ABSTRACT: This study is intended to contribute to the understanding of the probability that bio-based materials are chosen in residential buildings and to the understanding of the drivers and barriers for an increased use of bio-based building materials. For this purpose, semi-structured interviews were held with Swedish architects and contractors. The results indicate a low probability of selection of bio-based materials in Swedish residential building, mainly due to insufficient incentives, lack of knowledge and experience, bad examples, issues regarding performance and construction-related culture and habit. However, the attitude among contractors has started to change in a more positive direction. Green building certificates, as well as other environmental standards and regulations, were seen as a promising way to increase the use of bio-based materials. Evidence that the materials maintain a certain quality over time was also identified as an important measure to increase the incentives to select bio-based materials.

KEYWORDS: Construction industry, stakeholder perception, green building, diffusion of innovations

1 INTRODUCTION

The building sector accounts for about 40% of the energy use in Europe [1], uses more than 50% of the extracted materials [2], and is responsible for about a third of the water use and a third of the generation of waste [3]. Over the past years, the regulatory framework regarding these factors has become more stringent, on both a local and a national level [4]. This development is expected to continue during the coming decades.

The total energy use and climate impact of a building depends to a great extent on the amount of energy used during operation and on the environmental performance of that energy [5-6]. There are existing policies promoting energy efficiency and renewable energy use in buildings [2] and much research has been carried out in order to improve the energy-efficiency of buildings as well as to shift towards a more sustainable energy mix [7-8]. As these efforts are paying off, the production phase is starting to become a more significant feature of a building’s total energy use and climate impact [6, 9-10]. It has been shown that although the use phase is generally responsible for the largest share of a building’s environmental impact, the construction phase can reach a 50% share in some cases [11]. The EU has also recognized this and identified buildings as a key sector in The Roadmap to a Resource Efficient Europe [2]. This stresses the importance of implementing policies that promote resource efficiency and it mentions sustainable materials as one important aspect, together with waste recycling and improved design. For example, Finland has planned to include such requirements in their construction regulations in 2017 [4]. To further reduce energy use, the energy-intensity of materials is an important attribute to consider [9]. Bio-based materials are in this context of interest because it has been shown that the embodied energy in a building can quite easily be reduced by about 20% by material substitution to include a larger share of bio-based materials [6, 12]. Thus, it is of interest to consider ways to increase the proportion of bio-based materials used in buildings.

The European Standard EN 16575:2014 defines bio-based products as “a product wholly or partly derived from biomass” (p.5) and a product is defined as a “substance, mixture of substances, material or object resulting from a production process” (p.6). This definition is adopted in this article.

According to the theory of planned behaviour (TPB), the probability of a person acting in a certain way, e.g. choosing to use a bio-based material, is dependent on that individual’s attitude towards the behaviour, subjective...
norms, and perceived behavioural control [13]. Earlier, Norwegian architects’ use of wood as a structural material has been analysed based on the TPB [14] and the theory has also been used as a conceptual framework to investigate Swedish architects’ and structural engineers’ perceptions of structural timber in multi-storey construction [15]. Other studies regarding perception towards wood frame multi-storey constructions have also been reported (see [4] for an overview). Attitudes, subjective norms and perceived behavioural control of other bio-based building materials are under-represented and to the authors’ knowledge there are currently no studies that cover the three aspects of TPB for bio-based building materials in general. The present study is intended to contribute to the understanding of the probability that bio-based materials are chosen in residential buildings and to the understanding of drivers and barriers for an increased use of bio-based building materials.

2 THEORETICAL FRAMEWORK

2.1 THEORY OF PLANNED BEHAVIOUR

In the theory of planned behaviour (TPB), a person’s intention to behave in a certain manner together with perceived behavioural control can be used to predict or, as in this study, describe the expected behaviour (Figure 1) [12]. If the perceived behavioural control is equal to actual control, the expected behaviour reflects the actual behaviour. The intention to behave in a certain manner is dependent on the attitude towards trying and on subjective norms with regard to trying.

![Diagram of TPB](Image)

**Figure 1: Schematic view of parameters that influence expected behaviour based on the theory of planned behaviour (TPB) [14].**

According to the theory, the attitude towards a certain behaviour depends both on the attitude towards a successful performance and on the attitude towards a failed attempt, weighted according to the respective probabilities of these events. The subjective norm for a certain behaviour depends on the subjective norm regarding successful performance of the behaviour and on the probability of success as perceived by important others. The behavioural control depends on the level of control of both internal and external factors that may influence the execution of the action. Factors influencing behavioural control are e.g. past experience, knowledge, skills, presence of time, and opportunities.

In construction, it has been found that attitude and perceived behaviour control, but not subjective norm, influenced Norwegian architects’ intentions to use wood with statistical significance [14]. Perceived behavioural control was shown to have a greater impact than the attitude. Further, previous experience, which influences the perceived behavioural control, has been shown to impact the product decision to a great extent in construction [14, 16-17]. In the following sections, literature reports on the three aspects in TPB regarding bio-based materials are presented in more detail.

2.1.1 Attitude

Attitudes towards the use of wood have been shown to vary between building types and applications [18]. Wood is more popular in interior applications than in structural applications and in buildings that have historically often been made of wood. Swedish architects generally have a positive attitude towards using timber frames in multi-storey buildings but their attitudes towards both concrete and steel are more favourable [19]. Their positive perceptions of wood are related mainly to the environmental performance of the material. However, environmental performance was considered less important than many other aspects where concrete and steel was perceived to perform better than wood. Contractors have been shown to have a negative attitude towards using timber in construction, mainly due to established experience with concrete [15]. The major building companies are identified as the primary opponents of timber construction and they often select concrete by default. The perceived performance regarding stability, durability, fire safety, and sound transmission among actors in the construction industry needs to improve in order for wood to become a more attractive choice [15, 19].

2.1.2 Subjective norm

Positive norms regarding the use of timber in Swedish construction are that working with timber is seen to be inspiring and interesting [15]. Negative is that experience of working with timber is not perceived to positively influence the careers of architects and engineers within construction and that there is a culture of building in concrete.

2.2 Perceived behavioural control

Swedish architects have been identified as often having a significant influence in the selection of material for the façade [20]. However, their influence in the selection of structural materials is limited, in contrast to that of main contractors and public authorities, which are both considered to have a higher level of impact [15, 19]. In some building companies, policy directives regulate which frame material that should be used. In these cases, the decision regarding the material to select lies in the hands of
managers and economists at the top corporate level. Developers, who are in general both risk-averse and negative towards the use of timber, are also considered to have a high impact on the selection of structural material. Structural engineers have been identified to have a low impact level but to have a greater impact than architects. Timber material suppliers and end-users are also considered to have a low impact level.

Knowledge and education regarding timber construction in Sweden has been identified as being insufficient [15]. Further, insecure wood supply and insufficient support from suppliers regarding the use of wood in construction has been identified as contributing negatively to the perceived behavioural control.

2.3 INNOVATION THEORIES

To select a “green” product is in general considered to represent a change in behaviour by contractors and designers [16]. Bio-based materials could thus often be seen to be innovations according to Rogers’ [21, p.12] definition: “An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption”. Findings in the innovation literature are therefore of relevance to this study.

The innovation decision process consists of five main steps: knowledge, persuasion, decision, implementation and confirmation [21]. The knowledge step is the point where an awareness of an innovation and some understanding of its functions are gained. The next step, persuasion, occurs when an attitude toward the innovation is formed. The decision step involves activities leading to either adoption or rejection of the innovation and in the following step, implementation, it is put into use. In the final step, confirmation, reinforcement of the decision made is sought.

The characteristics of an innovation that influence the rate of adoption are also described in the theory. Innovations that are perceived to have greater relative advantages, compatibility, trialability, and observability and less complexity are adopted more rapidly than other innovations.

2.3.1 Drivers and barriers

Customers are seen as some of the most important actors for inducing Swedish contractors to incorporate innovations [22]. Hindrances for renewal are insufficient experience feedback, lack of time, and lack of financial resources. The latter two create a short-term and price-focused perspective that hampers the possibility of introducing new materials. One significant driver for change in the construction industry is perceived inefficiencies in current practice [23].

Barriers for the use of wood in construction that have been identified in the literature are that concrete is chosen by default and that there is a lack of incentive to choose something else, perceived higher maintenance costs, concerns about performance and durability, and codes, even though the fire regulations have changed for the better [20, 24]. Identified drivers are fast, dry, and quieter construction, better wellbeing of workers, and possibilities the possibility of pre-fabrication.

As with other innovations, new wood-based materials almost certainly need to be cheaper than the conventional alternatives, or must provide additional value to the product, since there is otherwise no interest within the industry to pay a premium [15]. Internalizing the external cost of greenhouse gas emissions, overcoming prejudices, and allocating risks between actors are other important factors to reach a successful diffusion, mentioned in the context of timber multi-storey buildings [4].

In the context of bio-based materials, obstacles for specifying “green” and low carbon are also of interest. Identified barriers regarding the specification of recycled products are a lack of information regarding available materials and products as well as of technical information and guidance, unfamiliarity, difficulties in locating suppliers and obtaining a reliable supply, lack of accreditation, and lack of time [25]. Further, the products are often perceived to a quality inferior to that of conventional options, the products are also often more expensive than conventional options, and clients are unlikely to pay a premium price. Drivers for the diffusion of green building technologies and materials are public policies and incentives [15, 26].

The main barriers to specifying low carbon building materials are the perception of its high cost, institutional culture, the conservative nature of clients, concerns about durability, lack of established standards, and low availability of materials [26]. Low availability mainly applies to reclaimed materials. Drivers for selecting low carbon materials are that actors feel morally obligated to choose materials with low impact, and requirements from clients. Regulations limiting the embodied carbon in a construction, reductions in material cost, and more information about material performance and design have been identified as important future drivers.

3 METHOD

The methodological approach rests on the theory of planned behaviour (TPB) [13] and on innovation theories [21]. TPB is used to evaluate the probability that bio-based materials will be selected and innovation theories are used as tools to interpret the results. Since the focus of the study is on capturing attitudes, perceptions and decision-making processes, a qualitative approach with semi-structured interviews was used.

3.1 INTERVIEWS

Swedish architects and contractors were selected for the interviews since they have been identified to have a large
impact on the selection respectively of façade materials and structural materials [15, 19-20]. Purposive sampling among Swedish architectural firms and contractors was used in the selection of respondents. The study targeted larger firms and also aimed at a geographical spread. Thus, the firms were selected based on size and geographical location. Four contractors and four architectural firms were selected and within these firms respondents were selected based on their experience of residential buildings. During the sampling, attention was also given to the respondent’s years of experience, gender, and background in order to get a spread among these parameters to better capture different viewpoints and information [28].

One of the architects is an expert on passive houses (architect 4), and one of the contractor representatives is a specialist in the area of energy and buildings and works specifically with green building certificates (contractor 2). Another contractor started as a construction worker but now has a role as project manager (contractor 4), and two have managerial roles of which one is a graduate engineer (contractor 1) and the other started as a carpenter (contractor 3). Of the architects, one has a managerial role and also a further education in wood engineering (architect 1). The distribution of gender and years of experience in the construction industry among the respondents is shown in Table 1. Within residential buildings, all the respondents mainly had experience of apartment buildings, although some also had experience of detached houses.

Table 1: Description of the interview group, regarding experience in the construction industry and gender.

<table>
<thead>
<tr>
<th>Category</th>
<th>Years of experience</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 10</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td>3</td>
</tr>
<tr>
<td>Architect</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Contractor</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

An interview guide was developed prior to the interviews which included a number of themes and relevant thematic questions coupled to each theme (Table 2).

Table 2: Interview guide.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Thematic questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention: attitude and subjective norm</td>
<td>Attitude towards bio-based materials.</td>
</tr>
<tr>
<td></td>
<td>Attitude towards innovations.</td>
</tr>
<tr>
<td></td>
<td>Career effects of knowledge and experience of bio-based materials.</td>
</tr>
<tr>
<td>Perceived behavioral control</td>
<td>Actors’ possibilities to impact the material selection in residential buildings.</td>
</tr>
<tr>
<td></td>
<td>Knowledge and experience of bio-based materials.</td>
</tr>
<tr>
<td>Drivers and barriers</td>
<td>Barriers regarding the use of bio-based materials.</td>
</tr>
<tr>
<td></td>
<td>Drivers regarding the use of bio-based materials.</td>
</tr>
</tbody>
</table>

The themes and the thematic questions cover the aspects of the TPB and seek to give a picture of the probability that bio-based materials are selected. To identify possible ways of increasing this probability, questions regarding drivers and barriers for an increased use of bio-based materials in residential buildings were included.

Three of the interviews were held face-to-face at the respondent’s office and the rest were conducted via telephone. The duration of the interviews was between 40 and 75 minutes. All the interviews were recorded and then transcribed. Each transcription was summarized and sent to the respondent for correction in order to strengthen the validity, as suggested in the literature [28]. In one case, a respondent made minor changes to the text.

3.2 ANALYSIS

During the analysis, the five phases commonly used in qualitative research were followed: compiling, disassembling, reassembling, interpreting, and concluding [28]. Sentences and phrases from the interviews were given labels and then they were sorted in categories. The data under each category was compared and interpreted, first for all respondents individually and then collectively, after which conclusions could be drawn. Before the disassembling, all the transcriptions and the summaries were read through several times.

4 RESULTS

Below, the results are presented for each thematic question followed by a summary of the results in Table 3.

4.1 ATTITUDE TOWARDS BIO-BASED MATERIALS

The attitude towards bio-based materials in the Swedish construction industry was perceived very differently by the contractors; from slightly negative because the materials are associated with low durability and moisture-related problems to a neutral or curious attitude. One architect described the attitude in the construction industry as sceptical but also mentioned that an interest is beginning to arise, albeit small at the moment. One of the contractors had also noticed an increasing interest in selecting bio-based materials and has initiated a dialog with a supplier of wooden framework systems. Another contractor company has begun to increase the use of wood in some projects. Further, two architects felt that the attitude towards bio-based materials is positive within their profession: “Everyone loves wood, so it is very popular.” (Architect 4)

All the architects also mentioned that their own views of bio-based materials are in general positive. Aspects mentioned were mainly connected to wood: living material, giving warmth, provides positive and good feelings, and possible to maintain. Other positive aspects mentioned were that most people can work with and use these materials, and that one does not get dirty when using
them. In addition, half the architects questioned stated that they do not connect any negative aspects to bio-based materials. Although, some negative aspects were mentioned by one of them as well as by the other two architects: i.e. that materials made of pulp lack character, unsuccessful earlier attempts to introduce the materials, clear-felled areas, and materials that mould.

In general, the contractors interviewed thought that bio-based materials are less harmful to the environment than other materials, a view shared with the architects, but only one contractor expressed positive associations towards bio-based materials. This particular respondent work with green building certification and did not connect any negative aspects with bio-based materials. The other contractors mentioned that bio-based materials are regarded as involving a risk because they are not tested, expressed doubts regarding compatibility with other groups of materials, viewed these materials as less durable and more sensitive to moisture, and connected them to trouble in fulfilling requirements regarding fire safety and acoustics.

Although the general view regarding the environmental performance of bio-based materials was positive, the majority of the respondents stated that they either had too little information to be able to judge the environmental performance or that many aspects need to be taken into consideration before one could make such a statement. However, both an increased internal and an increased external focus on environmental issues were identified. Harmful substances, energy consumption during the use-phase, and the residential environment are issues currently in focus.

### 4.2 ATTITUDE TOWARDS INNOVATIONS

All the respondents described the construction industry as conservative and more or less reluctant to introduce new materials and methods, mainly due to earlier bad experiences: “We test the new products directly on a full scale. […] For that reason, the industry has experienced large-scale failures and I believe that’s the reason why we are a bit conservative when it comes to new materials.” (Contractor 1)

Among the architects, three stated that they could consider being the first to try a new material whereas only one contractor stated the same. The fourth architect believes that one should be sceptical towards new materials and the other contractors would prefer that someone else tried them first. Uncertainties regarding quality over time are seen as a major risk and the contractors connect this with the warranty period they pledge and thus see a financial risk: “… most of our financial losses have been due to measures made during the warranty period. If we can avoid such measures by choosing materials of good quality, we have won a lot both financially and with regard to our trademark.” (Contractor 4)

### 4.3 CAREER EFFECTS

The majority of the respondents believe that knowledge and experience of bio-based materials is something that is valued within the construction industry nowadays, at least to some extent. Awards for wooden buildings are mentioned by one architect as one contributing factor for the increased interest.

### 4.4 POSSIBILITIES TO IMPACT MATERIAL SELECTION

The perceived possibilities to impact the material selection depend on the type of contract, on the point in time when the actor becomes involved, and on the application. In general, the architects felt that they could influence the exterior (mainly the façade) and not the frame and other materials inside the walls. The architects with longer experience expressed a greater potential to influence the material selection than the less experienced. The contractors felt that they, together with building engineers, had a large influence on the selection of frame material. With regard to the interior, both groups felt that it is the developer who has the greatest impact. Further, it is not unusual that contractors and developers have policy directives regarding what materials to use in certain applications and also contracts with certain suppliers.

Regarding the perceived possibility of influencing the amount of bio-based materials used in residential buildings, the architects had different views; some stating that architects could be key actors in increasing the use and others stating that their ability to have an influence was low compared with that of the contractors. The perceived level of influence corresponds to the perceived possibility of influencing the material selection. The contractors felt that they could influence the amount of bio-based materials used.

### 4.5 KNOWLEDGE AND EXPERIENCE

The knowledge of bio-based materials in the Swedish construction industry was considered to be low by all respondents. However, the views about whether this also applies to traditional wood products are divided. One respondent thought that the construction industry has a good knowledge of traditional wood products, whereas another respondent said that the knowledge of wood in general reaches only a basic level. These statements were strengthened by the fact that all respondents found it more or less difficult to remember examples of bio-based materials of which they had experience: “Wooden frames and bio-based sheet materials for cladding […] but then I actually have trouble coming up with something else right now.” (Contractor 3)

### 4.6 BARRIERS

One barrier identified is the existence and propagation of bad examples: “One barrier is that the examples that are
Lack of knowledge among both graduate engineers and architects as to how and where to use bio-based materials margins they are reluctant to incorporate new materials and explained that since the contractors have small profit is a barrier mentioned by two architects. One of them the respondent mentioned that many of the contractors have interests in other materials and thus have low incentives to change. One of the contractors agreed with that they are conservative but also emphasized that one reason to stick to a system, e.g. to a certain frame material, is to be able to streamline the use: “If one chooses a system, one would like to be faithful to it in order to become better at it. If we choose to use different frames in our buildings we will not gain feedback regarding what was good and what can be improved the next time. [...] One wants to become really good at something, not good at everything.” (Contractor 3)

Difficulties in fulfilling acoustic requirements were mentioned as a barrier by one contractor. A barrier mentioned by two architects was that bio-based materials are not marketed to the same extent as other materials: “I think it would be good if those who want to market wood materials did it in a clearer way and showed more examples. It doesn’t have to be extraordinary examples, it can be ordinary examples. Most materials are used ordinarily.” (Architect 3) However, the architect with most experience and knowledge about wood stated that wood construction is made visible to a great extent.

4.7 DRIVERS

The incentives for choosing bio-based materials are in general regarded as low by the respondents; three did not experience any incentives at the moment and another three saw green building certifications as a direct or indirect incentive to some extent. The other two respondents stated that the local strategies for timber construction exhibited by some municipal authorities act as an incentive.

Further, environmental impact is considered to be a criterion compared with selection criteria such as cost, durability, quality, availability, buildability, maintenance, aesthetics, moisture, and fire safety. However, in projects were green building certificate systems are implemented, there is an increased scope for environmental considerations and also a willingness to pay a premium, to some extent, if that is what it takes to fulfill the requirements, as long as quality over time is ensured. An increased interest in building certificate systems within residential buildings was noticed. Developers are perceived to have a positive attitude towards these systems, whereas constructors, and also to some extent architects, express a more negative attitude: “When they [certification requirements] are combined with requirements regarding acoustics and fire and with demands from the developer, it results in an inferior and enormously more expensive product.” (Contractor 1)

Nevertheless, all but one of the contractors state that the incentives to increase the use of bio-based materials would increase if these materials were highly valued in green building certifications systems: “None of the systems [green building certifications] says that you get a credit if e.g. 25% of all building materials are bio-based. The day such a credit exists we will work towards finding bio-based alternatives in our projects.” (Contractor 2)

The remaining contractor, as well as two of the architects, mentioned that demands and regulations regarding environmental issues could increase the use of bio-based materials: “There are no real requirements yet regarding that [climate impact of materials]. One could almost hope that such requirements will come, as we are interested in wood and think of it as a good material. [...] Standards and regulations have a large impact.” (Architect 1)

Increased knowledge of bio-based materials, an increased discussion about these materials and better access to information about them are mentioned as ways to improve the incentives by all architects and one of the contractors: “If I knew of more [bio-based] products that could solve my problems, or what to call them, then maybe I would choose them to a greater extent.” (Architect 2)

Two contractors and one architect stated that the advantages of bio-based alternatives must be highlighted; the advantages both for the customers and for the project.
Two of the contractors mentioned that one must prove that the bio-based alternatives are more cost-effective than the conventional ones or at least constitute a profitable option.

Half the respondents in both groups stress the importance of proving that the materials maintain a certain quality over time. The two contractors think that more research in this area would increase the industry’s incentive to choose more bio-based materials. Five of the respondents also request product and process development to increase the number of materials to choose from, to reduce the need for maintenance, to increase the durability, to improve the fire resistance, and to be able to get modified wood at a cheaper price and claddings with improved properties. Further, customer demand was mentioned as a driver by two contractors.

Table 2: Summary of the results.

<table>
<thead>
<tr>
<th>Intention</th>
<th>Architects</th>
<th>Contractors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitudes towards bio-based materials</strong></td>
<td>Positive Perceived a sceptical attitude within the construction industry but also noticed an increased interest</td>
<td>Mixed Indications of increased interest of selecting bio-based materials</td>
</tr>
<tr>
<td><strong>Attitudes towards innovations</strong></td>
<td>The industry is reluctant to introduce innovations, mainly due to earlier bad experience Uncertainties regarding quality over time are seen as one major risk</td>
<td>Most of the architects can consider being the first to try an innovation Most of contractors preferred that someone else first try an innovation</td>
</tr>
<tr>
<td><strong>Career effects</strong></td>
<td>Knowledge and experience of bio-based materials is valued within the construction industry to some extent</td>
<td>Knowledge and experience of bio-based materials is valued within the construction industry to some extent</td>
</tr>
<tr>
<td><strong>Possibilities to impact material selection</strong></td>
<td>Developers are perceived to have the greatest impact regarding the interior Can influence the exterior Mixed opinions regarding possibilities of influencing the amount of bio-based materials used</td>
<td>Large influence on the selection of frame material Perceived that they can impact the amount of bio-based materials used</td>
</tr>
<tr>
<td><strong>Knowledge and experience</strong></td>
<td>Knowledge of bio-based materials in the industry is regarded as low Indications of limited experience with bio-based materials</td>
<td>Knowledge of bio-based materials in the industry is regarded as low Indications of limited experience with bio-based materials</td>
</tr>
<tr>
<td><strong>Drivers and barriers</strong></td>
<td>Currently weak drivers; green building certification to some extent and local strategies for wood construction in some municipalities Important future drivers: • Stronger incentives in green building certification • Demands and regulations regarding environmental issues • Evidence that the materials maintain a certain quality over time • Increased knowledge of bio-based materials, an increased discussion about these materials and better access to information about them • Highlight relative advantages • Product and process development</td>
<td>Important future drivers: • Client demands • Proof of cost-effectiveness</td>
</tr>
<tr>
<td><strong>Drivers</strong></td>
<td>Low incentives for choosing bio-based materials Existence and propagation of bad examples Fire requirements Conservative industry</td>
<td>Want to streamline the use of currently used systems Acoustic requirements</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Lack of knowledge among building engineers and architects Insufficient marketing of bio-based materials</td>
<td></td>
</tr>
</tbody>
</table>
5 DISCUSSION

5.1 INTENTION
The attitude towards bio-based materials, where architects express a positive attitude and contractors a somewhat negative attitude, was found to be similar to the attitudes towards using structural timber described in the literature [15, 19]. However, the results indicate that the attitude among contractors has begun to change in a more positive direction. This can be explained by the identified increasing interest in environmental and sustainability issues and the increasing focus of society on shifting towards a bioeconomy. The easing of regulations regarding the use of timber in multi-storey buildings may also be a part of the explanation. A change regarding career effects is also indicated, since most of the respondents believe that knowledge and experience of bio-based materials is something that is valued within the construction industry nowadays, but which was not the case some years ago.

The general reluctance to introduce innovations in the construction industry negatively influenced the respondents’ intentions of using bio-based materials, since many of these materials are thought of as new. However, it seems that architects are more open towards innovations, since they may perceive lower risks of potential failure than the contractors, who must take into consideration warranty pledges and financial risks.

The major risk identified in the introduction of innovations was the concern of quality over time. Thus, it is crucial to prove quality by implementing the materials in pilot projects or in small-scale buildings in order to be able to use them as reference projects as well as to develop research methods where the durability can be simulated and evaluated relatively quickly with high accuracy. In this way, the perceived probability of failure could be lowered. Ways of sharing risks between actors could be an important measure to positively influence the attitude towards potential failure and thus increase the selection of bio-based materials.

When relating the results to innovation theories [21], it can be argued that some materials have gone through the implementation step but then failed in the confirmation step due to quality issues. These bad examples have also had a negative impact on the persuasion step, contributing to the circulation of bad rumours. Examples of successful use, and the spread of information about these, are thus crucial to positively influence the perceived probability of successful implementation. Emphasize and provide information about the relative advantages of using bio-based materials was also identified as a possible measure to increase the probability of bio-based materials being selected, which is a result that agrees with the innovation theories. Information about compatibility with other materials is also an area that could be improved in order to increase the probability of selection of bio-based materials, especially by contractors.

5.2 PERCEIVED BEHAVIOURAL CONTROL
As previous experience has been shown to influence the product decision in construction to a great extent, the identified lack of knowledge and experience of bio-based materials is indeed a significant barrier towards the selection of such materials. The lack of awareness and knowledge of available products indicate that the diffusion of many of the bio-based materials is still in the early stages. This is not surprising since many bio-based materials can still be considered to be relatively new on the market. The lack of knowledge of alternative materials could also to some extent be explained by the policy directives to developers and contractors regarding materials, which hamper their openness and search for innovations.

An easy-to-access overview of existing and upcoming bio-based materials, of low carbon materials, or of materials with low embodied energy could help to raise an awareness of alternative materials among professionals within the construction industry. As stated in earlier studies, a lack of education regarding other building materials than the conventional ones is an important barrier that has to be targeted [15].

In general, the contractors were perceived to have more influence than architects over the material selection as well as greater possibilities to contribute to a shift towards a greater usage of bio-based materials in residential buildings. However, since the architects expressed a more positive attitude towards bio-based materials and a greater openness towards introducing innovations, their possibilities of exerting an influence, by e.g. making suggestions, should not be neglected. Nevertheless, the contractors’ possibility of influencing the selection does not currently seem to be used to increase the use of bio-based materials, due e.g. to a lack of incentives to change current praxis. In the cases brought up during the interviews where bio-based materials were selected, the demand from the client was stated to be the main reason behind the selection, which complements earlier results [22].

Providing architects with information about costs, quality over time, relative advantages, and compatibility with other materials could increase their possibilities to gain support for their suggestions of alternative materials.

5.3 DRIVERS AND BARRIERS
The identified future drivers confirm earlier work [27]. However, the perceived importance of green building certification was higher in this study compared with studies in which regulations limiting embodied carbon were considered to be the key driver for the future. This could be explained by differences in client demands, where an increased interest in green building certificates was seen in this study, whereas a decreased interest has been seen in other.
The environmental issues considered in Swedish construction correlate with the aspects in focus in the most commonly used green building certification in the country. However, these aspects do not include e.g. embodied energy, embodied carbon, and to only a minor extent the use of materials from renewable sources. In order for the certification to become a tool for further decreasing the environmental impact during the construction phase, their scope must be extended to include such aspects as well. In order to make full use of the increasing interest in environmental issues, it is important to provide a decision basis to actors in the construction industry by evaluating the environmental performance of building materials and spreading these results. Further, if green building certification is to play a significant role as a future driver for the use of bio-based materials, it is of importance to improve the attitudes of the contractors and architects towards these systems, as well as their trust in them.

The identified barriers also correspond quite well to the barriers described in the literature [18, 22, 24-25, 27]. However, lack of accreditation, difficulties in locating suppliers and obtaining a reliable supply, lack of established standards, and low availability of materials was not mentioned as barriers in this study. This does not automatically mean that these are not perceived to be barriers for selecting bio-based materials. Nevertheless, the majority of these barriers are identified for recycled materials, and this indicates that there are differences in barriers facing recycled and bio-based materials.

The existence and spread of bad examples is a key barrier identified in this study that is not given emphasis in earlier work [18, 22, 24-25, 27]. However, related barriers, such as concerns about performance and durability as well as the perception that “green” materials are of low quality, are mentioned.

6 CONCLUSIONS

Semi-structured interviews with Swedish architects and contractors were performed to gain an understanding of the probability that bio-based materials are chosen in residential buildings and to identify drivers and barriers for an increased use of bio-based building materials.

The majority of the respondents mainly thought of wood and wood-based products as bio-based building materials. The conclusions should be read with this in mind.

The results indicate that the probability of bio-based materials being chosen in apartment buildings in Sweden is currently low, due to the lack of incentives to select bio-based materials, a general lack of knowledge of these materials, the conservative nature of and the limited profit margins within the construction industry, the somewhat negative attitude towards bio-based materials among contractors, the existence and spread of bad examples, risks associated with introducing new materials, and issues regarding durability, fire requirements and moisture.

A clear difference between architects and contractors was that the architects had a more positive attitude towards bio-based materials and a more open mind regarding the introduction of innovations, whereas the contractor perceived a higher level of behavioural control. However, the results indicate that the attitude among the contractors has started to change in a more positive direction.

Other main findings were that green building certificates, if altered, were seen as a promising way to increase the use of bio-based materials as well as other environmental standards and regulations. Evidence that the materials maintain a certain quality over time, the spreading of examples of successful implementation, further research and development aiming at achieving less expensive materials and materials with improved properties, increased knowledge and better access to information, and the need to develop ways of dividing risks between actors were also identified as important factors to increase the incentives to select bio-based materials. The main difference between the two groups was that contractors also saw customer demands and proof of cost effectiveness as drivers.

7 FUTURE STUDIES

A questionnaire to investigate whether the results in this study could be generalized to a wider population would be of interest. In such a study, small and medium-sized contractor companies and actors involved in detached houses could also be included. Actors from different countries would also be of interest in order to capture geographical differences and similarities. Further, since the developers are also actors of importance regarding material selection in residential buildings it would be interesting to capture their perceptions and attitudes regarding bio-based materials.

Another interesting area for further research is the attitudes of contractors and architects towards green building certificates and how their attitude could be improved, and how to best incorporate ways of promoting materials with low embodied carbon and energy in green building certification systems.

ACKNOWLEDGEMENT

Financial support from the Swedish Research Council Formas (Project EnWoBio, 2014-172) and SP Swedish Technical Research Institute is gratefully acknowledged. The authors also acknowledge COST Action FP1407 - Understanding wood modification through an integrated scientific and environmental impact approach (ModWoodLife).
REFERENCES


