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Familiarity, Use, and Perceptions of Wood Building Products: A Survey Among Architects on the United States West Coast

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Abstract

A wide variety of wood products exist for both structural and non-structural uses; however, these products are underutilized in non-residential construction in the US. Since architects are one of the key decision makers for material selection in the construction sector, we investigated architects' familiarity, use, and perceptions of wood products. We targeted American Institute of Architects certified architects on the US West Coast, a prominent area for the forest product industry, for our survey. Respondent familiarity with wood products and their specification of wood products showed a positive relationship. Durability, fire resistance, and strength were seen as weaknesses of wood products, a common theme from the last two decades of research on this topic. Despite any weaknesses, respondents from Washington and Oregon predict the use of wood in the construction industry to grow more in the next five years compared to steel and concrete. The tools architects value most for gathering information about building materials have evolved, with an increased use of digital media and internet. Moreover, collaboration with engineers, the other key technical specifiers, has been found to be relevant to increase knowledge as well as the use of wood in construction. The authors recommend that the forest products industry improves its internet presence, reaching professionals across disciplines (i.e., engineers and architects) to increase the use of wood as a construction material for the structure and building enclosure in non-residential buildings.

Keywords: architect perceptions, engineered wood products, wood construction industry

1. Introduction

Wood products represent approximately 80% - 90% of residential construction in the US (Sinha et al. 2013). While utilization of wood products in low-rise residential construction is high, the utilization of wood products in non-residential buildings is much lower (Gaston 2014; Kozak & Cohen 1999; O'Connor et al. 2004), making up roughly 10% market share, with steel accounting for 60%, and concrete 30% (Robichaud et al. 2009; Softwood Lumber Council 2010). Large potential exists to increase the amount of wood used in non-residential construction (Adair et al. 2013; Gaston et al. 2001). The 10% market share of wood products in non-residential construction is equal to about 1.5 billion board feet. It is estimated that by replacing applicable construction materials with wood products in non-residential buildings, there is potential for an increase to 15 billion board feet (Roth 2015). Architects and structural engineers are the two primary technical actors involved in the material selection for a given project. When specifying, architects generally consider visual and functional aspects, while engineers evaluate the structural performance of a material (Gaston et al. 2001;Kozak and Cohen 1997 and 1999; Laguarda Mallo & Espinoza 2015; O'Connor et al. 2003; O'Connor et al. 2004; Roos et al., 2010).

The perceptions and knowledge architects possess regarding building materials and their performance can differ, which results in different material specifications in building design. Architects' familiarity with wood products available for the structure and building envelope

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and how they perceive wood as a building material is therefore highly relevant for the wood products industry (e.g., manufacturers), in order to formulate effective communication and promotional strategies.

A wide variety of wood products are available in North America and in other regions for both structural and nonstructural uses (e.g., Mayo, 2015). Innovations in engineered wood products in particular allow for a wider range of design possibilities than in traditional uses of wood such as low-rise housing. With new products, such as cross-laminated timber (CLT), being introduced to North America, mid- and high -rise wood structures are being built (e.g., 8-story Carbon 12 building in Portland, Oregon, completed in 2017; 5-story First Tech Credit Union Headquarters in Hillsboro, Oregon, completed in 2018, 4-story Albina Yard building in Portland, Oregon, completed in 2016). Because of new products and building techniques, there has been an increase in interest among designers to incorporate wood products in construction (Hemström, 2010; Kitek Kuzman & Sandberg, 2017; Knowles et al., 2011). In order for architects to specify wood products, they need to be knowledgeable and familiar with the products available to them. Moreover, if they have a positive perception of these products, it is more likely that they will specify them in their projects.

This research builds upon past studies, and provides current familiarity, use, and perceptions of wood products, among architects on the US West Coast. This region is a prominent location for forest product manufacturers. Approximately half of Washington and Oregon are forestland (WFPA, 2017; OFRI, 2017), and approximately one third of California is forestland (USDA, 2016). Kozak & Cohen (1999) recommended investigation of architect perceptions of wood products in the Western US, since this region shows the highest market share of wood as a structural material in North America (including residential and non-residential construction). Information obtained in this study can support development of communication methods, product information, and educational materials for today's architects, with the aim of increasing the specification of wood products in non-residential construction, as well as maintaining the specification of wood use in residential construction.

Since perceptions can evolve rapidly, together with advances in the industry and marketing efforts, this research aims to fill a temporal knowledge gap from previous studies (e.g., Knowles et al. 2011; Kozak & Cohen, 1999; Robichaud et al. 2009), providing the most recent data on perceptions of different types of wood-based building materials, among an important category of material specifiers (architects) and in a specific geographic area, particularly relevant for the production and diffusion of engineered wood products.

2. Research objectives

1. Provide an update on the current state of US West Coast architects' familiarity, use, and perceptions of wood products.
2. Identify what US West Coast architects currently perceive as the most prominent advantages and disadvantages of using wood products.
3. Identify how US West Coast architects prefer to gather information about materials and what additional information they need to incorporate wood into their designs.
4. Identify approaches for the wood products industry to deliver information and address identified knowledge needs of these architects.

3. Literature review

3.1 Advantages and barriers to wood product use

Reported advantages of wood products by architects in past studies have included: aesthetics, ease of use, familiarity, and costs (Kozak & Cohen, 1999; O'Connor et al., 2004). Additionally, an array of barriers to wood products, reported by architects in past studies, have included fire resistance, strength, durability, cost, acoustics, and building codes (Bayne & Taylor, 2006; Knowles et al., 2011; Kozak & Cohen, 1999; O'Connor et al., 2003; O'Connor et al., 2004; Roos et al., 2010). Research suggests that there are perceived weaknesses to designing with wood and that these weaknesses need to be addressed. Poor acoustic insulation of wood is one of the weaknesses reported (Asdrubali et al., 2016).Various design challenges for high-rise wooden buildings, such as fire, wind, seismic performance and durability, are highlighted by Buchanan (2016). However, research also suggests some of these barriers may have already been addressed. For example, predictable fire performance of large timber members is reported in many studies (e.g., Karacabeyli and Douglas, 2013). Wood construction can provide cost savings due to wood products being relatively light weight compared to other construction materials, reducing foundation costs (Wood-WORKS! – Program of the Canadian Wood Council, 2018a). Cost savings from reduced construction time can also be achieved with prefabricated wood assemblies (Wood-Works! – Program of the Canadian Wood Council, 2018b). Research has also suggested that when correctly designed and built, wood structural systems are capable of matching or exceeding the lifespans of comparative materials (e.g., concrete), but that buildings in North America are commonly demolished for reasons other than durability (O'Connor, 2004). Finally, a study published in 1999, found that existing building codes would have permitted the use of wood construction in over 50% of all non-residential buildings, but it was actually used in only about 17% of non-residential buildings (Goetz & McKeever, 1999). Since then, the National Design Standard (NDS) for wood construction was updated in 2015 incorporating CLT, as was the International Building Code (IBC), allowing for increased height and floor areas of wood construction (Showalter et al., 2015). While wood products and wood construction systems have developed to provide increased performance and overcome some of the limitations of this material, facts on these innovations and advances do not necessary reach the architecture community (Williamson et al. 2009). In marketing, perceptions establish three of the four major stages of information processing (i.e., exposure, attention, interpretation) and precede information retention (Hawkins et al. 2007). Consumer choice is commonly determined by perceptions over reality, i.e., actual advantages and limitations of a given product. Therefore is it important to address the perceptions architects currently hold of wood products, so that they can reflect the actual performance and opportunities offered by these products.

3.2 Communication

Communication and education are key methods for increasing awareness of new products, which is critical for the adoption and diffusion of products (King, 1996). Communication can go one-way (i.e. from the sender to receiver), or two-way (i.e. back and forth from sender to receiver), but one-way is considered less effective due to the lack of discourse (Morsing et al., 2006). Examples of one-way communication could include articles, advertisements, and certification labels; examples of two-way communication could include web-based services, and education (Lähtinen et al., 2017). Historically, the forest products industry has mainly been production-oriented, rather than stakeholder-oriented (Juslin & Hansen, 2002), but the industry has been changing this approach to be more stakeholder focused. A component of building relationships with stakeholders is two-way communication (Lähtinen et al., 2017).

3.3 Perceptions of wood products

Previous studies on the perceptions of wood products have explored a variety of topics, including perceptions of wood product use in North America (Kozak and Cohen 1997; Kozak and Cohen 1999; O'Connor et. al. 2004; Robichaud et al., 2009); perceptions of wood product use in green building (Knowles et al. 2011); perceptions of wood use in tall buildings (Hammon, 2016; Hemström, 2010; Larasatie et al., 2018) and architect perceptions of CLT (Laguarda Mallo & Espinoza 2015). The studies most relevant to the current research (Kozak and Cohen 1999; O'Connor et. al. 2004; Robichaud et al., 2009) focused on opportunities and barriers of wood-use in non-residential construction and concluded that the wood products industry is not properly addressing specifier perceptions, thus missing important growth opportunities in the construction sector. Kozak and Cohen (1999) found that there is room to improve the competitiveness of wood products in the North American construction sector, but that regional differences must be taken into account. They suggested creating targeted campaigns that focus on regions of North America that are "wood friendly", such as western North America, to start.

Hammon (2016) and Laguarda Mallo & Espinoza (2015) highlighted that architects or end-users who were most familiar with wood (or specific wood products) were least concerned with potential obstacles or barriers to wood construction. Laguarda Mallo & Espinoza (2015) suggested that the success of CLT will greatly depend on the information about the material being disseminated to architects.

Another study identified drivers of material selection, and found that architects' knowledge of wood (e.g., physical, mechanical, and environmental properties), experience with the use of wood, perceived control of the use of wood, and attitudes toward wood used structurally in buildings three stories or higher, were all statistically significant influencers of architects' specification of wood products in urban construction (Bysheim & Nyrud 2009).

4. Methods

4.1 Setting and subjects

This study focused on American Institute of Architects (AIA) certified architects located on the US West Coast (i.e. California, Oregon, and Washington). AIA is the leading professional membership association for licensed architects and one of the most active organizations in connecting architects with continuing professional education programs (Roth, 2015). Therefore, this population was chosen as relevant for this study. A list of contacts was generated by the researchers using information from websites for all of the Washington, Oregon, and California AIA chapters. This is the most inclusive list available. Only one architect per architecture firm was contacted, with priority on the principal or main contact for the firm. This was, most likely, one of the people in the firm with a more extensive experience in using a broad range of construction materials and products, while the other people were excluded in the survey, to avoid duplicating some results about familiarity and use (see Table 1) due to architects in the same firm referring to the same project (i.e., questions on a firm's specification of wood products and use of building systems). Some architects in this region may not have been included if they were not listed on their AIA chapter website or did not have an available email. However, since the number of architects that could be possibly excluded from this study is unknown to the authors, it is difficult to evaluate its impact on the validity of the results. A total of 3,469 architects were identified, 297 from Washington, 172 from Oregon, and 3,000 from California.

4.2 Data collection

The questionnaire was administered online through the platform Qualtrics, and the questionnaire link was distributed through the emailing system MailChimp. Because the research involved human subjects, Institutional Review Board (IRB) approval at Oregon State University was obtained before distributing the questionnaire. Data was collected between June and November of 2017. Following an adaption of the Tailored Design Method (Dillman et al. 2014), three rounds of emails were sent to each architect, each round was two to three weeks apart.

4.3 Questionnaire

The questionnaire was developed for use in a broader international study with regional focuses on the US West Coast, Central and Eastern Europe, and Sweden (Markström et al. 2018). Questionnaire topics covered familiarity and perceptions of wood products, as well as the perceptions of the sustainability of wood products. However, in this paper we report only on familiarity and perceptions of wood products. Questionnaire items were generated by researchers across these regions, incorporating and building upon questions from previous wood product perception studies (Kozak & Cohen 1999; O'Connor 2004; Robichaud et al. 2009). Questionnaire items were worded equally in positive and negative formats as a means of minimizing any bias from researchers. Items in the questionnaire utilized 5-point, Likert-type scales, multiple choice, and short answer options. All questions had an "unsure" option to prevent respondents from providing incorrect information on questions, and to be able to differentiate on Likert-type scale questions between respondents who were unsure about a question versus respondents who were sure but had a neutral response.

A focus group for this specific study was held with regional experts in wood science, forest products marketing, civil engineering, and architecture, to further refine the questionnaire for the US West Coast. The questionnaire was also pretested with four architects within the target audience (Dillman et al. 2014). Their feedback helped to improve clarity and validity (Vaske 2008) to better coincide with the terminology architects use. Responses from the pre-test were not included in the final results. This study focuses on five topics: familiarity and use of wood products, advantages and weaknesses of wood products, perceptions of wood product use, how architects gather information, and respondent demographics (Table 1). Among these, the first two sections address the first research objective: "Provide an update on the current state of US West Coast architects' familiarity, use, and perceptions of wood products". Goal of questions in the third section is to identify what US West Coast architects currently perceive as the most prominent advantages and disadvantages of using wood products (2nd research objective). The last section of the questionnaire aims to identify how US West Coast architects prefer to gather information about materials, and what additional information they need to incorporate wood into their designs (3rd research objective), and consequently identify possible approaches to effectively deliver information about wood construction materials among architects (4th research objective).

Table 1 List of Questionnaire items and related research objectives.

Research Objective	Topic	Question	Type[1]
	Demographic	Where is your practice located?[2]	(MC)
		What percent of your projects are located in [selected location]?	(MC)
		What is your position at your company?	(SA)
		How many years of professional experiences do you have?	(MC)
1) Provide an update on the current state of US West Coast architects' familiarity, use, and perceptions of wood products	Familiarity and Use	Are you familiar with the following products? And have you used them?	(LS) (MC)
		Please rank the following structural engineered wood products that you are familiar with from most familiar to least familiar[3]	(R)
		Please rank the following non-structural engineered wood products that you are familiar with from most familiar to least familiar[3]	(R)
		Please rank the building systems that you use most	(R)
	Perceptions of use	In your opinion, in the last 5 years the use of wood products in the following types of construction has…	(LS)
		In your opinion, over the next 5 years the market for the following construction materials in the Pacific Northwest will…	(LS)
2) Identify what US West Coast architects currently perceive as the most prominent advantages and disadvantages of using wood products.	Advantages and Weaknesses	Please select 3 advantages of wood products that are most important to you	(S)
		Please indicate the degree to which you agree with the statement: Wood can be a durable material	(LS)
		Please list three weaknesses of wood products	(SA)
3) Identify how US West Coast architects prefer to gather information about materials and what additional information they need to incorporate wood into their designs. 4) Identify approaches for the wood products industry to deliver information and address identified knowledge needs of these architects.	Information	Do you believe you have enough information about wood products to integrate them into your building designs?	(MC)
		Do you collaborate with engineers who have expertise in timber design?	(MC)
		Please indicate what additional information about engineered wood products you would like to have:	(S)
		Please select the 5 tools for obtaining information about materials that are the most valuable to you. Then, rank those 5 tools in order from most valuable to least valuable.	(R)

1. Question types: MC = multiple choice, LS = Likert-type scales, R = ranking, S = select all that apply, SA = short answer

2 This question was used for screening at the beginning of the questionnaire, to make sure the sample only included the target population.

3. Engineered wood products that are commonly used in residential construction (e.g., plywood, oriented strand board, particleboard) were excluded from this question.

4.4 Data analysis

General data analysis was conducted using descriptive statistics. Differences among respondents based on location and experience level were analyzed using ANOVA. Descriptive data analysis of questionnaire items was conducted using Microsoft Excel (Microsoft 2013). Statistical analysis was conducted using the software SPSS (version 24.0; 2016). All statistical analysis used α=0.05 for significance levels. One-way ANOVA was used on items comparing groups of architects by state or years of experience. Scheffe's post-hoc test was used with groups exhibiting equal variance and Tamhane's T2 post-hoc test for groups exhibiting unequal variance. Levene's test for equality of variance was used to compare if architects who collaborate with engineers are more familiar with engineered products than architects who do not collaborate.

Items requiring respondents to rank items were analyzed using the Modified Borda count method (Emerson 2013). In a Modified Borda count, respondents rank 'x' number of items, the item they rank first receives a count of (x), the item they rank second receives a count of (x-1), the item they rank third receives a count of (x-2), and so on until the 'x'th item receives a count of (1) (Emerson 2013). The responses to the short answer question asking respondents to list three weaknesses of wood products were grouped to find reoccurring themes. Groups used for this were modeled after similar questions in related studies (Markström et al. 2018; O'Connor et al. 2004), using their top categories for wood product disadvantages or weaknesses, including: 'fire resistance', 'acoustic performance', 'code', 'performance/strength', 'decay/durability', 'difficult to design', 'quality', 'shrinkage', 'economics/cost', and 'labor skill'. Additional categories were created for responses that did not fall into categories defined by previous studies including: 'availability', 'aesthetics', 'perception/demand by client', 'lack of information', 'maintenance', and 'Glues/VOCs'. Unsure responses for all questions were not included in the statistical analyses. However, questions with high percentages of unsure responses were identified and reported where appropriate.

4.5 Response rate

Out of the 3,469 architects emailed, 263 emails bounced (i.e., delivery failure), and 533 architects completed the questionnaire resulting in an adjusted response rate of 16.6%. Other similar studies report response rates from architects being 7% to 22.7% (Gaston 2014; Kozak and Cohen 1999; Laguarda Mallo & Espinoza 2015; Markström et al. 2018; O'Connor et al. 2004). Washington and Oregon had higher response rates than California, of 25% and 42% versus 14%, respectively. The questionnaire did not require respondents to answer every question, resulting in sample sizes per item varying from 533 to 304. In general, the sample sizes per question trended higher to lower, from the beginning of the questionnaire to the end. There did not appear to be one particular question that caused respondents to stop.

4.6 Non-response bias

A common concern with questionnaires is that non-respondents would have completed the questionnaire differently than those who did respond, resulting in a non-response bias (Dillman et al. 2014). To check if there was difference in responses from architects who completed the questionnaire from those who did not, a shortened questionnaire containing four of the original 22 items was sent to architects that had not responded, resulting in 48 respondes. Statistically significant differences were found for the respondents' locations, there were fewer architect's from California in the non-respondent group ($p=0.04$) than the initial respondent group. Respondents in the non-respondent group indicated a significantly higher use of one out of the 19 wood products (glulam, $p<0.01$) than the initial respondent group. No significant difference was found for the other 18 products, which does not suggest any significant difference among the two groups. T-tests revealed no statistically significant differences between the groups of respondents for the rest of the shortened survey; which included years of experience, type of building systems primarily used, familiarity of types of wood products and use of wood products. The results of this work may need to be interpreted understanding that California may be underrepresented (as evident from the lower response rate in California for the full questionnaire); other areas showed no substantive non-response bias.

5. Results & Discussion

5.1 Respondent demographics

Of the 533 completed questionnaires, 13% (71) were from Washington, 12% (64) were from Oregon, and 75% (398) were from California. Seventy-eight percent of respondents indicated that most (76-100%) of their projects are located in the same state as their firm (n=533) (Table 2). Sixty-two percent (244) of respondents held a principal or other management role at their firm. Other respondents included designers 17% (66), designer/managers 18% (70), and technical roles 3% (12) (Figure 1). Overall, respondent experience level was high, aligning with most of them being the principal of their firm. Of

Table 2. Where respondent's firms are located, and percentage of respondents' projects located in same state as the firm.

	What % of projects are located in the same state as respondents' firms				
Location	0-25%	26-50%	51-75%	76-100%	Total
Washington	0	2	11	57	71
Oregon	3	6	10	38	64
California	13	10	45	319	398
Total	16	18	66	414	533

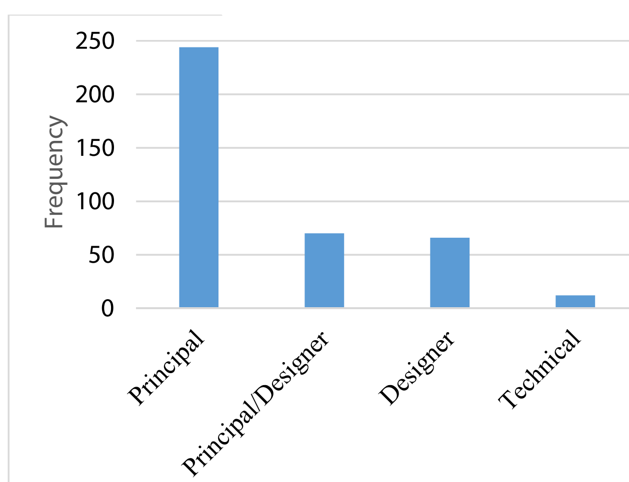

Figure 1. Respondent's role at their firm. (n=392).

the 398 respondents, 62% (246) had more than 25 years of experience, 23% (93) had 16-25 years of experience, 12% (46) had 5-15 years of experience, and 3% (12) had less than 5 years of experience.

5.2 Familiarity and use

There is a positive correlation between respondents' familiarity and use of the 19 wood products included in the study (Figure 2). Responding architects' familiarity with all wood products, when expressed in mean values of familiarity on a 5-point Likert-type scale, was at least a 2.5. This indicates that the responding architects were closer to being at least 'moderately familiar', than to being 'unfamiliar', with all of the wood products included in the study. Dimension lumber, plywood panels, and oriented strand board (OSB) were the only three products that received a mean familiarity rating of a 4.5 or higher, showing the respondents were 'very familiar' with those products. All products that had an average familiarity rating of 3.5 (familiar) or higher, had been used by at least 75% of respondents. All products that had an average familiarity rating of 2.5 to 3.4 (moderately familiar) had been used by less than 43% of respondents.

Generally, there was no relationship between years of experience and familiarity with wood products. Four of the 19 wood products did however show a statistically significant difference in familiarity based on how many years of experience an architect had (Table 3). The four products were sawn timbers, parallel strand lumber (PSL), light sandwich panels, and wood fiber insulation boards.

Several other products showed a similar pattern, but it was not consistent across all products. This suggests that communication should be designed to reach architects at all levels of experience.

When asked to rank familiarity with products in groups, respondents ranked glued-laminated timber (glulam) as the structural engineered wood product they were most familiar with; nail-laminated and dowel-laminated timber were ranked the lowest and were very

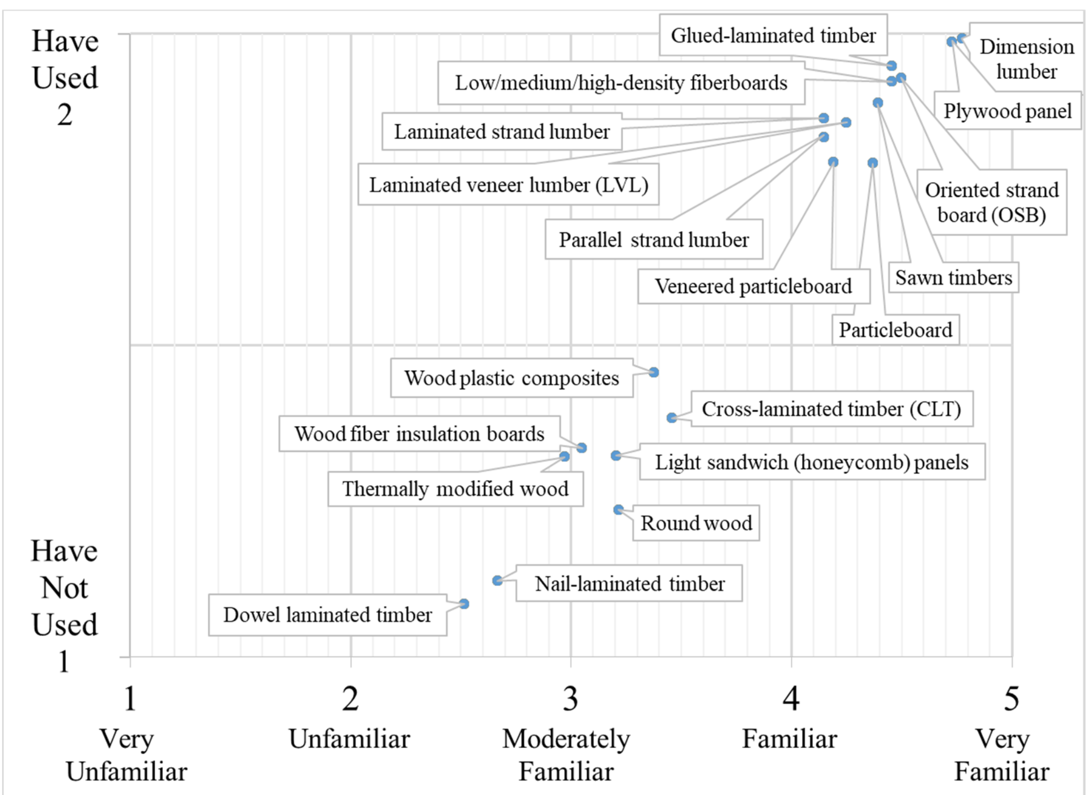

Figure 2. Respondent familiarity with various wood products versus if they have specified use of the product. Scatter plot showing mean values of familiarity and use of 19 wood products of all respondents. The x-axis displays familiarity, with 1 = "very unfamiliar" to 5 = "very familiar", and the y-axis shows use, with 1 = "have not used" and 2 = "have used" (varying responses per product, n=449 to n=377).

Table 3. Respondent familiarity with various wood products based on years of experience.

Product	Years of experience[1]				F-value	Df	p-value	ETA
	<5	5-15	16-25	25+				
Glued-laminated timber	4.50	4.17	4.45	4.53	2.50	392	0.06	0.14
Nail-laminated lumber	2.58	2.83	2.48	2.71	1.41	393	0.24	0.10
Dowel-laminated timber	2.25	2.48	2.48	2.56	0.48	390	0.70	0.06
Cross-laminated timber	3.75	3.48	3.28	3.51	1.48	391	0.22	0.11
Sawn timbers	4.00[ab]	4.07[a]	4.34[ab]	4.54[b]	5.66	390	0.01	0.20
Round wood	3.17	3.00	3.09	3.33	2.24	392	0.08	0.13
Parallel strand lumber	3.08[a]	3.80[ab]	4.26[bc]	4.24[c]	7.35	392	<0.01	0.25
Laminated strand lumber	3.92	3.91	4.23	4.16	1.26	392	0.22	0.11
Dimension lumber	4.83	4.78	4.80	4.78	0.02	392	0.99	0.02
Laminated veneer lumber	3.92	3.91	4.33	4.31	2.73	392	0.02	0.16
Plywood panel	4.75	4.74	4.78	4.70	0.15	388	0.79	0.05
Low/medium/high density fiberboards	4.08	4.33	4.54	4.46	1.50	387	0.14	0.12
Veneered particleboard	4.17	4.17	4.18	4.20	0.02	385	0.99	0.01
Particleboard	4.17	4.18	4.34	4.44	1.11	388	0.14	0.12
Oriented strand board	4.58	4.26	4.52	4.54	1.04	389	0.10	0.13
Light sandwich panel	2.33[a]	3.20[ab]	3.20[b]	3.28[b]	3.46	389	0.05	0.16
Wood plastic composites	2.83	3.20	3.42	3.44	2.04	391	0.15	0.12
Thermally modified wood	2.50	3.11	2.93	2.97	1.21	388	0.34	0.09
Wood fiber insulation boards	2.67[ab]	2.85[ab]	2.76[a]	3.18[b]	5.01	389	<0.01	0.18

1. Cell entries are means of respondents' familiarity of different wood products: 1 'very unfamiliar', 2 'unfamiliar', 3 'moderately familiar', 4 'familiar', and 5 'very familiar'.
2. Means that have different letters for superscripts differ at a $p < .05$ for Scheffe's post-hoc test for equal variance

close to each other (Figure 3, left). For the non-structural engineered wood products group, low/medium/high-density fiberboards were ranked first, with thermally modified wood and light sandwich panels ranked the lowest and were very close to each other (Figure 3, right).

Some of the wood products that respondents were less familiar with could potentially be attributed to the volumes or locations at which they are manufactured. For example, dowel laminated timber is not produced in a manufacturing setting on the US West Coast, thermally modified wood and wood plastic composite manufacturers are few. Glulam and laminated veneer lumber (LVL) manufacturers have a prominent presence along the US West Coast (APA, 2018). Additionally, some products have just recently been introduced in the North American market and have seen limited diffusion (e.g., CLT).

Regarding common wooden building systems, the responding architects said they are most familiar with light frame/panel (e.g., platform, balloon), followed by engineering frame systems (e.g., glulam post-beam, hybrid systems) and timber frame (e.g., solid timbers) (Table 4). Other building systems such as cross-laminated timber (e.g., walls, floors, hybrid systems), log construction, and other, were ranked as being considerably less familiar to the respondents, respectively.

These findings are an updated report on architect's familiarity with wood products. In 1999, Kozak & Cohen found that architects and structural engineers were most familiar with lumber studs, dimension lumber, and plywood, similar to the results of the present study; but were least familiar with structural insulated panels and PSL. In the present, architects were generally familiar with PSL (mean = 4.15) with the product. A study in 2015 found that 57.5% of architects were 'not very familiar' or 'had not heard about CLT' (Laguarda Mallo & Espinoza, 2015). Three years later 83.1% of architects were 'moderately familiar' or more with CLT and 23.3% ranked CLT as one of their top three most common types of wooden construction they specified. This is a considerable increase and shows that lessons learned for effective communication to architects regarding CLT could be tailored for and transferred to other existing or new wood products in the future. It should also be noted that the percentage of respondents ranking CLT

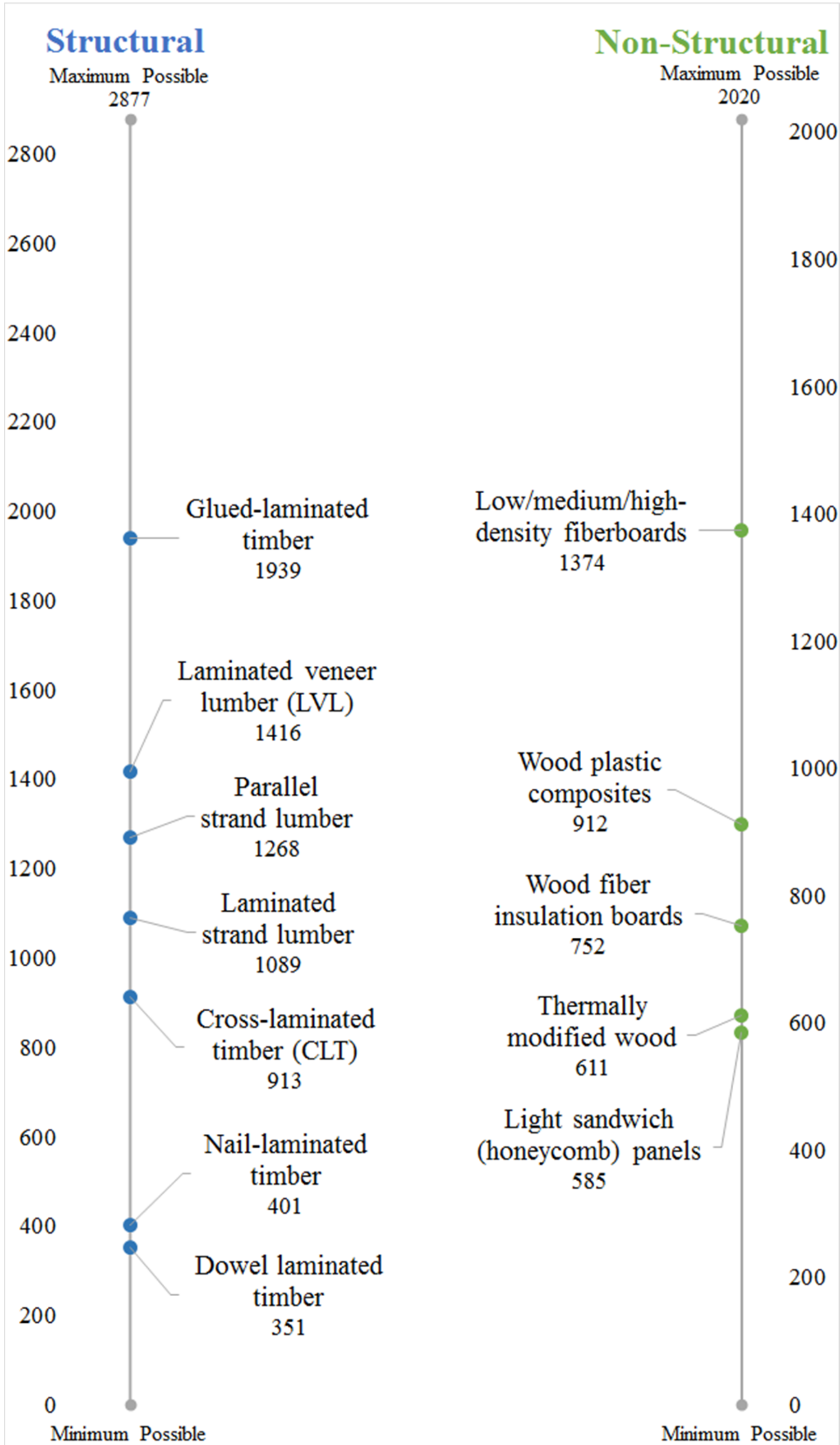

Figure 3. Structural and non-structural engineered wood products ranked by familiarity using a Modified Borda count. Left: Structural engineered wood product results, maximum possible count for one product was 2877, seven products, n=411. Right: Non-structural engineered wood product results, maximum possible count for one product was 2020, five products, n=404.

Table 4. Type of common wooden building systems respondents reported being most familiar with. (n=396).

	Type of construction	Modified Borda Count	# of times type was selected
	Light frame (e.g. platform, balloon)	1060	373
	Engineered frame system (e.g. glulam post-beam, including hybrid)	740	275
	Timber frame (e.g. solid timbers)	536	235
	Cross-laminated timber (e.g. walls, floors, including hybrid)	401	173
	Log construction	195	148
	Other [please specify]	58	15

as one of their most common types of construction is a strange result and should be investigated further since there should be a corresponding number of CLT buildings built or in the design phase for this to be accurate.

5.3 Advantages and weaknesses of wood products

When asked about advantages of wood products, respondents ranked 'ease of use', 'aesthetics', and 'cost' as the top three advantages of wood products (Table 5). Fire resistance and health tied for last. Responding architects in different states ranked the advantages only slightly differently, all three groups ranked 'ease of use', 'aesthetics', and 'cost', in the top three and had 'fire resistance', and 'health' somewhere in the last three positions. The attribute 'ease of use' was included by the researchers to mean designing with wood could be done with ease. It could have been interpreted by respondents differently as it is a less common phrase than the other attributes.

Interestingly, although 'cost' was in the top three advantages for wood products, 15% of respondents indicated it was a weakness of wood products. In 2015 another study in the same geographic location, responding architects identified cost as one of the biggest issues for wood products (Roth, 2015). Cost being reported as both a high-ranking advantage and as a weakness could be due to some wood products and building systems (e.g., glulam, timber frame) having higher relative costs

Table 5. Ranking of different advantages of wood products regarding how important they are to responding architects across and between states. (n=413).

			State					
	Total		Washington		Oregon		California	
Advantage	Rank	MBC[1]	Rank	MBC[1]	Rank	MBC[1]	Rank	MBC[1]
Ease of use	1	599	2	90	2	65	1	448
Aesthetics	2	559	1	98	1	67	3	400
Cost	3	547	3	73	3	63	2	414
Environmental impact	4	270	4	57	4	39	5	175
Seismic performance	5	193	6	7	6	9	4	178
Strength	6	190	5	24	5	16	6	151
Fire resistance	7	47	6	7	8	3	7	37
Health	7	47	8	4	7	8	8	35

1. MBC =Modified Boarda Count

compared to traditional building materials, such as steel and concrete, and others (e.g., dimension lumber, light frame) having much lower relative costs.

The top categories for weaknesses of wood products listed by responding architects were 'decay/durability' indicated by 61% of respondents, 'fire resistance' indicated by 48% of respondents, and "performance/strength' indicated by 39% of respondents (Table 6). Regarding durability, although it was the most frequently indicated weakness of wood, 74% of respondents indicated, in a separate questionnaire item, that they agree with the statement "wood can be a durable material". Therefore, it is possible that the responding architects believe that this weakness can be overcome with proper design and treatments.

An interesting difference of weaknesses reported by state included: 'decay/durability' where respondents indicating 'decay/durability' as a weakness in Washington (64%) was lower than in Oregon (78%) and California (79%). Other slight differences were seen in 'quality'. Architects in Washington (13%) and California (19%) were more critical than in Oregon (5%) regarding the 'quality' of wood products. Some examples of responses grouped in the 'quality' category included: "grade quality diminishing", "quality is going down", "guaranteeing that millwork is built to design intent", and "hard to maintain universal quality over a large quantity of one product type". These responses included concerns about quality at the material, product and built system level. Successfully increasing the use of wood products will require manufacturers and contractors to address the quality concerns of their stakeholders. Other researchers identify prefabrication and modularity (e.g. Johnsson & Meiling, 2009; Koppelhuber et al., 2017), BIM – Building Information Modeling (Aberger et al., 2018; Le Roux et al., 2016) and digital fabrication (Schindler, 2007) as factors that could, and are, moving the wood construction industry towards increased quality control in all stages of design and production.

Overall the advantages and weaknesses indicated by responding architects were similar to those of past studies. Advantages have largely remained the same over the years with aesthetics, ease of use, and costs being rated highly (Kozak & Cohen, 1999; O'Connor et al.,

Table 6. Weakness of wood products as indicated by respondents[1].

			State					
	Total		WA		OR		CA	
Weakness	(n=347)[2]		(n=45)[2]		(n=37)[2]		(n=265)[2]	
Decay/Durability	267	**77%**	29	**64%**	29	**78%**	209	**79%**
Fire Resistance	168	**48%**	19	**42%**	19	**51%**	130	**49%**
Performance/Strength	134	**39%**	16	**36%**	16	**43%**	102	**38%**
Dimensional stability	60	**17%**	9	**20%**	4	**11%**	47	**18%**
Quality	58	**17%**	6	**13%**	2	**5%**	50	**19%**
Environmental concern	54	**16%**	5	**11%**	8	**22%**	41	**15%**
Cost	52	**15%**	7	**16%**	7	**19%**	38	**14%**
Maintenance	40	**12%**	6	**13%**	4	**11%**	30	**11%**
Codes	27	**8%**	7	**16%**	5	**14%**	15	**6%**
Availability	21	**6%**	3	**7%**	1	**3%**	17	**6%**
Perception/demand by clients	16	**5%**	4	**9%**	3	**8%**	9	**3%**
Other[3]	16	**5%**	4	**9%**	1	**3%**	11	**4%**
Glues/VOCs	15	**4%**	3	**7%**	1	**3%**	11	**4%**
Labor skill	13	**4%**	2	**4%**	2	**5%**	9	**3%**
Lack of information	11	**3%**	3	**7%**	2	**5%**	6	**2%**
Aesthetics	9	**3%**	2	**4%**	1	**3%**	6	**2%**
Difficult to Design	8	**2%**	3	**7%**	0	**0%**	5	**2%**
Acoustics	3	**1%**	0	**0%**	1	**3%**	2	**1%**

1. Respondents were asked to each list 3 weaknesses, left column per group are frequencies, right column per group are percentages of architects in group who listed each weakness.
2. The n for each group is how many respondents who answered this question, not all respondents gave 3 weaknesses.
3. Other category includes weaknesses that were not mentioned at least 3 times.

2004). And disadvantages or weaknesses largely remaining the same with fire concerns, strength/performance and durability all being rated highly as concerns about use of wood products (Kozak & Cohen, 1999; O'Connor et al., 2004). There has not been significant change in perceptions of advantages and weaknesses of wood products in the last twenty years.

Aesthetics, the second most highly ranked advantage by this study's respondents, was reported as a 'very important' or 'important' characteristic for material selection by 94% of architects in another study (Laguarda Mallo & Espinoza, 2015), and was rated as the most important attribute in another study (Gaston, 2014). While this could be a promising attribute of wood products, structural performance and durability were reported as more important characteristics architects look for in material selection, with 98.6% and 97.8% of architects rating them as 'very important' or 'important' (Laguarda Mallo & Espinoza, 2015). Durability and performance/strength were in the top three mentioned weakness of wood products in the present study. Therefore, based on the responses from Laguarda Mallo & Espioza (2015), it is suggested that improving these particular characteristics of wood products, or the communication of these characteristics, could increase the likelihood of architects specifying wood.

The weaknesses identified by respondents are similar to the barriers indicated by the general public in the US in a survey from Hammon (2016). In their study, the public on the Pacific coast considered flammability, forest depletion, and strength as the biggest barriers, showing us that these weaknesses, perceived or real, are consistent across different stakeholders of the construction industry.

5.4 Perceptions of wood product use

Respondents believed that the use of wood products has remained the same in seven types of construction over the last 5 years (Figure 4). However, 34%-37% of respondents were 'unsure' about the past use of wood products in educational, institutional, civic, and higher education types of construction; 18% and 13% of respondents were 'unsure' about mixed-use and commercial (respectively), and only 4% of respondents were 'unsure' about residential.

When breaking down these means by state it was found that generally respondents in California were more likely to have the opinion that the use of wood products has decreased in the last five years (mean = 2.26 – 3.26), except for in residential construction, where Oregon (mean = 3.11) was slightly lower than California (mean = 3.13) (Table 7). Respondents in different states showed statistically significant differences in their opinions of change in wood product use over the past five years for all building categories except for residential and commercial.

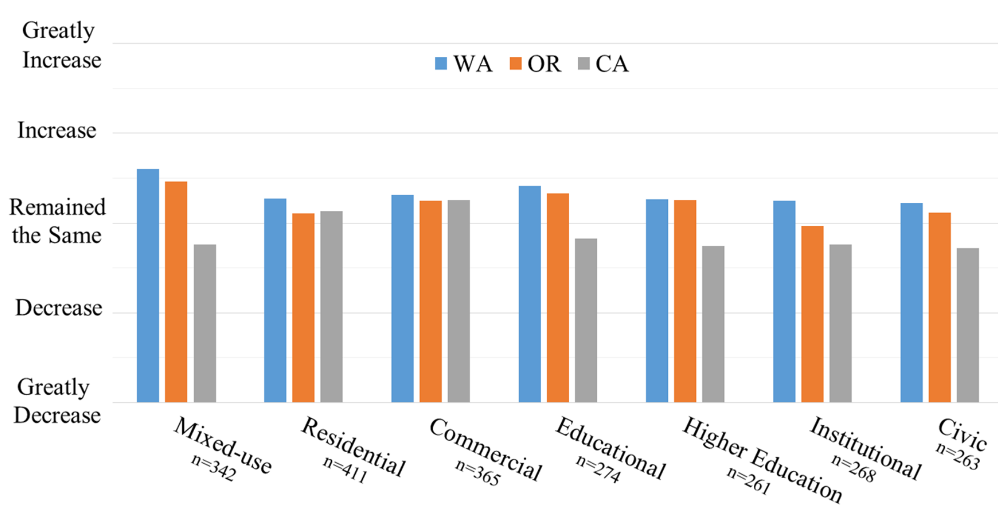

Figure 4. Respondent opinions on use of wood products in various types of construction over the past five years separated by state. Chart showing means of respondent opinions of wood usage trends in seven types of construction over the past five years, not including 'unsure' responses (per type of construction for all respondents n=261 to 411; SD=0.65 to 0.97).

Table 7. Respondent perceptions of how use of wood products in building types have changed in the last five years, based on state.

Types of construction	States[1]			F-value	Df	p-value	ETA squared[4] (η^2)
	WA	OR	CA				
Residential	3.28	3.11	3.13	1.31	408	0.27	0.08
Commercial	3.31	3.25	2.97	3.81	362	0.02	0.14
Mixed-use[2]	3.60[a]	3.47[a,b]	3.26[b]	3.74	339	0.03	0.15
Institutional[3]	3.24[a]	2.97[a,b]	2.76[b]	5.50	265	<0.01	0.20
Civic[3]	3.22[a]	3.11[a]	2.72[b]	7.02	260	<0.01	0.23
Educational[2]	3.41[a]	3.33[a]	2.83[b]	10.50	272	<0.01	0.27
Higher Education[2]	3.27[a]	3.26[a]	2.75[b]	8.09	258	<0.01	0.24

1. Cell entries are means of respondents' opinions of how wood use has changed in various buildings over the last five years: 1 'greatly decreased', 2 'decreased', 3 'remained the same', 4 'increased', and 5 'greatly increased'.
2. Means that have different letters for superscripts differ at a $p < .05$ for Scheffe's post-hoc test for equal variance
3. Means that have different letters for superscripts differ at a $p < .05$ for Tamhane's T2 post-hoc test for unequal variance
4. ETA squared (η^2) is a measure of effect size for use in ANOVA

Architects in Washington (mean = 3.22 – 3.41) and Oregon (mean = 3.11 - 3.33) were statistically significantly (f = 5.50 – 10.50, p < 0.01) more likely to think wood product use in civic, educational and higher education construction remained the same or increased slightly, than architects in California (mean = 2.83 and mean = 2.75) over the last five years (Table 7). Architects in Washington (mean = 3.60 & 3.24) were also statistically significantly (p = 0.147 & p = 0.200) more likely to think that wood use in mixed-use and institutional construction remained the same or increased slightly over the last 5 years, than architects in California (mean = 3.26 & 2.76).

In a study from 1999, only 8.9% of designers said they intended to use more wood in the future (Kozak & Cohen 1999). This went up fifteen years later, when a different study reported 32% of architects said they expected to use more wood in architectural elements in the next 5 years, while 62% expected to use the same amount in the future (Gaston 2014). Based on responding architect's perceptions of wood use in the last five years in the present study, the prediction from Gaston (2014) appears to have held true, and the trend for slow increases of wood use appear to have remained the same.

Looking forward, respondents' mean opinion was that the market for wood, steel, and polymers in the Pacific Northwest will grow over the next five years, while concrete will remain stable (Figure 5). It should be noted that 27% of respondents were 'unsure' about polymers, while 8% or less were 'unsure' about the other three products (n=426 to 429). When segmented by state, Washington

Figure 5. Projected market change for construction materials in the Pacific Northwest, by state. Chart showing respondent opinions about the growth or shrinkage of the market for four construction materials over the next five years in the Pacific Northwest, not including unsure responses (per type of construction for all respondents n=311 to 403; SD=0.71 to 0.87).

respondents predicted wood use and concrete use to grow, while Oregon respondents predicted only wood use to grow, and Californian respondents predicted wood use, steel use, and polymer use to all grow (Table 8).

The differences among respondents from different states suggests slightly different trends in wood use in different types of construction. Wood product manufacturers, distributors or others, which produce, sell, or promote products for particular types of construction could use this information to target particular locations. Stakeholders can also use this information to aim their communication efforts with architects in locations that already show momentum to use wood products, or with architects in locations with greater potential for increasing wood use.

However, it should be noted that both of the results in this section are from questionnaire items asking respondents to predict market trends. These results could have been more accurate predictors of market trends if the questionnaire items asked respondents to indicate projections of their own future material use.

5.5 Information

Three-quarters of respondents collaborate with engineers that have wood design expertise, 16% do not, and 9% were unsure if they did (n=432). When comparing these results to the respondents' familiarity with structural engineered wood products, respondents who collaborate with engineers that have expertise in timber design are more likely to be familiar with engineered wood products than those who do not. Respondents who collaborate with engineers that have expertise in timber design are statistically significantly more likely to be familiar with glulam, nail-laminated timber, CLT, PSL, and LVL, than those who do not (t-value = 2.138 to 3.681, p = 0.035 to <0.001) (Table 9). Effect size for all these products (r_{pb}=0.118 – 0.178) was between small and medium (Cohen 1988).

Seventy-eight percent (310) of respondents said that "yes" they have enough information about wood products to integrate them into their building designs, 13% (51) said no, and 9% (35) said they were unsure (n=396). Respondents who believe they have enough

Table 8. Respondent perceptions of how the market for different construction materials in the PNW will change in the next five years based on state.

	States[1]						
Material	WA	OR	CA	F-value	Df	p-value	ETA squared[4] (η^2)
Wood[3]	4.03[a]	3.98[a]	3.54[b]	13.34	400	<0.01	0.25
Concrete	3.54	3.29	3.48	2.02	389	0.13	0.10
Steel[2]	3.46[ab]	3.17[a]	3.51[b]	6.14	391	<0.01	0.18
Polymers	3.45	3.47	3.73	3.11	308	0.05	0.14

1. Cell entries are means of respondents' opinions of how the market for different construction materials in the PNW will change in the next five years: 1 'significantly shrink', 2 'shrink', 3 'remain stable', 4 'grow', and 5 'significantly grow'.
2. Means that have different letters for superscripts differ at a p < .05 for Scheffe's post-hoc test for equal variance
3. Means that have different letters for superscripts differ at a p < .05 for Tamhane's T2 post-hoc test for unequal variance
4. ETA squared (η^2) is a measure of effect size for use in ANOVA

Table 9. Familiarity with structural engineered wood products based on respondent collaboration with engineers who have expertise in timber design.

	Do you collaborate with engineers who have expertise in timber design?				
Products	Yes (83%)	No (17%)	t-value	p-value	Effect size (r_{pb})
Glue-laminated timber	4.51	4.25	2.35	0.02	0.12
Nail-laminated lumber	2.74	2.27	3.68	<0.01	0.16
Dowel-laminated timber	2.54	2.39	1.15	0.25	0.06
Cross-laminated timber	4.51	4.25	3.56	<0.01	0.18
Parallel strand lumber	4.25	3.94	2.14	0.04	0.13
Laminated strand lumber	4.18	4.04	1.05	0.30	0.05
Laminated veneer lumber	4.33	4.00	2.72	0.01	0.14

information about wood products to integrate wood into their designs are typically the same that collaborate with engineers that have expertise in timber design (Table 10). These findings highlight the importance of collaboration between the two main technical specifiers, architects and engineers, to increase the use of advanced engineered wood products as structural materials. This is also relevant to expand use of wood in non-residential applications, since the above mentioned wood products are mainly used in mid- to high-rise buildings and large span structures. If the wood products industry wants to capitalize and even foster collaboration between architects and engineers, inter-disciplinary communication models should be developed, overcoming jargon and disciplinary structures (e.g., across professional organizations and schools).

There was not a significant relationship between responding architects having enough information and their years of experience. It should also be noted that of the 310 respondents that indicated they have enough information about wood products to integrate them into their designs, 67% (208) ranked 'light frame/panel (eg. Platform, balloon)' as the building system that they use most.

The most frequently selected additional information responding architects would like to have about wood products, was 'technical information' (Table 11). However, a little less than one third of respondents who answered this question indicated they would like no additional information. This indicates that there are no specific knowledge needs perceived by responding architects. This may also be an indicator of how receptive this group of professionals could be to receiving more information about wood products.

The sources of information tools respondents indicated were the most valuable were internet searches, manufacturers, continuing education, consultants, professional associations, and colleagues (Table 12). Internet searches received a much higher count than other options, with 85% of responding architects ranking it somewhere in their top five most valuable sources (n=381).

In a study from 1997, responding architects indicated that manuals, reading materials, and continuing education were the most influential methods for obtaining product information; and association promotion, computerized information, and proactive marketing were the least influential (Kozak & Cohen 1997). A little more than a decade later, in 2009, responding architects indicated that design manuals, physical examples, and design or company specific internet sources were among the most effective sources of information about wood products; and scientific papers, personal sales calls and

Table 10. Comparison of frequencies of responses if respondents have enough information about wood products and if they collaborate with engineers who have timber design expertise.

		Collaborates with engineers who have expertise in timber design		
		Yes	No	Unsure
Has enough information about wood products to use them	Yes	251	33	25
	No	26	22	3
	Unsure	22	8	5

Table 11. What type of additional information respondents would like to have about wood products. (n=390).

Type of Information	# of times item was selected	% of respondents that selected item
Technical information	207	53%
Direct contacts with manufacturers	142	36%
Visits to built objects	114	29%
Visits to building sites	105	27%
Other	33	8%
None	118	30%

Table 12. Most valuable sources of information about materials. A higher Modified Borda Count (MBC) indicates a tool being more valuable. (n=381).

Tool	MBC
Internet search	1234
Manufacturers	759
Continuing education	703
Consultants	663
Professional Associations (AIA, etc.)	523
Colleagues	521
Conferences	260
Researchers	149
Newsletters	113
Owners	60
Developers	52
Contractors[1]	23
Other[2]	20
Trade publications[1]	10

1. If a respondent selected "other" they had the option to specify; contractors, and trade specifications were specified frequently, these two items were not a listed choice in the questionnaire.
2. The "other" category shown here is the count for "other" less the count for when "other" was specified as contractors or trade specifications.

internet discussion forums were among the least effective (Robichaud et al. 2009). Now roughly another decade later, in the present study, internet searches have gone from being the least influential source to being the most important. Additionally, a study in 2014 found that internet searches and professional associations were responding architects' preferred way for finding continuing education courses (Roth 2015). Continuing education courses were another top ranked source of information by respondents in the present study, and another place where architects can learn about new products, material properties, new building methods, etc. However, since the majority of responding architects claim they have enough information about wood products, they will unlikely search for additional information. Without additional information their perceptions on specific limitations and disadvantages of wood as a construction material, will likely remain unchanged. If the wood products industry wants to remove barriers limiting wood use in buildings, a stronger internet presence alone may not be sufficient; inter-disciplinary communication and participation in continuing education initiatives may also be necessary. Indeed, the architects in this study also indicated they value information from manufacturers, providing a case for manufacturers to host continuing education courses for architects, ideally with engineers, and improve their internet presence, which historically has been lacking (Sowlati, 2013). This is also supported by a finding from Roos et al. (2010) that architects desired more engagement with wood product suppliers for solutions.

6. Conclusion

AIA certified architects across Washington, Oregon, and California were surveyed in 2017. As might be expected, familiarity with a product and specification by architects go hand-in-hand. Products that respondents were most familiar with and used the most tended to be products traditionally used in residential construction and manufactured along the US West Coast. Manufacturers and distributors could benefit from communicating technical information to architects on the US West Coast regarding the products respondents were least familiar with (dowel laminated timber, nail laminated timber, thermally modified wood, and light sandwich panel). Responding architects' perceptions of advantages and weaknesses associated with using wood have remained consistent in the last two decades. Respondents had a positive outlook towards the most frequently reported weakness (durability), with a majority of them agreeing that wood can be durable. Innovations in wood durability, and in other fields addressing other weaknesses identified by the respondents, could lead to an increase in wood use. Change in the amount of wood used in different types of construction as perceived by the respondents, was fairly stable, with minimal change. Predictions for different materials used in construction in the next five years indicates that respondents in Washington and Oregon predict more growth for wood products than Californian respondents, whom predicted a higher growth for polymers. Lastly, the sources architects value most for gathering information about building materials have evolved, which means the way industry communicates with architects must evolve as well. To increase wood use, it is recommended that the forest products industry improves its internet presence, developing inter-disciplinary communication strategies. Last but not least, information not only must be more accessible to architects interested in specifying wood, but should reach also those architects who will not spontaneously search for this information, since many do not recognize their lack of knowledge.

6.1 Recommendations for future research

The information in this study should be periodically readdressed to ensure that communication is relevant, and efforts are successful in reaching the architecture community. Future research could be conducted to address how architects' educational background and participation in continuing education affects their perceptions of wood products as well as how their familiarity and perceptions affect their specification of wood products. Future work could also address architect's perceptions of the usefulness of social media as a means for receiving information from the wood products industry.

6.2 Limitations

While there could have been room for multiple interpretations on some measurement items in this study, the pretest process reduced the probability confusion. One particular instance of this was in the question regarding different building types designed by respondents. Recommendations from the expert group were followed to define the different categories of building types, however, we are aware that some categories can be seen as overlapping, (e.g., post and beam with CLT panel floors, a hybrid system, could be categorized as engineered frame or cross-laminated timber). Additionally, inclusion of a non-wood building type category would have provided a better overview of the big picture.

It is also possible that architects with a connection to wood, or to the university conducting the research, were more likely to complete the questionnaire. This could explain the higher response rate in the state of Oregon. Although California may be underrepresented in this study (as evident from its lower response rate) a significantly higher number of respondents (75%) were from California. This can be a potential source of bias, since codes and standards in this state, such as those related to seismic design, are particularly restrictive (e.g., California Building code, 2016). Despite these limitations, this study provides evidence that there is a need for improving wood products communication on the US West Coast. It also provides a framework for future statistical analysis in the field of wood product architectural surveys.

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