms that are NWPCA members.

There are two main classes of wood pallets: stringer-class and block-class. The stringer-class pallet is constructed using two or more stringers, multiple deckboards, and fasteners (*e.g.*, nails, screws, staples). The block-class pallet is constructed from rectangular blocks, multiple deckboards, and fasteners. Sixty percent of firms received both stringer-class pallets and block-class pallets. Forty percent of firms received only stringer-class pallets, while no responding firm received only block-class pallets. The pallet repair firms who repaired both stringer- and block-class pallets primarily repaired stringer-class pallets (93% of pallets repaired). Only one firm reported repairing more block-class pallets than stringer-class pallets. The dominance of stringer-class pallets among the received cores was also observed by Bush and Araman (2009), who reported only 3% of the received cores in their study to be block-class. The higher percentage of new stringer-class pallet production over block-class pallets found in Trebilcock (2013) could be the primary cause of the unbalanced ratio between stringer-class pallets and block-class pallets during the repair process. Another reason may be the additional equipment investment necessary to repair block-class pallets (Kirkaldy 2011).

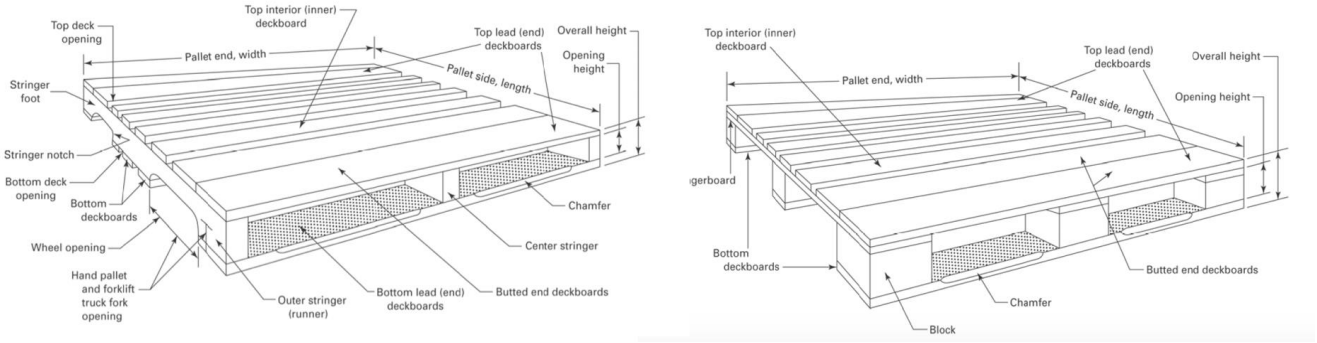

Fig. 3. Representative structure of stringer (left) and block (right) class pallet (Illustration from ANSI MH1 - 2016)

The most common sizes of cores received by responding repair firms were 48 × 40 inch (80%), 42 × 42 inch (5%), and 48 × 48 inch (4%). In comparison, Bush and Araman (2012) found that 48 × 40 inch stringer pallets accounted for 73% of the cores received by firms in the U.S. pallet and container industry in 2011. Figure 4 provides the percentages of the core sizes received by responding pallet repair firms.

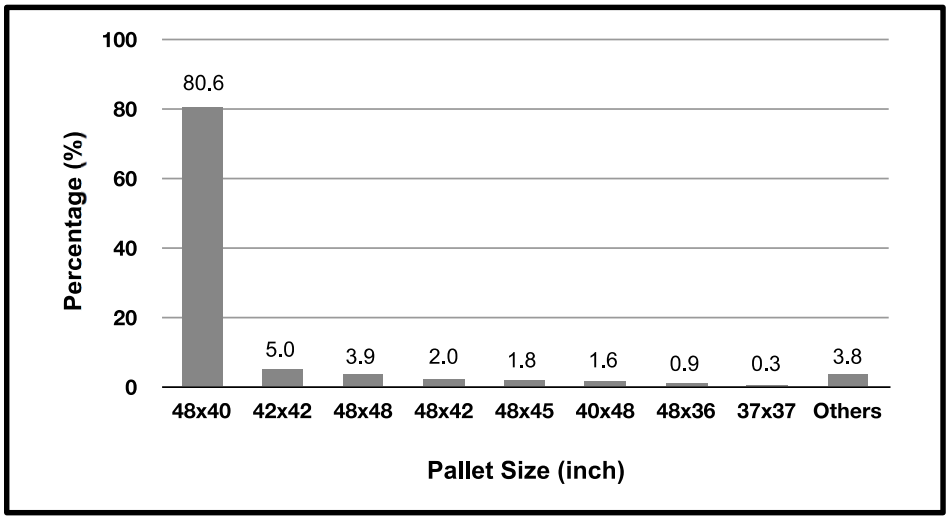

Fig. 4. Distribution of pallet sizes received by responding firms in 2012

Most responding firms (69%) reported procuring the majority of their cores from a travel distance of within 11 to 50 miles of the repair location. Twenty-three percent of firms traveled between 51 and 100 miles, and 6% traveled between 101 and 200 miles. Two percent reported collecting cores within less than 10 miles. No firm reported collecting cores more than 200 miles from the repair location.

In order to analyze the association between travel distance and other respondent characteristics (gross sales, number of pallets repaired, and geographical location), a Pearson chi-square analysis was performed. The analysis failed to reject the null hypothesis of independence at a 0.05 significance level (Table 1). The typical distance for collecting cores is most likely dependent on transportation costs, including fuel prices, and the number of cores available in a region (Bouffier *et al.* 1995). Also, competition for a limited number of cores may affect a firm's decision regarding the range they are willing to travel for collection.

Table 1. Results of Pearson Chi-square Analysis to Investigate Associations Between Core Procurement Distance and Respondent Characteristics

Respondent Characteristics	N	DF	Chi-square	P-value
Geographical location	34	24	31.261	0.1464
Number of repaired cores	34	12	11.238	0.5087
Gross sales	35	12	8.242	0.7660

Thirty-three percent of the firms reported repairing over one million cores in 2012. Thirty percent of the repair firms repaired 500,000 to 999,999 cores, and 18% repaired

100,000 to 499,999. Sixteen percent of the firms and 3% of the firms reported repairing 10,000 to 99,999 cores and fewer than 10,000 cores, respectively.

The responding pallet repair firms reported utilizing wood scraps for purposes other than repair. Sixty-three percent of firms reported processing wood on-site to make mulch or chips in 2012. Processing wood scraps on-site allows pallet repair firms to both avoid disposal tipping fees and generate sales revenue from the resulting products. Pallet repair firms that did not grind or chip wood scraps on-site sometimes contracted with third-party facilities to process their wood scraps. As the contamination level of shredded used pallets is generally low, ground wood pallet material is safe for reuse as animal bedding or litter (White and McLeod 1989). Bush and Araman (2014) report that pallet repair firms sell ground or chipped pallet material for landscape mulch (colored and uncolored), fuel, and animal bedding.

The choice to have grinding facilities on-site is dependent on several factors including finances, availability of space for grinding equipment, location of firms (industrial or residential areas), and regional market variation (LeBlanc 2003). Analysis of the data collected in this study failed to reject the null hypothesis of no statistically significant association between wood scrap processing on-site and gross sales, numbers of employees, cores received, cores repaired, or geographical region.

While many firms reported having scrap processing operations, only 11% had a furnace or boiler that could utilize wood scraps. The gross sales, number of repaired pallets, and employee numbers were not found to be statistically correlated to the use of a furnace or boiler. Economic feasibility resulting from the relative costs of wood recovery and processing options are likely to be the primary factors for the decision of whether to have a furnace or boiler to utilize wood scraps (SWANA 2002).

Process Types, Equipment, and Pallet Repair Procedures

Data were obtained from wood pallet repair firms regarding the typical methods and equipment types used in pallet repair. Figure 5 shows the processes and corresponding equipment types used by the responding wood pallet repair firms.

All responding repair firms used forklifts to unload and load pallets. At the majority of repair firms (87%), operators visually inspected incoming pallets to make pallet-grade decisions, while some firms (13%) employed scanning machines along with visual inspection. Firms reported using three methods to sort pallets based on assigned grades. Thirty-eight percent of firms sorted and stacked pallets using machine-controlled infeed/outfeed stackers, while 36% of firms manually sorted and stacked pallets. Forklifts were used for the sorting and stacking process at 26% of the responding firms.

Pallets that are unfit for repair are dismantled to create spare parts for pallet repair or ground for use as mulch or other products. Bandsaw dismantlers with manual feeds were used to dismantle pallets at most firms (87%). Other firms used dismantling bars and hammers (5%), machine-controlled infeed/outfeed dismantling bandsaw systems (5%), or disc/shear type dismantlers with manual feeds (3%).

To process the recovered boards, the majority of firms (62%) utilized machine-controlled infeed/outfeed trim saws. Other repair firms used single-head or dual-head table saws (20%) or radial-arm saws (18%) with manual feeds. Approximately three quarters of responding repair firms (74%) utilized a stringer notching process. Among these firms, the majority (69%) used single-head or dual-head notching machines with manual feeds. Others (31%) used machine-controlled infeed/outfeed single-head or dual-head notching machines.

Most firms (77%) repaired damaged pallets by manually using nail-guns on a repair table. Thirteen percent of firms reported using machine controlled infeed/outfeed nailing systems, while 10% reported using corrugated metal fasteners. The majority of the responding firms (64%) did not use metal plates for repair stringers. Among the firms who used metal plates, most firms (86%) used plating machines (platers) with manual feeds, while other firms (14%) used machine-controlled infeed/outfeed plating systems. The most commonly used stringer repair method was the application of companion stringers. Various types of companion stringers were applied, including half companion (used by 89% of responding firms), C-block (used by 36% of responding firms), and full companion type (used by 11% of responding firms). Some firms had the ability to apply more than one type of stringer repair.

Wood pallets received for repair may have a stamp signifying treatment in accordance with the International Standards for Phytosanitary Measures Number 15 (ISPM 15) (FAO 2009). This stamp must be removed when the pallet is repaired. The majority of firms (85%) used paint to cover the ISPM 15 stamp or to paint pallets to custom colors. Of the firms that used paint, 85% of firms painted or marked repaired pallets using spray paint or paint buckets and manually with rollers. High-pressure air spray systems and machine-controlled spray systems were used at 9% and 6% of responding firms, respectively. Forklifts were the main method of moving pallets within the firms (85% of respondents), followed by power conveyors (15%).

Overall Automation Levels of Pallet Repair Firms

The possible levels of automation for each process type, as quantified in this study, ranged from 1 to 3. The overall mean automation level of the responding firms was 1.97 (standard deviation: 0.24). The distribution of the respondent average automation levels is provided in Fig. 6.

Higher levels of automation, utilizing machine-controlled infeed/outfeed systems, were most common in the board-trimming and sorting/stacking processes, while completely manual practices were primarily used for the inspection, nailing, and painting processes.

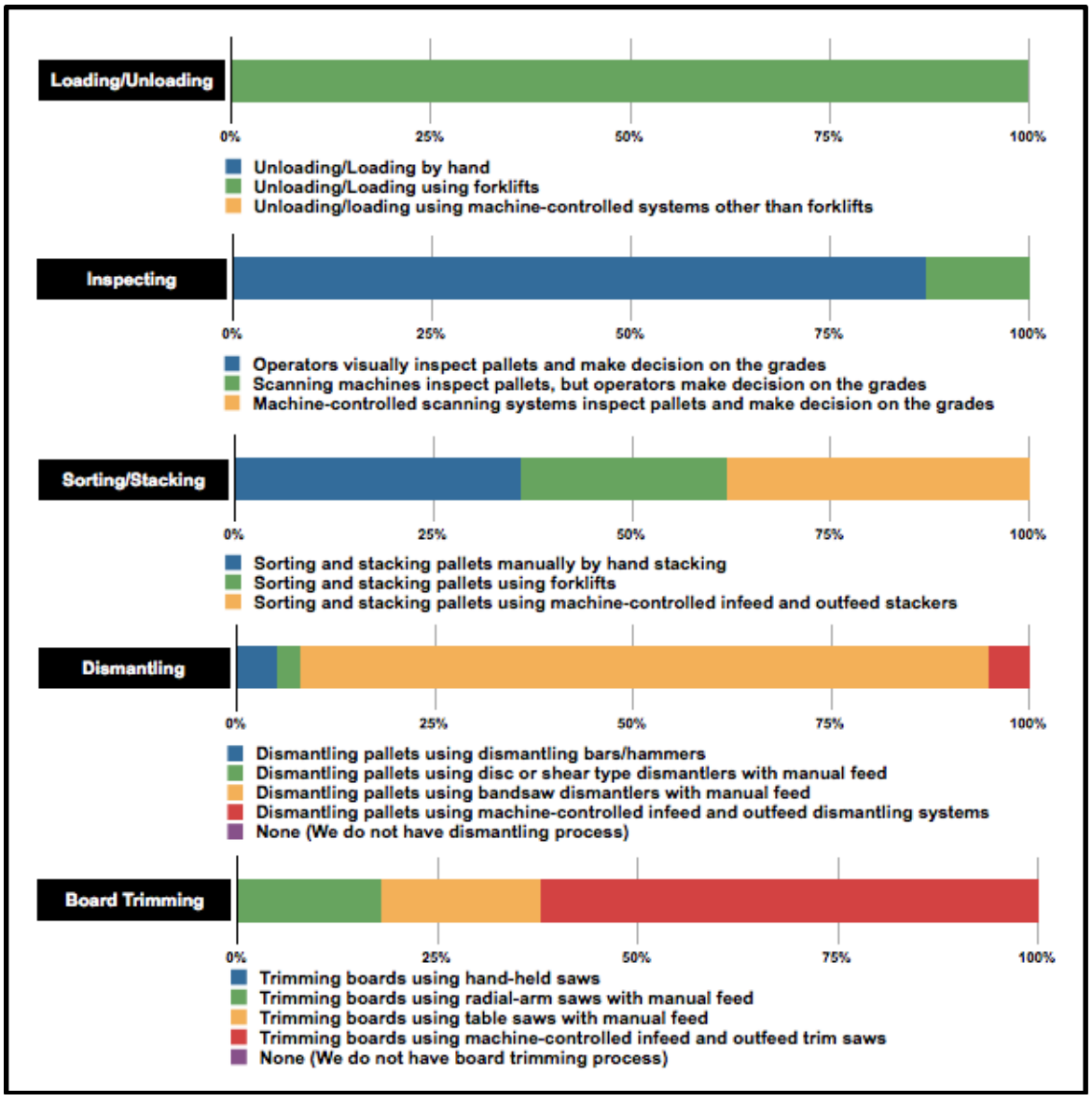

Fig. 5. Processes and equipment types used by responding U.S. pallet repair firms

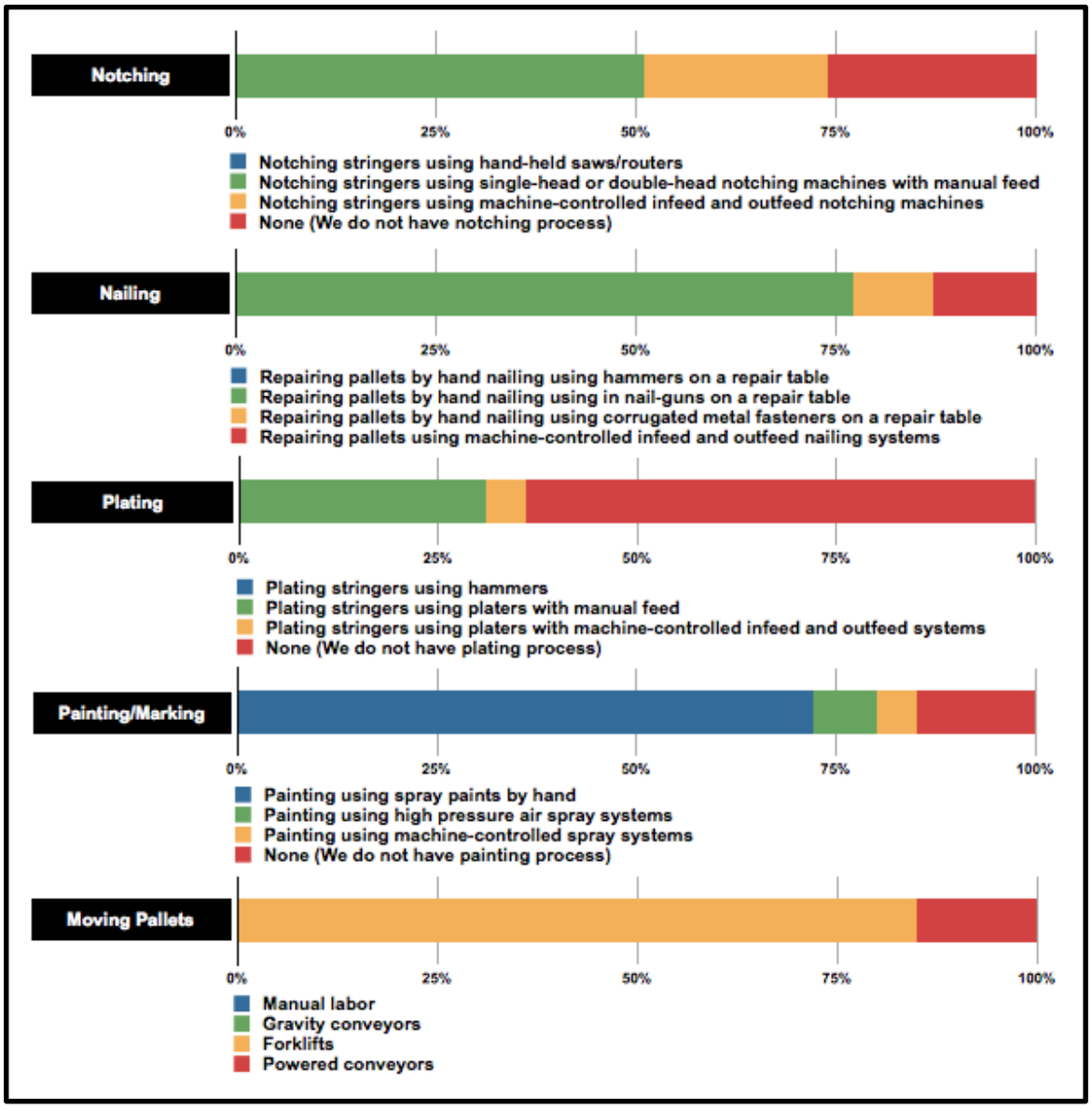

Fig. 5 (continued). Process and equipment types used by responding U.S. pallet repair firms

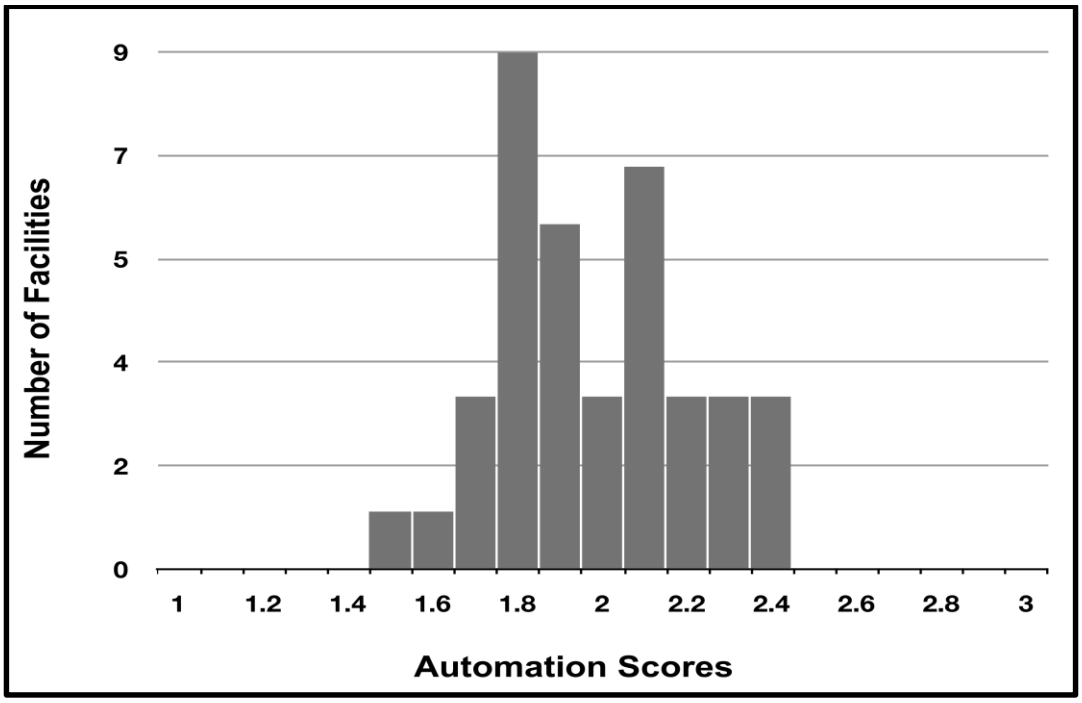

Fig. 6. Distribution of overall automation scores of responding pallet repair firms

The automation investment in the wood pallet repair process could be affected by several factors, including the technical and market availability of equipment (York 1992), economic feasibility (Michael and Millen 1985), as well as workload levels and labor/safety-related regulations (Karwowski *et al.* 1988). The high prices of fully automated pallet repair systems compared with alternatives could be the primary reason for the relatively low level of automation in the U.S. wood pallet repair industry. In the future, increasing competition in the overall wood pallet industry (Neville 2013) and the potential increase of the minimum wage could encourage pallet repair firms to adapt more automated systems for achieving higher productivity and quality.

Regulations regarding the work environment and labor safety may also impact the level of automation during pallet repair. For example, the strict worker safety regulations for protecting labor in European countries could be the main reason for the adoption of robotic pallet repair among European pallet manufacturers/recyclers (Brindley 2013). Increasing regulations regarding labor and safety could stimulate the adoption of automated equipment in the United States.

The Patient Protection and Affordable Care Act (PPACA) (2010), which is a relatively new federal law in the U.S., might be a factor resulting in the adoption of more automated equipment and systems in the wood pallet repair industry. The PPACA requires companies with 50 or more workers to offer a health insurance program or pay an annual penalty ($2,000) for each full-time worker. Adopting more automated equipment could be a strategy to maintain or increase the productivity of pallet repair companies while maintaining fewer than 50 employees. According to a personal interview with an automatic pallet repair system manufacturer, the demand for automatic pallet repair equipment increased after the PPACA law was proposed.

Limitations

Potential limitations to this study should be noted. The relatively low response rate (11.8%) in this study could reduce the generalizability of the research findings. While the NWPCA is the largest association in the U.S. wooden pallet industry, NWPCA membership may not be fully representative of the U.S. wood pallet repair industry. The sample frame of this study consisted of only NWPCA members. As such, it may have been biased toward larger companies with higher production than the wood pallet industry overall. In addition, the manner in which automation scores were formed, while we believe most appropriate, could impact the results.

CONCLUSIONS

1. The average U.S. wood pallet repair firm received approximately 1.28 million cores (median: 725,000 cores) in 2012. The majority of cores repaired by the responding companies were stringer-class pallets (93%). The most common pallet size received and repaired by firms was 48 × 40 inch. The most commonly used stringer repair method was the application of half companion stringers (89%). Most of the responding firms (69%) travelled 11 to 50 miles to procure cores. The majority of the firms (33%) repaired over 1 million cores in 2012, and a third of respondents (33%) reported 1 to 5 million dollars in gross annual sales.
2. For the repair process, most firms utilized high levels of manual labor with machinery support. There was no responding firm that used either a completely manual process or a fully-automated process to repair cores. The board trimming and sorting/stacking processes were often automated, while the inspecting, nailing, and painting processes were generally manual.

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