Swedish architects' perceptions of hindrances to the adoption of wood frames and other innovations in multi-storey building construction

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Summary

A better understanding of general hindrances to the diffusion of innovations (new products, services, processes, systems, or concepts) in the construction sector may help improve the sustainability of buildings. Adoption of innovations such as multi-storey wood frames may e.g. reduce the primary energy use and carbon dioxide emissions of building construction. This study uses a web-based questionnaire to collect information on Swedish architects' perceptions of hindrances to the adoption of innovations in building construction in general, and to the adoption of multi-storey wood frames in particular. Results show that the most influential hindrances to the general adoption of innovations were perceived as the focus on project costs instead of life-cycle costs, the economic risk adopting an innovation imply, the focus on traditional engineering models, the construction industry´s tendency to use proven materials and methods, and contractors' inability to adjust processes. Concrete and steel were perceived as more advantageous than wood with regards to several aspects influencing the innovativeness of the Swedish construction industry, but wood was perceived as better with regards to opportunities to support local industry. The architects also had more positive perceptions of the performance of concrete and steel in multi-storey buildings, than of wood. While gender and size of company seem to have little influence, perceptions of innovativeness and frame materials vary with age and regions.

Keywords: Innovation, construction industry, multi-storey buildings, architects, wood frames, Sweden

1. Introduction

An increased use of wood frames from sustainable forestry in multi-storey buildings will help reduce primary energy use and greenhouse gas emissions in building construction [1-6]. This is because the manufacturing of wood products often requires less primary energy compared with alternative materials; industrial process carbon emissions such as in cement manufacturing are avoided; carbon is stored in wood products; and wood by-products and wood products at end of life can be used to replace fossil fuels [1-6]. However, fire protection measures prohibited or discouraged the use of multi-storey wood frames in several European countries from the late 19th century until functional based requirements for building products were introduced in the late 1980's. In Sweden, the market share of wood frames has increased since they were re-allowed in 1994. It was about 15% in 2008 [7].

In the context of the Swedish construction industry, multi-storey wood frames can be understood as an innovation [8]. Mahapatra and Gustavsson [8], Gustavsson et al [9], and BRE [10] have summarized possible barriers to the diffusion of wood frames in multi-storey construction. The majority of such hindrances relate not only to the diffusion of multi-storey wood frames in particular, but to the diffusion of innovations in building construction in general. The construction industry in Europe is generally recognised as being slow to change [11-13], and the diffusion of innovations (new products, services, processes, systems, or concepts) often faces barriers inherent to the sector [8, 14-17]. This tendency has been addressed in several studies in different countries. In general, the characteristics of the industry, also referred to as liabilities, do not promote innovation [11]. The liabilities are related to the nature of the activities involved in construction and their organisation into projects (e.g. the lack of coordination and management of building projects and the division of work in different phases), the fragmented structure of the industry (e.g. the lack of competition between the few number of large contractors who rely on a large number of small local sub-contractors), the uncertain demand (due to e.g. the uniqueness of each building project), the difficulty to evaluate innovations (due to e.g. the size and long life-time of buildings), and the type of contractual agreements (e.g. the management of risks and costs and the level of influence and cooperation allowed from and between different actors).

In addition to these factors, the path dependency of an existing concrete-based construction system may also resist the diffusion of wood frames [8]. Path dependence means that present decision-making is affected by previous events or decisions that contributed to self-reinforcement of various interrelated aspects [18]. Such path dependence may manifest itself through a consistent use of traditional materials or methods, and be reinforced by institutions (knowledge, perceptions, and regulations, e.g. building codes and standards), actor networks (e.g. inter-firm collaborations regarding specific materials and methods), and sunk investments (e.g. investments in knowledge, tools and machinery involving specific materials or methods) [8, 19]. Here, perceptions held by the actors of the construction industry of how wood frames perform in relation to alternative materials in multi-storey buildings may influence the decision to adopt wood frames. Such perceptions may be accurate or inaccurate with respect to objective reality, but the perceptions rather than reality itself will often determine behaviours [20, 21]. Norwegian architects' intention to use structural timber in urban construction are found to vary with their perceptions towards and experience of structural wood [22]. And although wood frames are common in multi-storey residential buildings in the US ([23] cited in [24]), North-American architects and structural engineers perceive drawbacks with the structural use of wood in non-residential buildings [25, 26]. With increased building height and area wood is perceived as less appropriate than more 'proven' frame materials such as concrete and steel, due to perceived drawbacks regarding fire safety, strength, stability, and durability [25, 26]. This may influence what material the architects propose or assume in their design of the building.

The mentioned hindrances to the diffusion of innovations in building construction (discussed more in detail elsewhere, see e.g. [11, 27-30]) are mostly theoretically studied. In this paper, we conduct an empirical study to complement such theoretical analysis through a questionnaire circulated to Swedish architects involved in building construction. Architects are important actors in building construction as they produce the designs that describe how the building will be built [31]. We investigate architects' perceptions of the relevance of various hindrances to the general innovativeness of the Swedish construction industry, especially with regards to the use of wood frames instead of alternative frame materials in multi-storey buildings. Innovativeness here refers to the degree to which the construction industry tends to adopt innovations.

2. Method

We used a web-based questionnaire to gather information from the Swedish architects. The first part of the questionnaire (A) covered some background information on the respondents and the company. Part (B) contained questions on innovation in the construction industry (e.g., how innovative the Swedish construction industry is and the relevance of indicated hindrances to the Swedish construction industry). Part (C) contained questions on the choice of frame material and the performance of steel, concrete, and wood frames in multi-storey buildings (e. g how wood frames perform with regards to fire safety), while (D) covered questions regarding e.g. gender and years of work experience in the construction industry. Most questions comprised five-point Likert-type scales (e.g. 1=Completely disagree, 5=Completely agree).The extremes of the scales were named depending on the question.

The survey questionnaire was in the Swedish language and targeted architects working on multi-storey construction at architectural firms in Sweden. As Swedish architects are not obliged to be members of a professional association and no comprehensive e-mail list was found to reach the target group, the e-mail addresses of potential respondents were retrieved from the Swedish internet-based yellow pages (http://www.eniro.se) through a search on the keyword "architect". Where company web sites were returned, e-mail addresses were retrieved from the web sites. From the limited information available on these web sites it was difficult to assess which addresses belonged to individuals working specifically with multi-storey buildings. Although architects with a published profile directed solely towards detached houses were excluded, e-mail addresses may have been collected from individuals outside the target population.

E-mail invitations to complete the survey were sent to roughly 3,600 potential respondents in late March 2010. Four e-mail reminders followed the invitation. The first reminder was sent five workdays after the original send-out, the second six workdays later, and third and fourth reminders five workdays after the previous reminder. The survey invitation contained information on the purpose of the study, how the e-mail address was retrieved, and an individual hyperlink with which to login to the survey website.

2.1 Respondents

One week after the fourth reminder, 412 individual surveys were completed. Many e-mail addresses (208) were removed from the sample due to delivery failures and automatic replies stating that the individual had left his position or was on a long leave of absence. Other individuals (149) communicated by email that they did not belong to the target population, and 214 individuals renounced participation. There may be a variety of reasons for non-participation, such as a high level of survey fatigue in the target group, a lack of interest in the survey topic, and the length and complexity of the questions [32]. It is unknown how many invitations were hampered by spam filters or how many individuals were invited to complete the survey that did not belong to the target population. A few respondents indicated that they were invited through more than one e-mail address. This may have happened to individuals both within and outside of the target population. Based on emails received from survey recipients, time pressure was the most common reason for active non-participation, including several people who referred directly to pressure from their companies to invoice all work-hours. One person could not complete the survey due to technical problems.

The 412 survey respondents makes this a smaller group of respondents than surveys among North-American architects and structural engineers [25, 26] but larger than that of a web-survey among Norwegian architects [33]. Contact details of the respondents of those surveys (which were conducted for different purposes than the current survey) were acquired through professional associations, which could not be done for our survey, increasing the uncertainty regarding the size of the population. Studies have found no significant differences between traditional mail-in questionnaires and web-based surveys regarding the response rates and socio-demographic make-up of respondents [34].

The majority of respondents (93%) worked with architecture, while the rest worked with structural engineering, building construction, project management or interior design. The mean age was 48 years, ranging from 25 to 74, and 68% were men. The mean age was lower among women (44 years) than among men (51 years). About half of the respondents had at least 20 years of work experience within the construction industry. A majority (68% of n=199) of those with 20 or more years of work experience within the construction industry were above 54 years of age, while 91% of those with less than 10 years of work experience (n=103) within the construction industry were 44 years of age or younger. Concerning company characteristics, 26% of the respondents worked at a micro-enterprise (1-9 employees), 42% at a small enterprise (10-49 employees), and 17% and 16% at a medium-sized or large enterprise, respectively (according to definition of size of companies provided by the European Union [35]). A large proportion of respondents (62%) were located in the metropolitan areas of Sweden (Stockholm, Gothenburg or Malmo region). Those respondents were on average younger and had fewer years of work experience than the rest. They were also more likely to work at a medium or large-sized enterprise than were the respondents of non-metropolitan areas. Regarding in which statistical regions (Southern, Eastern or Northern Sweden according to Nomenclature des Unités Territoriales Statistiques, NUTS1) the respondents worked (n=395), 24% reported to work in Southern Sweden, 37% in Eastern Sweden, and only 7% in Northern Sweden. A third (33%) of the respondents was involved in projects in more than one statistical region of Sweden.

2.2 Analysis

Respondents used a five-point Likert-type scale to rate how innovative (1=Not innovative at all, 5=Very innovative) the Swedish construction industry is in general. They then rated their agreement (1=Completely disagree, 5=Completely agree) to the influence of various hindrances to innovativeness (see aspects in Table 1) within the Swedish construction industry. The mean agreement was used to rank the hindrances in order of relevance. Wilcoxon ranks test ($p \leq 0.05$) detected whether the rating of the hindrances were significantly different. The test compared the ranking of successive pairs of decreasing mean values. A significant result for the first pair of mean values automatically renders the following mean value significantly different from the first one. Such a test is suitable for comparing rankings among the same group of respondents [36]. The questionnaire also included an open-ended question allowing 250 characters on what could facilitate the adoption of innovations in the Swedish construction industry. About 50% (n=203) of the respondents replied to this question. Responses were analysed on a qualitative basis through content analysis and search for recurrent themes.

Respondents then rated how innovative (1=Not innovative at all, 5=Very innovative) they found different frame systems (on-site and prefabricated steel, concrete, massive timber, glue-laminated wood, and light-weight wood) in multi-storey buildings. The mean ratings were used to evaluate the perceived relative innovativeness of the materials. The respondents also rated how they perceive different frame materials (steel, concrete, and wood) to perform (1=Very poor performance, 5=Very good performance) with regards to some hindrances to the general innovativeness of the Swedish construction industry (opportunity to support local industry, how proven the method of construction is, experience of contractors, easiness to find suppliers, level of marketing from suppliers, and easiness to find affiliations/construction partners). To understand the perceptions towards the use of steel, concrete and wood frames in multi-storey buildings, the respondents then rated the importance (1=Not taken into account at all, 5=Very much taken into account) of different aspects in the choice of frame material in a building of 3-8 floors, and the performance (1=Very poor performance, 5=Very good performance) of steel, concrete and wood frames with regards to those aspects (also analysed in [37]).

Cross-tabulations with Chi-square test for independence ($p \leq 0.05$) tested for the influence of age, gender, years of work experience within the construction industry, geographical location, and size of company, on the perceived innovativeness of the Swedish construction industry; perceived relevance of hindrances to the innovativeness of the Swedish construction industry; how innovative different frame materials were perceived to be; perceived performance of steel, concrete and wood frames with regards to hindrances to the innovativeness of the Swedish construction industry; and perceptions of steel, concrete and wood frames in multi-storey buildings.

3. Results

3.1 General innovativeness of the Swedish construction industry

The respondents perceived the Swedish construction industry as not very innovative, with 56% (of n=322) rating 1 or 2, and only 5% rating 4 or 5 on the Likert-type scale. Most influential hindrances to the diffusion of innovations in Swedish building construction were perceived as cost aspects (focus on project costs rather than life-cycle costs, the economic risk associated with innovations), followed by a focus on traditional drawing/calculation models and a tendency to use proven materials and methods (Table 1). The next highest agreements were to that contractors lack ability to adjust processes and established collaborations regarding specific materials and methods. Aspects related to the nature of buildings (e. g. the long life-time, the site-specific nature of construction and the uniqueness of each building project) were least agreed to as influencing the innovativeness of the Swedish construction industry.

Table 1 Mean agreement (1=Completely disagree, 5=Completely agree) with the relevance of indicated hindrances to the innovativeness of the Swedish construction industry, arranged in decreasing order.

Hindrances to innovativeness of the construction industry	n	Mean	Std. Error of Mean	Wilcoxon test [a]
The focus on project costs rather than life-cycle costs.	396	4.34	0.04	
The economic risk associated with innovations.	399	3.95	0.04	*
Building projects focus on traditional drawing-/calculation-models.	400	3.84	0.05	*
The construction industry uses proven materials and methods.	402	3.79	0.05	n. s.
Contractors lack the ability to adjust construction processes to innovations.	400	3.76	0.04	n. s.
Established actor collaborations based on specific materials and methods.	400	3.75	0.05	n. s.
Conventional contract forms.	400	3.69	0.05	n. s.
Construction clients lack of interest in innovations.	401	3.64	0.05	n. s.
The division of project phases prevents a comprehensive overview.	402	3.60	0.06	n. s.
Innovations are inefficiently marketed.	399	3.42	0.04	*
The lack of coordination and management of building projects.	401	3.40	0.05	n. s.
The temporary character of building projects leads to insufficient knowledge transfer.	399	3.25	0.05	*
Current standards and building codes	399	3.18	0.06	n. s.
Competition is deficient.	397	3.14	0.06	n. s.
Subcontractors are too small	400	3.06	0.06	n. s.
The long life-time of buildings makes it difficult to evaluate innovations.	399	2.82	0.06	*
The site-specific nature of building projects leads to insecurities and lack of routines.	396	2.57	0.05	*
The tendency to support local industries.	396	2.49	0.05	n. s.
The uniqueness of each building project.	402	2.23	0.05	*

[a] An asterisk indicates that the ranking of this factor is significantly different from the preceding one at $p \leq 0.05$, and *n. s*. indicates not significant.

There were regional as well as age and gender differences regarding perceived relevance of hindrances to the innovativeness of the Swedish construction industry. Younger respondents and those of fewer years of work experience within the construction industry perceived a greater relevance of the influence of a tendency to use proven materials and methods, established actor collaborations involving certain materials and methods, conventional contract forms, construction clients lacking interest in innovations, and current standards and building codes. Respondents of longer work experience within the construction industry as well as respondents not working in the metropolitan areas of Sweden perceived a greater relevance of sub-contractors being too small to be able to adopt innovations. Respondents not working in the metropolitan areas also gave a higher relevance to the uniqueness of each building project as a hindrance. Women and respondents working at larger enterprises gave less relevance to the uniqueness of each building projects than did men and respondents of smaller enterprises. Female respondents also gave less importance to the long life-time of buildings than did male, but greater importance to building projects' focus on traditional drawing/calculation models and that the lack of coordination and management of building projects hinders the adoption of innovations.

The responses to the open-ended question of how to improve the innovativeness of the Swedish construction industry covered several broad themes. The most frequently mentioned themes were cost aspects (mentioned in 59 replies). Common comments included the importance of life-cycle perspectives on costs and of creating incentives for construction clients and contractors to take the risk to try something new. Respondents argued that as long as building projects focus on short-term costs, few projects will take risks. Financial incentives such as subsidies for energy efficient or sustainable building were frequently mentioned as a means to move forward by sharing risks with actors outside the building project. The next most frequently mentioned category was cooperation (36 replies). According to these respondents, dialogue, open discussions, coordination and enhanced cooperation would lead to a better understanding of the viewpoints of different actors and contribute to a shift from the present 'narrow mindedness' to trans-disciplinary competence and better solutions. Most of these respondents mentioned cooperation between all actors of the building project, while some suggested the need for increased cooperation between the construction client and the architect and structural engineer. Other frequently mentioned factors were knowledge and time (20 and 16 replies, respectively). These respondents felt that better knowledge of sustainability is needed among the actors participating in the building project, as well as a better diffusion of knowledge and research results within the industry. In this vein, 14 respondents mentioned that research results should be better communicated. More time to analyse and consider different technologies and materials in the initial stages of the building project was also requested. Contract or procurement forms and regulations were mentioned to a lesser extent (12 and 13 replies, respectively). Contracts were mostly mentioned with regards to their present negative impact on cooperation, time, and costs; whereas regulation comments mostly argued that building codes are too stringent.

3.2 Perceptions of the use of wood frames in multi-storey buildings

Massive timber and glue-laminated wood were perceived as the most innovative frame materials, whereas concrete were perceived least innovative (Table 2). Although prefabricated options generally were perceived as more innovative than on-site constructed systems, the main material content seemed more important to how innovative the frame system was perceived to be. Respondents working in the metropolitan areas of Sweden perceived on-site concrete frames, on-site light-weight wood frames, on-site steel frames, and prefabricated steel frames as significantly less innovative, than did the rest of the respondents, while on-site massive timber was perceived as significantly more innovative in the metropolitan areas of Sweden. Older respondents perceived prefabricated concrete and prefabricated steel frames as more innovative than did younger ones. Women and respondents working at larger enterprises perceived on-site massive timber as more innovative than did men and respondents working at smaller enterprises.

Table 2 Mean rating of how innovative (1=Not innovative at all, 5=Very innovative) different frame systems are in 3-8 storied buildings, arranged in decreasing values.

Frame system	n	Mean	Std. Error of Mean
Prefabricated massive timber	369	3.58	0.05
On-site massive timber	374	3.55	0.05
Prefabricated glue-laminated wood	368	3.42	0.05
On-site glue-laminated wood	371	3.42	0.05
On-site steel	370	2.91	0.05
Prefabricated steel	366	2.88	0.05
Prefabricated lightweight wood	369	2.69	0.05
On-site lightweight wood	370	2.65	0.05
Prefabricated concrete	371	2.65	0.06
On-site concrete	373	2.63	0.06

The respondents rated concrete frames better than steel and wood with regards to several aspects influencing the innovativeness of the Swedish construction industry (Table 3). Wood was rated best regarding the opportunity to support local industry, but was given the poorest rating with regards to the rest. Men and older respondents gave a better rating of wood with regards to the opportunity to support local industries, while those with longer years of work experience perceived wood to as better regarding easiness to find suppliers, than did the rest of the respondents. Respondents working in Northern Sweden perceived it easier to find affiliations regarding wood frames than did the respondents working in other regions or across Sweden.

Table 3 Mean perceived performance (1=Very poor performance, 5=Very good performance) of concrete, steel, and wood frames with regards to aspects influencing the innovativeness of the Swedish construction industry.

Aspects	Mean (n) Concrete	Mean (n) Steel	Mean (n) Wood
How proven the construction method is	4.43 (339)	4.05 (336)	3.11 (332)
Contractors' experience	4.22 (311)	3.75 (306)	2.90 (311)
Easiness to find affiliations/construction partners	4.05 (278)	3.70 (268)	3.18 (267)
Level of marketing from suppliers	3.49 (284)	3.23 (280)	3.14 (278)
Easiness to find suppliers	4.04 (307)	3.75 (296)	3.29 (297)
Opportunity to support local industry	3.37 (275)	2.86 (267)	3.58 (274)

Most important aspects when choosing frame material for buildings of 3-8 floors were perceived as project costs, fire safety, construction time, vertical and horizontal stability, sound insulation and acoustics, and energy efficiency of the building. In general, *engineering aspects* (such as fire safety, sound insulation, and stability) were perceived to be of great importance whereas *environmental aspects* (such as climate impact, energy use during construction and recycling of leftover materials from the building site) were perceived to be of less importance.

Table 4 Likert-type scale (1=Very poor, 5=Very good) mean values of the perceived performance of concrete, steel, and wood frames in relation to different aspects in the choice of frame material, arranged in decreasing order of importance.

Aspects	Mean (n) Concrete	Mean (n) Steel	Mean (n) Wood
Project costs	3.75 (260)	3.46 (251)	3.74 (238)
Fire safety	4.68 (368)	3.06 (355)	3.44 (351)
Construction time	3.72 (327)	4.13 (317)	3.81 (295)
Sound insulation and acoustics	4.40 (367)	3.01 (341)	3.39 (347)
Vertical stability	4.60 (304)	4.40 (297)	3.89 (281)
Horizontal stability	4.51 (297)	4.15 (287)	3.75 (272)
Energy efficiency of the building	4.03 (302)	3.33 (287)	4.03 (289)
Work environment	3.18 (275)	3.54 (266)	4.11 (273)
Durability	4.43 (328)	4.00 (319)	3.69 (302)
Transports	2.98 (252)	3.55 (247)	3.75 (248)
The building's design and aesthetics	4.02 (366)	4.27 (363)	4.16 (360)
Climate impact	3.52 (291)	3.21 (286)	4.07 (292)
Requests by users/The buildings flexibility	4.16 (361)	4.36 (358)	4.29 (349)
Sustainable development	3.19 (317)	3.18 (313)	4.26 (316)
Energy use during construction	3.08 (240)	3.13 (238)	3.97 (239)
Easiness to recycle materials	2.34 (326)	3.84 (326)	4.09 (324)
Easiness to renovate/demolish building	2.75 (331)	3.73 (327)	4.24 (325)

On average, the performance of concrete was most positively rated with regards to the engineering aspects, but poorly rated with regards to environmental aspects (Table 4). Wood was rated best performance with regards to environmental aspects. Wood and concrete were equally rated with regards to costs of the building project, construction time and energy efficiency of the building. The perceived performance of steel, concrete, and wood frames varied with age, respondents' geographical location, and gender. Men, older respondents and those with longer work experience within the construction industry perceived steel to perform better with regards to costs, energy efficiency, climate impact, and sustainable development, and concrete to perform better with regards to climate impact, than did women and the younger ones. Older respondents of longer work experience also perceived steel and concrete to perform better regarding the work environment and energy use during construction. They also rated steel better with regards to easiness to renovate/demolish the building. Moreover, those of longer years of work experience perceived steel to perform better with regards to fire safety and sound insulation and acoustics than did those of fewer years of work experience within the construction industry, and older respondents perceived steel and concrete to perform better with regards to transports than did younger ones. Respondents working in non-metropolitan areas perceived steel to perform better with regards to sound insulation and acoustics and energy efficiency than did the metropolitan ones. Women perceived wood to perform better with regards to sound insulation and acoustics, durability, and recycling, than did men. Older respondents and respondents from smaller enterprises perceived wood to perform better with regards to fire safety, than did respondents of lower age and larger enterprises.

4. Discussion

The mean age of the responding architects correspond to that among working architects in Sweden [38]. But due to the uncertainties regarding the studied population the results of this survey may not be representative for architects working with multi-storey buildings in Sweden at large. Still, the results give empirical evidence to and strengthen the conclusions of previous qualitative studies further.

The Swedish construction industry was perceived to be of low innovativeness. A similar assessment has been expressed in several studies (see e.g. [13, 27, 39]). Cost aspects were perceived as most important to the innovativeness of the Swedish construction industry and were also most frequently mentioned in the open-ended answers as to how innovativeness can be improved. The importance of costs have been emphasised in several studies (see [12, 14, 17, 40]) and was also found important in the choice of frame material. Several other aspects perceived as relevant to the innovativeness of the Swedish construction industry are related to costs [14, 28, 41]. For instance, the industry's tendency to use proven materials and technologies, acknowledged by the responding architects, is likely related to resulting ease of cost prediction [41] and the perceived financial risk of adopting something new [17, 29]. The architects' suggestions on how to overcome the costs issue included governmental subsidies and economic instruments making a life-cycle perspective more attractive. Similar measures have been suggested by UNEP [17]. Conventional contract forms and construction clients' lack of interest in adopting innovations were also perceived as a relevant hindrance to the innovativeness of the Swedish construction industry. Relating to this, better communication between the actors of the building project and more knowledge and time to evaluate different options were mentioned by the respondents as means to facilitate innovativeness. This has also been suggested by Blayse and Manley [27]. Such things are generally governed in the contract form, which is decided on by the construction client. That respondents not working in the metropolitan areas perceived the smallness of subcontractors and uniqueness of building projects as more important to the innovativeness of the Swedish construction industry may indicate such problems are stronger perceived in areas where the range of companies involved in building construction may be smaller.

Regarding frame materials, the respondents perceived wood frames as innovative, indicating that general hindrances to the innovativeness of the Swedish construction industry may apply to the diffusion of multi-storey wood frames. However, in line with studies not finding any significant cost differences depending on choice of frame material [42], concrete and wood were perceived as equally good with regards to costs. Thus, although costs may be important to the diffusion of innovations within the construction industry in general, it seems not perceived as an important hindrance to the diffusion of multi-storey wood frames. However, as concrete and steel was perceived as more proven materials than wood in multi-storey buildings and also as superior to wood with regards to contractors' experience, easiness to find affiliations/construction partners, the level of marketing from suppliers, and easiness to find suppliers, such aspects may indeed constitute hindrances to the diffusion of multi-storey wood frames.

Even though any tendency to support local industries was not perceived as a hindrance to the innovativeness of the Swedish construction industry, the regional differences with regards to the opportunity to support local industries may be significant to the adoption of multi-storey wood frames. The opportunity to support local industry through the use of wood was rated better in the non-metropolitan areas of Sweden than in the Stockholm, Gothenburg and Malmo region. Also, respondents in the North perceived it as easier to find affiliations/construction partners to build with wood frames, than did the rest. This may relate to that several suppliers of multi-storey wood frames, e .g Lindbäcks bygg and Martinssons trä, are located in northern Sweden. Also, the initial Swedish multi-storey wood building projects were located in non-metropolitan areas [43] with a closer relationship to forestry. It may also indicate a stronger tradition of using concrete in urban areas.

From the results of this survey it cannot be discerned whether that respondents in the metropolitan areas perceived wood as more innovative relate to e.g. a lesser use, or an increased discussion, of use of wood frames in urban areas. However, as older respondents perceived prefabricated concrete and steel as more innovative than younger, it seems perceived innovativeness of frame material may relate to years of work experience within the construction industry. Also, as younger respondents perceived a greater relevance of several hindrances to the innovativeness of the Swedish construction industry, they may perceive more of a need for change.

Regarding perceived performance of frame materials in multi-storey buildings, and relating to how proven the methods of construction were perceived to be, the perceptions were most favourable towards concrete frames with regards to the most important aspects of the choice of frame material. Should perceptions of wood be more positive with regards to engineering aspects, or were environmental aspects of greater importance in the choice of frame material, the decision to adopt wood frames might be easier. Such a shift may be accomplished through promotion of good examples of multi-storey wood frames and through consumer demand or policies encouraging greater importance of environmental aspects in construction projects. However, older respondents, who were more likely to have longer work experience and be male than the rest of the respondents, had more positive perceptions of steel and concrete frames, than did women and younger respondents, who tended to be more positive towards wood. Hence, such changes may already be happening.

5. Conclusion

The architects perceived the Swedish construction industry as not very innovative and seem to attribute it mostly to a short-term focus on costs and a tradition of using proven materials and methods. Wood frames were perceived as more innovative than steel and concrete frames, in particular in the metropolitan areas of Sweden. With the exception of costs, several general hindrances to the adoption of innovations in the Swedish construction industry seem to apply to the diffusion of multi-storey wood frames. Apart from the possibility to support local industry, current circumstances and perceptions seem to favour the use of concrete and steel, rather than wood. However, perceptions seem more favourable among younger architects than among those of longer work experience, indicating a shift towards more favourable conditions for the adoption of innovations, and the use of wood, in multi-storey construction.

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