Sustainable Production and Consumption 39 (2023) 373–381

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Greener homes: Factors underpinning Europeans' intention to live in multi-storey wooden buildings

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ARTICLE INFO

Editor: Dr. Luca Panzone

Keywords:
Multi-storey wooden buildings
Wooden construction
Theory of planned behavior
Structural equation model
Europe

ABSTRACT

Climate policies aimed at curbing greenhouse gas emissions embodied in the built environment support the wider implementation of multi-storey wooden buildings. A body of research on public perceptions toward wood as a structural building material is emerging, but close examination of behavioral factors underpinning prospective dwelling is scarce. We used contextualized constructs from the theory of planned behavior to quantify and compare the roles of attitudes, subjective norms, and perceived behavioral control on intentions to dwell in multi-storey wooden buildings. Structural equation models were fitted to survey data from seven European countries (Austria, Denmark, Germany, Finland, Norway, Sweden, United Kingdom; n = 7056). We found that attitudes consistently explain intention to dwell in multi-storey wooden buildings. We also found a varied pattern of relationships between factors underpinning intention across countries. An implication of our results is that national-level policies aimed at promoting social acceptability of dwelling in multi-storey wooden buildings should universally address attitudes toward such novel buildings. But in some countries policies might in addition be tailored to emphasize citizens' subjective norms or perceived behavioral controls.

1. Introduction

The construction of the built environment hinges upon large natural resource flows (Rees, 1992). This demand results in a wide range of environmental pressures owing to the effects of natural resource extraction and management practices (Ioannidou et al., 2017; Olivetti and Cullen, 2018; Torres et al., 2017). The manufacturing of construction materials generates a substantial amount of greenhouse gas emissions that directly contribute to a changing climate (Hertwich et al., 2019; Hertwich, 2021; Lützkendorf et al., 2015). Estimates suggest that the manufacturing of cement, steel, and aluminum construction materials accounts for 6 % of anthropogenic carbon emissions (UNEP, 2022). The global building materials sector must halve its greenhouse gas emissions by 2030 and become a net zero emitter by 2050 in order to meet goals under the Paris Agreement (Pramreiter et al., 2023).

One approach to reducing the negative impacts associated with the built environment is increasing the use of wooden load-bearing material in multi-storey building construction (Wimmers, 2017; Churkina et al., 2020; Pramreiter et al., 2023). These buildings, often referred to as *multi-storey wooden buildings*, are possible due to technological advancements allowing engineered wood products to substitute concrete load-bearing elements (Ramage et al., 2017; Foster and Ramage, 2020). Such a substitution could lead to a downscaling of global cement production and its associated carbon emissions (Churkina et al., 2020). Increasing demand for engineered wood may also trigger a chain of events along the wood product supply chain, extending to forest management and other land use practices (Mishra et al., 2022; Heräjärvi, 2019; Hurmekoski et al., 2020). For example, increased demand for engineered wood products may support the utilization of trees and fibers with low market value (USDA, 2020; Pramreiter et al., 2023) or enable sustainable forest management practices (Heräjärvi, 2019). However, Mishra et al. (2022) caution that drastic new demand for engineered wood products in construction may lead to a loss of unprotected forest or increased reliance on forest plantations, which carry their own set of environmental and management challenges (Malkamäki et al., 2018). Despite the potential drawbacks, Pramreiter et al. (2023) maintain that

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https://doi.org/10.1016/j.spc.2023.05.030
Received 6 March 2023; Received in revised form 2 May 2023; Accepted 22 May 2023
Available online 26 May 2023

increased demand for wooden construction materials could result in net climate and other environmental benefits through afforestation and reforestation.

For many policy-makers, multi-storey wooden buildings are an appealing pathway to simultaneously reduce greenhouse gas emissions and advance circular bioeconomy goals (e.g., Vihemäki et al., 2019; Toivonen et al., 2021). A challenge to this pathway is that multi-storey wooden buildings remain a niche technological innovation that competes against other well-established construction practices, chiefly concrete multistorey building production (Mahapatra et al., 2012). To date, there are a limited number of multi-storey wooden buildings finalized across the globe (e.g., see: Franzini, 2022: Appendix A; Salvadori, 2021). The wider uptake of multi-storey wooden buildings requires policymakers to institute regulatory and market-based interventions and promote societal acceptance (Mahapatra and Gustavsson, 2008; Mahapatra et al., 2012; Wimmers, 2017).

Promoting societal acceptance requires understanding whether citizens are willing to inhabit multi-storey wooden buildings and discerning the underlying reasons for this (un)willingness. To date, citizens' acceptance of multi-storey wooden buildings remains underexplored. Previous studies (e.g., Roos et al., 2022; Aguilar et al., 2023; Viholainen et al., 2020) provide a baseline for the perceptions citizens hold toward multi-storey wooden buildings, but the relationships underlying the intention to live in multi-storey wooden buildings have not been tested. Establishing these links would be valuable to identify factors explaining the behavior of citizens toward dwelling in these buildings and motivate them dwell there.

Here, we applied the theory of planned behavior (Ajzen, 1991) to study the behavioral intention to live in multi-storey wooden buildings. It posits that human behavior is driven by a combination of subjective perceptions, including attitudes, subjective norms, and behavioral controls. We used structural equation modeling to analyze responses from a survey of seven thousand citizens across seven European countries in order to answer the following research questions: (1) Do attitudes toward living in multi-storey wooden buildings, subjective norms regarding living in multi-storey wooden buildings, and perceived behavioral controls over living in multi-storey wooden buildings explain stated intentions to live in them? (2) Do factors latent to the intention to live in a multi-storey wooden building differ across European nations? Our findings advance behavioral knowledge underlying the choice of multi-storey wooden buildings as housing alternative. Our interpretations strive to provide European policymakers with practical information that could enhance social acceptability of these novel buildings.

2. Literature review

2.1. Citizen's acceptance of wood as a load-bearing housing material

Wood is one of the oldest construction materials, but fears of its combustibility led to its wide replacement with non-combustible elements (Wimmers, 2017). Common load-bearing construction materials used to carry and transfer a building's weight to the ground (e.g., walls, columns, beams) include a combination of steel, bricks and concrete. The contemporary use of wood as a construction material has focused much on non-structural applications, often justified for its aesthetic benefits, in spite of physical properties such as its lightweight with a high strength-to-weight ratio. Nonetheless, wood is amply used as a load-bearing material in low-rise building structures in parts of Asia, in North America and with a strong tradition in Fennoscandic European countries (Duguma and Hager, 2010; Wimmers, 2017). Many recognize the potential benefits of the wider use of wood as a load-bearing material in these markets and other regions of the world (Goverse et al., 2001; Wimmers, 2017; Churkina et al., 2020).

The investigation of citizens' acceptance of wood as a load-bearing housing material has emerged a research thrust in recent years with a number of studies conducted in forest-rich Fennoscandic European countries. Schauerte (2013) suggests that among selected interviewees in Sweden the cost of construction was the most important attribute as an opportunity and barrier to the use of wood in multi-storey buildings. Høibo et al. (2015) found citizens with stronger environmental values had a higher preference for wood as a construction material among Norwegians living in Oslo. Viholainen et al. (2020) found everyday usability and durability of residential materials of wooden buildings are valued among Finnish homeowners who lived in a wooden house for more than a year. Kylkilahti et al. (2020) discovered Finnish citizens appreciate attributes of multi-storey wooden buildings differently by their consumption styles in an explorative study with university students. Lähtinen et al. (2021) elicited housing values and analyzed their association with prejudices against multi-storey wooden buildings in Denmark, Finland, Norway, and Sweden. They report that prejudices against wood as a load-bearing material may not be related directly to wood properties nor building technologies, but to lifestyle preferences. Roos et al. (2022) studied the relationship between perception of sustainability, quality, and design of multi-storey wooden buildings and preference for such buildings among Finnish and Swedish consumers. Vehola et al. (2022) discerned that people with greater concerns over the seriousness of climate change were more likely to have positive views on using wood as a construction material in Finland and Sweden. Roos et al. (2023) analyzed socio-economic and attitudinal factors that affect Finnish and Swedish consumers' beliefs of the climate benefits and disadvantages offered by multi-storey wooden buildings.

Several studies included non-Nordic European countries in the analyses of perceptions toward multi-storey wood buildings. Among them, Viholainen et al. (2021) suggest that consumers generally approve using wood as a construction material but found country-specific differences in perceptions based on responses from a panel comprised of respondents from Austria, Denmark, Germany, Finland, Norway, Sweden, and the United Kingdom. Aguilar et al. (2023), after analyzing socio-economic and attitudinal determinants to preferences toward utilizing wood as a load-bearing material using a panel of the same lists of countries as Viholainen et al. (2021), report that past experience and knowledge dominated higher preferences toward wood over other load-bearing materials. In the US, Larasatie et al. (2018) report that American respondents deem multi-storey wooden buildings to be visually pleasing and welcome the use of renewable building materials, but also expressed concerns over their greater fire risks than other non-combustible materials.

Our study advances the current state of knowledge by investigating structural relationships between perceptions toward multi-storey wooden buildings and dwelling intentions. We estimated these relationships underpinning intention to live in a multi-storey wooden building framed by the theory of planned behavior as our theoretical framework. To the best of our knowledge, this is the first application of the theory of planned behavior to examine citizen's acceptance of wood as a load-bearing housing material.

2.2. Theory of planned behavior

The theory of planned behavior offers a framework positing that human behavioral actions are contingent on an individual's intention to engage in a behavior (Ajzen, 1991). Intentions represent motivational factors that influence a behavior such as willingness and conscious plans to perform the behavior; as a general principle, intention and the behavioral action have a positive relationship (Ajzen, 1991; Conner and Armitage, 1998). Ability to predict behavioral action using intention as a proxy is a strength of this theory since true behavioral actions are not revealed until an action is carried out.

The theory of planned behavior has roots in the theory of reasoned action (Ajzen and Fishbein, 1980). The latter models the intention to engage in a behavior as a function of attitudes toward the behavior (ATT) and subjective norms regarding the behavior (SN). ATT represents the degree to which the behavior is viewed favorably or unfavorably. SN represents the perceived social pressure to perform the behavior. A drawback of the theory of reasoned action is that it is only applicable to volitional behaviors. It provides a poor explanation and prediction of behaviors that require non-motivational factors to be performed, such as skills or resources that are not freely available to the individual (Conner and Armitage, 1998). The theory of planned behavior overcomes this drawback by recognizing perceived behavioral controls over the behavior (PBC). PBC represents the degree of an individual's confidence in his or her ability to perform the behavior. Jointly, ATT, SN, and PBC explain and predict intention; besides, PBC can serve as a direct predictor of the behavioral achievement (Ajzen, 1991). Inclusion of PBC has expanded the applicability of this model to non-voluntary behaviors (Conner and Armitage, 1998). To-date, the theory of planned behavior has been applied to investigate a variety of behaviors in a multitude of fields and found to hold a high degree of empirical validation (Ajzen, 2020; Bosnjak et al., 2020). Moreover, the theory of planned behavior also recognizes that ATT, SN, and PBC may have variable relationships with intention across different contexts (Ajzen, 1991), such as those found across nations.

The theory of planned behavior can be a viable alternative to utility models eliciting prospective consumer behavior from (stated) preferences (Ajzen, 2011, 2016). Utility models typically assess consumer attitudes and preferences in decision making, but rarely consider the role of normative pressure or preventative constraints to decision making (Ajzen, 2016). This is a limitation to housing studies research, because housing choices are shaped by individual preferences (e.g., ATT), but limited by contextual market constraints (e.g., PBC) (Wong, 2002; Jansen et al., 2011; Marsh and Gibb, 2011). Therefore, controlling for ATT, SN, and PBC provides important nuance to a complex phenomenon. Despite this advantage, the theory of planned behavior has seldom been applied in housing research. Some exceptions are found among housing studies researching intentions to purchase sustainable or green housing (Tan, 2013; Judge et al., 2019). In the context of multi-storey wooden buildings, researchers such as Aguilar et al. (2023), Høibo et al. (2015), Gold and Rubik (2009) have yet to explicitly control for subjective norms or perceived behavioral control.

In our research, we contextualized constructs commonly used in past applications of the theory of planned behavior to our prospective behavior of interest: intention to live in multi-storey wooden buildings. Henceforth, ATT denotes attitude toward living in multi-storey wooden building; SN denotes subjective norms regarding living in multi-storey wooden building; PBC denotes the perceived behavioral controls over living in multi-storey wooden building; and INT denotes the intention to live in multi-storey wooden building. We tested whether ATT, PBC, and SN are statistically associated with INT. It is worth noting that we did not evaluate the relationship between PBC and actual or observed residence in multi-storey wooden buildings, but only based on stated intentions to live in them. As the offering of multi-storey wooden building as a residential alternative grows, actual dwelling as an observed behavior could be studied in the future. Moreover, we emphasize our study of structural relationships over causal inferences. Sussman and Gifford (2019) called for caution in interpreting TPB in a uni-directional causal manner due to the possibility of reciprocal relationships between ATT, PBC, SN and INT, and potential endogeneity in cross-sectional models. Hence, given the cross-sectional nature of our data we cannot make any causal inferences. This and other empirical issues such as reverse-directional relationships (i.e. whether INT influences ATT, PBC, and SN) will be investigated in future research.

3. Methods

3.1. Survey instrument

This study is part of the project 'Nordic Forest-Based Sector in Bioeconomy', which focused on the role of forests and wood products in the transition to a sustainable bioeconomy. The data described within this manuscript are part of a larger questionnaire focused on citizens' perceptions toward multi-storey wooden buildings. The questionnaire was developed in English, subsequently translated to six additional languages by native-speaking experts, and pre-tested with native speakers prior to data collection. The final questionnaire was deployed in Austria, Denmark, Germany, Finland, Norway, Sweden, and the United Kingdom. A full copy of the questionnaire is available in the first section of the Supplementary Information (SI).

To frame our study, the questionnaire defined a *multi-storey building* as any building with a minimum of three floors, and *multi-storey wooden building* refers to a multi-storey building with a wooden load-bearing structure (Aguilar et al., 2023). Participants were informed that the structural load-bearing materials of a multistorey building could be made of several materials, including engineered wood products, brick, concrete, and steel. *Engineered wood* was defined as a material composed primarily of wood or wood in combination with other materials.

Past work examining public preferences toward multi-storey wooden buildings (Section 2.2) served as the foundation to our crafting of questions to study intention to live in a multi-storey wooden building. It is important to note that, as stressed by Fishbein and Ajzen (2011), there is no standard questionnaire for the application of the theory of planned behavior and specific questions should be selected for their appropriateness to the behavior in question, the target population, and time period, among others. We developed 19 questions in total, of which five measured ATT, five measured SN, five measured PBC, and four measured INT. Kline (1998) has previously suggested the inclusion of about five items to identify a concept in structural equation modeling. Though subject to controversy, we included both positively- and negatively-worded items within each construct as it is recommended to reduce response bias (Churchill, 1979). All responses were recorded using a unipolar 9-point scale (i.e., 1 = Strongly disagree, 9 = Strongly agree). Both unipolar and bipolar scales in the context of theory of planned behavior are equally justified (Ajzen, 1991). The full questionnaire also included a battery of socio-demographic and open-ended questions.

3.2. Data collection

Data collection was conducted online by the market research company Syno International (Syno, 2022) using consumer panels between May and June 2021. Consumer panels may be subject to bias (e.g., self-selection) that can challenge the integrity of a sample (Chandler et al., 2019; Smith et al., 2016). On the other hand, online consumer panels offer an affordable alternative to collecting data across multiple countries applying identical sampling windows and commonly have lower item non-response rates relative to other methods, which will also come with issues of self-selection and other sources of bias (Kwak and Radler, 2002; Barrios et al., 2011). Previous studies have successfully applied consumer panels to make market inferences about the wood products sector (e.g., Aguilar and Cai, 2010).

A link to the survey was distributed via email to a demographically representative sample of residents 18 years of age and older in each of the seven selected countries. Samples were drawn from Syno International's existing panels based on age, gender, and urban-rural dwelling. Data collection quality controls included the avoidance of multiple responses per participant and survey links shared only within socio-demographic segments to meet pre-determined study quotas (1000 complete questionnaires per country). Data collection and archiving followed European General Data Protection Regulation and complied with ISO quality standard 20252 for market and social research (ISO, 2019). On average, 42 % of individuals who received an email invitation to participate in the study completed the questionnaire. Additional details regarding survey response rates are available in the SI (Section 2). All data used in this manuscript are available online at the Harvard Dataverse [https://doi.org/10.7910/DVN/KTNTIL].

3.3. Statistical analyses

We parameterized structural relationships among ATT, SN, PBC and INT (Fig. 1) using structural equation models (SEMs). A SEM is comprised of a measurement and a structural model (Hair et al., 2010). The measurement model quantifies exogenous and endogenous latent constructs using observable items. The structural model describes the relationship between exogenous and endogenous latent constructs. Following Lattin et al. (2003), a measurement model can be expressed as:

$$X = \Xi \Lambda_x + \delta \tag{1}$$

$$Y = H \Lambda_y + \epsilon, \tag{2}$$

where Eqs. (1) and (2) denote exogenous and endogenous constructs, respectively. X and Y represent matrices of observed items, Ξ and H are matrices of latent constructs, Λ_x and Λ_y are matrices of factor loadings of observed items to latent constructs, and δ and ϵ are random error matrices. The structural model can be expressed as:

$$HB = \Xi \Gamma + u, \tag{3}$$

where B and Γ are coefficient matrices that capture the relationship between endogenous and exogenous latent constructs, and u is a measurement error matrix.

Our SEM was specified according to the contextualized theory of planned behavior constructs, where ATT, SN, and PBC are interrelated latent constructs forming INT. Our final specification included 11 reflective items from the original pool of 19 measures (see section 3 in the SI for additional information). We arrived at this selection after omitting prospective items that shared low internal consistency as indicated by lower Cronbach's alpha values (Anderson and Gerbing, 1988) as was the case for negatively-worded items (e.g., "People whose opinions I value prefer that I do not live in a multi-storey wooden building"). The adequacy of the final 11 items was ascertained through validity measures including standardized factor loadings, discriminant validity, composite reliability, and the average variance extracted after confirmatory factor analyses of the measurement model. Statistical thresholds of these validity measures are disclosed in the fourth section of the SI.

SEMs were estimated for the entire dataset and for each country in our sample. These estimations allowed us to test the ability of SEMs to assess structural ATT, SN and PBC relationships across all countries and by country-specific context. All SEMs were estimated using maximum likelihood. Other SEM estimation procedures include generalized least squares, weighted least squares, and partial least squares (see e.g., Hair et al., 2010), but we employed maximum likelihood because it is more robust in the presence of non-normality in large datasets with few missing values (Tanaka, 1984). Note that we conducted a robustness test by estimating SEMs using diagonally weighted least square mean-variance adjusted estimator (see SI section 5 for details). We calculated log-likelihood ratio tests to examine statistically-significant differences between ATT, SN and PBC structural path coefficients within a particular SEM (Gonzalez and Griffin, 2001). These tests helped guide our interpretations regarding the tailoring of policy interventions by country. We first estimated a full SEM model without parameter constraints. Then, we estimated a restricted model with the constraint that two parameters in Eq. (3) ($\Gamma_i = \Gamma_j$; $i \neq j$; $i,j =$ ATT, SN, PBC) were equal. We estimated the χ^2 probability of log-likelihood ratio of the full and restricted models to test the null hypothesis:

$$\Gamma_i - \Gamma_j = 0, \tag{4}$$

with the alternative being $\Gamma_i - \Gamma_j \neq 0$.

4. Results

4.1. Descriptive statistics

Our sample held equal gender representation, with the highest proportion of males in Austria (50.8 %) and the lowest proportion in the United Kingdom (48.2 %). The average respondent age was 45.0, the highest sample mean found in Denmark (47.3) and the lowest in Austria (38.6). The average household size was between two to three individuals, with about 30 % of respondents having at least one child. Most respondents (39.9 %) resided in a metropolitan environment of at least 100,000 inhabitants, of which the Finnish (47.4 %) and Danish (32.8 %) samples had the largest and smallest proportions, respectively. About 44 % of respondents had obtained a bachelor's or equivalent degree, with the highest and lowest proportions found, respectively, in

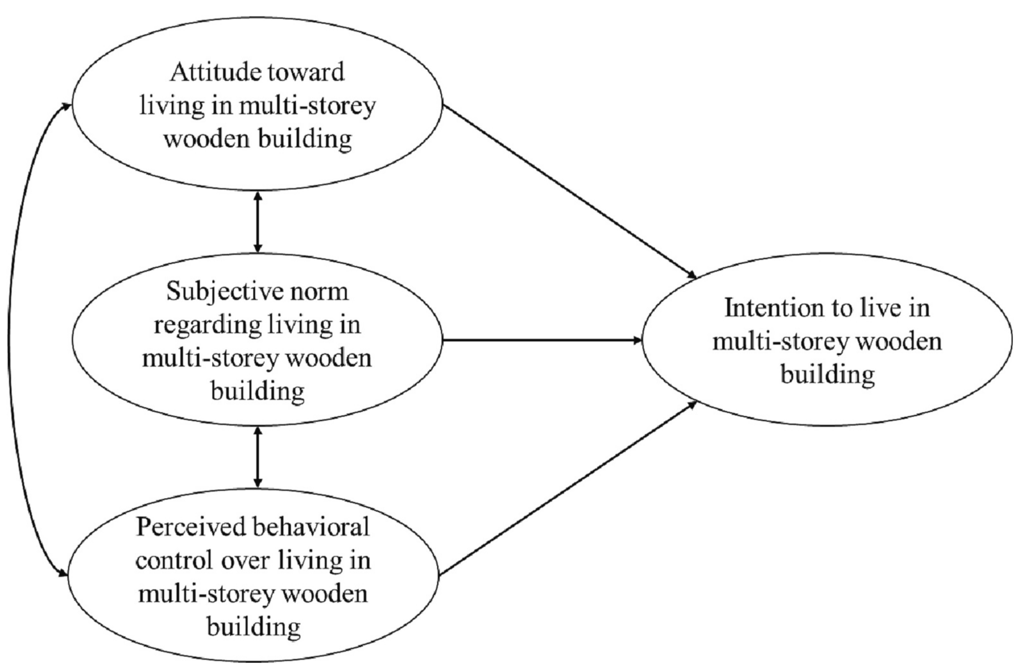

Fig. 1. Contextualized theory of planned behavior to living in multi-storey wooden building. Adapted from Ajzen (1991).

Norway (54.8 %) and Germany (36.2 %). These values are higher than the values reported in official statistics at the EU level among adults with tertiary education attainment in 18–69 years, which were 32.5 % for Austria, 36.2 % for Denmark, 28.1 % for Germany, 37.0 % for Finland, 42.2 % for Norway, 41.4 % for Sweden in year 2021 and 41.2 % for the United Kingdom in year 2019 (Eurostat, 2022). See SI section 6 for additional details on the sample demographic profile are disclosed. With the caveat of likely overrepresentation of individuals with higher education level than adult population averages, commonly found in online surveys (Shih and Xitao, 2008), our sample represented well countries' adult population profiles.

4.2. Structural Equation Models

Standardized factor loadings for the SEM estimated using the whole seven-country dataset are presented in Table 1. Heterotrait-Monotrait discriminant validity values <0.85 indicate the latent constructs were statistically distinctive from one another (Henseler et al., 2015). The standardized factor loadings were all strongly significant ($p < 0.001$). Overall, the model met acceptable fitness values commonly found in the literature (see: Hair et al., 2010), with the exception that PBC's average variance extracted (0.44) was lower than the commonly accepted threshold (0.50). PBC's composite reliability (0.69) was slightly low but still very close to the commonly accepted threshold of 0.70. A low average variance extracted of PBC indicates that the variance captured by PBC is lower than the variance attributable to measurement errors. This might question the convergent validity of PBC and items comprising this construct (Fornell and Larcker, 1981), with a common empirical remedy being to drop an item that lowers its convergent validity. We chose to keep all three items comprising the PBC measure because each of them represents important theoretical aspects: perceived current and future availability of multi-storey wooden buildings (PBC1, PBC2), and adequacy of information to make a decision to dwell in multi-storey wooden building (PBC3). Given that all the other fitness indicators met commonly accepted thresholds, we deemed the slightly low convergent validity of PBC to be an empirical challenge that does not compromise our findings. As a measure of this premise, we dropped PBC3 from the PBC and estimated the measurement model again. Though it provided a sufficient average extracted variance value of PBC (0.541), it slightly decreased the composite reliability to 0.67, and the discriminant validity between PBC against the other constructs. Fitness indicators of this alternative measurement model are provided in SI section 7.

The SEMs structural path coefficients, goodness-of-fit measures, and log-likelihood ratio tests of equality are shown in Table 2 for the whole dataset and individual countries. Goodness-of-fit measures fell within acceptable ranges, except for the root mean square error of approximation in the SEMs for Finland and the United Kingdom. Data from both countries showed slightly higher values than the acceptable threshold (> 0.80). Results of SEM estimations using diagonally weighted least square mean-variance adjusted estimator are available in section 8 of the SI.

The structural path coefficients values and statistical significance varied between datasets. ATT held the strongest relationship to INT as denoted by the larger coefficients for their structural paths, which is consistent with past reports investigating samples drawn from the same countries (Aguilar et al., 2023). ATT was statistically significant across the whole dataset and in each country. This relationship (Fishbein and Ajzen, 2011) indicates that positive attitudes toward dwelling in a multi-storey wooden building were associated with a positive intention to live in one, implying that studies on consumer perceptions about multi-storey wooden buildings are important probes to assess if consumers will be motivated to live in them. SN was statistically significant for the whole dataset and all countries except Austria and Germany. A statistically significant relationship between SN and INT likely indicates that citizens intend to live in multi-storey wooden buildings if influential referents' (e.g., family, friends) approve of the idea. This is in line with previous consumer housing research suggesting that household family members play a critical role in housing selection processes due to their involvement in the negotiation process (Levy et al., 2008). PBC was statistically significant for the whole dataset and all subgroups except Denmark, Finland or Norway. A statistically-significant effect between PBC and INT likely suggests that if a prospective citizen believes they can access the necessary resources to live in a multi-storey wooden building, they will have stronger intention to dwell in the building.

Log-likelihood ratio tests of equality varied depending on the dataset used. When testing equality of effects between paths to INT, we found that ATT and SN were different within all countries, with the exceptions of Finland and Norway. Tests reveal that structural path effects between ATT and PBC were only statistically significantly different in the case of Finland and Norway. The PBC coefficient was statistically significantly different from SN in all countries except the United Kingdom. Such heterogeneity found between countries may have various underlying causes worthy of future investigation. We refrain from speculating about what may be driving such differences between countries and focus on how these findings may be of value to European public policymakers interested in enhancing the social acceptance and demand for multi-storey wooden buildings.

Table 1
Standardized factor loadings, composite reliability (CR), average variance extracted (AVE) and discriminant validity of latent constructs in the measurement model (whole dataset, n = 7053).

Latent constructs	Items	Standardized factor loadings[†]	CR	AVE	Discriminant validity[a]			
					ATT	SN	PBC	INT
Attitude (ATT)	ATT1	0.72***	0.84	0.64		0.63	0.60	0.67
	ATT2	0.87***						
	ATT3	0.82***						
Subjective norm (SN)	SN1	0.66***	0.78	0.54			0.78	0.69
	SN2	0.77***						
	SN3	0.78***						
Perceived behavioral control (PBC)	PBC1	0.62***	0.69	0.44				0.66
	PBC2	0.76***						
	PBC3	0.60***						
Intention (INT)	INT1	0.83***	0.83	0.71				
	INT2	0.85***						

CR = Composite reliability (fitness threshold: >0.7).
AVE = Average variance extracted (fitness threshold: >0.5).
[†] Statistical threshold: >0.5; Type-I errors: * < 0.05, ** < 0.01, *** < 0.001.
[a] Heterotrait-Monotrait discriminant validity ratio (fitness threshold <0.85).

Table 2
Standardized structural path coefficients, robust standard errors, type I errors, log-likelihood ratio (LR) tests, and goodness-of-fit of estimated structural equation models using maximum likelihood estimation.

	All	AT	DE	DK	FI	NO	SE	UK
Sample size	(7053)	(1005)	(1006)	(1010)	(1009)	(1007)	(1008)	(1008)
Structural paths[a]								
ATT → INT	0.33***	0.38***	0.40***	0.21***	0.54***	0.27***	0.26***	0.17**
	(<0.001)	(0.052)	(0.046)	(0.050)	(0.055)	(0.074)	(0.065)	(0.053)
SN → INT	0.29***	0.15	0.12	0.44***	0.43***	0.39***	0.18**	0.46***
	(<0.001)	(0.085)	(0.063)	(0.069)	(0.120)	(0.088)	(0.068)	(0.086)
PBC → INT	0.24***	0.35**	0.43***	0.13	−0.05	0.10	0.35**	0.24**
	(<0.001)	(0.104)	(0.070)	(0.072)	(0.117)	(0.082)	(0.098)	(0.074)
LR test[b]								
ATT = SN	Reject	Reject	Reject	Reject	✓	✓	Reject	Reject
ATT = PBC	Reject	✓	✓	✓	Reject	Reject	✓	✓
SN = PBC	✓	Reject	Reject	Reject	Reject	Reject	Reject	✓
Goodness-of-fit								
RMSEA	0.063	0.067	0.061	0.070	0.085	0.065	0.067	0.087
GFI	0.967	0.955	0.966	0.955	0.940	0.952	0.961	0.942
CFI	0.968	0.963	0.973	0.962	0.947	0.961	0.967	0.948
TLI	0.953	0.946	0.961	0.945	0.923	0.943	0.953	0.925
SRMR	0.034	0.038	0.033	0.040	0.046	0.037	0.039	0.043

Type-I errors (* < 0.05, ** < 0.01, *** < 0.001).
[a] Robust standard errors.
[b] LR test based on non-robust standard errors.

5. Discussion

5.1. Policy implications: behavioral factors underpinning citizens' intention to live in multi-storey wooden buildings

The statistical significance of ATT, SN, and PBC in the whole seven-country SEM indicates that stated intentions to dwell in these novel wooden buildings may be explained by all three determinants identified by the theory of planned behavior. Differences between and within countries reflect on how the same theory recognizes that ATT, SN, and PBC may have variable relationships with INT across different contexts (Ajzen, 1991). Table 3 summarizes possible approaches to enhance the behavioral prospects for citizens to live in multi-storey wooden buildings and identifies in which countries each approach would on average be most effective guided by our SEM results.

Attitudes are formed according to a person's salient evaluations of attributes of the behavior (Fishbein and Ajzen, 2011). Thus, it is important for policymakers to deliver accurate information about multi-storey wooden buildings relevant to marked concerns of public to promote positive attitudes toward multi-storey wooden buildings. The existing literature suggest that consumers are concerned about the fire safety, structural durability, and environmental sustainability of multi-storey wooden buildings (e.g., Larasatie et al., 2018; Viholainen et al., 2020; Lähtinen et al., 2023). Limited knowledge of public about multi-storey wooden buildings (Kylkilahti et al., 2020; Larasatie et al., 2018) may result in misconceptions that contribute to negative attitudes toward multi-storey wooded buildings (Roos et al., 2022). Accordingly, an effective strategy to promote positive attitudes might include (1) ascertaining the most important attributes of multi-storey wooden buildings that saliently shape consumer attitudes, (2) identifying misconceptions about selected important attributes among the public in focus, and (3) rectifying misconceptions (e.g. through targeted information campaigns) existing in the public in focus. Given that ATT was significant in all the country-specific models, such a strategy might be tenable regardless of country-specific contexts.

Information channels, such as traditional media and social networks, may be important normative references shaping consumers' perception. Past research reports that real estate agents and developers may serve as key references due to their intermediary role promoting housing options in the context of multi-storey wooden buildings (Viholainen et al., 2020; Lähtinen et al., 2023). Therefore, policymakers in countries with a significant SN path coefficient to INT are advised to work closely with influential intermediaries (e.g. real estate agents). Policy initiatives may include (1) the use of information campaigns to raise recognition about multi-storey wooden buildings in the housing market, and (2) encourage real estate agents to communicate positively about this housing alternative to homebuyers.

Critically, PBC captures *subjective* perceptions about control - and not *actual* control - that constrain INT. To present a hypothetical situation, potential dwellers may subjectively believe a multi-storey wooden building is too expensive to purchase thereby driving down their intention to live in the building, while in actuality the market price was within their budget. Conversely, dwellers may believe multi-storey wooden buildings are cheap and affordable and thereby intend to live in them. However, dwellers might be constrained by market prices. This hypothetical example indicates that a statistical significant PBC reflects those subjective beliefs about constraints, regardless of what the actual constraints are. Limited information has been identified as a major constraint to the housing decision making process (e.g., Marsh and Gibb, 2011), thereby implying that subjective perceptions about limited information may lead to poor PBC. Based on this, policymakers from countries where PBC is a significant construct should consider the use of

Table 3
Summary of policy recommendations and possible strategies to support prospective citizens' intention to live in multi-storey wooden buildings.

Policy recommendation[a]	AT	DE	DK	FI	NO	SE	UK
ATT: Information campaigns targeting citizen misconceptions about wood	✓	✓	✓	✓	✓	✓	✓
SN: Information campaigns targeting real-estate agents' knowledge on wood and best practices for discuss wooden homes with clients	X	X	✓	✓	✓	✓	✓
PBC: Accessible wooden construction information platforms for citizens	✓	✓	X	X	X	✓	✓

[a] '✓' indicates that the policy approach is recommended for a particular country; 'X' indicates that the approach is likely unsuitable for that particular country.

public information platforms to motivate consumer intentions. In some cases, these information platforms may generate a double benefit, if the new information also rectifies misconceptions that lead to negative attitudes.

5.2. Policy implications: other contextual actions to advance citizens' intention to live in multi-storey wooden buildings

Citizens are often met with numerous constraints in their ability to find desirable housing choices (Wong, 2002; Marsh and Gibb, 2011). Past studies have identified a low level of citizens' self-reported understanding and knowledge about multi-storey wooden buildings (e.g., Larasatie et al., 2018; Viholainen et al., 2020; Kylkilahti et al., 2020) as a major constraint to the social acceptance of these buildings. Our results also point to limited awareness and we have noted informational actions targeting citizens and real estate agents to possibly advance positive INT. Here, we point to similar informational efforts across other decision-makers who can facilitate or obstruct the availability of multi-storey wooden buildings. The development and adoption of multi-storey wooden buildings is complex, among others, affected by public regulations, companies' business choices, and path dependency within the building sector (Hildebrandt et al., 2017; Lähtinen et al., 2019). Business practices, along with technological progress and an evolving regulatory framework, have enabled the expanded use of wood in load-bearing structures (Pelli and Lähtinen, 2020), but some have noted the lack of knowledge or hesitation to adopt (e.g., Roos et al., 2022; Hemström et al., 2011; Markström et al., 2018) or approve of (e.g., Franzini, 2022) the use of wood as a structural material as a general and major barrier to adoption in Europe. Context-specific gatekeepers might be identified and targeted for awareness campaigns to overcome other social barriers to expand the actual building of multi-storey wooden buildings.

In addition to communication-based strategies, other market-based interventions to address the cost-competitiveness of wood as a structural building material might be necessary. Some are already underway. For example, the EU's Carbon Border Adjustment Mechanism (European Commission, 2022) adopted by the EU Council and Parliament on 13 December 2022 aims to levy a carbon tax to imports of selected carbon intensive items carrying the greatest risk of carbon leakage beyond EU borders (cement, iron and steel, aluminum, fertilizers, electricity and hydrogen). The Mechanism is designed to support the decarbonization of EU industry and its transitional phase is expected to start by 1 October 2023. *Ex ante* evaluations of the Mechanism by the United Nations Conference on Trade and Development (2021) suggest it could favor production in developed countries that are relatively carbon efficient, could help reduce carbon emissions across the EU and beyond its borders, but overall reduction might be only a small percentage of global carbon emissions. Beyond carbon taxes over imported materials, potential carbon taxes levied based on all net carbon emissions could increase the economic competitiveness of wooden buildings due primarily to lower costs for energy used to manufacture wood construction materials (Sathre and Gustavsson, 2007). Expansion in the use of long-live engineering wood in the construction sector could lower the cost of reducing carbon emissions through the substitution of non-renewable products (Winchester and Reilly, 2020) also advancing European goals for a stronger bioeconomy.

5.3. Limitations and future research

There are several caveats inherent to our research. The first includes potential biases introduced when collecting self-reported information through questionnaires written in six different languages. This is a common challenge in multilingual surveys, as complex questions may lead to differing interpretations among respondents. We attempted to ameliorate this shortcoming through careful survey translations and language checks by bilingual experts. Another caveat relates to the measurements applied in the study. In later works, Fishbein and Ajzen (2011) have reformulated the theory of planned behavior into the theory of reasoned action. The latter model posits that ATT, SN, and PBC are respectively formed by behavioral beliefs, norm beliefs, and control beliefs. These beliefs constitute the formative measures for ATT, SN, and PBC. Ajzen (2020) maintains that ATT, SN, and PBC are best measured through reflective indicators. For example, reflective measures of attitude are collected using semantic differentials (e.g., Fishbein and Ajzen, 2011). The items collected for our research represented a mix of both reflective and formative measures. It is possible that mixing of reflective and formative measures contributed to relatively low measures of internal consistency among the indicators ultimately omitted from the study, which resulted in the relatively low Cronbach's alpha of the PBC construct. Beyond such caveats, the SEMs presented here represent stated behavioral intentions among our sample of prospective dwellers as of May–June 2021. As the supply of multi-storey wooden building is likely to grow in the future, their wider availability and likely increased awareness and knowledge among prospective dwellers will warrant the future examination of the structural relationships we have reported.

Future research should identify the salient beliefs underlying the ATT, SN, and PBC driving intentions to dwell in multi-storey wooden buildings. For example, residential attributes forming ATT toward multi-storey wooden buildings deserves greater research attention, as Franzini (2022) found that technical attributes of buildings are more important than evaluations of environmental attributes among Finnish municipal civil servants. Whether similar patterns are observed across the public requires further investigation. By extension, future research should ascertain which specific referents groups drive SN and what resources can effectively drive PBC. Of additional value, future efforts might also be well invested in determining possible co-causality and using formal causality tests on INT of ATT, SN, PB beyond the structural relationships reported here.

6. Conclusions

Transitioning toward a built environment that incorporates sustainable natural resource flows will require institutional frameworks and public acceptance. In the case of multi-storey wooden buildings, it is apparent that further work addressing shortcomings in public perceptions is necessary. To this end, this research identified that citizens' intention to reside in multistorey wooden buildings is driven by attitudes, subjective norms, and perceived behavioral control. However, the relationship between these perceptions is complex and varied across multiple European countries. Given this variation, and in the context of housing as a complex decision, we propose three target strategies which can be adjusted according to the most important determinants of TPB in that geographical context. Where ATT is significant, policy strategies to rectify misconceptions about multi-storey wooden buildings would be highly effective. In countries where SN is significant, we recommend working with influential referent groups (e.g., real estate agents) to increase the social appeal of multi-storey wooden buildings, Where PBC is significant, policymakers should prioritize accessible information platforms for citizens. We recommend future studies could investigate salient drivers underpinning the formation of ATT, SN, and PBC, and these to be contextualized to particular national market conditions in order to better guide policies promoting multi-storey wooden buildings.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was partly funded by the Nordic Forest Research (SamNordisk Skogsforskning) through financial support for the project

'Nordic Forest-Based Sector in Bioeconomy'. The views expressed in this manuscript are those of its authors and may not reflect those of the Nordic Forest Research. Any errors are the responsibility of the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2023.05.030.

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