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The Influence of Architects and Structural Engineers on Timber in Construction – Perceptions and Roles

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This study considers structural engineers' and architects' perceptions of structural timber in multi-story construction contexts. Qualitative approaches—interviews and focus groups—were used to investigate attitudes, perceived norms, and perceived factors that hamper or facilitate the prescription of wood use in construction. Wood was perceived as an appropriate building material. Architects', and even more so engineers', perceptions of negative aspects of wood focused on decay, instability and sound transmission. Although wood-based construction was seen as a required professional skill, it was not expected to improve one's professional status. Positive aspects of wood in construction included its strength, environmental friendliness, simple handling and appropriateness for use in conjunction with industrial methods, whereas knowledge gaps and weak support from the wood industry have reduced the use of wood among structural engineers and architects. Both professions perceived their influence on material selection to be weak. They sensed that most of the influence over material selection rested with developers and contractors. The paper contains suggestions on how to make these two professions more influential advocates for wood in construction.

Keywords timber-frame building, qualitative analysis, specifiers, stakeholders, timber design
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1 Introduction

To revitalize competitiveness and innovation in the building sector, European and Swedish building regulations have been revised, shifting from material-based to function-based requirements (Nord 2005, Boverket 2008). Thus, since 1995, timber has been permitted as a structural element of Swedish buildings that are taller than two stories (Näringsdepartementet 2004). Programs to promote wood-based construction in Sweden have introduced a number of demonstration timber construction projects (Bergström 2004, Sardén 2005), as has also occurred in several other European countries (Tykkä et al. 2010). Simultaneously, the construction industry has been establishing prefabrication building techniques that are improving quality and reducing building time (Bergström 2004, Näringsdepartementet 2004, Nord 2008). Timber construction is also claiming environmental and climate-based advantages (UNECE/FAO 2002 Ch. 3, Gustavsson et al. 2006, Upton et al. 2008, UNECE/FAO 2009 Ch. 11).

However, timber frames account for just 15% of multi-story apartment housing and 30% of hall-style buildings in Sweden (Gyllenstierna 2009). In most European countries, timber construction has a similarly low market share for multi-story construction (Tykkä et al. 2010).

The limited growth of timber construction may in part be linked with the attitudes of professionals regarding wood. Two key professions are architects and structural engineers (Kozak and Cohen 1999, Bengtson 2003, Bregulla et al. 2003, O'Connor et al. 2004, Bayne and Taylor 2006, Bysheim and Nyrud 2009). Architecture and structural engineering are the central technical professions involved in design and material selection in building construction; structural engineers are responsible for the static performance of buildings, while the architect generally considers the visual and functional aspects (Encyclopædia Britannica 15 January 2010, http://search.eb.com/eb/article-60155). According to Winch (1998), these professionals are 'system integrators' who should have a particular influence on construction-based innovation during the design stage, whereas the principal contractor has more power during the construction stage. Hence, the professions' attitudes toward wood in construction may be key factors for the diffusion of timber construction.

There are indications from other fields that status, norms, and self-image may influence the intentions and behavior (Ashforth and Mael 1989, Cialdini et al. 1991, Terry et al. 1999), e.g. the likelihood among architects and structural engineers of proposing wood as a structural material in construction.

Previous studies have also indicated that structural engineers and architects occasionally experience a lack of training for wood construction in specific applications (O'Connor et al. 2004). In this regard Bayne and Taylor (2006) found that insisting of wood construction would require 'self-education' and extra planning time.

The influence of architects and structural engineers on material selection is moderated by other 'stakeholders' – e.g., authorities, contractors, and developers (O'Connor et al. 2004, Nord 2008). Little is known about the attitudes and power relationships among these actors. While our two professional categories are often involved in the design process as consultants, they can also be employed, e.g., with a building contractor. Our study takes a broad view of the role of architects and structural engineers focusing on their general attitude, perceptions on, and power over the material selection in the building process.

The rationale for this research is that the perceptions of architects and structural engineers may influence any increase in timber construction (Bengtson 2003, Bregulla et al. 2003, O'Connor et al. 2004, Mahapatra and Gustavsson 2008). There is a gap in our knowledge regarding the perceptions of these key professionals on wood in construction, and to the degree the perceptions represent impediments to timber construction. We are also aiming to reach a deeper understand of these professionals' views on their influence on the structural material used for new buildings.

The purpose of this study is to explore the considerations that would influence the propensity of architects and structural engineers to suggest construction in wood. We have chosen a broad approach, which means that we include a range of aspects including the perceived performance of wood, the impact of wood construction experiences on professional values, and factors that may facilitate or hamper the decision to prescribe or

suggest the use of wood in construction. Furthermore, the study determines the relative influence of different actors on material selection, as they are perceived by architects and engineers.

This study focuses on the potential use of timber in multi-story residential buildings (taller than two stories) and larger projects such as schools, institutional buildings, and commercial buildings.

2 Material and Methods

2.1 Theoretical Framework

To address the different facets of these professionals' perceptions regarding wood, the Theory of Planned Behavior (TBP) (Ajzen 1991, 2001) was used as a conceptual framework. According to the theory, professionals' intention to prescribe timber-frame in building projects depends on *Attitude, Subjective norms,* and *Perceived behavioral control. Attitude*s represent a person's summary evaluation of an object or issue, captured using attribute dimensions such as good-bad, harmful-beneficial, and likable-dislikeable. Thus, *attitude* is interpreted as a professional's general stance about whether timber is a reliable, appropriate, high-performing building material. *Subjective norms* concern the professional's expectations regarding the normative reactions of other colleagues or key stakeholders' towards his/her engagement in timber constriction. It can also reflect the person's own normative beliefs about, in this case, building with wood (Cialdini et al. 1991). *Perceived behavioral control* covers perceived factors that facilitate or hamper the decision to propose the use of timber in construction. It encompasses perceptions regarding the capability and possibility to engage in timber construction. Here, control beliefs depend on perceived knowledge of wood construction techniques, access to information or the availability of systems that facilitate the actual process of working with wood.

As a framework for the second research question, stakeholder theory was used to assess professionals' perceived influence on material selection and how they evaluated the attitudes, and influence of other actors. A *stakeholder* is anyone who can affect or be affected by a process (Donaldson and Preston 1995, Mitchell et al. 1997). In our case, we investigated important actors in the material selection and building process, as they were perceived by architects and structural engineers. We also assessed the actors' attitudes and power.

2.2 A Qualitative Approach

Our objective was suitable for to the use of qualitative research because of scarce a priori knowledge of the questions and possible answers, and a focus on individuals' background, knowledge and reasoning rather than on statistical analysis survey answers (Bliss and Martin 1989). Gummesson (2000) highlights the advantage of the qualitative approach to understand decision making, and change-processes, which was in the focus for this study. Bryman supply several features of qualitative research that also motivated its application here: an openness on the respondents' priorities (within the main issue for the study), and an interest in contextual understanding (Bryman 2001). Qualitative data also have the advantage of locating meanings, perceptions, and assumptions that people place, in this case on the material selection process in construction (Strauss and Corbin 1990, Miles and Huberman 1994, Denzin and Lincoln 2000). A survey can produce representative information on some issues, but with the danger of omitting important information about perceptions among architects and engineers, or how processes are influenced by contextual factors. Hence our interest in peoples' motivations, perceptions, and decision-making processes led to the use of qualitative research methods.

2.3 Interviews

Purposive sampling among practicing architects and structural engineers in Sweden was used for all interviews (Gummesson 2000, Arbnor and Bjerke 2008). Industry experts were contacted and invited to provide contact details for potential respondents. Then, respondents were purposively selected based on their profession, role and geographic location.

While gender was not a specific sampling criterion, it is noted for the sake of completeness that

5 women and 21 men were interviewed. These figures are consistent with the distribution of men and women in the focus professions: architects are almost equally distributed between the sexes, whereas women are under-represented in structural engineering (www.arkitekt.se, www.scb.se, 11 February 2010).

Table 1 lists the outcome of the sampling process, illustrating that the particular persons interviewed all had specific personal experiences with construction and/or timber frame construction specifically.

Semi-structured interviews were used to achieve an in-depth understanding of motivations and to enable the interviewees to elaborate on their perspectives (Silverman 2005, Denscombe 2007). To provide a relevant basis for discussion prior to the interviews, a number of themes were chosen that focused on relevant topics. Within each of the three TPB concepts the most relevant thematic questions were formulated. The latter were based on the purpose of the study to describe the factors that would encourage or deter architects or structural engineers from working with wood, and previous literature. They were formulated so as not to restrict the interviewee's capacity to interpret them and respond in ways that they found appropriate. Table 2 shows how the themes map onto the research analysis framework.

Interviews were held face-to-face at respondents' offices, except for one that was conducted via telephone. Interviews were of 30 minutes to 2 hour duration and were recorded digitally. Each interview was transcribed and the transcriptions were sent to the interviewees for clarifications and corrections (Yin 2003, Denscombe 2007). In a few cases the respondents made changes to the text.

Table 1. The role category and profession of interviewees.

Category	Architect	Structural engineer	
Consultant	8	4	
Developer		1	
Contractor		2	
Academia/research	1	5	
Timber industry and timber-building industry		2	
Promotion organization	1	1	
Public authority	1		
Total number	11	15	26

This material was then subject to content analysis by all authors (Miles and Huberman 1994, Silverman 2005, Denscombe 2007). Sentences and phrases from the respondents' conversations were interpreted, compared, and sorted. Each interview was coded separately by two researchers. After a 'negotiation' process all three researchers reached a workable consensus regarding the coding principles and the coding outcomes (Silverman 2005, Denscombe 2007).

The transcripts from the interviews were also, in a second round, coded to identify the stakeholders that the respondents had identified and described. The data were reviewed and coded in a similar fashion as the previous analysis to assess the attitudes and influence of the different stakeholders from the interviewees' standpoint (Mitchell et al. 1997).

Table 2. Interview guide connecting the thematic questions with corresponding theoretical concepts.

TPB concept	Themes for the semi-structured interviews
Attitude	Factors influencing material selection in multi-story buildings and larger construction projects. Timber in construction: advantages and drawbacks compared to other materials.
Subjective norm	Professional status and career effects and as related to working with timber. Is wood construction professionally interesting?
Perceived behavioral control	Knowledge of, and access to, information about timber construction. Ease of planning and construction process.

2.4 Focus Groups

Focus groups were used in the triangulation process to validate the findings in the interviews (Barbour and Kitzinger 1999, Silverman 2005, Denscombe 2007, Stewart et al. 2007). One focus group exercise was held with eight structural engineers (including one woman); the other group was comprised of nine architects (including two women). The respondents were randomly selected from a professional directory. For practical reasons they resided in the Stockholm area. None of the participants had participated in the previous interviews to avoid interview fatigue among the subjects and to provide 'fresh' data in the focus group sessions. The sessions were led by an experienced moderator, and the discussion themes corresponded to the guide for the interviews. The sessions were video-recorded and a report was developed.

The documentations of the focus group exercises were consulted to verify the analysis of the interviews in terms of attitudes and perceptions (Barbour and Kitzinger 1999, Stewart et al. 2007). They were also used to verify and develop issues in the interviews. If nothing else is indicated, the results report aspects that were established in several interviews and in the focus groups.

3 Results

3.1 Qualitative TPB Analysis

Attitude

Architects thought that wood was a material that harmonized with local building traditions. "*In rural settings, timber is the natural choice in the Nordic countries. This is our cultural background*" (architect). Both architects and engineers also referred to aesthetic advantages of wood. One architect also noted that wood in buildings creates a pleasant indoor climate and atmosphere.

Energy efficiency and environmental requirements were other aspects that respondents noted in suggesting that wood has advantages compared to other materials. Furthermore, because wood is lightweight, developers can save energy and money during construction. Structural engineers appreciated timber's strength-to-weight ratio. In addition, glulam was seen as an important improvement: "*Timber is not appropriate for very large industrial buildings. But glulam is very suitable for large warehouses and hall buildings*" (engineer).

Fire-related properties of timber were seen by some as advantageous and in some cases as shortcomings of wood. It was noted that although timber is combustible, massive timber structures exhibit a predictable reaction to fire such that total collapse is less likely than it is for steel. The assumed sound transmission properties of timber buildings were cited as the most serious disadvantage. Poor form stability and movement connected to changes in moisture content were also listed as the drawbacks of timber.

Economic costs were reported to be the most important factor influencing material selection. They include price estimates for maintenance and risk costs as well as construction costs; "*budgets must be respected*", it was noted. Views regarding relative cost advantages of wood varied. Several respondents suggested that wood could be cost-competitive because of its low weight, while others, especially engineers, expected higher total costs due to perceived higher risks of wood-based construction.

Norms

Architects and engineers felt that working with timber construction was inspiring and interesting. However, several interviewees agreed with the assertion that "*Experience working with timber doesn't improve my career*" (architect). The norms might change if wood were used more frequently by the most famous architects: "*When the 'big names' engage in timber architecture, then it becomes interesting*" (architect). An established timber architecture prize was highly esteemed among the architects. For engineers, professional reputation was often associated with experience with large and prominent building projects, which implied a disadvantage for wood.

Perceived Behavioral Control

Practices for material selection in construction

tended to favor concrete. Corporate policies or 'platforms' of building enterprises prescribe which materials should be used, and timber structures are normally not included. The interviewees expressed the notion that conservative forces in the sector did not favor wood in construction, with references made to a 'culture' of building in concrete. In these circumstances, wood tended not to be selected.

Still, respondents judged wood to be appropriate for industrialized building methods where building components are prepared under dry factory conditions and then transported to the building site for swift assembly. However, engineers stressed that it was important to have confidence in an established construction method "*It is never good to be number one – it is better to be number two when it comes to applying something new (like a high-rise timber frame)*" (engineer).

Practically all respondents complained about a lack of knowledge and weak education in timber construction: "*Ninety percent of the education was about concrete"* (architect). It was also reported that students were taught that concrete is the only option for larger construction projects. *"Concrete dominated during the later years in my education" (engineer).* One respondent explained that his competency about wood was the outcome of on on-the-job training combined with other information sources: colleagues, professional journals and publications, the Internet, handbooks, software, courses and seminars, and information

Table 3. Summary of the TPB analysis.

TPB-concept	Main results
Attitude	*Mainly positive*
	Wood often creates links between the built and natural environment and local building traditions
	Natural, warm appearance
	Energy-efficient
	Environmental and climate advantages
	Strong and light material
	Mainly negative
	Sound transmission properties
	Poor form stability and movement
	Decay
	Ambiguous
	Fire properties
	Economic costs and risks
Subjective norm	*Mainly positive*
	Interesting to build with wood
	Mainly negative
	Professional norms are not compatible with wood
	For engineers, larger projects matter more
Perceived behavioral control	*Mainly positive*
	Appropriate for industrialized building methods
	Does not need much ground preparation
	Easy to make adjustment afterwards
	Mainly negative
	Few demonstration examples
	'Standard practice' and corporate culture are obstacles
	Insufficient education and knowledge
	Insecure wood supply
	Insufficient support from suppliers of wood in construction
	Neutral
	Codes, regulations, and authority decisions

from suppliers. However, if this opportunity is not available, skills in timber construction would not develop. The fragmented timber industry also provided insufficient information and support to architects, engineers, and contractors.

Engineers also complained about fluctuating prices and got the impression that domestic wood producers prioritized the export markets. This made planning and economic planning more complex. Codes, regulations, and authority decisions were of minor importance in material selection as long as functional requirements were fulfilled.

Examples of technical and systems innovation that facilitated wood construction included sound-insulated timber materials, panel products, fire-resistant wooden material, glulam, and engineered timber products. Pre-fabricated timber-building methods were seen as particularly promising as they shortened the building time and reduced risk. This trend was expected to continue. *"We need supply systems that fit together and demonstrate intelligent solutions that permit flexible solutions and appropriate span-lengths"* (architect).

Summary of TPB Analysis

A summary of the TPB analysis is shown in Table 3. The main factors that positively influence attitude are building tradition, environmental considerations, and perceived structural advantages of wood; and negative attitude referred to concerns about movements, decay and sound transmission. According to our results, professional norms and perceptions in the building sector do not lead to a superior status for wood. Behavioral control over wood construction is hampered by a superficial education on wood construction, and established practices and sunk investments in the sector that are adapted to concrete.

3.2 Stakeholders and the Decision Process

The Decision Process

The identified stakeholders in the building process were developers, contractors, architects, structural engineers (performing different functions), authorities (local and national), suppliers, and end-users. The building process is generally divided into a program phase, a design phase, and a construction phase (and finally a use phase). Material selection generally takes place in the program phase or design phase (for a thorough description of the building process, see Nordstrand 2000, Cigén 2003, Nord 2008)

The following section describes both the perceived attitudes and the power of each stakeholder.

Developers

The developer was the most influential actor in the process. "*The developer must prefer timber - otherwise it won't be timber"* (architect). Low costs and rapid assembly for timber houses could influence the final decision for this stakeholder. In prestigious public space projects, clients tended to be mainly concerned with architectural design and aesthetics. Here, any views regarding material selection usually related to the aesthetic feel of the building. However, in general developers were risk-averse in their planning of construction and any views they expressed regarding material selection were developed in a cost-constrained context.

Contractors

Several interviewees saw the dominating building firms as firmly planted in a tradition of using concrete. The contractor could also have an important element of control over material selection. "*The developer and the builder – it's mainly their decision"* (architect).

The respondents identified the major building companies as the primary opponents of timber construction. In some cases, when a contractor was developing a building for sale, the material selected was concrete by default. *"Our policy is to build in concrete. We believe in it, and we have made our calculations"* (engineer).

Architects

Architects were curious about timber use in the structural elements of buildings, but they con-

cluded that they had limited authority over the material choice. They valued wood as a building material and welcomed its environmental advantages. However, architects experienced some difficulty in ascertaining the advantages of timber for structural purposes. Timber was seen as belonging to the Nordic tradition and therefore as appropriate for smaller one- and two-family houses. However, although timber was viewed with positive curiosity, architects emphasized that they are 'material-neutral' and that the preferred material depended on the contextual factors for each project.

Architects are primarily responsible for producing a functional design that should also be aesthetically pleasing to the client. In prestigious public space projects, exposure of load-bearing elements could increase the attractiveness of a building. In housing projects, load-bearing elements were generally hidden in the structure. In such cases, the choice of the material for a load-bearing element was sometimes considered as the structural engineers' responsibility.

So architects combined a positive regard on wood with a limited influence in the material selection process. *"Swedish architects have a low level of influence on the building process compared to [in] other countries"* (architect). *"The major contractors already have policy directives about which material should be used where. It is very difficult for an architect to influence these decisions"* (engineer).

Structural Engineers

The structural engineers normally assumed responsibility for the structural aspects of the project. *"Architects can influence the visible parts; the engineer influences the frame"* (engineer). Several respondents said that professionals in this category mainly favored concrete. They sometimes had an indirect impact e.g. when they voiced unease regarding timber. Engineers were not always convinced that timber-building would be carried out with the necessary prudence on site. *"You can often not verify that it is turning out as you had planned"* (engineer).

Structural engineers' choice of materials for load-bearing elements was primarily influenced by their perceptions of the feasibility of their engineering design: "tried and tested" approaches are the preferred choices. Therefore, the choice of a load-bearing element was often influenced by the engineers' educational background and experience-based interpretations of regulatory codes.

Timber was viewed as suitable for one-family dwellings. For larger timber projects, engineers doubted the final performance of the timber construction. For some engineers, however, this view was combined with an overall positive view of timber construction and a curious desire to learn more.

The engineers' power was described as being stronger than that of architects. However, the structural engineers' thorough experience with concrete generally narrowed the set of available materials.

Authorities

Authorities play a potential key role in the material selection process. However, they do not prescribe the material to be used. Because building regulations do not specifically prescribe the building material, the main position of building authorities towards timber is neutral. No examples were reported of authorities' that favor one specific material in construction.

Wood Suppliers

While building component wood suppliers are rarely directly involved in most projects, they influence the process by issuing technical guidelines and providing service and support for their components and systems. In this regard steel and concrete suppliers were considered particularly helpful. Respondents working in the construction sector complained that timber material suppliers were rather anonymous and passive in marketing of timber products. Architects and structural engineers desired more product- and systems innovation and support as well as more active, personal marketing. Respondents noticed that current marketing efforts did not match those of other material providers.

End-Users

The end-users can be both the tenants and the cooperative owners of apartments. They were not expected to prefer any specific structural material. Some interviewees even claimed that the residents were often not aware of the material used for the structural components of the buildings. However, developers often assumed that perceived sound transmission currently makes the use of timber structures less common in multi-story buildings. One engineer expressed his view that *"The frame doesn't matter as long as the sound insulation is good"*. However, one architect thought that residents would appreciate living in a timber-frame house because of the unique 'timber atmosphere'. Another respondent observed that timber surfaces were less subject to vandalism than, for instance, concrete. It appears that final users ultimately primarily make decisions based on location and price/rent.

The end-users' power was assumed to be minimal because a timber frame would not be directly visible to the user and since there exists a communication gap between the contractor and the final user.

Summary of Stakeholder Analysis

A summary of the stakeholder analysis is presented in Table 4 and Fig. 1. Our main finding is that contractors and some professional structural engineers have a negative opinion about timber structures (although there are exceptions – e.g., among small, specialized contractors working on timber structures and among a small number of engineers). However, those who have knowledge and experience with timber generally reported positive opinions. Architects are curious about, and interested in, timber construction, although their influence is weak. Developers are predomi-

Table 4. Summary of stakeholder analysis.

Stakeholder	Perception	Power
Developer	In prestigious buildings: Aesthetics matter. Otherwise, focus on construction- and maintenance costs Risk-averse	Highest control over material selection
Contractor	Negative attitude due to established experience with concrete Corporate policy decisions to use concrete	Strong due to experience Has technical expertise and authority
Architect	Somewhat positive Interested but has a lack of experience and knowledge	Weak Unless there is a 'big name' involved and it is a special project
Structural engineer	Somewhat negative Education and work experience are mainly based on concrete. Perceives wood as risky	Weak, but scepticism can destroy a timber proposal
Public authorities	Neutral to slightly positive due to promotion campaigns. Since 1995, functional requirements replace material prescriptions	Potentially strong
Timber material supplier	Positive However, low activity to market wood construction	Weak due to fragmented industry
End-user	Neutral Price, location, comfort, and visual details matter more	Weak

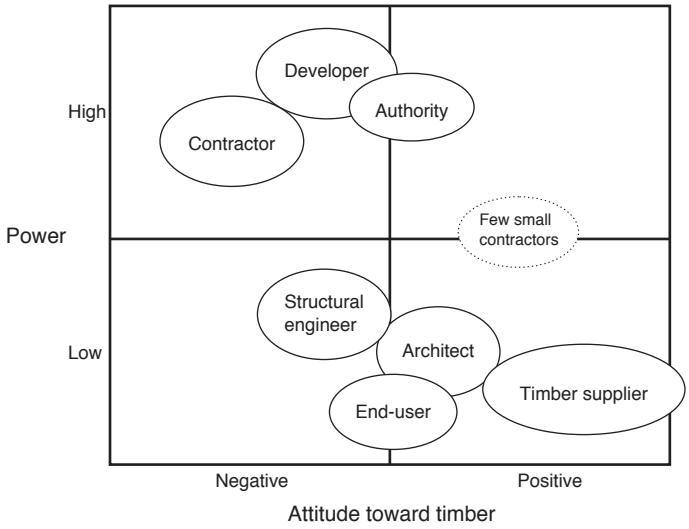

Fig. 1. Power and attitude in the process of material selection.

nantly negative in their attitude towards timber, mainly due to risk perceptions.

Our mapping provides a preliminary picture of the main positions among the stakeholders in the building process. However, it does not capture the dynamic aspects of the process. Changes in the building sector may include the emergence of new contractors who specialize in timber while the traditional contractors remain faithful to concrete. It is also possible that both architects and engineers will become more knowledgeable and favorable toward timber construction in the future.

4 Discussion

Our findings about the advantages and disadvantages of timber in construction confirm some results reported in other countries (O'Connor et al. 2004, Bayne and Taylor 2006, Bysheim and Nyrud 2009). Timber is appreciated for its link to tradition, familiarity, and flexibility ('forgiveness') in terms of use. We also corroborate previous studies' findings that lack of experience has hindered the diffusion of innovations in the building sector (Pan et al. 2008), and more precisely that a lack of education or experience, or both, have obstructed architects and engineers from promoting timber construction (O'Connor et al. 2004, Bayne and Taylor 2006, Bysheim and Nyrud 2009). Our findings about perceptions on wood in construction endorse the results of a study by Gold and Rubik (2009) that examined a sample of the German population. Insufficient education in timber construction, especially among engineers, and that much knowledge must be assembled on the job, resembles the findings of Kozak and Cohen (1997) based on a North American survey.

O'Connor et al. (2004) listed costs as one barrier to timber, although our study did not find this connection as being as clear-cut. In our study, different views were presented: some respondents claimed that, if correctly applied, timber was actually cost-effective; while others feared increasing costs due to perceived risk factors in wood construction. Our study found that the observed technical and policy changes involved pre-fabricated solutions and ongoing information and promotion campaigns.

The findings presented by Cialdini et al. (1991) can be used as a basis for a discussion on how to improve normative beliefs among architects and engineers. In the early stages, personal norms, and norms among peers could influence interests

to build in wood. Later, when timber construction gains momentum in society, descriptive norms ('that everybody is building in wood') could promote timber construction further. Promotion campaigns should consider both these stages of norm formation.

Bayne and Taylor (2006) identified similar barriers regarding timber – e.g., a knowledge gap, risk considerations, and a low degree of marketing. Bengtson's (2003) study, which was conducted in Sweden, highlighted the role of the different actors and the contextual factors that shaped the dominance of building in concrete in Sweden. Our findings, especially concerning the planning process and knowledge gaps, confirm those of Bengtson.

Our study has depicted several attitudinal aspects of perceptions regarding wood use in construction. The results are only partly in accordance with those of Bysheim and Nyrud (2009). However, the authors' results on behavioral control factors are supported by our results. Our respondents' emphasis on the role of knowledge and education is also confirmed by Bysheim and Nyrud.

Finally, our interview data clearly indicate that there are likely associations between attitudes, norms, and control beliefs and perceived power relations in the material selection.

5 Conclusion and Recommendation

One main finding of our study was that material preference among architects and structural engineers is influenced by attitudes regarding the properties of wood, normative beliefs and beliefs about the control and ease of building in wood. The sector's 'standard practices' based on concrete and steel (which are manifest in the corporate policies of contractors) as well as a sense of deficient knowledge are the main obstacles for architects and engineers for suggesting that wood be used. Regulations are no longer seen as a hindrance to timber construction. Our findings also point at connections between normative beliefs, education, perceived barriers to propose wood as a structural material, and the relative influence on material selection as it is seen by architects and engineers.

The most recent administrative development in the building sector perceived by our interviewees was the removal of restrictions on multi-story timber frames in 1995, along with ongoing campaigns promoting timber construction and technical innovation and developments (e.g., with regard to industrial building methods).

While timber is perceived as an recognized construction material, architects and, to a greater degree, structural engineers are reluctant to use timber in their designs due to concerns about form instability, fire, decay, and sound transmission. The advantages of timber structures included its low costs, flexibility, low weight, and low environmental impact – as well as opportunities to use industrialized methods.

Both groups spotted a professional challenge in working with timber, although experience in wood construction did not enhance their careers. Most respondents highlighted the need for more active engagement among timber material suppliers in solving their problems and providing hassle-free timber-based solutions.

The most influential parties in the process of material selection, from architects' and structural engineers' perspectives, were developers and contractors, whereas the final user was often not aware of the structural material of the building. Inexperienced engineers were uncomfortable about timber construction alternatives, and architects noted that they had a rather limited influence on material selection. Our finding that both engineers and architects believed they had only a limited power in the material selection suggest that their roles as 'systems integrators' (Winch 1998) should not be overstated. One cause for this limited impact may be that the preference for non-wood building methods lies more in the culture and 'standard practice' than in individual preferences. These strategic decisions on building material are made at the top corporate level of the larger contracting firms by managers and economists.

A synthesis of our results suggests that attitudes, normative beliefs and control beliefs together with the power balance in the material selection are related. Attitudes concerning the advantages and drawbacks of wood can reflect

broader perceptions in the building industry. This further impacts on the general normative belief whether wood construction knowledge would boost professional status or career. The limited role of wood in construction is also associated with shortage of planning tools, equipment and methods that facilitate wood construction. Finally, this situation can be overwhelming unless the wood industry thrust the position of wood on many fronts.

Considering the contextual and cultural implications of the long and dominant tradition of using concrete in multi-story construction in Sweden, our results indicate some measures that, if taken into account, would improve attitudes and norms toward wood construction, while perceived obstacles are lowered:

- Develop clearer business concepts for timber-based construction approaches that are transparent, cost-efficient, and that reduce uncertainty
- Develop prefabrication methods for wood. They reduce the risk factor in wood construction
- Improve education and training in wood building design and construction
- Provide information about the environmental performance of wood as a building material
- Improve the 'professional status' of wood via interesting design
- Support architects and engineers in pursuing wood construction and develop a dialogue with members in these professions

This work has contributed to our knowledge of a number of factors that influence decision-making in Swedish building contexts. Because decision-making is a complex process, a relevant issue for future research to investigate would be the interaction of different factors – e.g., knowledge, risk perceptions, economic considerations, etc. – when the building material is determined. These relationships and the respective strengths of each aspect could be examined further in both qualitative and quantitative studies.

It is also interesting to see that although, in theory, architects and structural engineers compare and assess different materials, their perceived influence on material selection is weak. One reason for this could be the fact that, in practice, there is little choice available regarding construction materials (c.f. 'established construction patterns' Bengtsson 2003), while another could be that the role of the specialist in the end is eclipsed by economic interests. This is a topic for further study.

It is of course sensible to be cautious when generalizing the results of this study onto a larger population of architects and structural engineers. Hence, a natural next step would be verify and confirm our results through a large-N study.

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