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Timber and Multi-Storey Buildings: Industry Perceptions of Adoption in Australia

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Abstract: The use of Engineered Wood Systems (EWS) as structural alternatives or complements of traditional materials, such as steel and concrete, is of growing interest and acceptance in the architecture, engineering, and construction industries. Gathering evidence from the Australian context, this paper proposes a roadmap for the adoption of EWS as the primary structural materials of medium-rise buildings, with the scope of increasing levels of public awareness about the potential and current shortcomings of these building technologies. A nation-wide survey with stakeholders at the forefront of adoption in structural design, construction, and property development, indicates that the demand for timber in multi-storey projects has promising prospects of growth, but faces circumstantial industry-wide hurdles in the short to medium term. Awareness of benefits and inclination towards more use of timber among designers are positive factors that provide a promising base for further adoption. The translation of positive front-end design attitudes into adoption, however, requires holistic long-term investment efforts with industry-wide education. The pathway to innovation for timber in multi-storey projects needs to grow beyond mere promotional strategies of its benefits, seeking to expand technical knowledge through education and reaching out beyond a group of already committed and knowledgeable stakeholders at the forefront of adoption.

Keywords: Engineered Wood Systems; adoption strategies; industry education

Citation: Marfella, G.; Winson-Geideman, K. Timber and Multi-Storey Buildings: Industry Perceptions of Adoption in Australia. *Buildings* **2021**, *11*, 653. https://doi.org/10.3390/buildings11120653

Received: 15 September 2021
Accepted: 8 December 2021
Published: 16 December 2021

1. Introduction

Labor-demanding construction methods and energy-intensive manufacturing of building materials are becoming economically and environmentally prohibitive for tall building construction. The sustainability of materials and systems traditionally used in large multi-storey applications, such as rigid frames of steel or reinforced concrete, is increasingly questioned due to high energy demands over the long term. As a result of this future uncertainty, a growing number of developers and designers are induced to champion or experiment with timber as an alternative to steel and concrete.

Although timber has been shown to be a viable structural material for the construction of high-rise buildings [1,2], its growth as a suitable and feasible alternative to steel and concrete appeals more to the medium-rise than the high-rise sector. The suitability of timber for medium-rise multi-storey buildings is reflected by the provisions of some building regulations. The National Construction Code of Australia, for example, prescribes deemed-to-satisfy conditions for timber buildings less than three storeys high, or multi-storey timber construction generally lower than 25 meters in effective height [3]. Nonetheless, the term Tall Wood Buildings (TWB) is regularly used to represent the emerging trend to use timber outside the sphere of traditional low-rise residential buildings [4]. The term 'tall' reflects the industry's intent to advocate the expansion of this technology in the broader market of multi-storey commercial construction, although its relevance in that sector pertains so far to examples of relatively low height if compared to the contemporary global tall building stock [5].

The technologies that facilitate the use of timber in taller than usual applications are part of the family of products and systems known as Engineered Wood Systems (EWS) or Engineered Wood Products (EWP). These materials and systems pertain above all to mass-timber construction (MTC), of which the most used products are Glue-Laminated Timber (GLT), Laminated Veneer Lumber (LVL), and Cross-Laminated Timber (CLT). Tall timber construction, though, is not exclusively limited to mass timber; it also includes prefabricated systems, such as cassette construction and traditional lightweight framing systems (also known as stick construction). Even these traditional technologies, when appropriately fire-protected, are suitable for multi-storey construction that complements or are alternatives to MTC solutions.

The material properties and manufacturing processes of EWS alleviate—and in some cases eliminate—some of the traditional shortcomings of light-weight timber framing, which after originating in the 1800s with balloon-frame construction, have evolved into the platform construction methods that still dominate low-rise residential construction in many countries such as Australia, North America, and parts of Central and Northern Europe. The manufacturing of engineered timber products such as GLT, LVL, and CLT has a higher level of dimensional and quality control than traditional timber framing. Higher production quality and precision open opportunities for customized prefabrication through structural elements of size much larger than those derived from traditional log conversion. The production characteristics of MTC products also allow structural engineers to predict stress by controlling member behavior through shaping, custom-sizing and jointing, and fire-safety behavior, by calculating a charring rate for exposed applications or by applying safeguards with encapsulation prescribed by codes.

In addition to the opportunities offered by customized large-scale structural design in timber, EWS promise to bring significant benefits concerning safety and efficiency to multi-storey construction [6]. In the Australian construction industry context, these benefits have been shown to provide tangible cost savings in project 'preliminaries' and the consequent reduction of demand for heavy lifting machinery and concrete handling equipment [7]. In the same industrial context, EWS are also commonly associated with prospects of direct cost savings for contractors and lessening of health and safety hazards due to a significant reduction of on-site labor [8].

Bolstered by the benefits available to structural designers and builders, EWS thus offer compelling marketing arguments to developers and architects who are willing to reconcile design aesthetics with environmentally friendly credentials [9–12].

The literature concerned with timber in multi-storey timber construction has expanded considerably over the last decade. The growing use and applications of this family of products are matched by an increasing wealth of research activity worldwide. Research in the field of mass timber and other EWS encompasses a broad range of topics, with studies mainly concerned with two frontiers of advancing knowledge. The environmental benefits of timber as a renewable material through life-cycle assessments is a recurrent topic [13–15]. Notwithstanding the proven environmental credentials of EWS, it has been nonetheless advocated that further reduction of energy consumption associated with the manufacturing of wood products is still possible and auspicial [16].

The second frontier of mainstream research in the topic offers abundant literature concerned with the testing and performance of structures, building elements, and materials. Research focus in this area gives priority especially to matters of fire safety [17,18], but not solely, with challenges for seismic design becoming an equally paramount engineering area in need of further research and regulatory updates [19].

This paper is concerned with a third frontier of research based on two premises. The first premise considers broader social and economic aspects as the fundamental driver for the adoption of mass timber in new markets and multi-storey applications. Any process of construction innovation depends on a multitude of factors. Although environmental awareness and engineering testing are necessary to reinforce the appeal of emerging technologies, these matters alone can hardly overcome the input of broader social and economic factors.

The second premise of this study is that, given the complexity and range of factors that inhibit or promote change in the building industry, innovation studies that deal with commercial applications should be fine-tuned to specific geographic contexts. By limiting the field of investigation to a specific environmental or industrial context, it is possible to consider and ascertain what constitutes an acceptable level of risk for developers, interpret cultural and professional design trends, study the gatekeeping effects of regulatory frameworks, and understand the implications of new methods of procurement and supply chain within established practices of labor and industrial relations.

Building-industry studies along these lines require a considerable amount of fieldwork in the commercial construction sector, an area of the industry where stakeholders are often reluctant to share information for fear of loss of competitive advantage or disclosure of marketing or litigation-sensitive information. Innovation studies that break a breach with industry participation in this sector are therefore most valuable, even when they are limited to a specific geographic context. Building-industry studies focused on cultural, regulatory, and economic factors do not only determine the existence of possible barriers for the adoption of new technologies, but also indicate what overarching strategies should be explored to intervene and overcome such barriers.

Despite the fundamental importance of the cultural, regulatory, and economic factors at the forefront of innovation, the academic literature on tall wood buildings in this thematic area is not as prolific as that concerned with the promotion of environmental benefits and testing of engineering performance and implications. Precedents are not absent, however, and there are signals that industry awareness of the critical importance of research in this direction is growing [20]. Several studies have highlighted how the successful adoption of timber in multi-storey construction depends primarily on non-technical factors of perception in early design proposals, above all among developers and architects, or from industry-wide dynamics controlled by regulatory hurdles, cultures of building practice, and market-driven forces.

Research in the North American context has focused on CLT, showing that despite substantial opportunities for the forest industry [21] and growing awareness among architects [22], perceptions of lack of awareness persist. This is especially acute among construction managers, contractors, and developers, thus configuring potential adoption obstacles to be overcome with further research [23].

Similarly in Europe, notwithstanding a long history of optimistic prospects for timber as a 'high-performance' construction material suitable for multi-storey construction [24], insufficient regulatory support and technical information have been found to act as significant barriers against innovation [25]. Despite significant developments in timber engineering research, the transfer of knowledge from the European scientific community to structural designers has lagged, leading to initiatives of the European Cooperation in Science and Technology (COST Action FP1402) with the scope of bridging these gaps. In the context of this international initiative, research undertaken by a working group of Cost Action FP1402 has found that translation of knowledge into effective guidelines for the implementation of timber connections continues to face obstacles, leading to the need for structural updates of the European standard for the design of timber structures [26].

Following a similar line of inquiry and interest in promoting the adoption of timber structures, some studies in Australia have focused on the market outlook of timber, identifying opportunities and barriers for the new fields of structural applications. These initiatives ultimately led to the adoption of an action plan by the Australian forest industry with the scope of campaigning on potential savings of 'money and carbon', whilst leveraging on the aesthetic appeal of timber in interior applications [27]. An Australia-based study has focused more specifically on multi-storey construction. Gathering evidence from fifteen interviews with experts and a closed-ended questionnaire with 74 participants, the study suggested that the primary perceived obstacles against innovation relate to fire risks, lack of industry awareness, and perception of high-maintenance demands after construction [28]. Other studies in the same region have analysed instead the broader political, economic, social, environmental, and legal landscape from the perspective of a manufacturer and with the aim to ascertain the economic feasibility of establishing local production of mass-timber products. Among the latest, of particular note is the precedent of Kremer and Symmons, who have adopted the PESTEL approach in their study of mass-timber production, which serves as the basis for this study [29].

The PESTEL model—Political, Economic, Social, Technological, Environmental, and Legal—is a long-standing framework used to investigate the factors that affect an organization's strategic position and to uncover business information that can be used to motivate or adapt to change [30]. The present paper borrows but modifies this approach, shifting focus to the economic, social, environmental, legislative, and industry factors impacting the adoption of EWS in the Australian construction industry. The scope is to provide detailed insight into a broader spectrum of issues concerning the adoption of EWS, not merely from the marketing perspective and business interests of product manufacturers, but including the voices and concerns expressed by designers, clients, and builders. The findings presented are from a project partially funded by the Australian forest industry, and builds on the precedent literature and a pilot study based in Australia [31], adding new knowledge regarding the potential for industry-wide change of EWS in the market of multi-storey commercial construction. The research has been designed to test the potential reception of these technologies by reaching out to a very large sample of participants, probing the industry with themes that are multi-faceted and relevant for different disciplines, building typologies and areas of socio-economic interest.

2. Materials and Methods

The findings of this study stem from a project designed to unveil themes, add new knowledge, and identify barriers and benefits related to the use of timber in medium-rise and high-rise buildings in Australia. The data collection stage was timed to coincide with the end of the first triennial of activity of the WoodSolutions Medium-Rise Advisory Program (MAP) in Australia. The MAP is a joint government–industry-funded initiative that was introduced by Forest Wood Products Australia (FWPA) in 2016. The scope of the initiative is to support and promote the expansion of knowledge and use of timber in multi-storey projects. Part of the scope of this study was to assist the Australian forest industry at the end the first triennial effort of the MAP, gathering evidence of the effects and impact of the initiative, and providing recommendations for a new triennial phase of activity of the MAP that commenced in 2019.

Data was collected through a two-stage intervention study of participants active in the architecture, engineering, and construction industry. The first stage of the study collected data with an in-depth survey distributed online. The survey focused on the broad use of engineered timber products, including but not limited to mass timber construction in mid-rise commercial construction projects. A modified PESTEL approach was utilized to interpret the findings of this study, probing the questionnaire on responses focused on dominant Economic, Social, Environmental, Regulatory (Legislative), and Industry (ESELI) factors, gaps, and barriers deemed to be influencing the adoption of timber outside the traditional domain of low-rise residential construction.

The political dimension of influence (i.e., matters of industrial relations or broader government policy intervention) could not be investigated due to restrictions inherent in the role and mission statement of the funding agency. The technological dimension of influence was investigated separately, being dealt with in part by another publication [32] and covered separately in the survey by targeting a restricted sample of participants with direct knowledge and experience with EWS. The second stage of the study was informed by the findings of the survey; it consisted of semi-structured interviews with 12 senior professionals of different disciplines (property development, architecture, engineering, and construction management) with direct experience in multi-storey projects that used, or closely contemplated using, timber as the primary structural material.

The purpose of this paper is to report results from the first phase, the survey, focusing on the part of the questionnaire with the largest sample of participants and providing a comprehensive roadmap of the most pertinent and broader economic, social, environmental, regulatory, and industrial context themes for facilitating the adoption of EWS in multi-storey projects.

2.1. Sample Selection

The survey consisted of a 25-min questionnaire designed to capture input from a diverse sample of participants across all disciplines of the built environment. The primary scope was to identify critical social, technical, and economic themes from which to reconstruct and prioritize gaps and barriers against the use of timber in multi-storey buildings. The questionnaire was structured to select participation mainly from individuals who were either knowledgeable, experienced, pre-committed, or well-informed on the topic of mass-timber construction and other EWS. The design proved to be successful in this sense, attracting a majority (48%) with more than 20 years of industry experience. This result, combined with the level of participants with 10 to 20 years of experience, constituted 69% of respondents (Figure 1).

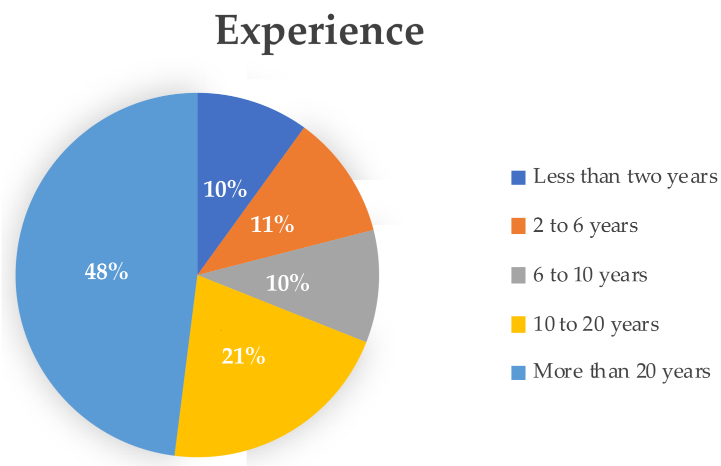

Figure 1. Level of experience of respondents.

Participants were recruited from a large database of approximately 17,000 international contacts held by the funding agency, reaching out to the full spectrum of professionals in the disciplines and commercial interests of the Australian building industry, with the largest pool of individuals coming from leading architectural companies, building designers, engineers, building consultants, and wood product manufacturers. The participants who chose to take part in the survey were mainly based in Australia. A significant component of participation came, however, from respondents located outside Australia, because of the international milieu in which the Australian construction industry operates. A sample of 682 respondents began the survey, with 164 voluntarily withdrawing after the initial demographic questions, leaving a core of 518 participants.

The online interface of the survey was designed and managed through a widely used commercial and proprietary software package, Survey Monkey, which allowed for the anonymity and de-identification of all respondents [33].

The survey gathered input from a broad range of participants, with architects or other building designers (21%), structural engineers (15%), and manufacturers or suppliers (16%) as the most represented professions. This group represented, in combination, more than half of the respondents. Construction professionals and tradespeople, who identified themselves as head contractors (8%), sub-contractors (3%), and project managers (3%), also had significant share of participation. Clients, developers and building owners, who in combination were only 5% of participants, and cost consultants (1%), were only marginally represented. See Figure 2 for a summary of the occupations of the respondents.

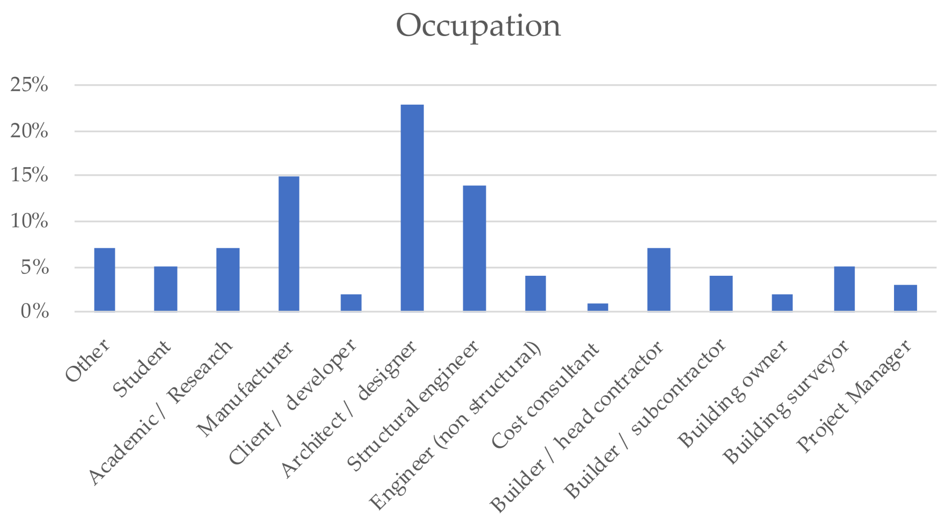

Figure 2. Respondents by occupation.

Most respondents declared to be based and mainly active in Australia in the states of Victoria (26%), New South Wales (20%), or Queensland (16%), followed by Western Australia (9%), South Australia (4%), and Tasmania (3%). Participation was recorded also from the Australian Capital Territory (ACT; 2%) and Northern Territories (<1%). This distribution reflects broadly the Australian population along the East Coast, although with some over-representation from Victoria and under-representation from New South Wales. Details are shown in Figure 3.

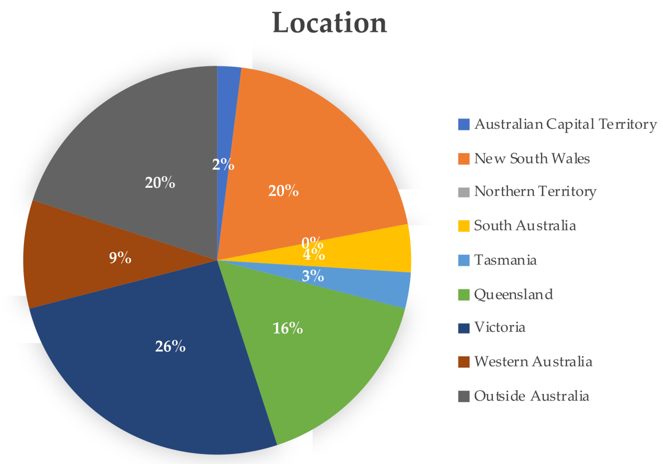

Figure 3. Location of survey respondents.

A significant number of respondents (20%) of the survey were based overseas. The specified locations of these participants were distributed worldwide (Europe, Africa, North America, South America, and South-East Asia) with New Zealand, United States of America, and United Kingdom being the most represented countries (Figure 4). The distribution of occupation among international respondents reflects the distribution of the full sample, with a prevalence of architects, engineers, and manufacturers. The high level of international participation in the survey confirms that the Australian market of engineered timber is inter-connected on a global scale. Judging from some open-ended responses, it is plausible to assume that some of these respondents have ongoing, or at least past, business ties with Australia.

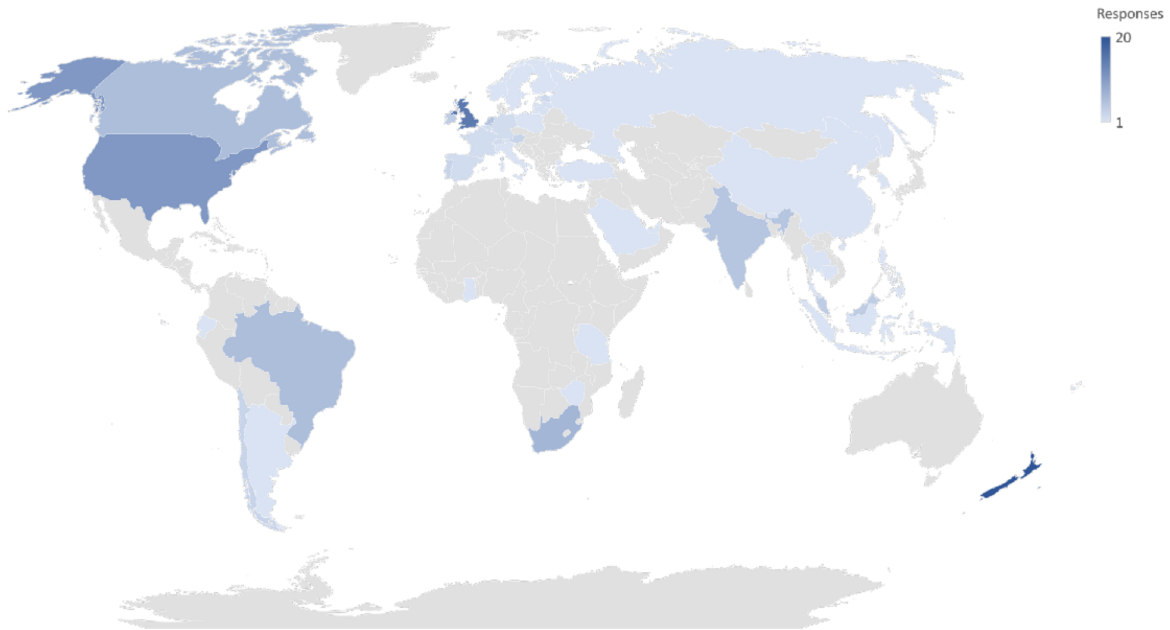

Figure 4. Global distribution of respondents outside Australia.

2.2. *Survey Instrument*

The intent of the survey was to intercept in prevalence the participation of senior industry representatives with a reasonable level of understanding and experience with EWS. The scope was to collect data suitable not merely for quantitative implications, but also for qualitative analysis based on a high-level of understanding among participants. The typical profile of the participant of this survey was an industry professional who was technically knowledgeable, experienced, informed, or familiar with the topic of timber in multi-storey applications or, at the very least, someone who possessed an established understanding of the culture, trends, and structure of the Australian architecture, engineering, and construction industry. This high level of experience or familiarity with the topic was confirmed by the positive disposition toward the use of timber expressed by the great majority of participants (84%), who declared they considered timber as a material appropriate for applications outside the traditional low-rise domestic market and suitable for multi-storey buildings higher than three floors.

The survey was comprised of 33 questions divided into four sections. Demographic questions (q1–q3) made up section one, followed the second section (q4–q14) which began by directly asking about the appropriateness of timber as a structural material for multi-storey buildings higher than three floors (q4). The remainder of the questions in this section focused on perceived economic, social, environmental, and industry advantages and disadvantages associated with EWS, specifically inquiring about the association between timber and environmental factors, public perceptions, social factors, regulatory issues, costing, and project finance. The 518 participants who proceeded beyond the demographic questions were given the opportunity to respond to the questions in sections one and two. See Appendix A for further survey details.

Question 15 provided the first of two exit points designed to progressively filter the respondents based on their experience with and knowledge of EWS. Section three (q16 to q24) delved into the technical aspects of EWS, with specific references to the dominant technologies used in multi-storey applications (CLT, LVL, GLT, timber cassette floors, and timber-framed walls). The second exit point was at question 25, and was designed to further narrow the respondent group to those who were the most experienced with EWS, as the subsequent questions (q26–q33) required the most specialized knowledge.

In an effort to assess the general industry awareness of and attitudes toward EWS, the focus of this paper is on the responses from the broadest group of respondents, namely those who responded to questions four through fourteen.

The first part of the questionnaire was designed to elicit the broadest possible indication of industry-wide perceptions, filtering responses by thematic factors (Economic, Social, Environmental, Legislative, and Industrial). The primary intent of this subset of questions (See Appendix A, q5–q13) was to identify overarching themes and barriers through perceptions that pertained simultaneously to the industry at large, rather than single disciplines in isolation. The conclusive open-ended question of the questionnaire allowed for corroboration of these broad and quantitatively based industry-wide perceptions with a qualitative assessment that was analysed further, and also by filtering responses by occupation and levels of experience (see Appendix B).

2.3. Methodology

Responses to the survey were analyzed first by summarizing the responses to the matrix questions and closed-end questions. Open-ended questions were interpreted using textual analysis software, NVivo [34]. Open-ended responses were analyzed using a simplified 'global analysis' method assisted by the software [35]. Responses were grouped in categories condensing progressively in vivo text into a tree of thematic coding summarized by keywords. Parent and child nodes were then visualized by the software, mapping relationships of the themes coded based on the identification of frequency values of the most recurring themes. This process helped rank qualitative themes with word clouds, hierarchy charts and heat maps. The results of this analysis are particularly valuable to gather insight from the open-ended questions, which were designed to extract perceptions and opinions not captured in the matrix and closed-end questions.

3. Results

Results are arranged according to the modified PESTEL framework mentioned earlier, focusing specifically on the economic, social, environmental, legislative, and industry (ESELI) factors that impact the adoption of EWS in Australia. Responses to matrix and closed-end questions are presented as simple percentages. The textual analysis of the open-ended question precedes a critical review of the combined results of the matrix, closed, and open-ended questions for each ESELI category.

3.1. Matrix and Closed-End Questions Results

3.1.1. Economic

Economic issues were investigated along two lines of inquiry, first by identifying major project cost factors and then by issues encompassing the insuring and financing of projects that feature EWS. Tangible (materials) and intangible (time) costs are examined under the dual assumptions that (1) the sum of tangible and intangible costs is more relevant than the cost of individual elements and (2) material substitutes and/or different combinations of the cost elements produce varying results. Finance and insurance are treated as a separate line of inquiry under the assumption that the probability of projects commencing that are not financed and/or insured is nil.

The prospect of cost savings associated with the use of EWS in projects generally stems from onsite reductions in construction time. Yates, Linegard, and Duic indicate a 26% reduction on a project in the UK that offset increased materials cost when substituting CLT for concrete [36]. Additional evidence from Lend Lease, the developer of the MTC Forte building in Melbourne, shows a 30% reduction in on-site time as well as increased safety, reduced construction traffic, and less waste [37]. This evidence is derived from a small number of case studies necessitating a broader understanding of the issue, therefore the respondents to this survey were asked to reveal their perceptions of the source of cost savings through the following question:

Which of the following do you consider a cost advantage associated with the use of timber in multi-storey buildings?

Top perceived cost advantages are reduced cost of construction time (74%), reduced cost of preliminaries such as cranes and temporary works (62%) and reduced structural costs (53%). Reduced cost of design and reduced cost of contract variations were only selected by 21% of the respondents, and reduced costs in maintenance and tendering/procurement were ranked lowest, selected by only 13% and 12% of the respondents, respectively. This question was phrased to elicit the perceived areas that are most likely to provide an economic advantage with the use of timber in multi-story applications—i.e., outside of their widespread use in domestic construction. The question did not ask to express a negative versus favorable judgment on the direct cost of materials by comparison with other structural materials (e.g., concrete or steel). The responses indicate that the most significant cost advantages perceived among respondents relate to possible savings in construction time and equipment ('preliminaries'), and therefore labor, as a significant component of the overall cost of the structure of a building. See Figure 5 for details.

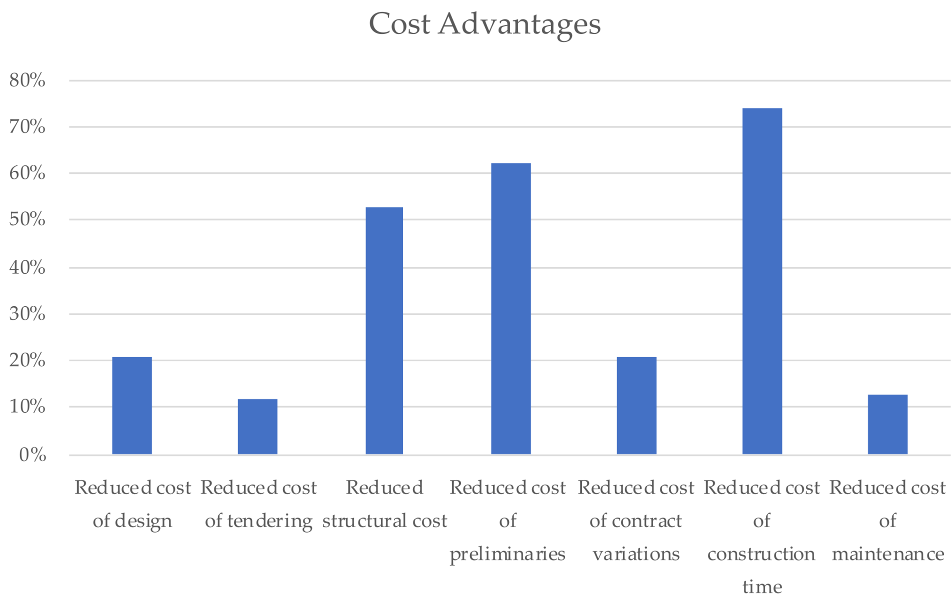

Figure 5. Responses to the question 'Which of the following do you consider a cost advantage associated with the use of timber in multi-storey buildings?'.

The second line of economic inquiry focused on financing and insuring projects that incorporate EWS. Work by Ahn, Pearce, Wang and Wang suggests the liability associated with the use of relatively new materials limits the insurability of such projects, particularly in the absence of long-term viability studies [38]. In Australia, the potential hazards that contribute to a general stigma around wood products include fire, flood, and to a lesser extent, seismic events, stimulating higher insurance premiums and potentially reducing the borrowing capacity of developers of EWS projects. These factors necessitated an inquiry into the financial issues associated with EWS adoption, where question 12 of the survey asks:

Which of the following financial disadvantages are related to the use of timber in multi-storey buildings?

As shown in Figure 6, while the majority of respondents indicated they were unaware of any financial disadvantages (58%), a reasonably large minority cited increased insurance premiums (29%) and special disclosure requirements to insurers (27%) as issues. Lack of traditional financing options were cited by 19% of the respondents and special disclosures to lenders by 17%. Only 5% indicated increased borrowing costs (higher interest rates) as a financial disadvantage of working with timber. Amongst the responses to the 'other' option, participants primarily indicated that surcharges were the result of lack of knowledge about the demonstrated suitability of a new material.

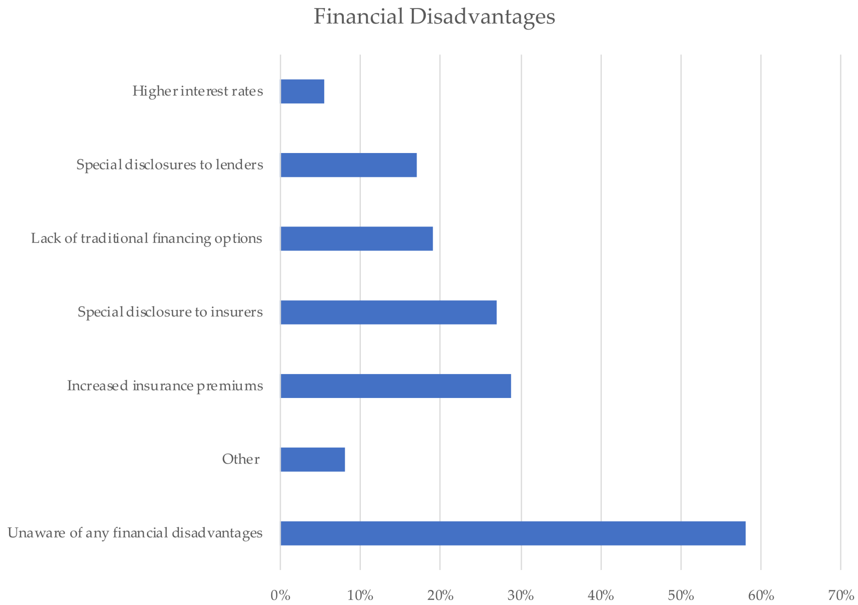

Figure 6. Responses to the question 'Which of the following financial disadvantages are related to the use of timber in multi-storey buildings?'.

Noting that innovative measures are often necessary to overcome financial hurdles, the respondents were then quizzed on the existence of self-financed projects by asking:

Are you aware of any projects, pilots or prototypes in Australia that were self-financed for the purpose of testing multi-storey timber design, materials, processes, performance or market acceptance? [yes, no].

The majority of respondents (80%) said they were not aware of any such pilot programs, whilst 20% said they were. Whilst no further explanation was sought, the existence of such projects underscores the willingness of the industry to test the potential feasibility of EWS for larger-scale use.

3.1.2. Social Factors

Social factors are measured by investigating the industry's understanding of consumer perceptions of EWS. This is assessed by focusing on the association biases of consumers, specifically the relationship between timber and several social factors, as perceived by the respondents to the survey. These measures are important for two reasons: firstly, this research assumes the average consumer has little to no technical knowledge of the use of timber in Australian construction, yet they are likely to have an opinion on timber based on their association with other factors. Second, it is important to understand how the industry perceives consumer opinion as this may influence the decision to incorporate timber in a project, ergo, if the market associates a product with negative factors, the industry may be prone to produce less of that product. This prompted the question:

In your opinion, how often are the following statements about public perceptions true? [never, almost never, sometimes, almost always and always].

The possible responses fall into positive or negative association categories. Figure 7 shows that, among the positive associations, the highest relative percent of respondents who agree that the perception is "always" or "almost always" true is in relation to "people associate timber with good aesthetics" (66%). This is followed by "people associate timber with green building design" (48%), "people associate timber with recycling" (29%), and "people associate timber with reduced energy consumption" (25%). Note that as the options progress from personal preference (aesthetics) to the more technical (reduced energy consumption), the less likely respondents are to cite the association as important, supporting the assumption that less-technical factors drive public perceptions. The results of the negative factors show that nearly half of the respondents "always" or "almost always" agree that "people associate timber with depletion of wildlife habitats" (49%) whilst 44% say "people associate timber with deforestation".

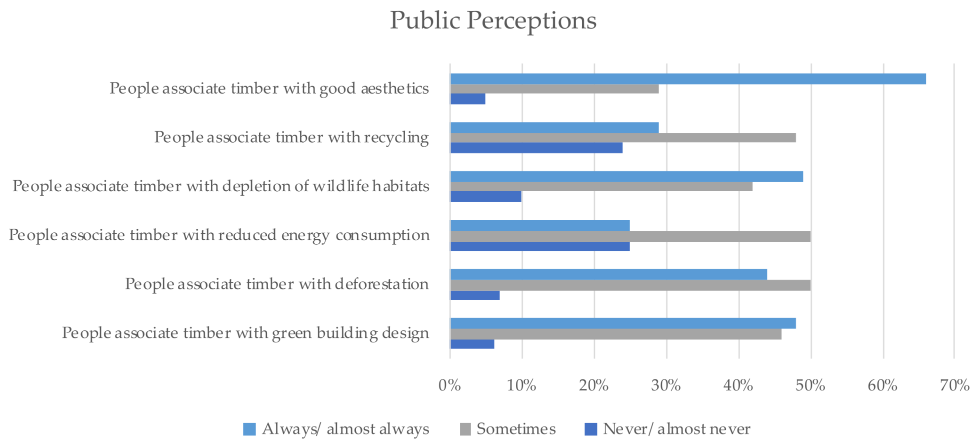

Figure 7. Responses to the question 'In your opinion, how often are the following statements about public perceptions true?'.

The respondents were then asked their perspective on issues of collective concern by identifying those that they believe have a positive, neutral or negative impact on the adoption of timber.

What impact do the following social factors have on the adoption of timber in multi-storey projects in Australia? [negative, very negative, neutral, positive, very positive].

The results shown in Figure 8 indicate that climate change awareness (62%) and the environmental movement (61%) are the most important social factors, whereas supportive government policy is viewed less favorably (36%). Few (18%) identify "resistance to change by the public" as an important social factor and 54% indicate resistance to change by industry as a negative social factor.

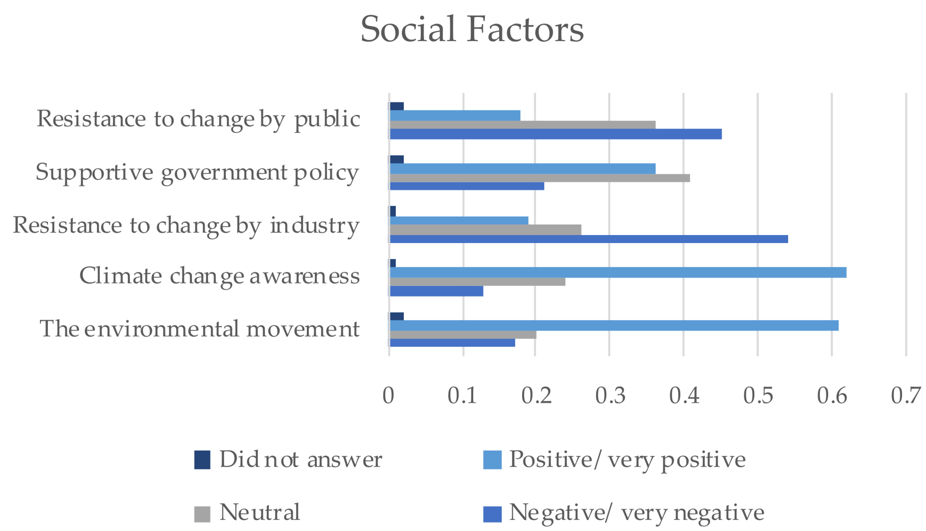

Figure 8. Responses to the question 'What impact do the following social factors have on the adoption of timber in multi-storey projects in Australia?'.

3.1.3. Environmental Factors

A number of environmental benefits are associated with the use of timber in construction. As a renewable resource, timber is arguably the most environmentally friendly of all building materials, particularly when farmed and managed in a sustainable manner. Trees capture and store carbon, thereby reducing the amount of carbon dioxide in the atmosphere. Carbon remains embedded in timber post-harvest, effectively creating a natural carbon storage system that is transferable to buildings. Even when factors such as the energy used to transform the raw material into building components are considered, timber is still a better option than steel [39].

The environmental benefits of timber extend to building sites. As EWS are manufactured offsite, onsite noise and waste are considerably less than when traditional construction materials are used. Further benefits are realized by reductions in traffic congestion when logistics are appropriately planned in advance, for example by prearranging routes for material delivery to minimize impacts [40].

In the survey, respondents were asked to comment on an array of environmental benefits through the following question:

> *The following is a list of possible environmental advantages associated with timber multi-storey buildings. Indicate your level of agreement or disagreement with each of the following possibilities as they relate to the environmental advantages of timber multi-storey buildings. [strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree].*

Among the seven options shown in Figure 9, respondents were asked to indicate if they strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with the proposed benefit. Among the respondents who either "strongly agree" or "agree", the top perceived environmental advantages are reduced carbon footprint (89%), sustainable production methods (89%) and less energy used in construction (82%). A large majority also found the use of timber to be advantageous on construction sites, with 68% indicating it contributes less waste and 61% indicating less noise. Less energy used in service (59%) and the potential to use under-utilized forests (50%) earned the fewest positive responses.

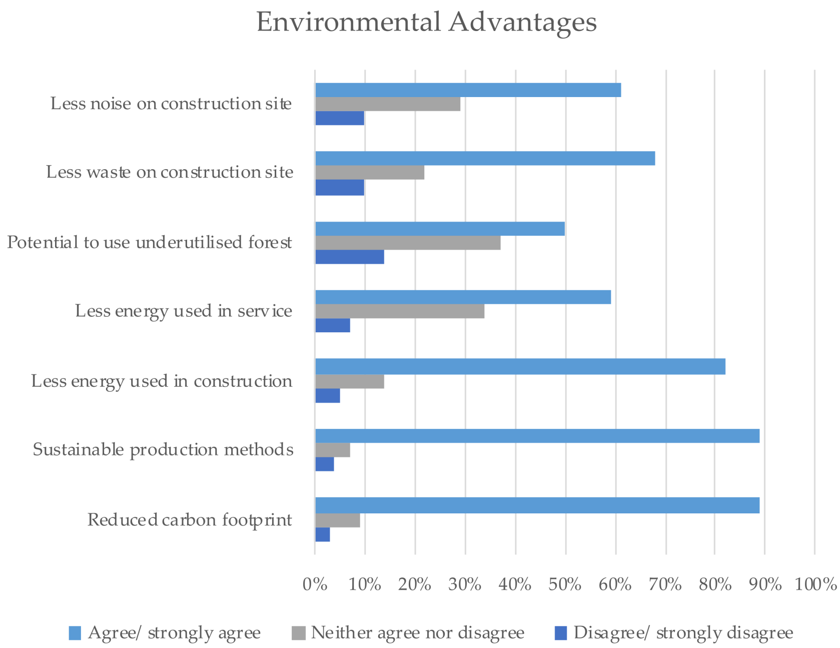

Figure 9. Responses to the statement, 'The following is a list of possible environmental advantages associated with timber multi-storey buildings. Indicate your level of agreement or disagreement with each of the following possibilities as they relate to the environmental advantages of timber multi-storey buildings'.

3.1.4. Legislative Factors

In Australia, regulations impacting the adoption of timber fall into two major categories: taxes and other government regulations. As timber naturally stores carbon, targeted, climate-based taxes designed to achieve carbon neutrality may incentivize the adoption of timber over other types of construction materials. Conversely, import restrictions or tariffs on timber increase cost, thereby disincentivizing its use. Until recently, little EWS were manufactured onshore, with the bulk of product originating in Europe, New Zealand, or North America, and thus subject to supply chain, exchange rate, and other import risks.

Regulations, namely those embedded in planning and building codes, are generally developed to obtain public benefits and keep people safe by mitigating or eliminating risk. Planning and building regulations in Australia exist at the federal, state, and local council levels with deemed-to-satisfy requirements for safety, health, amenity, and sustainability stipulated in the National Construction Code (NCC). Prescriptive building regulations may lack the flexibility necessary to keep pace with innovation, thus slowing the adoption of new materials. On that assumption, the Australian NCC provides opportunities for performance-based solutions as an alternative to the deemed-to-satisfy prescriptions of the Code. Since 2016, the NCC has been subject to two major revisions with the scope of facilitating the growing trend of timber applications in multi-storey construction beyond the traditional low-rise market [3]. These amendments, in essence, have opened plenty of opportunities and technical guidance for fully compliant prescriptive solutions for residential timber buildings in the medium-rise market (i.e., less than 25 m high) [41], and pathways for alternative solutions for "tall" timber buildings (i.e., more than 25 m high) in commercial applications [42].

On another front of the regulations, planning and built-form controls may be difficult to navigate when they contain conflicting information or incompatible standards, further impacting the adoption of new materials. For example, a 2019 report shows that mandatory height controls in the Victorian (Australia) planning system unintentionally penalized timber building systems by not accounting for the height variations required for the use of timber, rather than concrete, in building construction [43].

To understand the perceived impact of regulations, including taxes and bureaucratic requirements, on the adoption of timber, respondents were asked:

> *What impact do the following regulatory issues have on the adoption of timber in multi-storey projects in Australia? [very negative, negative, neutral, positive or very positive].*

Overall, the regulatory factors shown in Figure 10 were by and large not deemed to have any negative impacts. Most regulatory factors were considered neutral, positive, or very positive with wood-friendly legislation (72%), environmental policy (61%), and building code and standards (62%) viewed either positive or very positively. While the majority of respondents were positive or very positive on climate change-related taxes (49%), a large minority indicated a neutral position (36%). Traditional procurement methods earned the strongest negative/very negative rating (39%), and a majority were neutral on the impact of rules for planning approvals. Respondents were almost evenly split between negative/very negative (34%), neutral (31%), and positive/very positive (33%) in regard to rules for building approval.

3.1.5. Industrial Context Factors

Construction is an industry that is slow to innovate, especially when new materials and technologies are competing with traditional industries such as concrete and steel. Capturing market share involves changing the perceptions of industry participants by acknowledging the consumer demand that exists for wood products. Change also involves education; that is, educating builder/developers, engineers, and designers about the economic, environmental, and social advantages of wood as a complement or alternative to traditional construction methods and materials. Following the assumption that industry resistance is a potential factor limiting the adoption of timber in construction, participants were asked:

What impact do the following building industry factors have on the adoption of timber in multi-storey projects in Australia? [very negative, negative, neutral, positive or very positive].

Responses to the question support the premise that the current structure of the building industry does indeed restrict the expansion of timber products in the Australian market. Most factors elicit a negative or very negative response, particularly when compared to results from the economic, social, environmental, and legislative factors. Reliance on concrete/steel (65%), knowledge among engineers (46%), and attitudes of clients/developers (44%) are all perceived unfavorably. This aligns with earlier acknowledgement of the existence of an element of resistance to change by the industry as a social factor with a critical negative impact. Among the factors viewed to have more of a positive impact, product availability (42%) scores the highest. Knowledge among designers is the second-highest-scoring positive category at 38% but is also viewed negatively by an equal number. See Figure 11 for details.

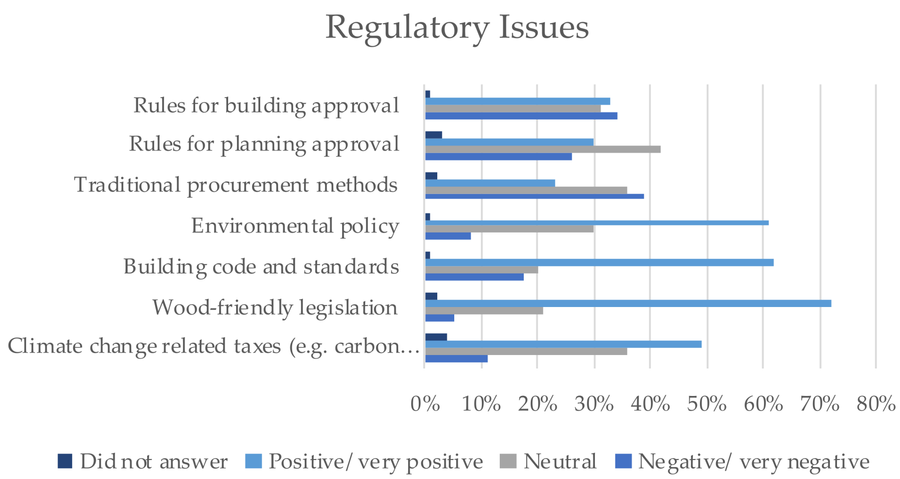

Figure 10. Responses to the question, 'What impact do the following regulatory issues have on the adoption of timber in multi-storey projects in Australia?'.

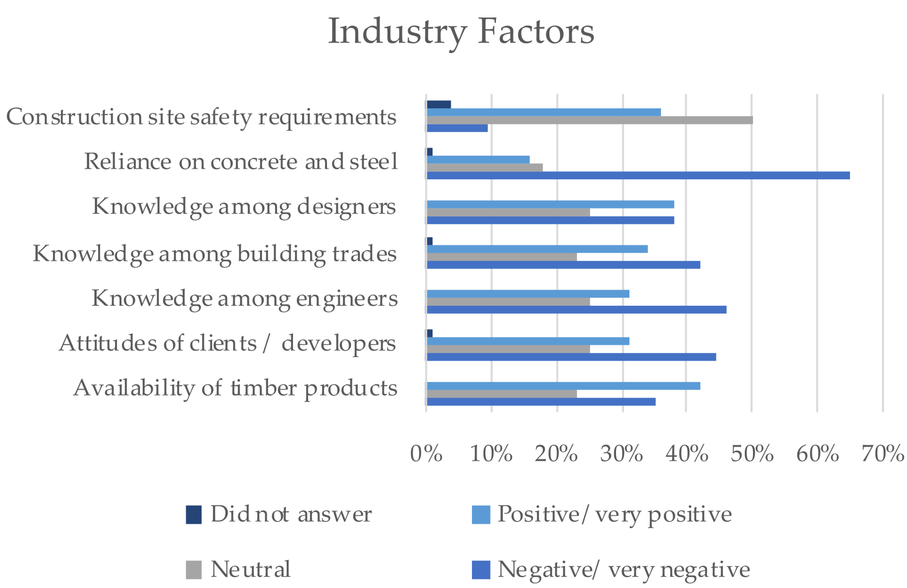

Figure 11. Responses to the question, 'What impact do the following building industry factors have on the adoption of timber in multi-storey projects in Australia?' [very negative, negative, neutral, positive or very positive].

3.2. Open-Ended Question Results

The first section of the survey concluded with a summary open-ended question (q14) seeking clarification on the key actions to be pursued to positively influence further adoption of timber. These respondents gave explicit suggestions about what a well-informed sample of the industry sees as priorities to improve the adoption of EWS in multi-storey construction, allowing for qualitative mapping by coding, with topics and sub-topics based on the answers of almost 400 participants to the question:

> *In summary, what could be done to improve the acceptance of structural timber systems in the medium and high-rise markets in Australia?*

This question allowed participants to conclude and summarize their opinion expressed until that point of the survey, focusing on economic, social, and environmental factors that affect or favor the adoption of timber in medium- and high-rise markets. The large number and variety of responses given to this question provided a structured network of parent and child nodes determined by coding through recurring keywords. Key themes were identified through an inductive content analysis of keywords, managed with the aid of the software, NVivo. See Figure 12 for details.

No. of responses	397
Sample	517
Response rate	77%
References coded	982

Parent themes	No. references
Change perceptions	369
Change the industry	315
Technological knowledge	183
Regulatory change	115

Figure 12. Word Cloud: what can be done to improve adoption of timber in medium and high-rise markets?

In the responses, the top-ten most used words relevant for the adoption of timber in multi-storey buildings are: 'design' (word count: 83), 'education' (79), 'use' (63), 'awareness' (59), 'engineers' (58), 'structures' (57), 'construction' (56), 'public' (53), 'fire' (52) and 'cost' (42).

A tree-map of topics, based on the content analyses of these responses, was further elaborated with the aid thematically filtered word clouds and hierarchy charts. The reading of these qualitative outputs indicates that there are four sets of opinions, through which it is possible to identify a roadmap to enhance adoption. See Figure 13.

Following a hierarchical structure based on the frequency of the themes raised in the comments, respondents stated that more adoption of timber will be supported by:

1. Changing public perceptions

This can be achieved by increasing the awareness and potential benefits of timber beyond a core of industry professionals who are already pre-committed. Change of perceptions should occur among the public at large (end users/consumers) through more dissemination of information, built examples, and further promotion strategies. Change of perceptions is required also within the property and construction industry itself, and specifically by raising awareness among developers, finance providers, and designers.

2. Changing industry perceptions

The key message shared by participants in this regard is to put more emphasis on 'education' within the industry. Further education seems an essential step to provoke systemic changes among construction professionals, thus opening more avenues for competitive tendering opportunities for the specification of timber in commercial projects. The word 'education' is to be taken in a broader sense, above all as a sharing of 'information' and 'knowledge' among professionals, and not necessarily a simple activity of 'schooling' at pre-employment stage. The exact term 'education' and some stemming derivations analysed qualitatively by responses give unequivocal evidence that this theme is felt as the valuable indicator on 'what could be done' to increase the adoption of timber.

3. Increasing technological know-how

A significant, albeit not dominant, set of responses points out the need of investing in specific technological change. Increased know-how seems pertinent above all to advance knowledge through research and development in the fields of sustainable performances, fire safety, structural engineering, durability, and maintenance.

4. Changing the regulatory context

A less statistically relevant, but not less valuable, set of suggestions in response to 'what could be done' indicate political or governmental intervention should be sought, either by a direct intervention of public authorities to pass wood-friendly legislation or to promote and finance projects directly, the implementation of further changes to building codes and regulations, review of processes of certification of materials and building approvals, and the development of more technical standards.

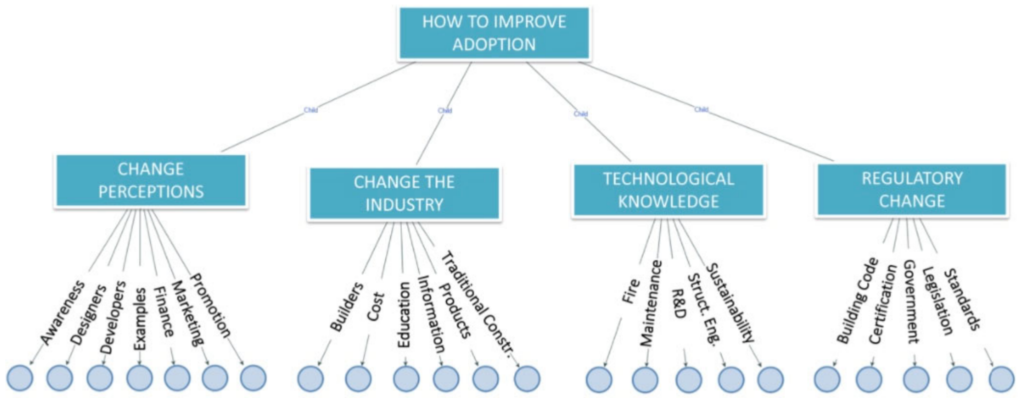

Figure 13. Tree map of themes identified to enhance adoption.

4. Synthesis of Results

The qualitative nature of this study makes it possible to draw some general observations about the most important economic, social, environmental, regulatory, and industrial context forces that are currently affecting or interacting with the process of adoption of timber as a primary structural material in commercial multi-storey construction. Here, the results from matrix, closed- and open-ended questions are synthesized in the context of the ESELI factors independently and as they relate to the other factors (where applicable).

4.1. Economic Factors

Knowledge of cost advantages and financial disadvantages is unequally distributed amongst the respondents. On the one hand, a sizable minority (39%) are aware of some of the cost-related advantages of EWS in multi-storey projects, most likely for the potential savings for the reduced impact of the cost of preliminary construction items, such as heavy-lifting equipment. Of concern is that this awareness is not more widespread. On the other hand, respondents indicated a general lack of awareness about the existence of specific insurance and financial barriers against the adoption of timber. Lack of awareness, however, does not exclude the existence of such barriers, as noted by 18% who cited special disclosures to insurers as an issue. The open-ended commentary of a small, but not insignificant, group of respondents (7%) (the "other" option; refer to Section 3.1.1) helps to clarify these concerns. The most recurring topics from these comments suggest that reluctance from insurers and financial institutions comes from general ignorance about the characteristic of products and systems. Other comments indicate fire safety, lack of durability, the possibility of delays, or insufficient financial coverage associated with overseas supply and prefabrication as key areas of perceived risk among insurers and financial institutions. Moreover, there is a general level of unawareness, even among respondents with more experience, about the existence of self-financed projects, pilots, or programs established with the scope of promoting timber in multi-storey construction.

4.2. Social Factors

While the industry appears to be reasonably well informed of the benefits and potential for timber in multi-storey buildings, their perception is that the public at large does not have the same grasp of the benefits. There is a generally diffused opinion that the public recognizes timber as 'aesthetically' pleasing or symptomatic of 'green building design'. This may indicate a saturation point for marketing campaigns focused on architectural aesthetics, which have been advocated and implemented in Australia in the last decade. The need to change perceptions, broadly within and outside the industry, through better "design" and "education" is the most dominant theme that emerged in the open-ended comments provided in response to "what can be done" to facilitate further adoption.

4.3. Environmental Factors

There is widespread consensus about the environmental advantages of multi-storey buildings built with timber, especially with respect to the carbon footprint offset given by a unique building material that is also renewable. The general understanding of the life cycle benefits of timber suggests that those with a lack of industry awareness of the environmental benefits of mass timber construction are not necessarily in need of further reminders of the carbon-offsetting benefits of the material as a naturally renewable source. Promotional campaigns in this direction may provide reassuring marketing messages for the public at large, but not necessarily advance adoption in an industry that is already aware of these almost self-apparent long-term environmental benefits. Several participants instead indicated ongoing dissatisfaction on the level of public awareness of other matters of environmental impact, especially those concerning the less adverse effects offered by EWS during the construction stage: less noise, less traffic, less material waste, less footprint, weight, and foundation.

More importantly it is the public, i.e., clients and users, but not necessarily the industry at large, that continues to be less aware of the specific environmental benefits of these technologies, including even matters of energy consumption and life cycle. A minority of respondents indicated lack of awareness about the impact that manufacturing of EWS may have on forests and natural habitats, whether negative or positive, thus not excluding the possibility that public concerns may arise with the association of this technology with deforestation. Despite a widespread concern that 'people' (i.e., outsiders of the industry) may be insufficiently aware of the full environmental benefits of EWS, the industry recognizes resoundingly that "the environmental movement" and growth in "climate change awareness" are social factors that are likely to most positively impact on the adoption of timber in multi-storey buildings over the long-term.

4.4. Legislative Factors

The findings of this study reinforce perceptions of the importance of regulatory aspects in the Australian industry context. Regulatory factors in Australia, however, are not necessarily an obstacle per se. Regulations can also act as facilitator for the adoption of timber. More importantly, it is essential to understand the role played in detail by the different elements of a regulatory regime, among which building codes and technical standards are some of the most critical influences of the innovation process. At the time of the survey, a predisposition to accept regulations as a positive opportunity—or at least as a non-critical barrier—derived most likely from the fact that a significant number of participants—by having a good level of knowledge in the topic—were most likely aware of recent changes brought to the National Construction Code of Australia (NCC). Since 2016, the NCC has opened the pathway for more use of timber in multi-storey construction through the Code's prescriptive provisions.

Among the potential difficulties arising for the approval of projects, complications associated with the release of building permits emerge as the highest concern, whereas there is less sense of emergency about the processes of approvals for planning and built-form regulations. The more experienced users of the sample state that building permit approvals are indeed a critical step to be overcome for the adoption of timber in multi-storey projects. Participants without direct project experience, however, seem generally unaware of such problems. The apparent contradiction of these responses suggests that the impact of regulations is probably a latent obstacle that is likely to grow in parallel with future adoption (Table A2, Appendix B).

Heat map studies filtered by industry role of the open-ended responses to Question 14 indicate that clients, developers, and more experienced designers and constructors do not necessarily have a high level of confidence in the role of government authorities, seeing the role of regulations as crucial in the roadmap for adoption (Table A3, Appendix B).

These results are consistent with studies that confirmed the importance of knowledge in fire-safety, suggesting that regulatory development in this area is plausibly still insufficient to reassure professionals and building authorities who may not have a strong environmental commitment or willingness to be at the forefront of innovation. Dominant methods of procurement and contractual agreements—especially the traditional ones based on open tendering managed by a general head contractor—may be another latent barrier against future innovation. This prospect seems a primary concern and obstacle among some respondents, particularly among those who stated to have direct project experience.

Notwithstanding a generally positive outlook that confirms the importance of the role of standards, building codes and regulations, it is noteworthy to indicate a possible limitation of this study posed by the low participation to the survey of regulators and building surveyors. From a quantitative standpoint, procurement and regulatory implications did not emerge as the most dominant theme to improve the adoption of timber but, given the limitations implicit in the sample considered by this study, the importance of these aspects should not be underestimated and points to the value of further research in this direction.

4.5. Industry Factors

Another critical theme that emerged from the survey indicates that there is a widespread 'knowledge gap' about timber as a structural material in multi-storey buildings. This perception is robust especially among the most experienced users of these technologies. A significant number of respondents indicated dissatisfaction about the current level of knowledge, above all and in order of importance, among engineers, builders, and designers.

In statistical terms, problems concerning the availability of timber products did not emerge as major concerns among respondents. The favorable response is however influenced by the relatively high participation of timber manufacturers in this study. The presence of a possible bias in this respect is suggested by a significant number of comments given via the open-ended responses, which instead indicated that matters of local supply are indeed critical aspects to be overcome.

Focusing on the Australian industrial context, the industry perceives that over-reliance on 'traditional' methods of multi-storey construction, concrete and steel, is a major cultural impediment that operates against the growth of timber in medium- and high-rise projects. This perception emerged from open-ended responses and aligns and qualifies further responses in another part of the questionnaire, which pointed to the perception of a cultural 'resistance to change' currently at work against the adoption of timber, both within the industry and among the public and consumers.

5. Conclusions

The results of this study provide an in-depth assessment of the perceptions and levels of knowledge and experience of Australian professionals of the architecture, engineering, and construction industry with Engineered Wood Systems (EWS) in multi-storey building applications.

The results of the survey, with over 500 participants, record a reasonable level of confidence and understanding of the technical and economic advantages of a family timber products, including CLT, LVL, GLT, and prefabricated cassette systems. Mass-timber products, in particular, are considered by most respondents as environmentally superior choices that are also technically adequate alternatives to concrete and steel in building structures. For senior professionals of the Australian design and building industry, timber is recognized as a structural material fit for architectural applications that encompass a broad range of destinations of use.

Nonetheless, the path towards a widespread use of these technologies is, according to the participants of this research, challenged by a cultural resistance to change within some sectors of the industry and by an overall lack of public awareness about the full potential and benefits of timber outside the traditional domestic market. A quantitative and qualitative assessment of the data collected by this survey shows that the Australian industry perceives the lack of technical know-how as a critical gap that should be overcome, in order of priority, among engineers, builders, and architects.

The rich open-ended commentary shared through this survey by over 400 participants located in Australia and overseas provides an in-depth resource to map the perceptions among different professional groups and Australian regions on the possibility of growth of timber in the commercial building market. In the context of a broad range of themes identified as either as beneficial or detrimental for the future adoption of timber, the most important theme that participants have proposed to accelerate innovation can be summarized as a need for proactive 'education', or, in other words, a holistic strategy with the scope of broadly advancing industry knowledge and public awareness. This holistic education-based strategy should be two-fold, engaging in parallel within and outside the building industry. On the one hand, there is industry demand for raising the technical bar among professionals, and on the other hand, for increasing awareness of the fitness for purpose of timber in multi-storey projects among the public and consumers.

The breadth of suggestions expressed by Australian professionals on what may be the best strategy to advance the adoption of timber in multi-storey projects suggest that such education should follow several paths in parallel, and not in isolation. Such indication reinforces, for instance, the validity of approaches similar to the one that European researchers have recently identified with COST initiative CA20139—Holistic Design of Taller Timber Buildings [44].

In Australia, the need for a similar holistic approach appears to be an equally relevant priority. Future efforts in achieving holistic outcomes for the adoption of timber should embrace the key themes identified by this study: improving public perceptions, overcoming a broader cultural resistance to change, increasing technical knowledge, and gaining industry confidence through more regulatory development and acceptance.

Author Contributions: Conceptualization, methodology, formal analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, project administration, and funding acquisition, G.M. and K.W.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was co-funded by FWPA (Forest and Wood Products Australia), grant number PNA461-1718 and the University of Melbourne, Faculty of Architecture, Building and Planning Research Development Grant.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Human Ethics Advisory Group of University of Melbourne (ID 1954986.1 approved on 11 October 2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data supporting the reported results are available through the authors.

Conflicts of Interest: The authors declare no conflict of interest. The funder FWPA had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A. Questionnaire Structure

Table A1. Summary of Survey Questions.

Topic	Question	Type of Response
Demographics	q1: How do you best describe your role in the industry? q2: How many years of industry experience do you have? q3: Where are you based?	Multiple selection
General	q4: Do you consider timber, as a structural material, appropriate for multi-storey buildings higher than 3 floors?	Yes/No/I don't know
Environmental factors	q5: Indicate your level of agreement or disagreement with each of the following possibilities as they relate to the environmental advantages of timber multi-storey buildings.	Matrix with Likert scale
	q6: Are there any other environmental advantages that you would like to mention?	Open ended
Social Factors	q7: In your opinion, how often are the following statements about public perceptions true?	Matrix with Likert scale
	q8: What impact do the following social factors have on the adoption of timber in multi-storey projects in Australia?	Matrix with Likert scale
Legislative factors	q9: What impact do the following regulatory issues have on the adoption of timber in multi-storey projects in Australia?	Matrix with Likert scale
Industry factors	q10: What impact do the following building industry factors have on the adoption of timber in multi-storey projects in Australia?	Matrix with Likert scale
Economic factors	q11: Which of the following do you consider a cost advantage associated with the use of timber in multistorey buildings.	Multiple selection
	q12: Which of the following financial disadvantages are related to the use of timber in multi-storey buildings?	Multiple selection
	q13: Are you aware of any projects, pilots or prototypes in Australia that were self-financed for the purpose of testing multi-storey timber design, materials, processes, performance or market acceptance?	Yes/No
Summary Question	q14: In summary, what could be done to improve the acceptance of structural timber systems in the medium and high-rise markets in Australia?	Open ended

Appendix B. Thematic Coding Analysis of Summary Question (q14)

Table A2. Heat map of themes identified as critical for adoption, filtered by years of experience.

THEMES CODED		YEARS OF EXPERIENCE					
P	C	More than 20 years (241)	10 to 20 years (88)	Between 6 and 10 years (34)	2 to 6 years (39)	Less than 2 years (35)	**Total (437)**
Perceptions	Awareness	15%	15%	6%	23%	23%	16%
	Designers	10%	9%	9%	10%	11%	10%
	Developers	5%	11%	21%	13%	3%	8%
	Examples	16%	15%	6%	15%	23%	16%
	Finance	4%	8%	9%	3%	3%	5%
	Marketing	10%	7%	6%	5%	11%	9%
	Promotion	19%	9%	9%	13%	20%	16%
Industry	Builders	9%	11%	3%	10%	9%	9%
	Construction cost	7%	9%	9%	13%	6%	8%
	Education	22%	20%	21%	15%	20%	21%
	Information	13%	9%	15%	18%	0%	12%
	Products	10%	11%	15%	10%	11%	11%
	Traditional Construction	8%	15%	15%	5%	23%	11%
Regulations	Building Code	7%	8%	3%	0%	6%	6%
	Certification	3%	3%	0%	0%	6%	3%
	Government authorities	10%	17%	3%	8%	3%	10%
	Legislation	3%	1%	0%	3%	6%	3%
	Standards	4%	5%	12%	0%	6%	5%
Technology	Fire	9%	13%	12%	13%	11%	11%
	Maintenance	7%	2%	6%	3%	3%	5%
	Research and development	3%	2%	12%	3%	14%	5%
	Structural engineers	8%	11%	12%	5%	14%	9%
	Sustainability	11%	11%	6%	8%	14%	11%
	Total (unique)	90%	91%	76%	74%	89%	88%

Table A3. Heat map of themes identified as critical for adoption, filtered by industry role.

THEMES CODED		**ROLE**														
P	C	Client/Developer (12)	Building Owner (8)	Architect/Designer (98)	Structural Engineer (65)	Engineering: Other (18)	Builder: Sub-Contractor (15)	Builder: Head Contractor (36)	Building Surveyor (22)	Project Manager (14)	Cost Consultant/QS (3)	Manufacturer/Supplier (69)	Academic/Research (30)	Student (21)	Other (28)	**Total (439)**
Perceptions	Awareness	25%	25%	14%	12%	0%	20%	31%	14%	14%	33%	14%	17%	24%	7%	16%
	Designers	8%	0%	9%	9%	6%	20%	3%	18%	21%	0%	12%	3%	10%	18%	10%
	Developers	17%	13%	10%	12%	11%	0%	0%	9%	14%	0%	9%	3%	5%	4%	8%
	Examples	0%	0%	17%	14%	17%	33%	17%	9%	0%	33%	13%	13%	10%	36%	15%
	Finance	8%	0%	6%	3%	0%	0%	6%	5%	14%	0%	6%	13%	0%	0%	5%
	Marketing	0%	38%	8%	6%	11%	13%	8%	5%	14%	0%	10%	0%	10%	14%	9%
	Promotion	25%	13%	12%	14%	11%	13%	17%	14%	29%	0%	17%	7%	24%	29%	16%
Industry	Builders	0%	0%	8%	8%	11%	27%	11%	14%	21%	0%	10%	3%	5%	7%	9%
	Construction cost	25%	0%	8%	9%	0%	7%	6%	5%	14%	33%	6%	7%	5%	11%	8%
	Education	17%	25%	16%	29%	28%	20%	22%	18%	21%	100%	19%	17%	19%	18%	21%
	Information	33%	13%	7%	18%	17%	0%	19%	9%	14%	0%	13%	10%	5%	0%	12%
	Products	25%	13%	12%	15%	6%	0%	6%	5%	0%	0%	16%	7%	0%	11%	10%
	Traditional construction	17%	0%	11%	6%	6%	20%	17%	23%	7%	33%	10%	13%	10%	4%	11%
Regulations	Building Code	17%	0%	10%	3%	6%	7%	8%	5%	0%	0%	6%	0%	5%	4%	6%
	Certification	8%	0%	2%	2%	6%	7%	3%	9%	7%	0%	1%	3%	0%	0%	3%
	Government/authorities	17%	0%	10%	8%	6%	13%	11%	0%	21%	0%	12%	10%	19%	4%	10%
	Legislation	8%	0%	3%	0%	6%	0%	3%	5%	0%	0%	3%	0%	10%	4%	3%
	Standards	0%	25%	5%	8%	6%	7%	0%	0%	0%	0%	7%	3%	0%	0%	5%
Technology	Fire	8%	0%	14%	12%	17%	13%	14%	9%	0%	0%	7%	7%	10%	7%	10%
	Maintenance	0%	13%	7%	3%	0%	7%	8%	9%	0%	0%	6%	3%	0%	4%	5%
	Research and development	0%	0%	2%	6%	22%	13%	0%	0%	0%	0%	6%	0%	5%	11%	5%
	Structural engineers	8%	0%	8%	15%	11%	13%	17%	0%	0%	0%	4%	7%	19%	11%	9%
	Sustainability	8%	13%	11%	8%	6%	13%	14%	5%	29%	67%	12%	7%	5%	11%	11%
	Total (unique)	92%	100%	86%	85%	94%	100%	97%	82%	86%	100%	84%	80%	86%	93%	87%

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