Professional Consumer Perceptions of Thermally-Modified Wood

A THESIS

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Shelby Lynn Gamache

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Dr. Omar Espinoza

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Dedication

For Stan.

Abstract

Thermal modification of wood is a chemical-free treatment that results in improved durability, enhanced resistance to rot and decay, and better dimensional stability. Thermally-Modified Wood (TMW) has multiple applications and offers an opportunity for sustainable and value-added uses for timber resources that are underutilized or affected by invasive species. The use of these resources can improve forest health and create economic opportunities in rural communities. TMW has experienced commercial success in Europe for more than 20 years, but it is in the very early stages of market adoption in the United States. Inadequate marketing efforts have kept consumer awareness of TMW very low, making the main goal of this research to identify the challenges and opportunities for TMW in the U.S.

To achieve this objective, a perceptions study among professional adopters of decking materials was conducted. In-person and online surveys were the major data collection methods used. The survey instrument included demographic and perception questions, as well as a conjoint analysis section. Results indicate the level of awareness among professional consumers is growing, but there is currently very little adoption of TMW among this group.

Consumers make product adoption decisions based on their perceptions about products' attributes and benefits. When asked to rate various wood-based decking materials on several attributes, participants perceived TMW's best attributes to be *Durability* and *Environmental Performance*, followed by *Aesthetics*. Perceptions about TMW's *Availability* was rated the lowest among all materials included in the study, which was to be expected because TMW is a relatively new material to the market. It was also found that professional consumer's perception of TMW's *Cost of Materials* was high, but lower and less expensive than tropical hardwoods and wood-plastic composites (WPCs). For the TMW market to increase its competitiveness, it will be important for companies to emphasize these positive attributes, as well as make TMW more readily-available to industry members.

Results from this research can help entrepreneurs and established industries create effective marketing plans for TMW products. Specific outcomes include increased understanding professional consumer's perceptions and preferences towards TMW and

competing decking materials, the formulation of business implications, and communication of research results to the TMW industry and other stakeholders.

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CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

The forest products industry is vital to maintaining many rural economies in the United States. However, the industry has faced significant challenges during the last two decades. Increased low-cost imports have taken market share away from domestic producers, with subsectors such as household furniture, flooring, and millwork particularly affected. Substitute materials are also threatening the market position of products such as siding, decking, and pallets. The economic downturn that started in 2007 and the slow recovery of the housing market has caused great job losses. This has generated negative, cascading effects across the industry, including reduced jobs and economic output. This decreased activity in the forest products sector has resulted in timber harvest volumes remaining well below sustainable levels. Lack of harvest can lead to poor forest management by negatively impacting tree species diversity, making forests more susceptible to attack by pests and invasive species, and can lead to increased wildfire risk.

Thermal-modification technology has the potential to create and expand forest products markets, particularly for traditionally underutilized and low-value species. This emerging, chemical-free technology produces sustainable value-added wood products with improved dimensional stability, resistance to biodegradation and weathering, extended service-life, and reduced environmental impacts. Despite shifts in consumer preferences for more environmentally-friendly products, this fledgling technology has not taken hold in the U.S. on a substantial scale due to insufficient marketing efforts.

Thermally-modified wood can be utilized to create a variety of products, but it is particularly suited for exterior decking, due to its high performance in outdoor applications and aesthetic qualities. The U.S. decking industry is substantial, and there is potential for thermally-modified wood to capture a niche of that market, particularly for environmentally conscious consumers with less price sensitivity than the general market.

This research identified decking industry members' perceptions of thermally-modified wood using conjoint analysis, a marketing research tool used to understand

how consumers make product selection decisions. Using this data, a strategic marketing plan was developed to address barriers to increased production and utilization of thermally-modified wood. In addition to helping entrepreneurs and established industries create effective marketing plans for thermally-modified wood products, this research has the potential to enhance the economic output in rural communities that depend on forest products and to strengthen the competitiveness of the forest products industry by increasing wood harvest volumes and production of value-added, chemical-free wood products.

Background on Thermally-Modified Wood (TMW)

Thermal-modification treatments for wood have been investigated since the early twentieth century (Hill, 2011). Despite this long history, product development and commercial success of thermally-modified wood (TMW) was only achieved in Europe in the 1990s, and the TMW market in the United States is still in its early stages of development. Market growth of TMW in Europe was driven in part by regulations limiting the use of toxic chemical treatments to protect wood from biological attack and biodegradation (Hill, 2011). In the U.S., potential demand for domestically-sourced TMW products may originate from, among other things, consumer demand for chemical-free treatments, and regulations preventing imports of illegally-harvested timber (International Network for Environmental Compliance and Enforcement [INECE], 2008). These factors may allow TMW to become a leading substitute for imported tropical hardwood species and pressure treated lumber for some applications (The International Tropical Timber Organization [ITTO], 2012).

Properties of TMW

The technical modification process of TMW heats wood to much higher temperatures than traditional wood drying (Kocaefe, Poncsak, & Boluk, 2008), sometimes in a reduced oxygen environment and over a relatively shorter period. An example of a temperature-time profile for thermal modification is depicted in Figure 1 (*ThermoWood Handbook*, 2003). This process has been developed over several decades, with the first recorded attempt to increase wood's resistance to biodegradation through thermal-modification in 1946 by Stamm et al. (Rapp & Sailer, 2000; Stamm &

Harris, 1953). Ultimately, thermal-modification alters the chemical composition of the wood by degrading cell wall compounds and extractives (Esteves & Pereira, 2009).

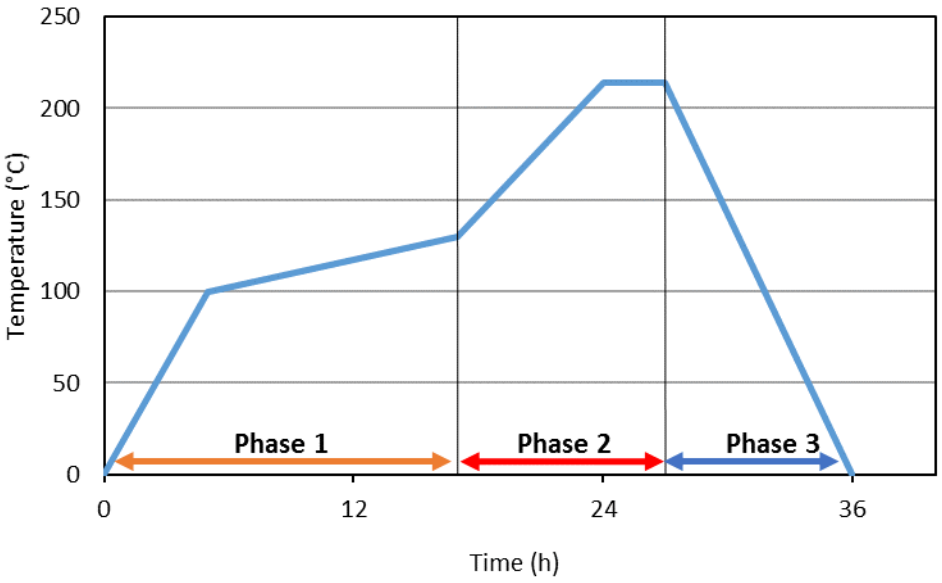

Figure 1. General overview of thermal modification process (*ThermoWood Handbook*, 2003).

As a result of thermal-modification treatment, wood's dimensional stability, moisture resistance, and resistance to rot and decay are improved (Leitch, 2009; Rapp & Sailer, 2000; *ThermoWood Handbook*, 2003), allowing it to be suitable for many exterior applications such as decking and siding (*ThermoWood Handbook*, 2003). However, thermal treatment causes a lost in weight and mechanical strength during the process (U. Yildiz, S. Yildiz, & Gezer, 2005) so it cannot be used in applications where structural performance is critical, such as support beams. Table 1 lists some of the advantages of wood with thermal-modification treatment, as indicated in the literature; and Table 2 lists some of the negative impacts on performance from thermal-modification.

Table 1. Some of the enhanced properties of wood from thermal treatment.

Property	Reference
Reduced equilibrium moisture content: swelling and shrinking due to moisture	Hakkou, Pétrissans, Zoulalian, and Gérardin (2005), Kocaefe et al. (2008), Repellin and Guyonnet (2005), Sinoven, Maunu, Sundholm, Jamsa, and Viitaniemi (2002), Tjeerdsma, Stevens, Militz, and Van Acker (2002) & Weiland and Guyonnet (2003)
Improved resistance to biological decay	Kocaefe et al. (2008), Rapp and Sailer (2000), Sinoven et al. (2002) & Weiland and Guyonnet (2003)
Darkening of color throughout entire thickness, often resembling the look of tropical hardwoods	Ibach (2010), Kocaefe et al. (2008) & Repellin and Guyonnet (2005)
Reduced emissions during use due to elimination of many volatile compounds	Repellin and Guyonnet (2005)
Improved dimensional stability	Hakkou et al. (2005), Kocaefe et al. (2008), Rapp and Sailer (2000), Sinoven et al. (2002), Tjeerdsma et al. (2002) & Weiland and Guyonnet (2003)

Table 2. Some of the negative impacts on wood properties from thermal treatment.

Property	Reference
Increased brittleness and cracking	Rapp and Sailer (2000)
Decreased mechanical strength, including resistance to bending in static and dynamic tests	Esteves and Pereira (2009)
Spotted appearance to the surface due to exudation of rosin	Rapp and Sailer (2000)
Low UV resistance of the heat-related brown hue during use	Rapp and Sailer (2000)

Environmental Performance of TMW

The environmental impacts of TMW products have not been studied extensively using life-cycle assessments (LCAs), a technique used to evaluate the environmental performance and potential impacts of a product throughout its entire product life. There are only a few publicly-available LCAs on TMW, all completed in Europe (Ferreira, Esteves, Nunes, & Domingos, 2014; Ferreira, Esteves, Nunes, & Domingos, 2016; Tran, 2005). A life cycle assessment (LCA) conducted by the ThermoWood® Association in Europe explored the environmental impact of one of their TMW products and found it has positive environmental benefits in the areas of climate change and human toxicity when compared to pressure treated lumber (Ala-Viikari & Virtanen, 2008).

Another environmental benefit of TMW is the potential to utilize locally sourced timber from certified forests. Locally sourced TMW would decrease the environmental impact from transportation when compared to tropical species. In addition, using locally sourced timber would alleviate concerns for illegal logging in tropical countries among

environmentally conscious consumers. There is evidence to suggest illegal logging accounts for 20-90% (median 40%) of industrial round wood production in countries where illegal logging is common, which includes many tropical countries (Contreras-Hermosilla, Doornbosch, & Lodge, 2008). The passing of the 2008 Lacey Act made the U.S. the first country to ban the import and trade of illegally harvested timber and its subsequent products (Bridegam & Eastin, 2014). In response to growing global concerns on the topic, similar policies were passed in 2013 and 2014 in the European Union and Australia, respectively (Bridegam & Eastin, 2014).

LCA studies have concluded that most of the environmental impact from TMW is the results of the large amount of energy needed during the heat-treating process (Ferreira et al., 2016). Over 75% of TMW's environmental impacts for "Acidification," "Eutrophication," "Global Warming," and "Abiotic Depletion" can be attributed to the energy consumption during the treatment process (Ala-Viikari & Virtanen, 2008). However, TMW and other wood products in general have significantly lower energy consumption demands for manufacturing and transport when compared to materials such as steel and concrete (Ala-Viikari & Virtanen, 2008). Despite this intensive energy consumption during production, TMW is considered a more environmentally friendly material when compared to other materials containing chemicals or petrochemicals, especially considering the potential for utilizing renewable energy for TMW production in the future. A new LCA study on TMW is currently underway in the U.S. by the Natural Resources Research Institute (NRRI) at the University of Minnesota (Aro, 2015).

Forest Stewardship

In addition to the benefits of being a chemical-free product, TMW also provides an opportunity to encourage and support proper forest management by making use of traditionally underutilized and low value resources, as well as utilizing locally sourced raw materials. The long-term sustainability of U.S. forests faces significant challenges from insect and disease epidemics, which may be amplified by climate change (Patton-Mallory, 2008). TMW can provide solutions to some of these challenges, such as the capacity to utilize timber affected by insect attack and disease.

The U.S. Forest Service estimates that approximately 56 million acres of National Forest lands need removal treatment (Forest Products Laboratory, 2000) and 36% of

these forests are at “most significant risk” of insect attack and disease (Krist et al., 2014). The mountain pine beetle (MPB) alone, was responsible for killing 6 million acres of trees in the Western region of the U.S. in 2008, and other beetle species damaged a combined 1.4 million acres (US Forest Service [USFS], 2009). Another pest, the emerald ash borer (EAB), threatens all species of ash and is the most destructive and costly invasive forest insect in the U.S. (Herms & McCullough, 2014). From 2006 to 2010, an average of 8.3 million acres of forests were damaged annually by pests such as EAB (USFS, 2011). In Southeastern Michigan alone, EAB has killed 20 million trees (Herms & McCullough, 2014; “www.emeraldashborer.info,” 2014). Given the extent of damage by these pests, it is important to find value-added uses for the affected wood material, which is still suitable for processing into numerous end-products (Forintek, 2003; Uyema, 2012). Effective forest stewardship requires insect-infested or diseased trees to be promptly removed; however, the timely removal of these low value and underutilized trees only occurs if loggers and landowners have an economic incentive to do so.

In addition to facing threats from insects and diseases, some of the effects of climate change threaten U.S. forests, which may result in the increased risk for larger and more frequent wildfires (Rustad et al., 2012) that endanger forests, safety, and property. Moreover, much of the timber found in several regions of the U.S. is hazardous fuel (e.g., small-diameter trees) that is often not efficiently removed, leading to fire risk. Effective forest management requires timely removal of woody hazardous fuels. However, like pest-infested trees, timely removal only occurs if loggers and landowners can profit – thus, economic incentives must exist. Traditional wood products markets cannot absorb all this existing low-quality timber (Bumgardner, Bush, & West, 2001), but a strong TMW market has the potential to catalyze increased harvest of these hazardous trees.

Economic Opportunities from TMW

While lumber markets are recovering across the U.S. after the Great Recession, hundreds of thousands of jobs have been lost in the forest products sector (Woodall et al., 2011), with small businesses and rural areas hit especially hard (B. Smith & Guldin, 2012). TMW has the potential to create economic opportunities in rural communities

where raw materials are harvested and processed by providing forest product diversification and market development of value-added products.

The U.S. forest products industry faces big challenges, with manufacturers losing considerable market share to overseas producers (Buehlmann, Bumgardner, Schuler, & Barford, 2007). Further, the Great Recession has reduced domestic demand for forest products, resulting in plant closures and thousands of layoffs (Woodall et al., 2011), while substitute materials continue to take market share from wood (particularly for exterior siding and decking). From 2005 to 2009, U.S. softwood and hardwood lumber shipments decreased by 41% and 42%, to less than 24 billion board-feet (Resource Information Systems, Inc. [RISI], 2012) and 6.7 billion board-feet, respectively (Hardwood Market Report [HMR], 2014). Lastly, TMW can improve the financial possibility of forest ownership by supporting forest products markets (USFS, 2013) and providing an outlet for low-value resources, such as small-diameter material, ash affected by EAB, and related species attacked by invasive pests and diseases (Brashaw, Ross, & Wang, 2012). However, it will also be important to maintain high quality aesthetic and processing requirements for TMW products, and industry-wide standardization should help balance these elements.

Status of the TMW Industry in the U.S.

Currently, TMW is a fledgling industry in the U.S., with growing interest among potential producers and industrial and residential consumers. Research conducted in 2015 identified the major obstacles hindering successful marketing of TMW products in the U.S. (Espinoza, Buehlmann, & Laguarda-Mallo, 2015). The study consisted of phone interviews with TMW producers and a survey of their web-based and printed promotional materials. The main findings from this research were:

- Major TMW products include exterior siding and decking, and interior millwork and flooring.
- Promotion occurs via tradeshow exhibitions, an internet presence, and advertising in trade magazines. Little advertising is aimed at end users.
- Promoted attributes include decay resistance, environmental friendliness, dimensional stability, excellent exterior performance, notable acoustic properties, an

exotic appearance like imported tropical hardwoods, machinability, and competitive price.

- Customers are not as price sensitive as those in common markets (e.g., pressure treated lumber); TMW is competitive in price with imported tropical hardwoods and naturally durable softwoods.
- All interviewees agreed that the major barrier limiting increased adoption in the U.S. was very low awareness among potential end users.

Wood-plastic composites (WPCs) and other competing materials have taken market share from solid wood (the share of solid wood in the decking market fell from 96% in 1995 to 72% in 2010 (Ganguly, Eastin, Crespell, & Gaston, 2010)). This decline is due, in part, to the perceived superior durability and environmental friendliness of solid wood substitutes (Ganguly et al., 2010). The author of this thesis believes TMW has potential to recover some of solid wood's lost market share. However, current and potential TMW producers need effective marketing strategies to identify customers' needs and to effectively formulate and communicate the value proposition offered by TMW products.

Importance of an Effective TMW Marketing Strategy

Adoption of new building materials by the construction industry is often slow, as liability issues encourage conservative industry behavior. Consumer perceptions also play a large role in the adoption of new products and technologies. Rogers (2003) proposed a five-stage model for the diffusion of innovations: (1) *awareness*, (2) *interest*, (3) *evaluation*, (4) *trial*, and (5) *adoption (or rejection)*. From the time a consumer becomes aware of a new product to when the decision to try the product is made, information can be received from multiple sources (e.g., manufacturers, word-of-mouth) to form perceptions about the product's benefits. The rate of product diffusion is dependent on potential adopters' perceptions of a product's attributes (Rao & Yamada, 1988; Srivastava, Mahajan, Ramaswami, & Cherian, 1985).

Marketing strategy may be defined as the "*analysis, strategy development, and implementation of activities in developing a vision about the market(s) of interest, selecting market target strategies, setting objectives, and developing, implementing, and managing the marketing program positioning strategies designed to meet the value*

requirements of the customers in each market target" (Cravens & Piercy, 2012). Effective marketing strategies facilitate product adoption and accelerate the rate of diffusion by: formulating an effective communications strategy to enhance product and brand awareness (Stage 1 of the adoption model, see previous paragraph); making technical information readily available for potential adopters (Stages 2, 3); making the product easily available for trial and adoption (Stages 3, 4); and providing high-quality, post-sales support to address adopters' concerns and facilitate repeat purchases (Stage 5).

This research on professional consumer perceptions of TMW and competing wood-based decking products has led to the development of a TMW Strategic Marketing Plan to facilitate the five stages of adoption and help TMW producers develop effective messaging and promotional strategies that increase awareness and position TMW products advantageously in the marketplace.

Research on Consumer Behavior, Preferences, and Perceptions

Consumer behavior research is the scientific study of the processes consumers utilize to choose, purchase, use, and dispose of products and services (Anderson, Fell, Smith, Hansen, & Gomon, 2005). Consumer preference and perception research focuses on consumer observations and opinions on the quality, appearance, and other variables of a product pre-purchase. While these preferences and perceptions may or may not reflect actual buying behavior, they do impact it (Hemström, 2010). There are two distinct groups of consumers this area of research focuses on: intermediate consumers, who include wholesalers, distributors, industry professionals, and retailers; and end consumers, who are the people ultimately using a product (Anderson et al., 2005).

There are many benefits to understanding consumer behavior, preferences, and perceptions of forest products. First, this information may provide valuable insights on the segmentation, market positioning, and management of forest products (Sande & Nyrud, 2008). This information may also be beneficial because positioning the production and marketing of forest products on consumer-based factors can help the industry target specific market segments and better utilize forest resources. Lastly,

because purchasing behavior is influenced by consumer perceptions and preferences, the study of these topics provides useful information for product developers, designers, engineers, and marketers, to develop, manufacture, and sell products that meet customers' expectations.

The forest products industry has been historically very traditional with its marketing techniques and tends to ineffectively utilize market opportunities (Hansen, Nybakk, & Panwar, 2014). Incorporating customers' input in the product development process and formulation of marketing strategies increases the chances of market success of a product or service. Research on potential TMW adopters' behavior, preferences, and perceptions will help the industry understand its customers' needs and priorities, and thus improve its offerings and messaging. Over the past thirty years, very little research has been done on consumer behavior, preferences, and perceptions of forest products. The literature review conducted for this research explored previous consumer behavior, preferences, and perceptions research of forest products for intermediate consumers. Intermediate consumers play an important role in the growth of certified products, as this group has great bargaining power over markets because of their influence on end consumer purchasing decisions (Porter, 2008). The main areas identified in previous research included: sustainability issues, such as acceptance and willingness to pay for forest products with environmental attributes, and preferences and perceptions of the quality, performance, and aesthetic attributes of forest products.

Sustainability Issues

The most studied area of consumer behavior, preferences, and perceptions of forest products are perceptions of environmental certification, particularly the acceptance of and willingness to pay for environmentally certified wood products. Vlosky and Ozanne (1998b) explored the perceptions and attitudes of U.S. intermediate and end consumers in the wood products value-chain, including manufacturers, retailers, contractors, architects, and end users, with regards to environmental certification and a willingness to pay a premium for these products. Their results indicated that these groups have contrasting views and attitudes on the need for environmentally certified wood products, as well as differences in opinion on willingness to pay for certified products and procedures. Manufacturers and retailers did not believe there was a need

for environmental certification, contractors were indifferent to it, and architects and end consumers believed there was a need for certification. When asked what entity would be most trusted to handle controlling the environmental certification process, manufacturers believed they were the most trusted group, while retailers, contractors, and architects preferred third party certification entities, and end consumers preferred non-governmental organizations (Vlosky & Ozanne, 1998b).

The same authors published another paper that explored the manufacturer's perspective in more detail (Vlosky & Ozanne, 1998a). Results indicated manufacturers believed their companies currently had policies already in place aimed at environmental stewardship and were not willing to pay a premium for certified raw materials or pay to become certified unless the increased costs were paid by consumers.

Architects are often involved in the selection process when choosing building materials, and have the potential to influence the utilization of wood products. Wagner and Hansen (2004) interviewed U.S. architects to understand their environmental concerns and design criteria concerning wood products, as well as their perceptions of the effectiveness of various environmental actions used by wood companies. Results illustrated that third party environmental certification was the most important environmental action for architects, followed by environmental advertising. They noted the advertisements also needed to promote quality, because using the term "environmentally sustainable" was only considered to be of medium importance. A general conclusion arising from this study was that forest products companies must improve both the quality, appearance, and environmental aspects of their materials; while also effectively communicating this to their clients.

Roos, Woxblom, and McCluskey (2010) interviewed architects and structural engineers to determine what they believed their influence and role was in utilizing wood materials for construction. Respondents indicated that they do not perceive themselves to have much control or influence over the use of wood in building projects. Both groups interviewed perceived wood as an appropriate building material, but they believed much of the control and influence over material selection comes from developers and contractors. The architects and engineers perceived the positive attributes of wood to be strength, environmental friendliness, and ease of handling, while they perceived the negative attributes of wood to include decay, instability, and poor sound transmission performance.

Estep (2015) aimed to identify opportunities for wood products in the affordable and green building industries by using a mail survey to target manufacturers, builders, and material specifiers in the Appalachia region. Builders and material specifiers both showed a preference for using certified wood products when possible. Builders preferred following green building standards, were willing to pay for local products, and cited the environmental attributes of certified wood products as the main reason for using them. Both builders and material specifiers utilized local retailers, websites, and magazines for learning about new wood products. In contrast, manufacturers felt the certification of wood products is unnecessary, but agreed that the green building market will continue to grow. In addition, manufacturers stated they are not doing a lot to market their products to the green building sector, but are encouraged to do so and included the environmental attributes of their wood products based on information collected from the builders and material specifiers.

Performance, Quality, and Aesthetics

Another area of the consumer behavior, preferences, and perceptions research is intermediate consumer perceptions of performance, quality, and aesthetic attributes of forest products. Cohen, Xie, and Ruddick (1992) collected perceptions data from building material retailers in response to the dramatic increased use of pressure treated solid wood products that the construction industry was seeing at the time. Using a mail survey, they collected data on perceptions of the attributes of pressure treated wood products and other basic market information. Results revealed that retailers considered *Straightness* and *General Appearance* of wood to be more important than *Price* to their customers. Retailers also considered *Wood Quality* and *Appearance* to be more important than technical considerations or *Brand Name*. The data showed there was room to improve the appearance of pressure treated lumber, as retailers believed their customers were willing to pay a premium for the visual upgrading of lumber products.

Eastin, Shook, and Simon (1999) considered factors influencing softwood lumber material substitution in the U.S. residential construction industry. Results showed that 90% of respondents had used at least one material substitute for softwood lumber. The attributes perceived as most important in influencing the substitution process by intermediate consumers were *Product Strength* and *Straightness*. In addition, the three

underlying factors that affected material substitution were the physical, technical, and economic/supply characteristics of a product.

Weinfurter and Hansen (1999) considered the perception differences of quality requirements between buyers and suppliers of softwood lumber products by interviewing lumber mill employees and their customers. Their results were similar to Cohen et al. (1992), who found that suppliers understand the importance their customers place on service and product quality, but also found that suppliers consistently rated the quality of their products higher than their buyers did. Weinfurter and Hansen (1999) also similarly found the largest perception gaps between buyers and suppliers were related to lumber appearance, and any quality improvement efforts made by lumber mills should focus on the appearance and consistency of their products.

Dunn, Shupe, and Vlosky (2003) were also concerned with wood quality and sought to understand homebuilder's perceptions of southern yellow pine in response to an industry-wide belief that overall lumber quality had decreased in recent years. Data was collected using a mail survey of the 500 largest U.S. homebuilder companies. Results indicated southern yellow pine was still regarded positively overall and considered a credible material to manufacture high-quality products with, although a considerable number of respondents believed that lumber quality in general had decreased over the last 50 years. The authors believed potential explanations for this perceived quality decline included using plantation wood grown rapidly, and possible kiln-drying technique errors.

R. Smith, Spradlin, Alderman Jr., and Cesa (2000) investigated the perceptions of U.S. highway decision makers concerning wood as a potential infrastructure material. A mail survey was sent to professional consumers, engineers, and academics in the transportation field. They were asked to compare wood to steel, reinforced concrete, pre-stressed concrete, aluminum, and plastic on 6 factor groups and 30 material attributes. The attributes considered most important to respondents for highway infrastructure material selection included: *Durability*, *Maintenance*, and *Cost*. Plastic was the only material rated lower than wood in perceived material performance across all groups of people interviewed.

Bysheim and Nyrud (2008) also examined professional consumer perceptions of using wood as a potential building material, noting that an increased use of wood products in urban construction would be a great market opportunity for the forest

products industry. Their target population was Norwegian architects, who were sent an online survey. Responses revealed that the three most important factors architects considered when utilizing wood as a structural material included: prior experience with using wood as a structural material, perceived behavioral control over using wood, and attitudes towards using wood in buildings over five stories high.

Hemström (2010) conducted a similar study a few years later, measuring architects' and structural engineers' perceptions towards using wood frames in multi-story buildings using an online survey. The construction industry has traditionally associated wood with negative characteristics such as: weak sound proofing and stability performance, as well as combustion. The positive characteristics of reducing energy use and CO_2 emissions were not enough to overcome these negative perceptions. Results from the survey revealed that the most important aspects this group considered when working with wood were: project cost, fire safety, construction time, sound insulation, acoustics, and stability. Respondents perceived concrete to be superior to both steel and wood frames when considering fire safety, sound insulation, and acoustics, but perceived wood and concrete frames equal in regards to cost and construction time. Respondents also felt both steel and concrete frames had better general stability than wood frames in buildings 3-8 floors tall. Despite these negative perceptions, interest in using wood frames in the future was high.

Bysheim and Nyrud (2011) also investigated the attitudes of Norwegian architects and civil engineers towards using wood in urban construction, with the primary goal of determining what influences key decisions when selecting building materials. The goal of this study was to increase the use of wood as a building material in urban construction once these influences were considered using structured interviews and an online survey. Data suggested the three most important factors influencing decisions when considering wood as a structural material were: the perceived risk of using wood, previous experience with wood, and fire-related properties of wood. When considering wood as a façade material, the most important factors were: perceived visual properties, fire-related properties, and previous experience.

Two recent studies have focused on the outlook for acceptance and adoption of a relatively new and innovative forest product, cross-laminated timber (CLT) by the U.S. architecture community. The first study on this topic sought to assess the market for CLT in the U.S., and find any potential barriers to its adoption using semi-structured

interviews (Laguarda-Mallo & Espinoza, 2014). Respondents indicated the main perceived benefit of using CLT is that it is an environmentally sustainable resource. Other perceived benefits included: a shorter construction time, comparable performance with concrete and steel, and a reduced weight. Perceived drawbacks of using CLT included: poor acoustic and vibration performance, as well as the volume of wood needed to produce CLT. Respondents believed awareness of CLT was still low in the U.S., and barriers to adoption included: issues with building codes, lack of availability in the U.S., and misconceptions about wood. Despite these potential barriers, respondents also believed there is potential for CLT to be a cost-competitive alternative to concrete structures in the future.

The second study on perceptions of CLT explored why this structural material has not experienced widespread U.S. adoption. Survey participants included members of architecture firms. Results indicated that respondents believed the main benefits of CLT to be its favorable environmental and structural performance, as well as its exceptional aesthetic properties. The main perceived disadvantages included high maintenance costs and fire performance, while the main barriers to adoption included building code compatibility issues, the initial cost of installation, and a lack of U.S. availability. In addition to assessing respondent perceptions, this study showed that for CLT to be successful in the future, product information must reach its target audience and accurately convey information to them (Laguarda-Mallo & Espinoza, 2015).

The U.S. Decking Industry

Decking is a particularly suitable application of TMW, because of its exterior performance and environmental and aesthetic advantages. These advantages can make TMW competitive against established decking materials, such as naturally durable softwoods, tropical hardwoods, and wood-plastic composites (Espinoza et al., 2015). Wood-plastic composites (WPCs) and other competing materials have taken a considerable portion of market share from solid wood decking materials over the past 10 years, with the demand for solid wood decking materials falling from 96.6% in 1995 to 71.6% in 2010 (Ganguly et al., 2010).

The total demand for decking products has fluctuated with the housing market over the past few decades, but as of 2011, the decking industry was a $3 billion market

in the U.S. (Kouteran, 2011) and this number is expected to continue rising with the rebounding economy following the Great Recession. It is estimated that 4.2% of U.S. households add a deck to their house every year, resulting in over 3 million new decks being added to homes (Ganguly & Eastin, 2009). In 2015, 23% of new single-family U.S. homes built had a deck, which was approximately 149,000 new houses with decks total (U.S. Census Bureau, 2016). Prosales Magazine, an industry trade magazine, reported demand for decking products would continue to rise at a rate of 4.1% from 2013 into 2015 to value $4.1 million that year, with wood decking products comprising approximately 62% of the market, synthetic materials comprising approximately 32% and metal products comprising approximately 6% (Busta, 2013). TMW has the potential to recover some of the dropping market share for solid wood if producers can develop effective marketing strategies to identify customers' needs and effectively formulate and communicate the value of TMW products.

Common decking materials available on the market include: pressure treated lumber, naturally durable softwoods (such as Western red cedar and redwood), tropical hardwoods (such as ipe), WPCs, plastics (PVC), and aluminum. Other materials and treatment methods, such as TMW, are less common but hold a small fragment of the market. Wood-based decking materials were selected to be the focus of this study. Each of the wood-based decking materials have their own industry makeup, with some materials being fragmented into many small players and others being dominated by a few large companies. In general, the market share and demand for solid wood products has decreased from 2000-2010, while market share of WPCs increased during that time (Table 3).

Table 3. Summary characteristics of total U.S. decking demand from 2000-2010 in millions of board feet of timber (mmbf) and millions of dollars (Ganguly et al., 2010). Percentages are share of total volume in mmbf.

	2000	**2010**	**% Change 2000-2010**
Total Demand (mmbf)	4,677	5,580	19.3%
Total Value ($millions)	$3,369	$6,390	89.7%
Solid Wood (mmbf, total)	4,366 (93.4%)	3,995 (71.6%)	-8.5%
Pressure Treated Lumber	*3,619 (82.9%)*	*3,225 (80.7%)*	*-10.9%*
Redwood	*349 (8.0%)*	*294 (7.4%)*	*-15.6%*
W. Red Cedar	*306 (7.0%)*	*360 (9.0%)*	*17.6%*
Other	*92 (2.1%)*	*116 (2.9%)*	*26.1%*
WPC	236 (5.1%)	1,396 (25.0%)	491.5%
Plastic & Other	75 (1.6%)	189 (3.4%)	152.0%

Intermediate Consumer Behavior for Decking

Shook and Eastin (2001) sought to characterize the U.S. residential deck material market, as this had not been completed since the 1980's. A mail survey was sent to residential construction firms asking them to rate the importance of 11 deck attributes, as well as their material use changes over the past two years. Overall, construction firms had decreased their use of naturally durable softwoods over the past two years. Respondents indicated the two most important attributes for decking materials were *Long Life* and *Beautifully and Aesthetically Pleasing*, with *Low Material Cost* being the lowest rated attribute. These results suggested price was not the determining factor when selecting decking materials for homebuilders.

Eastin, Ganguly, Shook, and Brackley (2005) explored deck and home builder material use in the U.S. decking market through a lens of assessing the market potential for Alaskan yellow cedar (*Cupressus nootkatensis*). The most important attributes to industry members when selecting materials included *Long Life*, *Visual Appearance*, *Consistent Material Quality*, and *Product Availability*, while the least important attribute was *Low Price*. These results are consistent with Shook and Eastin (2001) and suggested a primary focus on high material quality among industry members.

Ganguly and Eastin (2009) investigated trends in the U.S. deck market by conducting a national survey of deck and home builders. One of the topics explored was material use changes over the past two years. Overall, respondents had decreased their use of naturally durable softwoods and pressure treated lumber, and increased their use of WPCs, tropical hardwoods, and plastic. When asked to rate the importance of various decking material attributes, respondents indicated *Long Life*, *Consistent Material Quality*, *Beautifully and Aesthetically Pleasing*, and *Availability* were the most important, while *Low Heat Retention*, *Little Product Waste*, and *Low Material Cost* were the least important. Finally, respondents were asked to rate different decking materials on their performance for different attributes. WPCs were rated highest for *Long Life* and *Low Maintenance*, while pressure treated lumber was rated highest for *Availability*, *Strength*, and *Low Cost*.

End Consumer Behavior for Decking

One of the first studies to explore end consumer perceptions of decking material attributes was conducted by Fell and Gaston (2001), who published a report on material selection for outdoor projects in Canada. Exit surveys at home centers were used to collect data and results showed consumers sacrificed other attributes for long-lasting products. In addition, market segmentation showed material preference differences between urban, suburban, and rural consumers. Urban consumers preferred naturally durable materials, suburban consumers were indifferent to material type, and rural consumers' preferred pressure treated lumber.

Thomas (2004) explored end consumer preferences of three decking materials: naturally durable softwoods, pressure treated lumber, and WPCs. The methods used included collecting data in-person at four trade shows using a conjoint analysis survey. Results from this study indicated end consumers want long-lasting decking products and considered *Durability* to be a more important attribute than *Price* or *Hours of Maintenance*. This study also revealed decking material preferences can be segmented by end consumer age, with acceptance of WPCs increasing with age. In addition, female respondents preferred naturally durable softwoods and were less sensitive to price compared to males, and all respondents viewed pressure treated lumber negatively compared to the other two materials.

In 2008, a study explored end consumer preferences for new decking materials compared to "aged" decking materials that had been subjected to a stimulation of being used for two years (Nyrud & Høibø, 2008). Half of the study participants evaluated the new wood samples and half evaluated the "aged" wood samples using an in-person survey at a fair. Results showed that end respondents preferred materials with age effects, with the aged products rating higher on a Likert scale than the new products. Business implications of this study were that age effects may be used as a marketing advantage.

Nyrud, Roos, and Rødbotten (2008) used an in-person sensory analysis and hedonic study to measure preferences for five wooden decking materials using eighteen attributes. Respondents preferred a homogenous visual appearance and moderate color intensity for their decking materials. They also preferred samples made from untreated,

naturally durable wood and disliked samples made from pressure treated wood, as well as wood surfaces with uneven characteristics.

Roos and Nyrud (2008) explored end consumer preferences for various attributes of pressure treated lumber decking materials using an in-person conjoint analysis survey at a trade show in Norway. Results determined that the most important attribute overall was *Environmental Certification*, followed by *Price* and *Treatment/Visual Appearance*. Female respondents placed more importance on aesthetics and treatment, while male respondents were more price sensitive. From this data, the population was segmented into three groups. The first group was comprised of "green consumers," who were most concerned with environmental certification. The second segment included "exclusive consumers," who were focused on aesthetics, and the third was "special-offers consumers" who were the most price sensitive group. Overall implications of the study demonstrated an ongoing trend towards increased green consumerism, as well as an overall focus on aesthetics among all consumers.

The most recent study on end consumer perceptions of wood surface attributes used a sensory analysis and hedonic study to test what affects preferences for the overall visual homogeneity of wood products, which had been found in previous studies (Høibø & Nyrud, 2010). Ten different decking materials with various visual qualities were shown to potential consumers. Some attributes were material dependent, and some were production dependent. Results indicated that material and production dependent properties affected visual homogeneity, which meant that producers should focus on using high-quality raw materials as well as producing decking products that do not have a stained appearance.

Conjoint Analysis

Conjoint analysis was the main data collection and analysis methodology for this study, and is a market research tool that allows to understand why consumers choose one brand or supplier over another, by assessing the trade-offs customers are willing to make among competing products, product characteristics, and suppliers (Green, Krieger, & Wind, 2001). In conjoint analysis research, a product is viewed as a collection of attributes, with the assumption that buyers prefer a certain product because of the overall value (utility) obtained from consuming or using that product. The buyer's

preferences are dependent on their perceptions about the amount of each attribute that a specific product has (or does not have) and the relative importance the consumer attaches to those attributes. Common applications for conjoint analysis include: product development, assessments of a customer's willingness to pay, market segmentation, pricing decisions, and product design applications (Bumgardner et al., 2001).

There are several types of conjoint analysis studies, with different question styles and data analysis techniques. Choice-based conjoint (CBC) was selected for this study because it best simulates the purchasing decisions consumers make by asking respondents to choose product concepts instead of rating or ranking them (Orme, 2010). CBC exercises are flexible in their design, allow for measuring a "None" alternative, and are easier and more accurate for respondents to answer than traditional ranking-style conjoint analysis questions (SawtoothSoftware, 2015).

Previous Forest Products Studies using Conjoint Analysis

One of the first forest products consumer behavior studies to utilize conjoint analysis was completed by Bumgardner et al. (2001). An in-person survey of retail buyers and managers in the furniture industry was used to determine the importance of naturally-occurring character mark features of wood relative to other attributes. *Knot Size* was the attribute used to represent character marks, and *Finish*, *Style*, and *Aspect* were the other attributes considered. Results indicated opportunities did exist for increased use of character marks on furniture, but these knots should be somewhat harmonious and on the smaller side, since market conditions at the time favored no knots or few knots. The implications of this study were important to be able to make more efficient use of forest resources.

Bigsby and Ozanne (2002) studied the relative importance of five different outdoor wood furniture attributes for environmentally certified wood products. Data was collected using a mail survey that included conjoint analysis questions. The relative importance of the five attributes from highest to lowest were: *Source of the Wood*, the *Type of Forest* from which it is sourced, *Environmental Certification*, *Length of Warranty*, and *Price*, with the lowest price being preferred. Based on these results, four market segments were identified using cluster analysis. Two of the segments had key attributes that included environmental considerations, one segment was price sensitive and

wanted lower prices, and the final segment wanted locally sourced wood but also considered price.

Qingbin, Guanming, and Chan-Halbrendt (2004) used conjoint analysis to assess the market potential for producing fine furniture from low-grade lumber by evaluating end consumer acceptance and preference for chairs produced from low-grade lumber with character knots. Results showed that respondents considered *Design* to be the most important attribute, followed by *Price*, *Guarantee Policy*, and then *Density of Character Marks*, in that order. Character-marked furniture appeared to be acceptable to a large percentage of respondents, but the design of the chairs must be also appealing and the price and warranty must be competitive as well.

Another study used conjoint analysis to determine the relative importance of various attributes of a wooden CD holder, as well as identify any demographic and psychographic variables associated with respondents who rated *Environmental Certification* as the most important attribute (Anderson & Hansen, 2004). The results revealed that environmental certification was not important to the average buyer, so certified forest products would not easily demand a price premium in mainstream stores. However, results did suggest that certified forest product price premiums may be successfully implemented through market segmentation.

Veisten (2007) investigated end consumer willingness to pay for environmental attributes using both conjoint analysis and contingent valuation methods at two IKEA stores, one in England and one in Norway. The product used for the study was a wooden table without a pre-existing ecolabel. Three attributes were taken into consideration for the study, *Price*, *Ecolabel*, and *Wood Species*. The alternative prices used for the ecolabeled product were 10% and 25% higher than the original price attribute. Results indicated that 75% of participants in England and 70% of participants in Norway claimed an ecolabel would have some bearing on their wooden furniture purchases. In England, the median willingness to pay among participants using conjoint analysis was a 16% premium, while it was a 7.5% premium using contingent valuation. In Norway, the median willingness to pay among participants using conjoint analysis was a 2% premium, while it was a 6% premium using contingent valuation. Evidence from this study indicated that conjoint analysis yields higher willingness to pay estimates than conjoint valuation, yet this expected relation between conjoint valuation and conjoint analysis only occurred in England (Veisten, 2007).

The effects of environmental labeling, disclosure of forest origin, and price on consumer preferences was examined in both the U.S. and the U.K. using an online conjoint analysis survey (Aguilar & Cai, 2010). U.K. respondents bought more certified products and expressed stronger opinions on the need for forest certification. Data was analyzed using a conditional logit model, which found that environmental certification by the government or a third party had a favorable effect resulting from environmental labeling, but disclosing that a product has tropical origins had an unfavorable effect, even more so than disclosing "unknown origin." In addition, there was a decline in product preference as price premiums increased, and the degree of sensitivity to price changes was affected by demographic characteristics. A market analysis showed that a small share of both the U.S. and U.K. markets would prefer certified tropical hardwoods products even at as high as a 50% premium.

Thompson et al. (2010) used conjoint analysis data from two previous studies to determine if a relationship exists between demographic and psychographic characteristics and consumer-reported environmentally conscious intentions. Many marketing firms engage in environmental marketing to appeal to environmentally conscious consumers. The data from this study revealed there is a segment of environmentally conscious consumers who respond to and purchase certified/ecolabeled forest products, yet a clear segment for this group of consumers has yet to be established. This study found the segments reporting the strongest preferences for environmentally certified forest products are more likely to pay a premium for certified products and are more likely to display environmentally conscious behavior in other areas of their lives. In addition, the people found in these segments are most likely to be female and already familiar with environmental certification.

Problem Statement

Thermally-modified wood (TMW) is a chemical free treatment used to enhance the properties of wood by heating it in a high temperature environment for relatively short periods of time compared to traditional wood drying (Esteves & Pereira, 2009; *ThermoWood Handbook*, 2003). This technology has the potential to create and expand U.S. markets for traditionally underutilized and low-value tree species. Many tree

species from U.S. forests have insufficient durability for exterior applications without treatment because they are susceptible to rot and decay (Homan & Jorissen, 2004).

The enhanced properties and environmental performance of TMW make it a potential candidate to be an economically viable use for many U.S. wood species, as well as a sustainable and chemical free alternative to pressure treated lumber, imported tropical hardwoods, and competing materials containing petrochemicals such as polyvinyl chloride (PVC) and wood-plastic composites (WPCs). A strong U.S. TMW market also has the potential to expand markets for value-added wood products and create jobs to bolster struggling economies in timber-reliant rural communities, as well as make the forest products industry more competitive with other industries through the production of value-added products.

Despite these promising attributes, there is currently very little TMW manufactured or sold in the U.S. (Scheiding, 2014). At this time, there are only 10 producers of TMW in the U.S., compared to 118 producers in Europe and Russia alone (Scheiding, 2014). Manufacturers have very little experience with the effects of thermal-modification treatments on domestic tree species and both intermediate and end consumers are inexperienced with TMW performance and how it may fit their needs. Recent research has found this unfamiliarity with TMW can mainly be attributed to inadequate marketing efforts and a low level of awareness among intermediate and end consumers, as well as initially deceiving claims on the performance of TMW (Espinoza et al., 2015). The TMW industry is new in the U.S., and moving forward it is important to collect accurate information on consumer preferences and perceptions of this new material so effective communications strategies may be developed to encourage the growth of the industry.

Research Justification

The expansion of the TMW industry in the U.S. has the potential of creating new market opportunities for U.S. forest products, creating economic opportunities, particularly in rural communities (B. Smith & Guldin, 2012; Woodall et al., 2011). By providing consumer behavior, preferences, and perceptions data to the TMW industry, companies can develop products better suited to their customers' needs and develop effective marketing strategies. Ultimately, an expanding TMW industry in the U.S. can

create wealth and economic opportunity in rural communities where raw materials are harvested and processed.

Moreover, TMW products can be made from currently underutilized and low-value forest resources (Espinoza, Aro, & Donahue, 2015) and a strong demand for these products would encourage harvesting of small-diameter trees that pose hazardous fire risks or trees affected by invasive species or disease. The growth of the TMW industry has the potential to encourage and support good forest management practices and the forest product industry as a whole by providing diverse, value-added product options (USFS, 2013).

Research Objectives

The main objective of this project was to identify the challenges and opportunities for TMW industry expansion in the U.S. market related to professional, intermediate consumers, and formulate actions to support the growth of the TMW industry.

To achieve this objective, (1) the priorities and perceptions of potential adopters of TMW products were identified by comparing TMW to competing wood-based products. With this information, (2) a marketing strategy was developed to help the U.S. TMW industry better meet customer needs.

Expected Outcomes

Expected outcomes from this study include the identification of opportunities for employment creation in rural areas, as well as finding value-added and sustainable uses for U.S. forest resources. Additionally, this research can help entrepreneurs as well as established industries create effective marketing plans for TMW products. Expected specific outcomes include: understanding decking industry members' perceptions and preferences towards TMW, formulation of businesses implications based off these perceptions, and communicating results to TMW industry members and other stakeholders through a strategic marketing plan.

CHAPTER 2. METHODOLOGY

To achieve the objectives of this research, information on professional consumer perceptions of thermally-modified wood (TMW) was gathered, to better understand the challenges and opportunities for its market growth. Data thus generated was the major input to develop a Strategic Marketing Plan for the U.S. TMW industry. To accomplish this project's objectives, the process depicted in Figure 2 was followed. Each step of the research process is explained in detail in this chapter.

Figure 2. Outline of research process.

Literature Review

The first part of this project involved conducting an in-depth literature review, obtaining information from a variety of sources including peer-reviewed journals, books, manufacturer's websites, and government reports. The literature review focused on consumer perceptions and preferences of and wood products, information about the TMW and decking industries, and marketing strategy formulation. Results from the literature review were presented in Chapter 1.

Perceptions Study

The objective of this part of the study was to identify professional adopter's preferences and perceptions when selecting wood-based exterior decking products, as well as their perceptions of the various decking materials currently available on the market, including TMW. Primary data for this study was collected using a computer-based questionnaire containing demographic, user perceptions, and conjoint analysis questions to collect data from professional consumers at a trade show event called the "Deck Expo" and through an online survey. The product selected for this project was decking, because of its large market and suitable application of TMW. To increase

respondent's familiarity with all the decking materials included in the survey, deck samples were created for participants to examine in-person at the trade show event.

Product Selection

This project focused on wood-based exterior decking. Two major reasons for selecting this product were the large size of the decking market and the suitability of TMW for outdoor decking applications. Decking products are a particularly suitable application of TMW, because of its proven exterior performance and environmental and aesthetic advantages, which can make TMW competitive against established materials, such as naturally durable softwood species and tropical hardwood species or wood-plastic composites (Espinoza, Buehlmann, et al., 2015). Wood-plastic composites (WPCs) and other competing materials have taken a considerable portion of market share from solid wood over the past 10 years, with the share of solid wood decking materials falling from 96% in 1995 to 72% in 2010 (Ganguly et al., 2010). TMW has the potential to recover some of the declining market share for solid wood decking products, if producers can develop effective marketing strategies to identify customers' needs and successfully formulate and communicate the value of TMW products. These marketing strategies would increase TMW adoption if successfully implemented.

Sample Frame

The target audience for this study was comprised of potential professional adopters of decking materials, including: deck builders, residential contractors, and remodelers, as well as wholesalers, retailers, distributors, manufacturers, and architects/designers. The last five groups of professionals were added to the initial target audience following suggestions from industry members at a pre-testing event at the Natural Resources Research Institute (NRRI) in Duluth, Minnesota, which will be explained later in this chapter.

Professional consumers were chosen as our audience because they play an important and influential role in the material selection and construction of exterior decks. Nearly 80% of decks are installed by professionals (Ganguly et al., 2010) and 46% of decks built with new construction homes are subcontracted out to professionals by the homebuilders (Ganguly & Eastin, 2009).

Questionnaire Development

The main research instrument used in this project was a questionnaire created through an iterative process to ensure it effectively collected the required data. This process included considering attribute categories from previous studies, then submitting drafts to both industry professionals and members of the academic community for feedback, and making changes to reflect this feedback. Attribute categories used in previous studies on consumer perceptions of decking materials can be found in Table 4.

Table 4. Attribute categories from previous studies on consumer attitudes of decking materials.

Attribute	Description	Reference
Treatment	Modified with a treatment or no treatment	Nyrud et al. (2008)
Environmental Certification	Whether wood has been environmentally certified by one of the known systems (e.g., FSC)	
Ready-to-Assemble Decking	Whether decking can be assembled by Do-it-Yourselfers or requires professional assembly	
Material	Naturally durable wood (cedar and others), treated wood (ACQ and others), and WPCs	Thomas (2004)
Maintenance	Hours, cost, etc. needed per year on deck maintenance	
Durability	Number of years of service life	
Price	Price per lineal foot of decking material	
Beautiful & Aesthetically Pleasing	Appearance of material	Ganguly et al. (2010)
Quality Consistency	Consistency of materials received	
Availability	Availability of material	
Natural Decay Resistance	Ability to resist decay naturally without treatment	
Resistance to Splintering	Natural resistance of the material to splintering	
Price Stability	Fluctuations in price	
Workability & Ease of Use	Ease of working with the material	
Strength Properties	Strength of material	
Product Waste	Waste produced from product over its full lifecycle	

In the first step of the questionnaire development process, an initial version of the questionnaire was drafted based on the project objectives and literature review with the help of experienced industry members. The draft was then submitted to four academic reviewers and changes were made based on their feedback. Finally, an updated draft was sent to 13 industry professionals for feedback, of which three provided input.

After changes were made, the survey was transferred into Sawtooth Software's Lighthouse Studio (Sawtooth Software, 2016), and a conjoint analysis question block

was added using the software design tools. Sawtooth is a software developed for survey design, distribution, and analysis, via the internet or a computer, and is designed specifically for conjoint analysis studies.

Following this software update, a testing event was hosted at the Natural Resources Research Institute (NRRI) in Duluth, Minnesota, and industry members from the intended audience were invited. This testing event was conducted at the NRRI because of their strong industry connections and proximity to many industry members.

To set up for the event, two laptop computers, the deck samples (discussed in detail below), and other materials were set up in a conference room at the NRRI (Figure 3 and Figure 4) to resemble the Deck Expo booth setup as closely as possible. Participants were invited to arrive within a span of two hours, evaluate the deck samples, and take the questionnaire. For the testing, additional questions were included at the end of the questionnaire, asking participants to provide their feedback on the testing experience. After completing the survey and feedback questions, they were asked for additional feedback verbally, which was noted in writing. The feedback questions at the end of the survey included:

- What do you think about the length of the survey and the amount of time it took you to complete it?
- What do you think about the clarity and relevance of the questions? Please note any specific questions that seem unclear or irrelevant.
- What specific suggestions do you have to improve the survey?
- Please share any other comments you would like to add.
- Please leave a contact email/phone number if I may contact you with any follow-up questions regarding the feedback you provided.

Figure 3. Participants at the NRRI testing event answer the questionnaire and provide feedback.

Figure 4. Decking samples on display at the NRRI testing event.

Four NRRI employees participated in the testing event, all of whom have extensive experience with various wood products. Two external participants also provided feedback at the testing event. One of these external participants works for a wholesale company and the other has worked in the construction industry for over 40 years.

Various changes were made to the questionnaire based on the results from the testing event. The conjoint analysis block of questions brought many questions from participants, who were concerned that the options presented were not realistic. Conjoint analysis does have the potential to create product choices that are not realistic (because product profiles are generated randomly). The directions for how to answer the conjoint analysis questions were updated to make this point clearer.

In addition to improving the clarity of the conjoint analysis directions, a prohibition was added to the conjoint block of questions. Forest certification was used in the questionnaire as a proxy for the *Environmental Performance* attribute, and WPCs are not commonly certified. In response, a prohibition was added so the "WPC" material attribute level did not appear with the "certified" *Environmental Performance* attribute level in the same product profile. Adding prohibitions has negative effects on conjoint analysis survey efficiency by making some attribute levels have higher precision than others, so a design efficiency simulation with 100 hypothetical respondents was run to quantify this impact. The "Strength of Design" is a measurement of D-efficiency, which compares the efficiency of the survey design without prohibitions to the survey design with prohibitions (Table 5). The conjoint analysis design reports also utilize a standard error statistic to reflect precision, where lower errors indicate greater precision (Sawtooth Software, 2016). Sawtooth Software recommends that standard errors within each attribute level should be approximately equivalent and should not be larger than 0.05 (Sawtooth Software, 2016). The standard errors did not change significantly when this prohibition was added to the survey, so it was included (Table 5).

Table 5. Precision of survey design with and without prohibitions represented by standard error.

Attribute Levels	No Prohibitions	Prohibitions
Material		
Naturally Durable Softwoods	0.0708	0.0680
Pressure Treated Lumber	0.0680	0.0678
Tropical Hardwoods	0.0672	0.0679
Wood-Plastic Composite	0.0653	0.0796
Thermally-Modified Wood	0.0657	0.0675
Need for Maintenance		
5 Hours Annually	0.0464	0.0454
10 Hours Annually	0.0469	0.0478
15 Hours Annually	0.0467	0.0474
Durability		
Lasts 5-9 Years	0.0469	0.0466
Lasts 10-14 Years	0.0464	0.0470
Lasts 15-20 Years	0.0468	0.0466
Material Cost		
$4.00/ft.^{2}	0.0470	0.0473
$8.00/ft.^{2}	0.0465	0.0468
$12.00/ft.^{2}	0.0466	0.0460
Environmental Performance		
Certified	0.0324	0.0376
Not Certified	0.0324	0.0376
Strength of Design	433.74	421.19

Feedback from participants included simple changes to questions or wording of answer choices, such as adding the option of “Wholesale/Retail/Distributing” to the question about the type of business participants are involved in. The attribute *Durability* was defined more clearly, as one participant noted this attribute can have different meanings to different people. An explanation for how a set of “drag and drop” questions work was added, as well as broadening the environmental attribute to assess *Environmental Performance* instead of just encompassing environmental certification.

Another change made was altering the *Cost of Materials* attribute levels in the conjoint analysis question block. In the first draft of the questionnaire, the levels for cost were: $2.00/ft.^{2}, $4.00/ft.^{2}, and $8.00/ft.^{2}. These attribute levels were changed to: $4.00/ft.^{2}, $8.00/ft.^{2}, and $12.00/ft.^{2} based on feedback from professionals at the NRRI testing event. They noted that these prices better reflected the current prices ranges offered for decking materials.

Two testing participants noted the questionnaire seemed to be too long to be conducted at a trade show. The amount of time testing event participants took to take the survey is listed in Table 6. The first question of the survey asking “*Do you or your*

company build exterior decks?" was removed because of comments to reduce survey length and to include individuals or companies in the industry who may not be building decks. To make sure the survey did not allow participants who are not a part of the target audience to complete the survey, an additional response choice was added to the first question: "Do not purchase, sell, distribute, design, or work with decking materials." If this option was selected, participants were skipped to the end of the survey. A perception question on the *Overall Quality of Materials* was removed from the survey to reduce length as well.

Table 6. Length of time participants took to take the survey, including time to provide feedback.

Participant Number	Survey Time
10609	21min., 31sec.
10610	21min., 41sec.
10611	18min., 51sec.
10612	12min., 15sec.
10613	27min., 7sec.
10614	31min., 8sec.
Average	22min., 5sec.
Std. Dev.	6min., 33sec.

The final version of the questionnaire was constructed using Sawtooth Software's Lighthouse Studio (Sawtooth Software, 2016) and contained three major sections: demographic information, user perceptions, and conjoint analysis. Major sections, their components, and the measurement scales are shown in Table 7.

Table 7. Major components of the questionnaire.

Section	Component/Attribute	Scale of Measurement
Demographic Information	Type and size of company, location, materials used, and familiarity with TMW	Multiple choice with text entry for "others," constant sum, and ranking
User Perceptions	Need for maintenance, overall cost of materials, durability, aesthetics, availability, and environmental performance	Likert importance scale (e.g., 1 = "Not at all important," 6 = "Extremely important") and Likert scale of attribute content (e.g., 1= "Very difficult to find," 6= "Easy to find")
Conjoint Analysis	Material, need for maintenance, durability, material cost, environmental certification	CBC random task

The first section of the questionnaire consisted of seven general demographic questions about the type and size of company that participants work for, the type of

business they are involved in, which regions of the country their company operates in, the types of materials used for decking projects, and familiarity with TMW and forest certification.

The second section consisted of questions concerning user perceptions of how well the five materials performed for six attributes (*Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*). The first three questions in this section included ranking deck projects of different price ranges to determine what price points different decking materials are generally used at. The next question in this section inquired about the importance of each attribute being considered, then the questions following it sought to determine perceptions on how well the five decking materials performed for each attribute.

The third section of the questionnaire consisted of a choice-based conjoint analysis (CBC) exercise with 12 random tasks comprised of 4 concepts per task and a "None" option using five slightly different attributes (*Material*, *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification*). The exercise randomly selected questionnaires from 300 possible versions. Respondents were presented with four decking product concepts and a "None" option for participants who did not prefer any of the options (Figure 5) and were instructed to select the product they would be most likely to purchase. These product concepts were combinations of different attribute levels included in earlier sections of the questionnaire.

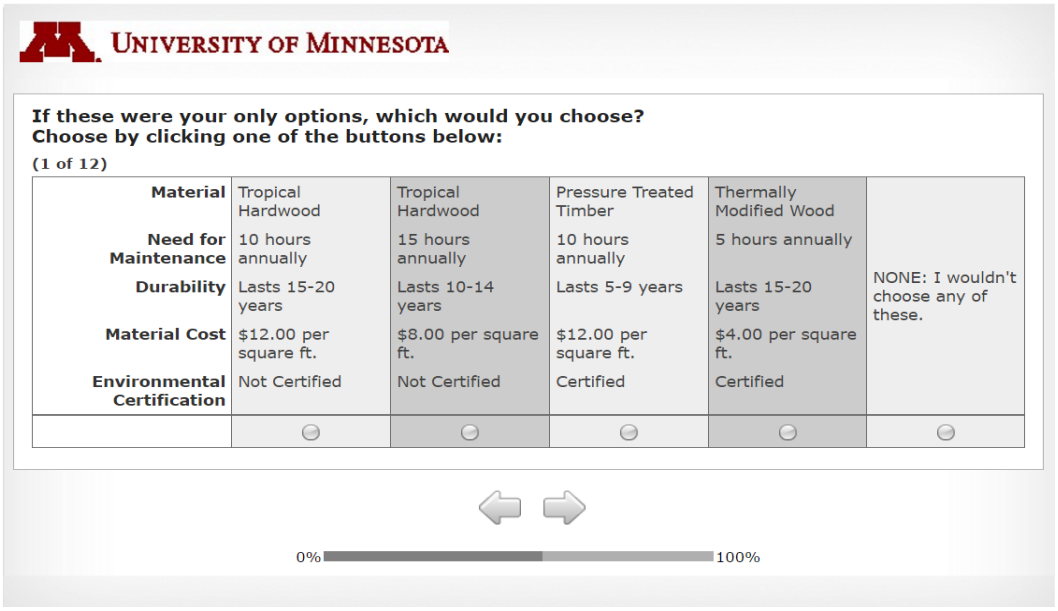

Figure 5. Example of potential question from the conjoint analysis section of the questionnaire.

Choice-based conjoint (CBC) was the type of conjoint analysis selected for this study because it best simulates the real purchasing decisions consumers make by asking respondents to choose product concepts instead of rating or ranking them (Orme, 2010). CBC exercises are flexible in their design, allow for measuring a “None” alternative, and are easier and more accurate for respondents to answer than a traditional ranking-style conjoint analysis questions (SawtoothSoftware, 2015). The entire questionnaire can be found in Appendix 1.

Sample Development

Product samples of TMW exterior decking and other competing wood-based materials were built and received thermal treatment at the Natural Resources Research Institute, Duluth, Minnesota, to use during the in-person Deck Expo data collection. The rationale for why certain materials were chosen for the deck samples is provided below.

Thermally-modified wood (TMW)

Aspen (*Populus tremuloides*) and ash (*Fraxinus spp.*) are both common species and are potential candidates for TMW. Aspen is the most abundant tree species in Minnesota, where the closure of paper and panel mills has left this resource largely underutilized (Ware, 2013). Billions of ash trees are currently threatened by the emerald ash borer (Jae-Woo, Matuana, & McCullough, 2005) and this invasive species has already killed tens of millions of ash trees in the Midwest. For these reasons, both species are viable sources for TMW applications.

Alkaline copper quaternary (ACQ) pressure treated Southern pine

Pressure treated Southern pine (*Pinus spp.*) is used throughout the U.S. for exterior decking applications. In 2010, these pressure treated wood products accounted for 58% of the exterior decking market (Ganguly et al., 2010).

Imported tropical hardwood

For this project, ipe (*Tabebuia impetiginosa*) was utilized to represent the tropical hardwoods section of the market. It is a popular, naturally durable tropical species for decking that accounted for 2-3% of decking applications in 2010 (Ganguly et al., 2010).

Naturally durable softwood

Western red cedar (*Thuja plicata*) is a naturally durable domestic tree species used to represent this section of the market. Naturally durable softwoods accounted for 12% of the decking market in 2010 (Ganguly et al., 2010).

Wood-plastic composite (WPC)

Producers claim WPCs, which are composed of wood fiber and plastic, require less maintenance than solid wood decking and they have successfully marketed the product as environmentally friendly. WPCs rapidly became popular in the 1990's, attaining 25% of the exterior decking market share by 2010 (Ganguly et al., 2010).

Six deck samples were built using the materials listed above at the NRRI in Duluth, Minnesota. The initial test deck was built to dimensions of 24" long, 24" wide, and 10" high with visible fasteners. After some research team discussion, a few changes were made, and the final deck samples were built to dimensions of 32" long, 24" wide, and 5.25" high, with non-visible fasteners. Images of the final deck sample design are shown in Figure 6.

Figure 6. Final deck sample design top and side views.

Data Collection

The data collection was conducted at an industry-focused trade show called the "Deck Expo" in Baltimore, Maryland on October 5th-7th, 2016 ("Remodeling Show, Deck Expo, JLC Live," 2016), where attendees included residential construction professionals, professional deck builders, railing professionals, remodelers, general contractors, and other specialty contractors. A booth was reserved at the show and attendees were asked

to observe the six decking samples of different materials, then complete the questionnaire using a laptop computer to record answers. Participants were asked to rank, rate, or choose from the five different decking products, including TMW, according to their preferences on the following attributes: *Need for Maintenance, Overall Cost of Materials, Durability, Aesthetics, Availability, and Environmental Performance*. A total of 63 questionnaire responses were completed at the show. Two responses were deleted and considered incomplete because the respondents only answered the demographic questions before dropping out of the survey, leaving a total of 61 complete responses for analysis.

The booth set up included three laptops and the deck samples prominently in front, so Deck Expo attendees could see and evaluate the samples when they approached the booth (Figure 7). Most participants approached the booth curious about what a university was doing at a trade show. They were then shown the deck samples, and the project objectives were described while avoiding statements that could bias their responses. Attendees were then invited to participate in the survey. Most participants did not have questions while taking the survey, but usually asked more about the project after they were finished. The average response time was approximately 11 minutes among attendees who participated in the survey. As additional incentive, the chance to win a $200 gift card was offered to participants.

Figure 7. Booth setup at the Deck Expo.

After the initial data collection at the Deck Expo, 42 additional complete responses were collected online from November 11th to December 20th, 2016, using the same questionnaire. The survey was distributed via a link in an article featured in *Professional Deck Builder* magazine (Wormer, 2016). Added to the responses obtained at the Deck Expo, a total of 103 responses were collected.

Data Analysis

To achieve the desired precision at a 95% confidence interval, at least 96 responses needed to be collected (Rea, 2005). Basic analysis techniques included descriptive statistics such as averages, standard deviations, and counts; and inferential statistics to test for significant associations between demographics and responses. The descriptive and inferential statistical analyses were completed using Microsoft Excel.

Conjoint Analysis

For this project, Deck Expo and Online participants were presented with a block of choice-based conjoint (CBC) analysis questions. By understanding the relative importance professional consumers placed on various product attributes, information was gathered about design and potential improvements of TMW to maximize consumer value and market share. The final expected outcome was to better understand the trade-offs professional consumers make among different product attributes, especially those that are influential to TMW's market viability.

CBC analysis in Lighthouse Studio (Sawtooth Software, 2016) processed the information collected using a statistical model to estimate utility functions of each decking attribute level. Utility functions were scaled to sum to zero within each attribute and demonstrated the perceived value of each feature, as well as how sensitive consumer perceptions are to changes of that feature (Orme, 2010). While the theory behind these statistical methods is easy to understand, they are highly sophisticated in practice, so Sawtooth Software was used to perform the analysis.

Marketing Strategy for the U.S. TMW Industry

The final output of this project was a Strategic Marketing Plan for the U.S. TMW industry to utilize effective marketing for their exterior decking products based on customer perceptions. The marketing strategy included:

- Positioning Strategy: Identified the most effective messaging for potential customers, including the most effective promotion and advertising media. By emphasizing the distinguishing features of TMW, the industry may occupy a distinct segment of the market related to other materials in the customers' mind.
- Product Strategy: Consumer perceptions of TMW exterior decking products relative to competing products, as well as customer's quality requirements for TMW. By understanding these product requirements, producers can incorporate these perceptions into product specifications and create an execution plan for further development of TMW.
- Price Strategy: Current consumer perceptions of TMW prices, and how the product should be positioned to reflect these prices. By understanding TMW is a high-end material that will likely capture a niche market share of consumer who are not price-sensitive, producers can target this group.
- Promotion Strategy: The methods and tools used to display TMW information to customers in a way that convinces them to purchase the product. Demonstrated the most effective ways of promoting TMW, including advertising, sales, publicity, and marketing.
- Distribution Strategy: The channel(s) of distribution through which potential customers may be reached. May include various individuals or organizations between a TMW producer and customer. By realizing the best routes to channel a product, the TMW industry may save both time and money.

Limitations

There are limitations to the methods and results from this study. Survey participants from the Deck Expo were asked to complete the survey or approached the booth and volunteered to participate in the study. This led to self-selection bias, a lack of randomization, and did not allow for an understanding of non-response demographics; thus, potential differences may exist between the sample and the population. Collecting

data at the Deck Expo may also had led to a bias resulting from the type of professional who attends this event. Attendees to the expo may have had an inclination for a particular material or materials that were present at the event and therefore differed from the population of interest. The location of the Deck Expo event (Baltimore, Maryland) may have also introduced a location bias to the results. The Online data collection was limited to readers of *Professional Deck Builder*, which, despite having a significant readership may not accurately represent the population of interest. The small number of participants to the Deck Expo and Online surveys make generalizations to the population of interest impossible. However, the author believes that the insights from this study are nevertheless useful to increase the understanding of professional adopter's perceptions and attitudes, and for marketing strategy formulation.

CHAPTER 3. RESULTS AND DISCUSSION

In the data collection phase of this research project, two surveys were conducted: one in-person survey at an industry-focused trade show called the “Deck Expo,” and an online survey, advertised through *Professional Deck Builder* magazine. In this chapter, a summary and analysis of the responses from the two surveys are presented. The analysis presented here was a major input for the formulation of marketing strategies for the thermally-modified wood industry sector, discussed in detail in the next chapter.

Response Analysis

In-Person Survey

The first survey was conducted in-person during a trade show called the “Deck Expo” in Baltimore, Maryland on October 6th and 7th, 2016 ("Remodeling Show, Deck Expo, JLC Live," 2016). Attendees included residential construction professionals, professional deck builders, railing professionals, remodelers, general contractors, and other specialty contractors. A booth was contracted at the show and attendees were invited to observe the six decking samples made of different materials, then complete a questionnaire using a laptop computer to record answers. In total, 63 responses were collected, but only 61 were included in the analysis because two respondents did not complete the survey and only recorded demographic information before dropping out. The average amount of time Deck Expo respondents took to complete the survey was 10 minutes and 50 seconds.

Online Survey

The survey was also conducted online through a link posted in an article published on *Professional Deck Builder* magazine’s website (Wormer, 2016) from November 11th to December 20th, 2016. According to the magazine’s website, it “provides deck builders with news and information on decks and outdoor living spaces,

including decking, railing, construction, safety, hardware, hardscape, porches, pergolas, and more." The *Professional Deck Builder* audience is comprised of industry members who are "engaged in the building, design, or sale or decks and deck products," according to the Editor, Andrew Wormer. The magazine's circulation is around 18,000, with 81% of its readership working as independent contractors or for companies comprised of less than five employees (*Professional Deck Builder*, 2013). Two additional reminders to complete the survey were sent out using a newsletter from the same magazine. In total, 70 responses were collected from the online survey, but only 42 were included in the analysis, as 27 responses were considered incomplete. In addition, one respondent noted they were a "homeowner" and did not work with decks as their occupation, and thus their response was dropped from the survey. The average amount of time Online respondents took to complete the survey was 16 minutes, 30 seconds.

Demographics

The first section of the questionnaire included seven demographic questions on profession, location and size of company, as well as an inquiry on prior experience with the products being considered. Another demographic question after the perceptions section of the survey asked respondents about their familiarity with forest certification. See Appendix 1 for a complete copy of the questionnaire used.

The first question in this section of the survey was "*How would you describe you or your company? Select all that apply. Multiple responses allowed*." It was a multiple-choice entry question, with text entry available for participants who selected the "Other" category. Deck Expo respondents reported "Remodeling" (29.5% of respondents) and "Deck Specialist" (23.0%) as the top two areas of businesses for their companies (Figure 8). Online respondents stated the same top two specialty areas of business, with 42.9% of respondents reporting being a "Deck Specialist" and 35.7% in the "Remodeling" business. In addition, "New Construction" was a considerably higher specialty area for Online respondents (21.4%) compared to Deck Expo respondents (8.2%). The "Other" category for Deck Expo respondents included specialties and professions in: consulting, marketing, trade associations, chemical additives, sales, and exterior replacement. Online respondents who reported in the "Other" category included specialties and professions in: consulting, deck waterproofing, a trade association, and a government

agency. A Chi-square test found no significant differences between professions reported by Deck Expo and Online respondents (χ^2=10.34, *p-value*=0.111).

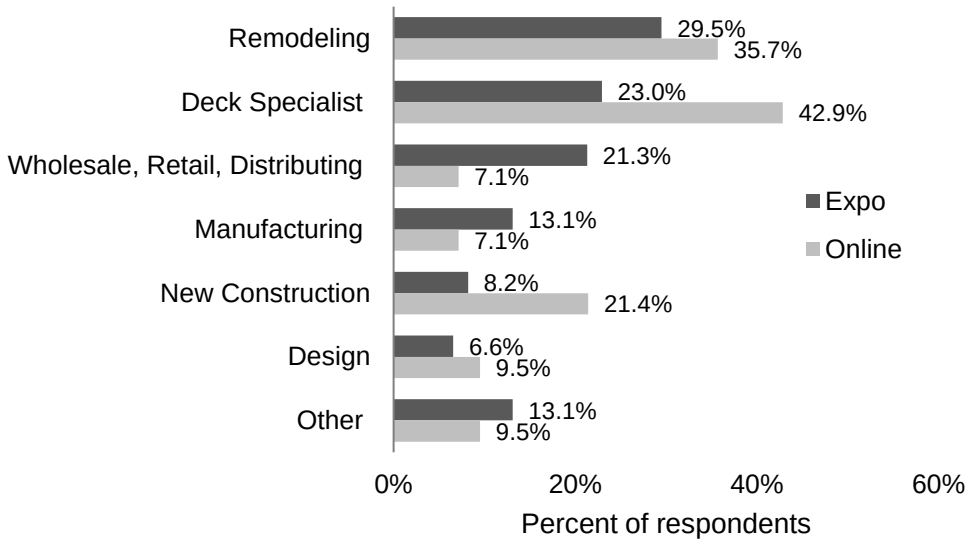

Figure 8. Type of profession reported by Deck Expo and Online respondents. Multiple responses were allowed.

The second question in the demographics section of the survey was "*Which of the following best describes the size of your company?*" This was a multiple-choice entry question with various numbers of employee options available to choose from. Firm size for Deck Expo respondents was more evenly distributed than Online respondents, with the latter heavily concentrated in smaller companies, as Figure 9 shows. While the highest percentage of Deck Expo respondents work for companies with 1-4 employees (31%), followed by companies with 20-49 employees (24.6%) (Figure 9), a substantial percentage (66.7%) of Online respondents reported working for companies with 1-4 employees, with the next closest employee range being 5-9 at 11.9% (Figure 9). This confirms information about the readership of the magazine where the link to the survey was posted (see the Response Analysis section earlier in this chapter). A Chi-square test exposed a significant difference in firm sizes reported by Deck Expo and Online respondents (χ^2=16.313, *p-value*<0.001).

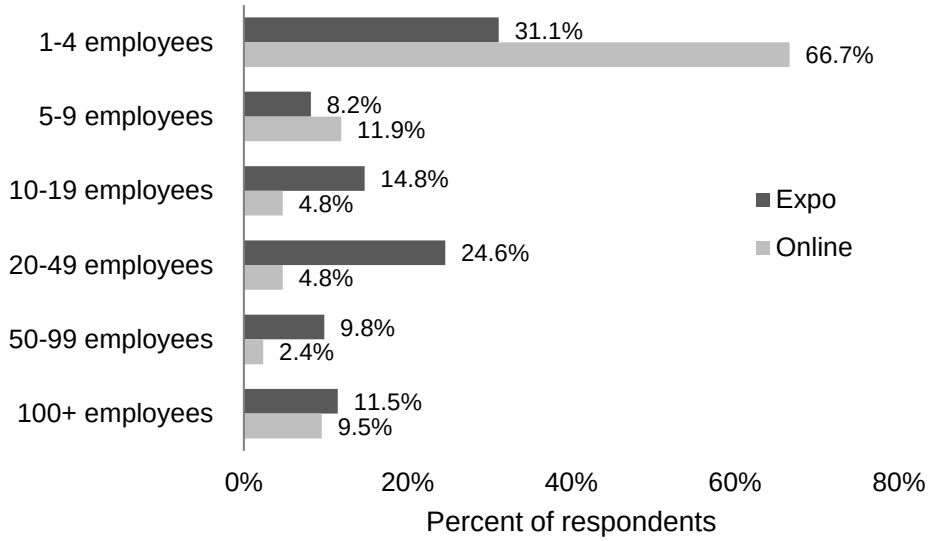

Figure 9. Size of company reported by Deck Expo and Online survey respondents.

The third question in the demographics section of the survey was "*What percent of your company's business is distributed within the following categories? Multiple responses allowed*." This was a constant sum-rating question where respondents had to determine the percentage of their company's total annual business for different areas of the construction industry. The question had a built-in check to ensure percentages entered by respondents added up to 100%. Table 8 summarizes the answers to this question and an explanation on how these figures were calculated follows. An "overall average" was calculated by averaging the percent of business reported by all respondents in a category, including those reporting no percent of their business in that category. A "specific average" was calculated by averaging the responses for those participants with some of their business in a given category (higher than 0%). The largest number of companies for both the Deck Expo and Online surveys reported being in "Repair and Remodeling" (78.7% and 85.7% of Deck Expo and Online participants reporting some of their business in this category, respectively), and "Single-family New Construction" (67.2% Deck Expo and 64.3% Online). The percent of the participants' business in most categories were comparable, and a t-test revealed significant differences only for commercial projects (*p-value*=0.02), with Deck Expo participants indicating a larger percent of their business in this area. Deck Expo responses from the "Other" option included business in: consulting, marketing, exterior replacement, trade

association, chemical additives, sales, and independent manufacturer's representative. Online respondents choosing the "Other" category included business in: outdoor spaces, fencing, pergolas, manufacturing, and consulting and inspections.

Table 8. Percent of respondents' business in different construction segments. Multiple responses were allowed. Asterisks denote significant differences (t-test).

Business Segment	Count and Percent		Overall Average		Specific Average	
	Deck	Online	Deck	Online	Deck	Online
Repair & Remodeling	48 (78.7%)	36 (85.7%)	47.5%	49.4%	60.3%	57.6%
Single-family	41 (67.2%)	27 (64.3%)	28.2%	29.8%	42.0%	46.4%
Multi-family	18 (29.5%)	10 (23.8%)	3.7%	2.9%	12.4%	12.1%
Commercial	26 (42.6%)	13 (31.0%)	8.7%*	2.9%*	20.3%	9.5%*
Institutional	8 (13.1%)	7 (16.7%)	2.2%	8.5%	17.1%	50.7%
Other	8 (13.1%)	5 (11.9%)	9.8%	6.5%	74.4%	55.0%

The fourth question in the demographics section of the survey was "*In which of the following regions does your company operate? (Select all that apply).*" This was a multiple-choice entry question in which multiple responses were allowed and a text entry box was included for respondents who selected the "Other" category. The response options encompassed four main regions of the U.S., with an "Other" category for international businesses (Figure 10). Responses suggest an over-representation of companies operating in the Northeast among Deck Expo respondents (62.3% of respondents reported having operations in this region, Figure 11). Online respondents reported a more even distribution of business location, which can be explained by the nationwide reach of the online Professional Deck Builder magazine where the survey was advertised. When Deck Expo respondents selected multiple locations, two indicated their businesses operated in the Midwest, Northeast, and South, and three indicated their businesses operated in the Midwest and Northeast, Midwest and South, and Northeast and South, respectively. Eleven respondents reported operations in all four regions. In contrast, only six Online respondents reported business operations in more than one region of the U.S., four of which selected all regions. The other two respondents reported operating in the Northeast and West, and Midwest and South, respectively. Deck Expo respondents who selected "Other" reported operations in: Canada, Europe, Australia, "international," and "global." Responses for "Other" from Online respondents included: Canada and "international." A Chi-square test found no

significant differences between company locations reported by Deck Expo and Online respondents (χ^2=5.649, *p-value*=0.227).

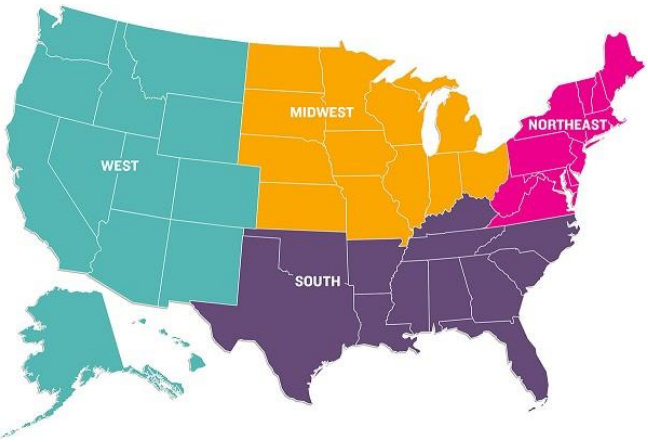

Figure 10. Regional map used to determine the location of Deck Expo and Online respondent's companies.

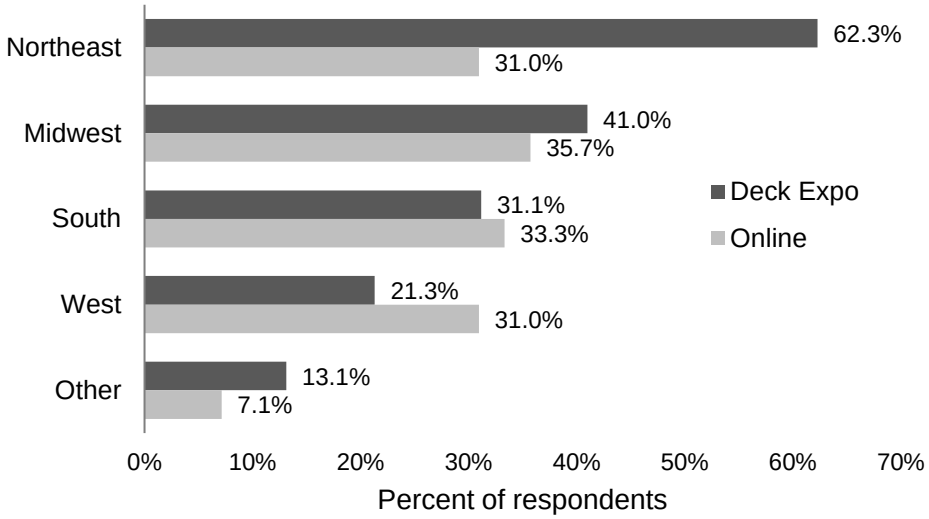

Figure 11. Geographical distribution of Deck Expo and Online respondents. Multiple responses were allowed.

The fifth question in the demographics section of the survey was "*How familiar are you with Thermally-Modified Wood?*" This was a multiple-choice entry question with only one answer allowed. If respondents selected "Very familiar" or "Somewhat familiar," they were directed to the next question. If respondents selected "Not very familiar" or "Haven't heard about it," they were sent to a "TMW Primer" (Appendix 1), which provided

basic information on TMW performance and applications. This was done so all respondents would be able to answer questions about their perceptions of TMW attribute performance. Respondents from both data collection sets answered this question analogously, indicating the industry has a similar familiarity with TMW. For Deck Expo respondents, 64% indicated they are “Very familiar” or “Somewhat familiar” with TMW, while 62% of Online respondents indicated being “Very familiar” or “Somewhat familiar” with the treatment (Figure 12). However, a considerable number of respondents reported little or no familiarity with TMW (36.1% and 38.1% for Deck Expo and Online respondents, respectively), which suggests an opportunity for educating and informing this professional audience about TMW. A Chi-square test found no significant differences between familiarity with TMW among Deck Expo and Online respondents (χ^2=0.939, *p-value*=0.816).

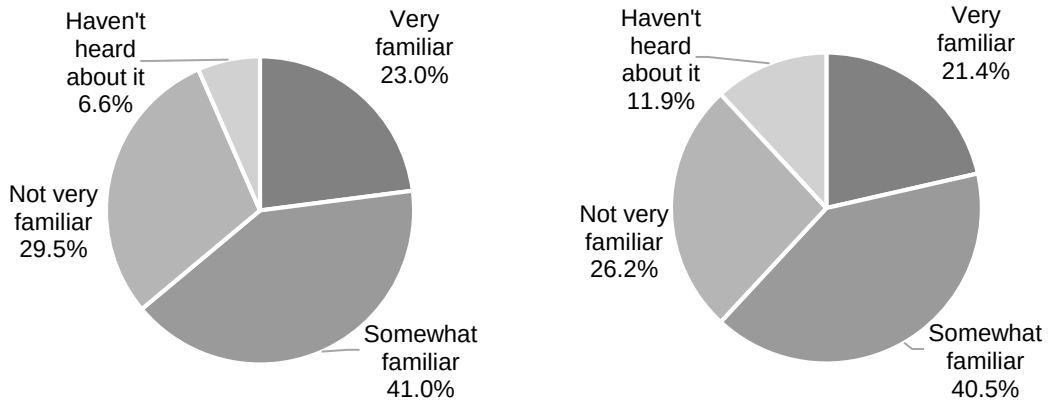

Figure 12. Deck Expo (left) and Online (right) respondents reported level of familiarity with TMW.

The sixth question in the demographics section of the survey was “*What percent of your company’s decking projects utilize the following as major materials? Multiple responses allowed.*” This was a constant sum-rating question where respondents had to determine the percentage of their company’s projects that use each material listed. This question had a built-in check to ensure percentages entered by respondents added up to 100%. Responses were analyzed by calculating an “overall average,” including companies that reporting 0% of their projects using a given material; and a “specific average” which only included companies reporting some of their projects using a given material. Results are summarized in Table 9.

Table 9. Percent of projects using different decking materials, as reported by respondents. Asterisks denote significant differences (t-test).

Decking Material	Count and Percent		Overall Average		Specific Average	
	Deck	Online	Deck	Online	Deck	Online
WPC	47 (77.0%)	32 (76.2%)	43.2%	32.2%	56.1%*	42.2%*
Pressure Treated	30 (49.2%)	26 (61.9%)	17.7%*	31.6%*	35.9%	51.0%
Naturally Durable	20 (32.8%)	23 (54.8%)	6.7%*	15.9%*	20.5%	29.1%
Tropical Hardwoods	26 (42.6%)	15 (35.7%)	12.2%	9.1%	28.6%	25.5%
Plastic	19 (31.1%)	11 (26.2%)	11.4%	7.6%	36.7%	29.0%
TMW	5 (8.2%)	0 (0.0%)	3.9%	0.0%	47.2%	0.0%
Other	3 (4.9%)	2 (4.8%)	4.9%	3.6%	100.0%	75.0%

In general, respondents utilized a wide range of decking materials for their projects (Table 9). The top two materials used in both Deck Expo and Online respondents' projects are WPCs and pressure treated lumber. However, Deck Expo respondents reported a larger percentage of their projects using WPCs than Online respondents, while the latter indicated a higher percent of their projects using pressure treated lumber; and this was consistent for both overall and specific averages (Table 9). This difference may be explained by the fact that a substantial number of the exhibitors at the Deck Expo were representing WPC products, so these participants may use WPC products to a higher degree than Online respondents. Considerable differences can also be seen in the percent of projects using naturally durable softwoods, which Online respondents seem to be using to a higher extent (Table 9). A t-test was run to identify significant differences between the two groups of respondents. For overall average, results showed significant differences in responses for pressure treated lumber and naturally durable softwoods (*p-value* of 0.03 and 0.03, respectively). For the specific averages, a significant difference was found for WPCs between the two groups (*p-value*=0.04), and although there was no significant difference for pressure treated lumber, it was very close to the cutoff value of 0.05 (*p-value*=0.07). Only 5 out of 61 Deck Expo respondents reported at least some of their projects use TMW; however, these participants indicated that, on average, 47.2% of their projects use this material. No Online respondents indicated using TMW for their decking projects (Table 9). Responses in the "Other" category for Deck Expo respondents included: vinyl and acetylated wood; and for Online respondents included: waterproof decking (i.e. solid surface), and hybrid bamboo.

The seventh demographics question in the survey was "*Are you familiar with forest certification?*" This was a YES/NO question. If respondents indicated they were familiar with forest certification, they skipped to the conjoint analysis section of the survey. If respondents indicated they were not familiar with forest certification, they were sent to a "Forest Certification Primer," (Appendix 1) providing information on what forest certification is and the two prominent forest certification systems used in the U.S. This question was included so respondents could have the information they needed to respond accurately to conjoint analysis questions using forest certification as an indicator of *Environmental Performance*. Roughly half of Deck Expo respondents (54%) indicated being familiar with forest certification, while slightly more Online respondents (62%) indicated familiarity (Table 10). A Chi-square test found no significant differences between Deck Expo and Online respondents' familiarity with forest certification (χ^2=0.619, *p-value*=0.431).

Table 10. Respondent familiarity with forest certification.

	Deck Expo	Online
Familiar	54%	62%
Not Familiar	46%	38%

Perceptions

The second section of the questionnaire included 10 questions regarding respondent's perceptions about five wood-based decking materials (pressure treated lumber, naturally durable softwoods, tropical hardwoods, WPC, and TMW) on six attributes (*Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*). The first three questions in this section asked respondents to select their top two material choices for projects at various price points, followed by a question on respondent's perceptions about the importance of each attribute being considered, and a final series of questions asked for their perceptions on how well the five materials perform for each attribute.

The first three questions in the perceptions section asked respondents their preference of decking materials for projects in three different price ranges. The question was "*Please select your TOP TWO choices from the following wood-based decking materials for a project with a total installation cost UNDER $5,000; BETWEEN $5,000*

and $15,000; and EXCEEDING $15,000, by dragging and dropping them into the empty box." These were ranking questions, where respondents were asked to select their top two choices of decking materials based on their perceived suitability for three different project price ranges. Results are summarized in Figure 13 and Figure 14. For "lower-end" projects (under $5,000), both Deck Expo and Online respondents selected pressure treated lumber and naturally durable softwoods as either their first or second choice. For projects at a mid-price range ($5,000 to $15,000), respondents from both surveys showed a preference for WPCs. Lastly, for "higher-end" projects (over $15,000), both Deck Expo and Online respondents exhibited an inclination towards tropical hardwoods, followed by WPCs (Figure 13 and Figure 14). The results also indicated that respondents do not consider TMW to be suitable for projects in the lower price range, but instead consider it more suitable for mid to high-end projects. This may be attributed to a perception that TMW is expensive compared to other materials, or, given the low level of awareness, this may originate from uncertainty about TMW costs. Deck Expo respondents indicated a higher preference for TMW compared to Online respondents, as a higher percent of Deck Expo respondents listed TMW as their first or second choice for all price ranges. A possible reason for this is that people attending the Deck Expo may be more interested in or open to new technologies and materials in general, and attend the Deck Expo to learn about these new trends. None of the materials showed a significant difference for first and second ranked choices between Deck Expo and Online respondents.

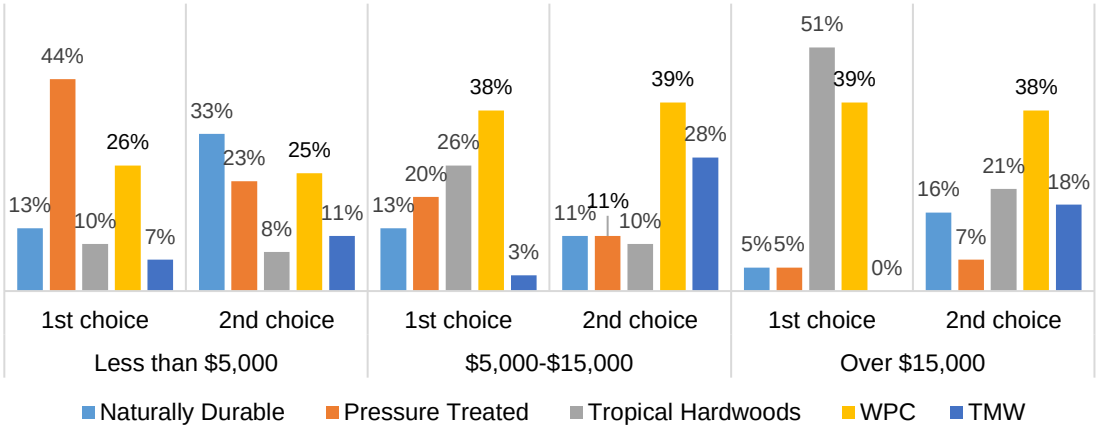

Figure 13. Percent of Deck Expo respondents selecting top two ranked choices for decking projects costing less than $5,000, between $5,000 and $15,000, and over $15,000.

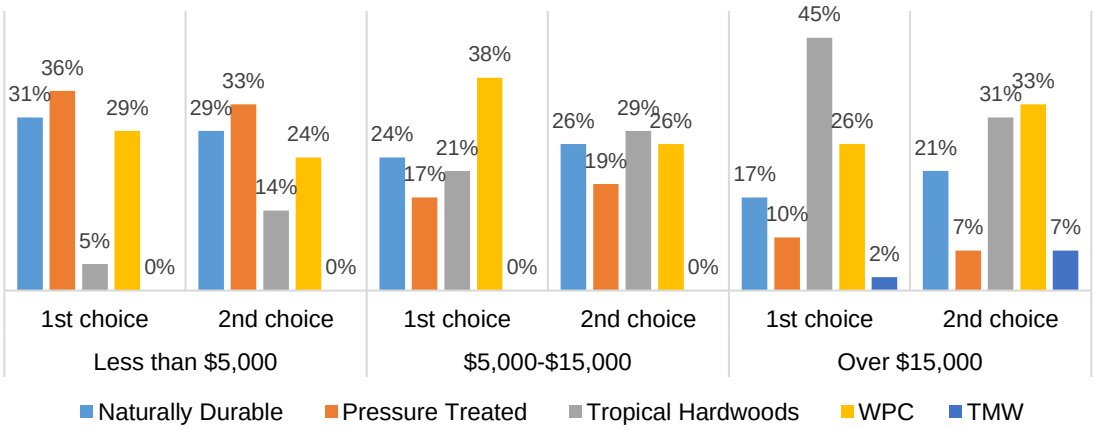

Figure 14. Percent of Online respondents selecting top two ranked choices for decking projects costing less than $5,000, between $5,000 and $15,000, and over $15,000.

The fourth question in the perceptions section of the survey was "*How important are the following material attributes to you when designing, constructing, or remodeling a deck?*" This was a matrix-style question with a Likert scale, where respondents were required to rate the importance of various decking material attributes. A limitation with this type of question is that it assumes participants perceive the difference between any two consecutive points on the scale as the same (for example, the difference between 1 and 2 on the scale is the same as the difference between 2 and 3). This limitation was addressed by providing a description for what each point in the scale represents (e.g., "Not at all important," "Slightly important," "Somewhat important," etc.). Responses to this question are summarized in Figure 15 and Figure 16. Both Deck Expo and Online respondents rated *Durability* and *Aesthetics* as the two most important attributes, with 78.7% of Deck Expo and 85.8% of Online respondents rating *Durability* as "Extremely important" or "Very important" and 82.0% of Deck Expo and 76.2% of Online respondents rating *Aesthetics* as "Extremely important" or "Very important" (Figure 15 and Figure 16). Likewise, respondents in the two groups consistently rated *Need for Maintenance* as the third most important attribute, with 68.6% of Deck Expo and 66.7% of Online respondents rating it as "Extremely important" or "Very important" (Figure 15 and Figure 16). *Environmental Performance* had the lowest importance rating for both groups of respondents, with 34.5% of Deck Expo and 33.3% of Online respondents rating it as "Extremely important" or "Very important" (Figure 15 and Figure 16). These results are consistent with a 2010 study on decking materials, where *Long Life* and *Beautiful and Aesthetically Pleasing* had the highest importance ratings for decking

material attributes (Ganguly et al., 2010). Chi-square tests of each attribute found no significant differences for material attribute importance reported by Deck Expo and Online respondents (*p-values* for all attributes greater than 0.05).

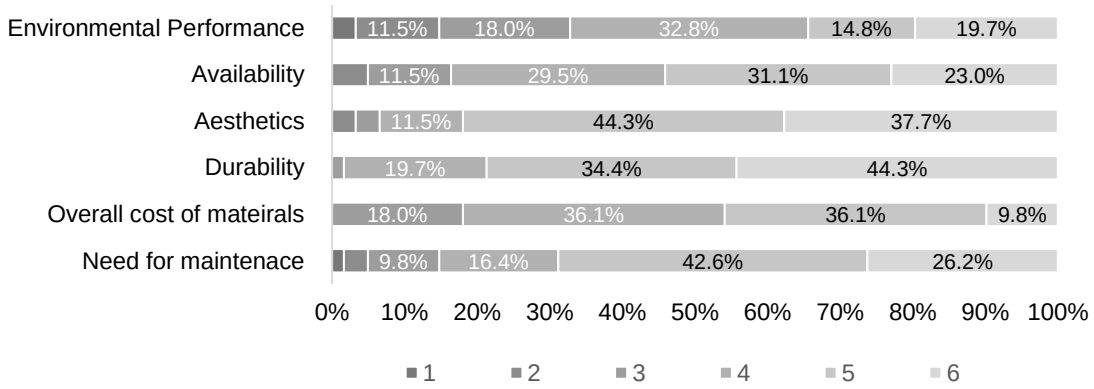

Figure 15. Perceived attribute importance among Deck Expo respondents when designing, constructing, or remodeling a deck, with 1 being “Not at all important” and 6 being “Extremely important.” Percentages lower than 5% are not shown.

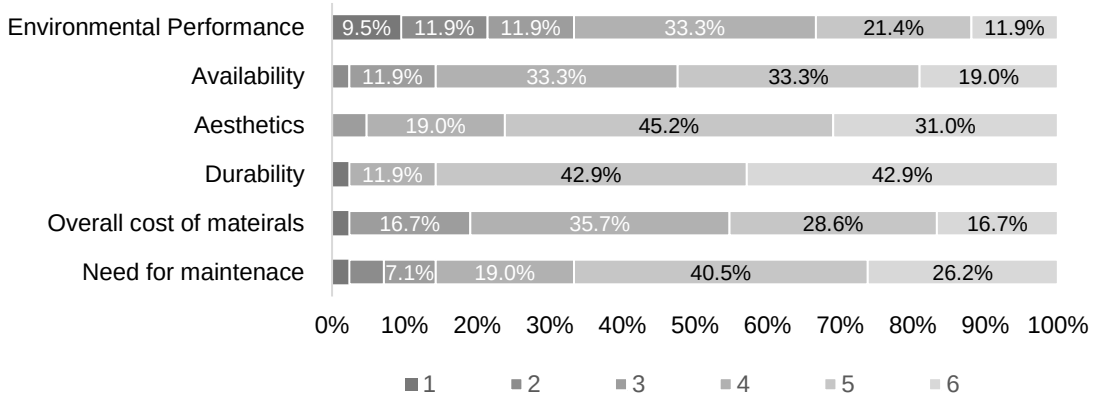

Figure 16. Perceived attribute importance among Online respondents when designing, constructing, or remodeling a deck, with 1 being “Not at all important” and 6 being “Extremely important.” Percentages lower than 5% are not shown.

The next set of questions asked respondents about their perceptions on the performance of six attributes for five wood-based decking materials (pressure treated lumber, naturally durable softwoods, tropical hardwoods, WPCs, and TMW). The scale for these questions included five choices ranging from low to high performance, as well as a “Do not know” option for respondents if they were unfamiliar with any of the materials. A complete listing of the questions used for the survey can be found in Appendix 1. Responses to these questions are summarized in the following paragraphs.

The fifth question in the perceptions section of the survey was "*Please rate the following decking materials on their NEED FOR MAINTENANCE (in hours of maintenance required per year).*" Most respondents from both groups reported they perceive WPCs to have a "Very low" to "Low" need for maintenance, with 87% of Deck Expo respondents and 81% of Online respondents selecting one of these two response categories. In addition, a considerable percentage of respondents from both groups (31% and 57% of Deck Expo and Online respondents, respectively) chose "Do not know" for their perception of TMW's need for maintenance. Chi-square tests of each material found no significant differences between perceptions of *Need for Maintenance* reported by Deck Expo and Online respondents (*p-values* between 0.173 and 0.593).

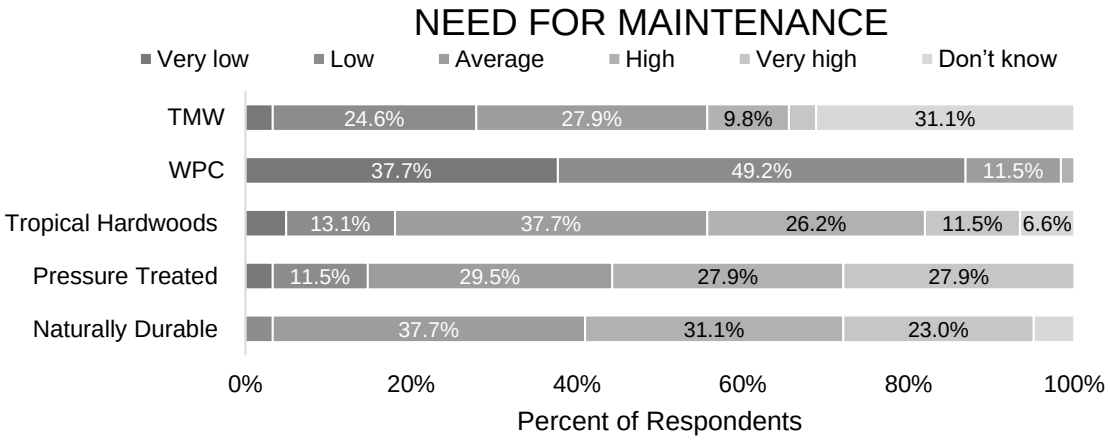

Figure 17. Perceived performance of decking materials on their *Need for Maintenance* among Deck Expo respondents. Percentages lower than 5% are not shown.

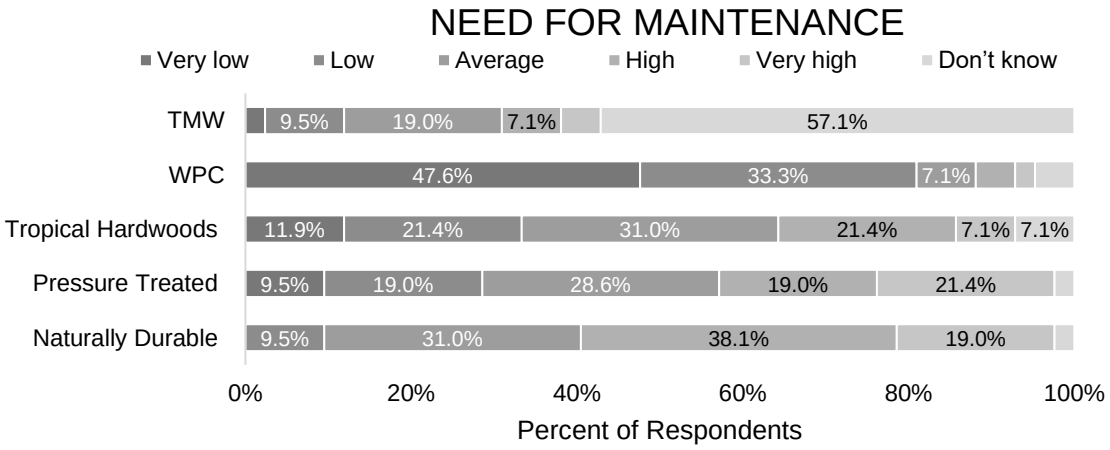

Figure 18. Perceived performance of decking materials on their *Need for Maintenance* among Online respondents. Percentages lower than 5% are not shown.

The sixth question in the perceptions section of the survey was "*Please rate the following decking materials on their OVERALL COST OF MATERIALS (including deck boards, railings, fasteners, etc.*" Pressure treated lumber was ranked highest for this attribute, with 79% of Deck Expo respondents and 69% of Online respondents perceiving it as "Very affordable" or "Affordable." This is consistent with previous studies, where pressure treated lumber was perceived as the lowest costing material option (Ganguly et al., 2010). A relatively high percentage of respondents chose "Do not know" for TMW, namely, 34% and 60% of Deck Expo and Online respondents, respectively. Chi-square tests of each material found no significant differences between perceptions of *Cost of Materials* reported by Deck Expo and Online respondents (*p-values* between 0.126 and 0.785).

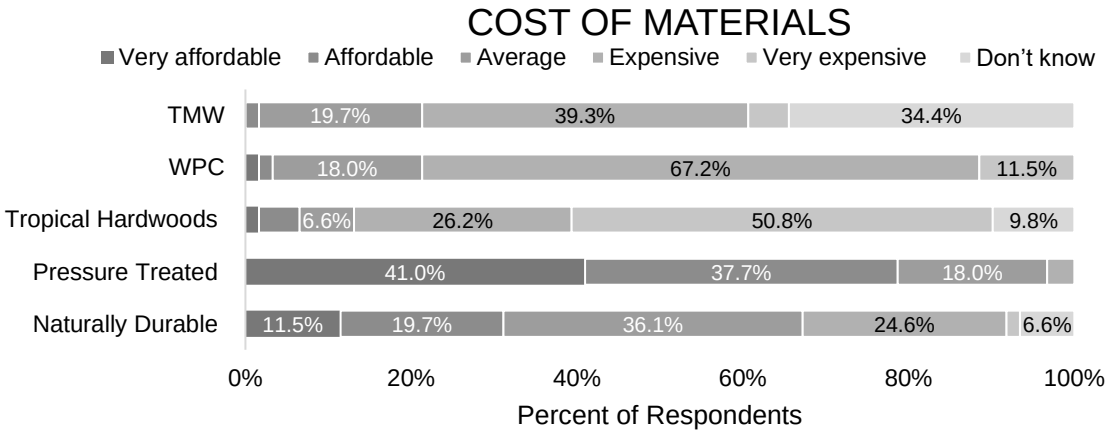

Figure 19. Perceived performance of decking materials on their overall *Cost of Materials* among Deck Expo respondents. Percentages lower than 5% are not shown.

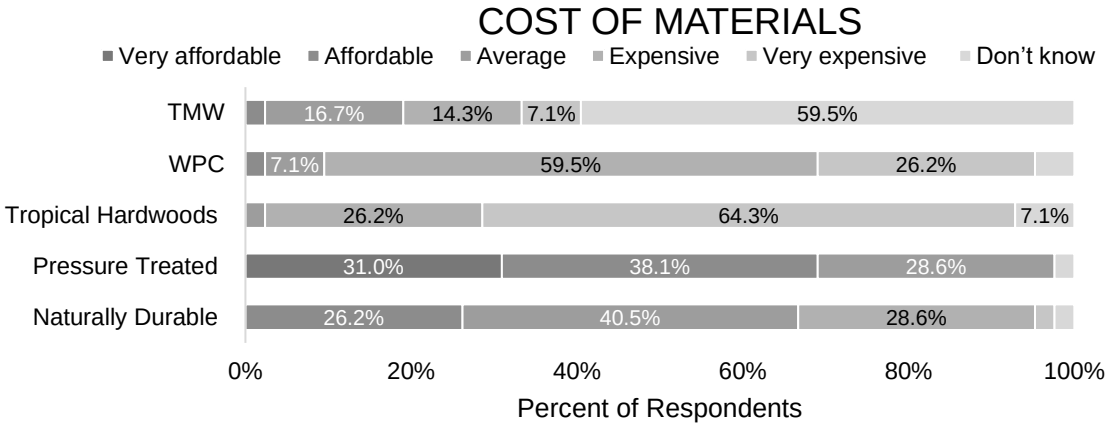

Figure 20. Perceived performance of decking materials on their overall *Cost of Materials* among Online respondents. Percentages lower than 5% are not shown.

The seventh question in the perceptions section of the survey was "*Please rate the following decking materials on their DURABILITY (number of years the deck lasts) based on your experience and perceptions.*" WPCs were rated the most positively for this attribute, with 56% of Deck Expo respondents and 50% of Online respondents rating WPCs as having "Very good" *Durability*. Chi-square tests of each material found no significant differences between perceptions of *Durability* among Deck Expo and Online respondents (*p-values* between 0.331 and 0.936).

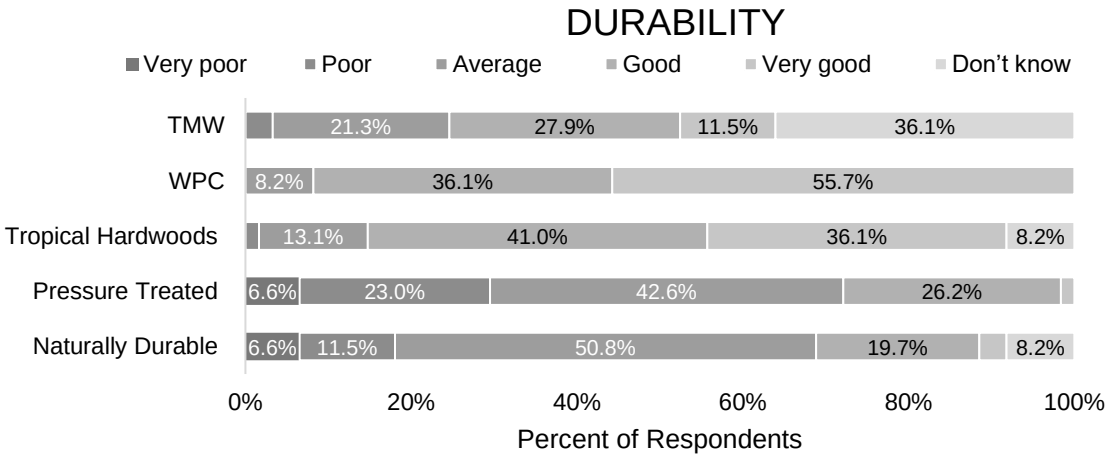

Figure 21. Perceived performance of decking materials on their *Durability* among Deck Expo respondents. Percentages lower than 5% are not shown.

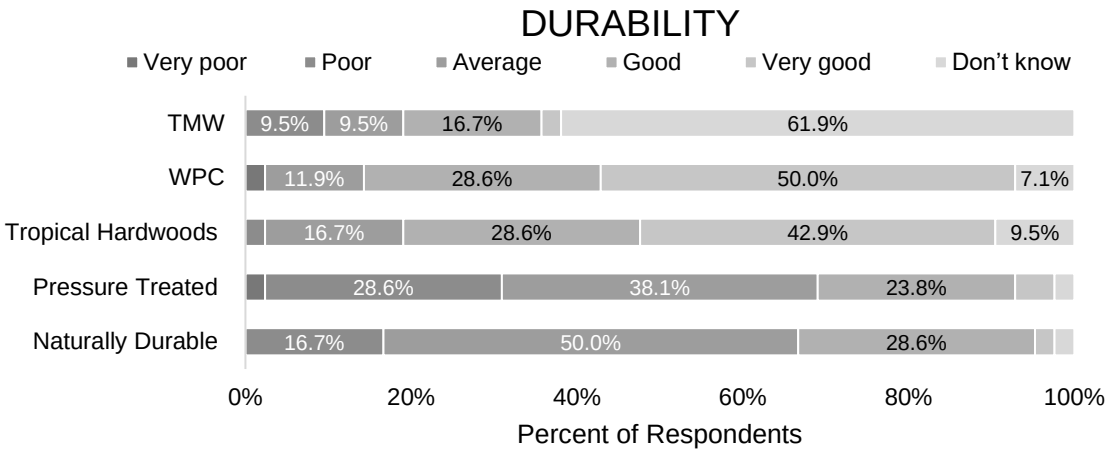

Figure 22. Perceived performance of decking materials on their *Durability* among Online respondents. Percentages lower than 5% are not shown.

The eighth question in the perceptions section of the survey was "*Please rate the following decking materials on their AESTHETICS based on your preferences.*" For this attribute, a lower percentage of Deck Expo respondents (28%) reported "Do not know" for TMW than Online respondents (55%). This can be explained in part by the availability of decking samples presented during the Deck Expo data collection event, which included two samples of TMW, one in aspen and another in ash. Tropical hardwoods were perceived as being the most aesthetically pleasing among both groups, with 62% of Deck Expo respondents and 60% of Online respondents rating them as "Very good" in this category. This is in discrepancy with the findings from a previous study, where naturally durable softwoods were rated higher than tropical hardwoods for aesthetics (Ganguly et al., 2010). Chi-square tests of each material found no significant differences between perceptions of *Aesthetics* reported by Deck Expo and Online respondents (*p-values* between 0.117 and 0.479).

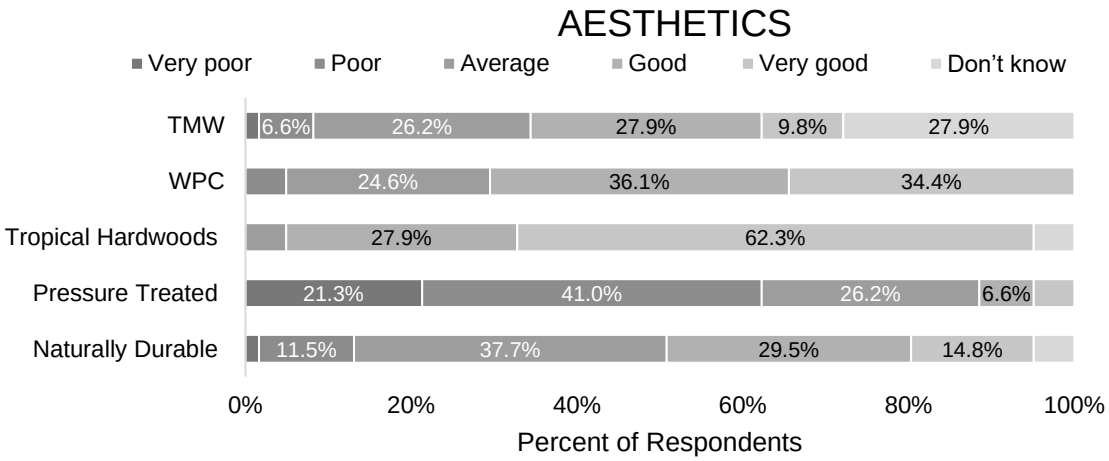

Figure 23. Perceived performance of decking materials on their *Aesthetics* among Deck Expo respondents. Percentages lower than 5% are not shown.

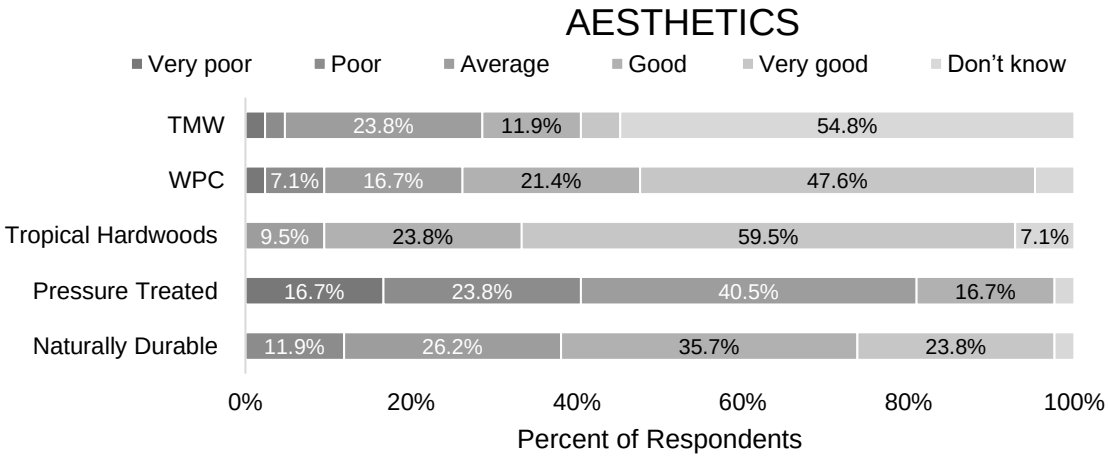

Figure 24. Perceived performance of decking materials on their *Aesthetics* among Online respondents. Percentages lower than 5% are not shown.

The ninth question in the perceptions section of the survey was "*Please rate the following decking materials on their AVAILABILITY (how easy they are to find and purchase).*" Pressure treated lumber was perceived as the easiest to find among both groups of respondents, followed by WPCs. TMW was perceived as "Very difficult to find" or "Difficult to find" among 41% of Deck Expo respondents and 31% of Online respondents. Chi-square tests of each material found no significant differences between perceptions of *Availability* reported by Deck Expo and Online respondents (*p-values* between 0.106 and 0.634).

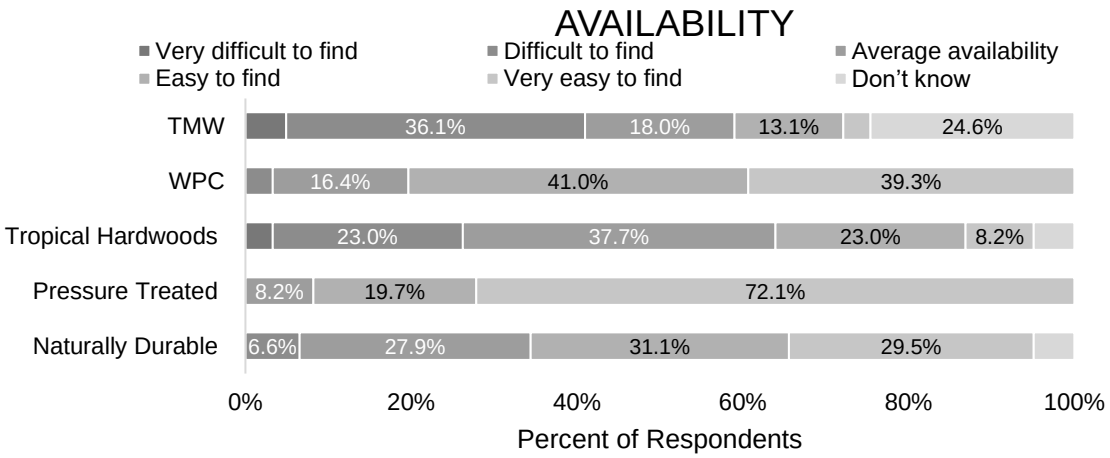

Figure 25. Perceived performance of decking materials on their *Availability* among Deck Expo respondents. Percentages lower than 5% are not shown.

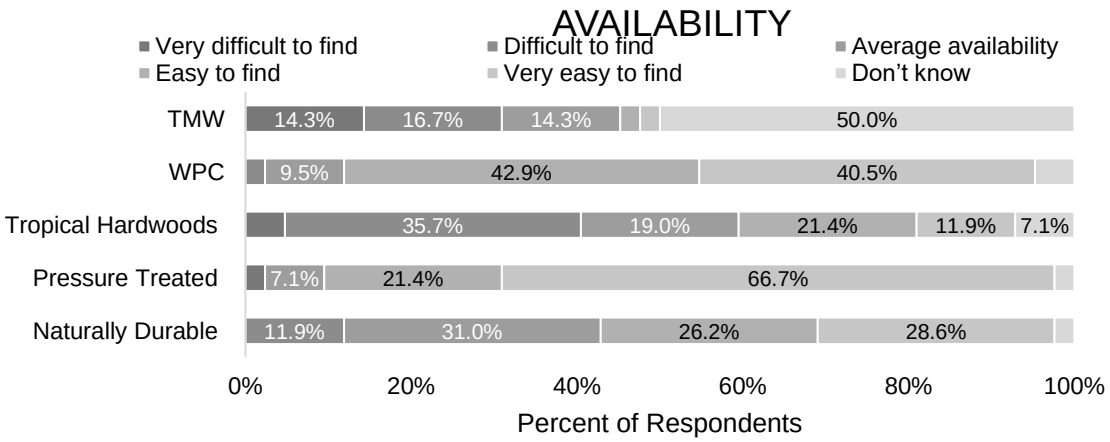

Figure 26. Perceived performance of decking materials on their *Availability* among Online respondents. Percentages lower than 5% are not shown.

The tenth question from the perceptions section of the survey was "*Please rate the performance of the following decking materials on their ENVIRONMENTAL PERFORMANCE based on your knowledge.*" The highest rated material for this attribute among both sets of respondents was WPCs, followed by naturally durable softwoods for Deck Expo respondents and tropical hardwoods for Online respondents. This may be attributed in part to the effective marketing campaign conducted by the WPC industry emphasizing the recycled origin of a proportion of their raw materials, such as "wood waste" and grocery bags (Trex, 2017b). However, life-cycle assessment (LCA) studies comparing WPCs to solid wood decking products show solid wood products have significantly lower environmental impacts (Schwarzkopf & Burnard, 2016).

Less than 5% of Online respondents rated TMW as having “Very good” *Environmental Performance*. This can be explained in part by the low level of awareness (60%) about this material among Online respondents. Chi-square tests showed a significant difference for TMW *Environmental Performance* perceptions between Deck Expo and Online respondents (χ^2=6.808, *p-value*=0.033), while there were no significant differences for any of the other materials (*p-values* between 0.585 and 0.898).

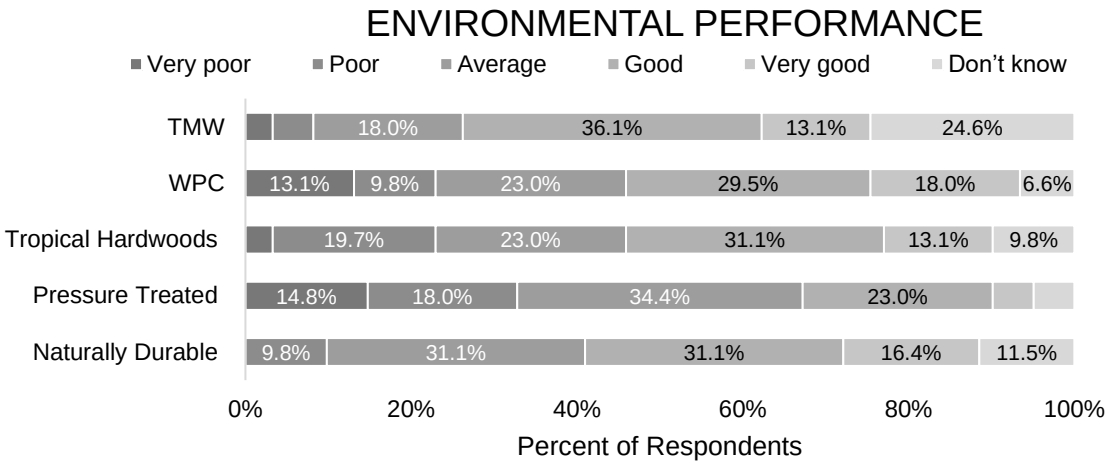

Figure 27. Perceived performance of decking materials on their *Environmental Performance* among Deck Expo respondents. Percentages lower than 5% are not shown.

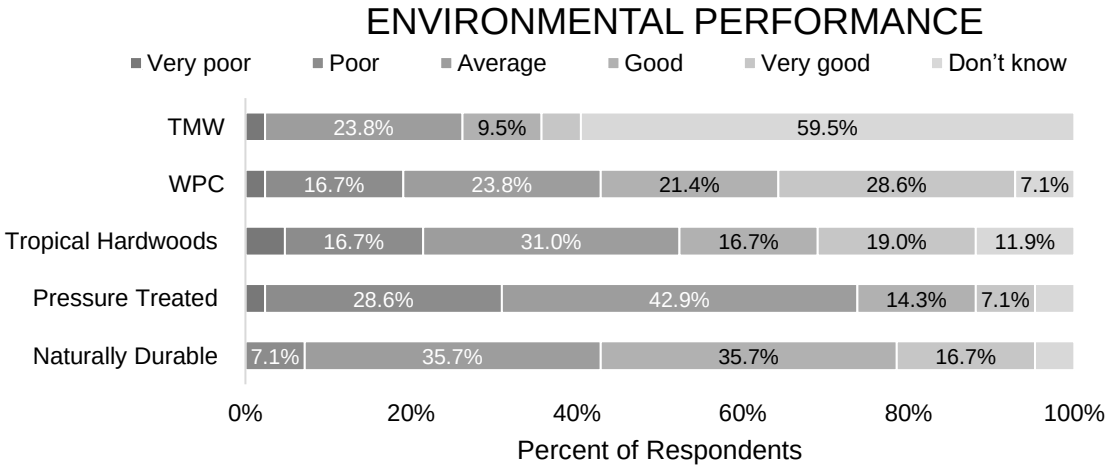

Figure 28. Perceived performance of decking materials on their *Environmental Performance* among Online respondents. Percentages lower than 5% are not shown.

It is important to note that many participants selected “Do not know” for each material’s attributes, but particularly for TMW. A larger proportion of Online respondents

were unfamiliar with TMW than Deck Expo respondents, which may be due to the in-person aspect of the Deck Expo data collection and the availability of the deck samples, including two made of TMW. It is unclear to what degree the perceptions about TMW are accurate, due to an overall lack of knowledge from both groups of respondents.

To make the analysis and interpretation of the perceptions questions simpler, a "perception index" was calculated, as a weighted average of the ratings selected (1 to 5) and the frequencies of responses. Thus, a perception index was calculated for each material, reflecting the respondents' perception of that material on the six attributes being evaluated; with values between 0 (for a negative perception) and 5 (for a positive perception). A limitation with reporting data this way is that the "Do not know" responses cannot be included in the calculation in order to avoid skewing the scales higher for materials respondents are unfamiliar with. However, the perception index can provide insight about how the average respondent viewed each material's attributes. The perception indexes calculated are displayed in Figure 29 and Figure 30. All attributes for the five materials were ranked in nearly the same order by Deck Expo and Online respondents, except *Environmental Performance*, where TMW was perceived as having better performance than the other materials among Deck Expo respondents who were familiar with the material, whereas Online respondents rated TMW's *Environmental Performance* lower than WPCs and naturally durable softwood species (Deck Expo = 3.7 and Online = 3.4). Both groups of respondents viewed TMW's *Availability* as the lowest among all materials and therefore perceived it as the most difficult to find (Deck Expo = 2.7 and Online = 2.2). For *Cost of Materials*, however, TMW was perceived as more affordable when compared with tropical hardwoods and WPCs among both Deck Expo and Online respondents. Except for *Cost of Materials*, WPCs were rated first or second for all attributes, and rated considerably higher for *Need for Maintenance*. Not surprisingly, pressure treated lumber had the highest rating for *Cost of Materials* and *Availability* by both Deck Expo and Online respondents.

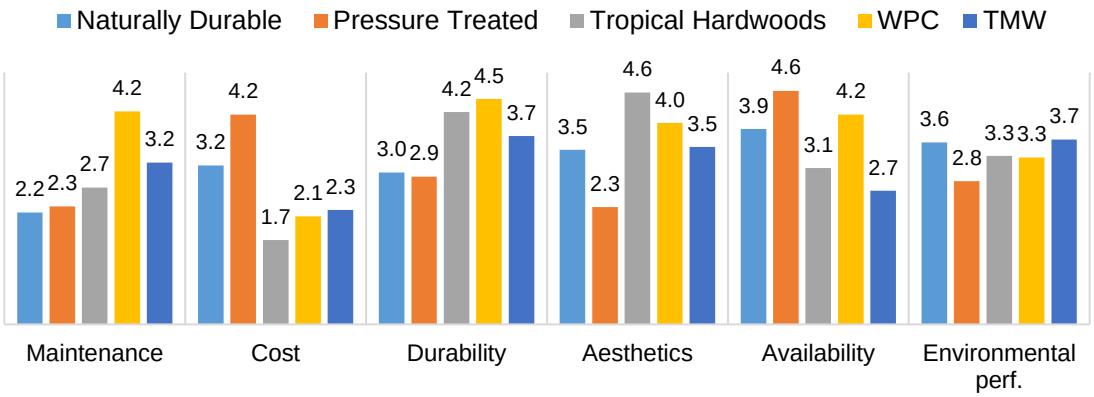

Figure 29. Comparison of perceived material performance among Deck Expo respondents for *Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*, NOT including "Do not know" option.

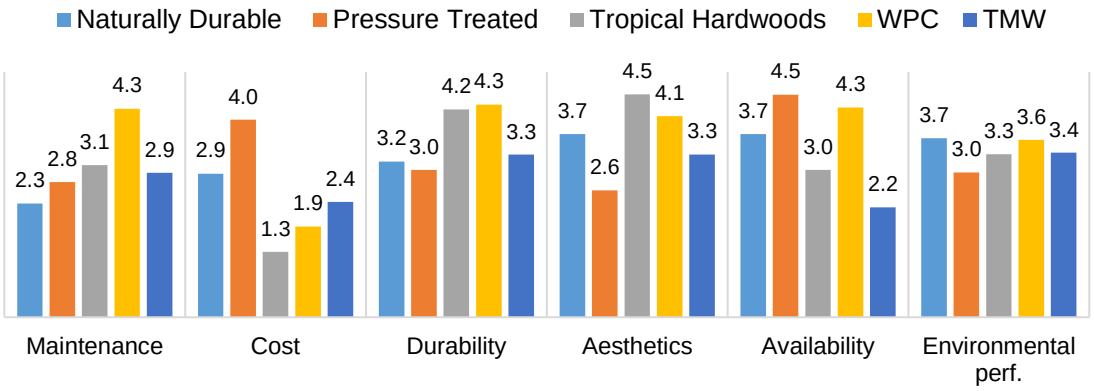

Figure 30. Comparison of perceived material performance among Online respondents for *Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*, NOT including "Do not know" option.

Conjoint Analysis

Conjoint analysis is a marketing technique that allows for an understanding of the relative importance consumers place on various product attributes. Conjoint analysis was included in this project to gather information about industry member's priorities, and to maximize consumer value and market share within the industry. Including a conjoint analysis component also allowed for a better understanding of the trade-offs professional consumers make among different product attributes, especially those that are influential to TMW's market viability. A detailed explanation of conjoint analysis and its associated methods for this study can be found in Chapter 1 and Chapter 2.

A full-profile choice-based conjoint (CBC) analysis block of questions was created for this survey using Lighthouse Studio Software (Sawtooth Software, 2016). The same software was used to analyze the data, which processes the information collected using a statistical model to estimate "utility functions." These utility functions demonstrate the perceived value of each feature, as well as uncover how sensitive consumer perceptions are to changes of those features (Orme, 2010) and for each attribute level.

Conjoint analysis questions present participants with a series of product alternatives and prompts them to select the product they would purchase if those were their only options. A "None" option is usually provided for participants who would not select any of the product alternatives available. The CBC section in this study included 12 random task questions with four product concepts per question, including the "None" option. The product concepts were comprised of five attributes (*Material*, *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification*), with a different number of levels for each attribute (Table 11). An example of a CBC question is shown in Figure 31. In total, Sawtooth Software generated 300 different versions of the CBC section and one of these versions was randomly shown to each survey participant. Appendix 1 includes a printout of the full questionnaire, including the conjoint section.

Table 11. Attributes and attribute levels for the conjoint analysis questions.

Attribute	**Levels**
Material	Naturally durable, Pressure treated, Tropical hardwoods, WPC, TMW
Need for Maintenance	5 hours annually, 10 hours annually, 15 hours annually
Durability	Lasts 5-9 years, lasts 10-14 years, lasts 15-20 years
Material Cost	\$4.00/ft^2, \$8.00/ft^2, \$12.00/ft^2
Environmental Certification	Certified, not certified

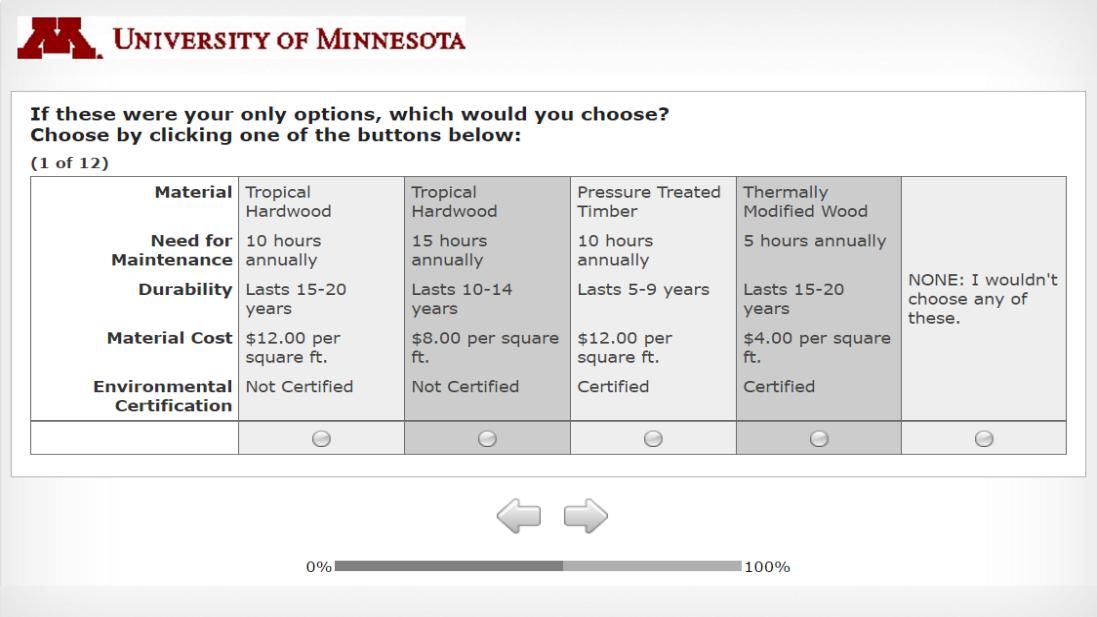

Figure 31. Example of a potential question from the conjoint analysis section of the questionnaire.

Aggregate Analysis

Logit analysis is a statistical technique used in marketing analysis to better understand consumer acceptance of a product by determining the intensity of their intention to purchase that product (Sawtooth Software, 2016). This is done by converting data into a "purchase probability," which is understood as "utility effects." These utility effects indicate the magnitude of consumer preference for each individual attribute level, ranging from -1 to 1, and centered on zero. Attribute levels with positive effects indicate it adds to the overall utility of the product, while attribute levels with negative effect indicate it "takes away" from the overall utility of the product.

Individual Utility Effects

Logit analysis first determines the maximum likelihood solution through an iterative process that provides a log-likelihood for the model and a root likelihood (*RLH*) value for the model to measure how well the solution fits the data (Sawtooth Software, 2016). The best possible *RLH* value is 1.0, which represents a perfect fit between the solution and the data. The worst possible value is the reciprocal of the average number of choices available in each random task question, which was five for this study, including the "None" option, making 0.2 the worst possible value. However, the *RLH*

value is rarely close to 1.0, and non-ideal outputs for this value have been used in the past (Thomas, 2004). Table 12 shows the outputs for the Deck Expo and Online data sets from Sawtooth Software's logit analysis.

Chi-square statistics were used to determine if the logit analysis was statistically significant. If statistically significant, logit analysis indicates the various attribute levels made a difference for participants. Logit analysis significance tests were conducted by determining the differences between observed and expected data (shown as "log-likelihood for this model" and "log-likelihood for null model" (Table 12)). The differences between the observed and expected data for Deck Expo and Online respondents were 146.42 and 135.63, respectively, and the Chi-square statistic was then calculated by doubling these differences. Degrees of freedom are equal to the number of estimated parameters (11), which was calculated by subtracting the total number of attributes (5) from the total number of levels (16). At 11 degrees of freedom a Chi-square statistic of 19.68 is significant for a *p-value* = 0.05. Therefore, respondent choices for both Deck Expo (χ^2 = 292.83) and Online (χ^2 = 271.26) data were significantly affected by the different attribute levels for the conjoint analysis questions. This is consistent with the results, where respondents consistently ranked the "better" attribute level higher, such as preferring low prices when compared to high prices.

Table 12. Logit analysis output for Deck Expo and Online respondents (Sawtooth Software, 2016).

Iteration	**Deck Expo**	**Deck Expo**	**Online Chi-**	**Online RLH**
1	288.86	0.24	267.56	0.27
2	292.82	0.24	271.25	0.27
3	292.83	0.24	271.26	0.27
4	292.83	0.24	271.26	0.27
Log-likelihood for this model	-1031.69		-578.96	
Log-likelihood for null model	-1178.11		-714.59	
Difference	146.42		135.63	
Chi-square	292.83		271.26	
Relative Chi-square	24.40		22.60	

Since respondent choices were significantly affected by individual attribute levels, an analysis of the utility effects from logit analysis was completed. Importantly, the utility effects used were scaled to sum zero within each attribute, meaning an attribute level with a negative number may not have been an entirely unattractive option, but rather the

other levels were better (Orme, 2010). For each individual attribute level, a positive utility effect indicates a consumer has a high probability of purchasing a product containing that attribute level, while a negative utility effect indicates they have a low probability of purchasing a product containing that attribute level.

Results are listed in Table 13 and show that, for both groups of respondents (Deck Expo and Online), WPCs had the highest utility effect for *Material* followed by tropical hardwoods; and pressure treated lumber had the lowest utility effect (Table 13). TMW had a positive utility effect for Deck Expo respondents (0.12) and a negative utility effect for Online respondents (-0.29). For Online respondents, a *Durability* of 15-20 years was the highest rated attribute level (0.72), followed by the lowest rated attribute level for a *Durability* of 5-9 years (-0.74) (Table 13).

Table 13. Utility effects for Deck Expo and Online respondents. Bold numbers represent the range of the utility effects for each attribute and respondent group.

Attribute Level	Deck Expo Utility Effect	Online Utility Effect
Material	**1.390**	**1.026**
Naturally Durable	-0.273	0.103
Pressure Treated	-0.856	-0.601
Tropical Hardwoods	0.471	0.358
WPC	0.534	0.426
TMW	0.124	-0.287
Need for Maintenance	**0.304**	**0.406**
5 Hours Annually	0.155	0.176
10 Hours Annually	-0.006	0.054
15 Hours Annually	-0.149	-0.230
Durability	**0.670**	**1.461**
Lasts 5-9 Years	-0.340	-0.739
Lasts 10-14 Years	0.010	0.018
Lasts 15-20 Years	0.330	0.721
Material Cost	**0.762**	**1.316**
$4.00/ft.^{2}	0.314	0.627
$8.00/ft.^{2}	0.134	0.062
$12.00/ft.^{2}	-0.448	-0.689
Environmental Certification	**0.328**	**0.462**
Certified	0.164	0.231
Not Certified	-0.164	-0.231

The overall importance of different attributes can also be evaluated using logit analysis utility effects by determining the range between individual attribute levels' utilities. The larger the range between the maximum and minimum utility effects for an attribute level, the more important that attribute is for participants' purchase decisions. Conversely, the smaller the range, the less important the attribute is. Using this technique, the most important attribute for Deck Expo respondents was *Material*, with a range of 1.39 between the most positive (WPCs) and most negative (pressure treated lumber) attribute levels (Table 13). The most important attribute for Online respondents was *Durability*, with a range of 1.46 between the most positive (lasts 15-20 years) and negative (lasts 5-9 years) attribute levels (Table 13). The least important attribute overall for both Deck Expo and Online respondents was *Need for Maintenance*, with a range of 0.304 and 0.406, respectively (Table 13).

This is consistent with a previous study where *Need for Maintenance* was also rated least important using utility effects as an indicator (Thomas, 2004). However, another study on decking advertisements in a print magazine from 1996-2006 found that WPC companies emphasized *Low Maintenance* the third most frequently of eight attributes and far more frequently than naturally durable softwoods or pressure treated lumber companies (Hamner, Hansen, & Tokarczyk, 2012). This likely indicates WPC companies consider the low maintenance of WPCs be a differentiating and important attribute for their material. Moreover, the results in Table 13 do not necessarily mean that *Need for Maintenance* is not an important attribute to consumers. It is possible respondents assume that maintenance needs are inherent to the materials, thus linking their perception of the *Need for Maintenance* attribute to the *Material* attribute. A potential limitation of conjoint analysis is that respondents with a strong preference for a certain attribute level may select the product concepts that contain that value without considering other attributes. In the perceptions section of the survey when *Material* was not one of the attributes being considered, *Need for Maintenance* was rated as the third most important attribute instead of the least important attribute (Figure 15 and Figure 16).

Overall Attribute Importance

Sawtooth Software's logit analysis can also provide overall attribute importance as a percentage, using the data for the range of effects within an attribute. As mentioned above, the larger the range of effects, the more importance participants place on that attribute for purchase decisions. The overall importance indicates the relative significance consumers place on that attribute compared to the other attributes included in the study (Figure 32).

Both Deck Expo and Online respondents placed the lowest importance on *Need for Maintenance* (9%), followed by *Environmental Certification* (10%) (Figure 32). This seems to contradict the results from the perception question about attribute importance, where both groups of respondents rated *Environmental Performance* lowest, but rated *Need for Maintenance* third when ranking them as "Extremely Important" or "Very Important" (Figure 15 and Figure 16). As stated previously, it is likely respondents associated *Need for Maintenance* with *Material*, bringing the overall importance of the former down. Deck Expo respondents placed more importance on *Material* (40%) compared to Online respondents (22%) and placed less importance on *Durability* (19%) compared to Online respondents (31%) (Figure 32), which is consistent with the perceptions of attribute importance data, where fewer Deck Expo respondents rated *Durability* as "Extremely Important" or "Very Important" (78.7%) than Online respondents (85.8%) (Figure 15 and Figure 16).

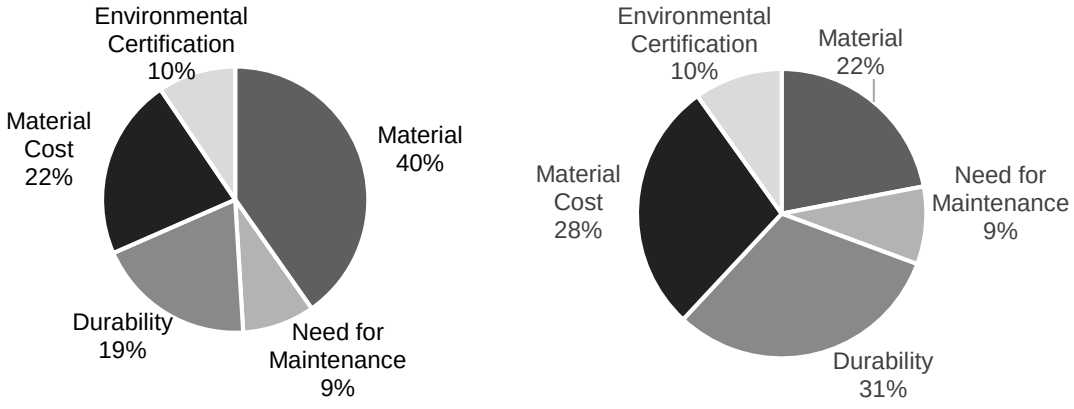

Figure 32. Overall attribute importance using logit analysis for Deck Expo (left) and Online (right) respondents.

A limitation of logit analysis and analyzing overall attribute importance is that it represents an average of all respondents, including extreme answers and without considering consumer segments with potentially distinct preferences. To identify sub groups of participants with distinct needs, a segmentation analysis using latent class estimation was conducted using the results from the conjoint analysis section of the survey.

Segmentation Analysis

In contrast to logit analysis, which determines the average part-worth utilities for all respondents, latent class estimation is a way to segment CBC data by dividing participants into subgroups with different preferences and determining the part worth utilities for each of those subgroups. Respondents within each segment have relatively similar preferences but the preferences between groups are different. The segmentation analysis using latent class estimation from the CBC question block is summarized in this section.

For the segmentation analysis, data from Deck Expo and Online respondents were merged into one data set because of the limited sample size. Chi-square and t-tests from the demographics and perceptions sections exhibited very few differences between these two groups of participants, thus allowing for the use of a combined data set.

The first decision in a segmentation analysis is how many segments to generate. A larger number of segments provides more detailed information about specific needs of customer groups, but it can be difficult to manage from a marketing perspective. On the other hand, a small number of segments may not be useful for formulating marketing strategy, as there is potential to miss opportunities that provide customized solutions for subgroups of customers with specific needs, thus increasing satisfaction. After running several simulations, it was decided to work with three segments, which provided rich enough information about distinct groups of customers and made interpretation feasible. This decision was supported by looking at the differences in percent certainty, Chi-square, and relative Chi-square, where the differences decreased rapidly from three to four, and four to five groups (Table 14).

Table 14. Latent class estimation of the efficiency of number of groups for segmentation.

Groups	% Certainty	Chi-square	Relative Chi-square
2	22.33%	845.40	33.82
3	26.62%	1007.54	26.51
4	30.22%	1143.89	22.43
5	32.59%	1233.79	19.28

The Chi-square statistic is technically used to test whether a solution fits significantly better than the null solution, but because this is almost always true, Chi-square is not normally used to select the number of segments. In addition, it tends to increase simply as the number of groups increase. "Relative Chi-square" is Chi-square divided by the number of estimation parameters. Currently, Sawtooth Software (Sawtooth Software, 2016) does not provide a theoretical basis for the relative Chi-square statistic, but through their analyses of many data sets, they recommend using it to select the ideal number of segments, and larger numbers are better, at least statistically (Orme, 2007). Despite the relative Chi-square statistic being largest for two groups, we chose to work with three segments because of the large size of the decking industry and because of the minimal differences occurring between groups larger than three.

Once it was decided three segments would fit the data and end goals of this study best, latent class estimation was used to sort respondents and determine part-worth utilities for each segment (Table 15). Part-worth utility functions model the utility for each attribute level independently of the others in order to estimate preferences for each attribute level in a product (Orme, 2010). While the initial analysis centers the numbers on 0 and ranges from -1 to 1, Sawtooth Software allowed for a re-scaling of the data to “zero-centered differences” with a much larger range to make utility comparison easier.

Table 15. Latent class analysis part-worth utilities rescaled to zero-centered differences for comparability. Bold numbers represent the range of part-worth utilities for each attribute and segment.

Attribute Level	Segment 1	Segment 2	Segment 3
Relative Segment Size	22%	53%	23%
Material	**367.52**	**73.92**	**315.21**
Naturally Durable Softwoods	-114.62	-23.41	78.74
Pressure Treated Lumber	-106.07	-35.28	-165.49
Tropical Hardwoods	70.26	-1.41	149.72
WPC	252.90	21.47	-70.48
TMW	-102.48	38.64	7.51
Need for Maintenance	**39.62**	**51.22**	**26.87**
5 Hours Annually	26.12	25.21	14.75
10 Hours Annually	-12.63	0.80	-12.12
15 Hours Annually	-13.50	-26.01	-2.63
Durability	**18.73**	**170.62**	**34.38**
Lasts 5-9 Years	-10.08	-86.89	-17.19
Lasts 10-14 Years	8.65	3.17	0.00
Lasts 15-20 Years	1.43	83.73	17.19
Material Cost	**38.05**	**150.17**	**79.05**
$4.00/ft.^{2}	4.48	71.12	28.35
$8.00/ft.^{2}	16.79	7.93	22.36
$12.00/ft.^{2}	-21.26	-79.05	-50.70
Environmental Certification	**36.08**	**54.06**	**44.5**
Certified	-18.04	27.03	22.25
Not Certified	18.04	-27.03	-22.25
Attribute Importance	**69.76**	**23.87**	**57.67**
Material	73.51	14.78	63.04
Need for Maintenance	7.92	10.25	5.37
Durability	3.75	34.12	6.87
Material Cost	7.61	30.03	15.81
Environmental Certification	7.21	10.81	8.90

Table 16 contains the demographic information associated with each of the three segments generated, including “Company Type,” “Size of Company,” “Type of Company Business,” “Location of Company,” “Familiarity with TMW,” and “Decking Materials Used.” Percentages may add up to more than 100% because some of the demographic questions allowed for more than one answer. This information is useful because it allows for a better understanding of who the “typical member” is within each segment.

Table 16. Demographic information for the three segments generated. For questions where more than one answer was allowed, percentages may add up to more than 100%.

Demographic	Segment 1	Segment 2	Segment 3
Respondent Profession			
Deck Specialist	41%	34%	13%
New Construction	14%	15%	13%
Remodeling	27%	43%	17%
Manufacturing	18%	8%	13%
Wholesale, Retail, Distribution	9%	13%	30%
Architect/Design	0%	6%	17%
Other	9%	11%	17%
Size of Company			
4 or fewer Employees	41%	55%	26%
5-9 Employees	14%	8%	13%
10-24 Employees	5%	11%	17%
25-49 Employees	36%	6%	26%
50-99 Employees	0%	9%	4%
100 or more Employees	5%	11%	13%
Type of Company Business			
Remodeling	86%	89%	74%
Single-family New Construction	50%	68%	78%
Multi-family New Construction	23%	26%	39%
Commercial	41%	34%	52%
Institutional	14%	11%	17%
Other	9%	9%	22%
Location of Company's Operations			
Midwest	32%	19%	30%
Northeast	41%	40%	30%
South	14%	21%	17%
West	5%	13%	13%
All U.S. Regions	9%	13%	26%
Other	5%	8%	13%
Familiarity with TMW			
Very Familiar	23%	21%	30%
Somewhat Familiar	36%	30%	61%
Not very Familiar	36%	34%	9%
Haven't Heard of it	5%	15%	0%
Decking Materials Used			
Naturally Durable Softwoods	18%	45%	52%
Pressure Treated Lumber	45%	70%	30%
Tropical Hardwoods	18%	40%	65%
TMW	0%	4%	13%
WPC	91%	81%	61%
Plastic	41%	25%	26%
Other	5%	6%	4%

Segment 1

According to Table 15, Segment 1 makes up 22% of the total sample, and 68% (Table 15) of this group described themselves as “Deck Specialists” or “Remodelers,” while no “Designers” were members of this segment. This segment had a large percentage of respondents from smaller companies, with 55% working for businesses who employ 9 people or less (Table 16). Regions where respondents of this segment operate include the Northeast (41%) and Midwest (32%) (Table 16). This segment had the highest percentage of respondents who use WPCs for at least some of their projects (91%) and the lowest percentage of respondents who use TMW for at least some of their projects (0%) (Table 16). Segment 1 strongly prefers WPCs over other materials, with a WPC utility effect of 252.90 compared to TMW (-102.48), pressure treated lumber (-106.07), and naturally durable softwoods (-114.62) (Table 15). Members of this group consider *Material* the most important attribute, while they are least concerned with *Durability* and *Material Cost* of all three segments, and have the lowest preferences towards environmental certification (Table 15).

Segment 2

Segment 2 makes up 53% of the total sample (Table 15) and 77% of this group described themselves as “Deck Specialists” or “Remodelers,” with 89% indicating that at least some part of their companies’ business is in remodeling (Table 16). This segment had the largest number of respondents from smaller companies, with 63% working for businesses who employ 9 people of less (Table 16). Regions where companies in this segment operate include the Northeast (40%) and the South (21%) (Table 16). Awareness of TMW was the lowest in this segment, with 49% of members reporting little or no familiarity with TMW (Table 16). Importantly, of all segments, this group was the least concerned with *Material* and placed the highest attribute importance on *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification* (Table 15). Although this segment was more neutral on *Material* than the other two segments, they did demonstrate a preference for TMW (38.64) compared to other materials, followed by WPCs (21.47) (Table 15). This segment seems to have a high sensitivity to price, because respondents ranked price as a more important attribute compared to the other two segments. This price sensitivity is consistent with Segment 2 having the highest

number of members (70%) utilizing pressure treated lumber for at least some percentage of their products (Table 16).

Segment 3

Segment 3 makes up 23% of the total sample (Table 15) and contains the largest percentage of “Wholesale/Retail/Distribution” and “Design” members of all three groups, making up 47% of the group (Table 16). This group has the highest proportion of people with at least some percentage of their business in single-family new construction (78%), multi-family new construction (39%), and commercial construction (52%) (Table 16). Segment 3 reported having the most companies with operations in all regions of the U.S. (26%) and “Other,” (13%) which indicated at least some international business (Table 16). Regarding awareness about TMW, 91% of Segment 3 members reported being “Very familiar” or “Somewhat familiar” with TMW, and 13% use TMW for at least some of their projects, which was the highest of the three groups (Table 16). This segment also had the lowest percentage of members using WPCs for at least some percentage of their projects (61%) (Table 16). and have the lowest preference for WPCs and pressure treated lumber among all three segments (Table 15). *Material* was the most important attribute to this segment and they have favorable perceptions of tropical hardwoods (149.72) and naturally durable softwoods (78.74), with a neutral perception of TMW (7.51) (Table 15).

Latent Class Utility Estimation by Demographic Groups

Latent class estimation also offers utilities for each demographic segment, using questions from the survey to separate respondents. Comparing these utilities was not a definitive process and required some judgement; however, the utility outputs for each demographic group can provide some insight the other segments cannot. To make comparison between each attribute level and demographic group easier, the results were re-scaled to “zero-centered differences” with a much larger range, where the attribute level with the largest positive utility can be understood as the most preferred. A summary of the results from these tables is outlined below.

Respondent Profession

- Deck construction specialists, remodelers, and manufacturers all preferred WPCs for *Material* (Table 17).
- New construction specialists preferred tropical hardwoods and WPCs almost equally for *Material* (Table 17).
- Wholesalers/retailers/distributors preferred tropical hardwoods for *Material* (Table 17).
- Architects/designers preferred tropical hardwoods for *Material*, and viewed TMW most preferably among company types (Table 17).
- All company types viewed *Need for Maintenance* similarly, which may be a result of linking this attribute to Material (Table 18).
- Remodelers had the highest preference for a long-life *Durability*, while manufacturers were the least concerned with *Durability* (Table 19).
- Remodelers had the highest preference for low *Material Cost*, while manufacturers were the least concerned with *Material Cost* (Table 20).
- Architects/designers had the highest preference for the certification attribute level for *Environmental Certification*, while this attribute mattered least to manufacturers (Table 21).

Size of Company

- This demographic varied widely among company sizes and did not follow any trends for smaller or larger sized companies.

Location of Company's Operations

- Companies located in the West had the highest preference for TMW, while companies located in the Midwest had the lowest preference for it (Table 17).
- Companies located in the South had the highest preference for a long-life *Durability*, while companies in the Midwest were the least concerned with Durability (Table 19).
- Companies located in the South and West had the highest sensitivity to *Material Cost*, while companies in the Midwest were the least price sensitive (Table 20).

Familiarity with TMW

- The lower a respondent's familiarity with TMW, the higher their preference for it. This may be the result of not having a negative stigma associated with it from inaccurate past marketing claims (Table 17).
- Respondents who are very or somewhat familiar with TMW have the lowest price sensitivity (Table 20).

Table 17. Utilities for *Material* attribute separated by demographic groups. Deck Expo and Online respondent data combined. Abbreviations: ND = naturally durable softwoods, PTL = pressure treated lumber, THW = tropical hardwoods, WPC = wood-plastic composite, TMW = thermally-modified wood.

***Material* Utilities**	**ND**	**PTL**	**THW**	**WPC**	**TMW**	**Range**	**% Importance**
Respondent Profession							
Deck Construction Specialist	-38.75	-72.16	37.45	79.28	-5.81	151.44	36.6%
New Construction	-18.91	-81.29	49.4	49.13	1.66	130.69	38.2%
Remodeling	-26.75	-65.25	31.35	51.67	8.98	116.92	31.6%
Wholesaler/Retailer/Distrib.	11.54	-103.66	76.38	8.72	7.04	180.04	43.7%
Manufacturer	-30.6	-97.71	66.77	84.73	-23.19	182.44	49.9%
Architect/Design	38.27	-114.6	90.2	-34.05	20.18	204.80	43.3%
Size of Company							
1-4 Employees	-26.93	-69.29	35.72	55.12	5.39	124.41	33.6%
5-9 Employees	-20.09	-95.64	65.49	63.27	-13.03	161.13	46.9%
10-19 Employees	1.53	-85.81	55.82	13.48	14.97	141.63	36.0%
20-49 Employees	-24.69	-121.11	92.19	90.96	-37.35	213.30	59.5%
50-99 Employees	-5.76	-57.92	24.78	5.58	33.32	91.25	23.0%
>100 Employees	-3.85	-82.91	52.26	21.54	12.96	135.17	35.8%
Location of Company's Operations							
Midwest	-9.81	-98.06	68.7	45.22	-6.05	166.76	45.6%
Northeast	-14.69	-87.53	56.38	45.72	0.12	143.91	40.1%
South	-6.72	-87.78	57.43	30.91	6.16	145.21	38.9%
West	2.87	-93.05	63.99	16.81	9.38	157.04	39.8%
Familiarity with TMW							
Very familiar with TMW	-12.76	-90.51	59.94	44.59	-1.26	150.45	41.6%
Somewhat familiar w/ TMW	-4.80	-99.63	70.81	36.90	-3.28	170.45	45.3%
Not very familiar with TMW	-38.70	-68.85	33.91	76.70	-3.06	145.55	35.1%
Have not heard about TMW	-33.62	-43.27	6.65	47.37	22.86	90.65	21.3%

Table 18. Utilities for *Need for Maintenance* attribute separated by demographic groups. Deck Expo and Online respondent data combined.

Need for Maintenance **Utilities**	**5 Hours**	**10 Hours**	**15 Hours**	**Range**	**% Importance**
Respondent Profession					
Deck Construction Specialist	24.77	-4.66	-20.11	44.88	9.1%
New Construction	23.16	-5.09	-18.07	41.23	8.6%
Remodeling	24.08	-3.33	-20.75	44.83	9.2%
Wholesaler/Retailer/Distributor	20.72	-6.76	-13.96	34.68	7.8%
Manufacturer	22.9	-7.8	-15.1	38.00	8.1%
Architect/Design	19.14	-7.02	-12.12	31.26	7.3%
Size of Company					
1-4 Employees	23.97	-3.86	-20.11	44.08	9.1%
5-9 Employees	22.35	-7.11	-15.24	37.59	8.1%
10-19 Employees	22.06	-4.79	-17.26	39.32	8.4%
20-49 Employees	22.14	-10.52	-11.62	33.77	7.5%
50-99 Employees	23.45	-1.44	-22.01	45.47	9.4%
>100 Employees	22.41	-4.65	-17.76	40.17	8.6%
Location of Company's Business					
Midwest	21.91	-6.95	-14.96	36.87	8.0%
Northeast	22.83	-5.7	-17.13	39.96	8.5%
South	22.33	-5.42	-16.91	39.24	8.4%
West	21.62	-5.72	-15.9	37.52	8.2%
Familiarity with TMW					
Very familiar with TMW	22.52	-6.04	-16.48	39.00	8.3%
Somewhat familiar with TMW	21.60	-6.95	-14.65	36.25	7.9%
Not very familiar with TMW	24.83	-4.24	-20.59	45.42	9.2%
Have not heard about TMW	25.34	-0.71	-24.63	49.96	10.0%

Table 19. Utilities for *Durability* attribute separated by demographic groups. Deck Expo and Online respondent data combined.

***Durability* Utilities**	**5-9 Years**	**10-14 Years**	**15-20 Years**	**Range**	**% Importance**
Respondent Profession					
Deck Construction Specialist	-57.84	4.48	53.36	111.20	22.6%
New Construction	-54.89	3.61	51.28	106.17	21.5%
Remodeling	-64.04	3.76	60.28	124.32	25.1%
Wholesaler/Retailer/Distributor	-46.08	2.43	43.65	89.73	18.1%
Manufacturer	-39.4	4.42	34.99	74.39	15.4%
Architect/Design	-45.56	1.28	44.28	89.84	18.0%
Size of Company					
1-4 Employees	-61.27	3.83	57.44	118.71	24.0%
5-9 Employees	-42.93	3.86	39.07	82.00	16.8%
10-19 Employees	-57.07	2.67	54.39	111.46	22.4%
20-49 Employees	-26.18	4.49	21.69	47.88	10.2%
50-99 Employees	-74.99	2.63	72.37	147.36	29.5%
>100 Employees	-57.70	2.90	54.80	112.51	22.6%
Location of Company's Business					
Midwest	-44.48	3.4	41.08	85.56	17.4%
Northeast	-52.05	3.5	48.55	100.60	20.4%
South	-53.36	3.11	50.25	103.61	20.9%
West	-51.8	2.71	49.09	100.89	20.3%
Familiarity with TMW					
Very familiar with TMW	-49.93	3.45	46.49	96.42	19.6%
Somewhat familiar with TMW	-44.56	3.17	41.39	85.95	17.5%
Not very familiar with TMW	-59.93	4.42	55.51	115.45	23.4%
Have not heard about TMW	-78.35	3.78	74.56	152.91	30.7%

Table 20. Utilities for *Material Cost* attribute separated by demographic groups. Deck Expo and Online respondent data combined.

***Material Cost* Utilities**	**$4.00/ft.^{2}**	**$8.00/ft.^{2}**	**$12.00/ft.^{2}**	**Range**	**% Importance**
Respondent Profession					
Deck Construction Specialist	47.91	12.39	-60.30	108.21	22.3%
New Construction	47.49	13.27	-60.77	108.26	22.1%
Remodeling	53.59	11.44	-65.03	118.62	24.2%
Wholesaler/Retailer/Distributor	43.75	15.66	-59.40	103.15	20.9%
Manufacturer	34.68	15.26	-49.94	84.62	17.8%
Architect/Design	45.95	16.76	-62.70	108.65	21.7%
Size of Company					
1-4 Employees	51.51	11.92	-63.43	114.94	23.5%
5-9 Employees	38.29	14.92	-53.21	91.51	19.0%
10-19 Employees	51.10	13.66	-64.76	115.86	23.4%
20-49 Employees	25.45	18.02	-43.47	68.92	14.8%
50-99 Employees	63.86	10.44	-74.30	138.16	27.6%
>100 Employees	51.05	13.36	-64.41	115.46	23.3%
Location of Company's Business					
Midwest	40.49	15.15	-55.64	96.13	19.8%
Northeast	45.80	13.99	-59.79	105.59	21.6%
South	47.50	13.95	-61.45	108.95	22.2%
West	47.24	14.49	-61.72	108.96	22.1%
Familiarity with TMW					
Very familiar with TMW	44.36	14.31	-58.67	103.03	21.1%
Somewhat familiar with TMW	41.03	15.30	-56.32	97.35	20.0%
Not very familiar with TMW	49.47	12.00	-61.46	110.93	22.8%
Have not heard about TMW	63.71	8.93	-72.64	136.35	27.5%

Table 21. Utilities for *Environmental Certification* attribute separated by demographic groups. Deck Expo and Online respondent data combined.

***Environmental Certification* Utilities**	**Certified**	**Not Certified**	**Range**	**% Importance**
Respondent Profession				
Deck Construction Specialist	13.74	-13.74	27.48	9.3%
New Construction	16.56	-16.56	33.12	9.6%
Remodeling	18.27	-18.27	36.54	9.9%
Wholesaler/Retailer/Distributor	19.38	-19.38	38.76	9.5%
Manufacturer	8.79	-8.79	17.58	8.8%
Architect/Design	24.42	-24.42	48.84	9.8%
Size of Company				
1-4 Employees	17.26	-17.26	34.52	9.8%
5-9 Employees	12.08	-12.08	24.17	9.2%
10-19 Employees	21.33	-21.33	42.66	9.8%
20-49 Employees	5.26	-5.26	10.53	8.0%
50-99 Employees	26.26	-26.26	52.52	10.5%
>100 Employees	20.50	-20.50	41.00	9.6%
Location of Company's Business				
Midwest	14.65	-14.65	29.30	9.2%
Northeast	16.39	-16.39	32.78	9.4%
South	18.4	-18.4	36.80	9.6%
West	19.72	-19.72	39.44	9.6%
Familiarity with TMW				
Very familiar with TMW	16.01	-16.01	32.02	9.5%
Somewhat familiar with TMW	15.65	-15.65	31.31	9.3%
Not very familiar with TMW	14.50	-14.50	28.99	9.4%
Have not heard about TMW	22.01	-22.01	44.02	10.4%

Summary of Results

This study collected data on U.S. decking industry professional consumer's demographics, perceptions of wood-based decking products, and choice-based conjoint analysis responses to understand their purchasing behavior.

The demographic information suggests most businesses in the target market work as remodelers or deck specialists and work for smaller companies, employing between one and four people. In general, respondents seem to utilize a wide range of decking materials for their projects, but the two materials most frequently used were wood-plastic composites (WPCs) and pressure treated lumber. Over 60% of respondents indicated that they are "Very familiar" or "Somewhat familiar" with thermally-modified wood (TMW). However, a considerable number of respondents also reported little to no familiarity with TMW (Deck Expo = 36.1% and Online = 38.1%), which suggests an opportunity for educating and informing this professional audience on TMW.

The information collected on perceptions of wood-based decking materials and their attributes suggests professional consumers consider *Durability* and *Aesthetics* to be the two most important decking material attributes, which is consistent with a 2010 study, where *Long Life* and B*eautiful and Aesthetically Pleasing* had the highest importance ratings for material attributes (Ganguly et al., 2010). When considering how well each wood-based decking material performed for individual attributes, such as *Durability and Availability*, many participants selected "Do not know," particularly for TMW. It is unclear to what degree the perceptions about TMW are accurate, due to an overall lack of knowledge from both groups of respondents. However, Deck Expo respondents who viewed TMW decking samples generally had more positive perceptions of TMW.

The information collected from the conjoint analysis component of the study suggests that WPCs have the highest utility effect of all decking materials, followed by tropical hardwoods, while pressure treated lumber had the lowest utility effect. TMW had a positive utility effect for Deck Expo respondents and a negative utility effect for Online respondents. The most important attribute overall for Deck Expo respondents was *Material*, whereas *Durability* was the most important for Online respondents. The least important attribute overall for all respondents was *Need for Maintenance*. However, this does not necessarily mean that *Need for Maintenance* is not important to professional consumers. It is possible that respondents assumed a degree of need for maintenance to each material, and thus linked their perception of *Need for Maintenance* to *Material*. A question in the perceptions section of the survey did not consider *Material* as one of the attributes and *Need for Maintenance* was rated as the third most important attribute instead of the least important attribute.

Overall, professional consumers in the decking industry surveyed for this research currently show a preference toward WPCs and tropical hardwoods, and seem to have mixed perceptions about TMW. This is likely the result of insufficient marketing by the TMW industry and professional consumers' lack of knowledge about the material. The next chapter will focus on applying the findings presented in this section to the development of a strategic marketing plan for the TMW industry.

CHAPTER 4. STRATEGIC MARKETING PLAN

This chapter contains marketing strategy recommendations for the U.S. thermally-modified wood (TMW) industry. Recommendations are based on primary and secondary data. Primary data consists of professional consumer perceptions, collected as a part of this research, which was described in detail in Chapter 3. Secondary data includes previous research on the topic. The marketing strategy focuses on the U.S. TMW exterior decking products industry, including manufacturers and distributors; however, the recommendations presented are broad in scope and are useful for the TMW industry in general. Information in this chapter includes a description of the current state of the TMW industry and its marketing practices, a situational analysis of the industry, a summary of results from the research conducted, and marketing strategy suggestions for the TMW industry.

Current State

Macroenvironment

State of Market Development

During the last two decades, thermally-modified wood (TMW) has achieved technical maturity and commercial success in Europe. Part of this success was due to increasing consumer concerns about the use of toxic chemicals for wood durability enhancement (Hill, 2011). However, TMW has not yet achieved the same commercial success and development in the United States. As of 2013, there were 118 producers of TMW in Europe and Russia (Scheiding, 2014) and the 2015 estimated annual TMW production capacity was 400,000 m^3 (Scheiding, 2015). In comparison, there are currently only 10 producers of TMW in the U.S. (Scheiding, 2015) with a 2012 North American TMW production capacity of around 100,000 m^3 (United Nations Economic Commission for Europe/Food and Agriculture Organization of the United Nations [UNECE/FAO], 2013). However, the U.S. production capacity is likely to rise, as many

companies are considering opening U.S. TMW production plants. A complete list of TMW producers worldwide can be found in Appendix 3.

Standards

There were no widely recognized standards or grades for the manufacturing or testing of TMW in the U.S. as of 2016. The development and recognition of standards for TMW products is important to ensure product quality and consistency, assure users about performance and safety, facilitate market access and trade, and build consumer confidence in the TMW industry. The only effort to date to address the need for standards in the U.S. resulted in a report titled *AWPA/ANSI guidance document for listing thermally-modified wood in AWPA standards* (Donahue & Winandy, 2014). This document lists the performance requirements for getting a TMW product approved by the American Wood Protection Association (AWPA), an ANSI-accredited standard-developing organization. It also contains information on why U.S. TMW standards are needed, who is responsible for driving the development of standards, and the data requirements needed to create TMW standards.

By contrast, Europe currently has three published standards for TMW. The first is "DS/CEN/TS 15679 Thermally-Modified Timber – Definitions and Characteristics," which was published in 2007 and approved in 2013 (European Committee for Standardization [CEN], 2007). This standard provides definitions and characteristics for TMW products; it requires manufacturers to document production data and mark products with the following information: manufacturer's name, production plant and internal production control, assortment or specification, reference to the CEN/TS standard, wood species, end use class, and scope of application (Institut für Holztechnologie [IHD], 2015). Another European standard is a specific certification program for TMW called "Quality Mark TMT," published in 2007 in Germany and updated in 2015 (Entwicklungs-und Prüflabor Holztechnologie [EPH], 2015). The final European standard is the "DIN 68800 Wood Preservation," which was published in multiple sections between October 2011 and February 2012 (German Institute for Standardization [DIN], 2011). Information on TMW and thermal or chemical modification for the preservation of wood can be found in the Annex A to Part 1 of the DIN 68800 standard (IHD, 2015). This standard also contains information on general prerequisites for wood protection against biodegradation and an overview of the available measures for wood protection and natural durability.

Industry Associations

Currently, there are no U.S. associations that represent TMW manufacturing or distributing companies. Associations play an important role in supporting and growing an emergent industry by combining resources to provide educational resources to members and the public, conducting market research, enhancing credibility and trust of members and their products, and advocating for their members. In Europe, the International ThermoWood® Association, which represents TMW producers and equipment manufacturers that use the ThermoWood® process, has been successful in advancing TMW in Europe by patenting their treatment processes, requiring standardization, audited quality control, conducting a life cycle assessment (LCA) on ThermoWood®, certifying raw materials used, and continuously conducting research and development activities (International ThermoWood Association, 2017). A similar association in the U.S. would greatly benefit the industry. Researchers at the University of Minnesota are hoping to secure funding over the next year to develop a plan for the formation of a U.S. TMW industry association, which, among other things, will address the current lack of standards.

Regulations

Concerns over illegal logging and chemical wood treatments have created opportunities for the TMW industry. The 2008 amendment of the Lacey Act has increased enforcement of regulations related to trade of illegally sourced timber (INECE, 2008), with harsh penalties for those that knowingly or unknowingly allow illegally harvested timber to enter the supply chain. This increased enforcement has the potential of opening market opportunities for domestically-sourced wood products, such as TMW. In addition, TMW shares some highly valued attributes with tropical hardwoods, such as a dark, rich color, and enhanced durability (Powell, 2010). Moreover, concerns for wood treatments involving potentially harmful chemicals has resulted in chemicals such as chromated copper arsenate (CCA) to be discontinued for residential uses in the U.S. (U.S. Environmental Protection Agency [EPA], 2016), creating opportunities for chemical-free treatments, including thermal-modification. However, it is worth noting that TMW is not recommended for ground contact use.

Technology

Nearly all TMW producers have a slightly different process for heat-treating wood, depending on the equipment used (Appendix 4), species treated, target properties, and final uses, among other factors. The following list is a summary of the TMW processes commonly used in Europe:

- *ThermoWood*® (International ThermoWood Association, 2017) is an international company founded in Finland, and dominates the market for TMW in Europe. Their process may be used only by members of the International ThermoWood® Association, and heat-treats wood in the presence of steam with low oxygen content (Sandberg & Kutnar, 2015). There are two ThermoWood® standard classes, Thermo-S and Thermo-D, which have slightly different processes from each other and for hardwoods or softwoods (International ThermoWood Association, 2017). The standard class used depends on what the end-use application of the lumber will be.
- *ThermoTreat 2.0* is an energy-efficient process that was developed by WTT in Denmark. It uses a closed system hydrolysis process at high pressures but lower temperatures that only takes approximately 12 hours to complete (Wood Treatment Technology [WTT], 2017).
- The *Plato* process was developed in the 1980s in the Netherlands and is a four-step process, which includes heating the wood under wet conditions, drying, heating the wood again, and curing the wood in dry conditions (Esteves & Pereira, 2009).
- *Retification* (Retiwood®) is a process developed by New Option Wood in France, which slowly heats up pre-dried wood in an atmosphere rich in nitrogen with a maximum 2% oxygen content (Esteves & Pereira, 2009).
- *Perdure* is another TMW process developed by New Option Wood. This process artificially dries fresh wood in an oven, then heats it up in a low-oxygen environment (Esteves & Pereira, 2009).
- *Oil Heat Treatment* (OHT) is a thermal-modification process developed by the company Menz Holz in Germany. OHT heats wood in a closed-process, hot oil medium to provide good heat transfer (Homan & Jorissen, 2004).
- Another collection of thermal-modification methods utilize heat and a vacuum. The most prominent company that uses this company is WDE-Manspell (WDE-Manspell, 2017).

While information is available about the processes used in Europe, there is very little published information about the thermal-modification technology and processes used by U.S. TMW producers. Sandberg & Kutnar (2015) reported at least one U.S. company using the ThermoWood® and Perdure processes in the U.S., in addition to a unique process called the *Westwood* process, which they noted is a variation of the ThermoWood® process developed specifically for hardwood species.

Awareness and Perceptions

As mentioned before, TMW is in its early stages of market development in the U.S., with just a few producers and distributors. At this stage, it is critical to increase awareness about the product and develop positive perceptions about its performance. Successful and visible projects utilizing TMW, like the University of Minnesota's Bell Museum of Natural History in St. Paul, Minnesota, will contribute to increased awareness and appreciation of TMW (Figure 33).

Figure 33. University of Minnesota's Bell Museum of Natural History in St. Paul, Minnesota (Coss, 2017).

When TMW was first introduced to the U.S., its market growth was affected by unsupported claims about its performance (Donahue & Winandy, 2014). These unsupported claims were compounded by the wide range of potential processing

techniques for TMW, which result in different product characteristics, even for the same species and end use. These factors have contributed to consumer confusion (Donahue & Winandy, 2014), and highlight the need for a unified industry marketing strategy, which this study attempts to address.

While awareness of TMW is slowly growing among industry professionals, there is still a very low level of awareness among end users (Espinoza et al., 2015). Recent work by the author confirmed awareness is still low among professional adopters as well, but a portion of this population has moved into the interest and evaluation stages product adoption because 22% of industry professionals surveyed for this study indicated they are “Very familiar” with TMW (More information on this can be found in the Research Summary- Results section of this chapter). It is reasonable to assume the level of awareness among the general population is much lower, which is still the most important barrier preventing the TMW industry from growing (Espinoza et al., 2015).

Industry Analysis

Size

In contrast to the 118 firms producing and distributing TMW in Europe, only ten firms currently produce or distribute TMW in the U.S. (Espinoza et al., 2015). Five of these firms are located in the Midwest, two in the South, two in the Northeast, and one in the West. However, U.S. TMW producers interviewed for a previous study generally agreed that the market is growing at a fast pace and interest in thermal-modification treatment is increasing, based on the amount of customer inquiries received (Espinoza et al., 2015).

While the current demand and production of TMW in the U.S. is small, there is potential for considerable growth. In Europe, for example, production volume for TMW has been consistently increasing since 2001. The total annual production in Europe was around 130,800m^3 in 2007 (Boonstra, 2008) and 280,000m^3 in 2013 (UNECE/FAO, 2014), a more than two-fold increase in less than six years. It is believed that with the proper marketing strategy and concerted industry effort, similar growth can be achieved in the U.S.

Distribution and Promotion

Espinoza et al. (2015) interviewed U.S. manufacturers and distributors of TMW products and results from that study are useful to understanding the U.S. supply chain of TMW. Manufacturers and distributors interviewed during the aforementioned study reported selling domestically to markets in California, Georgia, Iowa, Maine, Michigan, Minnesota, Oregon, Wisconsin, and the Southeast. Several companies also reported that they export a significant share of their production to a wide variety of international markets, including countries in Europe, North America, Asia, and Australia/Oceania.

Distribution channels for TMW in the U.S. include lumberyards and distributors of building products, followed by manufacturers and contractors to a lesser extent (Table 22). Some companies also utilize landscape architects and retail lumberyards as distribution channels. TMW producers interviewed indicated that they sell exclusively to distributors and other business customers; none of them marketed directly through retail channels.

The most common promotional channels for TMW producers and distributors are company websites, with all current producers using this channel (Table 22). This is followed by attendance at trade shows. Some of the events attended by TMW producers and distributors include the biannual International Woodworking Fair (IWF) in Atlanta (International Woodworking Fair, 2017), WoodWorks events (WoodWorks, 2017), and the Greenbuild International Conference and Expo (Greenbuild Expo, 2017). However, during the data collection phase for this study, at a deck products expo in Baltimore, Maryland, no producers or distributors of TMW decking products were present.

Table 22. Current distribution and promotional channels used by TMW producers (Espinoza et al., 2015).

Distribution Channels
Distributors
Manufacturers
Contractors
Architects
Other
Promotional Channels
Websites
Trade Shows
Trade Journals/Magazines
On-site Educational Events
Installed Displays

Messaging

Durability and improved rot resistance, as well as the dark, rich color and attractive, exotic appearance of TMW are the attributes most emphasized by TMW producers and distributors (Table 23). Other attributes highlighted by at least one U.S. TMW company include “better acoustic properties,” “locally sourced,” “lighter,” and “not a health hazard.” In addition, several TMW producers indicated they are careful not to over-promise benefits, stressing that TMW is not a “maintenance-free” material.

Table 23. Attributes emphasized by TMW producers (Espinoza et al., 2015).

Attributes Emphasized
Durability and improved rot resistance
Rich color, attractive or exotic appearance
Chemical-free, zero toxicity
Enhanced dimensional stability, lower hygroscopicity
Environmentally friendly
Competitive price compared to tropical
Machinability, sands and finishes easily

Between 1996 and 2006, a large increase in print advertisement frequency occurred in the decking industry. (Hamner et al., 2012). Most of this advertising growth occurred after 2001 in response to wood-plastic composites (WPCs) entering the decking materials market as a substitute to solid wood products. In particular, producers and distributors of naturally durable softwoods increased their number of advertisements by 300% during this period (Hamner et al., 2012). After 2006, this frequency fluctuated with the demand for decking products within the U.S. housing industry upturn and crash, with a more than 250% difference in the number of advertisements between the lowest and highest demand years (McGraw, Smith, & Chen, 2015). From 2002 to 2014, WPCs were the most common material advertised in Professional Deck Builder magazine, making up 38% of all ads (McGraw et al., 2015). The attribute promoted most frequently among all decking materials was aesthetics, followed by durability and color option availability (McGraw et al., 2015).

Decking Industry Structure

The decking industry is a $3 billion market in the U.S. (2011 figures) (Kouteran, 2011) and around 4.2% of U.S. households add a deck to their house every year, resulting in over 3 million new decks being added to existing homes each year (Ganguly & Eastin, 2009). These figures have continued to stay strong, and in 2015, 23% of newly built single-family U.S. homes completed had a deck, which equaled approximately 149,000 new houses with decks total (U.S. Census Bureau, 2016). Each of the common decking materials available has its own industry makeup, with some sections of the market being fragmented into many small players and others being dominated by a few large companies.

The *pressure treated lumber* industry is fragmented, comprised of many small to medium manufacturers and associations but three main suppliers, including Lonza, Koppers Performance Chemicals, and Viance (Cushman, 2015). The 2013 U.S. Census Bureau's manufacturer survey indicated a decline in the wood preservation industry (NAICS code: 321114). In 2008, there were 519 wood preservation business establishments with 13,432 employees and those numbers fell to 389 wood preservation business establishments with 8,287 employees in 2013 (U.S. Census Bureau, 2017). In addition, previous research detected regional differences in the use of pressure treated lumber for decks, where 73% of decks in the Southeastern region of the U.S. were made of pressure treated lumber, but only 30% of decks in the Northwest and Southwest regions were made from this material (Eastin et al., 2005).

Tropical hardwoods, imported to the U.S. from Brazil, Peru, and Malaysia, among others (Duery & Vlosky, 2006), have grown in popularity over the past 15 years. While there are many small importers of tropical hardwood decking materials, there are some big business players, such as the Iron Woods brand from Timber Holdings USA™ (Iron Woods, 2017). This company sells nine different species of tropical hardwoods, with ipe the most popular, and offer a 25-year warranty on their products.

Regarding *naturally durable softwoods*, there are currently two major industry associations. The first is Real Cedar©, the brand name for the Western Red Cedar Lumber Association (Real Cedar, 2017), a non-profit association representing 27 western red cedar producers. On its website, this association emphasizes the low maintenance costs, dimensional stability, and aesthetically pleasing qualities of cedar decking. The second major industry association is the California Redwood Association,

which has three producer members, all certified by the Forest Stewardship Council® (FSC®), and located in California, including: Humboldt Redwood™ (Humboldt Redwood, 2017), Big Creek Lumber (Big Creek Lumber, 2017), and Mendocino Forest Products Company® (Mendocino Forest Products, 2017).

Wood-plastic composite products (WPCs) have perhaps the most recognizable brand names of all decking materials among end consumers, because of their intense marketing efforts and the 15-30 year warranties offered. A summary of three of the WPC industry's most dominant brands, according to The Decking Superstore© (The Decking Superstore, 2017), follows:

- Trex® (Trex, 2017a) has been the market leader of WPC products since the company's formation in 1996. The company's website emphasizes the recycled nature of their raw materials and the low maintenance requirements of their decking products.
- AZEK Building Products' TimberTech® brand of composite decking products (TimberTech, 2017) states that 73% of the raw materials for their products are recycled, and offer a warranty of 30 years for their products.
- Fiberon® manufactures the Veranda® brand of composite decking products (Veranda, 2017) that are sold exclusively at The Home Depot® stores. They offer the shortest warranty at 15 years and are made from over 80% recycled materials, according to the company website.

Positioning of Decking Materials

Pressure Treated Lumber

Pressure treated lumber has traditionally been positioned as a low-cost decking material, but a study of decking product advertisements over a 12-year period, between 2002 and 2014, found the five attributes mentioned most frequently by pressure treated lumber producers were: environmental friendliness (81%), aesthetics (56%), durability (50%), strength (38%), and cost (38%) (McGraw et al., 2015). The same study also found pressure treated lumber producers utilized a "rational" appeal in 75% of their advertisements, which conveys a logical message to consumers about why a product fits their needs (McGraw et al., 2015). While the results of this research found the perception of pressure treated lumber's environmental friendliness and aesthetics to be

rather negative (Table 24), the attributes emphasized in the pressure treated lumber advertisements studied by McGraw et al. most likely demonstrate an attempt by the industry to shift these negative perceptions. According to the results of our study, the perceived advantages of pressure treated lumber among professional consumers are the low cost and high availability of this material (Table 24), with 73.9% of respondents perceiving pressure treated lumber to be “Very affordable” or “Affordable” and 90.0% of respondents perceiving it to be “Very easy to find” or “Easy to find.” An additional advantage of pressure treated lumber is that there are already many decks installed with this material, and homeowners may be less likely to switch materials when renovating or remodeling their current deck.

The results of the current study demonstrate that perceived weaknesses of pressure treated lumber include inferior aesthetics when compared to other materials, (received a score of 2.45 out of 5 for aesthetics using a weighted average perceptions index). There is also a perception of pressure treated lumber having extensive maintenance requirements, (received a score of 2.55 out of 5 for need for maintenance using a weighted average perceptions index, with 1 indicating very high maintenance and 5 indicating very low maintenance requirements) which may be associated with high costs. Pressure treated lumber is also perceived as having average environmental performance, receiving a score of 2.9 out of 5 on a weighted averages perceptions index for this attribute. This may be the result of a few separate environmental issues surrounding pressure treated lumber with the traditional use of chromated copper arsenate (CCA).

In 2003, the wood treatment industry voluntarily stopped manufacturing CCA for residential uses, including decking (EPA, 2016); but the perception of CCA as a harmful chemical treatment may have persisted after this discontinuation, and extended to the chemical treatments that were developed as replacements. In addition, consumers (professional and end users) may have questioned the performance and effectiveness of the new alternative treatments, such as alkaline copper quaternary (ACQ), acid copper chromate (ACC), copper azole (CBA-A and CA-B), copper citrate (CC), copper dimethyldithiocarbamate (CDDC), and copper HDO (CX-A). All CCA-alternatives utilize copper as their primary biocide. The most common CCA alternative, ACQ, has special installation requirements which requires using either hot-dipped galvanized copper or stainless steel fasteners to avoid corrosion (Groenier & Lebow, 2006). These special

installation requirements may have also added to the negative perception of CCA-alternative treated lumber.

Table 24. Comparison of decking material alternatives. Approximate price per linear foot information from Decks.com LLC. Perceived advantages and disadvantages are results from the current study.

Material	Price (per linear ft.)	Perceived Advantages	Perceived Disadvantages
Pressure Treated Lumber	$0.75 - $1.25	Cost and Availability	Maintenance and Aesthetics
Tropical Hardwoods	$4.00 - $5.00	Durability and Aesthetics	Maintenance and Cost
Naturally Durable Softwoods	$1.25 - $2.00	Aesthetics, Availability, and Environmental Performance	Maintenance
WPCs	$3.00 - $4.00	Maintenance, Durability, Aesthetics, and Availability	Cost
TMW	Not available	Durability, Aesthetics, and Environmental Performance	Cost and Availability

Tropical Hardwoods

Tropical hardwoods are generally marketed and positioned as having high quality and durability, as well as low maintenance requirements. An advantage of tropical hardwoods is their natural durability, which makes them highly resistant to decay and termites (Arango, Green, Hintz, Lebow, & Miller, 2006). In addition, appealing aesthetics is perhaps tropical hardwoods' most positively perceived attribute (Table 24), receiving a score of 4.55 out of 5 for aesthetics, using a weighted average perceptions index. This positioning, which emphasizes aesthetics, durability, and maintenance, was confirmed by a study of deck advertisements over a 12-year period between 2002 and 2014, which found the five attributes mentioned most frequently by tropical hardwood producers, by percentage, were: aesthetics (86%), durability (85%), maintenance (71%), strength (71%), and resistance to biodegradation (57%) (McGraw et al., 2015). The same study also found tropical hardwood producers and distributors utilized rational appeals in 100% of their advertisements, which convey a logical message to the consumer about why a product fits their needs (McGraw et al., 2015).

Despite these positive attributes, one major weakness of tropical hardwoods is their high price, which limits this material alternative to high-end uses and a relatively small market share. In contrast to common perceptions, the professional consumers that provided their input to this study seemed to perceive tropical hardwoods as having

average maintenance requirements (Table 24) (received a score of 2.9 out of 5 for maintenance requirements, with 1 indicating very high maintenance requirements and 5 indicating very low maintenance requirements, using a weighted average perceptions index), despite their positioning as a low-maintenance material. Another challenge for tropical hardwoods is that certain consumers may have questions about the legality or sustainability of timber harvested in some tropical countries. This has become a growing concern in recent years, with evidence to support that illegal logging causes a substantial amount of the deforestation that occurs in tropical countries (Contreras-Hermosilla et al., 2008).

Naturally Durable Softwoods

Naturally durable softwood species have traditionally been positioned as a high-end, quality product that carry higher upfront costs but are worth their value. Producers and distributors of naturally durable softwoods usually emphasize the "natural look and feel" of their products, as well as the environmental advantages of a material sustainably-harvested from U.S. forests. According to this study, perceived advantages of naturally durable softwoods among professional consumers include appealing aesthetics and environmental performance (Table 24), receiving a rating of 3.6 out of 5 for aesthetics and 3.65 for environmental performance, using a weighted average perceptions index. A 2014 life cycle assessment (LCA) study of redwood decking materials found that the amount of carbon stored in redwood decking, if emitted into the atmosphere as CO_2, is around ten times greater than the total CO_2 emissions from the manufacturing process (Bergman, Oneil, Eastin, & Han, 2014). A similar LCA from 2013 compared redwood decking to other materials and found the global warming potential (GWP) for redwood was negative (-163 kg CO_2-eq), while non-recycled WPCs and recycled WPCs, both had positive GWPs (264 kg CO_2-eq and 144 kg CO_2-eq, respectively) (Consortium for Research on Renewable Industrial Materials [CORRIM], 2013). Another advantage of naturally durable softwoods, as claimed by their producers and distributors, includes the ability to maintain cooler temperatures on sunny days, as well as their versatility to receive different colors and refinish, unlike other materials; especially WPCs.

This study found a perceived disadvantage of naturally durable softwoods to be high maintenance requirements (Table 24) (received a score of 2.25 out of 5, using a

weighted perceptions index, with 1 indicating very high maintenance and 5 indicating very low maintenance requirements) and although not perceived this way by current professional consumers, a traditional weakness of naturally durable softwoods has been their availability, which was historically limited to certain geographic regions of the U.S. (Ganguly & Eastin, 2009). Also, naturally durable softwoods have perhaps the greatest photo degradation from sunlight of all major decking materials when not properly maintained (Williams, 2005). Lastly, although not as expensive as tropical hardwoods, naturally durable softwoods are in the higher range of price.

Wood-Plastic Composites (WPCs)

Since their introduction in the 1990's, companies producing and selling WPCs have aimed at positioning this product as a low maintenance, durable material that is environmentally-friendly due to a portion of their raw materials having recycled origins. A study of deck advertisements over a 12-year period between 2002 and 2014 found WPC producers use emotional appeals in 61% of their advertisements, which is intended to produce an immediate feeling that the customer would experience by purchasing the product (McGraw et al., 2015). The five attributes mentioned most frequently by WPC producers in their advertisements over the same period included: color options (55%), aesthetics (45%), warranty (36%), maintenance (29%), and moisture resistance (29%) (McGraw et al., 2015). Another aspect of WPCs positioning strategy is acknowledging the high upfront cost of their products, but claiming a lower cost over the product's lifetime, especially when considering the "high maintenance costs" associated with solid wood decking products. WPC advertisements also highlight the innovation techniques occurring in the WPC industry (Hamner et al., 2012), which refers to innovative terminology (patent pending, new, improved, exclusive, etc.) and/or imagery (new product design, application). This focus on innovation differentiates the WPC industry from the traditionally conservative wood industry and indicates an emphasis on customers. According to the results of this study, perceived advantages of WPCs among professional consumers includes low maintenance requirements, high durability, appealing aesthetics, and high availability (Table 24) (received ratings of 4.25 for maintenance, 4.4 for durability, 4.05 for aesthetics, and 4.25 for availability, out of 5, using a weighted average perceptions index).

This study found the perceived disadvantage of WPCs among professional consumers to be high costs (Table 24), receiving a score of 2.0 out of 5 using a weighted average perceptions index. Another potential weakness of WPCs is that some end consumers prefer the look and feel of solid wood products, and may be willing to trade the perceived higher maintenance costs of solid wood products for their aesthetic advantages. A 2015 study exploring user perceptions of "naturalness" found users were quickly and easily able to recognize WPCs as significantly less natural than other wood products and gave them less favorable ratings for naturalness (Burnard et al., 2015).

Since their introduction, WPCs have been aggressively marketed as having better performance and environmental qualifications than pressure treated lumber. However, a 2011 life cycle assessment (LCA) study comparing ACQ pressure treated lumber with WPCs found that pressure treated lumber's environmental impacts were fourteen times lower for fossil fuel use, nearly three times lower for water use as well as greenhouse gas and smog emissions, and had almost half of the ecological toxicity impact of WPCs (Bolin & Smith, 2011). The proportion of non-renewable resources used in a WPC product directly affects its environmental impacts.

Market Share and Relative Price

Pressure treated lumber has been the dominant decking material since its introduction to the market in the 1970's, surpassing naturally durable softwoods (Winandy, 2004). However, pressure treated lumber has recently lost some of this dominant market share to alternative materials, dropping to around 57.8% of the total demand for decking materials by 2010 (Ganguly et al., 2010). Prices for pressure treated lumber decking are the lowest of all common decking materials, which is likely the reason it is still the most commonly used decking material. It is unlikely TMW will be highly competitive with pressure treated lumber until consumer demand for chemical-free products increase or government regulations restrict the use of pressure treated lumber. TMW and pressure treated lumber will probably occupy different market segments, at least initially, because of their price differences.

Tropical hardwoods have gained popularity in the U.S. in the last decades, capturing a niche market share of 1% in 2006 (Duery & Vlosky, 2006) to 2-3% in 2010 (Ganguly et al., 2010). Potential reasons for this growth are the appeal of tropical species' natural durability and aesthetics. Tropical hardwoods are comparatively more

expensive than most other decking materials and occupy the high-end of the market. Common tropical hardwood species imported to the U.S. for decking are ipe *(Handroanthus spp*.), cumaru (*Dipteryx odorata*), and tigerwood (*Astronium graveolens*). Prices for TMW are competitive with tropical hardwood decking products, and these two materials will likely compete to capture a niche of the market for consumers who are not highly sensitive to prices.

Domestic naturally durable softwood species such as western red cedar (*Thuja plicata*) and redwoods (*Sequoioideae spp*.) historically held a relatively constant market share, especially in the western region of the country. The market share of these materials began to fall in the early 2000's due to market pressure from WPCs (Ganguly & Eastin, 2009); and as of 2010, they occupied around 11.7% of the decking market (Ganguly et al., 2010). Prices for TMW are competitive with naturally durable softwoods, and these two materials will likely compete to capture a niche of the market for consumers who are not sensitive to high prices.

WPCs have recently been the fastest growing decking material, capturing a market share of 25.0% in 2010 since their introduction in the 1990's (Ganguly et al., 2010). Prices for WPCs can vary considerably depending on product quality, with some products costing more than TMW and some being competitively priced with it. WPCs and TMW will likely be in direct competition for some market segments, along with tropical hardwoods and naturally durable softwoods.

Consumer Analysis

Participants

Consumers in the decking industry can be categorized into two separate groups, intermediate consumers and end consumers. Intermediate consumers include deck specialists and contractors, wholesalers, retailers, distributors, manufacturers, and architects and designers. This group may have the greatest bargaining power over markets because they can influence purchasing decisions by end users (Porter, 2008). This influence over material selection and success is reflected by deck specialists and contractors installing over 80% of decks (Eastin et al., 2005). A previous study on architects and designers revealed that professional users are often involved in the selection process when choosing building materials, and have the potential to greatly

influence the utilization of wood products (Wagner & Hansen, 2004). In addition, it is easier to collect data on, and measure material selection of intermediate consumers compared to end consumers because of their exposure and experience with a wider variety of products.

The other group of consumers participating in the decking industry market is comprised of end users. They include homeowners, and sometimes renters, who are the final recipients of a product. A previous study found end consumers are responsible for specifying material type up to 30-50% of the time (Eastin et al., 2005), making them less influential but still important to material selection. This group of consumers has recently become more influential because of the growth of the do-it-yourself (DIY) market (Shook & Eastin, 2001).

Demographics

Demographic information was collected from this study and previous studies to help create the profile of an average professional consumer in the decking industry. Results from this study indicated remodelers and deck specialists are the two largest professions within the field. It also revealed the industry is still dominated by small firms of one to four people, which previous research has found as well (Eastin et al., 2005; *Professional Deck Builder*, 2013). The most common materials used by this study's participants were WPCs, followed by pressure treated lumber, but these results may be influenced by the number of respondents that attended the 2016 Deck Expo in Baltimore ("Remodeling Show, Deck Expo, JLC Live," 2016), who seemed to prefer WPCs.

Perhaps some of the most important demographic takeaways from this study is the information that reveals how preferences for TMW differ between demographic groups. Geographic location and profession were not overly important demographics for segmenting intermediate consumers, but industry members from the Western region of the U.S. and architects and designers currently view TMW most preferably. In addition, this study revealed the industry as a whole is still relatively unaware of TMW, with 37.1% of intermediate consumers reporting to have little or no familiarity with TMW. The environmental credentials of TMW can be further enhanced by chain of custody forest certification, yet 50.0% of respondents from this study reported being unfamiliar with forest certification. Over 485 million acres of forested land are certified by either the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative (SFI) worldwide,

with much of that certification occurring locally in North America (Fernholz, Howe, Bratkovich, & Bowyer, 2010). This widespread forest certification in North America make domestically harvested timber a good candidate to be certified, which can be made into materials such as TMW. The data collected on industry familiarity with these two topics demonstrates there is considerable opportunity to raise awareness of both TMW and forest certification.

Demographic information on end consumers collected by previous studies revealed people aged 45-64 will experience a market share growth for decking that is considerably higher than other age groups. This older and more affluent segment of the population is generally willing to spend more money on amenities such as decks (Ganguly & Eastin, 2009), which will be important to the decking industry over the next decades. Another study found that as consumer age increased, so did acceptance for WPCs. As the end consumer profile shifts to reflect this dominant market share by older age groups, the lifetime of a deck and the hours of maintenance necessary for upkeep may become more important than specific decking material and price among these older consumers (Thomas, 2004).

Buyer Motivation and Expectations

It is important to consider differences between intermediate and end consumer motivations and expectations. Much of the previous consumer behavior, preferences, and perceptions research on decking materials has explored what attributes are most important to both groups of consumers.

Shook and Eastin (2001) found price is not necessarily the dominant factor for industry members when selecting decking materials, and that professional consumer's perceptions of the decking materials available on the market varies considerably. The most important attributes for industry members who participated in this study were *Long Life and Beautifully/Aesthetically Pleasing* and Eastin et al. (2005) had similar findings, suggesting industry members are motivated by quality when selecting materials compared to price. Ganguly and Eastin (2009) also found *Longevity*, *Beauty*, *Consistent Material Quality*, and *Availability* to be the most important attributes and motivations of intermediate consumers.

Research on end consumers has revealed they are similarly motivated by quality compared to price. Eastin et al. (2005) found homeowners are motivated by high quality,

durability, and low-maintenance materials more than price of materials. Two additional studies on end consumers also found *Durability* and *Material* to be the two most important decking attributes (Fell & Gaston, 2001; Thomas, 2004). Another interesting finding from previous end consumer studies was that female end consumers may be a good demographic to target compared to males for products with high environmental performance potential such as TMW. These studies showed females are less sensitive to price, and the perception of a product having low environmental impact was more important to them compared to men (Roos & Nyrud, 2008; Thomas, 2004).

Consumer Perceptions Research Summary

Information Requirements

The main information requirements to achieve the objectives of this study was data on how professionals in the decking industry perceive attribute performance of wood-based decking materials. Information on demographics, perceptions of decking material attributes, and conjoint analysis marketing data was collected.

Research Methodology

This study was administered using a computer-based questionnaire containing demographic, user perceptions, and conjoint analysis questions to collect data from professional consumers at a trade show event, the DeckExpo ("Remodeling Show, Deck Expo, JLC Live," 2016), and online through a link posted on *Professional Deck Builder* magazine's website (Wormer, 2016). The product selected for this project was decking, because of its large market and suitable application of TMW. To increase respondent familiarity with all the wood-based decking materials included in the survey, deck samples were created for participants to examine in-person at the trade show event.

Research Results

Demographics

The first question in the demographics section of the survey was "*How would you describe you or your company? Select all that apply. Multiple responses allowed*." Deck Expo respondents reported "Remodeling" (29.5%) and "Deck Specialist" (23.0%) to be

the top two areas of businesses their company worked in (Figure 34). Online respondents reported the same top two specialty areas of business, with 42.9% of respondents reporting being a “Deck Specialist” and 35.7% in the “Remodeling” business. Considerably more Online respondents (21.4%) reported working in “New Construction” compared to Deck Expo respondents (8.2%).

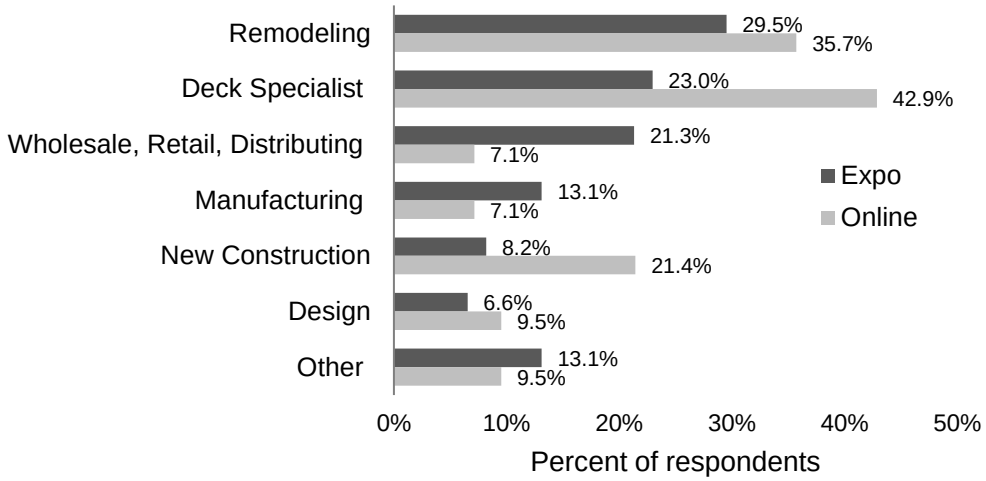

Figure 34. Type of company Deck Expo and Online respondents reported working for. Multiple responses allowed.

The second question was “*Which of the following best describes the size of your company?*” The highest percentage of Deck Expo respondents work for companies with 1-4 employees (31%), followed by 20-49 employees (24.6%). A large percentage (66.7%) of Online respondents reported working for companies with 1-4 employees, with the next closest range being 5-9 at 11.9%.

The third demographics question was “*What percent of your company’s business is distributed within the following categories? Multiple responses allowed*.” The largest number of companies for both Deck Expo and Online surveys were reported in repair and remodeling (78.7% and 85.7% of Deck Expo and Online participants respectively), and single-family housing construction (67.2% Deck Expo and 64.3% Online). Deck Expo respondents had a statistically significant larger percent of their business in commercial projects, at 42.6% compared to Online respondents at 31.0%.

The fourth question was “*In which of the following regions does your company operate? (Select all that apply).*” Responses suggest an over-representation of companies operating in the Northeast region among Deck Expo respondents (62.3% of respondents reported having operations in this region), while Online respondents

reported a more even distribution of business location. This can likely be explained by the nationwide reach of the online magazine where the survey was advertised.

The fifth question was "*How familiar are you with Thermally-Modified Wood?*" If respondents selected "Not very familiar" or "Haven't heard about it," they reviewed a "TMW Primer", which provided basic information on TMW performance and applications. This was done so all respondents could answer questions about TMW. Respondents from both data sets answered this question similarly, indicating that the industry as a whole has a similar familiarity with TMW. Over half of Deck Expo (64%) and Online (62%) respondents indicated they are "Very familiar" or "Somewhat familiar" with TMW. However, a considerable number of respondents reported little or no familiarity with TMW (36.1% and 38.1% for Deck Expo and Online respondents, respectively), which suggests an opportunity for educating and informing this audience on TMW.

The sixth question was "*What percent of your company's decking projects utilize the following as major materials? Multiple responses allowed.*" In general, respondents seem to use a wide range of decking materials for their projects. The top two materials used by both Deck Expo and Online respondents for their projects are WPCs and pressure treated lumber. However, Deck Expo respondents reported a larger percentage of their projects using WPCs than Online respondents, while the latter indicated a higher percent of their projects using pressure treated decking.

Perceptions

The next section of the questionnaire asked respondents about their perceptions of various wood-based decking materials and their attributes. The first three questions from this section were the same, except for the decking project price ranges listed. The question was "*Please select your TOP TWO choices from the following wood-based decking materials for a project with a total installation cost UNDER $5,000; BETWEEN $5,000 and $15,000; and EXCEEDING $15,000, by dragging and dropping them into the empty box.*" Results are summarized in Figure 35 and Figure 36.

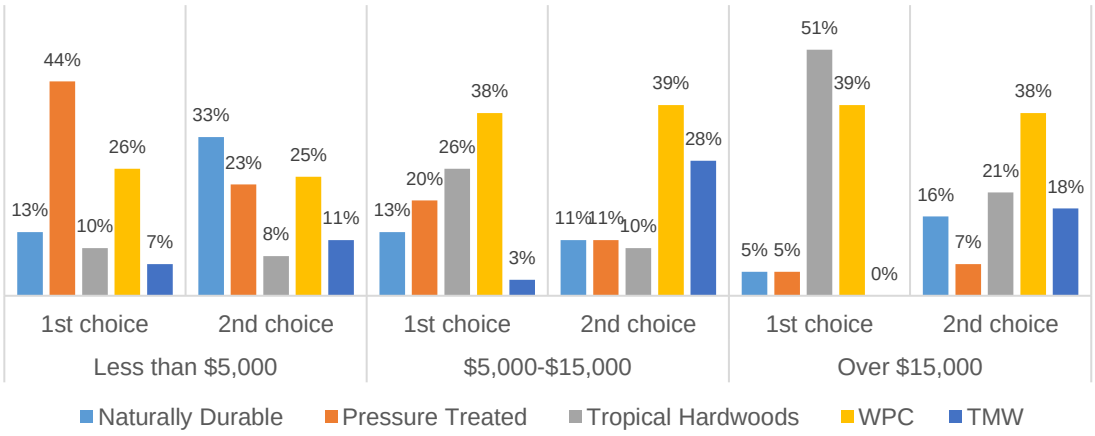

Figure 35. Percent of respondents selecting top two ranked choices among Deck Expo respondents for decking projects costing less than $5,000, between $5,000 and $15,000, and over $15,000.

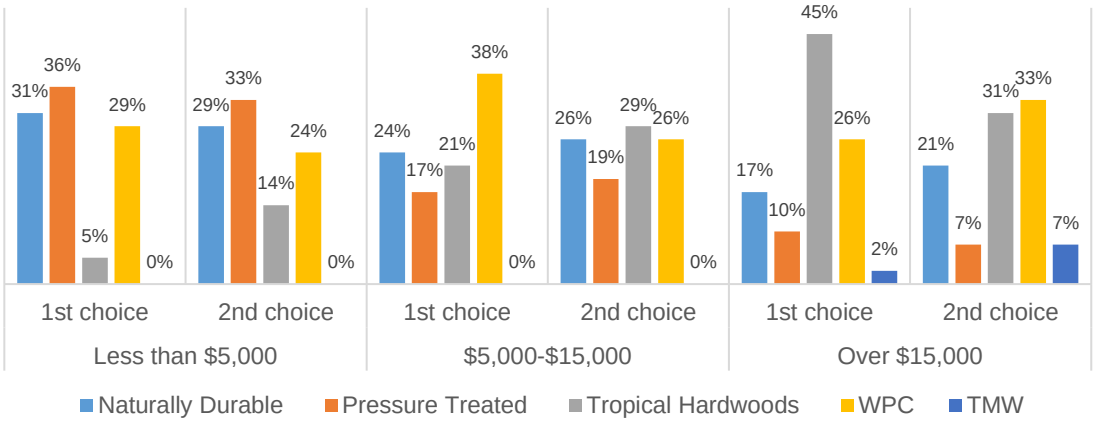

Figure 36. Percent of respondents selecting top two ranked choices among Online respondents for decking projects costing less than $5,000, between $5,000 and $15,000, and over $15,000.

The fourth question in this section was "*How important are the following material attributes to you when designing, constructing, or remodeling a deck?*" Both Deck Expo and Online respondents rated *Durability* and *Aesthetics* as the two most important attributes, with 78.7% of Deck Expo and 85.8% of Online respondents rating *Durability* as "Extremely important" or "Very important" and 82.0% of Deck Expo and 76.2% of Online respondents rating *aesthetics* as "Extremely important" or "Very important". These results are consistent with a 2010 study, where *Long Life* and *Beautiful and*

Aesthetically Pleasing had the highest importance ratings for decking material attributes (Ganguly et al., 2010).

The next six questions asked respondents about their perceptions on the attribute performance for five wood-based decking materials (naturally durable softwoods, pressure treated lumber, tropical hardwoods, WPCs, and TMW). The scale for each of these questions included five choices from low performance to high performance, and a “Do not know” option if they were unfamiliar with any of the materials. To make the analysis and interpretation of the perceptions question simpler, a “perception index” was calculated, as a weighted average of the ratings selected (1 to 5) and the frequencies of responses. Thus, a perception index was calculated for each material, reflecting the respondents’ perception of that material on the six attributes being evaluated; with values between 0 (for a negative perception) and 5 (for a positive perception). The perception indexes are summarized in Figure 37 and Figure 38.

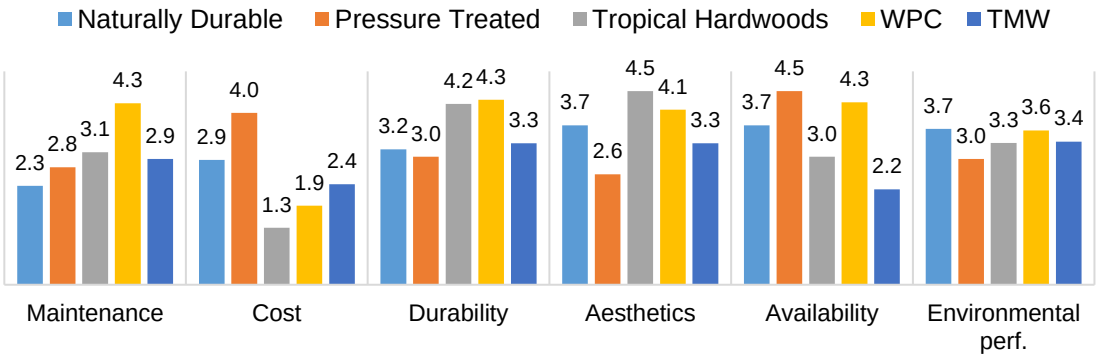

Figure 37. Comparison of perceived material performance among Deck Expo respondents for maintenance, cost, durability, aesthetics, availability, and environmental performance, NOT including "do not know" option.

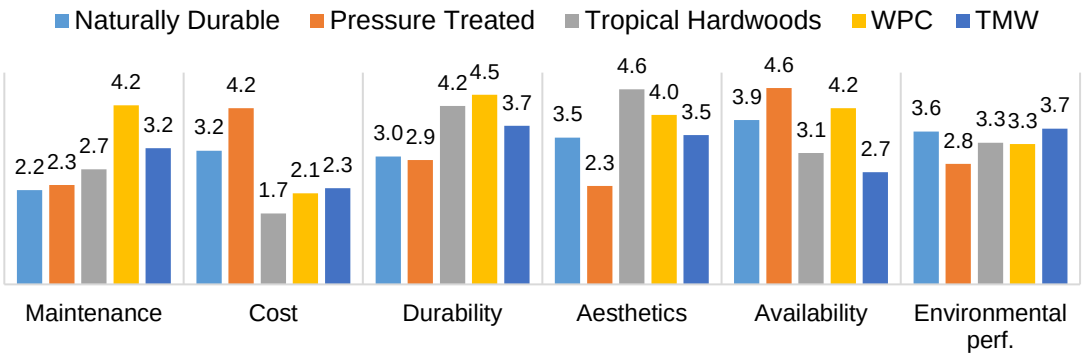

Figure 38. Comparison of perceived material performance among Online respondents for maintenance, cost, durability, aesthetics, availability, and environmental performance, NOT including "do not know" option.

Conjoint Analysis

Conjoint analysis is a marketing technique that identifies the relative importance consumers place on various product attributes. Including a conjoint analysis component in this survey allowed for a better understanding of the trade-offs professional consumers make among different product attributes, especially those that are influential to TMW's market viability. The data collected from this section may be understood as "utility functions," which demonstrate the perceived value of each product feature and uncover how sensitive consumer perceptions are to changes of those features and attribute levels (Orme, 2010).

Conjoint analysis questions collect information by presenting participants with a series of product alternatives, then prompts them to select the product they would purchase if those were their only options. A "None" option is usually provided for participants who would not select any of the product alternatives available. The conjoint analysis section of this study included 12 random task questions with four product concepts per question, including the "None" option. The product concepts were comprised of five attributes (*Material*, *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification*), with a different number of levels for each attribute (Table 25).

Table 25. Attributes and attribute levels for the conjoint analysis questions.

Attribute	Levels
Material	Naturally durable, Pressure treated, Tropical hardwoods, WPC, TMW
Need for Maintenance	5 hours annually, 10 hours annually, 15 hours annually
Durability	Lasts 5-9 years, lasts 10-14 years, lasts 15-20 years
Material Cost	$4.00/ft.^{2}, $8.00/ft.^{2}, $12.00/ft.^{2}
Environmental Certification	Certified, not certified

The conjoint analysis data was evaluated using logit analysis, a statistical technique used in marketing to better understand consumer acceptance of a product by determining the intensity of their intention to purchase that product (Sawtooth Software, 2016). This is done by converting data into a "purchase probability," which is understood as "utility effects." These utility effects indicate the magnitude of consumer preference for each individual attribute level, ranging from -1 to 1, and centered on zero. Attribute levels with positive effects indicate it adds to the overall utility of the product and consumers have a high probability of purchasing a product containing that attribute level. Attribute levels with negative effect indicate it "takes away" from the overall utility of the product and consumers have a low probability of purchasing a product containing that attribute level. The utility effects used were scaled to sum zero within each attribute, meaning an attribute level with a negative number may not be an entirely unattractive option, but rather the other levels were better (Orme, 2010).

Results from the logit analysis are listed in Table 26 and show that, for both groups of respondents (Deck Expo and Online), WPCs had the highest utility effect followed by tropical hardwoods. Pressure treated lumber had the lowest utility effect for *Material* (Table 26). TMW had a positive utility effect for Deck Expo respondents (0.12) and a negative utility effect for Online respondents (-0.29). For Online respondents, a *Durability* of 15-20 years was the highest rated attribute level (0.72), followed by the lowest rated attribute level for a *Durability* of 5-9 years (-0.74) (Table 26).

Table 26. Utility effects for Deck Expo and Online respondents. Bold numbers represent the range of the utility effects for each attribute and respondent group.

Attribute Level	Deck Expo Utility Effect	Online Utility Effect
Material	**1.390**	**1.026**
Naturally Durable Softwoods	-0.273	0.103
Pressure Treated Lumber	-0.856	-0.601
Tropical Hardwoods	0.471	0.358
WPC	0.534	0.426
TMW	0.124	-0.287
Need for Maintenance	**0.304**	**0.406**
5 Hours Annually	0.155	0.176
10 Hours Annually	-0.006	0.054
15 Hours Annually	-0.149	-0.230
Durability	**0.670**	**1.461**
Lasts 5-9 Years	-0.340	-0.739
Lasts 10-14 Years	0.010	0.018
Lasts 15-20 Years	0.330	0.721
Material Cost	**0.762**	**1.316**
$4.00/ft^2	0.314	0.627
$8.00/ft^2	0.134	0.062
$12.00/ft^2	-0.448	-0.689
Environmental Certification	**0.328**	**0.462**
Certified	0.164	0.231
Not Certified	-0.164	-0.231

The overall importance of different attributes can also be evaluated using logit analysis utility effects by determining the range between individual attribute levels' utilities. The larger the range between the maximum and minimum utility effects for an attribute level, the more important that attribute is for participants' purchase decisions. Conversely, the smaller the range, the less important the attribute is. Using this technique, the most important attribute for Deck Expo respondents was *Material*, with a range of 1.39 between the most positive (WPCs) and most negative (pressure treated lumber) attribute levels (Table 26). The most important attribute for Online respondents was *Durability*, with a range of 1.46 between the most positive (lasts 15-20 years) and negative (lasts 5-9 years) attribute levels (Table 26). The least important attribute overall for both Deck Expo and Online respondents was *Need for Maintenance*, with a range of 0.29 and 0.41, respectively (Table 26).

This is consistent with a previous study where *Need for Maintenance* was also rated least important using utility effects as an indicator (Thomas, 2004). However,

another study on deck advertisements found in a print magazine from 1996-2006 found that WPC companies emphasized *Low Maintenance* the third most frequently of eight attributes and far more frequently than naturally durable softwoods or pressure treated lumber companies (Hamner et al., 2012). This means WPC companies consider the low maintenance of WPCs be a differentiating and important attribute for their material. Moreover, the results in Table 26 do not necessarily mean that *Need for Maintenance* is not important to consumers. It is possible that respondents assume that maintenance needs are inherent to the materials, thus linking their perception of the *Need for Maintenance* attribute to the *Material* attribute. In the perceptions section of the survey when *Material* was not one of the attributes being considered, *Need for Maintenance* was rated as the third most important attribute instead of the least important attribute.

Logit analysis can also provide overall attribute importance as a percentage, using the data for the range of effects within an attribute. As mentioned above, the larger the range of effects, the more importance participants place on that attribute for purchase decisions. The overall importance indicates the relative importance consumers place on that attribute compared to the other attributes included in the study (Figure 39).

Both Deck Expo and Online respondents placed the lowest importance on *Need for Maintenance* (9%), followed by *Environmental Certification* (10%) (Figure 39). Deck Expo respondents placed more importance on *Material* (40%) compared to Online respondents (22%) and placed less importance on *Durability* (19%) compared to Online respondents (31%) (Figure 39), which is consistent with the perceptions of attribute importance data, where fewer Deck Expo respondents rated *Durability* as “Extremely Important” or “Very Important” (78.7%) than Online respondents (85.8%).

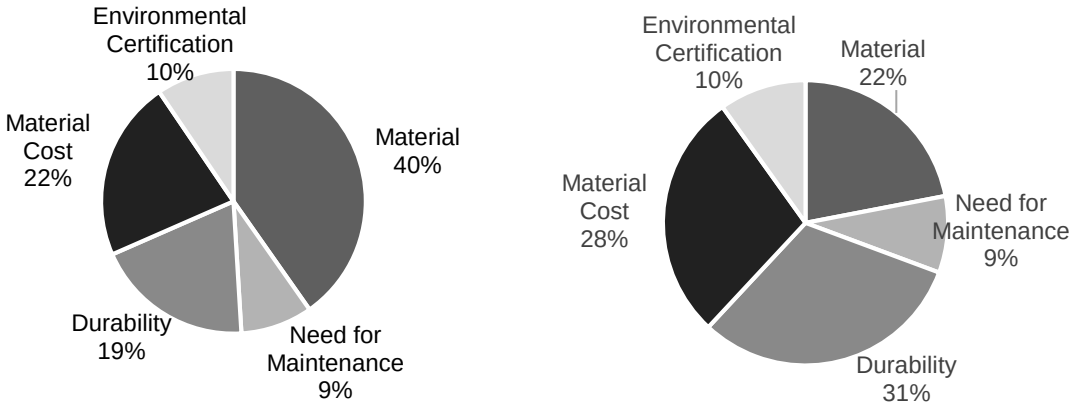

Figure 39. Overall attribute importance using logit analysis for Deck Expo (left) and Online (right) respondents.

Summary of Industry Situational Analysis

Industry Objective

The current industry objective for TMW in the U.S. is to increase market share and align consumer perceptions of the material with current scientific information on its performance.

SWOT Analysis

A SWOT analysis (Table 27) was utilized to describe the strengths, weaknesses, opportunities and threats to the TMW industry. It was compiled using a combination of literature review and data analysis from this study.

Table 27. SWOT analysis of thermally-modified wood industry.

Strengths
• Durability, aesthetics, and price comparable to tropical hardwoods • Improved durability compared to untreated material • Enhanced dimensional stability • Treatment is homogenous throughout the wood cross-section • Can be used indoors and outdoors • Real, solid, wood, with authentic, natural appearance • Heat treatment gives wood a darker, exotic appearance • Non-toxic • Sustainable • Recyclable • Benefits of solid wood and sustainable forest management • Less material needed in the long run due to added longevity from thermal treatment
Weaknesses
• Perception of TMW not being easily available • Low level of awareness among both intermediate and end consumers • Lack of industry standards • Perception of high price • Perception of brittleness • Lack of process standardization
Opportunities
• Niche market, costs are competitive with imported tropical hardwoods • TMW association could combine resources to advance industry • Growing number of environmentally-conscious customers • Growing concerns over chemical use • Growing concerns for illegal logging • Concerns for maintenance and sustainability, which the WPC industry has shown works as a promotional message • Can use both hardwoods and softwoods • Ability to use underutilized materials such as aspen • Ability to utilize species affected by invasive species, such as ash • Export markets, particularly places where wood is expensive, such as Japan • New product options such as musical instruments and gunstocks
Threats
• Substitute materials such as WPCs, tropical hardwoods, and naturally durable softwoods • Other treatments, such as acetylation (Accoya brand)

Marketing Strategy

Value Proposition

Thermally-modified wood has the potential to regain some of the lost market share of solid wood decking products because it provides a chemical-free and sustainable alternative to other competing materials. This research revealed professional consumers perceive TMW to have positive *Environmental Performance* and *Aesthetics*. These attributes will become increasingly preferred as consumers demand natural-looking and environmentally-friendly products. TMW can be differentiated from pressure treated lumber by its chemical-free treatment and ease of workability. It can be differentiated from tropical hardwoods by the potential to utilize local timber from environmentally certified forests, while having similar aesthetics. Finally, the differences between TMW and WPCs that should be promoted are the natural look and feel of solid wood, as well as superior environmental performance according to LCA studies.

Segmentation

Segmentation is a marketing technique that divides the market into groups of customers with common needs and characteristics, called market segments, and develops marketing strategies for each group, thus increasing customer satisfaction. Segmentation presents several benefits for companies. It can be used to track changes in a market, identify additional markets, and better understand competitor success; but most importantly, it allows companies to use resources more effectively, by targeting specific market segments, linking customer needs with product benefits. Sawtooth software allows to use conjoint analysis data to conduct market segmentation. This is advantageous as conjoint data reflects purchasing behavior well and thus constitutes an effective basis for segmentation. To understand segmentation data, the estimated preferences for each attribute level in a product are modeled using “utility functions” (Orme, 2010). While the initial analysis of these attribute level preferences centers the numbers on 0 and ranges from -1 to 1, the software used for analysis (Sawtooth Software, 2016) allowed for a re-scaling of the data to “zero-centered differences” with a much larger range to make utility comparison easier. An attribute level with a negative number may not be an entirely unattractive option, but rather the other levels were

better. For this analysis, intermediate, professional consumers were segmented into three groups based on psychographic information such as attitudes and preferences.

Segment 1

Segment 1 makes up 22% of the total sample, and 68% of this group described themselves as “Deck Specialists” or “Remodelers,” while no “Architects/Designers” were members of this segment (Table 29). This segment had a large percentage of respondents from smaller companies, with 55% working for businesses who employ 9 people or less (Table 29). The most common company operation locations for members of this segment includes the Northeast (41%) and Midwest (32%) (Table 29). This segment had the highest percentage of respondents who use WPCs for at least some of their projects (91%) and the lowest percentage of respondents who use TMW for at least some of their projects (0%) (Table 29). Segment 1 strongly preferred WPCs over other materials, with a WPC utility effect of 252.90 (using a “zero-centered differences” scale) compared to TMW (-102.48), pressure treated lumber (-106.07), and naturally durable softwoods (-114.62) (Table 28). Members of this group consider *Material* the most important attribute, while they are least concerned with *Durability* and *Material Cost* of all three segments, and have the lowest preferences towards a product being environmentally certified or not (Table 28). It is not anticipated that this segment will be targeted by the TMW industry because of its strong preferences towards WPCs and weak preferences for products with high environmental performance.

Segment 2

Segment 2 makes up 53% of the total sample and 77% of this group described themselves as “Deck Specialists” or “Remodelers,” with 89% indicating at least some part of their companies’ business is in remodeling (Table 29). This segment had the largest number of respondents from smaller companies, with 63% working for businesses who employ 9 people of less (Table 29). Regions where companies in this segment operate include the Northeast (40%) and the South (21%) (Table 29). Familiarity with TMW was lowest for this segment, with 49% of members reporting little or no familiarity with TMW (Table 29). Importantly, of all segments, this group was least concerned with *Material* and placed the highest attribute importance on *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental* Certification (Table 28).

Although this segment was more neutral on *Material* than the other two segments, they did demonstrate a preference for TMW (38.64) compared to other materials, followed by WPCs (21.47) (Table 28). This segment had a higher sensitivity to price because respondents ranked it as a more important attribute compared to the other two segments. This price sensitivity is consistent with Segment 2 having the highest number of members (70%) utilizing pressure treated lumber for at least some percentage of their products (Table 29).

Segment 3

Segment 3 makes up 23% of the total sample and contains the largest percentage of "Wholesale/Retail/Distribution" and "Architect/Design" members of all three groups, comprising 47% of the group (Table 29). This group has the highest proportion of people with at least some percentage of their business in single-family new construction (78%), multi-family new construction (39%), and commercial construction (52%) (Table 29). Segment 3 reported having the most companies with operations across the entire U.S. (26%) and "Other," (13%), which indicated at least some international business (Table 29). In addition, 91% of Segment 3 members reported being "Very familiar" or "Somewhat familiar" with TMW and 13% use TMW for at least some percentage of their projects, which was the highest of the three groups (Table 29). This segment also had the lowest percentage of members using WPCs for at least some percentage of their projects (61%) (Table 29) and have the lowest preference for WPCs and pressure treated lumber among all three segments (Table 28). *Material* was the most important attribute to this segment and they have favorable perceptions of tropical hardwoods (149.72) and naturally durable softwoods (78.74), with a neutral perception of TMW (7.51) (Table 28).

Table 28. Part-worth utilities for individual attribute levels rescaled to "zero-centered differences" for comparability.

	Segment 1	Segment 2	Segment 3
Relative Segment Size	22%	53%	23%
Overall Attribute Importance			
Material	73.51	14.78	63.04
Need for Maintenance	7.92	10.25	5.37
Durability	3.75	34.12	6.87
Material Cost	7.61	30.03	15.81
Environmental Certification	7.21	10.81	8.90
Material			
Naturally Durable Softwoods	-114.62	-23.41	78.74
Pressure Treated Lumber	-106.07	-35.28	-165.49
Tropical Hardwoods	70.26	-1.41	149.72
WPC	252.90	21.47	-70.48
TMW	-102.48	38.64	7.51
Need for Maintenance			
5 Hours Annually	26.12	25.21	14.75
10 Hours Annually	-12.63	0.80	-12.12
15 Hours Annually	-13.50	-26.01	-2.63
Durability			
Lasts 5-9 Years	-10.08	-86.89	-17.19
Lasts 10-14 Years	8.65	3.17	0.00
Lasts 15-20 Years	1.43	83.73	17.19
Material Cost			
$4.00/ft.^{2}	4.48	71.12	28.35
$8.00/ft.^{2}	16.79	7.93	22.36
$12.00/ft.^{2}	-21.26	-79.05	-50.70
Environmental Certification			
Certified	-18.04	27.03	22.25
Not Certified	18.04	-27.03	-22.25

Table 29. Demographic information for the three segments generated. For questions where more than one answer was allowed, percentages may add up to more than 100%.

	Segment 1	Segment 2	Segment 3
Relative Segment Size	22%	53%	23%
Respondent Profession			
Deck Specialist	41%	34%	13%
New Construction	14%	15%	13%
Remodeling	27%	43%	17%
Manufacturing	18%	8%	13%
Wholesale, Retail, Distribution	9%	13%	30%
Architect/Design	0%	6%	17%
Other	9%	11%	17%
Size of Company			
4 or fewer Employees	41%	55%	26%
5-9 Employees	14%	8%	13%
10-24 Employees	5%	11%	17%
25-49 Employees	36%	6%	26%
50-99 Employees	0%	9%	4%
100 or more Employees	5%	11%	13%
Type of Company Business			
Remodeling	86%	89%	74%
Single-Family New Construction	50%	68%	78%
Multi-Family New Construction	23%	26%	39%
Commercial	41%	34%	52%
Institutional	14%	11%	17%
Other	9%	9%	22%
Location of Company's Operations			
Midwest	32%	19%	30%
Northeast	41%	40%	30%
South	14%	21%	17%
West	5%	13%	13%
Entire U.S.	9%	13%	26%
Other	5%	8%	13%
Familiarity with TMW			
Very Familiar	23%	21%	30%
Somewhat Familiar	36%	30%	61%
Not very Familiar	36%	34%	9%
Haven't Heard of it	5%	15%	0%
Decking Materials Used			
Naturally Durable Softwoods	18%	45%	52%
Pressure Treated Lumber	45%	70%	30%
Tropical Hardwoods	18%	40%	65%
TMW	0%	4%	13%
WPC	91%	81%	61%
Plastic	41%	25%	26%
Other	5%	6%	4%

Positioning

Segments 2 and 3 are both comprised of potential TMW adopters if the marketing strategy is positioned in the correct way for each segment. Segment 3, comprised of wholesalers and designers, should be targeted first because of their influence over material selection. Segment 1 is unlikely to adopt TMW because of their strong preference for WPCs and lowest preference for *Environmental Certification* among all segments.

Segment 2 is a largely price-sensitive group, comprised of members from small companies who frequently utilize pressure treated lumber, despite viewing it least preferentially among all materials included in the survey. This segment currently has the lowest familiarity with TMW but also the most positive perception of it compared to all other materials and segment. For this reason, a positioning statement focused on this segment should aim to increase awareness of TMW while first emphasizing the similarities between pressure treated lumber and TMW, such as both being a solid wood material and gaining increased dimensional stability and resistance to biodegradation as a result of treatment. Then, TMW can be differentiated from pressure treated lumber by its potential sourcing from local forests. Before this group begins to utilize TMW, it will be important to overcome the industry's negative perception of TMW availability and cost. For this reason, this segment will likely be a secondary market segment to adopt TMW after segment 3.

Segment 3 is comprised of wholesalers, architects, and designers who consider *Material* to be the most important attribute for decking products and prefer tropical hardwoods, followed by naturally durable softwoods. A positioning statement that emphasizes the similarities between TMW and tropical hardwoods, such as similar aesthetics and price, will be important to increase market share of TMW among this segment. There is opportunity to gain market share from this group by stressing the growing number of environmentally-conscious customers who are concerned with chemicals and illegal logging from tropical countries, and suggesting TMW as an alternative to tropical hardwoods because it is non-toxic, recyclable, sustainable, and can utilize local species that come from certified forests. This group is comprised of wholesalers, architects, and designers, so it is unlikely they will be as affected by the negative perceptions of TMW having low availability and high costs as the other

segments may be. For this reason, this segment will likely be the first market segment to adopt TMW.

Product

TMW has excellent exterior performance in response to moisture changes, and thus is commonly utilized as decking, siding, flooring, pergola, and fencing products such as fence rails that do not come in direct ground contact. It also has desirable characteristics for acoustics such as reduced damping, sound velocity, “raditation ratio” and the sound properties of naturally-aged wood (Pfriem, 2015), so it may also be used for musical instruments. Another product TMW may be used for gunstocks (Espinoza et al., 2015).

These products can be made from a variety of hardwood and softwood species that have been thermally-modified. Common softwood species used for TMW include red pine (*Pinus resinosa*), southern yellow pines, and eastern white pine (*Pinus strobus*). Common hardwood species used for TMW include ash (*Fraxinus sp.)*, yellow poplar (*Liriodendron tulipifera*), elm (*Ulmus sp.*), maple (*Acer sp.*), cherry (*Prunus sp.*), oak (*Quercus sp.*), sweetgum (*Liquidambar styraciflua*), and eucalyptus (*Eucalyptus sp.*) (Espinoza et al., 2015).

Price

There is currently limited information on TMW prices in the U.S., but producers interviewed by Espinoza et al. (2015) indicated TMW is a high-end product and likely users will not be in a price-sensitive segment of the market. One producer of TMW noted prices are comparable to tropical hardwoods and naturally durable softwoods and should be positioned as a high-quality product because of this.

Results of this study indicate professional consumers currently perceive TMW prices to be high, but not as high as tropical hardwoods or WPCs. In addition, results from this study and previous research on professional consumer perceptions of decking attribute importance has consistently shown price is less important than attributes such as durability and aesthetics (Eastin et al., 2005; Ganguly & Eastin, 2009; Shook & Eastin, 2001; Thomas, 2004). For this reason, price should not be a limiting factor in

TMW success. Future research should explore professional consumers' willingness to pay for TMW to understand specific target price points for TMW producers.

Promotion

TMW should be promoted as a high-quality decking product by emphasizing its durability, aesthetics, and environmental performance. It can be positioned as a domestic alternative to tropical hardwoods because they share many attributes, including a dark, rich color. However, it will be important to distinguish TMW as locally-sourced, which may appeal to consumers.

Promotional Goals

The promotional strategy for TMW should consider that awareness among both professional and end consumers is still relatively low, and these groups of people will most likely be unfamiliar with TMW's performance and attributes. It will be important for TMW industry promotion to include a mixture of stimulating demand to create awareness and increase knowledge, as well as enhance industry image through advertising, publicity, personal selling, and sales promotion. In addition, this research demonstrated that respondents who viewed TMW decking samples in-person had more positive perceptions of it than respondents who did not. This indicated people who see TMW tend to like it more, and the industry should consider this when planning promotional events, such as trade show participation.

Promotional Mix

The most commonly used promotional channel for current TMW producers is company websites (Espinoza et al., 2015). Once a TMW association is established in the U.S., a website promoting TMW with links to specific companies would be a powerful tool for consumers to learn more about the material and increase awareness. Another potential promotional tool for increasing awareness would be advertising in industry trade magazines targeted at industry professionals (such as *Professional Deck Builder*).

A promotional channel that would be beneficial to producers would be having a presence at expo and trade show events across the U.S. to increase awareness among professional consumers. This type of promotion can be considered personal selling, which includes face-to-face presentations of information on products and sales

promotion. Appendix 5 offers a list of expo and trade show events targeted at professional consumers that would be beneficial for TMW producers to attend.

Distribution

Channels of distribution allow for efficient product transport from producers to consumers and the development of these distribution channels will be essential to the market success of TMW. Results from this study indicate deck industry professionals believe TMW is not easily available. This lack of availability may be a primary reason the U.S. TMW industry has not expanded rapidly as Europe's has. Given the small current size of the industry, establishing relationships with wholesalers and architects may be beneficial to increase awareness and make matching expected product supply with demand from the target market easier.

The geographical coverage of current TMW producers includes five companies in the Midwest, two in the South, two in the Northeast, and one in the West (Espinoza et al., 2015). This distribution of producers makes market potential in the Midwest easier, but results of this study indicate professional consumers in that region currently have the lowest preference for TMW.

Additional distribution channels may exist for other TMW product alternatives such as thermally-modified musical instruments and gunstocks. In addition, there is currently research being done at the University of Minnesota on thermally-modified oriented strand board (OSB), which could be another product providing an alternative distribution channel.

Strategic Marketing Plan Conclusions

Much more research has been conducted on the technical aspects of TMW compared to its market potential. This research sought to address some of these gaps by identifying decking industry member perceptions of thermally-modified wood using conjoint analysis, a marketing research tool used to understand how consumers make product selection decisions. A survey was administered to decking industry members using a computer-based questionnaire containing demographic, user perceptions, and conjoint analysis questions at a trade show event called the "Deck Expo" and online.

This primary data was then analyzed and used along with secondary data from previous research to compile the recommendations in this marketing plan.

Key findings of this research support results from previous studies that a majority of decking industry members work for smaller companies, employing between one and four people. In general, respondents currently utilize a wide range of decking materials for their projects, but the two materials most frequently used are wood-plastic composites (WPCs) and pressure treated lumber. Over half of respondents are “Very familiar” or “Somewhat familiar” with thermally-modified wood, but a considerable number also reported little to no familiarity with TMW, which suggests an opportunity for educating and informing this professional audience about TMW.

This research found *Durability* and *Aesthetics* to be the two most important attributes to professional consumers at this time, with *Cost of Materials* and *Environmental Performance* being less important. Overall, professional consumers surveyed for this research currently demonstrate a preference for WPCs and tropical hardwoods, and seem to have mixed perceptions of TMW. This is likely the result of unfamiliarity with TMW due to insufficient marketing efforts.

Three segments were identified based on the results from this research. One of these segments is unlikely to readily adopt TMW but the other two segments have the potential to adopt TMW if effective marketing strategies are adopted to position the material correctly. The first of these two potential adopter segments is comprised of wholesalers, architects, and designers. They have the highest current familiarity with TMW and prefer tropical hardwoods of all decking materials considered. For this segment, it will be important to differentiate TMW as a more environmentally-friendly alternative to tropical hardwoods that has similar aesthetic and price attributes. The second of the two segments with higher potential is comprised of remodelers who currently use pressure treated lumber for many of their projects, but show dissatisfaction with it compared to other decking materials. This segment currently has the lowest familiarity with TMW, so a positioning statement focused on this segment should aim to increase awareness of TMW while first emphasizing the similarities between pressure treated lumber and TMW, such as TMW’s solid-wood nature and its enhanced resistance to degradation as a result of treatment. TMW can be differentiated from pressure treated lumber by its potential sourcing from domestic forests and its improved dimensional stability.

Specific recommendations for positioning TMW were made, as well as suggestions on specific strategies for product, price, promotion, and distribution. An industry situational examination resulted in a SWOT analysis for TMW (Strengths, Weaknesses, Opportunities, and Threats).

The data collection methods of the research that led to this marketing plan had inherit limitations, including self-selection bias, and potential regional biases. In addition, the data set used was not based on a randomized sample of the population of interest, which means that the conclusions from this study cannot be statistically generalized to the entire target population of professionals in the decking industry. Finally, this marketing plan is intended to benefit the U.S. TMW industry and its communities and does not make recommendations specific to individual companies.

CHAPTER 5. CONCLUSIONS

The main objective of this research was to identify the challenges and opportunities for TMW industry expansion in the U.S. market related to professional, intermediate consumers, and formulate actions to support the growth of this emerging industry. This objective was accomplished by conducting a survey of industry members' perceptions of TMW and competing wood-based products, then formulating a marketing strategy for the U.S. TMW industry with the information collected. This chapter explores the main conclusions from this research, market strategy recommendations, limitations, and areas of future research.

Perceptions Study

This study collected data on U.S. decking industry professional consumers' demographics, perceptions of wood-based decking products, and choice-based conjoint analysis responses to understand their purchasing behavior. The demographic information suggests most businesses in the target market work as remodelers or deck specialists at smaller companies, employing between one and four people. In general, respondents utilize a wide range of decking materials for their projects, but the two materials most frequently used were wood-plastic composites (WPCs) and pressure treated lumber. Over 60% of respondents indicated familiarity with TMW, but a considerable number of respondents also reported little to no familiarity with TMW (35%), which suggests an opportunity for educating and informing this professional audience on this material.

The two most important attributes professional consumers who participated in this study considered when selecting decking materials were *Durability* and *Aesthetics*. In general, participants to this study reporting unfamiliarity with TMW's performance one several attributes.

The conjoint analysis component of the study suggested that WPCs have the highest utility effect (a buyer's liking for a product alternative) of all decking materials, followed by tropical hardwoods. Pressure treated lumber had the lowest utility effect and perceptions of TMW were neutral. The two most important attributes overall for the

conjoint analysis questions were *Material* and *Durability*, while the least important attribute was *Need for Maintenance*. However, data from the perceptions section of the survey suggests *Need for Maintenance* is important to professional consumers, but they assume a degree of need for maintenance to each material, and thus linked their perception of *Need for Maintenance* to *Material*.

Overall, professional consumers in the decking industry surveyed for this research currently show a preference toward WPCs and tropical hardwoods, and seem to have mixed perceptions about TMW. This is likely the result of insufficient marketing by the TMW industry and professional consumers' lack of awareness about the material.

Strategic Marketing Plan

Based on the data collected on professional consumer perceptions of TMW decking and competing materials, market strategy recommendations were made for the TMW industry. Three distinct consumer segments were identified. One of the three segments is unlikely to adopt TMW in the near term and should not be the focus of TMW marketing strategies at this time. The other two segments have the potential to adopt TMW if effective marketing strategies position the material correctly.

The first of these two potential adopter segments is comprised of wholesalers, architects, and designers. This group has the most familiarity with TMW and prefer tropical hardwoods of all decking materials considered. When targeting this segment, it will be important to differentiate TMW as a more environmentally-friendly alternative to tropical hardwoods, because the two materials share similar aesthetic and price attributes. The second of the two potential adopter segments will likely be secondary adopters of TMW after the first segment. This group is comprised of remodelers who currently use pressure treated lumber for many of their projects, but show dissatisfaction with it compared to other decking materials. This segment currently has the lowest familiarity with TMW, so a positioning statement focused on this segment, who placed the least importance on *Material*, should aim to increase awareness of TMW while first emphasizing the similarities between pressure treated lumber and TMW, such as both being a solid wood and having enhanced resistance to biodegradation as a result of treatment. Then, TMW can be differentiated from pressure treated lumber by its potential sourcing from local forests and improved dimensional stability.

Limitations

There are limitations to the methods and results generated from this study. First, it is likely that potential differences exist between the sample and the population because this study's data collection took place in-person at a trade show, leading to self-selection bias among participants, a lack of randomization, and a lack of understanding non-response bias. Collecting data at a trade show event may have also led to a bias resulting from the type of professional who attended the event. Trade show attendees may have had an inclination for a particular material or materials that were present at the event and therefore differed from the population of interest. In addition, the trade show event was limited in geographic scope, as attendance was expectedly higher from the region of the country where the event was held. The online data collection was similarly limited to readers of *Professional Deck Builder*, which despite having a significant readership may not accurately represent the population of interest. In addition, the total sample size of the survey was small, making generalizations to the population of interest difficult. However, the author believes that the insights from this study are nevertheless useful to increase the understanding of professional adopter's perceptions and attitudes, and for marketing strategy formulation.

Future Research

The future success of the TMW industry in the U.S. is contingent upon professional consumer acceptance and purchase of TMW products. This study assessed the attributes industry members consider most important, as well as their perceptions of TMW's performance for those attributes.

Future research should address professional consumer willingness to pay for TMW and expand the geographic scope to include more industry members. Data was collected at one trade show and among the readership of an online magazine, so future research could expand the geographical scope to include other regions and wider audience. Finally, the focus of this study included professional adopters, namely decking professionals, because these are influential on decking material decisions. Future research could include other important actors in the decking materials supply chain, such as landscape architects; and ultimately end users, whose priorities and needs may differ from those included in this research.

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APPENDIX 1. SURVEY QUESTIONNAIRE

Introduction

Welcome to the survey on professional consumer perceptions of wood decking products.

The objective of this study is to gather information on how professionals in the deck building industry perceive various attributes of wood-based exterior decking products. This research is a joint effort between University of Minnesota's Department of Bioproducts and Biosystems Engineering and the Natural Resources Research Institute. Please, bear in mind that your answers to the following questions will be kept strictly confidential and no company information will be disclosed.

Thank you for your time. If you have any questions, please feel free to let me know or contact me after the DeckExpo at gama0020@umn.edu; or my supervisor Dr. Omar Espinoza at oaespino@umn.edu.

Sincerely,

Shelby Lynn Gamache

Graduate Research Assistant
University of Minnesota
St. Paul, MN

1. *How would you describe you or your company? Select all that apply.*

- ☐ Deck Construction Specialist
- ☐ New Construction
- ☐ Remodeling
- ☐ Wholesaler/Retailer/Distributor
- ☐ Manufacturer
- ☐ Architect/Design
- ☐ Other (please specify): _____
- ☐ Do not purchase, sell, distribute, design, or work with decking materials.

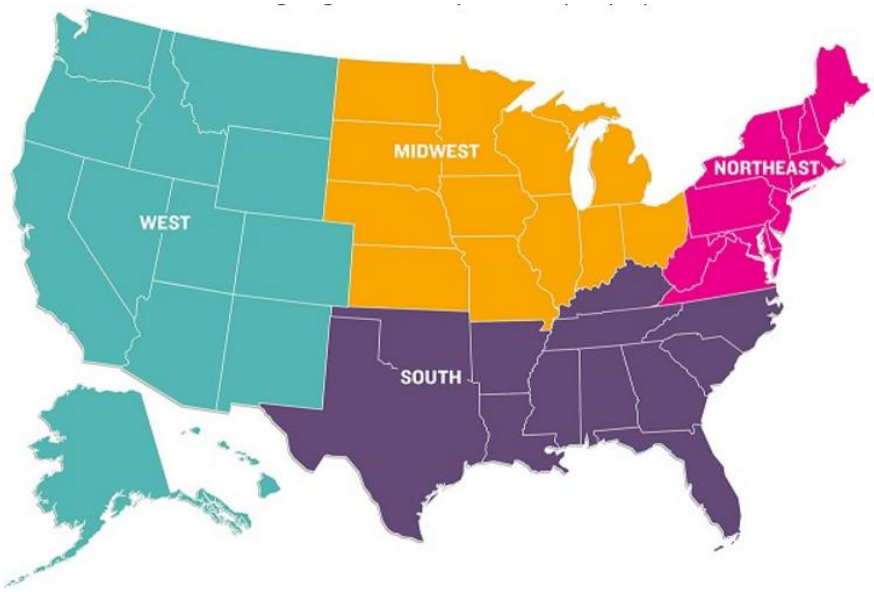
2. *Which of the following classifications best describes the size of your company?*

- ○ 1 to 4 employees
- ○ 5 to 9 employees
- ○ 10 to 19 employees
- ○ 20 to 49 employees
- ○ 50 to 99 employees
- ○ More than 100 employees

3. *What percent of your company's business is distributed within the following categories?*

- [ ] Repair and remodeling
- [ ] Single-family residential new constrction
- [ ] Multi-family residential new construction
- [ ] Commercial (e.g. stores, restaurants, etc.)
- [ ] Institutional (e.g. schools, government, etc.)
- [ ] Other (please specify): [ ]
- 0 Total

4. *In which of the following regions does your company operate? Select all that apply.*



- ☐ Midwest
- ☐ Northeast
- ☐ South
- ☐ West (including AK and HI)
- ☐ Other (please specify): _____

5. *How familiar are you with Thermally-Modified Wood?*

- ○ Very familiar
- ○ Somewhat familiar
- ○ Not very familiar
- ○ Have not heard about it

TMW Primer

What is Thermally Modified Wood?

Thermally Modified Wood (TMW) is a wood product that has been modified using a thermal modification technique that chemically alters wood by heating it to high temperatures while controlling the moisture content. TMW does not require the use of chemicals and the process is most often performed in a low-oxygen environment after initial kiln drying.

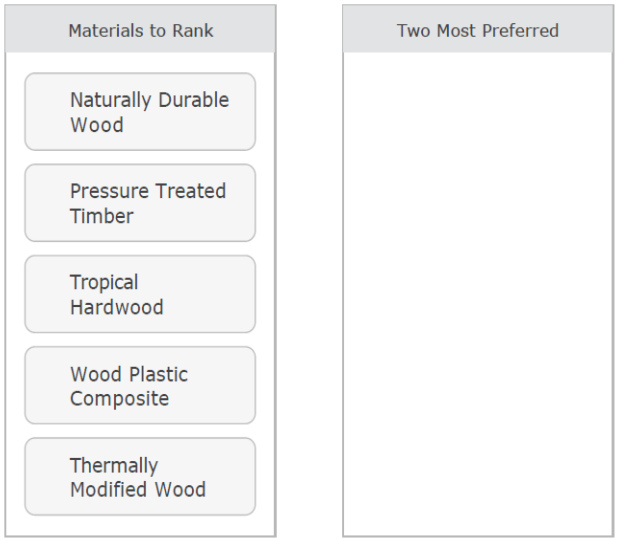
Thermal modification processing enhances wood in several ways: moisture absorption rates decrease by up to 60%, giving wood increased resistance to biological decay and increased dimensional stability. The thermal modification process also causes wood to become darker in color throughout its entire thickness, resembling attractive tropical wood tones. Scientific studies have demonstrated that TMW has a lower environmental impact than other wood products because it is a non-toxic product that achieves its performance enhancements without the use of chemicals.

TMW is suitable for many outdoor applications, such as decking, siding, and fencing because of its increased resistance to biological decay. It may also be used indoors for flooring, windows, doors, as well as indoor settings where moisture content may be high, such as bathrooms and saunas. In addition, TMW is also utilized for musical instruments and gun stocks. TMW is widely used in Europe, where it has been developed and favored due to environmental regulations.

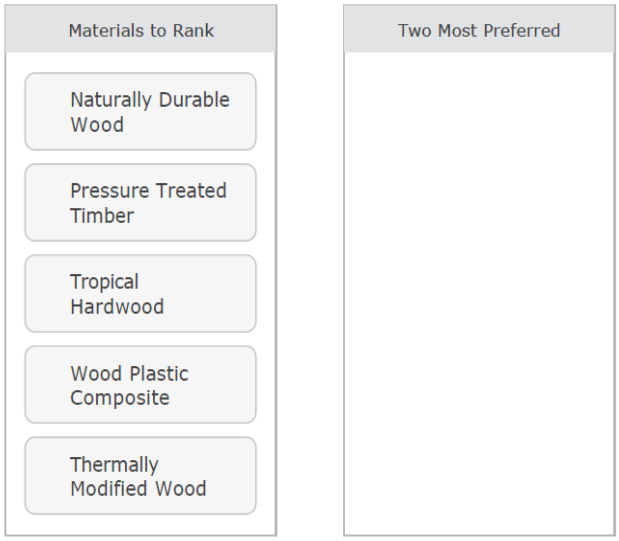
6. *What percent of your company's annual decking projects utilize the following as major materials?*

	Naturally Durable Wood (e.g. redwood, cedar)
	Pressure Treated Timber (e.g. southern yellow pine)
	Tropical Hardwoods (e.g. ipe, teak)
	Thermally Modified Wood
	Wood Plastic Composite (e.g. Trex™, Monarch™, TimberTech™, Veranda™)
	Plastic (e.g. polystyrene, PVC)
	Other (please specify):
0	Total

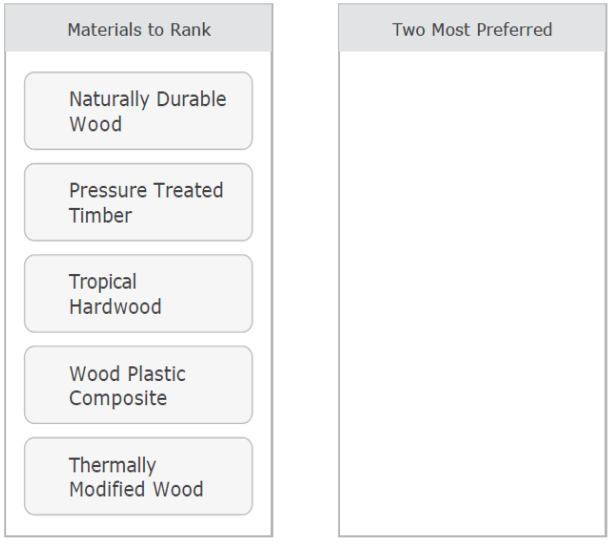
7. *Please select your **TOP TWO** choices from the following wood-based decking materials for a project with a total installation cost **UNDER $5,000** by dragging and dropping them into the empty box.*



8. *Please select your **TOP TWO** choices from the following wood-based decking materials for a project with a total installation cost **BETWEEN $5,000 and $15,000** by dragging and dropping them into the empty box.*



9. *Please select your **TOP TWO** choices from the following wood-based decking materials for a project with a total installation cost **EXCEEDING $15,000** by dragging and dropping them into the empty box.*



10. *How important are the following material attributes to you when designing, constructing, or remodeling a deck?*

ATTRIBUTES	Not at all important	Slightly Important	Somewhat important	Important	Very important	Extremely important
Need for Maintenance	○	○	○	○	○	○
Overall Cost of Materials	○	○	○	○	○	○
Durability	○	○	○	○	○	○
Aesthetics	○	○	○	○	○	○
Availability	○	○	○	○	○	○
Environmental Performance	○	○	○	○	○	○

11. *Please rate the following decking materials on their **NEED FOR MAINTENANCE** (in hours of maintenance required per year).*

	Very low maintenance	Low maintenance	Average maintenance	High maintenance	Very high maintenance	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

12. *Please rate the following decking materials on their **OVERALL COST OF MATERIALS** (including deck boards, railings, fasteners, etc.).*

	Very affordable	Affordable	Average	Expensive	Very expensive	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

13. *Please rate the performance of the following decking materials on their **DURABLITY** (number of years the deck lasts) based on your experience and perceptions.*

	Very poor durability	Poor durability	Average durability	Good durability	Very good durability	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

14. *Please rate the performance of the following decking materials on their **AESTHETICS** based on your preferences.*

	Very poor	Poor	Average	Good	Very good	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

15. *Please rate the performance of the following decking materials on their **AVAILABILITY** (how easy they are to find and purchase).*

	Very difficult to find	Somewhat difficult to find	Average availability	Easy to find	Very easy to find	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

16. *Please rate the performance of the following decking materials on their **ENVIRONMENTAL PERFORMANCE** based on your knowledge.*

	Very poor	Poor	Average	Good	Very good	Do not know
Naturally Durable Wood	○	○	○	○	○	○
Pressure Treated Timber	○	○	○	○	○	○
Tropical Hardwood	○	○	○	○	○	○
Wood Plastic Composite	○	○	○	○	○	○
Thermally Modified Wood	○	○	○	○	○	○

17. *Are you familiar with forest certification?*

- ○ Yes
- ○ No

Forest Certification Primer

Forest Certifcation ensures that the wood used to make a certified product comes from sustainably managed forests. The two forest certifciation systems in the U.S. are the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI). Certified products usually carry a logo or stamp (see below).

Conjoint Analysis Introduction

In the next section, we would like you to imagine that you are considering purchasing decking materials for your next project. We'll show you a description of different decking materials, and ask **which one you would choose**.

Some of the materials you are going to see **may not be currently available on the market** and **may combine characteristics that you would not normally see together**, but we'd like you to **imagine that they were available today**. It is important that you answer in the way you would if you were **actually buying decking materials**.

If you wouldn't purchase any of the materials we will show you, you can indicate that by choosing "None." By choosing "None," you indicate that you would buy other materials that are not listed, or you would continue using existing products.

CBC Random #1: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(1 of 12)

Material	Thermally Modified Wood	Pressure Treated Timber	Pressure Treated Timber	Naturally Durable Wood	
Need for Maintenance	10 hours annually	5 hours annually	5 hours annually	15 hours annually	
Durability	Lasts 15-20 years	Lasts 15-20 years	Lasts 10-14 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Certified	Not Certified	Certified	Certified	
	○	○	○	○	○

CBC Random #2: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(2 of 12)

Material	Naturally Durable Wood	Wood Plastic Composite	Tropical Hardwood	Tropical Hardwood	
Need for Maintenance	10 hours annually	15 hours annually	5 hours annually	10 hours annually	
Durability	Lasts 10-14 years	Lasts 10-14 years	Lasts 5-9 years	Lasts 15-20 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$8.00 per square ft.	$4.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Certified	Not Certified	Not Certified	Certified	
	○	○	○	○	○

CBC Random #3: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(3 of 12)

Material	Pressure Treated Timber	Tropical Hardwood	Thermally Modified Wood	Wood Plastic Composite	
Need for Maintenance	5 hours annually	15 hours annually	15 hours annually	10 hours annually	
Durability	Lasts 15-20 years	Lasts 10-14 years	Lasts 15-20 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$12.00 per square ft.	$8.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Not Certified	Certified	Certified	Not Certified	
	○	○	○	○	○

CBC Random #4: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(4 of 12)

Material	Tropical Hardwood	Pressure Treated Timber	Wood Plastic Composite	Thermally Modified Wood	
Need for Maintenance	10 hours annually	15 hours annually	5 hours annually	15 hours annually	
Durability	Lasts 5-9 years	Lasts 5-9 years	Lasts 10-14 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$4.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Certified	Certified	Not Certified	Not Certified	
	○	○	○	○	○

CBC Random #5: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(5 of 12)

Material	Thermally Modified Wood	Wood Plastic Composite	Naturally Durable Wood	Pressure Treated Timber	
Need for Maintenance	5 hours annually	5 hours annually	10 hours annually	10 hours annually	
Durability	Lasts 15-20 years	Lasts 10-14 years	Lasts 15-20 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$12.00 per square ft.	$4.00 per square ft.	$8.00 per square ft.	$8.00 per square ft.	
Environmental Certification	Certified	Not Certified	Not Certified	Certified	
	○	○	○	○	○

CBC Random #6: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(6 of 12)

Material	Naturally Durable Wood	Pressure Treated Timber	Wood Plastic Composite	Tropical Hardwood	
Need for Maintenance	15 hours annually	5 hours annually	15 hours annually	15 hours annually	
Durability	Lasts 15-20 years	Lasts 10-14 years	Lasts 10-14 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$4.00 per square ft.	$12.00 per square ft.	$8.00 per square ft.	
Environmental Certification	Not Certified	Certified	Not Certified	Certified	
	○	○	○	○	○

CBC Random #7: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(7 of 12)

Material	Thermally Modified Wood	Wood Plastic Composite	Tropical Hardwood	Naturally Durable Wood	
Need for Maintenance	10 hours annually	10 hours annually	5 hours annually	15 hours annually	
Durability	Lasts 10-14 years	Lasts 15-20 years	Lasts 15-20 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$8.00 per square ft.	$4.00 per square ft.	$8.00 per square ft.	$4.00 per square ft.	
Environmental Certification	Not Certified	Not Certified	Certified	Certified	
	○	○	○	○	○

CBC Random #8: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(8 of 12)

Material	Pressure Treated Timber	Pressure Treated Timber	Naturally Durable Wood	Wood Plastic Composite	
Need for Maintenance	10 hours annually	15 hours annually	5 hours annually	10 hours annually	
Durability	Lasts 10-14 years	Lasts 15-20 years	Lasts 10-14 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Certified	Certified	Certified	Not Certified	
	○	○	○	○	○

CBC Random #9: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(9 of 12)

Material	Wood Plastic Composite	Pressure Treated Timber	Tropical Hardwood	Thermally Modified Wood	
Need for Maintenance	5 hours annually	10 hours annually	5 hours annually	15 hours annually	
Durability	Lasts 15-20 years	Lasts 5-9 years	Lasts 10-14 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$4.00 per square ft.	$12.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Not Certified	Not Certified	Not Certified	Certified	
	○	○	○	○	○

CBC Random #10: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(10 of 12)

Material	Pressure Treated Timber	Wood Plastic Composite	Naturally Durable Wood	Tropical Hardwood	
Need for Maintenance	15 hours annually	5 hours annually	10 hours annually	5 hours annually	
Durability	Lasts 10-14 years	Lasts 5-9 years	Lasts 15-20 years	Lasts 5-9 years	NONE: I wouldn't choose any of these.
Material Cost	$12.00 per square ft.	$8.00 per square ft.	$8.00 per square ft.	$12.00 per square ft.	
Environmental Certification	Certified	Not Certified	Certified	Not Certified	
	○	○	○	○	○

CBC Random #11: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(11 of 12)

Material	Naturally Durable Wood	Tropical Hardwood	Thermally Modified Wood	Pressure Treated Timber	NONE: I wouldn't choose any of these.
Need for Maintenance	15 hours annually	10 hours annually	5 hours annually	15 hours annually	
Durability	Lasts 10-14 years	Lasts 15-20 years	Lasts 10-14 years	Lasts 5-9 years	
Material Cost	$4.00 per square ft.	$4.00 per square ft.	$12.00 per square ft.	$4.00 per square ft.	
Environmental Certification	Not Certified	Certified	Not Certified	Not Certified	
	○	○	○	○	○

CBC Random #12: If these were your only options, which would you choose? Choose by clicking one of the buttons below.

(12 of 12)

Material	Tropical Hardwood	Thermally Modified Wood	Thermally Modified Wood	Naturally Durable Wood	NONE: I wouldn't choose any of these.
Need for Maintenance	10 hours annually	10 hours annually	5 hours annually	10 hours annually	
Durability	Lasts 15-20 years	Lasts 15-20 years	Lasts 5-9 years	Lasts 10-14 years	
Material Cost	$12.00 per square ft.	$8.00 per square ft.	$8.00 per square ft.	$4.00 per square ft.	
Environmental Certification	Certified	Not Certified	Certified	Certified	
	○	○	○	○	○

18. *Additional comments on any of the wood-based decking products mentioned in this survey or comments on the decking industry in general you would like to add:*

19. *If you would like to receive a report of this study, please enter your email address below.*

20. *If you would like to be considered for the Amazon Gift Card Drawing, please enter your email address below.*

APPENDIX 2. IRB APPROVAL

IRB Determination

Jp <perke001@umn.edu> Wed, Sep 14, 2016 at 11:06 AM
To: Shelby Gamache <gama0020@umn.edu>

Hello Shelby,

I have reviewed your recent IRB Determination submission and have determined that no further review is required as the project does not meet the definition of human subjects research since the data collected is focused on materials and not the participants themselves personally.

The stamped form indicating this decision is attached.

--
Jeffery Perkey, MLS, CIP
IRB Analyst
Human Research Protection Program
University of Minnesota
direct line 612-626-5922
front desk 612-626-5654
irb@umn.edu

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APPENDIX 3. THERMALLY-MODIFIED WOOD PRODUCERS WORLDWIDE

Table 30. List of TMW producers worldwide by county. Information from: Feng (2016) and (Wolfram Scheiding, 2016).

Country	Producer	Website
Austria	Eiterbichler Zipf	www.hotholz.at
	Mafi Holzverarbeitung GmbH	https://mafi.com/en
	Mirako	http://www.mirako.at/index.php/en/
	Stia AG	www.stia.at
	Thermoholz Aberger KG	www.thermoholz-aberger.at
	Tilo GmbH	www.tilo.at
Brazil	VAP Holzsysteme®	N/A
China	Dongli Wood Industry	http://www.020dongli.com/
	Jizhong Industry	http://www.shizhong.com/
	Nature International Group Ltd.	http://nature86.com
	ChenLu	http://www.chenlumuye.com
	LvZe	http://muguaban88.com
Canada	Bois Perdure	http://www.perdure.com/
	Kisis	http://www.kisistechnologies.com/
	Weston Premium Wood	http://westonpremiumwoods.com/
Czech Republic	X-Hotwood	http://www.x-hotwood.com/
	FHS Frisch (bei Plzen)	N/A
	TimelessTimber	N/A
Denmark	Celloc	http://celloc.dk/
	Moldrup Systems Pte Ltd	http://www.moldrup.com/
Estonia	Brenstol Oü	http://thermory.com/
	HaServ Oü reola	http://www.haserv.ee/et/
	Priit Pütt Oü	http://www.hardwood.ee/en/
	Thermoarena Oü	http://thermoarena.com/
Finland	Sahakuutio Oy	http://www.sahakuutio.fi/fi/etusivu/
	Heinolan Ruskopuu Oy	http://www.ekoaspen.com/etusivu
	HJT-Holz Oy	http://www.hjt-holz.com/thermoholz/
	Metsä Wood	http://www.metsawood.com/
	Oy Lunawood Ltd	http://www.lunawood.com
	Stora Enso Wood Products	www.storaenso.com
	SWM-Wood Oy	http://www.swm-wood.com/en/swm-wood-2/
	Suomen Lämpöpuu Oy SLP	http://www.suomenlampopuu.com/en/
	UPM Kymmene Oyi	http://www.wisaplywood.com/fi/Pages/Default.aspx
France	Eurochêne	http://www.eurochene.com/
	Ducerf	http://www.ducerf.com/
	CRITT Bois	http://www.crittbois.com/
	BOISBMT	http://www.dumoulin-bois.fr/
	KIT FORET	http://www.kit-foret.fr/
	Stabilprocess	http://fr.stabilprocess.com/
	Retiwood	N/A

Region	Producer	Website
France	Jouen Frères	http://www.jouen-freres.fr/
	Sivalbp S.A.	http://www.sivalbp.fr/
Germany	MHD Menz Holz Design GmbH	N/A
	Holzindustrie Templin	http://www.hitemplin.com/
	Firstwood GmbH	http://www.firstwood.de/index.php
	Holzbodenwerk Krottenthaler	http://www.holzbodenwerk.de/
	Timura Holzmanufakter GmbH	http://www.timura.de/
	BES Bad Essener Säglwerk	http://www.bad-essener-saegewerk.de/
	OWI GmbH	http://www.owi-lohr.de/
	JEP HARDWOOD FLOORING	http://www.jep-parkett.de/
Italy	Florian Legno	http://www.florianinc.com/en/
	WDE Manspell	http://www.wde-maspell.com/
Japan	Koshii & Co. Ltd.	http://www.koshii.com/
Latvia	TermoWood Ex	http://www.termowoodex.com/
Lithuania	UAB Volunta Parket Vilnius	http://www.voluntaparket.lt/
Netherlands	Elder-oak	https://www.elder-oak.com/
	Firmolin Technologies Ltd	http://www.firmolin.com/index.php/nl-nl/
	Platowood	http://www.platowood.com/
New Zealand	Tunnicliffe's	http://www.tunnicliffes.co.nz/
Norway	Marnar Bruk Royal	http://marnarbruk.no/
Poland	TARTAK Stephen	http://www.tartakstefan.pl/v2/index.php
Portugal	Atlantic Wood	http://atlanticwood.pt/
	Palser	http://www.palser.eu/
Romania	J.F. Furnir SRL, Brasov	http://www.jffurnir.com/en/
Russia	Sudoma Sawmill	http://en.sudomasawmill.com/
Slovenia	Silvaprodukt	http://en.silvaprodukt.si/
Spain	De Buena Madera	http://www.grupo-gamiz.com/
	Thermogenik	http://www.termogenik/com/index.php
Sweden	Heatwood	http://www.heatwood.se/en/
	Thermoplus AB	N/A
Switzerland	Balz Maschinen AG	http://www.balz-holz.ch/
	ETS Röthlisberger SA	http://www.corbat-holding.ch/
Turkey	NovaWood	http://www.novawood.com/
	Arin Orman	http://www.arin.com.tr/
	NasWood	http://www.nasreddingroup.com/
U.K.	Brimstonewood	http://www.brimstonewood.co.uk/
U.S.	Thermory USA	http://www.thermoryusa.com/home
	EcoVantage	http://www.ecovantagewood.com/
	Bailey Wood Products	http://www.baileywp.com/
	Cambia	http://www.cambiawood.com/
	Arbor Wood Co.	http://arborwoodco.com/
	Northland Forest Products	http://www.northlandforest.com/
	Pakari	http://www.pakaritmd.com/
	Superior ThermoWood	N/A

APPENDIX 4. THERMALLY-MODIFIED WOOD EQUIPMENT MANUFACTURERS

Table 31. Most common brands of thermal-modification kiln providers in North America and Europe that provide both "open" (non-pressurized) and "closed" (pressurized) systems.

Company/Brand Name	Type of System	Country of Origin	Website
Jartek	Open (ThermoWood®)	Finland	http://www.jartek.fi/main-page
Luxhammer	Open (ThermoWood®)	Finland	http://www.luxhammar.com/
Valutec	Open (ThermoWood®)	Sweden	http://www.valutec.ca/
Mahild Drying Technologies	Open	Germany	http://www.mahild.com/index.php/en/
MEC Torrefaction	Open	Canada	http://www.mectorrefaction.com/company.html
Westwood	Open	United States	http://www.westwoodcorporation.com/
WTT	Closed	The Netherlands	http://www.wtt.dk/products/thermo-treatment
FirmoLin Technologies	Closed	The Netherlands	http://www.firmolin.com/index.php/en/
Huber Holz	Closed	Austria	http://huber-holz.at/

APPENDIX 5. LIST OF INDUSTRY-FOCUSED TRADE SHOWS AND EXPOS

American Institute of Architects (AIA) Conference of Architecture

- About: Every year, the AIA Conference on Architecture attracts thousands of architects and design professionals—a collection of talented and visionary individuals who are dedicated to improving the quality of life for all people in all communities.
- Upcoming Dates and Venue: Javits Center, New York, NY. June 21st-23rd, 2018.
- Website: http://conferenceonarchitecture.com/

Construction Super Conference

- About: The Construction SuperConference, now in its 32nd year, is recognized as the preeminent construction conference developed for mid- to senior-level professionals who work in any of the legal and commercial construction markets. Impactful plenary sessions and compelling panel discussions from top legal, consulting, and leaders of construction companies bring to the forefront challenging issues and new insights into the legal, business, and economic challenges and opportunities in today's construction industry. Participants will walk away with invaluable information and resources to assist them in meeting today's challenges. The conference will showcase many notable and expert in-house and outside construction counselors and consultants who will take up the many challenges of advising construction industry participants in a challenging economy. The program design of the conference allows ample opportunity to meet and network with representatives from the leading construction firms and the industry's top construction attorneys.
- Upcoming Dates and Venue: The Encore at Wynn- Las Vegas, NV. December 4th-6th 2017.
- Website: http://www.constructionsuperconference.com/

DeckExpo

- About: Remodeling Show | DeckExpo | JLC LIVE (R|D|J) is an annual trade-only residential construction mega-event that provides remodelers, deck builders, and other industry professionals with a vibrant exhibit hall filled with nearly 300 products and services from leading industry manufacturers, a strong educational conference program with business and job site training, and networking events every day of the event. Among the hundreds of exhibitors, the exhibit hall features LIVE installation clinics presented by leading industry professionals, interactive, hands-on workshops, and instructional exhibitor-led product demonstrations. Forge new relationships with product manufacturers on the exhibit hall floor, fellow construction professionals in the educational conference sessions, and during social functions like the Welcome Party, NAHB event, and other less formal get-togethers during the week.
- Upcoming Dates and Venue: Music City Center- Nashville, TN. October 25th-27th, 2017.
- Website: https://remodelingdeck.com/

East Coast Builders Conference (ECBC)

- About: The East Coast Builders Conference is today's residential building, remodeling and construction industry "must attend" conference event offering meaningful education that will help you enhance and advance the future for your company, shareholders, employees and your clients. Featuring educational tracks on Building, Remodeling, Design, Business and Kitchen and Bath, the ECBC sessions within these tracks will take a deep dive into current topics, such as Aging in Place, Technology, Legal, Subs & Trades and Marketing. Can't make it for a full day? Don't worry, watch our website as we will be adding mini educational sessions that will take place throughout the Exposition days! Join us at the ECBC in Atlanta, the only educational offering on the East Coast that offers you the opportunity to expand your knowledge, share your ideas, learn from your peers and help shape the future of the industry
- Upcoming Dates and Venue: Cobb Galleria Centre- Atlanta, GA. May 4th-5th, 2017.
- Website: http://ecbcshow.com/

FENCETECH

- About: The American Fence Association has been serving the fence, deck, railing and security industry since 1962. AFA is the largest and most comprehensive resource in the industry for the latest developments, tools, materials, standards, trends and discounts. FenceTech showcases products like aesthetic appearance of modern fence products, wood fence materials and accessories, gate operators & access control, security fence and access control, stainless steel cable, rod, mesh, and specialty products etc. in the Industrial Products, Security & Defense industries.
- Upcoming Dates and Venues: Phoenix Convention Center- Phoenix, AZ. February 5th-9th, 2018.
- Website: http://www.americanfenceassociation.com/fencetech/

Greenbuild International Conference and Expo

- About: "All In" encompasses the breadth of the sustainability and green building movement. Capturing all people, all sectors, all industries, all buildings, all cities and so much more, this theme welcomes everyone to grow as green building champions, and to do so at Greenbuild. When we come together at Greenbuild, we are one community of professionals, advocates and practitioners, students and teachers, designers and builders, and everything in between. We are all in. We invite people from every walk of life, from all over the globe, to learn with us and to help elevate green building principles and practices to the next level. "All In" also describes the depth of commitment we feel to our community and to our mission. We leave no stone unturned in our pursuit of what's next — new technology, new ideas and new ways forward. We are dedicated to transforming the market and changing the way the people all over the world experience buildings. We are all in.
- Upcoming Dates and Venue: Boston Convention and Exhibition Center- Boston, MA. November 8th-10th, 2017. McCormick Place (West Building)- Chicago, IL. November 14th-16th, 2018. Georgia World Congress Center- Atlanta, GA. November 20th-22nd, 2019.
- Website: https://greenbuildexpo.com/

International Builders Show™ (IBS)

- About: The International Builders' Show is organized by the National Association of Home Builders (NAHB) and is the largest light construction building industry tradeshow in the United States.
- Upcoming Dates and Venue: Orange County Convention Center- Orlando, FL. January 9th-11th, 2018.
- Website: https://buildersshow.com/Home/

International Woodworking Fair (IWF)

- About: The International Woodworking Fair is one of the top woodworking trade shows in the world for the furniture manufacturing, architectural woodwork, custom and general woodworking industries. Companies exhibiting at IWF include manufacturers, suppliers and retailers from the wood, plastic and related material processing industries. This premium trade show attracts thousands of visitors looking for the best technologies, supplies and products to support their ventures.
- Upcoming Dates and Venue: Georgia World Congress- Atlanta, GA. August 22nd-25th, 2018.
- Website: http://www.iwfatlanta.com/

Pacific Coast Builders Conference (PCBC®)

- About: Dedicated to advancing the art, science and business of housing, PCBC is the largest homebuilding tradeshow representing the west coast region. Launched in 1959 as a small educational conference at the Sheraton Palace Hotel in San Francisco, PCBC is now an annual two-day conference, product display and business exchange and is open to anyone professionally involved in the building industry, including builders, developers, architects, remodelers, designers, contractors, dealers/distributors and suppliers/manufacturers. In the past, PCBC was an acronym for "Pacific Coast Builders Conference". Over time the name became an inaccurate reflection of the audience, as the show now draws attendees from all over the United States, Canada, Mexico and more than 25 other countries. Today the show is known simply as PCBC. PCBC alternates each year between San Francisco and San Diego and has been endorsed as the official show of Leading Builders of

America (LBA), whose membership includes 20 of the largest publicly and privately held homebuilders in the nation.

- Upcoming Dates and Venue: Moscone Center- San Francisco, CA. June 26th-28th, 2018 and May 28th-30th, 2019.
- Website: http://www.pcbc.com/

Sunbelt Builders Show™

- About: The Sunbelt Builders Show™ is one of the largest building industry events in North America and is owned and operated by the Texas Association of Builders. The award-winning Show draws thousands of residential construction industry professionals from the United States, Canada and Mexico to more than 200 exhibit booths. Additionally, the Show features special networking events, keynote speakers, quality educational sessions and a solid sales and marketing atmosphere. Imagine an event powerful enough to lead an industry and reshape communities across the region. Imagine a gathering of thousands of residential construction professionals from every sector of the housing industry. Every year, more than 2,000 leaders in single and multi-family building, remodeling, land development, finance and management come together to share the latest information, exchange ideas, and foster lasting personal and professional relationships.
- Upcoming Dates and Venue: Hilton Anatole- Dallas, TX. August 2nd-3rd, 2017.
- Website: http://www.sunbeltbuildersshow.com/home

Woodworks™: Wood Products Council

- About: WoodWorks offers a wide range of in-person and online training opportunities, from Wood Solutions Fairs that include concurrent seminars and a trade show, to half-day workshops, lunchtime seminars and webinars.
- Website: http://www.woodworks.org/events-calendar/upcoming/

APPENDIX 6. RESOURCES

Natural Resources Research Institute (NRRI)

- About: Focuses on delivering research solutions to balance the economy, resources, and environment for resilient communities.
- Address: 5013 Miller Trunk Hwy Duluth, MN 55811
- Website: https://www.nrri.umn.edu/
- Email: nrriinfo@d.umn.edu
- Phone: (800) 234-0054 and (218) 778-2694

Forest Products Management Development Institute (FPMDI)

- About: Seeks to increase knowledge of wood products production and use, and associated issues strategies, and technologies on the part of forest products industry employees, key forest products consumer groups, and those involved in shaping national and regional forest policy.
- Address: Kaufert Lab 2004 Folwell Ave. St. Paul, MN 55108
- Website: http://fpmdi.bbe.umn.edu/
- Email: oaespino@umn.edu

U.S. Forest Service Forest Products Laboratory

- About: Mission is to identify and conduct innovative wood and fiber utilization research that contributes to conservation and productivity of the forest resource, thereby sustaining forests, the economy, and quality of life.
- Address: Forest Products Laboratory One Gifford Pinchot Drive Madison, WI 53726
- Website: https://www.fpl.fs.fed.us/index.php
- Email: mailroom_forest_products_laboratory@fs.fed.us
- Phone: (608) 231-9200