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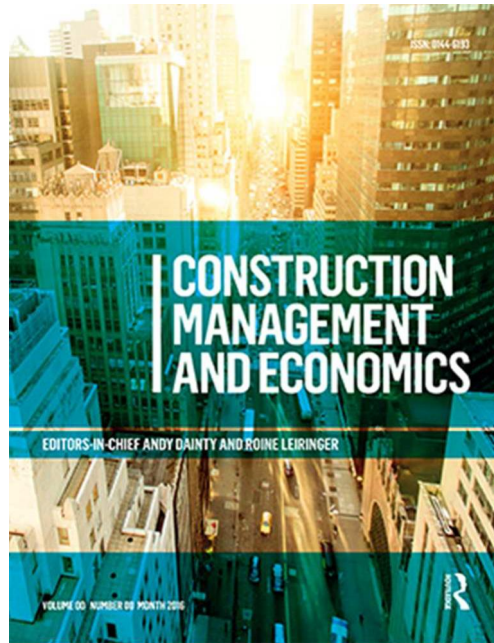
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4 **Internal and external factors of competitiveness shaping the future of**
5 **wooden multistorey construction in Finland and Sweden**
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Internal and external factors of competitiveness shaping the future of wooden multistorey construction in Finland and Sweden

ABSTRACT

In transitioning to a renewable material-based bioeconomy, growing public and industry interest is apparent for using wooden multistorey construction (WMC) as a sustainable urban housing solution in Europe, but its business implications are not well understood. In our study, we evaluate, which internal and external factors of competitiveness are shaping the future of WMC, especially in the context of Finland and Sweden. Based on a multi-level perspective of socio-technical transitions, we conducted a three-stage dissensus-based Delphi study. The identified internal and external factors affecting the future competitiveness of the WMC business emphasize the importance of skilled architects and builders and the role of standardized building systems. Based on our results, the key aspects influencing the future competitiveness of WMC in the region are related to the development of technical infrastructure and project-based business networks, while additional changes in regulatory framework are perceived as less important. We conclude that towards 2030, the strong cognitive rules founded in the concrete-based building culture in these countries is likely to inhibit the dynamics of the socio-technical regime level. A change is also needed in the WMC business culture towards more open cross-sectoral collaboration and new business networks between different-sized players.

Keywords: wood, business networks, Delphi method, competitiveness

Introduction

The construction sector is one of the main fields of economic activity in the European Union in terms of final energy consumption, greenhouse gas emissions, material extraction and water consumption (European Commission 2011). Discourse concerning the benefits of choosing wood material to implement green building solutions (Wang *et al.* 2014, Darko *et al.* 2017, Toppinen *et al.* 2018) has therefore emerged as a method for tackling sustainability problems and enhancing, for example, the resource and carbon efficiencies of material choices and the energy efficiency of buildings. In transitioning to a renewable resource-based bioeconomy (for a definition, see European Commission 2012), growing public and industry interest is apparent towards using wooden multistorey construction (WMC) as a sustainable urban housing solution, especially in Northern Europe (Bosman and Rotmans 2016). Despite this, its implications and future prospects are not yet understood with the exception of a few studies (such as Hurmekoski *et al.* 2018, Toppinen *et al.* 2018), giving impetus for our study.

The European-wide industry goal for wood construction includes tripling the share of WMC from 2015 until 2030 (Forest Sector Technology Platform 2012, hereafter FTP). The supporting role of regulatory environment (such as a “pro-wood” thinking) has been emphasized as an enabling factor for the WMC sector development towards the future (Toppinen *et al.* 2018). Despite recent growing public and industry interest in WMC as a sustainable urban housing solution, and the positive signs of related regulatory frameworks, the prospects for future market diffusion are not overly positive according to Hurmekoski *et al.* (2018). For example, the market share of wooden multistorey apartment buildings completed in Finland only increased from 1% to 6% between years 2010–15, despite intense promotional work and significant changes in building codes.

Increasing the share of WMC is hindered by the strong path dependencies of concrete building networks (Mahapatra and Gustavsson 2008, Hemström *et al.* 2017). Furthermore, Nordin *et al.*

(2010) concluded that re-structuring WMC business networks could partly solve the issue of a narrow WMC niche. According to Nordin et al. (2010), re-structuring comprises changing both internal (e.g. more collaboration with suppliers, on-site contractors and engineered wood product manufacturers to develop off-site construction methods) and external factors (e.g. implementation of R&D efforts with organizations and associations developing technical standards) affecting the WMC business.

A multi-level perspective approach (MLP) by Geels (2004) provides a foundational premise behind the emergence of socio-technical innovations in the construction sector. According to Rohracher (2001), institutions and socio-technical characteristics in the construction sector may either support or hinder potential of business renewal towards more sustainable building structures. As observed by Hemström *et al.* (2017), strong cognitive rules within the construction sector are founded within the concrete-based building culture, which focuses on cost considerations and perceived performance, and to a lesser degree on customer preferences. Competition between new players entering the industrial construction market, and collaboration between WMC and traditional (concrete-driven) construction businesses, are the key elements that require more in-depth analysis (Hemström *et al.* 2017).

To gain better understanding of the forces shaping the future of WMC, we will empirically focus on the institutional context of two Nordic countries (Finland and Sweden), where national bioeconomy strategies explicitly mention the objective of enhancing wood utilization in construction. Based on Kadefors (1995), we hypothesize that the barriers obstructing the market diffusion of the WMC are to some degree related to the institutional setting from which innovations, mutual learning and co-operative ways of creating value in a business environment emerge. Our research question is: which internal and external factors of competitiveness shape the future of WMC? Methodologically we

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4 use a three-stage dissensus-based Delphi approach to analyse the changing WMC business
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6 environment.

7 8 9 **Theoretical framework**

10 11 12 *MLP and the role of institutions in shaping the future of the WMC business system*

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15 From the perspective of understanding the innovation potential related to the future construction
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17 business in the European context, cross-cutting changes have been identified to deal with the shift
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19 from products to systems and services, blurring sectoral boundaries and cross-sectoral integration of
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21 sustainability demands (Weber and Schaper-Rinkel 2017). The competitiveness (i.e. superior
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23 performance within an industry assessed with chosen measures) and renewal of companies in the
24
25 construction sector have traditionally been affected by the strategic decisions made by firms, public
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27 authorities (e.g. regulation and public procurement initiatives), and professional bodies and trade
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29 associations (e.g. standardization and education) (Porter 1985, Betts and Ofori 1994, Lähtinen and
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31 Toppinen 2008). Similarly, linkages comprising company strategies, interactions between various
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33 construction sector actors, and the external business environment have been found to affect the
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35 future prospects of WMC sector (Mahapatra and Gustavsson 2008, Hemström *et al.* 2017).
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40 According to institutional theories, organizations are affected by normative pressures, which leads
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42 them to adopt similar behavioural patterns to create efficiency benefits (DiMaggio and Powell 1983,
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44 Zucker 1987). Formal institutions also tend to create lock-ins and hinder changes that might
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46 positively affect industry dynamics, for example, through innovation diffusion (Eriksson 2013).
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48 Based on theoretical assumptions made by the MLP on socio-technical transitions approach, three
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50 levels of processes affect the transformation of technologies and innovations: niche innovations, the
51
52 socio-technical regime and the socio-technical landscape (Geels 2002). As the socio-technical
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54 landscape level is an exogenous environment (e.g. deep cultural structures and macro-politics taking
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4 decades to form) (Geels and Schot 2007), niche level and the socio-technical regime level are the
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6 focus of our study. According to Fuenfschilling and Truffer (2014), niche innovations represent
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8 alternative socio-technical configurations in MLP, which do not have a high level of
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10 institutionalization. They are composed of small and unstable communities of interacting groups
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12 (e.g. actors entering and leaving, markets, technical standards not being developed, or unknown
13
14 user preferences) (Geels 2002, 2004). As a comparison, regime level communities are large and
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16 stable (e.g. deviating from mainstream practices is difficult, markets are developed, technological
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18 standards exist, and actors in business networks have aligned their processes with each other).
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22 In the construction sector, the roles and tasks of various actors have become highly routinized and
23
24 standardized over the course of time to manage the complexity of construction processes (Kadefors
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26 1995, Segerstedt and Olofsson 2010). Due to the established behavioral patterns, changing the
27
28 dynamics of the construction sector is not straightforward (Rohracher 2001): First, changing from
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30 niche level into socio-technical regime requires comprehension of how incumbent actors in the
31
32 construction sector interact with each other and what are their strategic interests. Second,
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34 information is needed on how different actors are shaping intentionally or unintentionally the
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36 institutional structures in the sector. As a solution to recognize the inseparability of technical and
37
38 socio-technical aspects in construction business, Rohracher (2001) has illustrated the dynamic
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40 interaction between technologies, institutions and interaction of actors in the industry. Construction
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42 sector actors are composed of individual organizations involved in the WMC business (i.e. firms,
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44 governmental agencies, industry and professional associations, interest organizations, R&D
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46 organizations and educational organizations). Following the approach illustrated in Figure 1, our
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48 analysis is conducted through the MLP on socio-technical transitions approach (e.g. Geels 2004,
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50 Geels and Schot 2007, see also Bosman and Rotmans 2016), complemented with the lens of
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4 institutional theories (e.g. Meyer and Rowan 1977, DiMaggio and Powell 1983, Scott 2008, Beckert
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6 2010).

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12 **Figure 1.** Dynamics between technologies, construction sector actors and institutions affecting the
13 market diffusion of WMC from niche innovation to regime level (modified from Rohracher, 2001).
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16 In our study, technologies and uptake of innovations comprise various solutions to implement
17 WMC. From the perspective of MLP, WMC may have mixed effects, for example, on other
18 building technologies by supporting certain ones and by provoking major crises in others (see
19 Dolata 2009). Formal institutions comprise behavioral patterns formed over time resulting from
20 path dependencies to control either internal or external factors affecting both technologies and
21 actors. Dynamics between technologies, institutions and interactions between actors may therefore
22 either limit or enhance the competitiveness of WMC in the markets and its potential to develop
23 from niche level into socio-technical regime level (Rohracher 2001, Dolata 2009).
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33 34 ***Construction sector as a business system***

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37 Construction sector is characterized by project-based and subcontracted businesses (Segerstedt and
38 Olofsson 2010), which requires a good fit and coordination between interdependent and non-
39 simultaneous tasks implemented within strict timelines (Blayse and Manley 2004). Due to this,
40 business networks and their ways of organizing project-based business processes are of fundamental
41 importance in construction sector operations (Gann and Salter 2000), for example, by providing
42 access to complementary resources and innovation platforms (Pulkka *et al.* 2016). In the
43 construction sector, the uptake of new building solutions has been found to be challenging despite
44 their perceived benefits (e.g., Carter 1967, Holt 2013). Traditions and patterns of behavior in the
45 construction sector operations are also key factors likely to affect WMC market diffusion (Nordin *et*
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4 *al.* 2010). In a recent study by Matinaro and Liu (2017), traditional organizational culture was found
5
6 to be a key aspect hindering innovativeness and sustainability in the Finnish construction sector.
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9 The organization of business networks in the construction sector usually targets a particular project
10 and is composed of firms managing the actual building processes (e.g. on-site contractors and client
11 service providers such as consultants) and supplying, for example, the materials and machinery for
12 the contractors (Gann and Salter 2000, Nordin *et al.* 2010). Thus, the coalitions in the construction
13 sector are characterized by temporariness (Blayse and Manley 2004), which results in a lack of
14 mechanisms for transferring experiences from individual projects to company-level decision-
15 making, and causes challenges, for example, for continuous learning (Drejer and Vinding 2006).
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25 Figure 2 is a theoretical illustration of the internal factors of project-based business networks, and
26 the external factors of regulatory framework and technical infrastructure, both affecting the
27 innovation potential and competitiveness of individual companies within the WMC business
28 system. According to management literature, examples of internal factors include resources and
29 processes in the control of individual companies and/or business networks (e.g. Barney 1986; Helfat
30 and Martin 2015), while external factors are either entirely or largely outside of their control (e.g.
31 Elenkov 1997; Acur *et al.* 2012). Both internal and external factors affect the competitiveness of
32 companies (e.g. Mauri and Michaels 1998 Hawawini *et al.* 2003), as also found to be the case in the
33 woodworking industries (Lähtinen 2007) and construction sector (Holt 2013). In our study, we
34 propose that these internal and external factors, managed through different formal institutions
35 within the construction sector business environment, affect the future competitiveness of the WMC
36 business, in line with Nordin *et al.* (2010).
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52 **Figure 2.** Internal factors (i.e. actions made by actors within project-based business networks) in
53 relation to external factors (i.e. actions made in regulatory framework and technical infrastructure)
54 affecting the competitiveness of the WMC business system (modified from Gann and Salter 2000).
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4 In business networks of a particular sector, the adoption of “institutionalized” best practices and
5 standards enhances the management of value chain activities and further the competitiveness of
6 companies (see e.g. Ketchen and Hult 2007). From the perspective of expected benefits, although
7 aspects of institutionalization, such as routines and efficient labour use, have improved the cost-
8 competitiveness of construction companies, project-based structures and strong cultural traditions
9 within the sector have simultaneously hindered the diffusion of innovations such as finding new
10 building solutions from engineered wood products for multistorey timber construction (Kadefors
11 1995). In line with management literature (e.g. Barney 1986; Helfat and Martin 2015), from the
12 perspective of the WMC business system, project-based business networks (i.e. internal factors)
13 control the development of learning and routines between various projects, the uptake of new “best
14 practices” and the search for optimal combinations through bidding processes. In comparison,
15 project-based business actors do not authorize e.g. the defining of building permit procedures, the
16 facilitation of knowledge diffusion throughout the construction sector or assuring the compatibility
17 of various technologies (i.e. external factors).
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36 Construction sector is characterized by several formal and informal institutions affecting the
37 competitiveness of companies abreast with their selection of technologies and interaction with other
38 actors operating in the sector. According to Kadefors (1995), there are six types of institutions in the
39 construction sector (illustrated in Table 1) affecting the transformation potential of the construction
40 sector towards new socio-technical regime either through actions made within project-based
41 business networks (internal factors), or in regulatory framework or technical infrastructure (external
42 factors) (see also Figure 2).
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Table 1. The six types of institutions in the construction sector defined by Kadefors (1995) as the actors controlling internal and external factors in the WMC business system.

Data and Methodology

We use Delphi methodology to qualitatively analyse a wide variety of problems in the emerging WMC domain, and the reliability and validity of our research results is strengthened through general verification strategies (Morse *et al.* 2002). These strategies comprise aspects of methodological coherence (suitability of the method to answer the research questions), sample appropriateness (selection of the experts), concurrent collection and analysis of the data, theoretical thinking (employment of solid theoretical background) and theoretical development (purposeful seeking of linkages concerning the results on new theoretical findings).

Iteration, participant and response anonymity, controlled feedback and statistical group response have been identified as key characteristics of a Delphi study. During its 50-year existence, numerous variants of the methodology have been developed (Landeta 2006), with the later ones (e.g. Policy Delphi, Argument Delphi and Disaggregative Policy Delphi) emphasizing the importance of finding reasons for dissensus rather than striving for consensus among experts (Blind *et al.* 2001, Hatcher and Colton 2007, Landeta 2006, Rowe and Wright 1999). Typically, bringing (geographically) dispersed experts together and sharing a personal viewpoint without group pressure due to anonymity are seen as advantages of utilizing the Delphi method. On the other hand, a lack of strict guidelines on how to implement a Delphi study and low participant commitment can be considered challenges or disadvantages of the method (e.g. Hung *et al.* 2008; Gupta and Clarke 1996).

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4 The methodological approach of our study is drawn from a three-round dissensus-based Delphi
5 study, which provides opportunities for recognizing important and interesting issues and possible
6 cognitive biases outside the evident consensus (Rowe and Wright 2011). Dissensus approach is
7 reasonable, when the main purpose of the study is to explore little understood, not well documented
8 phenomena (Steinert 2009), as in this case.
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15 As the Delphi method is suitable for implementing explorative research, we chose to utilize it in this
16 study: answering our research question requires achieving information concerning future aspects of
17 the factors shaping the WMC business development, with no existing empirical data available on
18 the topic. Therefore, we expected a variety of possible futures for WMC and factors affecting its
19 competitiveness. To map these possible developments, we aimed to collect as rich a dataset on the
20 views and opinions of experts as possible. Instead, the purpose was to also recognize possible weak
21 signals and alternative voices. Therefore, to have genuinely new information concerning the
22 renewal of the WMC business, the dissensus-based (in contrast to consensus seeking) Delphi was
23 seen to fulfill both the empirical and theoretical objectives of our study (see e.g. von der Gracht
24 2012; Steinert 2009). We thus believe that it would not be possible to gain sufficient in-depth
25 understanding of the future of the WMC without performing multiple interview rounds, especially
26 from the viewpoint of such a multifaceted measure as competitiveness.
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42 The number of Delphi panellists typically ranges from a few to 50, (also in the area of construction
43 engineering and management, see Hallowell and Gambatese 2010). However, the key criterion in
44 selecting the panel is the members' expertise and contribution to the topic. In our study, the
45 panellists involved were of Finnish and Swedish origin, and were required to have in-depth
46 knowledge of wood utilization in multistorey construction in the Nordic region. To collect data that
47 would provide an all-inclusive view, we proceeded to find experts representing various parts of the
48 WMC value chain. Therefore, we broke the WMC value chain into (1) forest resource ownership
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4 and raw material procurement, (2) wood products industry and primary processing and (3)
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6 construction industry, and searched for experts to represent these segments.
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9 We searched for possible panellists based on publicly available information on employees who
10 represented companies or formal institutions suitable for our sample frame, along with their
11 expertise, and enquired about the candidates' willingness to join the panel. Panel composition was
12 not revealed to the panellists at any point to minimize any bias that the group or group members
13 could cause to the panellists' opinions (e.g. dominant expert influence, persuasive skills,
14 unwillingness to reveal a change in previously expressed opinion; see e.g. Steinert 2009, von der
15 Gracht 2012). We collected data from a panel of 23 experts using dissensus-based Delphi during
16 2016–17 to elicit perceptions on the future pathways and sources of competitiveness in WMC in the
17 Nordic region (see Table 2).
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31 **Table 2.** Composition of the Delphi panel with their professional backgrounds and participation in
32 various stages of data collection.
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38 A total of 18 experts were interviewed during the first round, 17 responded to our second-round
39 online survey, and finally 16 experts were interviewed during the third round. Nineteen of the 23
40 experts had over ten years of experience from either the forestry, wood industry or construction
41 sectors. All panellists acted in high-level leadership or professional expertise positions, which we
42 believe improves the internal validity of our results.
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49 The time scale of our Delphi approach was extended towards 2030 and the study consisted of a
50 content analysis of the data collected during two thematic interviews (rounds 1 and 3) and a
51 structured online survey (round 2). We chose to begin data collection with the interviews, as this
52 enabled asking follow-up questions or asking interviewees to further elaborate on their responses, if
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4 needed. Abreast with strengthening the validity of our study by ensuring that all respondents had
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6 understood the questions in a similar manner, this approach allowed us to map as large a variety of
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8 opinions as possible at the beginning, which is a good base for the dissensus-based approach.
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11 Data collection is iterative in the Delphi process, and therefore the data from the first and second
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13 rounds was summarized, and controlled feedback was provided to the panellists always prior to
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15 beginning the next data collection phase (von der Gracht 2012). After the third round (interviews),
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17 despite marginal new information emerging, many issues began repeating in the panellists' answers.
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19 Based on this, we concluded that the information value gained from additional rounds would likely
20
21 be small, and the data collection process was stopped.
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25 The first-round interviews concerned general issues occurring in the business environment of WMC
26
27 business systems such as initiatives related to sustainable development, the overall state of the
28
29 forest industries, raw material supply and end-use markets. Abreast with these themes, questions
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31 related to existing patterns, such as the behaviour of individual organizations, characteristics of
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33 collaboration in value chains, structures in WMC business systems and institutions for acquiring
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35 information on the position of WMC in niche and socio-technical regimes were asked from the
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37 panellists. During the second Delphi round, emphasis was given to the themes and topics considered
38
39 the most thought-provoking or controversial during the first phase. The questionnaire mainly
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41 consisted of closed-ended questions in the form of 42 statements (some of which have already been
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43 reported in Toppinen et al. (2018), and are therefore excluded from here), and respondents were
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45 given five response options ranging from very low, neutral to very high. The third-round interviews
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47 were needed to prioritize the most important internal and external factors influencing WMC
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49 competitiveness, and to open up underlying rationale that remained unclear after the first two
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51 rounds.
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4 In the situation of mainly open-ended questions, we considered that the probability to get sufficient
5 information is greater by using interviews as compared to a questionnaire, since it is easier for the
6 informant to more freely speak than write, and also with scheduled interviews we could ensure that
7 the participation rate did not decrease. More importantly, in the interactive situation both the
8 informant and the researcher have a possibility to check in case of any obscurity. We found this
9 important, since the third round (based on the first two rounds) was likely to be the last round, but
10 also because of the purpose of the data collection was (not to find specific points of consensus but)
11 find weak signals and alternative voices.
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22 There are limitations in Delphi technique and throughout the years, the method has faced a lot of
23 criticism (e.g., Hung et al., 2008). Winkler and Moser (2016) identified the most frequent and
24 impactful cognitive biases in Delphi studies to be *framing bias* (i.e., how the issue is presented or
25 modified has influence on the person's assessment of the issue), *anchoring bias* (i.e., estimation of
26 a value for a variable referring to a known previous value), *desirability bias* (i.e., the informant's
27 stance towards the events desirability may influence on the judgement of the likeliness of an event
28 to take place), and *bandwagon effect* (i.e., influence of the behavior of group or the majority to the
29 informant's behavior or opinion, that bases on the information that the majority behaves or thinks in
30 certain way), and *belief perseverance* (i.e., the decision maker's aptitude – when receiving a
31 unconfirmatory advice – to overweight their own judgmental performance and underweight the
32 advice available).
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47 Winkler and Moser (2016) presented a list of recommendations for the design of Delphi study to
48 avoid these biases; the most important recommendation considers the panel, namely the authors
49 conclude that the panel should be heterogeneous, include mavericks and that pyramid search should
50 not be applied when choosing the panellists. In this study we have attempted to reach heterogeneity
51 of panel composition in terms of gender, years of experience, organizational position, and type or
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4 industry, however, the degree of reached heterogeneity is somewhat subjective issue. The panellists
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6 were chosen based on public information, and we did not use pyramid search.
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9 While in our study we have attempted to follow the recommendations considering Delphi studies,
10 particularly in terms of carefully choosing the panellists, retaining their anonymity and producing
11 feedback between rounds, the possibility of some degree of bias remains. This should be considered
12 when interpreting the results of this study.
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22 **Results**

23 *Wood as a future construction material*

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25 The interviewed Delphi panellists from both Finland and Sweden were fairly confident that wood
26 utilization would increase in the future as a more modern and sustainable building solution in the
27 construction sector. Multistorey buildings were the most commonly mentioned modern construction
28 solution, but certain respondents also identified infrastructural constructions, such as wooden
29 bridges, to be a growing segment for the WMC business. Two respondents mentioned that
30 engineered wood products (EWPs), such as cross-laminated timber (CLT), will open new
31 possibilities for utilizing wood in load-bearing structures, elements or as a substitute for concrete.
32 Hybrid buildings made of wood combined with other materials, such as concrete and steel, were
33 also mentioned in this discussion as a new opportunity to increase wood usage in the construction
34 sector. Regarding the connections between uptake of new technologies and interactions illustrated
35 in our theoretical framework of Figure 1, this is a signal of the potential of WMC to act as a driver
36 for increasing new forms of collaboration among actors, which traditionally have not co-operated
37 with each other.
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4 However, a lack of positive examples and experience of WMC as a dominant building technology
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6 and material choice was seen as a persistent problem, as indicated by one interviewee: “*No major*
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8 *issues exist that we could not tackle, we just happen to be at a very early stage.*” **Wood industry**
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10 **executive, Finland.** In reference to our theoretical framework, this indicates that WMC is occurring
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12 at the niche level. Deficiencies appear to exist within the institutions connected to internal factors of
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14 the WMC business systems (i.e. “Development related to the formation of new learning” and
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16 “Routines within business networks”), limiting the potential for developing and implementing new
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18 building solutions. Some respondents challenged the increasing collaboration between the wood
19
20 construction sector and concrete solution providers due to obstacles, such as the nonexistence of
21
22 similar optimum dimensions for construction materials and structures, and because of the on-going
23
24 public ‘wood vs. concrete’ antagonism. In relation to collaboration and innovation activities with
25
26 concrete building companies, WMC building does not seem to be even at the niche level. This claim
27
28 is supported by the institutional weakness referring to development efforts in common technological
29
30 standards and the alignment of business processes (i.e. “Formal standardization initiated by the
31
32 industry”). One respondent summarized the situation in the following way: “*I don’t think co-*
33
34 *operation [with the concrete business] will happen – there is just too much competition*” **Wood**
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36 **industry executive, Sweden.**

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41 Key challenges facing deepening collaboration cited by the experts included differing timespans in
42
43 which the actors of business networks operate and the new capabilities that various organizations
44
45 have to develop for enhancing the market diffusions of WMC building solutions. From a theoretical
46
47 viewpoint, this refers to the need of niche-level factor development in formal institutions related to
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49 internal factors of WMC business systems (i.e. “Standardization of skills and knowledge” and
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51 “Learning and routines”). Systematic development of knowhow is needed when implementing new
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4 building solutions within companies, to e.g. re-structure construction processes and enhance the
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6 uptake of new process innovation capabilities (see Table 1).
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9 Respondents also identified project length to be a timespan issue, as the following illustrates:

10
11 “*[Building] processes can be very long, even unbearably so.*” **Research manager from a forestry**
12
13 **expert organization, Finland.** The development of more sophisticated building solutions was seen
14
15 as a capital-demanding process for which only a few of the largest operators have the necessary
16
17 resources. Building contractors, especially ones that build with a range of materials, were not
18
19 interested in developing solutions, and are actually only interested in bringing solutions to the
20
21 markets. This is further illustrated by the following quote: “*We will not perform this validation [of*
22
23 *wood-based building solutions], which needs to be undertaken by the wood industry itself.*”
24
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26 **Building company executive, Finland.** Based on this, on-site firms, such as general contractors, are
27
28 willing to enhance WMC innovation diffusion. But, prior to that, in reference to our theoretical
29
30 framework, WMC business systems need to pay attention to re-structuring both the internal and
31
32 external factors affecting their operations *via* various informal institutions (i.e. “Formal
33
34 standardization initiated by the industry”, “Roles and interest organizations”, “Standardization of
35
36 skills and knowledge”). In practice, this means e.g. more profound collaboration with on-site
37
38 contractors to enhance innovation diffusion towards a socio-technical regime, standardized products
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40 technologically applicable with other materials along with the development of routines and skills
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42 that go beyond individual construction projects creating positive path dependencies and reshaping
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44 informal institutions in the course of time.
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49 ***Internal and external factors driving competitiveness of the WMC***

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52 Competitiveness of the wood construction industry has been discussed in-depth within the industry,
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54 which also became evident during the first round of interviews, as the following quote shows:
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4 “Everyone needs to take care of their own competitiveness, it is very challenging to play in every
5
6 field... I believe in network thinking, in which various actors co-operate by leveraging their own
7
8 strengths.” **Wood industry executive, Finland.** Theoretically, this refers to the need of a well-
9
10 functioning division of work and institutional WMC business system specialization in reference to
11
12 internal factors, such as knowledge development and the identification of best practices within
13
14 collaboration networks, to secure efficient processes and good quality project implementation
15
16 (i.e.”Standardization of skills and knowledge).
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20 A respondent in one interview explicitly stated that he sees the industry as going through a
21
22 paradigm shift, and other experts similarly talked about an on-going change that they saw taking
23
24 place in their institutional and business environment. Therefore, in the next two rounds, we focused
25
26 on more explicitly mapping expert perceptions of what the external and internal factors and
27
28 institutional changes are that impact the competitiveness of the industry. Table 3 presents the
29
30 likelihood and desirability of the second-round statements concerning the competitiveness and
31
32 development of the industry. Please note that the original five-point statement scaling has been
33
34 clumped into three categories (low, neutral and high) to simplify presentation in Tables 3 and 4.
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41 **Table 3.** Percentages of likelihood and desirability of round two statements concerning the
42
43 competitiveness and development of the industry by 2030 (n=17).
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46 The majority of the panellists considered statement 2030, *the overall product offering of the wood*
47
48 *product industries is significantly more diverse than today*”, to be both highly likely and desirable.
49
50 Respondents also believed that the wood product industries will offer more value-added products by
51
52 2030. However, a great deal of uncertainty appears to exist when compared to certain other
53
54 statements concerning this issue: for example, statement “*By 2030, the wood construction industry*
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4 *will still struggle with competitiveness and lack of value-added products*” was seen as undesirable
5
6 by more than half of respondents (59%), which is a logical outcome. Certain respondents believe it
7
8 likely that issues with competitiveness and a lack of value-added products will still exist in 2030
9
10 (35%), others are neutral in their views (24%), and certain respondents do not consider this at all
11
12 likely (41%). Based on this, we concluded that the topic deserved further attention in the final
13
14 (third) interview round.
15

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18 Regarding changes at both the niche and socio-technological regime levels, experts considered it
19
20 desirable that WMC business systems will operate in a completely new way by 2030, but 59% of
21
22 the panellists assessed the likelihood of this happening to be moderate. The panellists were more
23
24 positive about how consumers will view the industry in 2030 compared to how wood construction
25
26 is regarded as a modern way of building: 88% of the panellists believed this development highly
27
28 likely and 94% considered it desirable. When the panellists were asked about the role of the
29
30 multistorey building segment within wood construction business, the majority believed it becoming
31
32 a dominant field to be both likely (59%) and desirable (71%). Also, information flow from the
33
34 construction site to the forests was believed to become more rapid in the future. Thus, compared
35
36 with our theoretical framework, panellists were more optimistic towards issues directly unrelated to
37
38 internal and external factors of WMC business systems as such (e.g. consumer attitudes or the role
39
40 of WMC within the wood construction sector). Instead, they were having a weaker trust in drastic
41
42 changes occurring within actual WMC business systems that would allow them to become large,
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44 stable and coherent at socio-technical regime level.
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49 Table 4 summarizes the likelihood and desirability of the second-round statements related to the use
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51 of wood as a building material in the future. Eighty-two per cent of the panellists considered wood
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53 becoming a competitive building material by 2030 to be highly desirable, and 65% viewed this to
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55 be highly likely. When panellists were asked about the competition for wood as a building material,
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4 47% were neutral in their views, whereas 41% believe that increasingly intense competition over
5
6 the raw material is highly probable. Furthermore, panellists did not consider it likely that the cost of
7
8 wood-based materials would represent a significantly larger proportion of the overall costs of WMC
9
10 by 2030.
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13 Statement “*By 2030, it will be possible to make more value-added products from lower quality raw*
14
15 *materials due to technological development*” continued on from a perspective raised by previous
16
17 literature, but to which respondents had differing opinions in the interviews. During the first-round
18
19 interviews, several panellists argued that technological development in the future will enable actors
20
21 in the wood construction business to manufacture value-added products from lower quality raw
22
23 materials. During round two, this development was considered both highly likely (88%) and
24
25 desirable (82%). Finally, experts anticipate that in the future, builders will be more educated in
26
27 terms of available materials and hybrid solutions.
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35 **Table 4.** Percentages of likelihood and desirability of round two statements concerning wood as a
36 raw material by 2030 (n=17).
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40 In sum, the panellists appear to be highly like-minded in believing that the wood industry will be
41
42 more diversified by 2030, and that due to technological development, more value-added products
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44 made from lower quality raw materials will be available on the market. However, some scepticism
45
46 remained, especially on whether the industry will still struggle with competitiveness. Experts do not
47
48 fully appear to believe in the transformative power of building regulations and emerging business
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50 opportunities in WMC. Therefore, we investigated reasons for this in the next Delphi-round using
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52 interviews to enable more in-depth insights (von der Gracht 2012).
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4 In Delphi round three, panellists were asked about the most important internal and external factors
5 influencing WMC competitiveness. Based on the previous rounds, panellists were provided with a
6 list of ten internal and external factors, and were asked to name three of the most important items
7 from the external and internal viewpoints, or to define additional factors if they considered
8 something to be missing from the provided list. Figures 3 and 4 show the panellists' answers and
9 how frequently the provided option was chosen as one of the three most highly ranked factors.
10 Please note that only 16 experts responded to this question, and every panelist did not rate three
11 factors, thus giving us only 45 votes.
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22 Construction process speed (nine times) and standardization (eight times) were the internal factors
23 chosen most often by the panelists (Figure 3). These responses signal the need for decreasing costs,
24 and thus improving cost-competitiveness. Increased speed and standardization would also increase
25 end-user value. Plain cost-efficiency was the third most chosen option (seven times). The speed of
26 the construction process may partly be a question of being at the early stage of the learning curve.
27
28 As one of the expert comments: "*Repetition [of multistorey building projects] will bring speed. So
29 far no wooden multistorey building [project] has completely succeeded.*" Accumulating experience
30 and learning will speed up the process and decrease costs up to a certain point. Naturally, the risk is
31 that if the disadvantageous cost competition situation slows down the diffusion of WMC processes,
32 it will take longer for the industry to reach (or prohibit the industry from reaching) the positive
33 learning effects.
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50 **Figure 3.** Frequency of perceived importance of internal factors influencing competitiveness.
51 Sixteen respondents of round three were asked to name three of the most important items from the
52 internal viewpoint and to justify their choices.
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4 In line with the two previous Delphi rounds, here too respondents do not consider raw material
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6 issues as the most important factor. In light of the answers concerning the development of the
7
8 industry by 2030 (especially the positive view regarding the diversity of overall product offerings
9
10 and value-added products), it is interesting that only two respondents believe combining different
11
12 materials in hybrid structures to be one of the three most important issues. Responses to the latter
13
14 question may have been given with the current situation in mind, while the question in round two
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16 was considered from a more future-oriented viewpoint. On the other hand, from the innovativeness
17
18 point of view, the new value-added products will not be realized if the industry lacks the
19
20 willingness or capability to look outside of the box. In our case, development of hybrid construction
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22 solutions represents a natural avenue for gaining higher functional benefits, e.g. by taking advantage
23
24 of technological properties of different materials.
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28 In terms of influential external factors (see Figure 4), nearly 70% of respondents ranked “*Improving*
29
30 *WMC know-how*, for example, via the education of architects and builders” as one of the three most
31
32 important external factors. “Influence from city planning” and “Building regulations concerning
33
34 WMC” were both chosen nine times.
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41 **Figure 4. Frequency of perceived importance of external factors influencing competitiveness.**
42 Sixteen respondents in round three were asked to name three of the most important items from the
43
44 external viewpoint and to justify their choices.
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47 Among the provided alternatives, “public subsidies” was not considered important, but “demand for
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49 WMC via public procurement” and “R&D to adopt new construction technologies in WMC” were
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51 both chosen five times. Thus, the bulk of the answers points towards issues that can be directed by
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53 means of regulatory framework. Only one expert considered the “image of wood as part of the
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55 bioeconomy” as one of the most important factors, and two believed “housing quality needs” to be
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4 the most important factor. The demand side appears less important in the answers, which may be
5
6 due to question design. This could portray the similar attitude by one of the experts, who
7
8 commented: “*End-users are not important. Municipalities are*”.
9

10 11 **Discussion**

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14 In our study, we approached the future of WMC business in Finland from the viewpoint of our
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16 research question aiming to identify factors shaping the future competitiveness of WMC. By using
17
18 additional insights available from Sweden, we were able to envisage WMC development to that in
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20 construction markets also in more general. From the perspective of institutions (see Figure 2 and
21
22 Table 1), both external factors related to regulatory framework and technical infrastructure, and
23
24 internal factors of business networks were operationalized in the expert views as issues affecting the
25
26 future of WMC. From the perspective of theoretical interlinkages between MLP and institutions
27
28 affecting the future of WMC, our empirical results supported the assumption of three-dimensional
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30 dynamics (i.e., technologies, institutions and interactions between actors) shaping the potential of
31
32 WMC to move from a niche innovation into socio-technical regime level.
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37 According to our results, the importance of educating architects and builders gained highest support
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39 among the panellists. In comparing with Table 1, the views emphasized most by the experts fell
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41 within the external factor category of “Formal standardization initiated by the industry” and within
42
43 the internal factor categories of “Standardization of skills and knowledge” and “Learning and
44
45 routines”. Thus, although “Governmental regulation” (external) and “Roles and interest
46
47 organizations” (external) were also mentioned by the experts as factors impacting the future of
48
49 WMC, they were less interesting to the respondents. In addition, although “Tendering system” is
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51 currently the dominant routine for organizing work in construction projects, it was not directly
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53 approached during the third-round expert interviews.
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4 The purpose of the “Formal standardization initiated by the industry” and the applicability of the
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6 construction components independently from suppliers enhances, for example, efficiency and cost-
7
8 competitiveness (e.g. Dubois and Gadde 2002). From the regulatory framework perspective,
9
10 industry standardization is a non-legislative approach for implementing guiding norms, for
11
12 example, for a particular industry. According to our results, the Delphi experts did not believe
13
14 builders to be interested in developing standardized wood construction systems, and wood industry
15
16 was seen as a key player in the standardization work. Abreast with cost-competitiveness,
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18 standardization based on new material based solutions (such as cross-laminated timber elements)
19
20 was seen as an opportunity to substitute concrete in construction processes.
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24 As an internal factor of competitiveness, “Standardization of skills and knowledge” was similar to
25
26 “Formal standardization initiated by the industry”, but instead of formal instructions received from
27
28 outside the project-based business networks, skills and knowledge were seen to be connected with
29
30 developing capabilities that enable companies to re-engineer their construction processes (e.g. Roy
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32 *et al.* 2005, Roos *et al.* 2010). Furthermore, our Delphi experts considered skills and knowledge
33
34 development highly crucial for learning, developing the division of work, and for allowing the
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36 partners to focus on their specific strengths within the larger business network. This could be a
37
38 relevant issue especially in case of developing more advanced hybrid material based construction
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40 solutions.
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44 “Learning and routines” within the construction industry is related to issues of developing new
45
46 social patterns, practices and processes that may enhance innovation diffusion (Bresnen 2003, Roos
47
48 *et al.* 2010). In WMC business networks, the need for “being innovative when developing new
49
50 building solutions” was emphasized, for example, to increase the speed of WMC building projects.
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52 Abreast with this, fierce competition between wood and concrete construction affects the future
53
54 development potential of the entire construction sector, and business renewal experiences,
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4 challenges in finding optimal component dimensions to consolidate the products and processes of
5
6 WMC and concrete companies. Essentially, these are the main issues affecting the possibilities of
7
8 developing competitive hybrid building solutions.
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11 Regarding “Learning and routines”, potential benefits exist for the WMC and concrete companies in
12
13 hybrid building, if new social patterns would develop between the business networks of these
14
15 industries (Wang *et al.* 2014). As a result of social linkages, the potential of finding innovative
16
17 component dimension solutions, enabling a better fit between WMC and concrete products, could
18
19 also be developed. For example, challenges related to co-operation between the actors and the long
20
21 timespans of the construction projects were identified as problems during the first Delphi round,
22
23 and further inquiry into the matter confirmed these to be critical issues. Possibilities exist, for
24
25 example, in building new cross-sectoral collaboration relationships between actors from wood
26
27 industry and construction industry, and by moving away from the cost efficiency-centered mindset
28
29 towards stronger customer orientation, as also emphasized in the previous literature (Bygballe and
30
31 Ingemansson 2014, Matinaro and Liu 2017).
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36 Our results are in line with Hemström *et al.* (2017) for Sweden, which found that the strong
37
38 cognitive rules in construction are founded in the concrete-based building culture. Although this
39
40 feature is likely to also inhibit the dynamics of the socio-technical regime towards 2030, there are
41
42 also signals that the dynamics in the form of more frequent interactions between actors (e.g.,
43
44 business collaboration between wood and concrete driven companies) and the related technological
45
46 development (e.g., development of hybrid building solutions) could evolve. The institutional
47
48 structures may also be a source of change. Our panellists voiced that the WMC at the niche level
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50 could represent the key channel of future change towards a greener construction sector.
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4 According to Toppinen et al. (2018), there appears to be a lot of potential for WMC growth when
5
6 considering the need to tackle climate change and growing consumer interest in “green and
7
8 responsible construction”. Enhancing a greener image of the entire construction sector is a
9
10 fundamental issue for the building companies, and this could be supported by increasing utilization
11
12 of wood as the main material in structures and facades, or wood to be used as a combination of
13
14 other materials such as concrete or steel in hybrid solutions, like suggested in Wang. *et al.* (2014).
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18 In addition, although previous studies have found issues in governmental regulation to be an
19
20 important factor in mobilizing the future potential of WMC (e.g. Mahapatra *et al.* 2012, Wang *et al.*
21
22 2014, Hurmekoski *et al.* 2015, Hurmekoski *et al.* 2018), these issues gained much less attention
23
24 among the experts in our study. Instead, discussion concerning the regulatory framework was
25
26 mostly related to procedures that the WMC sector actors themselves have more control over, such
27
28 as construction system development. This may be related to the fact that most governmental
29
30 regulatory barriers for the diffusion of WMC have now been removed in these countries. Instead of
31
32 changes in legislation, the WMC sector’s future potential is more of a responsibility of the sector
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34 itself via developing technical infrastructures (i.e., technologies) and embedded in WMC business
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36 networks (i.e., interactions between actors, reshaping standards, and developing firm-specific
37
38 capabilities).
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42 In reference to the theoretical framework employed, our results showed that using MLP combined
43
44 with institutional aspects can help to explain the importance of various internal and external factors
45
46 affecting the competitiveness and the potential for business renewal in the construction industry.
47
48 However, neither institutional theories, nor MLP provide detailed approaches for identifying the
49
50 interconnectedness of various institutions when aiming to move from one regime to another. For
51
52 example, in the case of WMC, the importance of regulatory barriers for business renewal has
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54 diminished, and progress towards the socio-technical regime level is more strongly influenced by
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4 internal factors such as the standardization of skills and complementary knowledge base. Yet, due
5
6 to path dependencies, previous external regulatory barriers still affect the potential for internal skills
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8 development within business networks: if a certain technology or material choice is prohibited by
9
10 regulation at some point in time, it is likely to cast a long shadow on professional education and the
11
12 industry culture. However, interlinkages between governmental regulation (control of external
13
14 impacts) or the standardization of skills and knowledge (control of internal impacts) are only one
15
16 example of the potential application area for developing new theoretical approaches, and future
17
18 research should aim to also identify other application areas.
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22 **Conclusions**

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25 From theoretical perspective, we used the MLP approach at the interface of construction and wood
26
27 industries in analyzing the internal and external factors of competitiveness that are shaping the
28
29 future of WMC. We assumed that influential institutions in the WMC domain are to some degree
30
31 illustrative of a regime change potential toward the future in more general, and on how re-
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33 structuring business networks could partly solve the issue of WMC being a narrow strategic niche.
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35 To this end, we applied a dissensus-based Delphi approach to enable mapping as large a variety of
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37 opinions as possible, and eventually to identify key internal and external factors of competitiveness.
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42 Our results illustrate the key importance of educating architects and builders and the role of
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44 standardized building systems to gain better cost efficiency in WMC, which are falling within the
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46 external factor category of “Formal standardization initiated by the industry” by Kadefors (1995),
47
48 and within the internal factor categories of “Standardization of skills and knowledge” and
49
50 “Learning and routines” (see Table 1). Instead, the remaining two categories from Kadefors (1995),
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52 “Governmental regulation” (external factor) and “Roles and interest organizations” (external
53
54 factor), were emphasized less in our study.
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4 From a practical perspective, our results indicate that collaboration and R&D (as internal factors of
5 competitiveness) in the business networks is a fundamental issue for promoting the growth and
6 competitiveness of the WMC sector in the future. In re-organizing their business networks,
7 companies are at the beginning of their learning curves, which causes challenges to establish regime
8 level communities or standardization of products, but which also provides some promising
9 opportunities like re-engineering construction processes. These findings appear to be in line with a
10 recent study by Hurmekoski *et al.* (2018), which concluded that the main potential for wood
11 construction growth comes from industrial prefabrication, often linked with large-scale building
12 projects. In a case study of the city of Gothenburg, Esteban and Jaaniso (2016) also found that
13 successful introduction of WMC solutions into urban construction requires intense collaboration
14 between the public and private sectors, and academia.
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28 We conclude that towards 2030, the institutional stickiness and strong cognitive rules founded in
29 the concrete-based building culture are likely to inhibit the WMC market diffusion. We also
30 welcome a change in the WMC business culture towards a more collaborative mindset that could
31 better capitalize on the emerging niche innovations. The formation of new alliances between large
32 incumbents and new small players in the ecosystem are likely to play a much more important role
33 towards 2030 to enable WMC market share growth. Therefore, factors enabling formation of
34 alliance partnerships to share the risks in WMC projects is an area that merits further investigation.
35 Construction companies are also increasingly concerned with establishing closer connections to
36 customers and end-users, which have traditionally been weak in the field (see also discussion in
37 Bygballe and Ingemansson 2014). Studying end-user needs and user-driven innovations in
38 promoting the business case of WMC therefore constitutes another interesting area for future
39 research.
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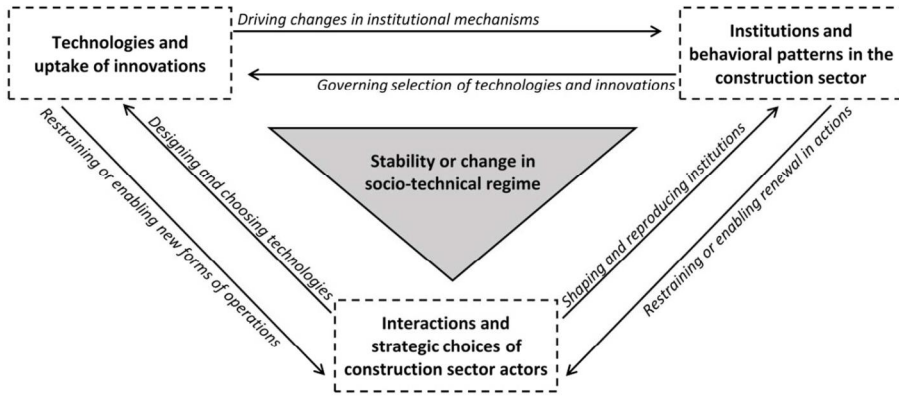
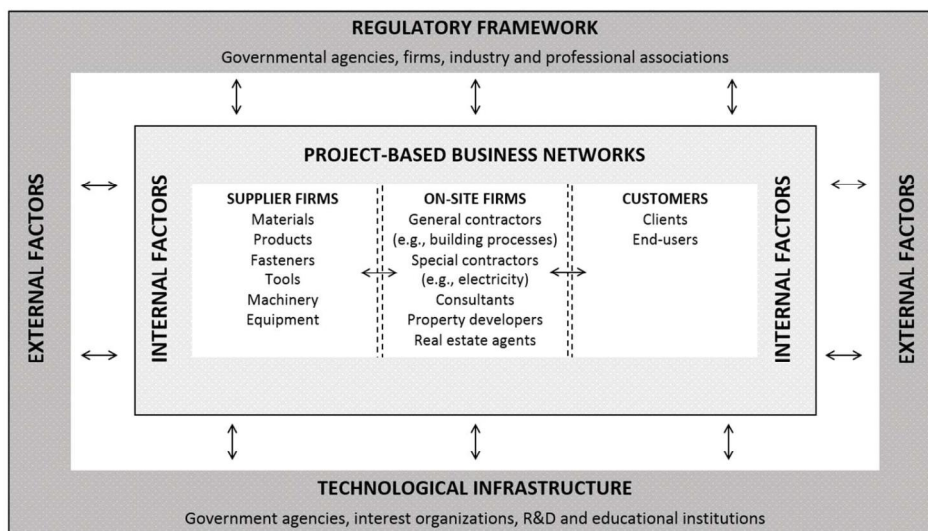


Figure 1. Dynamics between technologies, construction sector actors and institutions affecting the market diffusion of WMC from niche innovation to regime level (modified from Rohracher, 2001).

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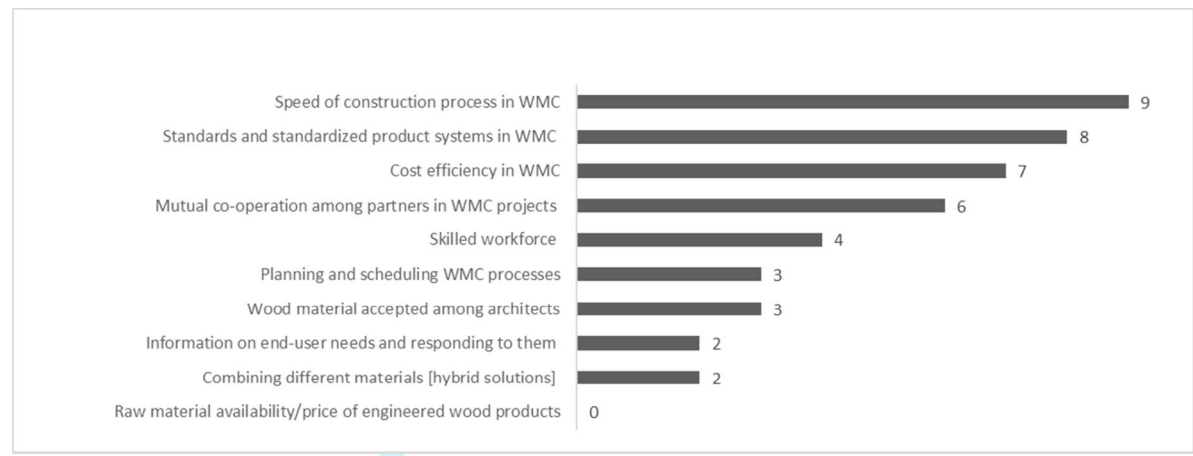
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(Fig. 3)



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(Fig 4)

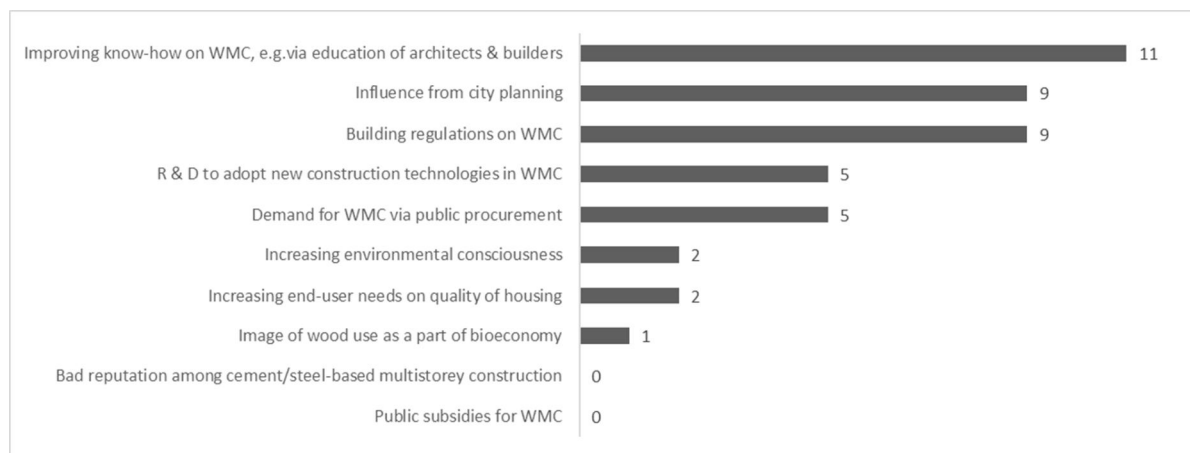


Table 1. The six types of institutions in the construction sector defined by Kadefors (1995) as the actors controlling internal and external factors in the WMC business system.

INSTITUTION*	POSITION IN THE WMC BUSINESS SYSTEM	PURPOSE OF THE INSTITUTION WITHIN THE WMC BUSINESS SYSTEM
1. Learning and routines	Project-based business networks (Control of internal factors)	To develop social patterns, practices and processes that support the dissemination of information and knowledge diffusion between separate projects, also enhancing the uptake of new routines and process innovation capabilities as, for example, customer needs become more diverse (Bresnen 2003).
2. Standardization of skills and knowledge	Project-based business networks (Control of internal factors)	To enhance capabilities for re-engineering construction processes and defining new “best practices” without compromising efficient and error-free project implementation (Roy <i>et al.</i> 2005).
3. Tendering system	Project-based business networks (Control of internal factors)	To find an optimal combination of, for example, suppliers for a given construction project by using bidding processes (e.g. Hatush and Skitmore 1997).
4. Governmental regulations	Regulatory framework (Control of external factors)	To ensure that good practices are being followed in building permit procedures, building supervision, technical solutions and building usage (e.g. The Land Use and Building Act (132/1999))
5. Roles and interest organizations	Regulatory framework (Control of external factors)	To facilitate knowledge diffusion throughout the construction sector and provision of normative directions for member companies and other organizations, for example, through negotiations and lobbying (Vermeulen <i>et al.</i> 2007)
6. Formal standardization initiated by the industry	Technological infrastructure (Control of external factors)	To assure that components and technologies are applicable with each other independently from selected suppliers in the bidding processes (Dubois and Gadde 2002)

*Defined as “rule” in MLP (see Geels and Schot 2007).

Country	Gender	Years of professional experience	Title	Organization type	Participation in rounds
Finland	Female	1	Executive	Building industry	1–3
Finland	Male	12	Technical manager	Building industry	3
Finland	Female	16	Planning executive	Building Industry	1–3
Finland	Male	26	Production director	Building industry	1–3
Finland	Male	3	Field manager	Forestry	1–3
Finland	Male	15	Research manager	Forestry	1–3
Finland	Male	16	Owner	Forestry	1, 2
Finland	Male	31	Managing director	Forestry	1–3
Finland	Male	15	Senior advisor	Public sector	3
Finland	Male	23	Managing director	Wood ind. Association	1, 3
Finland	Male	5	Senior vice president	Wood industry	1, 2
Finland	Male	14	Senior vice president	Wood industry	1–3
Finland	Female	22	Director of CSR	Wood industry	1, 2
Finland	Male	22	Sales executive	Wood industry	1–3
Sweden	Male	12	Academic expert	Building ind. Expert	1–3
Sweden	Male	15	Academic expert	Building ind. Expert	3
Sweden	Male	17	Vice pres. market dev.	Forestry	1, 2
Sweden	Male	21	Senior advisor	Forestry	1, 2
Sweden	Female	10	Managing director	Public sector	3
Sweden	Male	8	Sales manager	Wood industry	1, 2
Sweden	Male	11	Managing director	Wood industry	2, 3
Sweden	Male	11	President	Wood industry	1
Sweden	Male	15	Managing director	Wood industry	1–3

Table 3. Percentages of likelihood and desirability of round two statements concerning the competitiveness and development of the industry by 2030 (n=17).

STATEMENT	LIKELIHOOD (%)			DESIRABILITY (%)		
	Low	Neutral	High	Low	Neutral	High
<i>By 2030, the overall product offering of the wood product industries will offer a significantly more diverse range of wood products than today.</i>	6	12	82	6	6	88
<i>By 2030, wood product industries will offer significantly more value-added products than today.</i>	0	29	71	0	12	88
<i>Wood product industries are going through a paradigm shift, and will operate in a completely new way by 2030.</i>	6	35	59	0	24	76
<i>By 2030, the wood construction industry will still struggle with competitiveness and lack of value-added products.</i>	41	24	35	59	29	12
<i>By 2030, large-scale wooden construction, such as wooden multistorey building projects, has become the most important segment within wood construction.</i>	12	29	59	0	29	71
<i>By 2030, the flow of information from the construction site to the forests will be significantly faster.</i>	0	18	82	8	18	82
<i>By 2030, consumers will see wood construction as a modern way of building.</i>	0	12	88	0	6	94

Table 4. Percentages of likelihood and desirability of round two statements concerning wood as a raw material by 2030 (n=17).

STATEMENT	LIKELIHOOD (%)			DESIRABILITY (%)		
	Low	Neutral	High	Low	Neutral	High
<i>By 2030, wood has become a competitive construction material in its own right</i>	0	35	65	0	18	82
<i>By 2030, new wood-based products (for example advanced biomaterials made of wood) will create significantly more competition over raw materials</i>	12	47	41	24	47	29
<i>By 2030, the cost of raw materials will be a significantly larger proportion of the overall costs of wood construction.</i>	12	71	18	18	71	12
<i>By 2030, it will be possible to make more value-added products from lower quality raw materials due to technological development.</i>	0	12	88	0	18	82
<i>By 2030, builders will be significantly more educated about all available materials and hybrid solutions.</i>	0	12	88	0	6	94