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Material Characteristics and Adoption Challenges Affecting Intention to Use Engineered Wood for Housing: The Role of Ecological Perception

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ABSTRACT

Engineered wood has significant potential to support low-carbon construction in Indonesia; however, its adoption in the residential sector remains limited due to uneven knowledge distribution, concerns regarding durability, and limited ecological literacy. This study examines how material characteristics and adoption barriers influence users' intention to adopt engineered wood, and whether ecological perception mediates these relationships within the Indonesian context. A mixed-methods sequential explanatory approach was employed to integrate qualitative insights into perceptual attributes with quantitative modeling of their relationships, enabling a systematic examination of adoption mechanisms rather than a purely descriptive assessment. Data were analyzed using Exploratory Factor Analysis and multiple regression. The results show that knowledge of engineered wood remains segmented, with higher levels observed among highly educated respondents, formal-sector workers, and urban residents. The findings further indicate that ecological perception emerges as a key explanatory factor shaping adoption intention, exceeding the influence of purely technical attributes. Material perceptions are positively shaped by technical attributes such as strength, dimensional stability, and thermal performance, while concerns related to long-term durability and initial cost remain key barriers to adoption. User interest is influenced not only by technical understanding but also by ecological awareness and professional experience, underscoring the importance of social and psychological factors in material selection. Overall, the results clarify the mechanisms through which perceptual and technical factors interact, providing evidence-based insights for policies and strategies aimed at accelerating the adoption of engineered wood in Indonesia's low-carbon housing development.

Keywords: adoption, carbon, engineered, perception, wood

1. Introduction

The construction industry is one of the sectors with the highest global carbon emission contributions. It accounts for more than one-third of global energy-related emissions and represents a major challenge in achieving climate change mitigation targets [1][2]. These high emission levels are largely attributed to the dominant use of concrete and steel, which exhibit high carbon intensity throughout the building life cycle [3], [4]. This condition has intensified the demand for more environmentally friendly and sustainable construction materials.

In this context, engineered wood has emerged as a potential solution to support the development of low-carbon buildings in Indonesia [4]. Numerous international studies indicate that engineered wood has substantial potential to reduce carbon emissions through carbon sequestration mechanisms and by decreasing reliance on energy-intensive materials. Partial substitution of concrete and steel with engineered wood can reduce life-cycle emissions by approximately 30–50% [5][6]. Products such as cross-laminated timber (CLT), glued laminated timber (Glulam), and laminated veneer lumber (LVL) have also been shown to possess a lower carbon footprint compared to conventional materials, depending on the carbon accounting methodology employed [2][7][8].

From a technical perspective, engineered wood offers high structural performance, energy efficiency, and considerable application flexibility [9][10]. From a design standpoint, the aesthetic qualities and visual warmth of engineered wood provide added value in sustainable building design [11]. Furthermore, the integration of digital technologies such as Building Information Modeling (BIM) has facilitated more efficient planning and construction processes involving engineered wood systems [12]. Despite these advantages, technical performance alone has been shown to be insufficient to ensure material adoption, particularly when users perceive risks related to durability, maintenance, or contextual suitability.

From the perspective of user behavior, existing research suggests that environmental awareness and ecological perception play a critical role in shaping interest in adopting environmentally friendly products [13][14][15]. Ecological perception influences how users cognitively evaluate material attributes and how they emotionally respond to environmental claims, thereby affecting adoption intention beyond purely technical considerations[16]. Accordingly, this study assumes that stronger ecological perception is positively associated with users' intention to adopt engineered wood.

Despite the growing body of global evidence, most of this evidence is derived from European and North American contexts [8], where regulatory frameworks, climatic conditions, and user familiarity with timber construction differ substantially from those in tropical countries such as Indonesia, leaving their applicability to tropical climates such as Indonesia insufficiently validated [17]. In Indonesia, existing studies have primarily focused on general barriers to green building implementation, such as high initial costs, limited regulatory frameworks [18], and a lack of incentives [19][20]. Compared to international studies, relatively little attention has been given to micro-level psychological factors, such as ecological perception or perceived environmental responsibility, particularly in relation to specific construction materials. This imbalance limits the understanding of how global findings on engineered wood adoption translate to the Indonesian context.

In addition, negative perceptions regarding the durability of wood in tropical climates particularly related to moisture, decay, and pest infestation continue to pose significant barriers [6][21]. Limited literacy regarding the technical performance of engineered wood further reinforces resistance to its adoption [22]. It is therefore expected that perceived technical limitations and adoption barriers negatively influence users' intention to adopt engineered wood, while ecological perception plays a mediating role in this relationship.

Consequently, few studies have integrated technical characteristics, adoption challenges, and ecological perceptions into a single causal model to explain user interest in engineered wood within the Indonesian context. This indicates a conceptual gap in understanding ecological perception not merely as an independent factor, but as a mediating mechanism linking material attributes and perceived barriers to adoption intention.

In response to this challenge, this study examines the potential role of engineered wood as a low-carbon construction material and investigates the factors influencing users' intention to adopt it within the Indonesian context. By explicitly examining these factors, the findings of this study are expected to provide empirical evidence on how engineered wood can be positioned as a viable low-carbon alternative within Indonesia's construction sector, thereby supporting both climate mitigation goals and material transition strategies.

Based on these research gaps, this study proposes three main research questions: (1) How do the technical and ecological characteristics of engineered wood influence users' intention to adopt it? How do the challenges or barriers associate with engineered wood affect users' adoption intention? (3) To what extent does ecological perception mediate the relationship between material characteristics and adoption barriers and the intention to use engineered wood? These questions are derived from the proposed relationships between material characteristics, adoption barriers, ecological perception, and adoption intention. The originality of this study lies in its integrative approach, which combines technical performance, perceived adoption barriers, and ecological perception within a unified analytical model tailored to the Indonesian context.

This study aims to analyze the influence of the technical and ecological characteristics of engineered wood on users' adoption intentions. Specifically, it seeks to: (1) examine the effect of adoption barriers on user intention; and (2) explain the mediating role of ecological perception. The scientific contribution of this study lies in strengthening the empirical understanding of the determinants of low-carbon material adoption in Indonesia. Practically, the findings are expected to inform policymakers, industry stakeholders, and academics in developing strategies for education, certification, and promotion of low-emission construction materials.

2. Method

2.1. Research Approach

This study employs a mixed-methods approach using a sequential explanatory design to integrate qualitative exploration with quantitative validation [23]. The first phase consists of qualitative research aimed at exploring public perceptions, experiences, and evaluations of engineered wood attributes within the context of sustainable residential design. Findings from this phase were used to construct measurable variables that were subsequently tested quantitatively. This exploratory phase was designed to inform the operationalization of constructs that directly correspond to the research questions concerning material characteristics, adoption barriers, and ecological perception.

The second phase involves a quantitative survey designed to empirically examine the relationships among material characteristics, usage challenges, ecological perception, and user adoption intention. Quantitative methods were selected to statistically test the hypothesized relationships derived from the qualitative findings and research questions. This sequential approach enables the study to capture cognitive, social, and experiential aspects of users while complementing them with statistically robust findings.

2.2. Qualitative Data Collection

The qualitative phase was conducted to explore respondents' perceptions and experiences regarding the use of engineered wood in sustainable residential contexts. A total of 115 respondents participated in this stage by completing an open-ended questionnaire. The questionnaire was distributed between March and April 2025 through social media platforms. Data were collected using an open-ended online questionnaire designed to capture respondents' narratives in a flexible and in-depth manner. Purposive sampling was applied, with selection criteria based on respondents' interest in or experience with wood-based materials. This approach ensured that the data collected were relevant and reflected practical and informed understandings of engineered wood usage. However, the use of purposive sampling may limit the generalizability of the qualitative findings, as the sample represents individuals with pre-existing exposure or interest in wood-based construction materials [24].

2.3. Quantitative Data Collection

The quantitative phase was conducted to empirically test the relationships among material characteristics, usage challenges, and the intention to use engineered wood. A total of 125 respondents participated in this phase. The research instrument consisted of a structured online questionnaire employing a five-point Likert scale, covering the domains of material characteristics, usage challenges, and adoption intention.

A cross-sectional survey design was applied [23]. Data collection was conducted online through questionnaire distribution via social media platforms. This approach allowed for efficient data acquisition but may be subject to self-selection bias, which should be considered when interpreting the findings. This approach proved effective in capturing empirical insights into the factors influencing the intention to adopt engineered wood among potential user groups.

2.4. Data Analysis

Data analysis was conducted sequentially. The qualitative phase produced a set of perceptual attributes, which were subsequently grouped through thematic analysis into four main domains: (1) knowledge-related characteristics of engineered wood, (2) impacts derived from material characteristics, (3) usage challenges, and (4) interest in architectural elements. The coding process followed the stages of open coding, axial coding, and selective coding, as outlined in constructivist Grounded Theory [25] and thematic analysis frameworks [26].

In the quantitative phase, all identified attributes were used as inputs for Exploratory Factor Analysis (EFA), applying an eigenvalue criterion greater than 1 and varimax rotation, as recommended in factor modeling literature [27]. EFA was employed to identify latent constructs underlying users' perceptions and to reduce observed variables into coherent factors aligned with the research questions. Specifically, EFA addressed the first research question by structuring technical and ecological attributes into interpretable dimensions.

The EFA results indicated that Material Characteristics comprised three factors which are Ecological Perception, Adaptability, and Structural Durability. They were consistently treated as characteristic variables in the subsequent regression modeling [23][28]. Meanwhile, the Usage Challenges domain was formed by two factors, namely Accessibility and Material Quality. These factors were subsequently used to address the second research question by examining how adoption barriers influence users' intention to adopt engineered wood.

The structure of the factor derived from the EFA was then employed in multiple linear regression analysis to examine the effects of each variable on the intention to use engineered wood [27]. Regression analysis was applied to test the expected directional relationships among material characteristics, usage challenges, ecological perception, and adoption intention, as well as to assess the mediating role of ecological perception.

Through this analytical sequence, qualitative findings were directly integrated into quantitative modeling via a connecting technique within the mixed-methods sequential explanatory design [29]. This integration ensures coherence and linearity across the research process, from exploratory investigation to empirical testing. Nevertheless, the cross-sectional nature of the quantitative phase limits causal inference, and the results should therefore be interpreted as associative rather than strictly causal [30].

3. Results and Discussion

3.1. Respondent Characteristics Based on Knowledge of Engineered Wood

Respondent characteristics related to knowledge of engineered wood are presented in Table 1. The table summarizes the profiles of participants involved in the first stage of data collection (qualitative phase) and those included in the second stage (quantitative survey phase). Overall, both datasets reveal consistent patterns regarding the distribution of respondents' knowledge across key demographic variables, indicating alignment between the exploratory qualitative findings and the broader quantitative results. However, the quantitative dataset provides a more detailed characterization of respondents' knowledge by incorporating income-based categories. This additional dimension allows for a more nuanced understanding of how socio-economic status may influence familiarity with engineered wood products. In particular, the quantitative analysis highlights variations in knowledge levels across different income groups, offering insight into potential disparities in access to information, exposure to innovation, and purchasing capacity.

Based on Table 1, male respondents exhibit a higher level of knowledge regarding engineered wood compared to female respondents. Nevertheless, the overall level of knowledge in both groups remains relatively high, indicating that understanding of engineered wood has reached both genders, with a slightly stronger dominance among male respondents. Respondents aged 20–30 years exhibit higher levels of knowledge than those under 20 years of age. This pattern indicates that young adults represent the cohort most familiar with engineered wood concepts, potentially reflecting greater exposure through higher education, academic training, or early-stage professional engagement.

Comparison across educational levels reveals a clear and hierarchical pattern. Respondents with a senior high school education exhibit the lowest level of knowledge. Knowledge levels increase among diploma holders and further rise among respondents with a bachelor's degree. The highest level of knowledge is observed among postgraduate respondents. This pattern confirms a positive relationship between educational attainment and knowledge of engineered wood.

Based on occupational categories, respondents employed as civil servants demonstrate the highest level of knowledge regarding engineered wood. This is followed by private-sector employees and self-employed respondents, who display similarly high levels of knowledge. Students show a moderate level of knowledge, while respondents who are not employed exhibit the lowest level of knowledge among all occupational categories. These findings indicate that engagement in professional activities contributes to greater exposure to innovative building materials.

Respondents living in urban areas show the highest level of knowledge about engineered wood, followed by those in suburban areas, while respondents in remote areas demonstrate the lowest level of awareness. This pattern suggests that proximity to urban centers is associated with better access to information, technology, and innovations in building materials.

Table 1 Respondent characteristics related to knowledge of engineered wood in qualitative and quantitative study.

Respondent Attribute	Basic knowledge about Engineered wood			
	Qualitative Study		Quantitative Study	
	Yes	No	Yes	No
Gender				
Male	87%	13%	81%	19%
Female	72%	28%	76%	24%
Age				
< 20 years	100%	0%	73%	27%
20 – 30 years	78%	22%	79%	21%
Highest Educational Attainment				
Senior High School	82%	18%	65%	35%
Diploma	100%	0%	67%	33%
Bachelor's Degree	78%	22%	80%	20%
Postgraduate Degree	88%	13%	100%	0%
Occupation				
Private-sector Employee	83%	17%	74%	26%
Civil Servant/ *ASN*	100%	0%	100%	0%
Student	80%	20%	79%	21%
Self-employed	85%	15%	86%	14%
Unemployed	83%	17%	73%	27%
Place of Residence				
Urban	88%	12%	88%	13%
Suburban	73%	28%	59%	41%
Rural / Distant from City	44%	56%	73%	27%

Respondent Attribute	Basic knowledge about Engineered wood			
	Qualitative Study		Quantitative Study	
	Yes	No	Yes	No
Monthly Income			**Yes**	**No**
< IDR 2.200.000			82%	18%
IDR 2.200.000 – 4.400.000			72%	28%
IDR 4.400.001 – 6.600.000			78%	22%
> IDR 6.600.000			93%	7%
No income			79%	21%

Based on monthly income distribution, knowledge of engineered wood generally increases with higher income levels. Respondents in the highest income category (> IDR 6,600,000) show the highest level of knowledge (93%), followed by those earning < IDR 2,200,000 (82%), respondents with no income (79%), and those in the IDR 4,400,001–6,600,000 range (78%). The lowest level of knowledge is observed in the IDR 2,200,000–4,400,000 group (72%). This pattern suggests that economic capacity may influence access to information, exposure to construction innovations, and engagement in housing-related decision-making. Higher-income groups are likely to have greater interaction with formal construction markets, professional developers, and digital information sources where engineered wood is more frequently introduced. However, relatively high awareness among lower-income and no-income respondents indicates that knowledge is not determined solely by purchasing power. Other factors such as occupational background, social networks, or media exposure may also play an important role. Overall, while a positive association between income and knowledge is observable, the relationship is not strictly linear, suggesting the need to consider additional socio-demographic variables in explaining public awareness of engineered wood.

As shown in Figure 1, knowledge of engineered wood across the demographic categories generally exceeds 50%, indicating relatively widespread awareness among respondents. The only notable exception appears in the rural/distant-from-city group during the qualitative stage, where the percentage falls below the 50% threshold. This exception highlights a spatial disparity in awareness, suggesting that geographic distance from urban centers may limit access to information and exposure to material innovations.

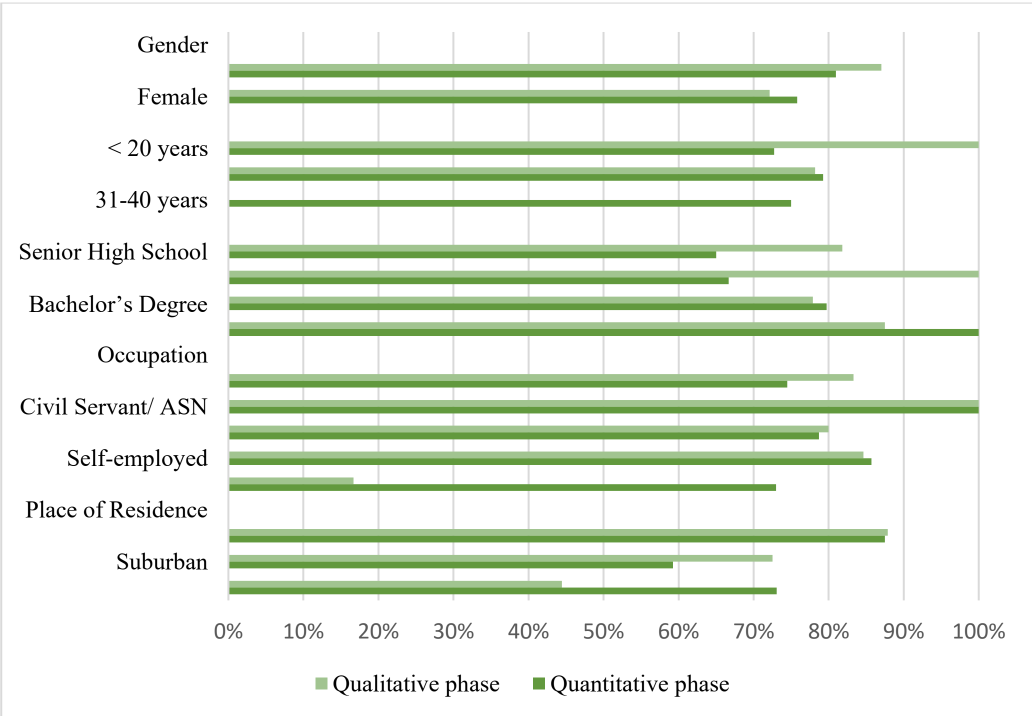

Figure 1 Bar chart illustrates respondents' knowledge of engineered wood across two data collection stages.

These patterns suggest that knowledge dissemination is shaped by education, professional engagement, and urban proximity. For Indonesia, this represents both an opportunity and a challenge. The relatively high baseline awareness provides a favorable foundation for expanding engineered wood adoption, particularly in urban and educated markets. However, uneven distribution across socio-economic and spatial contexts indicates the need for targeted outreach, capacity building, and policy support in rural and lower-access regions. Given Indonesia's abundant timber resources and growing demand for sustainable construction, strengthening technical standards, public awareness, and industry collaboration could significantly enhance the development and diffusion of engineered wood as a resilient and low-carbon building material.

3.2. Effects of Engineered Wood Characteristics (C)

This section addresses the first research question concerning how technical and ecological characteristics of engineered wood influence users' intention to adopt it. Factor analysis identified three primary dimensions with high mean scores and strong internal consistency (Cronbach's alpha > 0.90): Ecological Perception (Mean = 4.12), Adaptability (Mean = 4.08), and Structural Durability (Mean = 3.81), as shown in Table 2. Ecological Perception showed the highest loadings on attributes such as environmental friendliness, aesthetics, comfort, and material quality, indicating that respondents strongly associate engineered wood with sustainability and positive sensory experience. This finding aligns with previous studies showing that environmental values are a major driver of interest in engineered timber materials [31].

Adaptability emerged as the second key dimension, characterized by flexibility, lightweight properties, innovation, and design versatility. This suggests that respondents perceive engineered wood as a material compatible with flexible and future-oriented construction practices, consistent with prior research highlighting its design advantages [31]. Meanwhile, Structural Durability demonstrated strong loadings on strength, long service life, and ease of maintenance. Although its mean score was lower than the other factors, technical performance remains a fundamental prerequisite, as also emphasized in earlier studies [32]. This indicates that structural reliability is expected as a baseline requirement but does not independently drive adoption unless accompanied by ecological and experiential benefits.

Table 2 Factor analysis of engineered wood characteristics.

Ecological Perception	**Adaptability**		**Structural Durability**
Mean	4.1245	4.0842	3.8110
Standard Deviation	0.7497	0.7525	0.7901
Cronbach's Alpha	0.9263	0.9025	0.9297
Eigenvalue / Variance Explained	5.7904	4.459	4.1445
Cumulative Percentage (%)	27.573	48.807	68.543
C - Unique material character	0.753	0.350	0.041
C - Warm and friendly impression	0.753	0.231	0.256
C - Low-emission material	0.753	0.277	0.124
C - Aesthetic quality	0.726	0.460	0.076
C - Sustainability	0.712	0.416	0.237
C - Indoor comfort	0.671	0.278	0.362
C - Certified material	0.653	0.084	0.402
C - Material quality	0.626	0.009	0.549
C - Innovation and future potential	0.524	0.510	0.358
C - Renewable material	0.470	0.477	0.296
C - Flexibility (structural)	0.104	0.738	0.411
C - Innovative application	0.435	0.670	0.301
C - Lightweight	0.473	0.670	0.162
C - Design flexibility	0.428	0.652	0.262
C - Efficiency	0.396	0.583	0.344
C - Alternative construction material	0.419	0.554	0.421
C - Minimal dimensional change	0.121	0.267	0.792
C - Long service life	0.227	0.337	0.757

Ecological Perception	Adaptability		Structural Durability
C - Strength and robustness	0.443	0.208	0.702
C - Ease of maintenance	0.292	0.453	0.664
C - Structural resistance	0.058	0.551	0.637

The factor structure reveals that respondents evaluate engineered wood primarily through ecological and experiential values, followed by adaptive capacity, while technical performance functions as a supporting condition. This suggests a shift in material evaluation, where sustainability, aesthetics, and versatility play a more influential role than purely structural considerations. Consequently, promoting engineered wood may be more effective when emphasizing its environmental benefits, design flexibility, and user experience, while maintaining clear assurance of its technical reliability.

3.3. Challenges Associated with Engineered Wood Utilization (Ch)

This section complements the first research question by examining how perceived barriers shape users' evaluations of engineered wood. The factor analysis indicates that challenges related to the use of engineered wood are grouped into two main factors: Accessibility and Material Quality, as can be seen in Table 3.

Table 3 Factor analysis of challenges associated with engineered wood.

	Accessibility	Material Quality
Mean	2.8132	2.7802
Standard Deviation	0.9680	0.8603
Cronbach's Alpha	0.6976	0.6596
Eigenvalue / Variance Explained	1.5514	1.5254
Cumulative Percentage (%)	38.786	76.921
Ch - Lack of familiarity	0.921	0.149
Ch - Limited accessibility	0.667	0.497
Ch - Vulnerability to pests	0.150	0.918
Ch - Perceived low material quality	0.487	0.642

The Accessibility factor records a mean value of 2.81, with the highest loadings on lack of familiarity (0.921) and limited accessibility (0.667), while the Material Quality factor has a mean value of 2.78, with strong loadings on perceived vulnerability to pests (0.918) and low material quality (0.642). Cronbach's alpha values for both factors indicate moderate reliability, suggesting heterogeneous perceptions among respondents. The dominance of lack of familiarity highlights limited exposure, experience, and technical knowledge of engineered wood, while accessibility constraints reflect underdeveloped supply networks and limited market availability in Indonesia [33][34].

Concerns related to Material Quality are primarily driven by perceptions of biological vulnerability and doubts about long-term performance. Despite technological improvements that enhance durability, respondents continue to associate engineered wood with susceptibility to pests, indicating a gap between material innovation and public understanding [35]. Additionally, perceptions of low material quality suggest persistent uncertainty regarding its reliability, consistent with previous findings [36]. These results indicate that informational barriers and quality-related perceptions remain key obstacles to adoption, highlighting the importance of improving technical communication, market availability, and user familiarity.

3.4. Interest in Engineered Wood Utilization (I)

Table 4 presents the factor analysis results examining respondents' interest in applying engineered wood in residential buildings, identifying two distinct dimensions: Structural Interest and Aesthetic Interest. Both factors demonstrate acceptable reliability and together explain a substantial proportion of the variance in preferences, indicating that respondents differentiate between functional and experiential applications. The

Structural factor records a mean value of 3.64, with the highest loadings on roof elements (0.747), building structure (0.703), and stairs (0.602). This suggests moderate openness to using engineered wood in load-bearing components, particularly in lightweight structural applications, consistent with previous studies showing selective acceptance in structural elements perceived as safe and reliable.

Table 4 Factor analysis of interest in engineered wood applications.

	Structural Interest	Aesthetic Interest
Mean	3.6447	3.9615
Standard Deviation	0.7454	0.6235
Cronbach's Alpha	0.838	0.6855
Eigenvalue / Variance Explained	2.564	1.8839
Cumulative Percentage (%)	25.64	44.479
I - Roof	0.747	0.082
I - Building structure	0.703	0.189
I - Stairs	0.602	0.306
I - Walls	0.560	0.424
I - Flooring	0.544	0.402
I - Door and window frames	0.523	0.397
I - Interior applications	0.183	0.693
I - Decorative engineered wood	0.100	0.589
I - Exterior applications	0.426	0.578
I - Natural wood elements	0.203	0.296

In contrast, the Aesthetic factor shows a higher mean value of 3.96, with dominant loadings on interior (0.693), decorative (0.589), and exterior applications (0.578). This indicates stronger interest in visually expressive uses, where surface appearance, texture, and spatial atmosphere play a significant role in shaping preferences [37]. Interior elements such as walls and flooring also contribute to this dimension, reinforcing the perception of engineered wood as a flexible material for enhancing residential environments [33]. These findings demonstrate that respondents are more strongly attracted to the aesthetic and experiential qualities of engineered wood, while structural applications are accepted more cautiously and depend on perceptions of safety and reliability.

3.5. Effects of Characteristics and Challenges on the Intention to Use Engineered Wood

The regression analysis in Table 5 examines the influence of Characteristic factors (C) and Challenge factors (Ch) on the intention to use engineered wood (I), distinguishing between Structural Intention and Aesthetic Intention. All variables were standardized, allowing the coefficients (β) to reflect the relative strength of each predictor. The models explain 20% of the variance in structural intention and 18% in aesthetic intention, indicating that material characteristics and perceived challenges moderately contribute to adoption intention. Overall, characteristic factors show stronger effects than challenge-related factors.

Table 5 Effects of characteristics and challenges on the intention to use engineered wood.

	I -Structural STDZ		I -Aesthetic STDZ	
	Rsq 0.20		Rsq 0.18	
	Pvalue 0.0017		Pvalue 0.0051	
	β	Pvalue	β	Pvalue
C – Ecological Perception STDZ	0.3711	0.0198	0.3094	0.0415
C – Adaptability STDZ	-0.1427	0.4389	0.0713	0.6855
C – Structural Durability STDZ	0.2172	0.1445	0.0130	0.9270
Ch – Accessibility STDZ	-0.0856	0.4610	0.0618	0.5774
Ch – Material Quality STDZ	-0.0643	0.5983	-0.0845	0.4696

Ecological Perception emerges as the most influential predictor, with coefficients of $\beta = 0.3711$ for structural intention and $\beta = 0.3094$ for aesthetic intention. This indicates that stronger perceptions of environmental friendliness and sustainability are associated with higher intention to use engineered wood, consistent with prior research identifying ecological value as a key driver of preference for low-carbon timber construction [38]. In contrast, Adaptability and Structural Durability show weak and statistically non-significant effects, suggesting that while respondents recognize the technical and functional advantages of engineered wood, these attributes alone do not substantially increase adoption intention [39].

Challenge-related factors demonstrate generally negative relationships with intention. Accessibility records $\beta = -0.0856$ for structural intention and $\beta = 0.0618$ for aesthetic intention, while Material Quality shows $\beta = -0.0643$ and $\beta = -0.0845$, respectively. These results indicate that perceived difficulty in obtaining the material and doubts about its quality tend to reduce adoption intention, consistent with previous findings [40]. Such perceptions are partly influenced by prior experiences with conventional timber, which can shape assumptions about durability and performance [41].

The results indicate that ecological perception is the primary driver of adoption intention, while technical attributes and perceived challenges play a secondary role. This suggests that increasing adoption may depend more on strengthening awareness of environmental benefits, alongside improving material availability and addressing quality-related perceptions through clearer technical communication and user education.

4. Conclusion

The findings indicate that respondents' knowledge of engineered wood remains segmented, with higher levels of understanding observed among highly educated individuals, formal-sector workers, and urban residents, and lower levels among respondents with lower educational attainment, those who are not employed, and those residing in non-urban areas. The consistency of this pattern across the two data collection stages suggests that these disparities are structural and relatively stable, thereby providing a reliable basis for examining the relationships among knowledge, perception, and adoption intention toward engineered wood. In relation to the first research question, these results indicate that technical knowledge alone does not uniformly translate into adoption intention across different social groups, highlighting the importance of perceptual and contextual factors.

From the perspective of material characteristics, technical aspects such as strength, dimensional stability, and thermal performance contribute to positive perceptions of engineered wood as a residential building material. Nevertheless, concerns regarding long-term durability and initial costs remain key barriers that constrain its adoption. Interest in using engineered wood is influenced not only by technical understanding but also by ecological awareness and professional experience, underscoring the importance of social and psychological factors in material-related decision-making. These findings directly address the second research question by demonstrating that adoption barriers exert a negative influence on users' intention, while ecological perception plays a critical role in shaping how material characteristics and challenges are evaluated.

Furthermore, the analysis confirms the mediating role of ecological perception, as proposed in the third research question, indicating that users' ecological awareness partially bridges the relationship between material characteristics, perceived barriers, and adoption intention.This mediating effect suggests that improving ecological perception can mitigate negative evaluations arising from technical or economic concerns.

These findings highlight the need for integrated educational and policy strategies that extend beyond improving material literacy alone, and instead focus on strengthening trust through technical guidelines, quality certification schemes, and regulatory support. From a policy perspective, the results suggest that targeted incentives, standardized certification systems, and clear regulatory frameworks are essential to reduce uncertainty and enhance confidence in engineered wood applications. For industry stakeholders, the findings underscore the importance of transparent performance communication, demonstration projects, and professional training to address durability-related concerns.Academically, this study contributes empirical evidence from a tropical context and supports the development of integrative models that combine technical, ecological, and behavioral dimensions in low-carbon material adoption research.

In this way, the present study advances understanding of the dynamics of perception, challenges, and adoption interest related to engineered wood in tropical contexts and provides a conceptual foundation for future research and cross-sectoral collaboration aimed at accelerating the transition toward low-emission, biomass-based construction materials in Indonesia. Future studies are encouraged to extend this framework through longitudinal designs and broader population samples to further examine causal mechanisms and enhance generalizability.

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6. Conflict of Interest

The authors declare no conflict of interest related to the publication of this article. This research was carried out independently and objectively, with no financial, institutional, or personal affiliations that could have affected the findings or interpretations reported in this study.

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