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Use of wood products in multi-storey residential buildings: views of Swedish actors and suggested measures for an increased use

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\textbf{ABSTRACT}

Many studies have shown that wooden buildings in general have a lower climate impact than buildings built of conventional materials such as concrete and steel. In Sweden, however, only about 10% of the multi-dwelling buildings are built with timber frames. The goal of this empirical study is to provide a broad picture of the views of Swedish actors regarding the use of wood products in multi-storey residential buildings and suggest measures for an increased use. A questionnaire concerning the use of wood products in construction was sent out to Swedish developers, main contractors, and architects and 100 answers were received. The study shows that the views of the groups of actors differ in some respects and factors that may either facilitate or be obstacles to an increased use of wood products were identified and discussed.

\textbf{Introduction}

In Sweden, it is highly important to focus on the material production area to decrease emissions from the construction and property sector. The construction and property sector in Sweden is annually responsible for about 22 million tons of greenhouse gas emissions, including emissions from imported construction materials (Boverket 2016). The domestic part of these emissions is responsible for almost 20% of the total greenhouse gas emissions in the country, and the construction and property sector is thus one of the sectors that needs to make changes in order to reach the Swedish government’s goal of having zero net emissions of greenhouse gases to the atmosphere by 2045 (Government Offices of Sweden 2017). About one third of the annual emissions from this sector originate from the heating of buildings, and two thirds from the construction of new buildings and renovation (Boverket 2016). During construction, the main factor responsible for the emissions is the material production (Liljenström et al. 2015).

To a greater degree using wood products instead of the conventional materials could be one key part of the solution to decrease the climate impact of buildings. About 90% of the multi-dwellings in Sweden are constructed with concrete frames (TMF n.d.) and in these buildings the concrete is responsible for about 50% of the climate impact of the building components (Liljenström et al. 2015). One strategy to decrease the climate impact is to use a material with less climate impact instead of the conventional concrete. Engineered wood products (EWPs) such as cross-laminated timber (CLT) and laminated veneer lumber (LVL) have proven to be a successful alternative (Börjesson and Gustavsson 2000, Nässén et al. 2012, Guo et al. 2017, Lu et al. 2017, The et al. 2017, Mantanis et al. 2018). The selection of insulation material has also proven important in order to reduce the climate impact (Liljenström et al. 2015) and in this application as well, replacing glass wool, polystyrene, polyurethane, or rock wool by wood-based insulation material has been shown to have the potential to decrease the climate impact (Schiavoni et al. 2016, Hill et al. 2018). Overall, after reviewing various LCA studies, Asdrubali et al. (2017) come to the conclusion that wooden buildings in general cause lower environmental impacts than conventional buildings.

If a decreased climate impact from residential buildings is to be achieved by increasingly substituting conventional materials with wood products, creating an understanding of the market for wood products is vital. Several studies have contributed to this understanding by studying Swedish market conditions (Kadefors 1995, Roos et al. 2010, Hemström et al. 2011, Hemström et al. 2017, Lindgren and Emmitt 2017, Thiger et al. 2017, Markström et al. 2018), market conditions in several countries including Sweden (Tykkä et al. 2010, Mahapatra et al. 2012, Hurmekoski et al. 2015) and markets in other countries than Sweden (e.g. Bysheim and Nyrud 2009, Riala and Ilola 2014, Mallo and Espinoza 2015). These studies have together covered topics related to institutional structures, innovation diffusion, barriers and drivers of adoption, influence of regulations, and perceptions of architects, structural engineers, and contractors. However, the main focus has been on frame materials and views and perceptions of architects. In Sweden, architects have some influence over...
material selection but developers and contractors are perceived to have more influence in general (Roos et al. 2010, Hemström et al. 2011, Markström et al. 2018).

The aim of the present empirical study was to obtain a broad picture of the views of Swedish actors regarding the use of wood products in multi-storey residential buildings, focusing on differences and similarities between the three groups of actors, and from this information identify and discuss factors that may either facilitate or be obstacles to an increased use of wood products in such buildings. In order to achieve this goal, the following specific objectives were proposed: (i) to estimate the relative influence of the actors over material selection in multi-storey residential building projects, (ii) to learn the material preferences of the actors in multi-storey residential buildings and their attitudes towards using wood products in these projects, (iii) to estimate the level of awareness and experience of wood products, (iv) to identify the main reasons why wood products are selected or not selected, (v) to identify the main hindrances for the use of wood products in multi-storey residential buildings, and (vi) to assess the intended future use of wood products and the support for measures with a potential to contribute to a more extensive use of wood products.

Literature review

The construction industry in Sweden

During 1965 to 1975, large investments in new builds were made due to the housing shortage in the mid-1960, but then the investments decreased until mid-1980 when they started to increase again (BI 2015). In the beginning of the 1990s, changes in the fiscal policy led to impaired conditions for residential construction. This, in combination with a depression, again led to a decreased housing demand. During the beginning of the twenty-first century, the demand of new housing started to increase yet again but the development was disrupted in 2008 due to a financial crisis and a new depression. In year 2013, an increase could again be seen, mainly for multi-apartment dwellings (three or more apartments). In year 2016, more than 42,000 apartments were built and 73% of those were in multi-apartment dwellings (SCB 2017).

Of the low-rise housing (one or two storeys) in Sweden, about 90% have timber frames, often pre-fabricated off-site (Swedish Wood n.d.). For multi-storey buildings, there was a ban to build in wood between 1874 and 1994. When the ban was lifted it was replaced with function-based requirements regarding fire safety. With the use of e.g. sprinklers and fireproofing treatments, it is possible for high-rise timber buildings to meet the requirements. The majority of multi-dwellings are, however, still constructed with concrete frames. Between year 2007 and 2015, one can roughly say that 90% of the multi-dwellings were built with concrete frames and 10% with timber frames (TMF n.d.).

Technical information

The favourable strength-to-weight ratio of wood makes it an ideal material for tall buildings and the low self-weight compared to that of concrete means that the costs of transport and foundation work are lower (Asdrubali et al. 2017). Timber buildings are faster to build than concrete buildings and they give rise to less waste on the building site. Since timber buildings are light-weight constructions, the question of lateral stability is however especially important (Kuzman and Sandberg 2017). For timber buildings of 6–7 storeys it is thus common practice to build the ground floor in concrete and to secure the timber structure to it.

In general, EWP for load-bearing purposes have better material properties and a better structural performance than sawn timber (Asdrubali et al. 2017). To add bracing and shear strength to the timber frame, wood-based panels (e.g. plywood, particleboard, OSB, fibreboard) can be used. Such panels can also provide acoustic and thermal insulation functions or be used for finishers such as parquet floors and internal coatings (Table 1). In Sweden, the EWP primarily used in timber construction range from laminated solid wood to various wood-based composites (Kuzman and Sandberg 2017). Modified wood is another type of wood product, and these materials can be used as e.g. cladding.

One technical difficulty in the construction of multi-storey timber buildings is fire protection (Kuzman and Sandberg 2017). Wood has good fire-resistant properties compared to e.g. steel, and the collapse of timber structures due to fire is not very common (Asdrubali et al. 2017). One way of dealing with fire performance is to assume a rate at which timber chars and then use timber with a large enough cross-section to withstand fire for a certain time (Ramage et al. 2017). Smaller cross sections of timber can be covered with a layer of non-flammable material such as gypsum or inorganic-bonded panels to ensure encapsulation of fire, and the use of sprinklers can also reduce the risk for occupants and are especially recommended in multi-storey timber buildings (Asdrubali et al. 2017, Östman et al. 2017, Ramage et al. 2017). Problems include the variability of fire performance of gypsum plasterboards (standards are currently under development), the lack of statistical information on the fire performance of large and high timber buildings,

<table>
<thead>
<tr>
<th>Product</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLT (glued-laminated timber)</td>
<td>Beams, columns, trusses</td>
</tr>
<tr>
<td>CLT (cross-laminated timber)</td>
<td>Walls, flooring, roofing</td>
</tr>
<tr>
<td>LVL (laminated veneer lumber)</td>
<td>Beams, columns, trusses etc.</td>
</tr>
<tr>
<td>LSL/PSL (laminated/parallel strand lumber)</td>
<td>Beams, columns</td>
</tr>
<tr>
<td>WPC (wood-plastic composites)</td>
<td>Cladding, decking</td>
</tr>
<tr>
<td>TMT (thermally modified timber)</td>
<td>Cladding, decking</td>
</tr>
<tr>
<td>Furfurylated wood</td>
<td>Cladding, decking (light) civil works, joinery</td>
</tr>
<tr>
<td>Acetylated wood</td>
<td>Structural sheeting</td>
</tr>
<tr>
<td>Plywood</td>
<td>Flooring, ceiling and wind-shield, infill</td>
</tr>
<tr>
<td>LDF/MDF/HDF (low-/medium-/high- density fibreboard)</td>
<td>Thermal insulation and sound proofing</td>
</tr>
<tr>
<td>OSB (oriented strand board)</td>
<td>Structural sheeting and decking, i-joint web</td>
</tr>
<tr>
<td>Particleboard</td>
<td>Flooring, ceiling and panel infill</td>
</tr>
<tr>
<td>WFI (wood fibre insulation board)</td>
<td>Thermal and acoustic insulation</td>
</tr>
<tr>
<td>Sandwich panels</td>
<td>Structural/non-structural components with thermal and acoustic insulation properties</td>
</tr>
</tbody>
</table>

uncertainties regarding charring rates of EWPs, and the influence of timber cladding on the spreading of exterior fire (Östman et al. 2017).

If they are properly designed and maintained timber buildings can last for centuries (Asdrubali et al. 2017). The durability of timber building elements against microbiological attack is however, strictly dependent on the moisture level in the elements over time (Mahnert and Hundhausen 2018). Changes in moisture content can cause withdrawal and swelling/shrinkage, and this can in turn lead to cracks or warping of the wooden elements, and too high relative humidity in the surroundings may lead to mould growth on wooden surfaces. External timber structures and timber frames in glass walls thus need extra attention in the design and selection of wood type (sapwood, heartwood, species etc.), and coverings, overhangs, ventilation, and wind and vapour barriers are important factors to consider. Modified wood, such as acetylated or thermally modified timber, has a greater durability against microbiological attack and a greater dimensional stability than untreated wood and is estimated to have a long design life, e.g. about 80 years for acetylated wood (Bongers et al. 2010). For wooden exterior cladding materials, there is, however, a need to further study the cost of maintenance throughout the life cycle (Kuzman and Sandberg 2017).

The sound insulation properties of low-density wood species are not particularly good, since the wood is a lightweight material and acoustic insulation properties are highly related to density. The control of sound insulation by separate frames and sounds barriers is contrary to the principle of achieving structural rigidity (reinforcement, joints, and continuous structures) and it may thus be a challenge (Asdrubali et al. 2017). Multi-layered constructions with porous materials and air gaps behind the board or panelling can usually provide a sufficient level of sound insulation and, by increasing the mass of the flooring construction, the low-frequency footstep insulation can be improved, but a suspended ceiling may be necessary to fulfil the normative restrictions. Insulation against noise transmission in timber buildings is, however, an area which requires further research to ensure a high-quality living environment (Kuzman and Sandberg 2017).

Industrial prefabrication with wood-based products has the potential to improve the productivity, quality, and environmental performance of construction (Hurmaekoski et al. 2015). The use of pre-fabricated building modules is cheaper than building on-site, partly due to substantial time savings at the construction site, and it is becoming more common for multi-storey buildings (Kuzman and Sandberg 2017). Other advantages are less transport, less disruption of neighbours to the construction site, and good cost control. There is still a need, however, for further developing the pre-fabrication, e.g. by integrating installations to a greater extent.

Empirical work done so far

When it comes to wood-frame multi-storey construction, the established construction practice is based on concrete and masonry and this creates institutional lock-ins (Roos et al. 2010, Hurmekoski et al. 2015, Hemström et al. 2017). At lager contracting firms, decisions on building materials are made at top corporate level which means that individual practitioners may have limited impact (Roos et al. 2010). Most of the professionals who specify products have a preference for products with which they are familiar, especially in projects where time is highly prioritised (Emmitt and Yeomans 2008, Lindgren and Emmitt 2017). Previous experience, in terms of amount and whether it has been positive or negative, affect product choice to a great extent (Emmitt and Yeomans 2008, Byenheim and Nyrud 2009, Mallo and Espinoza 2015). Construction professionals in Sweden have earlier been reported to have negative perceptions regarding engineering properties of wood (Mahapatra et al. 2012) but Swedish architects have in general been found to have a positive attitude to and show a large interest towards timber frames in multi-storey buildings (Hemström et al. 2011). The positive attitude is mainly due to the environmental performance of timber frames but the architects’ attitudes towards concrete and steel are, however, even more positive. Although considered as a conservative branch of industry, there is a scope for gradual improvements in the construction industry (Thiger et al. 2017).

Construction cost (Tykkä et al. 2010) or total life cycle costs (Riala and Illola 2014) tend to be a key determinant for the choice of building material and construction technology. LCC-studies indicate that, when constructing multi-storey residential buildings in the Nordic countries, there are small differences in price between buildings with wooden frames and buildings with concrete frames (Eriksson 1995, Gustafsson 1998, Nässén et al. 2012, Pal et al. 2017). Studies in other countries indicate that construction with timber could be up to three times cheaper (Hossain et al. 2015, Lu et al. 2017). One important barrier for the selection of wood products is the perception that wood products involve higher costs due to a more frequent maintenance and/or shorter life cycles (Riala and Illola 2014). Architects’ are not in general as price-focused as other stakeholders and aesthetics of the product is instead a selection criterion of great importance for them (Emmitt and Yeomans 2008).

In the context of increasing the use of wood products in multi-storey buildings, attitudes towards wood use, uptake of environmental policies, standardisation and regulation, and risk allocation and financial arrangements has all been identified as key drivers to change (Hurmaekoski et al. 2015). Environmental concerns, legislative compliance, and political decisions have also been recognised as drivers by others (Tykkä et al. 2010, Lindgren and Emmitt 2017). Barriers are e.g. deficient knowledge (Roos et al. 2010, Tykkä et al. 2010).

Method

This study is a continuation of a previous study published by Markström et al. (2018) about the perception of EWPs by Swedish architects. To gather the data needed to fulfil the objectives of the project, an online questionnaire was sent to Swedish firms within the architectural, construction, and real estate sectors. Online questionnaires are a low cost approach often used in market research, but they often
have the disadvantage of low response rates, a 10–15% response rate being normal (Sue and Ritter 2007, Lavrakas 2008). The QuestionPro software was used to design the questionnaire, distribute the survey, and collect responses.

Sample frame and survey implementation

The target population was architects, developers, and main contractors involved in the construction of multi-storey residential buildings in Sweden. Delimitation to firms with 10 or more employees was made for architectural firms and to firms with 20 or more employees for construction and real estate firms. An online business directory was used to prepare a list of architectural firms, construction firms, and real estate firms in Sweden that fulfil the above conditions. The firms on the lists were checked and those that were certainly not involved in the construction of multi-storey residential buildings were removed. This left 109 architectural firms, 294 construction firms, and 275 firms within real estate, i.e. a total of 678 firms. A distribution list was then created including one or several e-mail addresses for each company, depending on company size and available contact information. When possible, e-mail addresses to specific employees with a position in line with the target population were used. Otherwise, a general e-mail address to the company was used.

In all, the questionnaire was sent to 1,154 respondents in November 2017, and three reminder e-mails was sent to those participants who had not returned the questionnaire, one week, two weeks, and three weeks after the initial e-mail. Of the respondents, 65 notified that they were not available during the survey period (due to sick leave, parental leave, or job change) or that they did not have experience during the survey period (due to sick leave, parental leave, or job change) or that they did not have experience of multi-storey residential buildings and a total of 100 useable responses were received which gave an adjusted response rate of 9%.

Survey questionnaire

In the survey design, findings in previous studies of the market for wood products, the theory of planned behaviour (Ajzen 1985), and innovation diffusion (Rogers 2003) has provided guidance and inspiration. The questionnaire contained 26 questions of which eight concerned demographics. The following topics were addressed: 1) role in the building process and experience with multi-storey residential building projects, 2) material preferences, 3) influence over material selection and use of wood products, 4) experience of specific wood products, 5) reasons for selecting or not selecting wood products, 6) obstacles to using wood products, 7) attitude towards using wood products and future use, 8) measures that could increase the use of wood products, and 9) company and individual demographics. The questionnaire was sent to two researchers to assess clarity and relevance, one with expertise of questionnaire design and implementation as well as of the architectural profession, and one with expertise regarding wood products and timber construction. A final version of the questionnaire was developed based on the feedback received.

The materials included in the survey are those presented in Table 1. CLT, GLT, LVL, and PSL/LSL were given as examples of frame materials; WPC, TMT, acetylated and furfurylated wood as examples of cladding materials; WFI, and sandwich panels as insulation materials; and plywood, LDF/MDF/HDF, particleboard and OSB as surface materials. As a whole group, these materials are hereafter referred to as wood products.

Data analysis

The respondents were split into three groups based on their typical role in the building projects; developer, main contractor, and architect. Frequency analysis was used and charts and tables were calculated to display similarities and differences among the groups of respondents. Pearsons’ chi-square test was then used to determine if the differences seen were statistically significant or not. The significance level used was \( p \leq 0.05 \).

To estimate which the main factors preventing the use of wood products are, a score for each factor included in the study was calculated:

\[
S_j = \sum_{j=1}^{N} x_{ij} \ast y_j
\]

where

\( S_j = \) score for factor \( i \) \( (i = \{1, 2, 3, \ldots 26\}) \), \( x_{ij} = 1 \) if respondent \( j \) \( (j = \{1, 2, 3 \ldots N\}) \), \( N \) = number of respondents) selected factor \( i \) as a hindrance and 0 if not, \( y = \) the importance of the category factor \( i \) belongs to according to respondent \( j \) \( (y = \{1, 2, 3, \ldots 5\}) \).

Each score was normalised (by dividing it with the sum of the scores for all 26 factors and multiplying it with 100) so that a total of 100 points was divided between the 26 factors included.

The equation follows the principle of the Fishbein attitude model (Ajzen and Fishbein 1980) with the difference that one factor (attribute) at a time among several respondents are considered instead of several attributes among one respondent at a time.

Limitations

The target populations were actors with experience of multi-storey residential buildings, regardless of their experience of wood products. One limitation of the study is that actors with no experience of building multi-storey residential buildings with timber constructions or with no interest in these types of buildings may hesitate to answer, thus giving rise to a non-response bias. In an attempt to avoid such bias, it was stated in the invitation that answers were valuable regardless of what experience the respondents had of wood products. This could, however, have been more clearly stated, since a few of the respondents said that they did not match the target population since they had no experience of timber constructions in multi-storey buildings. After e-mail correspondence, most of them answered the questionnaire. This gives an indication that there were probably more respondents who misinterpreted the target population.
Another limitation is that it is not possible to calculate the response rate with certainty since it is improbable that all the respondents absent during the survey period or without experience of multi-storey residential buildings have notified this. Nor are any statistics of how many architects, developers and main contractors are involved with multi-storey residential buildings available. It is thus difficult to estimate the confidence level and margin of errors. Further, the sample frame excluded small firms which may have different views. The results must thus be generalised with caution.

To reduce the interview bias, both the design and the order of the questions has been carefully considered. The researchers are, however, aware of and have not tried to hide the fact that one goal of the study is to identify and discuss factors that may facilitate or hinder an increased use of wood products. In that respect, the study is in favour of wood and there is thus a risk that the respondents’ answers, unintentionally, reflects that. This is not seen as a major issue since the focus has been on differences between groups of respondents but it is still important to keep in mind when interpreting the results.

Even after careful survey design and test implementation, there is always a risk that the questions are interpreted differently and that technical problems may arise preventing some respondents from being able to complete the questionnaire.

Results with comments

Firstly a description of the respondents is presented and secondly a summary of the results structured in accordance with the objectives of the project.

Respondents

The developers were roughly half of the respondents and the main contractors and architects each represented a quarter of the total (Table 2). The average ages of the respondents in the different groups were similar and in all the groups there were more men than women.

Of the 21 counties in Sweden, 18 were represented in one or more of the groups (Table 2). Compared with the share of new building projects in Sweden in 2016, there is an indication that Stockholm County may be under-represented and that the counties Västra Götaland, Västerbotten, and Norrbotten may be somewhat over-represented (Figure 1).

The sizes of the companies where the respondents work varied, as well as the respondents’ experience of projects where residential buildings with three or more storeys have been built (Figure 2) and the share of those projects where wood products have been used (Figure 3).

i) Influence over material selection

The respondents were asked to rate their influence over material selection in residential building projects with three

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**Table 2. Description of the groups of respondents.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of respondents</th>
<th>Age range; average</th>
<th>Gender distribution</th>
<th>Counties* represented (in total 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developers</td>
<td>49</td>
<td>28–71; 47</td>
<td>82/16/2</td>
<td>16</td>
</tr>
<tr>
<td>Main contractors</td>
<td>28</td>
<td>29–65; 45</td>
<td>89/11/0</td>
<td>14</td>
</tr>
<tr>
<td>Architects</td>
<td>23</td>
<td>33–73; 49</td>
<td>61/35/4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>28–73; 47</td>
<td>79/19/2</td>
<td>18</td>
</tr>
</tbody>
</table>

*See Figure 1.

---

**Figure 1.** Distribution of new building projects in Sweden in 2016 (left) and geographical location (county) of the respondents (right). T = total no. of respondents, D = developers, M = main contractors, and A = architects.

---

**Figure 2.** Distribution of projects where multi-storey residential buildings have been built.
or more storeys (Figure 4). Significant differences regarding influences between actors were found:

- Frame: developers have most influence; main contractors second most influence; and architects least influence.
- Cladding: developers and architects have more influence than main contractors.
- Insulation: main contractors and developers have more influence than architects.

Figure 2. Size of the companies where the respondents work (left) and respondents experience of residential buildings with three or more storeys (right).

Figure 3. Share of residential building projects [%] with three or more storeys where wood products have been used as frame, cladding, insulation, or surface layer.

Figure 4. Influence over material selection in residential buildings with three or more storeys; 1 = no influence, 5 = great influence.
Surface layers: developers and architects have more influence than main contractors.

ii) Material preferences and attitudes

The respondents were asked to rank the three materials which they generally prefer as frame, cladding, and insulation in residential buildings with three storeys or more. The first and second choices are seen in Figure 5. The differences seen regarding preferences for timber and concrete frames as well as for cladding materials for first choice are significant. This implies that architects more often and developers least often, have timber as first choice in those two applications compared with the other two groups. For insulation materials, a similar analysis were not possible to conduct since too few respondents ranked another option than mineral wool as their preferred choice.

The results above are strengthened by the fact that, when asked directly about their attitude towards using wood products in different applications, the architects were in general the group with the most positive attitude (Figure 6):

- The architects were more positive than the other two groups to the use of wood products as cladding (statistically significant).
- The architects were more positive than the main contractors to the use of wood products as frame, insulation, and surface layer (statistically significant).

The stated attitudes to the use of wood products as frame, cladding, insulation and surface layer are mainly positive or neutral, but there is also a non negligible share of respondents with a negative attitude towards the use of wood products in these applications. Surface layer, which is the only indoor application, is the application fewest stated a negative attitude to (statistically significant).

iii) The level of awareness and experience of wood products

The respondents were asked to rate their experience on a scale ranging from one (no experience) to five (substantial experience), and the averages within the different groups were quite similar in the range of 2.5–2.9 (Figure 7). In
general, the respondents perceive that they have little or some experience of wood products. No significant differences regarding amount of experience were found between the groups.

The majority are aware of the existence of the wood products included in the study, except for PSL/LSL, furfurylated and acetylated wood, where about half of the respondents had not earlier heard about them (Figure 8). The shares which have used the products vary greatly (3–92%), but the majority (>75%) have used GLT and different types of sheet materials (plywood, LDF/MDF/HDF, PB, and OSB). In general, the respondents that have used wood products have had positive experiences. When comparing the groups of actors, negative experiences were more frequently stated among developers than among the other two groups (statistically significant). This indicates that the troubles arise mainly during the operational phase of the building.

Two examples with high shares of negative experience among the respondents who have used the material are furfurylated wood and acetylated wood, where all of the developers who have used these materials — although only a few of the total — have had negative experiences. The architects
who have used them have all had a positive experience. The share of negative experiences among the respondents who have used thermally modified timber (17%) is also worth mentioning, where it is again mainly developers who have had negative experiences (about a third of those who have used the material). None of the architects and only a few of the main contractors have had any negative experience of thermally modified timber. A fifth of the respondents who have used PSL and/or LSL have also had negative experience and again, it is mainly the developers (about a third of those who have used the material). Another observation is that it is only the developers who have had a negative experience with CLT (16% of those who have used the material). About 50–60% of the respondents in each group (a total of 58 respondents) have had at least one negative experience with wood products, and they were asked to explain in what way the experience was negative. Among the developers, maintenance and renovation needs were most frequently mentioned, whereas the architects mostly mentioned appearance (Figure 9). The answers among the main contractors were more diverse, but the two reasons most frequently mentioned were that the appearance changed with time and that the product did not work for the intended application.

iv) Reasons not to select wood products

The respondents who said they had heard of at least one of the mentioned wood products but not yet used them (in total 96 respondents), were asked what were the main reasons (maximum three) why the materials had not yet been selected. Lack of knowledge and information was in the top three in all groups (Figure 10). This reflects the respondents’ estimation of their own knowledge of wood products which was that only a small share had substantial knowledge (Figure 11).

That the material selection is not (only) the respondents to make, uncertainties regarding quality over time, that there has not yet been a need for the products, and too much maintenance are all important reasons for one or two of the groups (Figure 10). A noticeable share of the developers and main contractors also mention risks connected to mould and moisture, and that the material is too expensive as reasons why the materials have not yet been selected. Difficulties fulfilling fire requirements are perceived to be similar within all the groups, but it is mainly the main contractors who also perceive difficulties in fulfilling acoustic requirements.

iv) Reasons for selecting wood products

When asked about the main reasons (maximum three) for selecting wood products, the architects most frequently mentioned aesthetic appeal followed by low climate impact, and common practice (Figure 12). The first two are also the main reasons for selection by the developers, together with the best option from a financial point of view. Among the main contractors, however, customer demand was by far the most frequently mentioned reason followed by common practice and best option from a financial point of view. The other reasons were mentioned with more or less the same frequency.

Figure 10. Reasons why some wood products have not yet have been selected. The main three reasons in each group are encircled.
Note: it was possible to select up to three reasons.

Figure 11. Respondents’ knowledge of wood products: 1 = no knowledge, 5 = substantial knowledge. y-axis = proportion of respondents [%].
frequency within the three groups. The main reasons for selecting wood products are thus: aesthetic appeal, low climate impact, common practice, best option from a financial point of view, and customer demand.

Official strategies for timber construction were mentioned as a main reason why wood products were selected by 20–25% of the respondents in each group (Figure 13), and this indicates that these strategies, at least to some extent, fulfill their purpose. Roughly, one third of the respondents (33%) work in a municipality which has such a strategy, one third in a municipality which does not (28%), and one third (39%) are uncertain whether the municipality has a strategy for timber construction or not.

When asked about their views of the strategies, almost half of the respondents had no opinion (Figure 13). Of those who had an opinion, the architects are those who are most positive about the strategies (statistically significant), where the majority state that the strategies contribute to an increased use of wood products, and only a few that the strategies give an unfair competitive advantage or that the strategies have the wrong focus to increase the use of wood.

The respondents were also asked for their opinion regarding decreasing the climate impact of buildings and most of the respondents consider that the focus should be not on any specific material but instead on materials with a low climate impact in general (Table 3). Nevertheless, more than half of the respondents consider that an increased use of wood products and other bio-based products is important in order to decrease the climate impact of buildings and hardly anyone believed there is no need to focus on the climate impact of building materials.

Table 3. Respondents’ opinions about decreasing the climate impact of buildings. D = developers, M = main contractors, A = architects.

<table>
<thead>
<tr>
<th>Opinions</th>
<th>D</th>
<th>M</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is important to increase the use of wood products and other bio-based products in order to decrease the climate impact of buildings</td>
<td>53%</td>
<td>50%</td>
<td>74%</td>
</tr>
<tr>
<td>To decrease the climate impact of buildings, the focus should be on materials with low climate impact in general – not on any specific group of materials</td>
<td>73%</td>
<td>64%</td>
<td>61%</td>
</tr>
<tr>
<td>There is no need to focus on the climate impact of buildings</td>
<td>0%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Neither of the alternatives correspond with my opinion</td>
<td>6%</td>
<td>4%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: multiple answers were possible.
v) Factors hindering the use of wood products

On average, the architects mentioned more hindrances to the use of wood products than the others (9 compared with 6–7). All the architects and about 70% of the rest of the respondents think that conservative forces and a culture of building with other materials hinder the use of wood products (Figure 14). The majority of the architects and of the developers also think that concerns about moisture and/or a short life span hinder their use.

Laws and regulations is another hindrance that about 60% of the respondents in each group mention, and lack of technical knowledge or training is also frequently mentioned, especially among the architects who also frequently mention insufficient information regarding costs. That the use of wood products is associated with financial risks is something that half of the developers see as a hinder. Negative perceptions are perceived as a hindrance by many of the architects but by fewer of the respondents in the other two groups. This is not surprising since the architects in general have a more positive attitude towards the use of wood products.

On average, the respondents have similar views on the importance of the four groups of factors that could prevent the use of wood products (Figure 15).

When the results presented in Figures 14 and 15 are combined (Equation (1)), an indication of the relative importance of the factors is obtained (Figure 16) assuming the simplification that all factors indicated as hindrances within a category by a respondent are of the same importance. The most important factors among main contractors were: 1) conservative forces and a culture of building with other materials, 2) laws and regulations, and 3) lack of technical knowledge or training. The first and third factors mentioned are main factors among the architects. All three factors plus two factors additional – concerns about moisture and/or short life span, and concerns about financial risks – are main factors among the developers.

vi) Future use of wood products

Few of the respondents think that they, in five years’ time, will suggest or advocate the use of wood products to a lesser extent than today, and a noticeable share of the respondents
think that they will suggest or advocate their use to a greater extent than today for all applications (frame, cladding, insulation, surface layer) (Figure 17). As mentioned in the limitations of the study, one has to keep in mind the risk of interview bias in this case.

Significant differences between actors were found regarding cladding; a larger proportion of the architects (compared with the other two groups) think that they will suggest or advocate the use of timber cladding to a greater extent within five years’ time, and a larger proportion of the developers think that they will suggest or advocate wood products to a lesser extent.

vi) Measures with a potential to increase the use of wood products

At the end of the questionnaire, the respondents were asked to indicate which, if any, of the suggested measures with a potential to contribute to a more extensive use of wood products they would like to see implemented. One measure that the Swedish government is considering to introduce is a requirement to report the estimated climate impact of buildings from a life-cycle perspective (Näringsdepartementet 2017). This suggestion seems to be supported by the architects but less by the developers and main contractors (significant difference between the support by architects and the others) (Figure 18).

Most of the architects would also like to see more demonstration projects, whereas the other two groups of actors do not appear interested in such projects (Figure 18). The measures that most developers would like to see are instead related to product development regarding moisture resistance, fire and acoustics performance, service-life, and pre-fabrication. These types of product development are frequently mentioned among all respondents, but among the contractors and architects the majority would also like training on how to construct with wood products. About half of the architects and main contractors would also like more information about material properties, and many of the architects feel that there is a need to develop tools and guides for designing with wood products.

Discussion

This study provides a broad picture of the views of 100 Swedish actors regarding the use of wood products in
multi-storey residential buildings. Important to remember is that small firms (less than 10 employees for architectural firms and less than 20 for construction and real estate firms) were excluded from this study and their views may thus be somewhat different. Due to the difficulties to estimate the confidence level and margin of errors, the results should be generalised with caution and therefore, the results should be seen as indications about the general views and could be used as a foundation and inspiration for further studies in the area of the use of wood products in buildings. What strengthen the results is that they to a large extent complement earlier findings.

On the basis of the results, a few factors that may affect an increased use of wood products in multi-storey residential buildings have been identified. These factors are discussed below.

Factors that may facilitate an increased use of wood products in buildings

Incentives to select materials with a low climate impact

It is encouraging that, of the measures connected to climate impact included in this study, the measure that the Swedish government is considering (requirement to report the climate impact of buildings) received the greatest support. Nevertheless, most of the respondents do not seem to be ready for a measure that limits the allowed climate impact of a building, which may be the next step in the government’s strategy. Higher credits for low climate impact materials in environmental certifications for building have a greater support. It is not surprising that the non-compulsory instruments are the ones that receive greater support among the respondents.

In an increasing number of Swedish municipalities there are official strategies for timber construction. This study indicate a need to investigate how these strategies could be improved to better facilitate an increased use of wood products since an unneglectable share of the respondents is of the opinion that the strategies have the wrong focus to fulfil their purpose. The results further indicate that, if the main purpose of the strategies is to decrease the climate impact, most of the respondents in this study consider that the focus should be not on any specific material but instead on materials with a low climate impact in general. Such a switch of focus could lead to an increased support for the strategies from the actors and also has the potential to better complement the possible introduction of requirements to report a building’s climate impact. To focus on materials with low climate impact in general, instead of specific materials, is in line with earlier research that has shown that performance-based and material-neutral regulations and standards are more effective. A careful definition of what is meant by “low-climate-impact materials” is in that case needed and there is also a risk that such a change could lead to a weaker support for wood products.

Training and information

Training in how to construct with wood products together with more information about the material properties and costs seems to be promising measures, since this tackles one of the main hindrances – lack of technical knowledge or training – and the study also indicate that a relatively large proportion of the respondents want such measures. To provide accurate information about maintenance needs and product life-spans, especially to developers, is of importance in order to tackle the current uncertainties about the quality over time of some of the wood products.

Research and investigations of how such training and information can best be provided and further incorporated into the vocational educations are thus of importance.
**Product development**

Laws and regulations, regarding e.g. fire and acoustic performance are seen to be a major hindrance among the developers and main contractors, but not among half of these respondents, as well as the architects, would like product developments with regards to moisture resistance, fire performance, acoustic performance, and increased service life. A noticeable share of the respondents also mention risks related to mould and moisture, and difficulties in fulfilling fire requirements as reasons why some wood products have not yet been selected in any project. Earlier studies have also identified the need for further research regarding fire protection and sound insulation (Kuzman and Sandberg 2017, Östman et al. 2017), and a lot of research and development is being directed towards increasing the durability of wood with different treatments, see e.g. (Candelier et al. 2016).

**Economic incentives**

Financial aspects are mentioned relatively frequently among the developers and the main contractors, both as a reason for selecting wood products and as a reason for not doing so. This goes in line with earlier findings that, for these actors price is an important factor when selecting materials (Emmitt and Yeomans 2008, Tykkä et al. 2010). The economic gains or losses as a result of using wood products differ of course between products and are dependent on what product is being replaced. Unfortunately, this study gives no clear answers regarding which materials are perceived to be good options from an economic point of view and which are not. It can however be concluded that an increase in the possibility of using pre-fabricated products could affect the economic incentive to select wood products, and it is a measure that a large proportion of the respondents wish to see implemented. It is also an area of research and development where a need for improvements has been identified (Kuzman and Sandberg 2017).

**Factors that may be obstacles to an increased use of wood products in buildings**

**Mismatch in influence and material preferences**

A mismatch regarding material preferences and influence over material selection when it comes to increasing the use of wood products as frame material has been identified. This since developers are those who have the greatest influence over the selection of frame material, and at the same time are those who are least in favour of using timber as a material in frames. Architects on the other hand, have the least influence but the strongest preference for timber frames. The mismatch is reflected in the main reasons for not selecting wood products, since “I want to use them but it is not (only) my decision” enters the top three reasons among architects and main contractors, but not among developers.

**Conflict of interest**

Developers and architects both have a relatively great influence over the selection of cladding material but the results indicate that their preferences for using wood products as cladding differ. In general, architects have a positive attitude and the tendency is that they want to increase their use of wood products in this application. The same does not apply for developers. Signals given are instead that developers hesitate to use wood products as cladding, mainly due to issues connected to maintenance and renovation needs. Further research and monitoring of maintenance needs and costs are thus of importance.

**Bad experience of wood products**

When a product is relatively new to the market, even a few setbacks could solidify a negative attitude, which may result in never reaching the critical mass of adopters (Hurmekoski et al. 2015). Negative experiences could thus create an aversion of using the products and such an aversion may prove difficult to overcome. In general, the respondents in the study who have used wood products have had positive experiences. Of those who have had negative experiences with one or several of the wood products included in the study, the majority are developers, which indicates that the troubles arise mainly during the operational phase of the building. More maintenance and a shorter life span than expected are the two major problems mentioned by the developers. A more detailed study about experiences of certain wood products is thus of interests to provide the wood product industry and the research community with more precise feedback on problem areas.

**Factors that may not prove to be as effective as expected**

**Demonstration projects**

According to the results, an increase in the number of demonstration projects does not seem to be the best way to increase the use of wood products in Sweden since it is mainly architects who favour such projects, and they already prefer wood products to a greater extent than the other actors. Within the research community, however, demonstration projects have been identified as vital to show the various actors the technical and business potential of wood products (Kuzman and Sandberg 2017). That the main contractors and developers in this study generally does not ask for more demonstration projects could mean that they already think that there are enough of such projects for residential buildings or that they think that other measures are of greater importance. It would thus be of interest to further investigate the role of demonstration projects when it comes to increasing the use of wood products in buildings.

**Conclusions**

The empirical study has provided a broad picture of the views of Swedish actors regarding the use of wood products in multi-storey residential buildings by answering a number of questions.

The conclusions are that the views of the groups of actors differ in some respects and that introducing further incentives to select materials with a low climate impact, training in how
to construct with wood products together with more information about the material properties and costs (e.g. maintenance needs and product life spans), product development (e.g. fire protection and acoustic insulation), and further economic incentives (e.g. increased possibilities to use prefabricated elements) all are measures that will facilitate an increased use of wood products in multi-storey residential buildings in Sweden.

Factors that are considered to constitute obstacles to an increased use are: mismatch in influence and material preference (regarding frame material), conflict of interest (regarding cladding material), and bad experiences of wood products.

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