Journal of Construction Engineering, Management & Innovation Volume 9 Issue 3 (2026) 728

Contents lists available at www.goldenlightpublish.com/journals/jcemi/2-toc

Journal of Construction Engineering, Management & Innovation

Journal homepage: www.goldenlightpublish.com/journals/2/jcemi

Factors influencing the adoption of mass timber in the South African construction industry: A UTAUT-based approach

Ferdinand Senam Hassan*, Schalk Grobbelaar

University of Pretoria, Department of Engineering and Technology Management, South Africa

* Corresponding author: F. S. Hassan (ferdinand.hassan@tuks.co.za)

https://doi.org/10.31462/jcemi.2026.728

Received 14 May 2026; Revised 6 July 2026; Accepted 17 July 2026; Available online 22 September 2026

Keywords

Mass timber
PLS-SEM
Adoption
South Africa

Abstract

The global construction industry is under pressure to reduce its carbon emissions, and mass timber has emerged as a promising alternative to conventional building materials such as concrete and steel. While hundreds of multi-storey timber buildings have been constructed worldwide, there is limited evidence of corresponding growth in Africa. This study investigates the factors influencing design professionals' behavioural intention to adopt mass timber in the South African construction industry. A conceptual model was developed by extending the Unified Theory of Acceptance and Use of Technology (UTAUT) with three context-specific constructs: perceived environmental motivation, personal resistance, and perceived cost. Data were collected from 92 architects and structural engineers through a structured survey and analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). Iterative measurement model assessment led to the removal of social influence due to indicator reliability and discriminant validity failures, the merger of effort expectancy and facilitating conditions into a single construct termed execution capability, and the reduction of the instrument from 43 to 33 indicators. The final structural model explained 66.2% of the variance in behavioural intention and demonstrated high out-of-sample predictive power. Three predictors were statistically significant: perceived environmental motivation was the strongest predictor, followed by execution capability and performance expectancy. Personal resistance and perceived cost were not significant. The findings suggest that environmental credentials, rather than technical performance or cost, are the primary driver of intention to adopt mass timber among South African design professionals, and that professionals do not distinguish between the ease of using mass timber and the infrastructural conditions enabling its use. The study contributes to the limited empirical literature on mass timber adoption in Africa and demonstrates the need for context-specific modifications when applying UTAUT to construction material adoption.

1. Introduction

Timber use for structural purposes is not new; it is perhaps the oldest building material. Over time, it was replaced by concrete, brick and steel in building construction projects. Over the past decade, however, timber construction has seen a resurgence. Hundreds of multi-storey timber buildings have been constructed worldwide [1-3], driven by the development of mass timber, whose improved strength, stability, and fire resistance exceed those of sawn timber and are comparable to those of conventional materials [2]. Mass timber products, particularly prefabricated cross-laminated timber CLT elements, are increasingly recognised as part of the broader Modern Methods of Construction (MMC) movement, an environmentally oriented industrialised building approach that has seen exponential research growth in recent years [4]. Still, there is little evidence of corresponding growth on the African continent as in the rest of the world.

Local reports in South Africa provide some insight into growing interest in mass timber [5], and there is corresponding research on technical aspects, including fire resistance [6] and structural performance [7]. However, to the authors' knowledge, only one study has empirically investigated the adoption of mass timber in South Africa and to date, no study has used structural equation modelling to test a theoretically grounded adoption model for mass timber in an African context. Therefore, this study seeks to empirically investigate the factors influencing the intention of design professionals in the South African construction industry (SACI) to adopt mass timber in their building projects. In doing so, the study seeks to answer the question: to what extent do determinants of technology adoption impact the behavioural intention of SACI design professionals to use mass timber in their building projects?

This study contributes to the literature in four ways. First, it provides the first Partial Least Squares Structural Equation Modelling (PLS-SEM) test of a Unified Theory of Acceptance and Use of Technology (UTAUT) based adoption model for a construction material in an African context, converting factors previously identified through qualitative and descriptive research into a statistically testable structural model. Second, it extends UTAUT with three context-specific constructs (perceived environmental motivation, personal resistance, and perceived cost) and tests their predictive power alongside the core UTAUT variables. Third, the analysis yields a novel construct, execution capability, formed from the empirical merger of effort expectancy (EE) and facilitating conditions (FC), which identifies a boundary condition on the EE-FC distinction when the unit of adoption is a construction material rather than an individually operated technology. Fourth, the finding that perceived environmental motivation dominates performance expectancy as a predictor of behavioural intention challenges the conventional UTAUT hierarchy in which performance is the primary driver. The rest of the paper is structured as follows. Section 2 reviews the literature on mass timber adoption. Section 3 presents the conceptual model and hypotheses. Section 4 details the methodology, including the research philosophy, survey design, sampling strategy, and data analysis approach. Section 5 reports the results of the measurement and structural model assessments. Section 6 discusses the findings, their theoretical and practical implications, and the limitations of the study. Section 7 concludes the paper.

2. Literature Review

The drive towards a sustainable built environment is one of the reasons for the increasing use of mass timber [2]. Globally, the building and construction industry accounts for 37% of carbon dioxide (CO_2) emissions, with 10% arising from the production of aluminium, brick, concrete, glass, and steel [8]. Decarbonisation of the construction industry has tended to focus on reducing operational carbon emissions, but this has proven inadequate, as an increase in embodied carbon emissions is projected to offset gains [2, 9]. To ensure countries meet net-zero emissions targets by mid-century, embodied carbon reduction measures have been touted as potential solutions. One such pathway is the use of sustainably sourced, bio-based, regenerative materials, such as timber [10].

Timber has relatively low embodied carbon emissions [11-14]. This means that the carbon emissions associated with raw material extraction, manufacturing, transportation to the site and the actual construction process [15] are lower for timber than for conventional materials such as steel and concrete. When timber's biogenic carbon sequestration capabilities are considered, carbon emissions from timber buildings are further reduced, and studies show the potential for this to contribute to net-negative carbon emission effects from buildings [13, 14, 16]. These benefits are based on certain caveats: that timber structures last longer than the trees from which they were produced [14], that end-of-life activities for timber buildings are properly accounted for [11], and that the carbon benefits may be more substantial in taller buildings [11, 14].

The structural performance of mass timber is also well-established. Timber is a lightweight material, and mass timber is much lighter than comparable structural materials. Despite this, it can achieve comparable strength and stiffness with conventional materials [17, 18]. This lower weight reduces the loads transferred to supporting columns and foundations throughout the structure [19]. The benefit is particularly significant in seismic conditions, where earthquake forces increase with building mass. For instance, [18] found that the base earthquake load in a six-storey steel-framed building was reduced to approximately two-thirds of that of a comparable concrete-floored structure. Similarly, [17] reported that replacing concrete slabs with CLT in a sixty-storey tower reduced lateral displacement during an earthquake. Across these studies, the stresses inside the CLT panels stayed comfortably below the strength of the material [17, 18], and mass timber is being used for the main structures of tall wood buildings globally [2].

Over the past decade, there has been an uptick in studies investigating the factors influencing the adoption of mass timber in the construction industry. One of the earliest studies was by [20], who utilised a mixed methods approach to investigate barriers to the use of cross-laminated timber (CLT) in high-rise multi-family housing projects in the United States (US). The study concluded that CLT was perceived by industry professionals as superior to concrete in terms of environmental performance and construction process simplicity. Additionally, CLT construction was observed to require less labour and cost less than concrete construction. Seismic performance was also important, perhaps because the US is a high-seismic region [20]. Since then, other studies have added depth to the conversation around mass timber adoption, though clustered in a few regions.

Mallo and Espinoza investigated the factors impacting the adoption of CLT in the US from the perspectives of CLT experts [21], architects [22], and engineers [23]. Across all three studies, participants identified environmental performance, structural performance, and aesthetics as the highest-ranked competitive benefits of CLT, while lack of material availability and incompatibility with building codes were regarded as barriers [21-23]. A recent investigation by Ahmed and Arocho covered a wider range of construction industry stakeholders in the US, including contractors, subcontractors, and consultants [24], as well as architects and engineers [25, 26]. Similar to previous work, they observed that material unavailability [24] and incompatibility with building codes [25, 26] were significant barriers.

In Australia, Kremer and Symmons introduced a financial feasibility component into their investigation of mass timber adoption by interviewing insurance industry stakeholders, as well as architects and builders [27]. They found that negative perceptions of the material's properties, difficulty in integrating mass timber construction MTC into traditional construction methods, and risk aversion among financiers, such as insurance bodies, were limiting adoption [27]. Another study tested whether perceptions of risk associated with mass timber use were statistically significant and found that MTC was considered to have a risk-to-reward ratio similar to that of conventional construction methods [28]. Marfella [29] found that a lack of public awareness in Australia was driving cultural resistance to the use of engineered wood products EWP for multi-storey buildings, despite the majority acceptance of timber's benefits within the construction industry, while [30] noted that lack of material supply, lack of financial support, high material costs and persistent perceived limitations of timber as barriers.

Across the globe, several independent studies have corroborated these findings in their respective local contexts. Pilathottathil [31] observed a lack of knowledge and awareness amongst industry professionals, high material and insurance costs and low cultural acceptance as barriers to the adoption of CLT in the United Arab Emirates. Similarly, Low [32] observed that a lack of awareness, limited availability of materials, and high material costs were limiting the use of mass timber in Singapore. Similar barriers were also observed by Espinoza [33] in Europe. Two studies provide insight into the adoption of mass timber in Africa. Simeon [34] observed that CLT's pleasant aesthetics, its prefabrication and use in modular construction projects, and the potential for significant cost savings from time saved during construction are drivers of its use in Nigeria, while Murphy and Smallwood [35] noted that the use of CLT in South Africa is still at an early stage with low level of awareness, high initial material costs and negative perceptions of timber contributing to its limited use.

Across the studies discussed above, several trends can be observed: knowledge and awareness seem important for increased use, cost and material availability are significant threats, building codes need to be updated to accommodate mass timber construction, and cultural resistance must be overcome. This study seeks to add to the knowledge base on the adoption of mass timber in South Africa and Africa and to statistically test some of the factors identified as critical to mass timber adoption.

3. Conceptual Model

Adoption behaviour is a well-researched field with roots in psychology and applications in the Information Systems (IS) field. One of the earliest models of behavioural adoption is the Theory of Reasoned Action (TRA), proposed by Ajzen and Fishbein, which provides that an individual's behavioural intention captures the motivational factors that influence behaviour [36]. In TRA, behavioural intention is itself a function of two independent determinants: the attitude toward the behaviour, reflecting an evaluation of the action, and subjective norm, which represents the perceived social pressure from significant others to perform or abstain from said behaviour [37]. Under this framework, individuals are viewed as rational actors who process available information and consider the implications of their actions before deciding to engage in a specific behaviour. TRA assumes that if a person has an intention, they will perform the behaviour, but fails to account for the specific resources, skills, or cooperation from others required to do so. Hence, Ajzen extended TRA by including perceived behavioural control – the perceived difficulty of performing the behaviour – as another determinant of intention and behaviour [38].

The Technology Acceptance Model (TAM) developed by [39] represented a significant departure from the broader psychological focus of TRA and Ajzen's extension, the theory of planned behaviour (TPB). While TRA and TPB were designed to explain human behaviour in general, TAM was introduced to explain Information Technology (IT) adoption in the workplace [40]. Similar to TRA and TPB, the use of technology is explained by behavioural intention, which in turn is influenced by two constructs: perceived usefulness and perceived ease of use. TAM is a highly successful model and has been used across various contexts. A meta-analysis of empirical studies using TAM revealed that perceived usefulness is a significant predictor of behavioural intention, and that behavioural intention, in turn, adequately predicts actual use [41].

Beyond TRA, TPB, and TAM, several other adoption models have been proposed [36]. The proliferation of technology adoption theories often led researchers to a methodological compromise in which they had to select a preferred construct while disregarding significant explanatory contributions from alternative models [42]. Hence, Venkatesh and colleagues proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) to capture the complexity of behavioural intention and adoption holistically. UTAUT has been highly successful in explaining behavioural intention to use technology and has been applied across various industries and contexts [43], including the construction industry [44].

In UTAUT, technology adoption is a function of a person's behavioural intention (BI) to use the technology and the presence of facilitating conditions (FC) – the available infrastructure that supports its use. BI, in turn, is a function of performance expectancy (PE), effort expectancy (EE), and social influence (SI). PE refers to the belief that using a technology will improve performance; EE is the ease associated with using the technology; and SI describes a person's perception that people important to them want them to use the technology [42]. UTAUT's predictive success in explaining technology adoption provides the basis for selecting it as the underlying framework. In this study, however, the model is further modified to reflect the characteristics of the SACI and mass timber adoption.

The construction industry is often perceived as conservative and slow to adopt innovation [45, 46], and various reasons have been offered to explain this perceived quality. Resistance is one such reason expressed through behaviours that oppose or avoid change, whether through passive inertia or active opposition [47]. In the SACI, several studies have highlighted resistance to change as a key challenge to the adoption of various technologies [48-50], often as a property of the industry [51]. For timber and other alternative building materials, resistance is framed as a preference for traditional materials such as concrete and brick [52], despite the potential benefits of these alternative materials [53]. Hence, this study conceptualises resistance to change as a measurable, individual-level construct, named as personal resistance (PR).

Perceived cost (PC) is another important factor, consistently utilised in the adoption literature to extend technology acceptance models [54]. Across mass timber and SACI literature, cost is frequently cited as a barrier to technology adoption [32, 35, 51]. This includes high material costs for mass timber, especially compared to other materials [22], as well as associated costs throughout the technology or building lifecycle, including maintenance costs [32, 55]. Hence, PC is included as a construct in this study. Finally, perceived environmental motivation (PEM) is included in the conceptual model as a determinant of behavioural intention to adopt mass timber. It is based on the Integrated Framework for Encouraging Pro-Environmental Behaviour (IFEP), which posits that behaviour is driven by three competing goals: normative, hedonic and gain [56].

According to IFEP, pro-environmental behaviour occurs when driven by normative goals such as biospheric values, environmental beliefs, and moral obligations [57], and overriding competing hedonic and gain considerations [56]. In the context of mass timber adoption, PEM reflects the extent to which design professionals are motivated by environmental considerations when making material decisions. This aligns with previous literature, which suggests that individuals with stronger environmental motivation are more likely to prioritise sustainability outcomes over competing concerns, such as cost [56, 58]. Accordingly, the conceptual model is defined in Fig. 1.

Behavioural intention (BI) is retained from UTAUT as the dependent construct representing a professional's likelihood of adopting mass timber in their construction projects. In this study, BI is adopted as the outcome variable, rather than actual use. In the construction context, the actual use of a structural material or system is a collective, project-dependent event, which limits the extent to which professionals can adopt it, even when intentions are high [59]. Performance expectancy is positioned as a determinant of behavioural intention, alongside effort expectancy, social influence and facilitating conditions. The emergent constructs, personal resistance, perceived cost and perceived environmental motivation are also included alongside the core UTAUT constructs as antecedents of behavioural intention.

PE captures the extent to which a construction professional believes that mass timber can deliver the core performance outcomes required of a building project. PE is expected to exert a significant influence on behavioural intention to adopt mass timber. This leads to the first hypothesis statement, H1. EE reflects perceptions regarding the ease with which a construction professional can design and construct buildings using mass timber. EE is expected to influence behavioural intention to adopt mass timber. This leads to the second hypothesis statement, H2. SI refers to the extent to which peers, influential stakeholders, clients, and industry norms shape a construction professional's adoption decisions. SI is, therefore, expected to affect behavioural intention to adopt mass timber. This leads to the third hypothesis statement, H3. FC refers to the availability of organisational, technical, regulatory and institutional support necessary to enable the adoption of mass timber in the construction industry. FC, is expected to influence the behavioural intention of adopting mass timber in practice. This leads to the fourth hypothesis statement, H4.

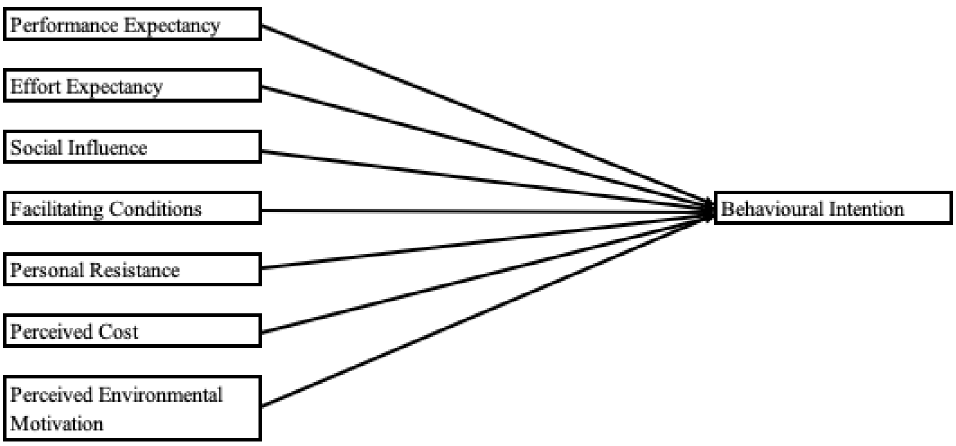

Fig. 1. A conceptual model for mass timber adoption in the South African construction industry

PR refers to a construction professional's reluctance to adopt mass timber despite an acknowledgement of its benefits. PR is expected to negatively influence behavioural intention to adopt mass timber. This leads to the fifth hypothesis statement, H5. PC reflects construction professionals' perceptions that adopting mass timber entails higher direct and indirect financial expenditures. PC is treated as a distinct construct in the framework and is expected to negatively influence behavioural intention to adopt mass timber. This leads to the sixth hypothesis statement, H6. PEM captures the extent to which pro-environmental considerations influence the intention to adopt mass timber. PEM is, therefore, expected to positively influence behavioural intention to adopt mass timber. This leads to the seventh hypothesis statement, H7. The hypotheses are provided below.

H1: Performance expectancy has a positive effect on construction professionals' behavioural intention to adopt mass timber.

H2: Effort expectancy has a negative effect on construction professionals' behavioural intention to adopt mass timber.

H3: Social influence has a positive effect on construction professionals' behavioural intention to adopt mass timber.

H4: Facilitating conditions have a positive effect on construction professionals' behavioural intention to adopt mass timber.

H5: Personal resistance has a negative effect on construction professionals' behavioural intention to adopt mass timber.

H6: Perceived cost has a negative effect on construction professionals' behavioural intention to adopt mass timber.

H7: Perceived environmental motivation has a positive effect on construction professionals' behavioural intention to adopt mass timber.

4. Methodology

4.1. Philosophy and approach

This study is situated within a structured methodological framework informed by the research onion [60]. At the philosophical level, the study adopts a positivist paradigm, seeking to test theoretically derived relationships between latent constructs using observable data, assuming that these relationships can be objectively measured [61]. This also aligns with previous studies that have empirically tested UTAUT [62, 63]. The study follows a deductive research approach, in which hypotheses are derived from prior literature and subsequently tested empirically [61]. This is consistent with the objective of validating a conceptual model that integrates core UTAUT constructs with context-specific extensions, rather than generating theory inductively [60].

4.2. Strategy

The research strategy is quantitative, employing a structured inferential survey instrument to collect data from design professionals in the SACI. The restriction to design professionals is deliberate. While empirical construction adoption studies often sample across multiple construction trades, pre-survey discussions with industry professionals highlighted substantial differences in responsibilities and decision focus of the various professions, complicating the development of valid and consistent measurement items across groups. In South Africa, architects and structural engineers act as primary agents in early-stage design decisions, where material choices are typically established. Accordingly, this study focuses on these professions, collectively referred to as design professionals, to enhance construct validity and align the unit of analysis with those most directly involved in material specification. The study adopts a cross-sectional time horizon, capturing perceptions and intentions at a single point in time, which is appropriate given the focus on behavioural intention rather than longitudinal adoption behaviour [60].

4.3. Instrument design

The use of a structured survey enables the operationalisation of the constructs defined in the conceptual model through multiple indicators and facilitates statistical analysis of relationships between variables [61]. The survey was divided into five sections. The first section provided a background to the study and a working definition of mass timber, and then requested informed consent from respondents. The next section asked respondents about their familiarity with mass timber. This was designed as a filter to ensure that only responses from professionals with some familiarity with the material would be considered. The third section was designed to operationalise the conceptual framework in Fig. 1.

All constructs were measured using multi-item scales adapted from the literature on UTAUT operationalisation in the construction industry, mass timber construction adoption, and technology adoption in the South African construction industry. The statements are provided in Table 1. Responses were captured on a Likert-type scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). The fifth section asked respondents to indicate what building type and height they felt mass timber would be suitable for. Respondents were then asked to provide some background information, including their highest academic qualification, their primary professional role (architects, structural engineers, or others), professional qualifications, the type of organisation they belonged to, gender, age, experience, and primary location of practice. Finally, respondents interested in a follow-up interview for a follow-up study were asked to provide their contact details. Prior to distribution, the instrument was reviewed by four subject-matter experts: a professional engineer, a professional architect, a professor of management studies, and a professional holding both architectural and engineering qualifications. Their feedback was used to refine the wording of indicators for clarity and contextual relevance in the South African construction setting.

Table 1. Construct-item measurement statements

Construct	Item code	Statement	Theme	References
Performance expectancy	PE1	I believe mass timber can meet the structural strength required for buildings.	Structural Strength	[33], [59], [64]
	PE2	I am confident that mass timber structures can meet deflection, vibration, and other serviceability performance requirements.	Serviceability	[21], [23], [32]
	PE3	I believe that mass timber can be designed to meet the fire resistance ratings required in building projects	Fire resistance	[25], [21], [20], [65]
	PE4	I am confident that mass timber can be detailed to prevent moisture-related damage over the buildings lifespan	Moisture resistance	[20], [34]
	PE5	Using mass timber can allow me to achieve the design solutions I need without compromising functionality.	Design functionality	[59], [34]
	PE6	I do not believe using mass timber in South Africa can improve project outcomes (time, cost, and quality	Negatively coded performance driver	[27], [32], [34] [66]
Effort expectancy	EE1	It is easy for me to learn how to design and build with mass timber.	Ease of learning	[65]
	EE2	Integrating mass timber systems into current project plans is straightforward	Ease of workflow integration	[20]
	EE3	I can adapt my typical design process to include mass timber without much difficulty.	Ease of design adaptation	[22], [27]
	EE4	Designing mass timber buildings to meet regulatory approvals is easy	Ease of achieving approval	[67], [68]
	EE5	Mass timber systems do not fit well into the way most of my projects are currently delivered.	Negative coded effort driver	[69]
Social influence	SI1	Industry professionals whose opinions I value encourage me to use mass timber.	Role model influence	[65]
	SI2	Common practice among my peers shapes my perception of mass timber.	Peer influence	[70],
	SI3	My organisation's culture supports the adoption of mass timber.	Organisational influence	[32],
	SI4	The willingness of others in my project teams to adopt mass timber affects my own likelihood of using it.	Project team influence	[69], [70]
	SI5	The willingness of clients to adopt mass timber affects my own likelihood of using it.	Client influence	[27], [66], [69]
	SI6	The opinions and expectations of people important to me professionally have little influence on whether I adopt mass timber.	Negatively coded social influence	[65]
Facilitating conditions	FC1	I have access to the necessary technical resources to confidently specify mass timber for structural purposes.	Availability of technical resources	[32], [29],
	FC2	Mass timber construction is compatible with existing building regulations.	Compatibility with regulation	[66], [69],
	FC3	There is a sufficient supply of mass timber products available locally to support projects.	Material supply and availability	[22], [25],
	FC4	I have sufficient information about mass timber to implement it successfully.	Information availability	[35]
	FC5	The available information on mass timber construction is sufficient to guide my professional decisions.	Sufficiency of information	[71]
	FC6	I lack adequate support to confidently adopt mass timber in my projects.	Access to professional support	[72]
Personal resistance	PR1	Even if the technical evidence supports it, I still feel hesitant to use mass timber.	Affective resistance	[27], [52]
	PR2	I am reluctant to replace traditional materials such as concrete or brick with mass timber.	Preference for established materials	[31], [52], [59],
	PR3	I find it difficult to trust mass timber, as I have personally not used it before.	Resistance due to lack of experience	[22], [28], [70]
	PR4	Mass timber feels too new and unproven for me to recommend it	Technological immaturity	[35], [69]
	PR5	I am willing to consider mass timber on a project even if I have never used it before.	Reverse coded resistance	[27]

Table 1. Cont'd

Perceived cost	PC1	I believe mass timber construction is more expensive than conventional building methods.	Relative cost	[69], [73]
	PC2	I consider the cost of mass timber to be a barrier in my material selection decisions.	Cost as a decision barrier	[59], [69],
	PC3	I believe that sourcing materials for mass timber construction increases overall project costs.	Supply chain cost implications	[32], [64]
	PC4	The benefits of mass timber justify the financial investment required to use it.	Reverse coded perceived cost	[27], [70]
	PC5	I do not think that mass timber construction is financially viable in South Africa.	Financial viability	[35]
Perceived environmental motivation	PEM1	I am more likely to use mass timber because it has strong environmental benefits.	Environmental motivation	[27], [71]
	PEM2	The sustainability benefits of mass timber increase my interest in using it in projects.	Sustainability as a driver	[59], [74]
	PEM3	Environmental impact is an important factor if I use mass timber.	Environmental impact as a driver	[59], [70], [75]
	PEM4	I would prioritise mass timber over materials that contribute to increasing the carbon footprint of buildings.	Preference for low-carbon materials	[21]
	PEM5	I do not consider the environmental benefits of mass timber to be important.	Negatively coded environmental driver	[23], [59], [74]
Behavioural intention	BI1	I intend to recommend mass timber for future building projects.	Recommendation intention	[22], [65], [70],
	BI2	I am likely to consider using mass timber in the design of a building within the next two years.	Consideration in the short-term	[23], [59], [75]
	BI3	If given the opportunity, I would actively advocate for the use of mass timber in my projects.	Advocacy for mass timber use	[27], [59], [65]
	BI4	I plan to learn how to implement mass timber systems in my work.	Willingness to consider	[32], [30]
	BI5	I do not see myself using mass timber in my work anytime soon.	Negatively-coded intention driver	[23], [75]

4.4. Sampling

The study employed a non-probability sampling strategy, combining purposive and convenience sampling to target design professionals involved in material specification decisions within the South African construction industry. The survey was distributed through established architectural and structural engineering professional networks, including the South African Council for the Architectural Profession (SACAP), the Structural Division of the South African Institute of Civil Engineers (SAICE-SSD), the Green Building Council of South Africa (GBCSA), and a timber construction email list operated by the York Timbers Chair in Wood Structural Engineering at the University of Pretoria. These channels were selected to ensure access to respondents with relevant expertise and decision-making exposure to material selection processes.

Access to potential respondents was mediated through these bodies, and the researcher did not have direct access to the underlying membership email databases. As a result, the distribution of the survey was contingent on the willingness and internal processes of these bodies. For instance, the survey was circulated twice through the GBCSA and SAICE-SSD, but only once through the other bodies. This potentially introduced variability in exposure across respondent groups and limited the researcher's ability to standardise follow-up procedures, potentially affecting response rates and sample composition. The sampling process was further constrained by South Africa's data protection framework, specifically the Protection of Personal Information Act (POPIA), which restricts access to and use of personal contact information, and is strictly enforced by the researchers' institutional ethics committee. Compliance with POPIA necessitated indirect distribution through third-party organisations and precluded the use of direct sampling frames, follow-up reminders to individual participants, or targeted recruitment strategies. Consequently, the study relied on voluntary participation, increasing the likelihood of self-selection bias, where individuals with a pre-existing interest in sustainability or mass timber may be overrepresented.

Despite these constraints, 110 responses were obtained. After applying filters to exclude non-design professionals and respondents who had not heard of mass timber before clicking into the survey, 92 complete responses remained. Respondents from different registration categories within the architectural and engineering professions were retained in the sample. This included architectural technologists, candidate architects, candidate engineers and other registered professionals who participate in the design and specification of structural systems. Their inclusion was considered appropriate because these individuals form part of the regulated professional pathways recognised by SACAP and the Engineering Council of South Africa (ECSA), and are actively involved in design-related decision-making within construction projects. Consequently, the study adopted an inclusive definition of architectural and structural design professionals rather than restricting participation solely to professionally registered architects and engineers. Still, this study's sample should be interpreted as indicative rather than representative of the broader population of South African design professionals.

4.5. Data analysis

Partial Least Squares Structural Equation Modelling (PLS-SEM) was selected as the analytical technique for this study. PLS-SEM is a variance-based approach to structural equation modelling that simultaneously estimates relationships between constructs and their indicators (the measurement model) and between constructs (the structural model) by maximising the explained variance in the endogenous constructs [76]. Several reasons guided this choice. First, the primary research objective is prediction-oriented: the study aims to identify which factors predict behavioural intention to adopt mass timber, rather than to confirm a well-established causal theory. PLS-SEM is the preferred method when the analysis concerns testing a theoretical framework from a predictive perspective [77]. Second, PLS-SEM achieves high statistical power across a range of sample sizes [76, 77]. Moreover, PLS-SEM does not impose distributional assumptions on the data. Given the applied nature of the study and the specialised target population – design professionals in the South African construction industry – the data could not be assumed to follow a multivariate normal distribution. This departure from normality makes PLS-SEM a suitable analytical approach [77].

The analysis was conducted using the SEMinR package [78] in R [79] with RStudio serving as the Integrated Development Environment (IDE) [80]. SEMinR provides a domain-specific syntax for specifying and estimating PLS-SEM models, running bootstrap analyses, and executing the PLSpredict procedure [81]. All constructs were specified as composites using mode A (reflective) weighting, consistent with standard PLS-SEM practice for reflective measurement models [81]. The measurement model was assessed using the systematic four-step procedure recommended by [76] for reflective measurement models: inspecting indicator reliability, internal consistency, convergent validity, and discriminant validity.

Indicator reliability was assessed by examining model outer loadings, with a preferred threshold of 0.708, indicating that the construct explains more than 50% of the indicator's variance [77]. Indicators with loadings below 0.40 were removed, while those with loadings between 0.40 and 0.708 were considered for removal only if their deletion improved composite reliability or convergent validity above threshold values, with consideration for content validity maintained [76]. Three metrics were used to assess the internal consistency of the constructs: Cronbach's alpha (α), the reliability coefficient ρA, and composite reliability ρC [77]. Acceptable values range from 0.70 to 0.95; values above 0.95 indicate problematic indicator redundancy that compromises construct validity [76]. The reliability coefficient ρA, which typically lies between the conservative α and the liberal ρC, was treated as the primary indicator of internal consistency [77].

To assess convergent validity, the average variance extracted (AVE) was computed for each construct, with a minimum threshold of 0.50, indicating that each construct explains at least 50% of its indicators' variance [76]. For discriminant validity, the heterotrait-monotrait ratio (HTMT) of correlations served as the primary discriminant validity criterion, with thresholds of 0.90 for conceptually similar constructs and 0.85 for conceptually distinct constructs [77]. Bootstrapped confidence intervals (10,000 subsamples, percentile method) were used to test whether HTMT values were significantly below the threshold [76]. The Fornell-Larcker criterion was computed for completeness but was not relied upon as the primary measure of discriminant validity, based on recommendations by [76, 77]. Similarly, cross-loadings were examined as a supplementary diagnostic when concerns about discriminant validity arose.

The measurement model assessment was conducted iteratively. Where indicators were removed, the model was re-estimated, and all criteria were re-evaluated before proceeding. This iterative process, documented in detail in the results section, led to the removal of 10 indicators (reducing the instrument from 43 to 33 items) and the structural revisions described in the results section. Following the establishment of a satisfactory measurement model, the structural model was assessed using the procedure recommended by [76]. Variance inflation factor (VIF) values were computed for all predictor constructs to ensure that collinearity did not bias the regression estimates. VIF values below 3 were considered ideal; values above 5 indicate probable collinearity issues, while values between 3 and 5 indicate the constructs should be assessed for possible collinearity issues [77].

The bootstrapping procedure (10,000 subsamples) was used to assess the statistical significance of the path coefficients. A two-tailed test at the 5% significance level was applied, producing 95% bias-corrected confidence intervals [81]. Path coefficients, bootstrap t-statistics, p-values, and confidence intervals are reported for all hypothesised relationships. The models' explanatory power was then assessed by computing the coefficient of determination (R^2) for the endogenous construct [77]. The R^2 values were compared against the recommended standard by [81]. R^2 values greater than 0.75 indicate the model has a high explanatory power; R^2 of around 0.50 indicates the model has a moderate explanatory power, while values below 0.25 indicate weak explanatory power [77, 81].

Finally, the model's out-of-sample predictive power was assessed using the PLSpredict procedure with k=10 folds and r=10 repetitions [82]. Additionally, the mean absolute error (MAE) for each indicator of the endogenous construct was compared with a naïve linear regression (LM) benchmark. The classification criteria are as follows: if PLS-SEM produces lower prediction errors than the LM benchmark for all indicators, the model has high predictive power; if the majority of indicators produce lower errors, the model has medium predictive power; if the minority produce lower errors, the model has low predictive power; and if all indicators produce higher errors than the LM benchmark, the model lacks predictive power [81].

Since all data were collected from a single self-report instrument at one point in time, common method bias (CMB) was assessed. As a preliminary screen, Harman's single-factor test was conducted by entering all indicators into an unrotated principal component analysis; although this test is recognised as insensitive to moderate levels of CMB [83], the first component explained only 34.63% of the total variance, well below the 50% threshold that would indicate a dominant common factor. The more rigorous full collinearity assessment approach recommended by [84] was then applied, in which VIF values are computed for all latent variables by regressing them simultaneously on a dummy criterion variable; VIF values of 3.3 or lower indicate the absence of common method bias [85]. The maximum full collinearity VIF observed was 2.939, below the 3.3 threshold. Together, these results suggest that common method bias does not pose a substantial threat to the validity of the findings, though the limitation of single-source cross-sectional data is acknowledged in Section 6.3.

Ethics approval for this research was granted by the Faculty Committee for Research Ethics and Integrity of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. The reference number is EBIT/307/2025.

5. Results

5.1. Descriptive statistics

Table 2 shows the distribution of survey respondents. The majority of respondents were male and above 40 years of age. Architects and structural engineers – the primary target groups for this survey – accounted for 53% and 30% of respondents, respectively. The remaining 16% included related professions such as architectural technologists and builders or contractors.

Table 2. Respondent characteristics

Characteristic	Category	Frequency	Percentage
Gender	Male	74	80%
	Female	17	18%
	Prefer not to say / Non-binary	1	1%
Age (years)	20 to 29	4	8%
	30 to 39	19	21%
	40 to 49	22	24%
	50 to 59	17	18%
	Above 60	27	29%
Profession	Architect	49	53%
	Structural Engineer	28	30%
	Other	15	16%
Professional Qualification	Professional Architect (PArch)	37	40%
	Professional Engineer (PrEng)	22	24%
	Candidate Architect	4	4%
	Candidate Engineer	2	2%
	Other	27	29%
Work Experience (years)	0 to 5	4	4%
	6 to 10	10	11%
	11 to 15	11	12%
	16 to 20	17	18%
	Over 20	50	54%
Experience with Mass Timber	Familiar with but not used	53	58%
	Used in a few projects	31	34%
	Uses regularly	8	9%
Organisation Type	Consultant	54	59%
	Contractor	8	9%
	Property Developer	9	10%
	Other	21	23%

They were, however, included in the survey because of their professional backgrounds in architecture and structural engineering. A combined 64% of respondents have South African professional licences (PArch and PrEng), while a further 6% are candidate architects and engineers. The remaining 29% do not have a professional license. More than half of the respondents (54%) have over 20 years of experience. In fact, only 15% of respondents had 10 years or less of experience. Similarly, over half of the respondents (58%) have not used mass timber even though they are familiar with it. Only 9% of respondents regularly use mass timber in their projects.

Respondents were overwhelmingly positive about the potential use of mass timber in construction, with 91% indicating it can be used for residential buildings, 68% for institutional buildings, and 64% for commercial buildings. Only 3% felt that mass timber is not suitable for any kind of building. Similarly, when asked to indicate the number of building floors for which mass timber would be suitable for, the highest frequency was for two to four floors with 82% of respondents, followed by single-storey buildings with 50% of respondents and five to twelve floors with 26% of respondents. Again, only 3% felt that mass timber is not suitable for any kind of building.

5.2. Measurement model evaluation

The measurement model was assessed following the systematic procedure detailed in 4.5. The initial measurement model comprised eight composite constructs measured by 43 indicators: Performance expectancy (PE1–PE6), effort expectancy (EE1–EE5), social influence (SI1–SI6), facilitating conditions (FC1–FC6), personal resistance (PR1–PR5), perceived cost (PC1–PC5), perceived environmental motivation (PEM1–PEM5), and behavioural intention (BI1–BI5). Indicator reliability assessment was conducted by inspecting the initial outer loadings of the model. All constructs exhibited adequate indicator loadings in the initial model, except for SI, for which four of its six indicators - SI2 (−0.062), SI4 (−0.289), SI5 (−0.098), and SI6 (0.035) - returned loadings well below the 0.40 minimum threshold. These items were subsequently removed. The corresponding indicator reliability values (squared loadings) confirmed that these items explained less than 1% of construct variance each. The remaining two items (SI1 = 0.712; SI3 = 0.860) were retained, and the model was re-estimated, yielding acceptable values.

Internal consistency reliability was then assessed using Cronbach's alpha (α), the reliability coefficient, ρA, and composite reliability, ρC. All constructs demonstrated acceptable values except the PC construct, which exhibited a ρA of 0.981, substantially exceeding the 0.95 upper threshold. This signalled problematic indicator redundancy within the cost measures. To address this, PC2, the indicator with the lowest outer loading in the construct, was removed, which reduced ρA from 0.981 to 0.921, bringing it below the 0.95 ceiling while preserving content validity. After re-estimation, composite reliability values for all constructs fell within the acceptable range: ρC values ranged from 0.797 (SOCINF) to 0.894 (FACCON), and all ρA values remained below 0.95.

Convergent validity was assessed using the AVE; values of 0.50 or higher indicate that the construct explains at least 50% of the variance among its indicators. Following the removal of SI2, SI4, SI5, SI6, and PC2, all constructs achieved AVE values above the 0.50 minimum: PE (0.545), EE (0.503), SI (0.663), FC (0.586), PR (0.590), PC (0.594), PEM (0.641), and BI (0.600). Discriminant validity was then assessed using the HTMT values with thresholds of 0.90 for conceptually similar constructs and 0.85 for conceptually distinct constructs. The initial discriminant validity assessment revealed critical problems with SI. The bootstrapped HTMT 95% confidence intervals for SI–BI and SI–EE were 1.305 and 1.150, respectively, both of which substantially exceeded 1.0. With only two remaining indicators, SI could not be empirically distinguished from the other constructs. Given that the construct had already lost four of its six indicators to reliability failures and now failed discriminant validity with only two items remaining, there was insufficient measurement basis to retain it. Social Influence was therefore removed from the model, reducing it to seven constructs.

A second discriminant validity assessment was conducted without SI, and the bootstrapped HTMT analysis revealed a persistent problem between EE and FC. The original HTMT estimate was 0.929, and the 95% confidence interval upper bound was 1.001, indicating that the confidence interval included 1.0 and thus that the two constructs could not be empirically distinguished. Cross-loading analysis revealed that EE1, EE2 and EE5 loaded substantially onto FC, confirming a persistent lack of empirical distinctness between the two constructs. This finding aligns with established theoretical arguments in the UTAUT literature. Venkatesh [42] noted that EE and FC share conceptual overlap: both capture aspects of the ease or difficulty of using a technology, with EE reflecting individual perceptions and FC reflecting environmental and infrastructural support. They noted that using both constructs to predict behavioural intention could lead to redundancy. Having observed this redundancy empirically, all five original EE items (EE1–EE5) and all six FC items (FC1–FC6) were therefore combined into a single construct labelled execution capability (EXECAP), measured by 11 indicators (EC1–EC11, where EC1–EC6 correspond to FC1–FC6 and EC7–EC11 correspond to EE1–EE5).

Following the merger, the model comprised six constructs: PE (PE1–PE6), EXECAP (EC1–EC11), PR (PR1–PR5), PC (PC1, PC3–PC5), PEM (PEM1–PEM5), and BI (BI1–BI5). The initial post-merger assessment revealed that EXECAP's AVE was 0.484, falling marginally below the 0.50 threshold. The indicator with the lowest reliability was EC11 (formerly EE5, loading = 0.636, indicator reliability = 0.405). This item was removed, which raised the AVE to

0.509, satisfying the convergent validity criterion, and reduced EXECAP to 10 indicators (EC1–EC10). All other composite reliability metrics remained within acceptable bounds: ρC ranged from 0.853 (PC) to 0.911 (EXECAP), and all ρA values remained below 0.95. Discriminant validity assessment via bootstrapped HTMT revealed two pairs with borderline values: PE–PR (original HTMT = 0.890, 95% CI upper bound = 0.971) and PE–BI (original HTMT = 0.761, 95% CI upper bound = 0.913). Cross-loading analysis showed adequate separation, with all indicators loading at least 0.10 higher on their assigned construct than on any other construct. However, PE6, a negatively framed item and the lowest-loading indicator on PE by a substantial margin (0.590 vs the next lowest at 0.725), was contributing to measurement noise. PE6 was removed, improving the AVE of PE from 0.545 to 0.605 and reducing the PE–PR bootstrapped HTMT 95% CI from 0.971 to 0.903. Similarly, PR5 (0.614), the lowest-loading indicator on PR, was also removed, reducing the PE–PR bootstrapped HTMT 95% CI from 0.933 to 0.903. The process is modelled in Fig. 2.

The final measurement model is displayed in Fig. 3. It comprised six constructs and 33 indicators: performance expectancy (PE1–PE5), execution capability (EC1–EC10), personal resistance (PR1–PR4), perceived cost (PC1, PC3–PC5), perceived environmental motivation (PEM1–PEM5), and Behavioural Intention (BI1–BI5).

All outer loadings exceeded the 0.40 minimum, with the majority exceeding the preferred 0.708 threshold. The EXECAP construct retained several indicators in the 0.63–0.67 range (EC2, EC6, EC9, EC10), which were retained to preserve content validity given that the construct was newly formed from the merger of two theoretically meaningful scales. The highest loadings were observed for PEM4 (0.908), PE5 (0.832), and FC-origin items EC4 (0.828) and EC5 (0.767). The outer loadings are displayed in Table 3.

All constructs demonstrated acceptable reliability. Cronbach's alpha ranged from 0.799 (PC) to 0.892 (EXECAP). The reliability coefficient ρA ranged from 0.849 (PR) to 0.923 (PC), with all values remaining below the 0.95 threshold. Composite reliability ρC ranged from 0.853 (PC) to 0.911 (EXECAP). All AVE values exceeded the 0.50 minimum: PE (0.605), EXECAP (0.509), PR (0.687), PC (0.593), PEM (0.641), and BI (0.600). These values are displayed in Table 4.

The HTMT values for all construct pairs fell below the 0.90 threshold for conceptually similar constructs: the highest value was PE–PR (0.815). The values are displayed in Table 5. Bootstrapped HTMT confidence intervals (10,000 subsamples, 90% two-sided / 95% one-sided) confirmed discriminant validity for most pairs. The PE–PR pair returned a 95% CI upper bound of 0.902, which is at the 0.90 threshold. This borderline result is interpretable in light of the conceptual relationship between these constructs. Personal resistance captures a preference for maintaining current standards and a reluctance to change that persists despite positive evidence, while performance expectancy reflects a belief in the practical benefits of mass timber. Barrane [52] found that professionals' evaluations of the usefulness of mass timber directly influenced opposition to the material; in that context, low performance expectations directly sustained preference for conventional materials. On the other hand, [86] found that performance expectancy had no effect on employee attitudes toward e-procurement, yet it still emerged as the strongest predictor of behavioural intention. This suggests that rational performance appraisal (PE) and affective disposition (PR) can operate as separable psychological channels that nonetheless converge on the same behavioural outcome.

In a sample of South African design professionals evaluating a material that most have never specified, both patterns plausibly coexist: some respondents resist because they doubt the material's performance, others resist despite acknowledging its merits. The combined effect is empirical proximity between the constructs without necessarily being conflated as conceptual identity, which is precisely the condition for which the 0.90 threshold was recommended [87]. Moreover, cross-loading analysis confirmed clean separation: all PE indicators loaded at least 0.18 higher on PE than on PR, and all PR indicators loaded at least 0.16 higher on PR than on PE. The PE–BI pair returned a 95% CI upper bound of 0.884, comfortably below the 0.90 threshold. The Fornell-Larcker criterion was also satisfied for all construct pairs, with the square root of each construct's AVE exceeding its highest correlation with any other construct. The bootstrapped HTMT confidence interval test results are displayed in Table 6.

5.3. Structural model assessment

Following the establishment of a satisfactory measurement model, specifying direct paths from all five predictor constructs, performance expectancy (PE), execution capability (EXECAP), personal resistance (PR), perceived cost (PC), and perceived environmental motivation (PEM) to the single endogenous construct, behavioural intention (BI), the structural model was assessed using the procedure recommended by [76]. This procedure involves assessing collinearity among predictor constructs, assessing the relevance and significance of the path coefficients, examining the coefficient of determination (R^2), and evaluating the model's out-of-sample predictive power using PLSpredict [81]. The steps are detailed in Table 7.

Collinearity was assessed using VIF, with all predictor constructs returning VIF values below the threshold of 3: PEM (1.292), PC (1.844), EXECAP (1.858), PE (2.206), and PR (2.362). Collinearity among the predictor constructs was therefore not a concern and did not bias the regression estimates. Next, path coefficient significance was assessed using the bootstrapping procedure with 10,000 subsamples [76].

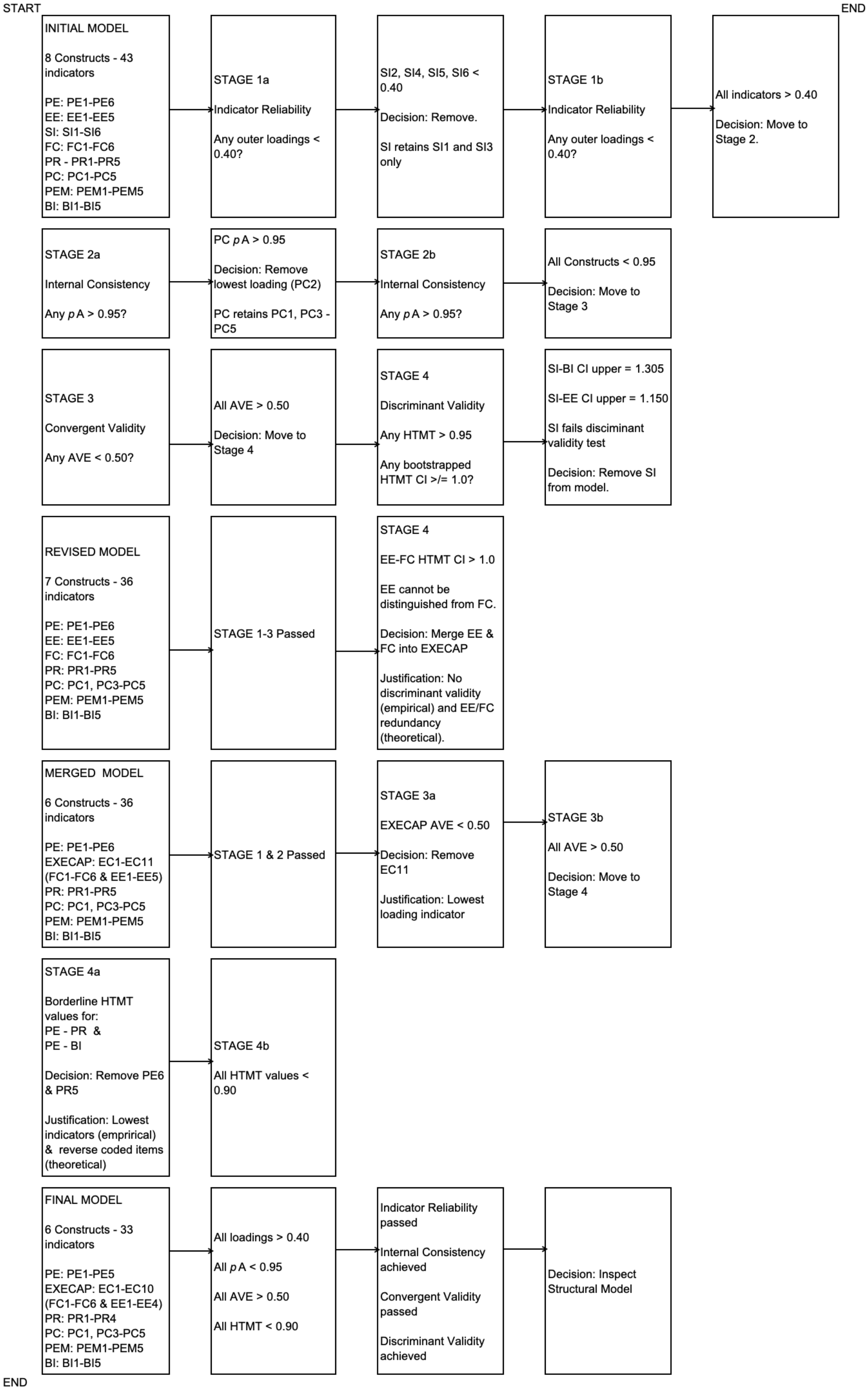

Fig. 2. Measurement model investigation iterations

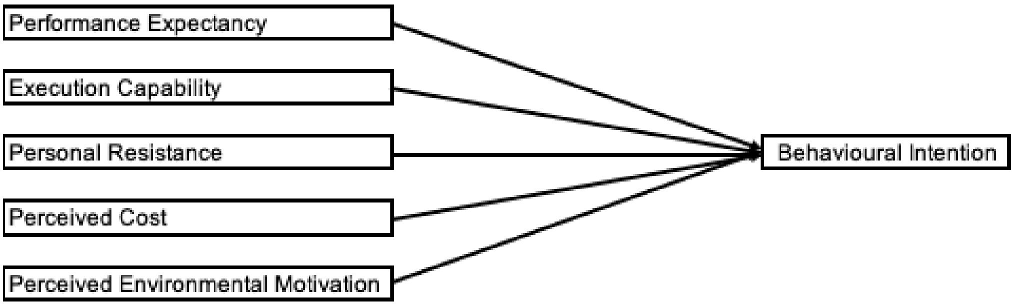

Fig. 3. Final merged model

Table 3. Merged model outer loadings

	PE	EXECAP	PR	PC	PEM	BI
PE1	0.75053455	0	0	0	0	0
PE2	0.78460395	0	0	0	0	0
PE3	0.72708557	0	0	0	0	0
PE4	0.79208224	0	0	0	0	0
PE5	0.83159637	0	0	0	0	0
EC1	0	0.75376811	0	0	0	0
EC2	0	0.63382576	0	0	0	0
EC3	0	0.71785244	0	0	0	0
EC4	0	0.82844004	0	0	0	0
EC5	0	0.76680614	0	0	0	0
EC6	0	0.66507491	0	0	0	0
EC7	0	0.71268699	0	0	0	0
EC8	0	0.73404514	0	0	0	0
EC9	0	0.64352905	0	0	0	0
EC10	0	0.65170131	0	0	0	0
PR1	0	0	0.82414202	0	0	0
PR2	0	0	0.8299394	0	0	0
PR3	0	0	0.85704726	0	0	0
PR4	0	0	0.8023474	0	0	0
PC1	0	0	0	0.69385235	0	0
PC3	0	0	0	0.80729071	0	0
PC4	0	0	0	0.84229481	0	0
PC5	0	0	0	0.72813318	0	0
PEM1	0	0	0	0	0.84506598	0
PEM2	0	0	0	0	0.80544332	0
PEM3	0	0	0	0	0.80236019	0
PEM4	0	0	0	0	0.90814765	0
PEM5	0	0	0	0	0.61152798	0
BI1	0	0	0	0	0	0.84509449
BI2	0	0	0	0	0	0.81190272
BI3	0	0	0	0	0	0.7517888
BI4	0	0	0	0	0	0.77415999
BI5	0	0	0	0	0	0.6792396

Table 4. Merged model reliability and convergent validity

	Cronbach's alpha	*p*A	*p*C	AVE
PE	0.83854446	0.85744503	0.88441343	0.60530114
EXECAP	0.89207453	0.89777665	0.91137731	0.5087432
PR	0.84794184	0.84932677	0.8975135	0.68657521
PC	0.7991557	0.92263865	0.85289755	0.59319696
PEM	0.85890098	0.9022934	0.89789095	0.64107119
BI	0.83177994	0.83901176	0.88173284	0.59984945

Table 5. Merged model discriminant validity

	PE	EXECAP	PR	PC	PEM	BI
PE	0.7780110*					
EXECAP	0.58042286	0.7132624*				
PR	0.81525959	0.70620233	0.8285983*			
PC	0.55119698	0.67604177	0.62051343	0.7701928*		
PEM	0.42067294	0.22404116	0.27532738	0.44030996	0.8006692*	
BI	0.73037277	0.65981986	0.66778011	0.50596983	0.68032378	0.7744995*

* = Square root of AVE

Table 6. Merged model discriminant validity

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	5% CI	95% CI	Boot P Val
PE→EC	0.580423	0.590659	0.109551	3.829966	0.403010	0.760513	0
PE→PR	0.815260	0.816770	0.054188	3.409248	0.723600	0.901737	2.00E-04
PE→PC	0.551197	0.579644	0.091379	4.911470	0.442945	0.741453	0
PE→PEM	0.420673	0.435194	0.123746	4.681595	0.235646	0.643694	0
PE→BI	0.730373	0.736843	0.092168	2.925391	0.583434	0.885166	6.00E-04
EC→PR	0.706202	0.706370	0.082531	3.559842	0.560569	0.834451	0
EC→PC	0.676042	0.676044	0.076232	4.249619	0.545332	0.794463	0
EC→PEM	0.224041	0.279177	0.078204	9.922281	0.172144	0.422861	0
EC→BI	0.659820	0.661867	0.081995	4.148782	0.519450	0.790204	0
PR→PC	0.620513	0.621178	0.088058	4.309499	0.470771	0.759348	0
PR→PEM	0.275327	0.308841	0.089423	8.103852	0.173805	0.463190	0
PR→BI	0.667780	0.667107	0.082636	4.020266	0.524865	0.796758	0
PC→PEM	0.440310	0.456928	0.082818	6.758045	0.326046	0.598845	0
PC→BI	0.505970	0.527306	0.105482	4.683529	0.357700	0.702950	0
PEM→BI	0.680324	0.690475	0.081439	3.925339	0.556701	0.823735	0

Table 7. Structural model assessment criteria

Assessment Step	Indicator	Metrics and Interpretation
Collinearity Assessment	Variance Inflation Factor (VIF)	VIF < 3 → Ideal 3 </= VIF </= 5 → Possible collinearity but not critical VIF > 5 → Critical collinearity issues
Significance Testing	Path Coefficients (β)	Significant if: $p < 0.05$ and, 95% CI does not include zero (0)
Effect Size	f^2	f^2 >/= 0.35: Large f^2 >/= 0.15: Medium f^2 >/= 0.02: Small $f^2 < 0.02$: No effect
Explanatory Power	Coefficient of Determination (R^2)	$R^2 > 0.75$ → Substantial $R^2 \sim 0.50$ → Moderate $R^2 < 0.25$ → Weak Note: Interpret relative to model complexity
Predictive Power (Out-of-sample)	PLSpredict (Compare PLS-SEM Model to Linear Model (LM) using root mean squared error (RMSE) or mean absolute error (MAE)	Lower error for: all PLS-SEM indicators vs LM → High predictive power; majority/equal number of PLS-SEM indicators vs LM → Medium predictive power; minority PLS-SEM indicators vs LM → Low predictive power; no PLS-SEM indicators vs LM → No predictive power.

A two-tailed test at the 5% significance level was applied, consistent with standard practice for path coefficient assessment [81]. The 95% confidence intervals were examined alongside the bootstrap t-statistics and p-values. Three of the five hypothesised paths were statistically significant. The values are provided in Table 8.

PEM→BI ($\beta = 0.455$, $t = 5.654$, $p < 0.001$, 95% CI [0.283, 0.600]) was the strongest predictor, indicating that respondents who perceived mass timber as environmentally beneficial reported substantially higher behavioural intention to adopt the material. The large f^2 effect size (0.463) confirms that this relationship is not merely statistically significant but substantively important. EXECAP→BI ($\beta = 0.326$, $t = 3.852$, $p < 0.001$, 95% CI [0.151, 0.483]) was the second-strongest predictor. The result suggests that respondents who perceived greater organisational, regulatory, and infrastructural readiness to implement mass timber reported higher behavioural intentions to adopt mass timber. The medium f^2 effect size (0.150) indicates a meaningful unique contribution beyond the other predictors. PE→BI ($\beta = 0.256$, $t = 2.864$, $p = 0.007$, 95% CI [0.082, 0.438]) was the third predictor, although its effect was substantially lower than PEM and EXECAP. This suggests that the perceived performance advantages of mass timber predict behavioural intentions, albeit modestly. The small-to-medium f^2 effect size (0.090) indicates a modest but genuine unique contribution.

Two paths were not statistically significant: PR→BI ($\beta = -0.111$, $t = 1.265$, $p = 0.202$, 95% CI [−0.296, 0.053]) and PC→BI ($\beta = 0.064$, $t = 0.661$, $p = 0.593$, 95% CI [−0.149, 0.232]). For the relationship between PR and BI, the coefficient's direction is theoretically consistent: higher resistance is associated with lower behavioural intention. However, the relationship did not reach statistical significance. The confidence interval spans zero, confirming that the effect cannot be distinguished from no relationship at the 5% significance level. The negligible f^2 effect size (0.013) further indicates that PR contributes virtually no unique explanatory power beyond the other predictors. Similarly, the wide confidence interval for the relationship between PC and BI, spanning from negative to positive, indicates that the result is indistinguishable from zero and should not be interpreted substantively, despite the positive sign suggesting a counterintuitive relationship: that higher perceived cost is weakly associated with higher behavioural intention. The negligible f^2 effect size (0.005) confirms the conclusion that PC contributes essentially no unique explanatory power.

The model's explanatory power was assessed using the R^2 value for behavioural intention, which was 0.662, with an adjusted R^2 of 0.642. Following the guidelines of [81], which considers values of 0.75, 0.50, and 0.25 to be substantial, moderate, and weak, respectively, the model demonstrates moderate-to-substantial explanatory power. The five predictor constructs collectively explain approximately 66% of the variance in behavioural intention to adopt mass timber. The adjusted R^2 accounts for the number of predictor constructs and confirms that the explanatory power is not merely an artefact of model complexity. Finally, the model's out-of-sample predictive power was assessed using the PLSpredict procedure [82]. The mean absolute error (MAE) was used as the primary prediction statistic, comparing PLS out-of-sample (OOS) errors against LM OOS errors for each indicator of the endogenous construct. The PLS-SEM model produced lower out-of-sample MAE values than the LM benchmark for all five BI indicators as shown in Table 9.

6. Discussion

This study set out to test a conceptual model of mass timber adoption in the South African construction industry, extending UTAUT with domain-specific constructs drawn from three prior literature reviews. The initial model was refined based on measurement and theoretical evidence.

Table 8. Merged model path significance

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI	Bootstrap P Val
PE→BI	0.2561	0.2601	0.0894	2.8641	0.0825	0.4376	0.0072
EXECAP→BI	0.3258	0.3211	0.0846	3.8516	0.1514	0.4830	0.0004
PR→BI	-0.1106	-0.1077	0.0874	-1.2649	-0.2955	0.0535	0.2020
PC→BI	0.0643	0.0497	0.0972	0.6609	-0.1486	0.2319	0.5930
PEM→BI	0.4552	0.4490	0.0805	5.6536	0.2827	0.5999	0.0000

Table 9. Merged model OOS prediction

Indicator	PLS OOS MAE	LM OOS MAE	Does PLS outperform LM?
BI1	0.538	0.735	Yes
BI2	0.629	0.675	Yes
BI3	0.514	0.612	Yes
BI4	0.595	0.733	Yes
BI5	0.890	1.034	Yes

Social influence was removed during the measurement model assessment due to fundamental reliability and discriminant validity failures, while effort expectancy and facilitating conditions were combined to form a new construct, execution capability, based on measurement results and supported by theoretical evidence from [42]. The final structural model explains 66.2% of the variance in behavioural intention (Adj. $R^2 = 0.642$), representing moderate-to-substantial explanatory power. Of the five hypothesised predictors, three were statistically significant: perceived environmental motivation, execution capability, and performance expectancy, while personal resistance and perceived cost were not statistically significant and exhibited negligible effect sizes. The PLSpredict analysis confirmed high out-of-sample predictive power, with the PLS-SEM model outperforming the linear model benchmark on all five Behavioural Intention indicators. Each of these findings is discussed in turn below, followed by consideration of the model's theoretical and practical implications.

PEM emerged as the strongest predictor of BI ($\beta = 0.455$, $p < 0.001$), with a large effect size ($f^2 = 0.463$) that substantially exceeds those of all other constructs. This result positions environmental concern as the primary driver of behavioural intention to adopt mass timber among South African construction professionals, with both theoretical and practical significance. Introduced as an extension to UTAUT in the conceptual model to test whether the sustainability credentials of mass timber are important to potential users, its dominance suggests that mass timber's identity in the South African market is fundamentally tied to its environmental credentials, rather than to purely technical or economic considerations. The finding corroborates [88], which examined green building adoption in Pakistan and found that environmental concern was the single strongest predictor across all measured constructs ($\beta = 0.378$, $p < 0.001$). The present study's effect size ($\beta = 0.455$) exceeds that benchmark, suggesting that environmental motivation may be even more salient in the mass timber context than in general green building adoption.

The literature also supports PEM's dominance. Giorgio [69] observed in their interviews with construction professionals in Canada that the use of mass timber is primarily motivated by its superior environmental performance, specifically its renewable nature, lower greenhouse gas emissions compared to concrete and steel, and the long-term carbon storage capabilities of mass timber buildings. Markstrom [70] also observed similarly strong environmental motivations in an analysis of Swedish architects. Additionally, an investigation of the factors influencing the adoption of mass timber in Singapore found that its lower carbon emissions and potential for sustainable forest practices ranked among the top 10 adoption drivers [32]. PEM's dominance should, however, be placed in context. This investigation sought to measure the effect of environmental motivation on intention to use; actual use of mass timber may be impacted by other factors. According to [59], while sustainability is highly valued by stakeholders, it provides insufficient motivation for adoption unless it is balanced by clear commercial opportunities.

EXECAP, the merged construct formed from EE and FC, was the second-strongest predictor of BI ($\beta = 0.326$, $p < 0.001$) with a medium effect size ($f^2 = 0.150$). The emergence of this construct is an intriguing finding from this study, necessitated by the persistent failure of EE and FC to achieve discriminant validity across multiple model measurements. Respondents did not empirically distinguish between their individual perceptions of ease of use and the environmental or institutional conditions enabling adoption. This lack of discriminant validity between EE and FC aligns with the original logic of [42], who argued that FC's influence on BI is often redundant when EE is present. Venkatesh [42] posited that if a user perceives a technology as easy to use, they implicitly assume the necessary support structures exist, effectively "capturing" FC within the EE construct. Previous studies using UTAUT to explain adoption in the construction industry [62, 86, 89, 90] have independently observed the distinct influences of EE and FC on BI, contradicting the conceptualisation by [42]. However, those studies examined individually operated technologies, where the distinction between a system's ease of use and its supporting infrastructure is clear. Unlike an IT system, which a user operates individually within a pre-existing organisational infrastructure, a construction material can only be specified when supply chains, regulatory frameworks, skilled labour, and design tools are all available simultaneously. For mass timber in South Africa, the question of whether the material is easy to use is inseparable from whether the conditions exist to use it at all. We propose that this is a structural feature of mass timber and, potentially, a construction material adoption, which differs from IT system adoption for which UTAUT was proposed.

PE was the final predictor of BI ($\beta = 0.256$, $p = 0.007$) with a small-to-medium effect size ($f^2 = 0.090$). This finding is consistent with the central prediction of UTAUT; the degree to which a professional believes mass timber can deliver the core performance outcomes required of a building project, structural adequacy, construction speed, and aesthetic quality, significantly predicts their intention to adopt it. PE is typically reported as the strongest predictor in UTAUT studies across various technology adoption contexts [91], and some studies in the construction industry have observed similar results [63, 86, 92-94]. In this study, however, it was the third-strongest predictor, with both PEM and EXECAP producing larger effects. This relative positioning suggests that the intention to adopt mass timber in South Africa is not principally a question of whether the material performs adequately. Rather, the dominance of environmental motivation and execution readiness suggests that respondents may already recognise mass timber's performance potential but are more strongly influenced by its sustainability alignment and the systemic conditions that enable its practical implementation. These results are consistent with [88], which found that environmental concern was a more important factor for intention to build green buildings. It is instructive to observe that, in construction adoption studies where PE was the most dominant factor, the technologies were information systems.

The non-significant factors also bear further discussion. PR did not significantly predict behavioural intention ($\beta = -0.111$, $p = 0.202$, $f^2 = 0.013$). The coefficient's direction is theoretically consistent: higher resistance is associated with lower behavioural intention, but the effect is not distinguishable from zero. The negligible effect size indicates that resistance contributes virtually no unique explanatory power beyond the other predictors. Given the prominence of resistance to change in the SACI technology adoption literature, this finding is particularly notable. Ibem [95] observed that resistance to change was the second most common barrier to the adoption of e-tendering in their survey of South African construction professionals. In a survey measuring factors affecting the adoption of information technology systems in the SACI, resistance to change was also identified as the largest barrier to adoption [96]. Similarly, a principal component analysis of barriers to the adoption of construction 4.0 technologies in the SACI ranked resistance to change as the single most important barrier [97]. Across the SACI technology adoption literature, resistance to change is a constant theme [98].

One plausible explanation lies in the group of respondents this survey targeted. The survey sample represents a self-selected group of professionals who are aware of and have actively engaged with the technology. Compared with the general population of South African architects and structural engineers, and with the novelty of mass timber construction in the SACI, respondents in this study are likely to be classified as the Innovator or Early Adopter groups of the Innovation Diffusion curve. This is relevant because resistance theory contends that resistance is not uniform across an industry; it is highest among "Laggards" and decreases as one moves toward the "Innovator" end of the spectrum [99]. Given that the respondents are likely innovators or early adopters, their reported resistance is likely to be low. For instance, the survey was circulated through the Green Building Council South Africa, whose members might be predisposed toward sustainable construction practices, and may therefore report higher environmental motivation and lower resistance to green materials than the broader population of design professionals. Another possible explanation could be "Circle of Blame", proposed by [66] as a barrier to the adoption of CLT in the United States. In the SACI, professionals tend to externalise resistance, citing "the industry" as the primary barrier [51, 98]. If respondents do not view themselves as the source of resistance, self-reported data will underrepresent the construct, reflecting a lack of personal resistance while shifting the burden of non-adoption to external stakeholders. Still, the non-significance of PR in this study should not be interpreted as evidence that resistance is unimportant for mass timber adoption in general; it reflects the characteristics of this particular sample, and a broader sample may produce different results.

The other non-significant factor is PC ($\beta = 0.064$, $p = 0.593$, $f^2 = 0.005$). The wide confidence interval [−0.149, 0.232] spans zero, confirming that the result is statistically indistinguishable from no relationship. The non-significance of cost is surprising given that it is consistently cited as a barrier to mass timber adoption. Giorgio [69] found that the majority of construction professionals in their study cited cost as a barrier to mass timber adoption. Similarly, a survey of construction professionals in the United Kingdom revealed that the perceived high cost of CLT was a barrier to adoption [59]. In South Africa, high initial material costs have been described as a barrier to the use [35], therefore, this study's non-significant measurement of PC deserves some explanation. One potential reason could again be traced to the composition of survey respondents, who largely have positive opinions of mass timber, likely creating a positive bias that overshadows cost considerations.

According to [58], under a normative goal frame, pro-environmental actions are primarily driven by a sense of right and wrong, rather than cost considerations, especially in low-cost situations. While construction projects are typically capital-intensive, the phase of behavioural intention, which this research examines, can be reasonably expected to be less cost-sensitive compared to the subsequent stage of actual adoption. In this study, respondents indicated that environmental motivation is the primary driver of behavioural intention; hence, the influence of other concerns, such as cost, is likely to have been suppressed. This is reinforced by the respondents' professional roles: while they may contribute to budgetary discussions, they may lack the ultimate financial authority to compel a more critical evaluation of expenses. Despite design professionals' intention to use mass timber, other project stakeholders may sometimes override eventual use [28, 69]. As with PR, the non-significance of PC is specific to this sample; cost is likely to function as a decisive barrier at the project level and among the broader population of construction decision-makers.

SI was removed from the initial model during measurement model assessment due to indicator reliability failures, four of six indicators loaded below 0.40, followed by discriminant validity failure of the two remaining indicators. While this removal was data-driven, it raises questions about SI's role in the adoption of mass timber. SI was developed in the context of individual technology adoption, where peer pressure, supervisor encouragement, and subjective norms directly shape personal technology use decisions [42]. The items used to operationalise SI in this study were adapted from construction and technology adoption literature, with items measuring role models, peers, organisations, project teams, and clients. The failure of the construct suggests that these groups provide social cues in ways that do not align with one another and that these sources are too varied to be captured by a single reflective scale.

6.1. Theoretical implications

The findings contribute to the UTAUT literature in several ways. First, the study demonstrates the utility of UTAUT as a theoretical foundation for studying construction material adoption, while simultaneously identifying the need for context-specific modifications. The original UTAUT framework was modified by the addition of perceived environmental motivation, the removal of social influence, and the merger of effort expectancy with facilitating conditions before it could adequately explain behavioural intention to adopt mass timber. These modifications suggest that applying UTAUT to mass timber adoption requires rethinking the boundary conditions of its core constructs. Barrane [52], one of the only studies to apply UTAUT directly to mass timber adoption, similarly found that the model requires contextual reinterpretation beyond the original framework. Additionally, the emergence of execution capability as a single construct challenges the theoretical distinctiveness of effort expectancy and facilitating conditions in contexts where the unit of adoption is not an individually operated technology but a material, embedded, complex project environment, such as the construction industry. Respondents' inability to separate perceptions of ease from industry readiness suggests these factors constitute a single factor. Specifying mass timber is not easy if supply chains do not exist, building codes do not accommodate it, and contractors lack experience with it. Ease of use and enabling conditions are functionally inseparable for a material embedded in a complex project environment. This merger serves as a conceptual contribution of this study and may have implications beyond mass timber, potentially extending to the adoption of other construction material innovations.

Furthermore, the dominance of perceived environmental motivation over the core UTAUT constructs signals that for construction materials perceived as environmentally significant, sustainability values may outweigh technical performance as the primary driver of intention. Batool [88] documented a similar pattern for green building adoption in Pakistan, where environmental concern exceeded all other UTAUT predictors. The present study extends this finding to a specific material, suggesting that environmental motivation is not merely a secondary consideration but a primary driver that should be included in adoption models for sustainable construction technologies. Finally, the non-significance of perceived resistance and perceived cost as independent predictors, despite their prominence in the literature, suggests that barriers that are salient at the industry or organisational level may not function as reliable individual-level predictors. This has methodological implications for future UTAUT-based studies in construction; future studies may want to specify the level at which these constructs operate.

6.2. Practical implications

The findings carry several implications for industry practitioners and policymakers seeking to promote mass timber adoption in South Africa. The dominance of perceived environmental motivation suggests that industry promotion of mass timber should reinforce its environmental credentials. Communication strategies that frame mass timber primarily in technical performance terms may be less effective than those emphasising its sustainability contribution. The significance of execution capability underscores the need for interventions that simultaneously reduce perceived effort and improve enabling conditions. Standards bodies such as the South African Bureau of Standards should prioritise regulatory pathways that accommodate mass timber within existing building code frameworks, providing the formal legitimacy that enables specification. Manufacturers and industry bodies must establish reliable local supply chains for engineered timber products; without accessible materials, design intent cannot translate into construction practice. Professional bodies can integrate mass timber design into continuing professional development programmes, addressing the technical competence dimension of execution capability. For policymakers, isolated interventions are likely to fail; providing guidelines without simultaneously addressing supply chain gaps and regulatory barriers will not reduce the perceived difficulty of adoption, because professionals experience these conditions as a single, integrated challenge. Finally, the non-significance of perceived cost and perceived resistance as independent predictors suggests that cost interventions alone, such as subsidies or tax incentives, and resistance-focused communication campaigns may have limited direct effects on individual behavioural intentions in this sample, though cost likely operates as a decisive factor in project-level decision-making.

6.3. Limitations

Several limitations should be acknowledged. First, the sample size of 92 respondents, while meeting the minimum requirements for PLS-SEM estimation, limits the statistical power to detect small effects. The non-significance of personal resistance and perceived cost may partly reflect insufficient power to detect genuinely small but non-zero effects and, in the case of personal resistance, may additionally reflect self-selection bias that compressed the construct's variance. Replication with a larger and more representative sample would strengthen confidence in these findings. Second, the use of behavioural intention as the dependent variable, rather than actual adoption behaviour, is a recognised limitation of UTAUT-based research.

While its use is justified in the construction context, where actual material use is a collective, project-dependent event that limits individual-level behavioural observation, it further contributes to the well-documented intention-behaviour gap. Additionally, the removal of social influence from the model limits the study's ability to speak to its role in mass timber adoption. The measurement failure does not mean social influence is irrelevant; rather, it indicates that the construct as operationalised did not function in this context. Future research should consider using alternative operationalisations. Furthermore, although the instrument underwent expert review for content validity, a statistical pilot test was not conducted prior to full distribution. The discriminant validity issues encountered during analysis (particularly the EE-FC collapse and the SI measurement failure) may have been identified earlier through a pilot study, and future researchers adapting UTAUT constructs to construction material contexts are advised to include this step. Finally, the cross-sectional, single-source design introduces the risk of common-method bias. Although the CMB tests reported in Section 4.5 did not indicate a challenge, separating the predictor and criterion measures would provide stronger assurance in future studies.

Qualitative research is needed to explore why the constructs in the model behaved as they did, complementing the quantitative findings and providing the contextual depth necessary to inform targeted interventions. Research exploring potential moderating effects, including professional role (architects versus structural engineers, or the addition of other construction professionals), project type (residential, commercial, industrial), and geographic location, would help establish whether the observed relationships are stable across the South African construction industry. The execution capability construct warrants further investigation across other construction innovation contexts to determine whether the merger of effort expectancy and facilitating conditions is a general feature of construction material adoption or specific to mass timber adoption in the South African construction industry.

7. Conclusions

This study tested a UTAUT-based conceptual model of mass timber adoption in the South African construction industry using PLS-SEM with data from 92 construction professionals. The analysis required iterative refinement of the measurement model, resulting in the removal of social influence due to indicator reliability and discriminant validity failures, the merger of effort expectancy and facilitating conditions into a single construct (execution capability), and the removal of 10 indicators from the original 43-item instrument. The final structural model explained 66.2% of the variance in behavioural intention and demonstrated high out-of-sample predictive power. Three predictors significantly influenced behavioural intention to adopt mass timber: perceived environmental motivation, execution capability, and performance expectancy. Personal resistance and perceived cost were not significant predictors in the presence of the other constructs. These results suggest that UTAUT provides a viable theoretical foundation for studying the adoption of construction materials but requires context-specific extensions and structural modifications to adequately capture the dynamics of this complex system.

Declarations

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

There is no specific funding or grant related to this paper. However, the second author is the Chairperson of the York Timbers Chair in Wood Structural Engineering for a Sustainable Built Environment and African Bio-economy at the University of Pretoria. The first author has received bursaries from the Chair. The York Timbers Chair supports research that promotes the adoption of structural wood products in South Africa’s timber-based built environment and bio-economy.

Author Contributions

F. S. Hassan: Conceptualisation, Methodology, Formal analysis, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualisation, Project administration. S. Grobbelaar: Resources, Writing – Review & Editing, Supervision.

Acknowledgments

The research was supported by the York Timbers Chair in Wood Structural Engineering for a Sustainable Built Environment and African Bio-economy at the University of Pretoria. The Chair aims to promote the adoption of structural wood products within the context of a sustainable, timber-based built environment and the wood-based bio-economy in South Africa.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

Ethics approval for this research was granted by the Faculty Committee for Research Ethics and Integrity of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria. The reference number is EBIT/307/2025.

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The authors used Grammarly to identify errors in spelling and grammar and have reviewed and take full responsibility for the final content.

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