Professional Consumer Perceptions about Thermally Modified Wood

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Thermal modification of wood is a chemical-free treatment that results in improved durability, enhanced dimensional stability, and a change in color throughout the entire thickness of the wood. Thermally Modified Wood (TMW) provides an opportunity for sustainable and value-added uses for timber resources that are underutilized or affected by disease or pests. TMW has commercial success in Europe, but it is in the early stages of market adoption in the United States. The main goal of this research was to identify the challenges and opportunities for TMW in the U.S. by investigating professional adopters' perceptions of various decking materials, including thermally modified wood. In-person and online surveys were conducted for this purpose. Participants perceived that the most favorable attributes of TMW are *Durability*, *Environmental Performance*, and *Aesthetics*. Professional users of decking materials also considered the *Cost* of TMW to be relatively high, but competitive with that of tropical hardwoods and wood-plastic composites. A block of conjoint analysis questions helped to uncover the target audience's priorities and tradeoffs that they are willing to make between the different product attributes. Results from this research are useful to inform the formulation of effective marketing strategies.

Keywords: Thermally modified wood; Thermally modified timber; Consumer perception; Conjoint analysis; Decking; Marketing

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INTRODUCTION

Civilizations have known for centuries that heating wood changes its properties. This knowledge was used, for example, to make wood more durable for outdoor applications by burning its surface (Lennon 2011). Thermal modification of wood has been scientifically investigated since the 1930s (Hill 2011). In thermal modification, wood is subject to relatively high temperatures under controlled conditions, which leads to changes in the chemical and physical properties of wood (Rapp and Sailer 2001; Finnish ThermoWood Association 2003; Leitch 2009).

Because of thermal modification, some of wood's properties are enhanced, such as dimensional stability and resistance to decay (Table 1). This makes Thermally Modified Wood (TMW) suitable for exterior applications, such as decking and siding. Thermal modification also causes a loss in weight and mechanical strength (Table 1); thus, TMW may not be suitable for applications where structural performance is critical, such as support beams. Table 1 lists some of the advantages and disadvantages of TMW as a raw material for value-added products, as indicated in the literature.

Table 1. Changes in Wood Properties from Thermal Modification

Property	Reference
--- Enhanced Properties ---	
Reduced equilibrium moisture content: swelling and shrinking due to moisture	Sinoven *et al.* (2002); Hakkou *et al.* (2005); Kocaefe *et al.* (2008)
Improved resistance to biological decay	Rapp and Sailer (2001); Sinoven *et al.* (2002); Weiland and Guyonnet (2003); Kocaefe *et al.* (2008)
Darkening of color throughout entire thickness, often resembling the look of tropical hardwoods	Repellin and Guyonnet (2005); Kocaefe *et al.* (2008); Ross (2010)
Reduced emissions during use due to elimination of many volatile compounds	Repellin and Guyonnet (2005)
Improved dimensional stability	Tjeerdsma *et al.* (1971); Rapp and Sailer (2001); Sinoven *et al.* (2002); Weiland and Guyonnet (2003); Hakkou *et al.* (2005); Kocaefe *et al.* (2008)
--- Negative Impacts ---	
Increased brittleness and cracking	Rapp and Sailer (2001)
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 (2001)
Low UV resistance of the heat-related brown hue during use, leading to graying/fading of the wood's color	Rapp and Sailer (2001)

Product development and commercial success of TMW were achieved in Europe in the 1990s. There are now more than 118 estimated producers (Scheiding 2014) in Europe and Russia, and the latest figures available indicate an annual production capacity of 400,000 m^3 (Scheiding 2015). 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 addition, Europe has an International ThermoWood® Association, which represents TMW producers and equipment manufacturers that use the ThermoWood® process. It 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).

In the U.S., the market for TMW is still in its early stages of adoption, with low awareness among intermediate and final users, only 12 producers (authors' unpublished research), and no industry standards or associations that represent TMW manufacturing or distributing companies. TMW has the potential to create and expand U.S. markets for traditionally underutilized and low-value timber, such as small-diameter logs and insect-infected trees. Some have suggested the enhanced properties and environmental performance of TMW make it an economically viable use for many U.S. wood species, as well as a sustainable and chemical free alternative to non-structural pressure treated lumber, imported tropical hardwoods, and competing materials containing petrochemicals such as polyvinyl chloride (PVC) and wood-plastic composites (WPCs).

The goal 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 growth of the TMW industry. To achieve this objective, the priorities and perceptions of potential professional adopters of TMW products were identified by comparing TMW to competing wood-based products.

METHODOLOGY

To accomplish the research objectives, in-person and online surveys were conducted in the fall of 2016 among professional users of decking materials. Decking was chosen as the product for this study due to the suitability of TMW for this application, and the large size and growth potential of the market, which was estimated to be $3 billion in 2011 (Kouteran 2011).

Sample Frame

The target audience for this study was comprised of professional adopters of decking materials, including deck builders, residential contractors, and remodelers, as well as wholesalers, retailers, distributors, manufacturers, and architects/designers. Professional consumers were targeted because of their important and influential role in the material selection and construction of exterior decks. Nearly 80% of decks are installed by professionals, and 46% of decks built with new construction homes are subcontracted out to professionals by the homebuilders (Ganguly and Eastin 2009).

Questionnaire Development

The main research instrument used in this project was a questionnaire created through an iterative process. An initial version of the questionnaire was drafted based on the project objectives, literature review, and help from experienced industry members. The draft was submitted to four academic reviewers and industry professionals, and changes were made based on their feedback. Finally, the survey was transferred into Sawtooth Software's Lighthouse Studio (Sawtooth Software 9.4.0, Orem, UT, USA), and a conjoint analysis question block was added using the software's design tools. Sawtooth is a software developed for conjoint analysis survey design, distribution, and analysis, *via* the internet or a computer. Conjoint analysis is a marketing research method for analyzing consumer preferences and trade-offs among competing products (Green *et al.* 2001). For this study, participants were presented with a block of Choice-Based Conjoint Analysis (CBC) questions. CBC is one variation of conjoint analysis where respondents are presented with a number of product concepts at a time, and are then asked to select one according to their preferences (Orme 2010).

The survey instrument was further refined by conducting a testing event at the Natural Resources Research Institute (NRRI) in Duluth, Minnesota, attended by industry members from the intended audience. Participants to the testing event were asked to provide their feedback on the questionnaire's clarity, relevance, and time required for its completion. The questionnaire contained three major sections: demographic information, user perceptions, and a CBC block. Table 2 lists the major sections of the questionnaire, its components, and the measurement scales that were used.

Table 2. 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, 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, and Environmental Certification	Choice-Based Conjoint Analysis (CBC) random task

Survey Implementation

The data collection was conducted in-person at the Deck Expo trade show in Baltimore, Maryland, in October of 2016, and online through a link posted in *Professional Deck Builder* magazine. Trade show attendees included residential construction professionals, professional deck builders, railing professionals, remodelers, general contractors, and other specialty contractors. Product samples of TMW exterior decking and other wood-based decking materials were fabricated at the Natural Resources Research Institute (NRRI) in Duluth, Minnesota, to use during the in-person Deck Expo data collection. The materials chosen for the deck were representative of the materials included in the questionnaire, and included: Thermally modified aspen (*Populus tremuloides*) and ash (*Fraxinus* spp.), pressure-treated Southern pine (*Pinus* spp.), imported tropical hardwood-ipe (*Tabebuia impetiginosa*), naturally durable softwood-Western red cedar (*Thuja plicata*), and wood-plastic composite (WPC). A booth was setup at the Deck Expo and attendees were asked to observe the six decking samples, then complete the questionnaire using a laptop computer to enter their answers.

Data Analysis

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 (Microsoft, Redmond, WA, USA) and SPSS (IBM, Armonk, NY, U.S.), respectively. CBC analysis in Lighthouse Studio (Sawtooth Software 9.4.0, Orem, UT, USA) was used to process 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).

Study 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 they approached the booth and volunteered to participate in the study. This may have led to self-selection bias; thus, potential differences may exist between the sample and the population. Collecting data at the Deck Expo may also have led to a bias resulting from the types of professionals that attend this event. 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. The location of the Deck Expo event (Baltimore, Maryland) may have also caused an over-representation of participants surrounding the event's location. The Online data collection was limited to readers of *Professional Deck Builder*, which, despite having a significant readership (18,000 according to the editor) may not accurately represent the population of interest. Because of these limitations, generalizations to the population of interest cannot be made. Moreover, because of the way participants were recruited, a non-response bias analysis could not be performed. However, the authors believe the insights from this study are useful to increase the understanding of professional adopters' perceptions and attitudes towards TMW and other competing decking materials. In addition, conjoint analysis is a proven methodology used in social sciences, including marketing and management, and efforts were made to create a reliable and valid research instrument through feedback from experts and industry members, as well as conducting a testing event of the questionnaire.

RESULTS AND DISCUSSION

In total, 63 responses were collected from the Deck Expo data collection event, out of which two incomplete responses were dropped from the analysis. A total of 70 responses were collected online but only 42 were included in the analysis, as 27 incomplete responses were dropped. Incomplete responses included any responses that did not complete the demographic and perception sections of the survey. A response rate calculation or non-response bias analysis could not be carried out for the reasons detailed in the previous section.

Demographic Information

The first section of the questionnaire included seven demographic questions on type of company and main industry segment, location and size of company, and prior experience with the materials included in the study. Table 3 contains a summary of responses to the demographic questions.

When asked how they would describe their company, both Deck Expo and Online respondents reported "Remodeling" and "Deck Specialist" as the top two areas of businesses for their companies. No significant differences were found between responses from Deck Expo and Online participants ($\chi^2 = 10.34$, *p-value* = 0.111). When participants were asked how their company's business is distributed within various segments of the industry, the largest number of respondents from both data sets reported being in the "Repair and Remodeling," and "Single-family New Construction" businesses. A *t*-test revealed significant differences only for commercial projects (*p-value* = 0.020), with Deck Expo participants indicating a larger percent of their business in this area.

Respondents also reported the size of their company by choosing from a list of employee count ranges. Firm size for Deck Expo respondents was more evenly distributed than online respondents, with the latter heavily concentrated in smaller companies, as Table 3 shows. Two-thirds of online respondents reported working for companies with 1-4 employees, compared to a slightly less than one-third for Deck Expo participants (Table 3). Statistical tests confirmed significant difference in firm sizes between Deck Expo and Online respondents ($\chi^2 = 16.313$, *p-value* < 0.001).

Regarding the U.S. region where participants operate, responses suggest an over-

representation of companies operating in the Northeast among Deck Expo respondents (Table 3). Online respondents reported a more even distribution of business location, which can be explained by the nationwide reach of the *Professional Deck Builder* online magazine, where the survey was advertised. However, no significant differences were found between company locations reported by Deck Expo and Online respondents (χ^2 = 5.649, *p-value* = 0.227).

Respondents indicated that they utilize a wide range of decking materials for their projects (Table 3). The top two materials used by 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 use pressure treated lumber (Table 3). Considerable differences can also be seen in the percent of projects using naturally durable softwoods, where online respondents seem to be using it to a higher extent (Table 3). Statistical tests showed significant differences in responses for pressure treated lumber and naturally durable softwoods (*p-value* = 0.030 for each). Only 5 out of 61 Deck Expo respondents reported at least some of their projects use TMW, however, these participants indicated that, on average, almost half of their projects use TMW. No online respondents indicated using TMW for their decking projects (Table 3). Lastly, respondents were asked about their familiarity with forest certification. Roughly half of Deck Expo respondents (54%) indicated being familiar with forest certification, while more online respondents (62%) indicated familiarity (Table 3). No significant differences were detected between Deck Expo and Online respondents' familiarity with forest certification (χ^2 = 0.619, *p-value* = 0.431).

Familiarity with TMW

Survey participants were asked about their familiarity with TMW, with answers given in a 4-point scale (Fig. 1). Awareness was similar for both Deck Expo and online respondents, with over 60% reporting being "Very familiar" or "Somewhat familiar" with TMW (Fig. 1). However, a considerable number of respondents reported little or no familiarity with TMW (36.9% overall), which suggests an opportunity for educating and informing this professional audience about TMW. Statistical tests found no significant differences between familiarity with TMW among the two groups (χ^2 = 0.939, *p-value* = 0.816).

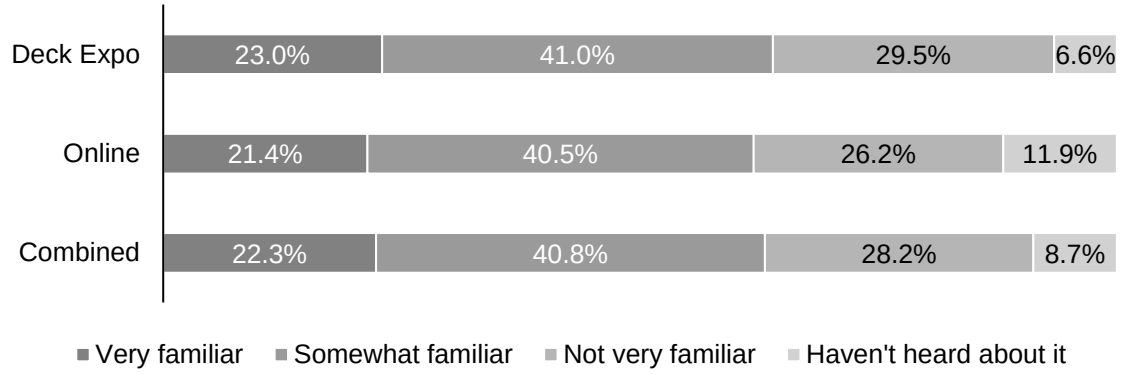

Fig. 1. Respondent reported familiarity with TMW

Table 3. Respondent Demographic Information

Demographic	Deck Expo	Online	Total
Number of Responses (n)	61	42	103
Company Description			
Deck Specialist	23.0%	42.9%	32.9%
Repair & Remodeling	29.5%	35.7%	32.6%
New Construction	8.2%	21.4%	14.8%
Wholesale, Retail, Distribution	21.3%	7.1%	14.2%
Manufacturing	13.1%	7.1%	10.1%
Architect/Design	6.6%	9.5%	8.0%
Other	13.1%	9.5%	11.3%
Type of Company Business			
Remodeling	78.7%	85.7%	82.2%
Single-family New Construction	67.2%	64.3%	65.7%
Commercial*	42.6%	23.8%	33.2%
Multi-family New Construction	29.5%	31.0%	30.2%
Institutional	13.1%	16.7%	14.9%
Other	13.1%	11.9%	12.5%
Company Size*			
4 or fewer employees	31.1%	66.7%	48.9%
5-9 employees	8.2%	11.9%	10.1%
10-24 employees	14.8%	4.8%	9.8%
25-49 employees	24.6%	4.8%	14.7%
50-99 employees	9.8%	2.4%	6.1%
100 or more employees	11.5%	9.5%	10.5%
Company Location			
Northeast	62.3%	31.0%	46.6%
Midwest	41.0%	35.7%	38.3%
South	31.1%	33.3%	32.2%
West	21.3%	31.0%	26.1%
Other	13.1%	7.1%	10.1%
Materials Used			
Wood-Plastic Composite (WPC)	77.0%	76.2%	76.6%
Pressure Treated* Lumber*	49.2%	61.9%	55.5%
Naturally Durable* Softwood*	32.8%	54.8%	43.8%
Tropical Hardwoods	42.6%	35.7%	39.2%
Plastic	31.1%	26.2%	28.7%
Thermally Modified Wood (TMW)	8.2%	0.0%	4.1%
Other	4.9%	4.8%	4.8%
Familiarity with Forest Certification			
Familiar	54%	62%	58%
Not familiar	46%	38%	42%

Data show percent of respondents, unless noted
Multiple answers were allowed for all questions except Company Size
Asterisks denote significant difference between Deck Expo and online respondents

Professional Adopter Perceptions

The second section of the questionnaire included questions regarding respondents' perceptions about five wood-based decking materials (pressure treated lumber, naturally durable softwoods, tropical hardwoods, WPCs, and TMW) on six attributes (*Need for Maintenance*, *Cost of Materials*, *Durability*, *Aesthetics*, *Availability*, and *Environmental Performance*). The two data sets were combined for this section as few differences were found between Deck Expo and Online respondents.

For the first question, respondents indicated their preference of decking materials for projects in three different price ranges, including low-end projects (under $5,000), mid-range projects (between $5,000 and $15,000), and high-end projects (over $15,000). Specifically, participants were asked to select their first and second choice of materials for projects in the three price ranges. Results are summarized in Fig. 2. For low-end projects, both groups of respondents selected pressure treated lumber and naturally durable softwoods as their first or second choice. For projects priced at a mid-range, respondents showed a preference for WPCs. Lastly, for high-end projects, responses indicate an inclination towards tropical hardwoods, followed by WPCs (Fig. 2). The results also suggest that respondents consider TMW a suitable option for mid-range to high-end projects. This may be attributed to a perception that TMW is expensive compared to other materials, given the low level of awareness, this may also originate from uncertainty about TMW costs. None of the materials showed a significant difference for the first and second ranked choices between Deck Expo and online respondents.

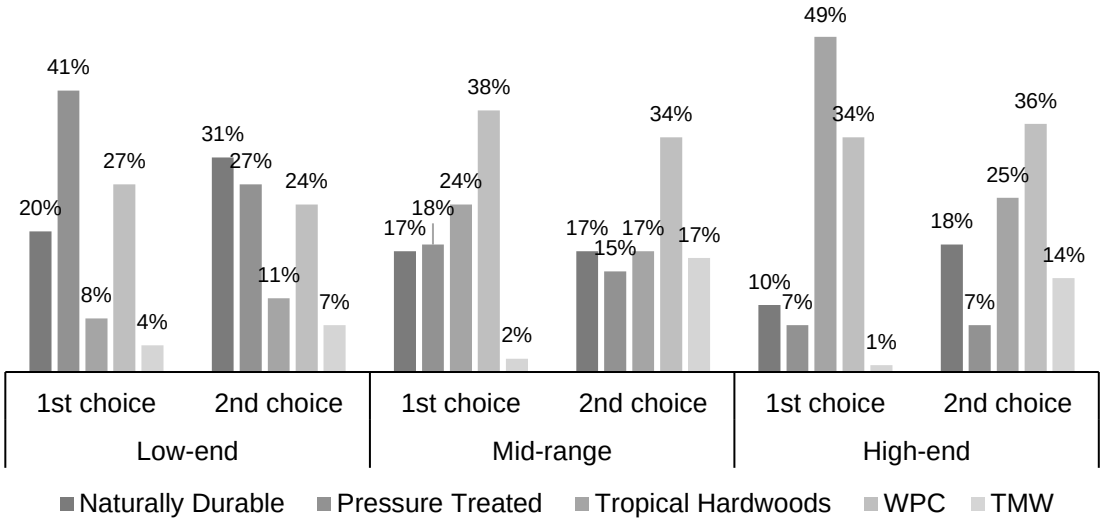

Fig. 2. Percent of respondents selecting top two choices for decking projects in three price ranges

Respondents were also asked 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 "*Don't know*" option for respondents if they were unfamiliar with any of the materials or their properties. To make the analysis and interpretation of these 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 1 (for a negative perception) and 5 (for a positive perception). A limitation with reporting data this way is that the "*Don't know*" responses cannot be included in the calculation in order to avoid skewing the scales higher for materials with which respondents were unfamiliar. However, the perception index can provide insight about how the average respondent viewed each material's attributes. A combined perception index for both groups of respondents is displayed in Fig. 3, as the only difference in the responses occurred for *Environmental Performance*. TMW was perceived as having better *Environmental 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 TMW as the material most difficult to find (Fig. 3). For *Cost of Materials*, TMW was perceived as more affordable than tropical hardwoods and WPCs. Except for *Cost of Materials*, WPCs were rated first or second for all attributes, and rated considerably higher for *Need for Maintenance*, which may reflect the high emphasis that WPC companies make on this property in their messaging. Pressure treated lumber had the highest rating for *Cost of Materials* and *Availability* (a higher perception index for *Cost of Materials* indicates a perception of a material having relatively *lower* cost), which is consistent with the relatively lower price of pressure treated lumber and its widespread adoption (most decking projects still use pressure treated lumber as major material in the U.S.).

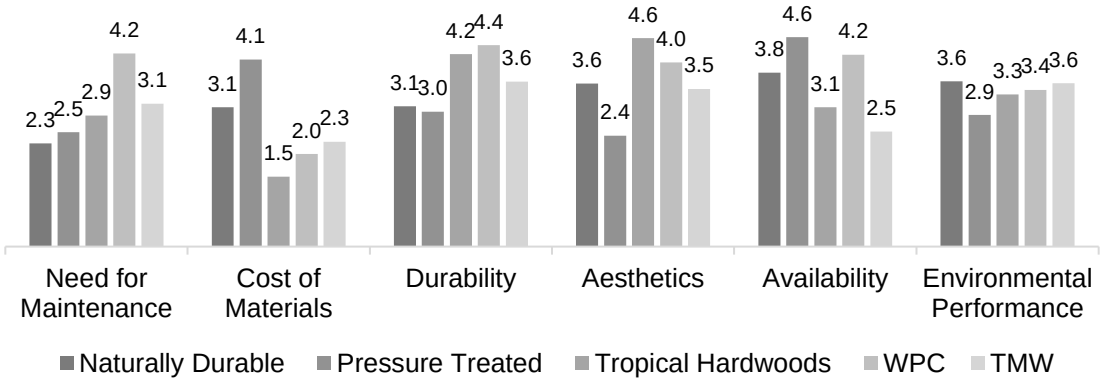

Fig. 3. Perception index, showing perceived material performance. Index calculation does not include those respondents who selected the "*Don't know*" option. A higher index denotes a perception of better performance (*e.g.* higher index for cost indicates a perception of lower cost)

Table 4. Attributes and Attribute Levels for Conjoint Analysis Questions

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

Conjoint Analysis

Conjoint analysis is a marketing technique that provides understanding of the relative importance consumers place on various product attributes. It was included in this project to gather information about industry member's priorities. 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 full-profile Choice-Based Conjoint Analysis (CBC) block of questions was created for this survey using Lighthouse Studio. The same software was used to analyze the data, which processed the information collected using a statistical model to estimate "utility functions." These utility functions denote the perceived value of each feature, as well as uncover how sensitive consumer perceptions are to changes of those features and for each attribute level (Orme 2010). Part-worth utilities can also be found, which indicate the utility associated with a particular level of an attribute independently of the others (Table 4). CBC questions present participants with a series of product alternatives and prompt 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 a "*None*" option. The product concepts were comprised of five attributes (*Material*, *Need for Maintenance*, *Durability*, *Material Cost*, and *Environmental Certification*), and each attribute could take different values, or levels (Table 4). The values for these levels were determined based on a combination of literature review, consultation with experts, and feedback from the testing event. The software generated 300 different versions of the CBC section and one of these versions was randomly shown to each survey participant.

Results from the CBC section of the survey were analyzed in two parts, aggregate and segmentation analysis. Aggregate analysis determines the average part-worth utilities for all respondents using a statistical technique called logit analysis and represents an average of all respondents, including extreme answers and without considering consumer segments with potentially distinct preferences. In contrast to aggregate analysis, segmentation analysis is a way to section 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. For this study, both aggregate and segmentation analyses were carried out. Only results from the aggregate analysis are presented in this paper.

The statistical technique used for aggregate analysis was logit analysis, which helps to understand consumer acceptance of a product by determining the intensity of their intention to purchase that product (Sawtooth Software). 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.

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. 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 CBC 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. 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 of the logit analysis are listed in Table 5 and show that, for both groups of respondents, WPCs had the highest utility effect for *Material* followed by tropical hardwoods, and pressure treated lumber had the lowest utility effect (Table 5). 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 to 20 years was the highest rated attribute level (0.72), followed by the lowest rated attribute level for a *Durability* of 5 to 9 years (-0.74) (Table 5).

The overall importance of different attributes can also be evaluated using logit analysis utility effects by determining the range between individual attribute levels' utilities (shown in bold in Table 5). The larger the range for an attribute level, the more important that attribute is for participants' preferences. 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 5). The most important attribute for online respondents was *Durability*, with a range of 1.46 between the most positive (lasts 15 to 20 years) and negative (lasts 5 to 9 years) attribute levels (Table 5). 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 5). This is consistent with a previous study where *Need for Maintenance* was also rated the least important using utility effects as an indicator (Thomas 2004). However, another study on decking advertisements in a print magazine from 1996 to 2006 found that WPC manufacturers 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 likely indicates WPC companies consider the low maintenance of WPCs to be a differentiating and important attribute for their material. Moreover, the results in Table 5 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.

Logit analysis can also calculate the 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 (Fig. 4).

Table 5. Utility Effects for Deck Expo and Online Respondents

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 to 9 Years	-0.340	-0.739
Lasts 10 to 14 Years	0.010	0.018
Lasts 15 to 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
Numbers in bold font represent the range of the utility effects for each attribute and respondent group, calculated as the maximum value minus the minimum value.		

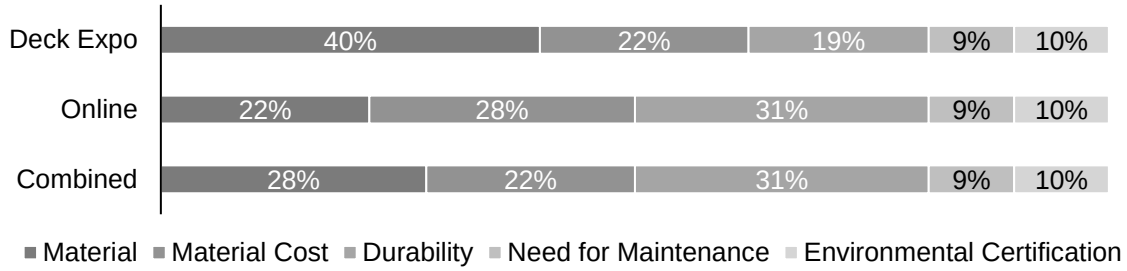

Fig. 4. Overall attribute importance using logit analysis

Both Deck Expo and online respondents placed the lowest importance on *Need for Maintenance* (9%), followed by *Environmental Certification* (10%) (Fig. 4). 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%) (Fig. 4).

CONCLUSIONS

Professional users of decking materials were surveyed in the Fall of 2016 to learn about their perceptions on various decking materials, including Thermally Modified Wood (TMW). The objective of the study was to identify opportunities and challenges for the

TMW industry in the United States. A total of 103 participants answered a computer-based questionnaire, including a Choice-Based Conjoint Analysis (CBC) section.

1. Over three-fifths of respondents indicated that they have at least moderate familiarity with TMW, but a considerable number of respondents also reported little-to-no familiarity with TMW, which suggests an opportunity for educating and informing this professional audience on TMW.
2. When considering how well each wood-based decking material performed for individual attributes, such as *Durability and Availability*, many participants selected "*Don't know*," particularly for TMW. However, Deck Expo respondents who viewed TMW decking samples generally had more positive perceptions of TMW.
3. The most important attribute when selecting decking products for Deck Expo respondents was *Material*, whereas *Durability* was the most important for online respondents. The least important attributes were *Cost of Materials* and *Environmental Performance*.
4. Overall, professional consumers surveyed for this research demonstrated the highest preference for WPCs and tropical hardwoods, the lowest preference for pressure treated lumber, and seem to have mixed perceptions of TMW. TMW had a positive utility effect for Deck Expo respondents and a negative utility effect for online respondents. This is likely the result of unfamiliarity with TMW and inconsistent marketing efforts across the industry.

Results from this research can help entrepreneurs and established industries create effective marketing plans for TMW products. Results are currently being used to create a publicly-available, and industry-focused document with strategic marketing recommendations. Lastly, outcomes from this study can be used to identify opportunities for employment creation in rural areas, as well as find value-added and sustainable uses for U.S. forest resources.

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