

Architects' perceptions of structural timber in urban construction

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ABSTRACT

Norwegian architects' perceptions regarding the use of timber as a structural material in urban construction is investigated. Increased use of timber for urban construction represents a substantial market opportunity for the wood industry. A theoretical model based on Ajzen's Theory of Planned Behavior was developed to explain architects' intentions to use timber as a structural material in urban construction. A questionnaire was used to measure attitudes towards the physical, mechanical and fire related properties of sawn wood. The model was tested empirically and the results indicated that experience with use of wood as a structural material, perceived behavioural control over the use of wood and attitudes towards the use of wood in multi storey buildings were important factors in the architects' specification process.

INTRODUCTION

Greater participation of consumers in any decisions made in the professional service context has been increasingly encouraged by consumer groups. Information that provides insight into the professional decision making would then be expected to be of interest to the end users (White & Johnson, 2001). Previous research also provides some evidence that the use of appearance of wood products in indoor settings have a positive impact on people's emotional states and psychological health (cf. Rice et al. 2006; Tsunetsugu et al. 2007). The selection of building materials is generally referred to by the building industry as 'specification', and is carried out by 'specifiers' (Emmitt, 2002). To fix the time and place for the specification and identify all involved decision makers and their reasons for choosing a particular construction material can be difficult (Mackinder, 1980). Furthermore, the task of understanding the material selection process is complex, as the material selection process may be influenced by multiple parties, e.g. architects, engineers, contractors and end-users. In many instances there has been observed poor communication and misunderstandings on the part of manufacturers to understand the nature of the specification process and there is a need for them to have a better understanding of the behaviour and motivation of the specifiers (Emmitt, *et al.*, 2008). To achieve a thorough understanding of the specification process we need a better knowledge of the individuals who influence the selection of construction materials. This study aims at investigating one group of the specifiers involved in the building process: the architects. Architects have traditionally been the major specifiers, but with the introduction of new methods of procurement and growth of other specialists, the specification now includes a wide variety of building professionals (Emmitt, 2002).

The specification process

Emmitt, *et al.* (2008) defined three different phases during which the architect will be involved in activities related to specification: conceptual design, detail design and production.

Conceptual design. The initial phase is the briefing stage where the performance parameters should be agreed on and stated in the design brief. A feasibility study and sketch designs are produced for client approval before submission for planning consent. Confirming generic materials to be used on exterior cladding is common in this phase in the process. These initial decisions about major materials influence the decisions in the second phase.

Detail design. In the second phase, a large number of drawings and schedules are produced, during which the designer will be making decisions that can be related directly to the building product selection. In this phase, input from structural engineers, quantity surveyors and the client may influence the architects' specification decisions. It is during this stage compliance with building codes, regulations and standards must be ensured.

Production. In the final phase, the abstract ideas of the design are realized in form of the finished building. It should be noted that the proceedings in which a building is designed and then eventually built is rarely a neat and ordered process. Even though all decisions concerning specification of building material should have been confirmed in the second phase, there may be pressure to change the specification in this last phase. This can be due to cost related issues, supply difficulties or to improve buildability on site. Last minute changes imposed by clients or external control agencies can also be a reason for changing the specification.

Literature review

Kozak and Cohen (1999) examined US and Canadian architects' and engineers' choice of construction material in non-residential buildings. They found that timber was not perceived as a suitable construction material in non-residential buildings. Timber was most common in housing for the elderly, while timber was not used in buildings for industrial purposes, offices, schools and public buildings. As the building height increased, the use of wood decreased. Architects attitudes were positive towards using structural timber when they had previous experience of using structural timber. Architects who are more independent in the material selection process also tend to use timber more often and architects who used most of the time designing buildings with less than five stories tended to use timber more often.

O'Conner *et al.* (2004) investigated architects' and engineers' use of timber in non-residential buildings. Four categories of barriers to the use of timber in construction were found: codes, costs, performance and the infrastructure of the design and construction industry. Code regarding fire properties was perceived as one of the biggest challenges to using timber. The costs of using timber was perceived as higher than for other construction materials, when used in complex structures or structures with longer span. Perceived obstacles related to performance were strength, durability, stiffness, quality and shrinking. Little access to qualified personnel and lack incentives to diverge from established practices were also considered as obstacles to the use of timber in non-residential buildings.

Bayne & Taylor (2006) examined the barriers to the use of timber in non-residential buildings. Most common obstacles to the use of wood were performance, costs and building erection time. Aesthetical properties, fire and energy related properties were perceived as the advantages of using timber. It was indicated that timbers were suitable for smaller buildings, such as housing for the elderly, schools, public buildings, smaller office buildings and clinics.

Denizou *et al.* (2007) investigated mechanisms influencing the material selection process, with emphasis on the use of timber in urban construction. In the cases where timber was used, dedicated architects and/or consultants was a common denominator. In the case where timber was not used, and the architect to a large extent could control the material selection process, aesthetical considerations were a determining factor. Contractors emphasized tradition, competence and access to competent craftsmen as important factors in the material selection process. Timber was not perceived as suited in buildings above three stories. Using timber was perceived as difficult and expensive and fire related properties also influenced the use of timber negatively. Architects play an important part in the design process, but their choice of material are frequently overruled by the constructor and building owner.

Wagner & Hansen (2004) compared material preferences among architects and engineers in the United States and in Chile. The architects from the United States did not put much emphasis on properties related to price and environmental properties of the building material when choosing timber. Other areas, such as dimensional stability, were perceived to have bigger potential for improvement. As their colleagues from the US, Chilean architects were not concerned with the environmental attributes of wood. Architects from both countries perceived uniform quality as an important attribute. Fire related properties were given less emphasis than prior literature has suggested (cf. Kozak & Cohen, 1999). Architects in both countries were positive towards the aesthetical properties of timber.

Kozak & Cohen (1997) examined how architects and engineers learn about structural materials. Architects were given sufficient training in use of wood during studies, while engineers were given little education about the use of wood, compared to other materials such as concrete and steel. Architects and engineers, who at the time did not specify wood, would be most influenced through the use of physical examples, such as examples of good building practice or case-studies.

THEORY AND HYPOTHESIS

Theory of planned behaviour

A model based on Ajzen's Theory of Planned Behavior was applied for the analysis (Ajzen, 1985, 1991). Ajzen's theory has successfully been employed in previous studies linking attitudes and behaviour (see Conner & Armitage 1998; Sutton, 1998). Theory of planned behavior suggests that a person's behavioral intention is determined by three independent variables: i) attitudes, ii) subjective norms and iii) perceived behavioral control.

The attitude variable measures a person's evaluation of the behavior of interest. Attitudes arise from the beliefs about the consequences resulting from performing the behavior. The more favorable a person is towards performing the behavior in question, the stronger intentions to perform the behavior according to Ajzen's theory.

Subjective norms measure the perceived social pressure to either perform or refrain from performing a behavior. A measure of subjective norms is a function of a person's perceptions of important referents' evaluation of the behavior, whether they would approve or disapprove of the person performing the behavior, and the persons motivation to comply with the evaluation of these referents'. The intention to perform a given behavior increase with the aggregated subjective norm (Ajzen 2002a).

Perceived behavioral control measures the person's perception of the relative ease, or difficulty, of performing the behavior of interest. The variable reflects a person's self-efficacy, the

necessity of obtaining the cooperation of others to accomplish the behavior.

Intention is a measure of how hard the person is willing to try and how much effort is to be put into performing the behavior. Given that the person can decide at will to perform or not perform the behavior; the stronger the intention to perform the behavior, the more likely it is that the action is performed. The performance of most behaviors depends, at least to some degree, on other factors such as opportunity, time, money, skills, and cooperation of others, collectively representing a person's actual control over the behavior.

Hypotheses

The hypothesis in this study was based on Ajzen's Theory of planned behavior and results from previous research (Ajzen, 1985, 1991; Kozak & Cohen, 1999; Bayne & Taylor, 2006; Wagner & Hansen, 2004; Denizou *et al.*, 2007).

Attitudes towards combustible properties. Kozak & Cohen (1999) found combustible properties of wood to be perceived as the most disadvantageous and implementing protective measures with regards to fire was also perceived to be difficult. Results from Bayne & Taylor (2006) and Wagner & Hansen (2004) also indicated that combustible properties were actually viewed as positive by architects.

Attitudes towards construction costs. According to Bayne & Taylor (2006), previous research indicated that lead time and costs, commercial risk, lack of information on connection detailing and timber fabricators was important factors when choosing timber as a structural material. American architects did not emphasize costs as an important factor when choosing timber as a structural material (Wagner & Hansen, 2004).

Attitudes towards environmental aspects. Wagner & Hansen (2004) indicated that the architects did not perceive environmental aspects of wood as important, even though the American architects, as opposed to the Chilean architects, recognized the positive environmental attributes of wood. Energy related properties were also regarded as positive (Bayne & Taylor 2006).

Attitudes towards aesthetical aspects. Aesthetical aspects of wood were emphasized by the architects, and wood was perceived as a material that was easy to adapt to the desired design, and the material had character (Bayne & Taylor, 2006). Wood was also perceived as a warm material, a consistent material with a unique texture (Wagner & Hansen, 2004).

Attitudes towards different building types and building heights. Bayne & Taylor (2006) found architects in general were positive to the use of timber in residential buildings. In most cases, they were negative towards use of structural timber in most non-residential buildings, but structural timber were favored in for some applications, such as buildings for educational purposes, small office-buildings and clinics. The most promising types of buildings for increased use of wood was smaller buildings, such as churches, clinics and public buildings. It was indicated that structural timber had a bigger potential as structural material in such buildings, compared to larger commercial structures.

Attitudes towards physical and mechanical properties. Kozak & Cohen (1999) examined qualitative dimensions of wood, including perceived physical and mechanical drawbacks of using structural timber. Some of the most commonly cited disadvantages of using wood were strength, durability and deterioration.

Subjective norms. (Emmitt, *et al.*, 2008) found that architects usually get information about unfamiliar products from colleagues in the office before exploring other sources of information, implying that the norms regarding the specification of building materials are related to the use of

favorite products and manufacturers. According to (Emmitt, 2001), young practicing architects must learn the art of product specification in practice, often having to rely to a large extent on more experienced colleagues when choosing construction material. This makes for a strong tendency for specifiers to choose materials familiar to their colleagues in the office, reinforcing the tendency to use familiar products.

The contribution from external agents was also found to be greater than first anticipated. Influence from these reference individuals (e.g. engineer, builder, contractor or end user) were exerted at different points of time during the specification process. Reference individuals both introduced architects to further knowledge about building product innovations, but also led to the discontinuance of adopting new building materials. According to Ajzen's theory, reference individuals in the construction process that are positive to the use of structural timber, will enforce architects intentions to use structural timber.

Perceived behavioral control. According to the Theory of planned behavior, intentions and perceived behavioral control, in this case with regards to the use of structural timber, will be the most important variables explaining and predicting the use of structural timber. If the architect's perceived behavioral control is realistic, it can be used as a substitute for actual control over the use of structural timber (Ajzen, 1991, 2002a).

Previous behavior. Previous experience is considered to be one of the most important measures of actual behavioral control. Emmitt (2008) claimed that when architects sought information from colleagues, the specifier would have a tendency to investigate materials previously used by the office, meaning that the adoption of the building material would constitute confirmation of adoption by the colleagues in the office. Denizou *et al.* (2007) found that experience with wood products made it easier for the architect to use structural timber in constructions, as the experience made it easier to promote the use of wood to the builder, again making it easier to gain acceptance for using wood from the contractor.

METHODS

Sample

Invitation to participate in a web-based questionnaire was mailed to 1314 Norwegian architects. The architects received one reminder after three weeks. The survey was anonymous. A total of 285 architects completed the questionnaire, resulting in a 26 percent adjusted response rate (285/1100, 214 invitations never reached the recipient, mainly due to invalid e-mail addresses) somewhat below other quantitative surveys involving architects (Kozak & Cohen, 1999; Wagner & Hansen, 2004; Damery & Fiset, 2001), but above what O'Conner *et al.* (2004) reported.

Measures

Previous studies (Kozak & Cohen, 1999; Wagner & Hansen, 2004; Damery & Fiset, 2001) and examples from Ajzen (1991, 2002) and Francis *et al.* (2004) suggested the formatting and wording of the items used in the study. The items used a five-point Likert scale (1: "strongly disagree", to 5: "strongly agree"). High value reflected strong preferences for timber, except for the items regarding physical and mechanical properties as well as some of the items related to perceived behavioral control.

Intentions. The architects' intentions to use structural timber in urban was measured using generalized intention (Francis *et al.*, 2004).

Attitudes towards combustible/fire properties. Items evaluated perceived properties with regard to combustibility, increased risk for extensive damage in case of fire when using structural timber, difficulty with implementing fire protective measures and use of structural timber with regards to building regulation codes

Attitudes towards aesthetical aspects. Items evaluated attitudes towards the aesthetical aspects, including visual appeal of structural timber, adapting to desired design, multiple visual expressions and combining wood with other visual materials.

Attitudes towards construction costs. Items evaluated the cost of using structural timber compared to substituting materials, and included product price, total cost, planning cost, assembly cost and maintenance cost.

Attitudes towards environmental aspects. Items evaluated the energy use, ease of re-use, energy use during construction phase and CO₂-emissions of structural timber compared to other materials.

Attitudes towards physical and mechanical properties. Items evaluated commonly perceived drawbacks to using wood as a structural material, regarding sound, deterioration, combining timber with other materials, wind bracing, insulation, ease of use in construction, strength, maintenance, variability of the material and shrinking and swelling

Attitudes towards different building types and building heights. Items evaluated attitudes towards end use of structural timber for single- and multi family unit dwellings, apartment buildings, office and commercial buildings, public and health buildings, hotels and restaurants, and buildings for other purposes such as dams, bridges and tunnels. Items also evaluated attitudes towards structural timber in various building heights.

Subjective norms. Items evaluated the strength of normative beliefs and motivation to comply with important referent individuals in the construction process, including other architects, engineers, real estate developers, builders, contractors, end users, public authorities and research communities.

Perceived behavioral control. Items evaluated the perceived capability of using timber as a structural material, ease of use, independence in material selection process, and if there were frequently unforeseen events in the material selection process preventing the use of structural timber.

Past behavior. The architects were asked about their experience with structural timber in various building types and for different building heights for the last ten years.

RESULTS

Descriptive statistics

Table 1 presents descriptive statistics for selected items.

Table 1: Descriptive statistics, relative shares in percent

Item	1 (strongly disagree)	2	3	4	5 (strongly agree)	Mean	Std.dev
I want to use timber as a structural material	5.0	5.0	21.5	28.7	39.8	3.93	1.12
I plan to use timber as a structural material	16.0	17.0	23.6	17.0	26.1	3.20	1.41
Using structural timber increase the risk for fire	27.0	30.2	27.0	12.6	3.2	2.35	1.00
Using structural timber increase the risk for extensive damage in case of fire	13.0	30.6	32.0	18.0	6.0	2.37	1.08
Structural timber is visually appealing	1.4	1.4	11.4	30.6	55.3	4.37	0.87
Structural timber is easy to adapt to desired design	1.4	2.5	21.1	41.8	33.3	4.03	0.88
Total building cost is higher when using structural timber compared to substitutes	5.4	24.4	54.8	12.5	2.9	2.83	0.82
Maintenance cost of structural timber is higher compared to substitutes	8.5	21.7	40.2	23.5	6.0	2.97	1.02
When using structural timber. energy consumption is higher compared to substitutes	4.6	7.1	27.9	42.0	18.4	3.63	1.01
CO ₂ emissions are lower when using structural timber. compared to substitutes	2.8	5.0	29.1	31.9	31.2	3.84	1.01
Sound insulation is difficult when using structural timber	11.0	27.2	29.0	27.4	8.1	2.92	1.13
Maintenance is difficult when using structural timber	21.6	33.9	30.4	12.0	2.1	2.39	1.02
Timber is a variable material	30.9	34.5	28.7	4.4	1.5	2.11	0.94
Shrinking and swelling is a problem when using structural timber	9.5	27.9	35.3	21.9	5.3	2.86	1.03
I am qualified to specify structural timber	2.8	14.4	32.4	32.0	18.3	3.49	1.04
The use of structural timber is entirely up to me	26.9	26.5	26.1	17.7	2.8	2.43	1.14

According to the results presented in Table 1, many architects wanted to use structural timber, but few were actually planning to do so. They were also positive to fire and aesthetically related properties, costs of using structural timber compared to substitutes and the energy related properties of the material. The architects were also positive to the physical and mechanical properties of structural timber. They felt qualified to specify structural timber in buildings, but did not perceive the choice of using structural timber as being entirely up to them.

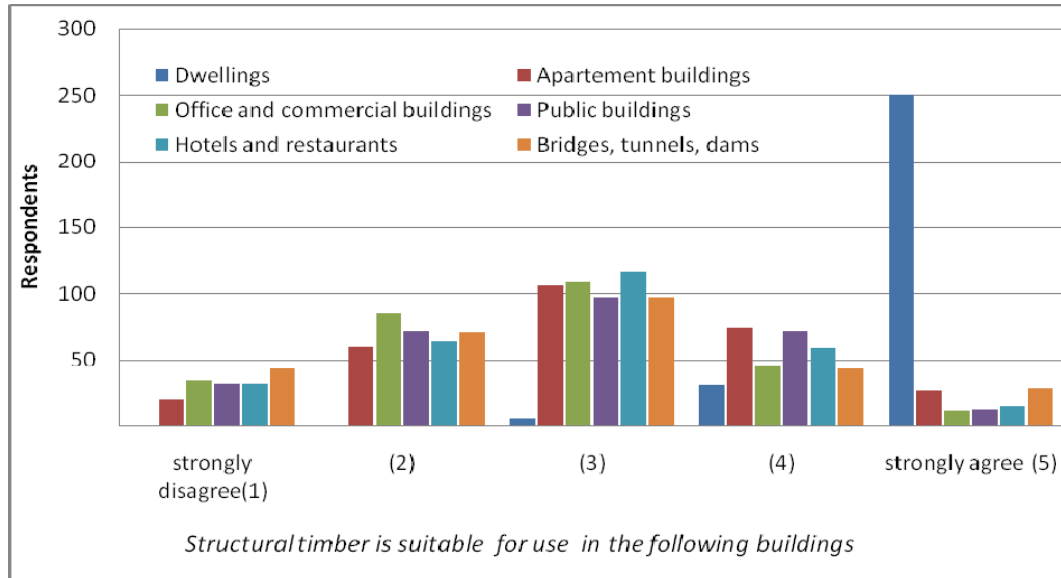


Figure 1: Attitudes towards structural timber in different building types

Fig. 1 illustrates the architects' attitude towards using structural timber in different building types. They had positive attitudes towards timber in buildings for residential purposes, but were negative towards use in other types of buildings. Attitudes towards the use of structural timber for different building heights are presented in Fig. 2.

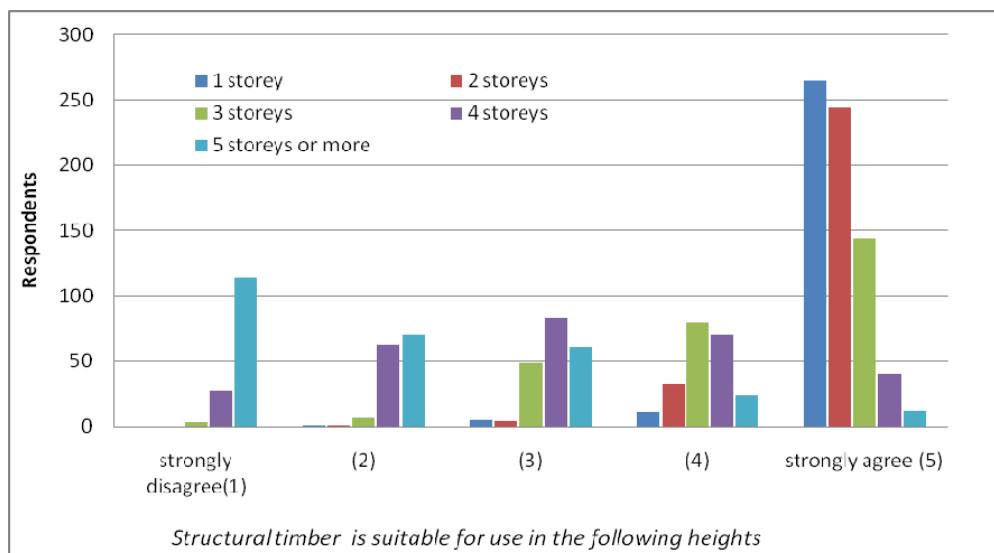


Figure 2: Attitudes towards use of structural timber in different building heights

The architects' are positive to use in buildings up to three storeys.

Fig. 3 shows the architects' experience with structural timber in different building types. They have little experience with structural timber in other building types other than residential buildings.

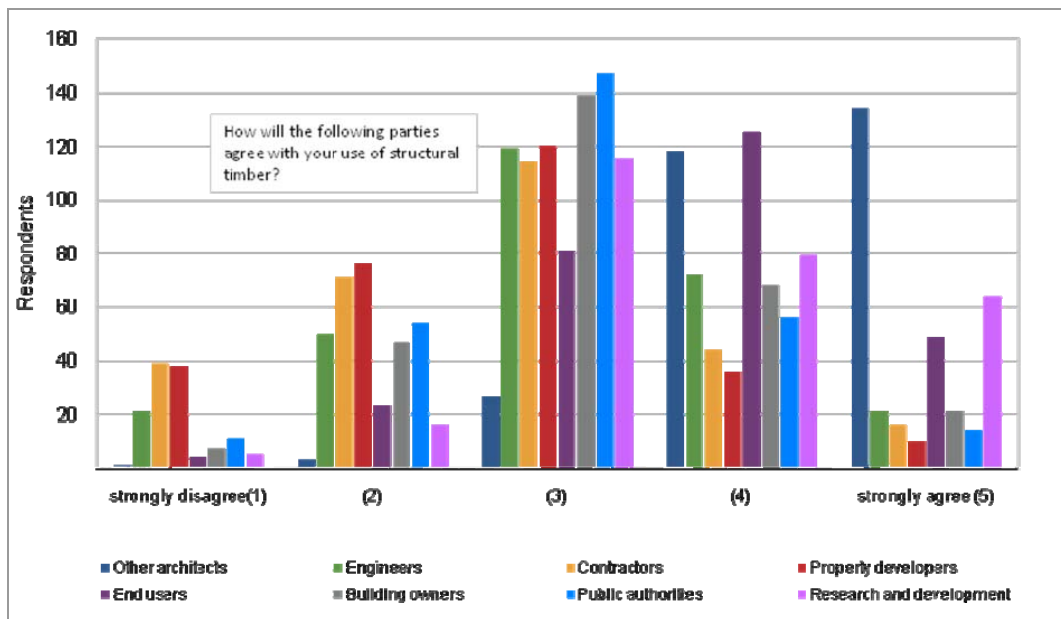


Figure 3: Architects' perception of norms regarding use of structural timber

With regard to norms about using structural timber, 89 percent of the architects strongly agreed (i.e. scores = 4 or 5) that other architects would react favorably to them using timber for structural purposes. Contractors and real estate developers were perceived as negative towards the use of structural timber.

Factor analysis

Exploratory factor analysis with pairwise exclusion of variables with missing values was performed in order to decide the least number of items to represent the interrelation between the variables. The variables used in the factor analysis satisfied assumptions about skewness and kurtosis (Pallant, 2007). Ten variables did not satisfy the assumptions, and were therefore removed from the data set.

The variables shown in Table 1 did not violate assumptions about divergence, convergence and reliability. The Keyser-Meyer-Oklín-value was 0.775, exceeding the recommended value of 0.6, and Bartlett's test of sphericity reached statistic significance ($p < 0.05$), supporting the factorability of the correlation matrix (Tabachnick & Fidell, 2007). The correlation matrix showed coefficients with correlation values above 0.3 for some of the factors. Therefore, *maximum likelihood* extraction method was used.

After an inspection of the scree plot, with the further support of parallel analysis which showed eleven components exceeding the corresponding criterion value, it was decided to keep eleven factors for further analysis. The parallel analysis was performed using software developed by Watkins (2000).

The Cronbach alpha coefficients for the different factors are listed in Table 2, with all factors exceeding the recommended alpha value of 0.7. Factor loadings below 0.45 were excluded from further analysis.

The eleven-component solution explained a total of 71.2 percent of the variance, with the three

first factors explaining 35 percent of the variance. Total variance explained for all variables are listed in Table 2. To aid in the interpretation of the components, *oblimin* rotation was performed. The rotation solution revealed a simple structure, with all factors showing several strong loadings on each component, and all components loading substantially on only one component.

Table 2: Exploratory factor analysis

	Factor										
	1	2	3	4	5	6	7	8	9	10	11
Cronbachs Alpha	0.84	0.97	0.92	0.85	0.84	0.82	0.80	0.80	0.75	0.80	0.73
Total variance explained (%)	14.80	11.38	8.05	6.98	6.15	4.92	4.32	4.11	4.05	3.33	3.06

Extraction Method: Maximum Likelihood.
 Rotation Method: Oblimin with Kaiser Normalization.

Table 3 lists the item loadings on the different factors, and includes suggestions for categorizing the factors. Items are listed in descending order according to loading strength.

Table 3: Factor names and indicators

Factor	Name	Variable in model	Indicators
1	Building height	attitude	4 storeys, 3 storeys, 5 storeys or more
2	Perceived behavioral control	perceived beh. control	easy to use, can use if want to, control the use of, qualified to use
3	Experience	experience	experience dwellings, 1 storey buildings, 2 storey buildings
4	Physical and mechanical	attitude	insulation, easy to build with, strong material, wind bracing, combine with other materials
5	Environmental	attitude	energy use during construction, binds CO2, energy use, re-use
6	Intensions	intentions	plan to use, expect to use, want to use structural timber
7	Building types	attitude	hotel and restaurant, office and commercial, public buildings and hospitals, apartment buildings, dams, bridges and tunnels
8	Aesthetical	attitude	multiple expressions, easy to adapt to design, visually appealing
9	Norms	norms	contractor, property developers, building owner, engineer, public authorities
10	Costs	attitude	price, total cost, planning cost, assembly cost
11	Fire	attitude	fire protective measures, fire regulation codes

DISCUSSION

The interpretation of the eleven components in the factor analysis was consistent with previous research suggesting experience, habit and height as important factors for architects' choice of building material (Emmitt, 2001; Emmitt & Yeomans, 2008; Denizou et al., 2007) The factor analysis indicated that the following factors influenced architects' intentions to use structural timber in urban buildings:

- Attitudes towards using structural timber in buildings three to five stories or more.
- Perceived behavioral control over the use of structural timber
- Previous experience with the use of structural timber in urban construction.

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