Building material preferences with a focus on wood in urban housing: durability and environmental impacts

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Abstract

As societies urbanize, a growing proportion of the global population, and an increasing number of housing units will be needed in urban areas. High-rise buildings and environmentally friendly, renewable materials must play important roles in sustainable urban development. To achieve this, it is imperative that policy makers, planners, architects, and construction companies understand consumer preferences. We use data from urban dwellers in the Oslo region of Norway to develop an understanding of material preferences in relation to environmental attitudes and knowledge about wood. We emphasise wood compared with other building materials in various applications (structural, exterior and interior) within urban apartment blocks. We use 503 responses from a web-panel. Our findings show that Oslo area consumers tend to prefer materials other than wood in various applications in apartment blocks, especially structural applications. Still, some respondent prefer wood, including some applications in apartment blocks where wood is currently not commonly used. The best target for wood-based urban housing includes younger people who have strong environmental values. As environmental attitudes evolve in society and a greater proportion of consumers search out environmentally friendly product alternatives, the opportunities for wood to gain market share will most likely increase.

Key words: Consumer preferences, wood, building materials, urban building, environment, durability

Introduction

By 2050, UN estimates place global population at approximately 9.6 billion (UN 2014). Currently, global demand for housing is approximately five million units per year (UN Habitat 2014). As global population increases, an increasing number of housing units will be needed in urban areas. Housing density, as well as green building represent significant factors in sustainable urban development (Dunse et al. 2013). Thus, high-rise buildings made of environmentally friendly, renewable materials will play an important role in a more sustainable built environment.

Human dwellings must serve many different, and often conflicting, purposes to meet the broad needs of consumers. As a shelter, physical or technical quality is important. As a home, function is important. And, as a capital good, economic quality is important (Thomsen 2014). In each case, meeting consumer preferences for the materials used in buildings is critical. For a more sustainable future built environment it is therefore imperative that policy makers, planners, architects, and construction companies understand consumer housing (Vasanen 2012) and material preferences.

Many consumer preference studies specific to building materials have been conducted (e.g., NAHB 2013, Davies et al. 2002), including studies specific to wood that investigate, for example, visual evaluations of wood or specific products made from wood (Broman 2001, Nyrud et al. 2008, Høibø and Nyrud 2010) as well as haptic perceptions of products such as flooring (Berger et al. 2006). While some studies compare wood to other materials (e.g., Fell et al.

2006), few, if any, compare consumer perceptions among concrete, steel, and wood, in the context of the urban built environment. Therefore, our understanding of consumer preferences for wood versus other materials in various applications within urban housing is limited, especially in relation to varying individual backgrounds and migration to cities, which may result in in knowledge and experience differences with respect to building materials. This, in turn, may relate to varying attitudes when it comes to durability and environmental issues. Although homeowner and renter preferences today often have little influence on material selection and therefore are weak predictors of building materials use in multi-family construction, information about consumer preferences is valuable for those who make these decisions. This is particularly important when new building systems and materials are introduced.

In many regions around the world, materials used in high-rise urban buildings have traditionally differed from materials used in one and two storey rural and suburban houses. Preference for building materials is related to tradition (Craig et al. 2002) and should be studied in the context of their use. People moving into urban areas may have different preferences than those who grew up in cities. In Norway, for example, wood is the dominant structural material used in one and two storey houses (Statistics Norway 2013), while it is rarely used in high-rise buildings. Therefore, we could expect newcomers who grew up in wood houses in Norway to have different structural material preferences than people who grew up in cities where the dominant structural material, according to Store norske leksikon, (2007) has been concrete.

Similar to the global situation, the population in Norway is urbanizing. A recent forecast suggests that by 2020 the Oslo region will receive up to 310,000 new inhabitants, and an additional 600,000 in the period from 2020 to 2040. This population growth will play a major role in the urban development in this region (Tandberg and Morstad 2012).

In this study we use data obtained from urban dwellers in the Oslo region to build a better understanding of material preferences in relation to environmental attitudes. We also use insights regarding the importance of durability and knowledge about wood with an emphasis on wood compared with other building materials in various urban housing applications. We believe that more knowledge about such attitudes, in relation to material preferences, is important for planning a more sustainable future built environment. Therefore, the objectives of this study are to examine preferences for different structural, cladding and indoor building materials in urban housing as well as to understand how these relate to concerns about the environmental impacts and durability of the materials, and the experience and knowledge about wood of the respondent.

The remainder of this paper is organized as follows. First, a general background is given to provide the context of consumer perspectives on materials used in the urban built environment. This is followed by an explanation of methods used in the study. Results are presented, and are followed by a lengthy discussion exploring the practical implications of our findings.

Background

Durability

Perceptions of durability and solidity are an important aspect influencing building material preferences. In several studies brick cladding is found to be the most preferred cladding material (McManus and Baxter 1981; NAHB 2013). McManus and Baxter (1981) regard the key factor in the preference for brick to be its durability and low maintenance cost. Furthermore, Craig et al. (2002) find bricks to be the most preferred and to be regarded the most durable cladding material by responding consumers. In recent decades in Norway, durability has been an area of focus regarding maintenance of outdoor wooden claddings. Individuals who are highly concerned about durability may have a lower preference for wood used as outdoor cladding, particularly on city buildings. To know more about these attitudes in relation to material preferences, both when it comes to the structure, building envelope and indoor use, is important for future sustainable housing, since useful service life of a building partly depends on what people prefer, not only the physical integrity of the building.

Use of building materials varies within and between countries and continents partly due to traditions, which are often the result of the availability and suitability of materials. Norway has a long tradition of using wood as a building material, particularly in one and two storey dwellings, which represent approximately 78% of all dwellings in Norway (Statistics Norway 2013). The presence of 800 year old wooden buildings illustrates this long tradition, and that wood also can be regarded to be durable when it is properly used. However, in contrast to one- and two-storey housing, wood is scarcely used as a structural and cladding material in multi-storey buildings (3 storeys and more) and in city centres, due to building regulations and traditions.

Recent developments near city centres predominantly consist of four- to eight-storey buildings. Such structures are suitable for housing and for commercial, cultural, and public functions. They are also easily constructed using wood-based products (Mahapatra and Gustavsson 2008). Revised building codes and increased use of sprinkling makes it easier to use timber in such buildings. However, since preference for building materials is related to tradition (Craig et al. 2002), and therefore should depend on the context in which the materials are used, we expect lower preference for structural use of wood in city buildings for most consumers. We also expect low preference for untreated wood, since it is rarely used as cladding.

Environmental Impact

In Europe, approximately 50% of resource extraction can be attributed to the building industry (European Commission, 2011). Globally, buildings constitute approximately 40% of raw material and 40% of energy use (Roodman and Lenssen 1995). Given the major environmental impacts of the modern built environment through material transformation, energy use, and greenhouse gas emissions, sustainable development requires substantial attention to the materials used in the housing sector.

Energy considerations in the building sector have traditionally focused on operational use (Sartori and Hestnes 2007; Stephan et al. 2011), since the embodied energy (energy consumption related to material used in construction) has been relatively low, in the range of 10-20% (Hernandez and Kenny 2011). However embodied energy is becoming more important due to a relatively smaller impact from operational use, but also due to a higher consumption of materials and energy embodied in the buildings (Hernandez and Kenny 2011)..

The overall direction of findings demonstrates timber-framed buildings have a lower global warming potential than concrete and steel structures (Robertson et al. 2012) and are more positive from a carbon perspective (Ritter et al. 2011).

As consumers gain knowledge regarding environmental impacts of various materials,   preference patterns are affected (Campbell et al. 1999). In addition, policy decisions inform consumers about the impacts of material use. Because increased knowledge plays a role in determining pro-environmental actions (Keith 2011; Darner 2009; Hines et al. 1987), consumers may, over time, change their material preferences towards those with lower environmental impacts. These changes may lead to more positive attitudes about wood as a building material. In European countries, domestic wood is regarded as an environmentally friendly material (Rametsteiner 1998). We therefore expect consumers with environmentally sensitive attitudes to have a greater preference for wood compared with consumers with less environmental concern.

Materials and methods

The focus of this study is on apartment blocks within cities, rather than detached, single-family homes. The questions about material preferences were therefore asked in relation to use in apartment blocks.

Sampling

A random sample of 503 respondents from the central part of the Oslo region (Oslo, Asker, Bærum, Lørenskog, Lillestrøm, Oppegård, Ski, Ås, Vestby and Frogn) participated in the study. The sample was from a recruited probability panel provided by TNS Gallup, AS. The main source of recruitment for their panel is telephone listings. Their sampling matrix is designed to weight for biases due to groups of people that are difficult to reach. Their panel is ISO certified (26362:2009). Panel members are not made aware of the nature of the study prior to accessing the electronic questionnaire. In total, the questionnaire was sent to 1212 persons. Data collection ceased when the designed number of responses for our data analysis was obtained. 503 persons completed the questionnaire giving a response rate of 42%. There were 172 persons that opened but did not complete the questionnaire.

Table 1. Approximately here

Measure and Questionnaire Development

Table 2 shows the measurement items from the questionnaire that we use for the statistical models discussed below. For most preference variables, a nine-point scale was used. This scale ranged, for example from “not important” to “very important” or from “do not like” to “like very much”.

Table 2 approximately here

One significant set of questions focused on material application in three areas of a building: 1) structural components, 2) external cladding, and 3) interior applications. For material preferences in the structural part of the building, respondents reacted to concrete, steel and wood. For external cladding, respondents reacted to untreated wood cladding, painted or stained wood cladding, metal sheeting, and stone/brick. For interior applications the options were untreated wood, lacquered stained or painted wood, paint or wallpaper on gypsum boards, paint or wallpaper on wood-based boards, and paint or wallpaper on concrete. For interior applications we included a question about how much of the interior area of their home they would prefer to have covered with wood. The options were “all over”, “some wall and ceiling areas”, “no area at all”, and “do not know”. Respondents also provided information about the importance they place on durability and solidity.

A question was included about material preference based on health and well-being impacts of the indoor environment. The options were untreated wood;

lacquered, stained or painted wood; paint or wall paper on gypsum boards; paint or wall paper on wood-based boards; and paint or wallpaper on concrete. A question about the importance of using building materials that are environmental friendly and do not contribute to pollution and greenhouse gases was also included.

Finally, a question was included about the structural material used in the housing of their childhood (prior to the age of 16). The options were wood, wood in combination with other materials, other materials, and do not know.

The electronic questionnaire incorporating all of the above questions was developed together with experts at TNS Gallup, AS. A substantial sample (54) of respondents was used to test the questionnaire. Most respondents understood the questions and were able to effectively respond. Therefore, no significant changes were made to the questionnaire and these respondents were included in the final data set. We also obtained extensive demographic data about respondents via the TNS Gallup, AS panel database.

Analysis

The statistical software JMP version 10.0 from the SAS Institute Inc. (2012) was used in data analyses. Firstly, the data were carefully analysed using data plots. The patterns of the plotted data indicated a number of concerns regarding non-normality and heteroscedasticity. Given the assumptions of normality and homoscedasticity in linear regression, we based our analyses on multiple logistic regression as the primary analysis tool (Hosmer and

Lemeshow, 2000). Logistic regression calculates probabilities for each response level (Hosmer and Lemeshow, 2000) and in our case gave nine probabilities depending on the values of the independent variables. To accomplish this result, eight fitting lines were calculated (when a nine-point scale was used; see Figure 2 and Figure 2 footnote). The dependent variables were defined as ordinal. A “do not know” option was included in several of the questions. Responses of "do not know" were treated as missing values and were not included in the analyses.

Results

Figure 1 provides a basic picture of respondent material preferences. For structural products, respondents most prefer concrete and least prefer wood. With respect to external cladding, untreated wood and metal sheeting are roughly equivalent and least preferred. Painted or stained wood is more preferred than these and stone/brick is the most preferred cladding material. In interior applications, untreated wood is the least preferred. Paint or wall paper on gypsum boards and lacquered, painted, and stained wood are most preferred. Paint or wall paper on wood based boards is the third most preferred and paint or wall paper on concrete is the second least preferred.

***Figure 1 approximately here ***

Structural Materials

We use logistic regression to gain insights into what impacts respondent preferences for materials in each of the three applications. Table 3 includes four separate models and includes R^2 values and p-values for the different variables and interaction effects. Since there are a number of interaction effects in the models, including three variable interactions, we present profile plots that show how the preference probabilities for the different materials change with different values of the independent variables. Each row in each figure represents a specific setting of the variables. Only a few combinations of variable settings are shown in the figures. The footnote to Figure 2 explains in detail how the figures work.

Figure 2 corresponds to Model 1 in Table 3. The profile plots in Figure 2, row 1 show that concrete in general is the most preferred structural material (largest probability for 9 and 8 preferences), followed by steel and wood (row 1, left column).

Figure 2 approximately here

Figure 2 (footnote text). The profile plots show preferences for different structural materials, depending on values of various independent variables in Model 1 (Table 3). Five rows of plots are included to show how preferences for the different structural materials change with changes in independent variable values. The thick dashed, vertical lines indicate where the researcher set the value of the independent variables. The distances between the horizontal lines in the first column of plots show the probability for the different preference values for concrete. The probability for a preference of 9 is the distance between the upper most line and 1.00. The distance between line 7 and 8 shows the probability for a preference value 8. The probability for the lowest preference value is between 0.00 and the lowest line. For example, in row 3, column 1, almost half of the respondents rate their preference for concrete as the highest value of 9, given the levels of the other variables indicated by the vertical dashed lines in each box of the row. Although some of the data in Figure 1 is categorical, lines between categories are provided only for ease of visual interpretation of changes in level from one category to the next.

Respondents who consider durability to be highly important have the highest preference for concrete and the lowest preference for wood. In other words, as the importance of durability and solidity increases the difference in preference between concrete and wood increases. The models include the squared value of durability and solidity ($ImpDS^2$) in order to improve model fit. For those respondents who consider environmental friendly materials to be important (ImpEnv), the difference in preference between wood and the other structural materials decreases, as preference for wood increases. With increasing knowledge about wood, the difference between the preference for steel versus wood decreases.

Respondents who had lived in a house with structural elements of wood in combination with other structural materials before they were 16 years old do not differentiate among structural materials to the same extent as those who had lived in dwellings where the structure was entirely of wood. Those with no wood in their childhood home have the largest difference in material preferences, and lowest preference for wood compared to the other structural materials. Males show greater differences in preference among materials than females.

Table 3 approximately here

Females who, 1) rate durability and solidity as important, 2) rate environmental friendliness as important, 3) claim high knowledge about wood, and 4) lived in a childhood house with wood in combination with other materials have higher preference for wood than other materials. Steel is the least preferred structural material among these women (row 2, Figure 2). On the other hand, females who, 1) rate durability and solidity as important, 2) rate environmental friendliness as important, and 3) say they have little knowledge about wood, have lower preference for wood than the other materials (row 3, Figure 2). Since the pattern is similar for men, it means that for people with high concerns about durability, the preference for wood considerably increases with increasing knowledge about wood (row 2 and row 3, Figure 2). In contrast, for people with low concerns about durability, the preference for wood somewhat decreases with increasing knowledge about wood (row 4 and row 5, Figure 2). For steel, the results are the opposite (row 2 - 5, Figure 2). Model wise, this is due to the significant interaction effect between type of structural material, importance of durability and solidity and knowledge about wood as a building material (MStr * ImpDS * KnW, Model 1, Table 3).

Those who claim high knowledge about wood and state that durability is important have higher preference for concrete than those who do not consider durability important (row 2 and row 4), The same is valid for those with little knowledge about wood (row 3 and row 5, Figure 2). This means that lower concerns about durability considerably decreases the preference for concrete. Figure 5 also shows, that this effect is somewhat larger when knowledge about wood is low (row 2 - 5, Figure 2).

For material preferences in the structural part of the building, 16%, 19% and

18% of respondents answered “do not know” for concrete, steel and wood respectively.

Outdoor Cladding

Similar to Figure 1, row 1 in Figure 3 shows that stone/brick represents the most preferred cladding material (largest probability for 9 and 8 preferences), followed by painted and stained wood, metal sheeting and untreated wood.

Figure 3 approximately here

Respondents who consider durability and solidity (ImpDS) to be especially important have greater preferences for stone/brick. Respondents who consider environmental friendliness (ImpEnv) to be especially important have a greater preference for painted or stained wood and untreated wood, but stone/brick remain the most preferred. The older the respondent the greater the preference for stone/brick and the lower the preference for untreated wood. Women have somewhat higher preference for painted and stained wood compared to men and somewhat lower preference for untreated wood (row 2 and row 3, Figure 3).

Young respondents placing high importance on environmental friendly materials and low importance on durability and solidity hold highest preference for wood materials (row 2, Figure 3). On the other hand, older respondents placing low importance on environmental friendliness and higher importance on durability and solidity much prefer stone/brick compared to other cladding materials (row 4, Figure 3).

For cladding material preferences, 7%, 9%, 7% and 8%, of respondents answered “do not know” for Painted or stained wood, Metal sheeting, Stone/bricks and Untreated wood respectively.

Indoor Materials

As with Figure 1, row 1, Figure 4, shows that lacquered, painted or stained wood and paint or wallpaper on gypsum boards, on average, are the most preferred indoor wall and ceiling materials (largest probability for 9 and 8 preferences). They are followed by paint or wallpaper on wood-based boards, paint or wallpaper on concrete, and untreated wood panels as the least preferred.

Figure 4 approximately here

Respondents rating environmental friendliness as highly important (ImpEnv), prefer lacquered, painted or stained wood, and untreated wood over other materials. For older respondents the preference for paint or wallpaper on concrete increases, and preference for gypsum boards and untreated wood decreases. Women prefer untreated wooden panels somewhat less than men.

Young male respondents who consider environmentally friendly materials to be of high importance have a high preference for wood materials. However, these respondents prefer paint and wallpaper on gypsum boards similar to lacquered, painted and stained wood (row 2, Figure 4). In contrast, older respondents placing low importance on environmentally friendly materials have low preference for both types of wood materials compared to non-wood materials (row 3, Figure 4). Older women placing low importance on environmental friendly materials have a low preference for wallpaper on concrete and a particularly low preference for untreated wood (row 4, Figure 4).

For indoor material preferences, 6%, 6%, 6%, 6% and 5%, of respondents answered “do not know” for Lacquered, painted or stained wood, Paint or wall paper on concrete, Paint or wall paper on gypsum boards, Paint or wall paper on wood based boards and Untreated wood respectively.

Indoor Materials: Health and Well-being

In addition to general preferences for different indoor materials, respondents provided their perceptions of the same indoor materials and their role in health and well-being. Differences in preferences between various materials do not change significantly based on respondent age. However, involvement in remodelling or not, has a significant impact (Model 4, Table 3 and Figure 5).

Figure 5, row 1 shows that lacquered, painted, or stained wood is the most preferred indoor wall and ceiling material (largest probability for 9 and 8 preferences) with regard to health and well-being provided by the indoor environment. Treated wood is followed by paint or wallpaper on gypsum boards, paint or wallpaper on wood-based boards, paint or wallpaper on concrete, and untreated wood panels are the least preferred.

Respondents placing high importance on environmentally friendly materials (ImpEnv) most prefer lacquered, painted or stained wood when it comes to providing a good indoor environment for health and well-being. They also have higher preferences for untreated wood compared to respondents less focused on environmentally friendly materials. Respondents with remodelling experience have lower preference for untreated wood compared to respondents without this experience. Women prefer untreated wooden panels somewhat less than men and lacquered, painted, stained wood panels somewhat more than men.

Figure 5 approximately here

Figure 5 row 2 shows that male respondents without remodelling experience who also place high importance on environmentally friendly materials have the highest preference for the two wooden panels when it comes to making an indoor environment conducive to health and well-being. On the other hand, male respondents with remodelling experience and placing low importance on using environmentally friendly materials have the lowest preference for the two types of wooden panels (row 3, Figure 5). Row 4 shows that women with remodelling experience and placing low importance on using environmentally friendly materials have even lower preference for the untreated wooden panels than men.

For indoor material preferences when it comes to health and well being, 8%, 10%, 8%, 10% and 10%, of respondents reacted with “do not know” for Lacquered, painted or stained wood, Paint or wall paper on concrete, Paint or wall paper on gypsum boards, Paint or wall paper on wood based boards and Untreated wood respectively.

Indoor Materials: Extent of Coverage

To determine how preferences for different indoor materials are related to the proportion of wood the respondent would like to have on walls and ceilings, the different indoor material preference variables are tested in a multiple model. All variables contribute significantly (Model 5, Table 4). The majority of respondents want to use wood on some parts of the walls and ceilings. Few want wood all over, and few do not want wood at all.

Increasing preference for untreated wood, lacquered, painted or stained wood and paint or wallpaper on wood based boards increases the preference for using wood on all walls and ceilings and decreases the preference for using no wood at all (row 1, Figure 6). For paint or wallpaper on gypsum boards and paint or wallpaper on concrete, the results are the opposite (row 1, Figure 6).

Figure 6 approximately here

For respondents with a high preference for lacquered, painted, or stained wood (row 2, Figure 6), increasing preference for untreated wood accompanies a decreasing preference for wood on all walls and ceilings. In other words, an increasing preference for untreated wood translates to less desire to cover all walls and ceilings with wood. However, there is an increased desire for “some wood”, when preference for lacquered painted or stained wood is high. Model-wise this result is due to the interaction effect between the preferences for using untreated wood and preference for using lacquered, painted or stained wood (UnW * LPStW), see Model 5, Table 4.

Discussion

For large buildings, concrete is the most widely used structural material in Norway and wood is used infrequently. The high preference in this study for concrete as a structural material in apartment blocks with 3 or more storeys, compared with wood as a structural material (Figure 1a and Figure2) therefore fits well with material traditions in urban areas with high-rise housing. This result is in accordance with Craig et al. (2002) who find traditional materials to be most preferred and Ærø (2006) who finds personal tradition from a life style perspective strongly influences residential choice.

When it comes to cladding, tradition also appears to play a role, since stone/brick, which are common urban cladding materials, were the most preferred apartment block materials. This is similar to McManus and Baxter (1981), Craig et al. (2002) and NAHB (2013) who find brick to be the most preferred cladding material. In contrast, metal sheeting which is not an uncommon cladding material on urban apartment blocks is least preferred, very similar to untreated wood. Consequently, factors other than tradition must also play important roles. Metal sheeting is common on industrial buildings. This might have a negative effect on preference for this material when it is used in areas for housing, while stone/brick might be regarded more upscale and luxurious than the other materials, resulting in higher preference.

Attitudes towards durability and solidity have a major effect on both structural and cladding material preference, (Table 3, Figure 2 and Figure 3). Respondents rating durability and solidity important have very high preference for stone/bricks, compared with respondents who rate durability and solidity as less important. Craig et al. (2012), find brick to be rated the most durable of the cladding materials studied, and brick together with roughcast the most preferred. The general, low preference for wooden claddings compared to stone and brick, could be related to the relatively high focus that has been placed on wooden cladding maintenance in Norway. Untreated wood is uncommon and likely not perceived to be durable by most people, resulting in low preference.

Many respondents likely have limited knowledge about building materials, a factor that may play a key role in material preference. We find a significant interaction effect between the importance of durability, knowledge about wood and type of structural material, resulting in significant impact of durability concerns when knowledge about wood is low (Figure 2, row 3 and row 5), and a smaller impact of durability concerns when knowledge about wood is high (Figure 2, row 2 and row 4). For respondents with limited knowledge about wood, increasing concerns about durability decrease the preference for wood in structural applications, and considerably increases the preference for concrete. For respondents with high knowledge about wood, however, increasing concerns about durability and solidity only somewhat change the difference in material preference. These findings are logical, since people with little knowledge about a non-traditional solution, which in this case is wood used as a structural material in high-rise buildings, will to a greater extent choose the “safe” and well known option: concrete structure.

Construction material in the respondents’ childhood homes, which likely contributed to some material experience, also played a role in their structural material preferences. Respondents who grew up in a home with a structure that combined wood with other materials have higher preference for structural use of wood in apartment blocks than those who grew up in pure wood construction and those who grew up in a home with no use of wood in the structure. These findings show that experience with and knowledge about materials, and how they might be combined in a building significantly influence material preferences.

In contrast to preference for structural wood, we find no significant effect for knowledge about wood on outdoor cladding material preference or indoor material preference. This might be due to people, in general, having more knowledge about or direct experience with these parts of a building than what is hidden in the structure. This may translate to low variation in knowledge and preference, and lower explanatory power. The higher number of “do not know” responses for structural material preferences compared with the other materials demonstrates that people are more unsure about structural material use than about cladding and indoor materials on walls and ceilings.

The respondents' attitudes regarding the importance of using environmentally friendly materials and how this may influence their preferences for certain materials, are in accordance with our suggestion in the introduction that concerns about the environment may increase the preference for wood, compared to other building materials. This should result in a relatively high preference for wood, since European consumers regard domestic wood to be one of the most environmentally friendly materials (Rametsteiner 1998). However, the environmental friendliness of a wood product is less of a determining factor for a purchase compared to other product features like quality and durability (Rametsteiner 1998). This is in accordance with our findings for structural and cladding materials, in which durability is a more important factor than the environment for both structural and cladding material preference. For indoor walls and ceilings material preference, on the other hand, durability is not of significant importance, while concern about the environment is significant.

People in general may not have substantial knowledge about the building industry and the environmental impact of the use of different materials. Rametsteiner (1998) concludes that Europeans' positive image of wood appears to be led by a "halo effect" back to the forest, since when they were asked to assess the environmental friendliness of different phases in the product life cycle, respondents, rated forestry and harvesting more environmentally friendly than the manufacturing and disposal of wood products. With regard to the indoor environment and health issues, peoples' knowledge appears to be limited (Keith 2011). Keith (2011) finds that California consumers have limited knowledge about the indoor environment and volatile compounds even though the chemicals used in buildings are a major source of chemical exposure for Americans, causing significant health issues (Mendell 2007, Sharpe 2004).

If increased knowledge about environmental effects is relevant in determining pro-environmental actions (Keith 2011, Darner 2009, Hines et al. 1987), more knowledge about materials in relation to environmental issues may change the general attitude towards different materials compared with what we find in our study. This suggestion may be strengthened by what we find for knowledge about wood as a building material and what this means for structural material preference. It may also be strengthened by our finding, that for young male respondents who are concerned about the environment, but not concerned about durability, the two wooden cladding materials were the two most preferred. For older men with high concerns about durability and low concerns about environment on the other hand, stone/bricks were much more preferred than all the other materials. In addition, untreated wood is not preferred. Durability of wooden cladding, which is important for environmental impact, to a great extent depends on how wood is used in the facades, for instance, with regard to how cross-sectional wood surfaces are exposed to weather. How the building industry addresses this issue will most likely play an important role in how wood facades will be judged in the future by consumers, because durability plays an important role in preference

(McManus and Baxter 1981; Craig et al. 2012)

Our findings indicate that the preference for wood products in the built environment increases with increasing concern about environmental impacts. Additionally, younger respondents are more likely to view wood favourably. As environmental awareness in society increases, it will influence pro-environmental actions (Keith 2011, Darner 2009, Hines et al. 1987) and may result in further positive reactions towards wood. Together the findings suggest a positive future for wood construction in city regions.

For indoor materials, the importance of using environmentally friendly materials contributes positively to wood use preference. However, we find a significant negative effect of remodelling experience with regard to preferences for using untreated wood. The significant negative effect of remodelling experience when it comes to use of untreated wood and its implications for indoor pleasantness and health (Figure 5, Model 4, Table 3), may be due to a trend in Norway to paint old indoor pine and spruce panels to increase the light levels in indoor environments. This trend is a shared experience among the Norwegian public that has been affected by the media, particularly television, which favours light, indoor environments. The lower preference for untreated wood may also relate to a greater preference for visual harmony and homogeneity in surfaces. Painted and stained wood has a more homogenous appearance than untreated wood panels with knots. Scots pine indoor panels with knots have been a common indoor wall and ceiling material in one and two storey dwellings in Norway. Broman (2000) finds consumer preference for wood to be influenced by harmony. Harmony is related to homogeneity (Nyrud et al. 2008), while a positive correlation between visual homogeneity and consumer preference occur for decking materials (Høibø and Nyrud 2010).

Despite the generally low preference for untreated wood, most respondents prefer using some wood on indoor walls and ceilings. In other words, the highest preference is for a combination of materials that includes wood in some way on indoor walls and ceilings, even when it is untreated.

The relatively high preference for lacquered, painted or stained wood may be related to the generally positive attitude about wood as an environmentally friendly material (Rametsteiner 1998), together with a preference for a lighter indoor environment, which is partly affected by the media.

Conclusions

The increased use of wood-based materials may be an important element of more sustainable future built environment. Our findings indicate that Oslo area consumers often prefer materials other than wood in various housing features. With regard to structural and cladding materials, tradition is an important factor in consumer preferences. However, some segments are more open to and even more favourable towards wood in housing, also in parts of apartment blocks where wood is not commonly used. The appropriate target for wood-based urban housing is younger people who have strong environmental values. Concerns about durability for wood products is quite real in consumer perceptions, so designs that can alleviate these concerns and information/education illustrating the same would be adviseable for specifiers and developers if they choose to integrate wood more extensively into their projects. Our findings also suggest that as environmental attitudes evolve in society and a greater proportion of consumers search for environmentally friendly product alternatives, the opportunities for wood to gain market share will increase.

The key takeaway for policy-makers is that knowledge of wood increases preference for its use in each of the three settings. So, if increased use of wood is a goal for carbon or other environmental reasons, consumer education may be a logical tool, along with accompanying incentives for the use of wood within the construction sector.

Although our findings provide a number of encouraging signs, it must be remembered that the data for this study are specific to the Oslo region of Norway and is therefore not necessarily generalizable to other locations.

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Figure captions

Figure 1. Mean preference for structural materials, cladding materials and indoor wall and ceiling materials

Figure 2. Profile plots showing preferences for structural materials, depending on the values of the independent variables in Model 1

Figure 3. Profile plots showing preferences for outdoor cladding materials, depending on the values of the independent variables in Model 2

Figure 4. Profile plots showing preferences for indoor materials, depending on the values of the independent variables in Model 3

Figure 5. Preferences for indoor materials with regard to indoor environment, depending on the values of the independent variables in Model 4

Figure 6. Preferences for the proportion of indoor wall and ceiling area where the respondents would like to have wood, depending on the values of the independent variables in Model 5

Figure 1

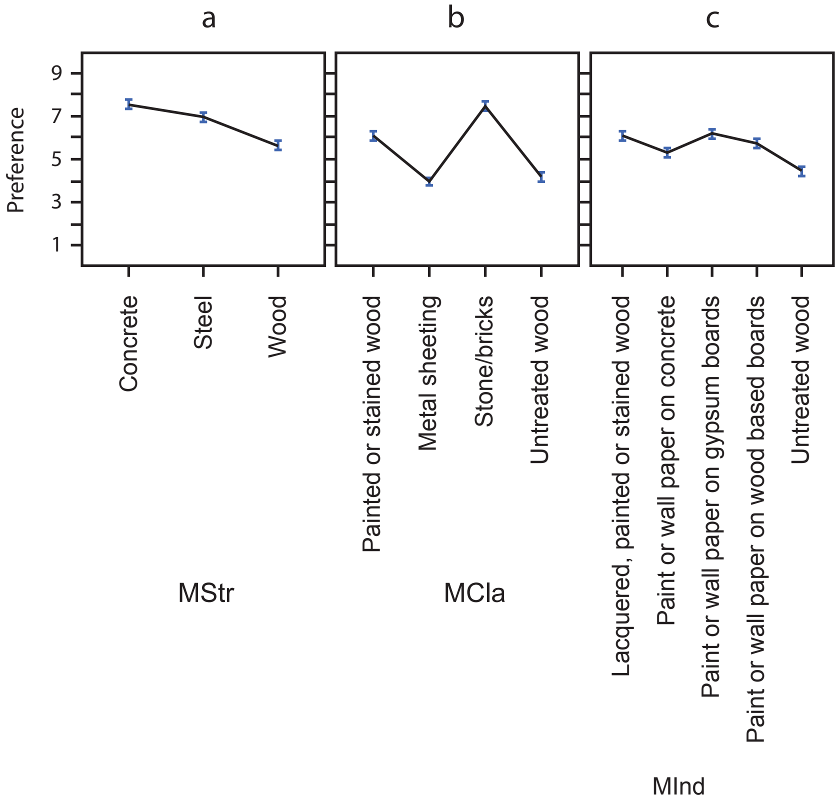

a
b
c
Preference
9
7
5
3
1
Concrete
Steel
Wood
Painted or stained wood
Metal sheeting
Stone/bricks
Untreated wood
Lacquered, painted or stained wood
Paint or wall paper on concrete
Paint or wall paper on gypsum boards
Paint or wall paper on wood based boards
Untreated wood
MStr
MCla
MInd

Figure 2

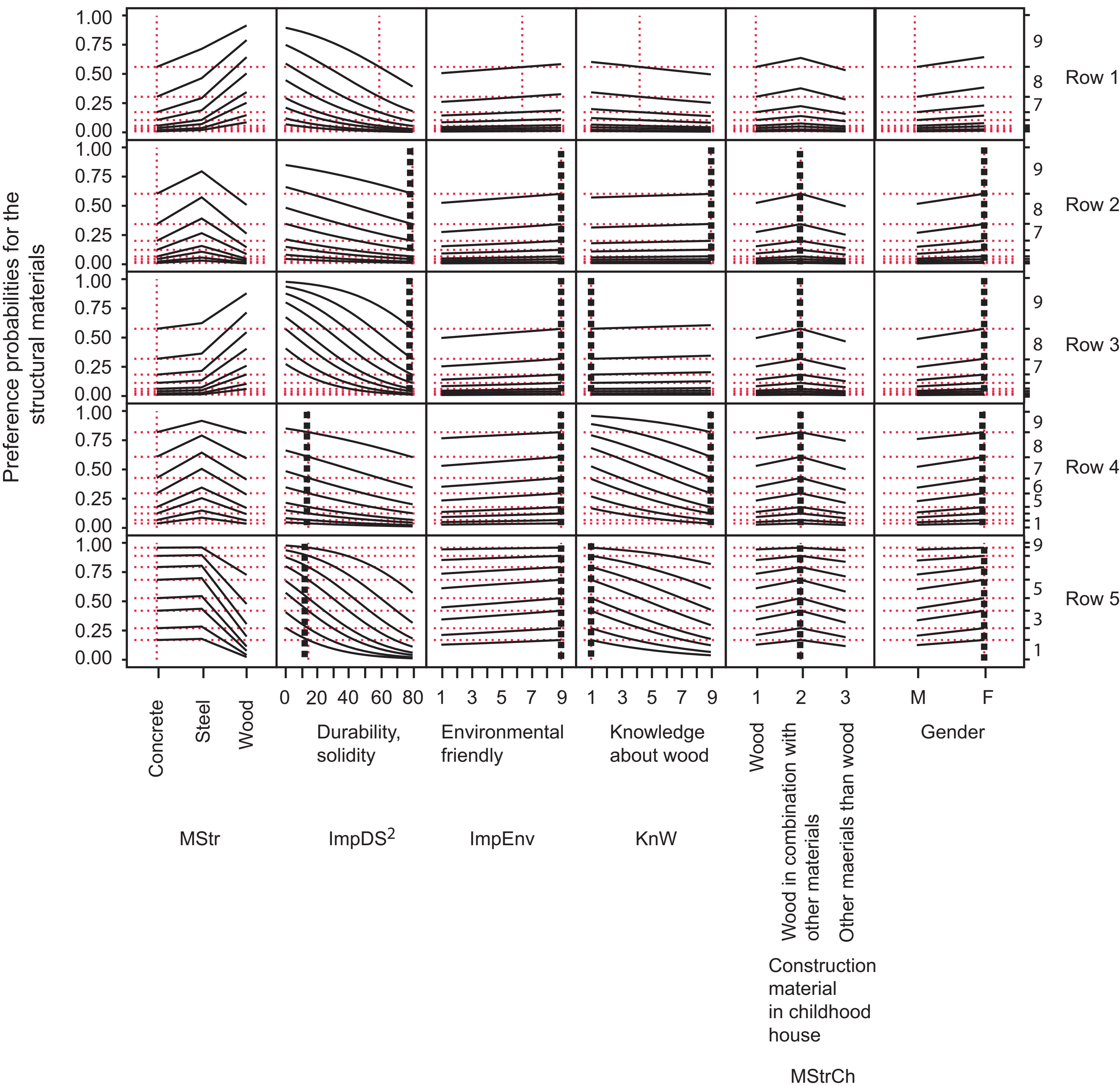
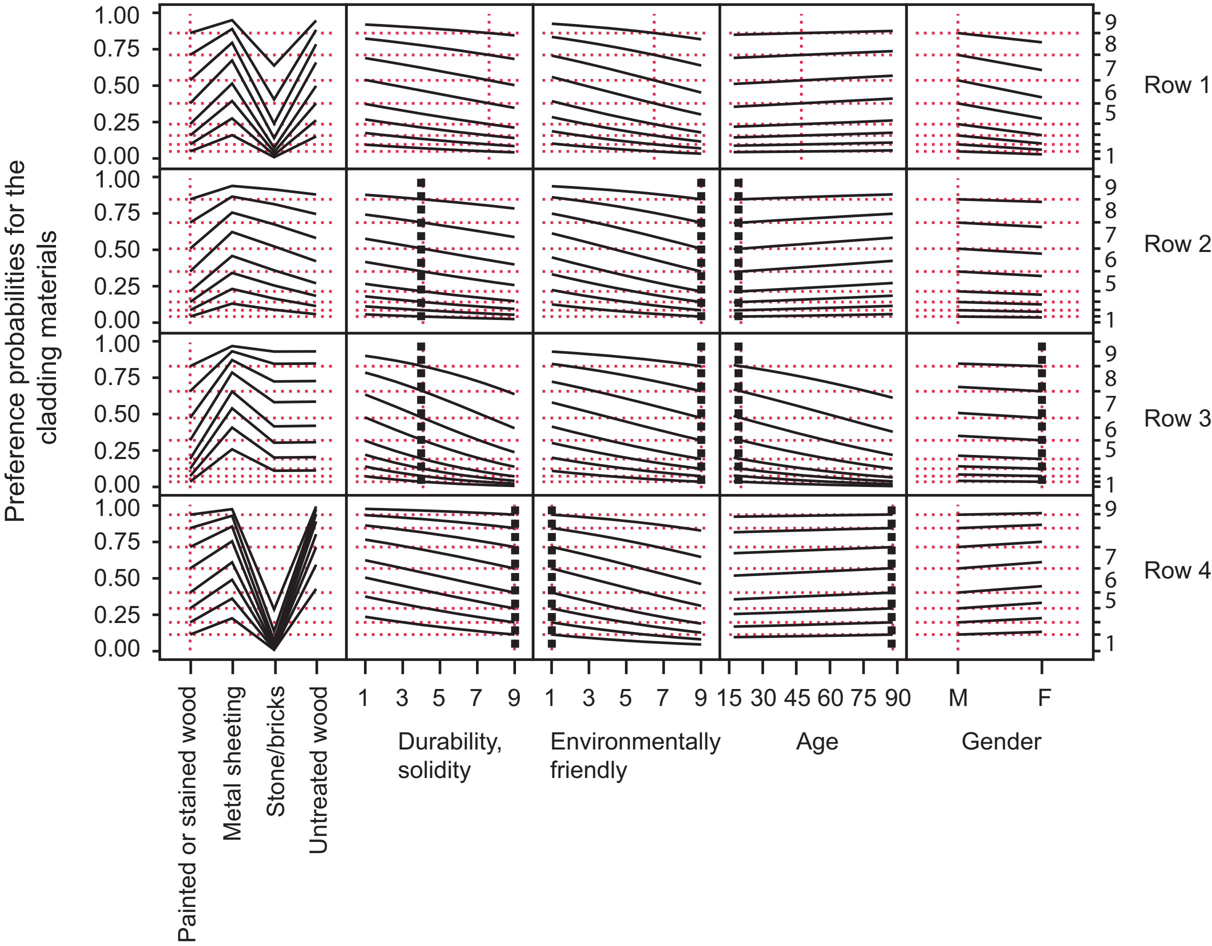

Preference probabilities for the structural materials
1.00
0.75
0.50
0.25
0.00
Row 1
Row 2
Row 3
Row 4
Row 5
Concrete
Steel
Wood
MStr
0 20 40 60 80
Durability, solidity
ImpDS2
1 3 5 7 9
Environmental friendly
ImpEnv
1 3 5 7 9
Knowledge about wood
KnW
1 2 3
Wood
Wood in combination with other materials
Other maerials than wood
Construction material in childhood house
MStrCh
M F
Gender

Figure 3



Preference probabilities for the cladding materials
1.00
0.75
0.50
0.25
0.00
Row 1
Row 2
Row 3
Row 4
Painted or stained wood
Metal sheeting
Stone/bricks
Untreated wood
MCla
1 3 5 7 9
Durability, solidity
ImpDS
1 3 5 7 9
Environmentally friendly
ImpEnv
15 30 45 60 75 90
Age
M F
Gender

Figure 4

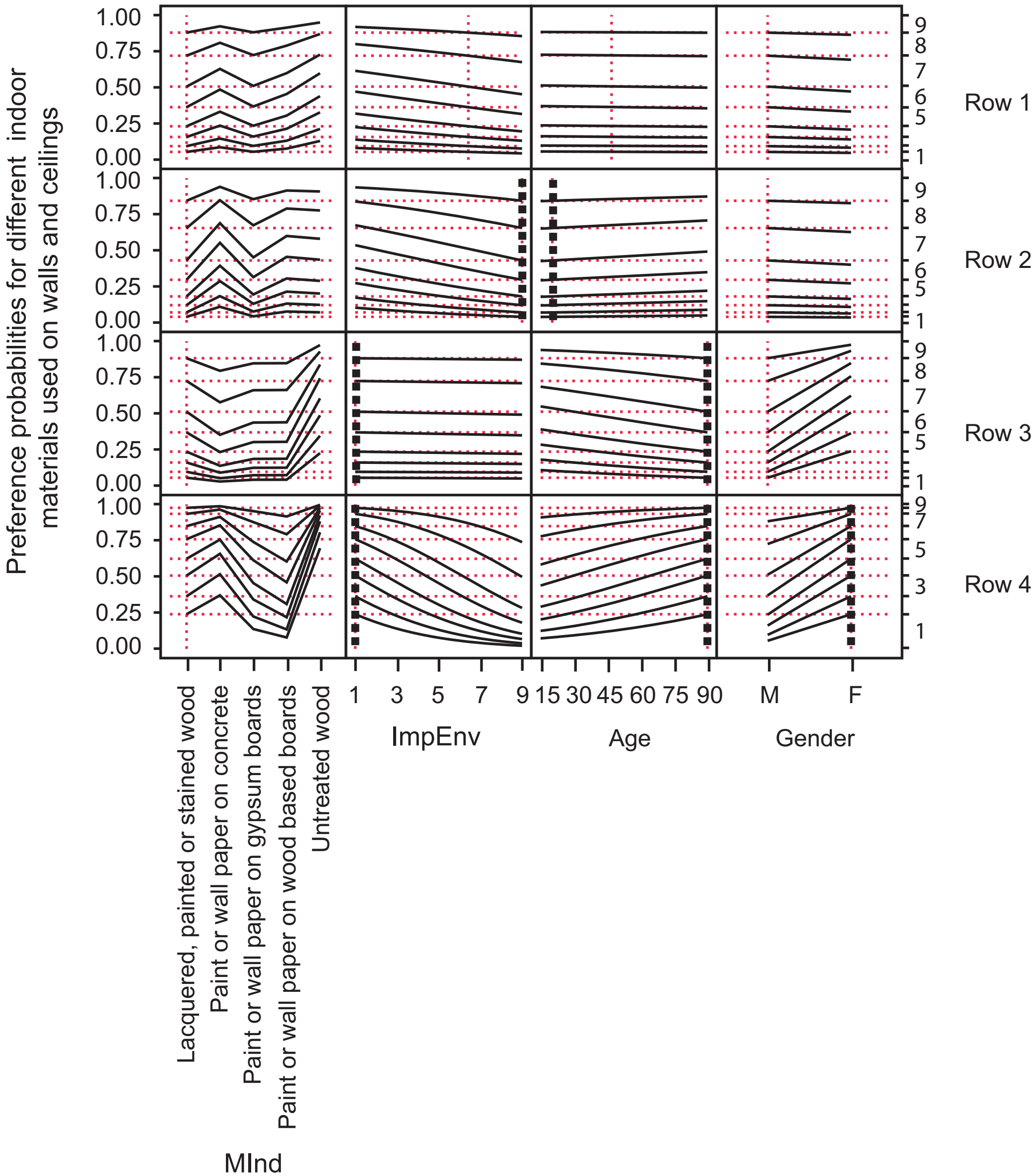

Preference probabilities for different indoor materials used on walls and ceilings
1.00
0.75
0.50
0.25
0.00
Row 1
Row 2
Row 3
Row 4
9
8
7
6
5
3
1
Lacquered, painted or stained wood
Paint or wall paper on concrete
Paint or wall paper on gypsum boards
Paint or wall paper on wood based boards
Untreated wood
MInd
1 3 5 7 9
ImpEnv
15 30 45 60 75 90
Age
M F
Gender

Figure 5

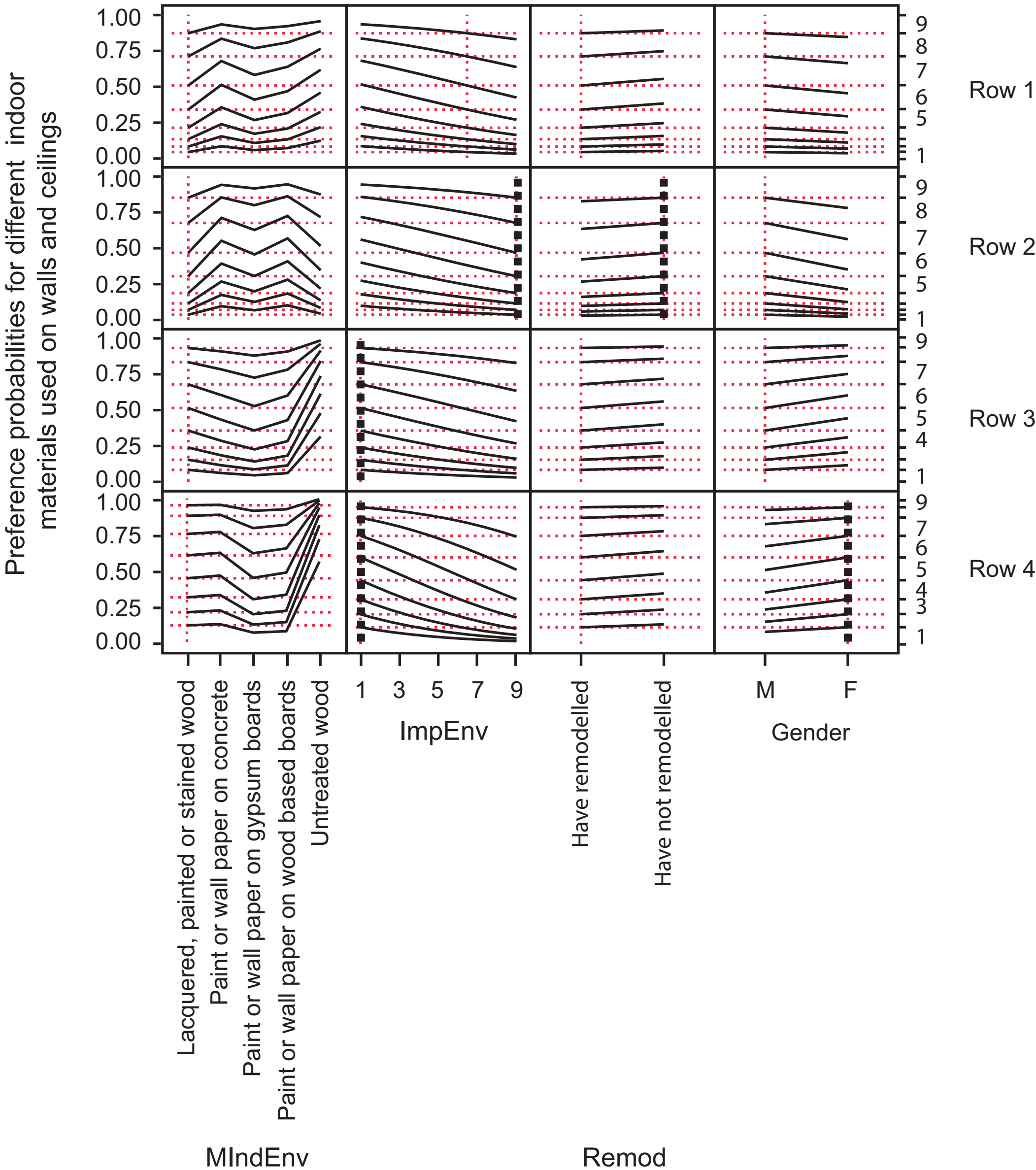
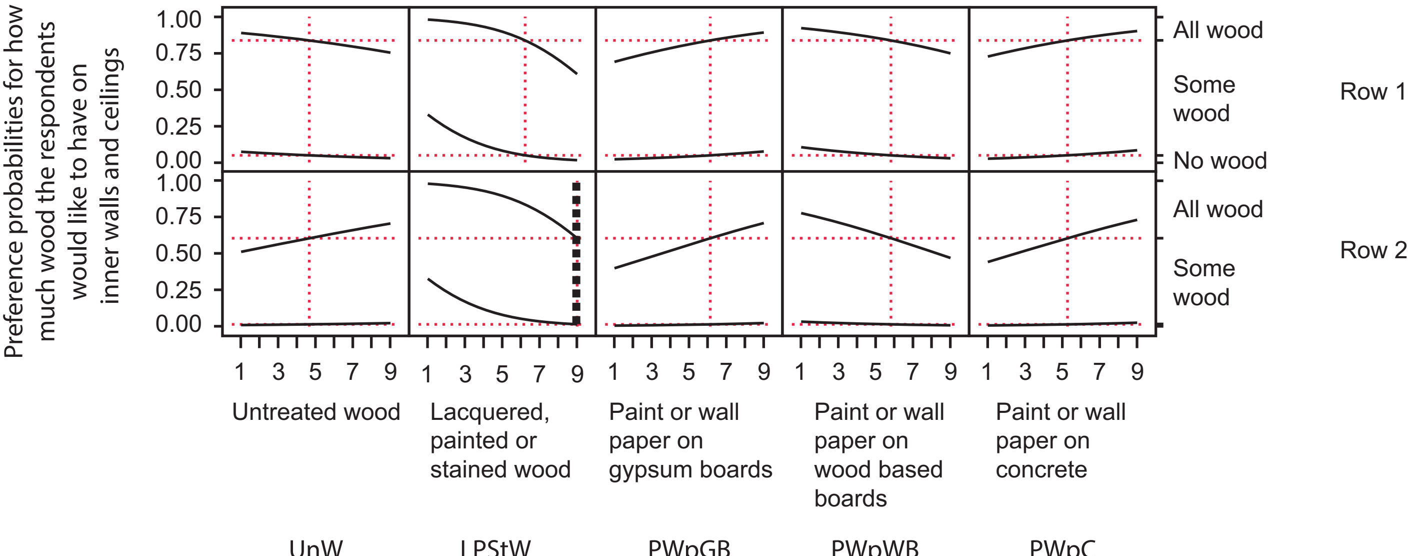

Preference probabilities for different indoor materials used on walls and ceilings
1.00
0.75
0.50
0.25
0.00
Row 1
Row 2
Row 3
Row 4
Lacquered, painted or stained wood
Paint or wall paper on concrete
Paint or wall paper on gypsum boards
Paint or wall paper on wood based boards
Untreated wood
MIndEnv
1 3 5 7 9
ImpEnv
Have remodelled
Have not remodelled
Remod
M F
Gender

Figure 6



Preference probabilities for how much wood the respondents would like to have on inner walls and ceilings
1.00
0.75
0.50
0.25
0.00
All wood
Some wood
No wood
Row 1
Row 2
1 3 5 7 9
Untreated wood
Lacquered, painted or stained wood
Paint or wall paper on gypsum boards
Paint or wall paper on wood based boards
Paint or wall paper on concrete
UnW
LPStW
PWpGB
PWpWB
PWpC

Table 1. General Characteristics of Study Respondents

N	N
Respondents participating	503
Age (mean = 46.6, SD = 16.7)	
Gender female/male	259/244
Remodelling of own dwelling yes/no	251/252
Construction material in childhood house wood/partly wood/no wood/don’t know	292/95/60/76

Table 2. Descriptions, Abbreviations, and Levels of Study Variables

Variables	**Abbreviation**	**N levels**
Preference for type of material for structural use	MStr	3 materials 9 point scale
Preference for type of material for outdoor cladding	MCla	4 materials 9 point scale
Preference for type of material used on indoor walls and ceilings	MInd	5 materials 9 point scale
Type of material used on indoor walls and ceilings, importance due to indoor environment	MIndEnv	5 materials 9 point scale
Proportion of indoor wall and ceiling area where the respondents would like to have wood	PrAW	3 point scale
Importance of durability and solidity of the materials	ImpDS	9 point scale
Importance of using environmental friendly materials (limited pollution or greenhouse gases)	ImpEnv	9 point scale
Knowledge about wood	KnW	9 point scale
Construction material in childhood house	MStrCh	3 options
Remodelling of own dwelling or not	Remod	Yes/no
Respondent's age	Age	
Respondent's gender	Gender	F/M
Preference for Untreated wood	UnW	9 point scale
Preference for Lacquered, painted or stained wood	LPStW	9 point scale
Preference for Paint or wallpaper on gypsum boards	PWpGB	9 point scale
Preference for Paint or wallpaper on wood based boards	PWpWB	9 point scale
Preference for Paint or wallpaper on concrete	PWpC	9 point scale

Table 3. Statistics for Multiple Logistic Regressions Models 1 to 4

	Model 1 Structural Materials	Model 2 Outdoor cladding	Model 3 Indoor materials	Model 4 Indoor materials & environment
Summary statistics for the different models				
Entropy R^2/Gen R^2	0.060/0.21	0.091/0.33	0.022/0.092	0.019/0.080
p-values for the independent variables in the different regression models				
MStr	<0.0001			
MCla		<0.0001		
MInd			<0.0001	
MIndEnv				<0.0001
ImpDS		0.031		
$ImpDS^2$	<0.0001			
ImpEnv	0,83	0.0044	0.017	<0.0001
KnW	0.075			
MStrCh	0.58			
Age		0.35	0.16	
Gender	0.77	0.38	0.95	0.66
Remod				0.78
MStr * $ImpDS^2$	<0.0001			
MStr * ImpEnv	0.015			
MStr * KnW	0.040			
MStr * MStrCh	0.023			
MStr * Gender	0.022			
$ImpDS^2$ * KnW	0.65			
MStr * $ImpDS^2$ * KnW	0.038			
MCl * ImpDS		<0.0001		
MCl * ImpEnv		0.0027		
MCl * Age		<0.0001		
MCl * Gender		0.0004		
ImpDS * Age		0.063		
ImpDS * Gender		0.25		
Age * Gender		0.46		
ImpDS * Age * Gender		0.039		
Mind * ImpEnv			<0.0001	
Mind * Age			0.051	
Mind * Gender			0.030	
ImpEnv * Age			0.48	
ImpEnv * Gender			0.0061	
Age * Gender			0.94	
Mind * Age * Gender			0.027	
ImpEnv * Age * Gender			0.032	
MIndEnv * ImpEnv				<0.0001
MIndEnv * Remod				0.0044
MIndEnv * Gender				0.0074
ImpEnv* Gender				0.0091
Nr of observations	379	440	451	431

Table 4. Statistics for Multiple Logistic Regression Model 5

Entropy R^2/Generalized R^2: 0.22/0.38						
p-values for the different variables in Model 5						
UnW	LPStW	PWpGB	PWpWB	PWpC	UnW * LPStW	PWpWB * PWpC
0.024	<0.0001	0.015	0.0066	0.0044	0.0001	0.027