Preference of Using Wood and Wood Products in the Construction Industry in Peninsular Malaysia

Jegatheswaran Ratnasingam,[a,*] Hazirah Ab Latib,[a,*] Wai Cheng Ng,[b] Mutthiah Cellathurai,[b] Khoon Ark Chin,[a] Abdul Latib Senin,[a] and Choon Liat Lim [a]

The objective of this study was to determine the preferences of architects for wood and wood products for specific applications and to assess the attributes that influenced its utilization in the construction sector in Peninsular Malaysia. A questionnaire survey was conducted among 500 practicing architects throughout Peninsular Malaysia, with a response of 27%. The application of wood and wood products by architects was focused primarily on non-structural applications rather than structural applications. It was found that cost, customer demand, durability, natural beauty, availability, ease of design, and workability were primary considerations for architects in specifying wood and wood products in building construction. A factor analysis of the results showed that building regulations, material quality and beauty, customer demand, and design and assembly were the primary determinants that influence architects specifying and using wood and wood products in building construction. It was apparent that the use of wood and wood products in building construction in Peninsular Malaysia has the potential to be further increased through advertising and marketing in the material among the general public, as well as architects and specifiers.

Keywords: Construction; Attributes; Wood; Wood Products; Architects; Specification

*Contact information: a: Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia; and b: IB Design & Consultancy, Unit 8B, Jalan 14/2A, Taman Kuchai Lama, 52000 Kuala Lumpur, Malaysia; *Corresponding authors: hazirahablatib@yahoo.com;jegaratnasingam@yahoo.com*

INTRODUCTION

The Malaysian Construction Industry

Malaysia's construction sector plays an important role in the country's economy, contributing almost 31% of the gross domestic product (GDP) in 2016 (Cheah 2017). The Malaysian construction industry can be differentiated into two broad categories. One category is general construction that includes residential development, nonresidential development, and civil engineering work.

The second category is specific construction exchange works that include metal works, electrical works, pipes, sewerage and sterile work, refrigeration, aerating and cooling work, painting work, carpentry, tiling and flooring work, and glass work that encompasses overall infrastructure development. Figure 1 shows the status of the construction industry in Malaysia.

Under the Construction Industry Master Plan (CIMP), Malaysia's construction sector is envisioned to be a highly efficient and productive industry, employing highly skilled workers adept at utilizing modern techniques and technology to deliver high quality products and services, by 2020/2021 (Cheah 2017).

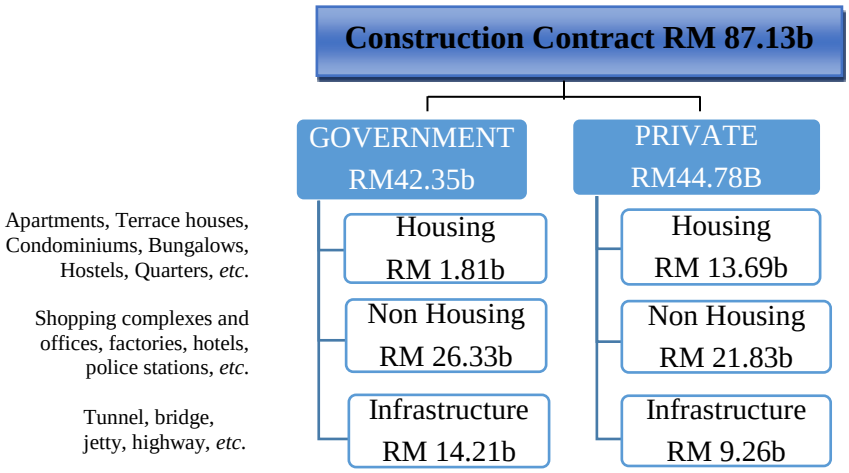

Fig. 1. Status of the Construction Industry in Malaysia (CIDB 2015)

Despite the significant efforts by the government to boost the construction industry in the country, the adoption of green technology, especially with the use of sustainable materials, currently within the industry has been rather unenthusiastic. In this context, the use of wood and wood products in the construction industry in Malaysia has also been relatively small compared to its overall production and export volumes (Chung *et al.* 2014), as wooden buildings constitute less than 3% of the total amount of buildings constructed. Based on statistics provided by the Department of Statistics (DOS), the use of wood and wood products as construction materials for 2016 was valued at RM 5.76 billon, which is comprised mainly of sawn timber at RM 3.636 billion, plywood (waterproof) at RM 890 million, wooden door and window frame at RM 480 million, flooring and wall panels at RM 317 million, and other wood materials at RM 342 million, as well as gypsum plaster board at RM 95 million (Cheah 2017).

According to the Construction Industry Development Board (CIDB), traditional wood and wood products predominated the integrated building system (IBS) wood materials by a ratio of 85:15 in 2016 (Cheah 2017). The term IBS refers to the construction system which focuses on the use of pre-fabricated components, in a controlled environment or on-site, in the construction process. Inevitably, there are increasing efforts by many agencies including the Malaysian Timber Industry Board (MTIB) and the CIDB to promote the wider use of wood and wood products for construction within the country (Chung *et al.* 2014).

Wood as a Construction Material

Generally, building materials are considered sustainable when they score well in many or all of the following criteria: renewability, low energy consumption, low CO_2 emissions, sourced locally, reusable and recyclable, minimal waste, and non-polluting. In this context, wood emerges as an excellent choice that fits these criteria well. Wood also offers a number of environmental benefits over other building materials, and has exceptional physical and mechanical properties (Guiles 2014).

Wood is a renewable resource, containing a large quantity of solar energy, hence requiring low amounts of fossil fuel for manufacturing. It is also an independent source of energy when burned as wood biomass. Wood is often sourced locally, and the responsible

use of wood encourages sustainable forest management in the country of origin. It can be recycled to a certain extent, but not as extensively as metals and glass (Gustavsson and Sathre 2006). Modern timber construction produces little waste, although the waste it does produce can be burnt for energy.

The production of wood is generally non-polluting or carbon-neutral at all stages (Upton *et al.* 2008), and the environmental benefits of using wood-based building materials has been revealed through research conducted by the Consortium for Research on Renewable Industrial Materials (CORRIM). The results of a life-cycle analysis for wood-framed houses *versus* steel-framed and concrete-framed houses (Table 1) revealed the advantages of wood building materials within the context of environmental performance (Guiles 2014).

Table 1. Life-cycle Analysis of Timber

	Steel-framed house	Concrete-framed house
Energy use:	uses 17% more energy	uses 16% more energy
Global warming potential:	has 26% more global warming potential	has 31% more global warming potential
Air emissions:	has 14% more air emissions	has 23% more air emissions
Water emissions:	has over 300% more water emissions	has roughly the same level of water emissions
Solid waste production:	Produces roughly the same level of solid waste production	produces 51% more solid waste
Source: Guiles (2014); all data shown are in comparison to wood-framed houses		

In addition, wood has excellent insulation properties, and consequently, wooden houses have the ability to maintain a pleasant climate, both in the summer and winter seasons (Wagner and Hansen 2004). Therefore, information about thermal conductivity and the variables affecting this property are of special interest from the standpoint of building insulation (Wang *et al.* 2014).

Furthermore, wood components are characterized by their ability to withstand tensile, compressive, and bending stresses. They have a good strength to weight ratio, a property that makes wood one of the best construction materials. They are resistant to corrosion and are able to bear heavier loads and dampen vibration (Ellingwood *et al*. 2004). Furthermore, wood is easily machined to various shapes and is consequently used extensively in load-bearing structures and filling wooden buildings, such as wooden windows, doors, stairs, and walls, and also in the manufacture of furniture. Therefore, it is no surprise that a number of organizations throughout the world are already promoting wood and wood products and have proclaimed their benefits as a construction material; these organizations include the US Green Building Council, Canadian Wood Council, New Zealand Green Building Council, Wood Products Council, Slovak Association of Wood Processors, and the Research Institutes of Sweden (RISE) (Gustavsson and Sathre 2006).

Nevertheless, there are some weaknesses of wood as a building material that may minimize its use in building construction. The notable drawbacks include wood's requirement for appreciable maintenance, especially in relation to its lower fire resistance, lower resistance to rot, fungus, and mildew, and lower resistance against natural disasters, such as storms or hurricanes (Ellingwood *et al.* 2004; Lippke *et al.* 2011).

Wood Construction Systems

On account of its ease of formability and workability, wood structures have found practical application in all historical periods of mankind, from then until now. Wood is used by all architectural styles and types of buildings, where wood is amply available as a building material (Ratnasingam and Chung 2016). The systems of wood construction can be classified as follows: (i) log, (ii) panel (prefabricated), (iii) timber-frame, (iv) post and beam, (v) half-timbered, and (vi) cross-laminated timber (CLT) (Roos *et al.* 2010).

In recent years, the construction of multistory buildings has become widespread using half-timbered construction as the notable type of timber framing, particularly in Germany and Western Europe. The advent of cross-laminated timber (CLT) as a versatile material that can be fully combined with other building materials has led to its increased use for building detached houses and especially for multistory apartment buildings. Due to its excellent load distribution properties in two directions, CLT presents reduced limitations to architectural, residential, or utility building projects. In fact, in German-speaking countries, the use of wood in architecture is on the upward trend, representing nearly 50% of new housing start-ups. However, in Scandinavia and in the USA, it is up to 90% of new housing constructions (Ratnasingam and Chung 2016).

When comparing the utilization rate of wood against other types of construction materials, the determining factor affecting architects' intentions to specify wood in the construction of urban buildings is the building height. Generally, wood is widely used in single-story buildings, but as the building height increases, wood is used less, and other materials are preferred (Kozak and Cohen 1999). Needless to say, the process of selecting building materials depends on the architects as well as the consumers themselves. Furthermore, it must be understood that the consumers' desire to use wood is affected by their knowledge of the physical, mechanical, and environmental properties of wood as a building construction material (Kozak and Cohen 1999).

Current Construction Scenario in Malaysia

According to Bank Negara Malaysia (2016), Malaysia will need to build approximately 210,000 units of new houses between now and 2020 to cope with the housing needs of the population. Although there is a surplus of office space in major urban locations, the demand for affordable residential units is still high, especially those priced below the RM 275,000 price point (Bank Negara Malaysia 2016). However, the influence of expanding construction activity is gradually replacing the traditional timber architecture in many rural communities. This phenomenon is mainly caused by two factors: firstly, the high cost of timber as a building material (due primarily to its reduced supply in the market) relative to cheaper masonry materials, and secondly, the diminishing number of craftsmen that build timber architecture (Chung *et al.* 2014). As a result, architects in Malaysia have designed only a limited number of timber buildings. It is necessary for architects to understand the structural properties and visual quality of timber, in addition to its spiritual value.

Although several studies have conclusively shown that wood and wood products are increasingly used in building construction in Western Europe, North America, and Scandinavia (Thomas and Ding 2018), there is almost no report on the utilization of wood and wood products in the construction sector in Malaysia. Therefore, in this study, an assessment of attributes and types of application for wood and wood products for construction was performed. The objectives of this study were as follows: (1) to determine architects' preferences for wood and wood products for specific applications, and (2) to

assess the attributes that influence the extent of the utilization of wood and wood products in the construction sector in Peninsular Malaysia.

EXPERIMENTAL

Methodology

Target respondents

The study was conducted *via* a questionnaire-based survey sent to 500 practicing architects throughout Peninsular Malaysia registered with the Architects Association of Malaysia (AAM), better known as Persatuan Arkitek Malaysia (PAM). The response rate from the potential respondents was 27%, or 135 architects, at the end of a four-week period. The respondent architects were identified and selected from the membership database of PAM, and those selected had some prior experience in specifying and using wood and wood products in their previous projects.

Questionnaire-based survey

A three-part questionnaire was designed and used in this study to gather the required information. The questionnaire was prepared after discussions with several senior architects, industry experts, contractors, and officials from the Public Works Department (PWD), who have been involved in formulating standards and building codes, in addition to specifying and designing buildings using wood and wood products; also, the questionnaire was prepared by referring to the previous study by Chung *et al.* (2014). This was all to ensure that the questions in the study were relevant and could meet the study objectives.

The first part of the questionnaire compiled data on the background of the respondent architect, such as age, gender, working experience, specialization, and her/his previous experiences working with wood and wood products.

The second part of the questionnaire required the respondent architect to reveal the common wood and wood products used in her/his projects and their applications. The choice of the product type was determined by the preferred application specified by the architects, which encompassed two broad categories, *i.e.*, (i) structural applications that include floor boards, floor joists, floor decks, roofs, beams, and columns, and (ii) non-structural applications, including exterior decorations, interior decorations, doors and door frames, windows and window frames, gates, stairs, and ceilings. These applications were ranked by their importance according to the respondent architect's preferences.

The third part of the questionnaire evaluated the factors that influenced the respondent architect to use wood and wood products for the particular applications, indicated previously in the second part of the questionnaire. A total of 23 attributes of wood and wood products were included in the study, which were availability, customer demand, availability of craftsmanship, finish quality, cost, building comfort, thermal-insulation, sound-insulation, non-rusting, durability, fire resistance, health and safety, building standards, local council regulations, IBS, recyclability, sustainability, environmental impact, beauty, uniqueness, ease of assembly, ease of design, and ease of renovation. These attributes were rated on the basis of the Likert's five-point rating scale, from 1 (strongly unimportant) to 5 (strongly important).

Data collection

The questionnaire was initially pre-tested among 25 randomly selected practicing architects around the Klang Valley, Malaysia in September 2017. After obtaining the responses and comments from the respondents, the questionnaire was modified accordingly to ensure clarity and ease of implementation. The revised questionnaires were then distributed to the selected 500 architects, with a stamped and addressed envelope to return the questionnaire. After two weeks, a follow-up reminder was made through telephone to all the potential respondents, and at the end of the fourth week, a total of 135 architects (27% of the sample population) had returned their completed questionnaires.

Data analysis

The data from the questionnaires were compiled and tabulated using Microsoft Excel software (Microsoft, version 2010, Las Vegas, NV, USA) to facilitate analysis. The analysis of data was conducted using the Statistical Package for the Social Sciences (SPSS; IBM, version 25, New York, NY, USA). The effects of the attributes of wood and wood products on their preferential applications and extent of specification, as well as utilization in building construction, were analysed. The comparison mean between the test factors was performed using the non-parametric statistical method *via* the Mann-Whitney U and Kruskal-Wallis tests as the data in this study was an ordinal (Ho 2006). These tests were required to validate the use factor analysis, to establish the important variables that determined wood and wood products use in the construction sector. Factor analysis was then carried out on the 23 attributes of wood and wood products, to simplify them into smaller groups of several attributes that determine their extent of specification and utilization in building construction, as suggested in the paper by Nicholls and Roos (2006).

RESULTS AND DISCUSSION

The results of this study are presented in three parts: (1) the preferred applications of wood and wood products in building construction, (2) the attributes of wood and wood products for construction purposes, and (3) a factor analysis of the attributes of wood and wood products for construction purposes.

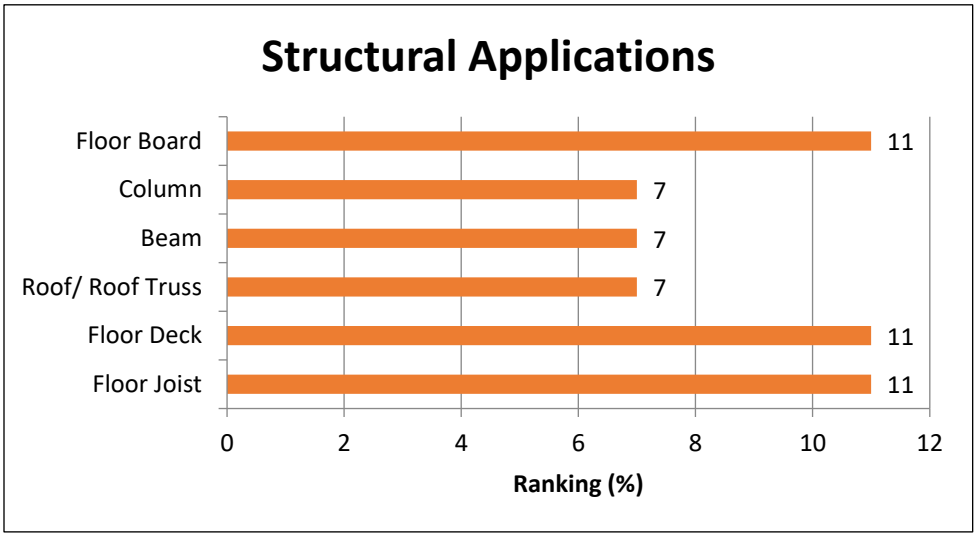

Fig. 2. Preferred applications of wood and wood products in building construction

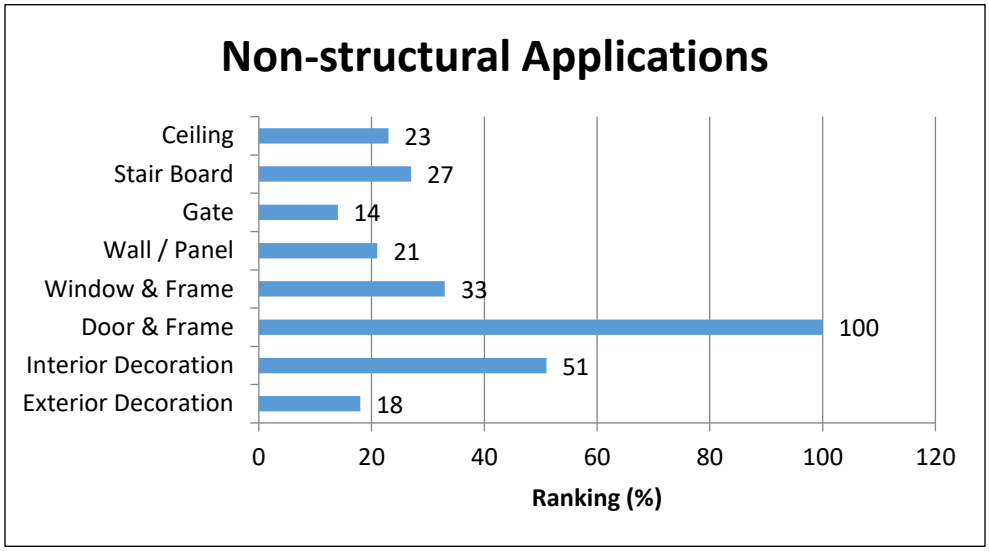

Fig. 3. Preferred applications of wood and wood products in building construction

The application of wood and wood products in building construction is focused primarily on non-structural applications rather than structural applications (Figs. 2 and 3). This preference among architects to specify wood and wood products for non-structural applications appears attributable to the perceived lower quality, higher cost, lower customer demand, and the prevailing strict building regulations against wood and wood products (Wagner and Hansen 2004). In fact, the study by Chung *et al.* (2014) also supports similar views expressed by architects, especially those intending to work with wood and wood products in the Malaysian construction sector.

Several factors were reported by the architects regarding their preferences for using wood and wood products in their construction projects. The factors are summarized in Table 2. Among all of the factors, it was obvious that the higher prices, lower durability, and stricter building regulations had encouraged most architects to specify wood and wood products primarily for non-structural applications.

Table 2. Factors for Choosing Wood and Wood Products for Specific Construction Applications

Structural	Cost Non-durable Fire Hazard Local Building Regulations Inconsistent Quality
Non-structural	Beauty Customer Demand Image/Social Status Familiarity Environment-friendly

Table 3. Mean Importance Rating of Attributes of Wood and Wood Products for Construction Purposes

No.	Attributes	Structural	Non-structural
1	Availability	**4.2**	**4.0**
2	Customer Demand	**4.6**	**4.8**
3	Available Craftsmanship	3.0	3.5
4	Finish Quality	**4.7**	**4.7**
5	Cost	**4.5**	**4.1**
6	Building Comfort	3.6	2.5
7	Thermal Insulation	3.5	2.5
8	Sound Insulation	3.0	2.6
9	Non-Rusting	2.5	2.5
10	Durability	**4.4**	**4.1**
11	Fire Resistance	**4.3**	**4.1**
12	Health and Safety	3.0	3.6
13	Building Standards	**4.0**	1.5
14	Local Council Regulations	3.9	1.6
15	Industrialized Building System	2.9	1.3
16	Recyclability	2.9	3.1
17	Sustainable Material	3.0	3.3
18	Environmental Impact	2.8	3.1
19	Beauty/Aesthetics	3.8	**4.4**
20	Uniqueness of Material	3.8	**4.6**
21	Ease of Assembly	3.3	**4.2**
22	Ease of Design and Workability	3.4	**4.3**
23	Ease of Renovation	3.3	**4.2**

Note: Figures in bold represent the highest ranking attributes that are important for each application

The attributes of wood and wood products preferred by architects for construction purposes were then evaluated. Table 3 presents the mean ranking of the effect that wood and wood products had on its application. It was apparent that cost, customer demand, durability, natural beauty, availability, and ease of design and workability were the primary considerations of architects when specifying wood and wood products for particular applications in building construction.

These findings were contrary to other reports on the attributes that influenced the selection of wood and wood products for construction purposes. In the study by Hemström *et al.* (2011), building comfort, natural beauty, and energy efficiency received the highest importance in Western Europe and North America. In contrast, the report by Gold and Rubik (2009) suggested that the poor durability and other technical properties were more important hindrances to applying wood and wood products to a wider range of applications in the construction sector. In another study by Ratnasingam and Chung (2016), it was reported that the impending fire hazard, low durability, building regulations, and cost were more important than that of the attributes of higher living comfort, environment-friendly, energy efficiency, and even ease of assembly in dictating how wood and wood products were utilized in building construction in Asia. In Japan and New Zealand, wood utilization in construction was well received, especially due to its ability to withstand shocks during earthquakes, along with its ease of assembly, renovation, and construction (Ellingwood *et*

al. 2004). Other studies (Marsono and Balasbaneh 2015; Roos *et al.* 2010) examined several appearance-based attributes of wood and wood products and found that the perceived non-durability and poor fire resistance played important roles in influencing architects in specifying and designing buildings using wood and wood products in tropical environments. Against these elements of background, it appears that the cumbersome building regulations, fire safety issue, and higher cost associated with using wood for construction are the primary factors that minimize the use of wood and wood products for construction in Malaysia.

Effect of Factors on Attributes

Table 4 confirms that the demand, cost, hazard, building regulations, beauty, and installation were the main reasons for architects choosing wood and wood products for either structural or non-structural applications in building construction. A statistical analysis was conducted to determine if the six factors had any effect on the type of applications suited for wood and wood products in building construction.

Table 4. Determinant Factors of the Utilization of Wood and Wood Products in Building Construction

Factors	Attributes		Mean	Chi-sq	Sig.
Demand	Availability	S	14.10	1.034	0.037
	Customer Demand	NS	15.70		
	Available Craftsmanship				
Cost	Finish Quality	S	15.60	0.917	0.039
	Cost	NS	17.10		
Hazard	Durability	S	16.50	0.816	0.037
	Fire Resistance				
	Health and Safety	NS	15.00		
Regulation	Building Standards	S	19.15	0.772	0.041
	Local Council Regulations				
	Industrialized Building System	NS	14.50		
Beauty	Beauty/Aesthetics	S	16.90	0.648	0.0449
	Uniqueness of Material	NS	14.10		
Installation	Ease of Assembly	S	13.90	1.214	0.597
	Ease of Design and Workability				
	Ease of Renovation	NS	17.50		

Note: S denotes structural application, NS denotes non-structural application

The Kruskal-Wallis statistical analysis was conducted to determine the significant difference in the attributes that influenced the selection of wood and wood products between the types of applications in building construction. The results of the analysis shown in Table 4 revealed that only the factors of demand, cost, hazard, building regulations, and beauty of the material were important determinants in the uses of wood and wood products in building construction. In fact, this result corresponded to the preliminary study by Chung *et al.* (2014), who found that customer demand and hazard were perceived to be the primary concerns of architects when specifying wood for building construction in Malaysia.

Table 5. Effects of Factor Difference in the Utilization of Wood and Wood Products for Building Construction

Factors	Attributes		Mean	Mann-Whitney-U	Sig.
Demand	Availability	S	14.10	96.50	0.327
	Customer Demand	NS	15.70		
	Available Craftsmanship				
Cost	Finish Quality	S	15.60	92.50	0.093
	Cost	NS	17.10		
Hazard	Durability	S	16.50	63.50	0.047
	Fire Resistance				
	Health and Safety	NS	15.00		
Regulation	Building Standards	S	19.15	62.50	0.041
	Local Council Regulations				
	Industrialized Building System	NS	14.50		
Beauty	Beauty/Aesthetics	S	11.97	66.14	0.039
	Uniqueness of Material	NS	18.91		

Note: S denotes structural application, NS denotes non-structural application

The second part of the analysis was to determine whether there was any significant difference in demand, cost, hazard, and building regulations between the structural and non-structural applications of wood and wood products. The Mann-Whitney U test was applied for this analysis. As shown in Table 5, no differences were observed between the demand and cost factors' influence on wood and wood products for structural and non-structural applications, as the P-value was larger than 0.05. However, the building regulations, hazard, and beauty factors showed a difference when using wood and wood products for structural and non-structural applications. These results appeared to coincide with the report by the CIDB (2015) that states that the local building regulations have a strong influence on architects specifying wood and wood products for building construction in the country. In fact, similar findings were also implied by the Architects Association of Malaysia (AAM), who suggested that the unclear building regulations and the concern about the anticipated hazard and risks (*i.e.*, durability, fire resistance, and inconsistent quality) are the primary concerns of practicing architects when specifying wood and wood products for construction purposes (Hemström *et al.* 2011).

Factor Analysis of Attributes of Wood and Wood Products for Construction Purposes

A factor analysis assumes that all variables in the study have correlations to some degree (Ho 2006), and that the degree of correlation among the variables can be examined using the Kaiser-Meyer-Olkin method. The analysis indicated that the correlation among the variables showed an index value of 0.392, which was quite low, suggesting that the correlation between the variables are weak. The Bartlett's test of sphericity of the correlation matrix yielded a value of 93.14 and an associated level of significance of less than 0.001. Hence, the correlation matrix indicated significant correlation among at least some of the variables, and therefore the factor analysis was appropriate for the data collected in this study.

The factor analysis grouped the 23 variables into four main groups of attributes, which could be defined as follows: (1) building regulations, (2) material quality and beauty, (3) customer demand, and (4) design and assembly. Instead of describing the attributes of wood and wood products in accordance to the many variables that influenced their use in building construction, the factor analysis resulted in the consolidation of the many variables into four distinct groups, as shown in Table 6.

Table 6. Four Factor Solutions from the Factor Analysis of Attributes of Wood and Wood Products for Construction Purposes

No.	Attributes	*Group 1* Building Regulations	*Group 2* Material Quality and Beauty	*Group 3* Customer Demand	*Group 4* Design and Assembly
1	Availability	0.211	0.166	**0.637**	-0.108
2	Customer Demand	-0.419	0.180	**0.716**	0.410
3	Available Craftsmanship	-0.316	-0.048	**0.691**	0.426
4	Finish Quality	0.359	0.411	**0.788**	-0.118
5	Cost	0.316	0.369	**0.898**	-0.129
6	Building Comfort	0.144	**0.699**	0.416	0.316
7	Thermal Insulation	0.219	**0.544**	-0.399	0.382
8	Sound Insulation	0.139	**0.521**	-0.217	0.413
9	Non-Rusting	0.218	**0.586**	-0.198	0.407
10	Durability	**0.618**	0.144	0.427	-0.037
11	Fire Resistance	**0.718**	0.219	0.414	-0.049
12	Health and Safety	**0.599**	-0.187	0.388	-0.041
13	Building Standards	**0.883**	0.191	0.216	0.411
14	Local Council Regulations	**0.798**	0.159	0.241	0.396
15	Industrialized Building System	**0.693**	0.140	0.081	0.445
16	Recyclability	-0.244	**0.511**	-0.107	0.215
17	Sustainable Material	-0.261	**0.519**	-0.102	0.202
18	Environmental Impact	0.229	**0.661**	-0.135	0.231
19	Beauty/Aesthetics	-0.141	**0.905**	-0.418	-0.169
20	Uniqueness of Material	-0.166	**0.894**	0.312	-0.177
21	Ease of Assembly	0.242	-0.271	0.117	**0.617**
22	Ease of Design and Workability	0.227	-0.267	0.213	**0.814**
23	Ease of Renovation	0.310	0.299	0.218	**0.711**

Factor analysis showed that the factors encouraging the use of wood products can be categorized into four main groups, which influence the architects' decision to specify the material in their project. The variance of the factors accounted for 29.5%, 21.8%, 18.1%, and 14.1%, respectively, of the total variance observed among the various variables.

In this context, this study revealed that in the application of wood and wood products for construction purposes, building regulations, material quality and beauty, customer demand, and design and assembly were of primary importance in determining their use and are often taken into consideration by architects. In fact, this result supports the claims by the House Builders Association of Malaysia, who argued that the extent of

the use of wood products in the construction industry in Malaysia is determined by regulation, construction practices, and customer demand, rather than the lack of awareness of wood and wood products among specifiers, architects, and contractors (Ratnasingam and Chung 2016). In fact, despite the advertisements and promotional campaigns by the relevant authority, the use of wood by architects in their projects has not seen significant improvements.

Implications for the Industry

The results of this study show that the four major determinants of the utilization of wood and wood products in building construction are building regulations, material quality and beauty, customer demand, and design and assembly. Therefore, it is important to revisit the existing building regulations and local council building by-laws to encourage wider use of wood and wood products in building design and construction. As professionals, architects are governed by the Architect's Profession Act, which must be complied to when designing and specifying building details (Marsono and Balasbaneh 2015). Furthermore, it is also important to increase the awareness of using wood and wood products among the general public to allay any fears related to the perceived low quality of wood products. In this context, the roles of relevant agencies, such as the MTIB and Malaysian Timber Council (MTC), in disseminating information about wood and wood products to the general public is important. To boost confidence in the utilization of wood and wood products in building construction, consistent quality of the materials must be ensured through proper quality control and product verification (Ratnasingam and Chung 2016). The use of wood and wood products in building construction can also be improved, provided that long-term stress loading of members and joints, as well as related strength data, is made available through rigorous testing and analysis by relevant research institutes. This is particularly important considering the diversity in the tropical hardwood resources and the growing importance of lesser-known timber species (Ramage *et al.* 2017). It must also be emphasized that proper training of craftsmen for wood construction, as suggested by Hannon *et al.* (1978), must also be attended to in the country to ensure quality workmanship of the constructed buildings. Inevitably, expansion in the use of wood and wood products in the building construction in the country will depend on not only increasing the awareness of wood materials among potential customers, but also on increasing the economic viability of the wood and wood products as a construction material.

CONCLUSIONS

1. This research was initiated to ascertain architects' preferences for using wood and wood products in their building projects in Peninsular Malaysia. In general, the respondents reported that they preferred using wood and wood products for non-structural applications.
2. The determinants of the utilization ofwood and wood products in building construction in Peninsular Malaysia were customer demand, cost, hazard, building regulations, and the material's beauty. The study also showed that determinant factors for the utilization ofwood and wood products varied according to local conditions.

3. The determinants of using woodand wood products in building construction in Peninsular Malaysia can be categorized into four major groups, namely building regulations, material quality and beauty, customer demand, and design and assembly, which influenced architects when specifying and designing buildings.
4. To encourage wider utilization of wood and wood products in building construction in Peninsular Malaysia, it is important to increase the awareness and appreciation of strength data, material's quality, and its other beneficial properties among the general public, as well as the practicing architects and other building professionals.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Persatuan Akitek Malaysia (PAM) for their support with this study. The financial support from the Universiti Putra Malaysia under the PUTRA-Grant-IPS scheme that made this study possible is also acknowledged.

REFERENCES CITED

Bank Negara Malaysia (2016). *The 2015 Housing and Construction Scenario in Malaysia* (Report No. 8), Bank Negara Malaysia Press, Kuala Lumpur, MY, pp.89.

Cheah, S. L. (2017). *Status of Malaysian Construction Sector: The House-Buyers' Perspective* (Edge Property Report 2016), Edge Group Publication, Kuala Lumpur, Malaysia.

Chung, T. M., Kee, T. S., and McNulty, T. (2014). *Understanding the Consumer Perception of Wood Products in Building Construction, PAM Internal* (Report No. 8), Kuala Lumpur, Malaysia,pp.24-29.

CIDB (2015). *An Analysis of the Construction Sector in Malaysia*, Construction Industry Development Board (CIDB) Press, Kuala Lumpur, Malaysia.

Ellingwood, B. R., Rosowsky, D. V., Li, Y., and Kim, J. H. (2004). "Fragility assessment of light-frame wood construction subjected to wind and earthquake hazards," *Journal of Structural Engineering* 130(12), 1921-1930.DOI: 10.1061/(ASCE)0733-9445(2004)130:12(1921)

Gold, S., and Rubik, F. (2009). "Consumer attitudes towards timber as a construction material and towards timber frame houses: Selected findings of a representative survey among the German population," *Journal of Cleaner Production* 17(2), 303-309. DOI: 10.1016/j.jclepro.2008.07.001

Guiles, J. (2014). "Evaluating the environmental performance of wood building materials," ESF, (http://www.esf.edu/ecenter/eis/woodmaterials.htm), Accessed 14 Jan 2018.

Gustavsson, L., and Sathre, R. (2006). "Variability in energy and carbon dioxide balances of wood and concrete building materials," *Building and Environment* 41(7), 940-951. DOI: 10.1016/j.buildenv.2005.04.008

Hannon, B., Stein, R. G., Segal, B. Z., and Serber, D. (1978). "Energy and labor in the construction sector," *Science* 202(4370), 837-847.DOI:10.1126/science.202.4370.837

Hemström, K., Mahapatra, K., and Gustavsson, L. (2011). "Perceptions, attitudes and interest of Swedish architects towards the use of wood frames in multi-storey buildings," *Resources, Conservation and Recycling* 55(11), 1013-1021. DOI: 10.1016/j.resconrec.2011.05.012

Ho, R. (2006). *Handbook of Univariate and Multivariate Data Analysis and Interpretation with SPSS*, Taylor and Francis Group, Boca Raton, FL, USA.

Kozak, A. R., and Cohen, H. D. (1999). "Architects and structural engineers: An examination of wood design and use in nonresidential construction," *Forest Products Journal* 49(4), 37 46.

Lippke, B., Oneil, E., Harrison, R., Skog, K., Gustavsson, L., and Sathre, R. (2011). "Life cycle impacts of forest management and wood utilization on carbon mitigation: Knowns and unknowns," *Carbon Management* 2(3), 303-33. DOI:10.4155/cmt.11.24

Marsono, A. K. B., and Balasbaneh, A. T. (2015). "Combinations of building construction material for residential building for the global warming mitigation for Malaysia," *Construction and Building Materials* 85, 100-108. DOI: 10.1016/j.conbuildmat.2015.03.083

Nicholls, D. L., and Roos, J. (2006). "Lumber attributes, characteristics, and species preferences as indicated by secondary wood products firms in the continental United States,"*HolzalsRoh-und Werkstoff* 64(4), 253-259. DOI:10.1007/s00107-005-0071-y

Ramage, M. H., Burridge, H., Busse-Wicher, M., Fereday, G., Reynolds, T., Shah, D. U., Wu, G., Yu, L., Fleming, P., and Densley-Tingley, D. (2017). "The wood from the trees: The use of timber in construction," *Renewable and Sustainable Energy Reviews* 68(1), 333-359.DOI:10.1016/j.rser.2016.09.107

Ratnasingam, J., and Chung, T. M. (2016). "Wood use in building construction: The Malaysian dimension," *Asian Woodworker* 14(3), 18-23.

Roos, A., Woxblom, L., and McCluskey, D. (2010). "The influence of architects and structural engineers on timber in construction: Perceptions and roles," *Silva Fennica* 44(5), 871-884.

Thomas, D., and Ding, G. (2018). "Comparing the performance of brick and timber in residential buildings: The case of Australia," *Energy and Buildings* 159, 136-147. DOI:10.1016/j.enbuild.2017.10.094

Upton, B., Miner, R., Spinney, M., and Heath, L. S. (2008). "The greenhouse gas and energy impacts of using wood instead of alternatives in residential construction in the United States," *Biomass and Bioenergy* 32(1), 1-10. DOI:10.1016/j.biombioe.2007.07.001

Wagner, E. R., and Hansen, E. N. (2004). "Environmental attributes of wood products: Context and relevance to U.S. architects," *Forest Products Journal* 54(1), 19-25.

Wang, L., Toppinen, A., and Juslin, H. (2014). "Use of wood in green buildings: A study of expert perspectives from the UK," *Journal of Cleaner Production* 65(1), 350-361.DOI:10.1016/j.jclepro.2013.08.023

Article submitted: February 19, 2018; Peer review completed: April 29, 2018; Revised version received: May 15, 2018; Accepted; May 16, 2018; Published: May 22, 2018.
DOI: 10.15376/biores.13.3.5289-5302