INTERNATIONAL JOURNAL OF SUSTAINABLE CONSTRUCTION ENGINEERING AND TECHNOLOGY
ISSN: 2180-3242 e-ISSN: 2600-7959

IJSCET

Vol. 16 No. 2 (2025) 280-299
https://publisher.uthm.edu.my/ojs/index.php/ijscet

Toward Net Zero Carbon Buildings in Vietnam: Fostering Sustainable Mindsets Among The Future Construction Workforce

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DOI: https://doi.org/10.30880/ijscet.2025.16.02.017

Article Info

Received: 21 January 2025
Accepted: 26 August 2025
Available online: 15 September 2025

Keywords

Sustainable mindsets, Net Zero Carbon Buildings, future construction workforce, sustainability education, Vietnam

Abstract

Developing a sustainability mindset among future construction professionals is critical for advancing Net Zero Carbon Buildings (NZCB) in Vietnam. This study analyses 613 student survey responses using one-way and two-way ANOVA to examine differences in Sustainability awareness and Benefits, Motivation & Opportunities, and Barriers related to Sustainable mindset across academic years and majors. The results reveal significant gaps: early-year students demonstrate notably lower awareness than final-year students and former students. Similarly, students in Construction Management show less awareness compared to those in Architecture and Civil Engineering. However, significant differences in perceived Benefits, Motivation & Opportunities, and Barriers were found only between early-year and more advanced students, rather than across majors. These findings highlight the importance of integrating sustainability education early in university curricula and tailoring it to specific professional tracks. The results provide a valuable evidence base for shaping policies and educational reforms to cultivate sustainability competencies among Vietnam's future construction workforce, thereby supporting the national NZCB agenda.

1. Introduction

Sustainable development has increasingly become a central objective in global policy agendas, particularly within the construction and architectural sectors [1]. As a key driver of socio-economic infrastructure, the construction industry significantly contributes to national development. However, it is also a major source of environmental degradation and social challenges. The imperative for sustainability in construction has, therefore, garnered growing scholarly interest. Existing research underscores that the pursuit of sustainability in this sector necessitates fundamental changes in design philosophies, material choices, construction methodologies, and operational frameworks.

In response to these challenges, the Vietnamese government has implemented a range of strategic initiatives, including national plans, regulatory frameworks, and policy commitments aimed at promoting sustainable construction practices [2]. These efforts emphasise the adoption of green materials and the implementation of energy-efficient building solutions. Alongside adherence to international benchmarks, Vietnam has also developed its own green building certification system—LOTUS—which assesses sustainability performance based on criteria adapted to the local context [3]. Notably, the 2024 national roadmap for construction development, issued by the Prime Minister, positions sustainability as a core strategic objective through 2045 [4].

Enhancing sustainability awareness and fostering sustainable mindsets among key stakeholders in the construction sector has been widely identified, both in domestic and international literature, as a critical strategy for driving systemic change [1], [5], [6]. Nevertheless, most empirical studies to date have concentrated on the capabilities and awareness of professionals such as architects and engineers operating within investment, consulting, and contracting entities [7], [8], [9]. Comparatively limited attention has been paid to students and recent graduates in architecture and construction, despite their emerging role as the next generation of professionals who will shape the built environment [10], [11]. This gap in the literature is particularly concerning, as an insufficient understanding or commitment to sustainability at the early stages of professional development may lead to suboptimal decisions with long-lasting environmental, economic, and social repercussions [12], [13].

This study employs a mixed-methods design, integrating qualitative insights from a comprehensive literature review with quantitative data gathered through surveys and statistical analyses. The research focuses on assessing the current level of sustainability awareness and mindset among students and alumni from Vietnamese universities offering programs in architecture and construction. Additionally, it investigates key enablers and obstacles that influence the development of sustainability knowledge. The outcomes of this study are expected to provide both practical and scholarly contributions, offering an evidence-based foundation for enhancing educational curricula aimed at strengthening sustainability competencies within Vietnam's future construction workforce.

2. Literature Review

2.1 Sustainability in Built Environment

Sustainable development constitutes a critical conceptual foundation in contemporary academic and policy discourse. It was first explicitly and comprehensively articulated in the Brundtland Report [14], published by the World Commission on Environment and Development (WCED). The report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition has since underpinned a wide array of international development strategies, emphasising the principle of intergenerational equity and the imperative to maintain a balanced integration of economic advancement, social well-being, and environmental stewardship. The United Nations' adoption of the Sustainable Development Goals (SDGs) in 2015 further operationalised this concept through 17 measurable objectives, encompassing poverty alleviation, environmental conservation, and the promotion of social justice [15].

In previous research, the concept of sustainable development has been significantly elaborated and diversified. Glavič and Lukman describe it as a holistic and interdependent system wherein economic, environmental, and social dimensions are intrinsically linked [16] . Munasinghe proposed the "sustainability triangle," highlighting the necessity of assessing trade-offs among these dimensions when formulating development priorities [17]. Berardi offers a sector-specific interpretation by applying the concept to urban and construction contexts, advocating for the creation of built environments that both minimise ecological impact and enhance economic efficiency and quality of life [18]. These theoretical contributions underscore that sustainable development should not be regarded as an abstract or static ideal but rather as a dynamic and context-sensitive construct.

Within the construction sector, sustainable development is frequently conceptualised through the lens of resource efficiency, environmental responsibility, and enhancement of human living standards. Häkkinen and Belloni argue that sustainable construction entails a dual imperative: minimising the environmental footprint of buildings while maximising their long-term value [19]. This involves the adoption of environmentally preferable materials, the integration of renewable energy technologies, and the reduction of life-cycle operational costs. Despite its widespread relevance, sustainable development remains an inherently complex and evolving concept. Naredo posits that the term's success lies in its semantic plurality, which enables broad applicability but also invites interpretive ambiguity [20]. Van Den Bergh provides a critical examination of twelve theoretical approaches to sustainable development, concluding that it is a fundamentally interdisciplinary paradigm, requiring insights from multiple fields to be meaningfully applied [21]. Crucially, sustainable development is not a static or universally fixed construct. It is adaptive and must be contextualised23 according to specific socio-economic, environmental, and cultural conditions. While this adaptability poses definitional challenges, it also enables more innovative, responsive, and context-appropriate applications across diverse sectors, regions, and institutional settings.

In this study, sustainable development is conceptualised as a dynamic process aimed at achieving an equitable integration of economic viability, social equity, and environmental protection to meet present needs without impairing the capacity of future generations to meet theirs. This definition incorporates not only the efficient utilisation of resources and the mitigation of environmental degradation but also the promotion of quality of life and the advancement of societal equity. In the context of the construction industry, this conceptualisation is further operationalised through three primary dimensions: “Sustainable design and construction” (The implementation of green technologies and environmentally responsible materials to reduce energy and resource consumption); “Efficient resource management” (The strategic use of material and human resources to balance economic efficiency with long-term environmental sustainability); and “Social value generation” (Ensuring that built environments meet the functional and well-being needs of individuals and communities, while simultaneously raising public awareness regarding environmental responsibility).

This definition serves as the theoretical foundation for the development of this study’s research instruments, including survey questionnaires designed to assess the level of awareness, mindset, and influencing factors associated with sustainability knowledge acquisition among students and recent graduates in architecture and construction disciplines. Furthermore, it informs the analysis and formulation of policy and educational recommendations aimed at enhancing the capacity of Vietnam’s future construction workforce to contribute to the national objective of achieving net-zero emissions by 2050.

2.2 Sustainable Awareness and Mindsets

Awareness of sustainable development is defined as the ability to recognise and understand core concepts, values, and the overarching importance of sustainability within its economic, social, and environmental contexts.

2.2.1 Awareness of Sustainable Development

Awareness of sustainable development is defined as the ability to recognise and understand core concepts, values, and the overarching importance of sustainability within its economic, social, and environmental contexts. According to Olsson and Gericke, awareness entails more than mere familiarity with the basic principles of sustainable development; it also encompasses the ability to assess the implications of both individual and collective actions for the long-term stability of socio-ecological systems [22].

This awareness is constructed upon three principal components:

- **Conceptual comprehension**: A clear understanding of what sustainable development entails, its necessity, and the advantages it offers to current and future generations [14].
- **Problem recognition**: The ability to identify sustainability-related challenges, including but not limited to climate change, natural resource depletion, and social inequality [18].
- **Impact correlation**: An understanding of how specific human activities, such as construction, production, and consumption, affect environmental integrity and social cohesion [17].

Awareness is widely acknowledged as a foundational step in fostering sustainable behaviours. Individuals who are well-informed about sustainable development are more likely to participate in and advocate for sustainability-oriented initiatives, thereby contributing to meaningful and lasting societal transformation.

2.2.2 Mindset for Sustainable Development

A sustainability-oriented mindset refers to an individual’s cognitive orientation and practical disposition to integrate sustainability principles into everyday decisions and long-term strategies. As suggested by Bossel, such a mindset demands a systems-thinking approach, where economic, social, and environmental dimensions are simultaneously considered and balanced when addressing complex challenges [14].

This mindset may be characterised by several key attributes:

- **Multifaceted analysis**: The capacity to assess problems and interventions from multiple perspectives, thereby ensuring that no single dimension—economic, social, or environmental—is prioritised to the detriment of the others [16].
- **Innovative solution design**: The ability to conceive and implement creative, environmentally responsible strategies that yield enduring societal benefit [18].
- **Futures thinking**: A commitment to intergenerational equity, whereby short-term interests are judiciously balanced against long-term impacts on future societies and ecosystems [14].

In the construction industry, a sustainability-oriented mindset is evidenced in the design and execution of projects that not only optimise cost-effectiveness but also minimise ecological disruption and promote social well-being. It is, therefore, more than a theoretical orientation—it embodies the ability to operationalise sustainability values through concrete and context-sensitive actions [16], [17].

2.2.3 The Benefits, Motivation and Opportunity of Acquiring Knowledge in Sustainable Development

The acquisition of knowledge pertaining to sustainable development represents a critical component in preparing students to meet the evolving demands of their respective professional fields. This process transcends the mere assimilation of information; it entails the meaningful integration and application of sustainability principles into real-world practice, thereby enhancing professional competence and contributing to the advancement of environmental and societal well-being.

In contemporary higher education, the cultivation of sustainability-related knowledge is widely acknowledged as essential. Michalos et al. contend that acquiring such knowledge enables students to develop vital competencies, including the ability to assess environmental impacts, employ environmentally responsible materials, and design energy-efficient structures [23] These competencies are increasingly recognised by employers within the architecture and construction sectors, wherein sustainable standards are no longer optional but fundamental. Similarly, Carteron and Decamps argue that the integration of sustainability into academic curricula not only deepens students' understanding of their professional roles but also provides a robust platform for contributing to global sustainable development objectives [24].

Furthermore, the accumulation of sustainability knowledge significantly enhances graduates' employability in a highly competitive labour market. Employers now seek candidates who possess both technical proficiency and the ability to operationalise sustainability principles across various professional contexts. A comprehensive understanding of sustainable strategies—alongside their application in design, construction, and project management—confers a considerable advantage upon graduates entering the field. This underscores the dual function of sustainability knowledge: it serves not only individual academic and professional development but also constitutes a distinguishing factor in the pursuit of employment opportunities [22].

The successful acquisition and application of knowledge in sustainable development are contingent upon two principal factors: *motivation* and *opportunity*. As noted by Olsson and Gericke, students engaged in sustainability-integrated curricula tend to exhibit higher levels of intrinsic motivation [22]. Key enablers include curricula explicitly addressing sustainability themes, access to professional seminars and workshops, and participation in internships with organisations committed to sustainable practices. Such opportunities not only facilitate knowledge acquisition but also foster a clearer understanding of students' potential contributions to wider sustainability efforts. In addition, the role of media and digital platforms in supporting sustainability education should not be underestimated. Major et al. highlight the value of online platforms in disseminating a diverse range of information on sustainable innovations and practices, thereby enabling students to remain informed and inspired. This observation is corroborated by findings from the present study, in which students acknowledged the significant role of media and social networks in promoting educational content related to sustainable development [25].

2.2.4 The Challenges of Acquiring Knowledge in Sustainable Development

The process of acquiring and implementing knowledge pertaining to sustainable development within the construction industry encounters numerous substantial challenges. These impediments arise from a confluence of factors, including limitations in policy frameworks, insufficient awareness, fragmented educational curricula, economic constraints, and inadequate personal motivation.

Deficiencies in Policy Support: A prominent challenge is the inadequacy of robust policies and incentive structures to promote sustainable development initiatives. Scholarly evidence underscores the critical importance of well-formulated and effectively implemented policies in fostering both the dissemination and practical application of sustainability principles [19], [24]. In the context of Vietnam, policy measures concerning sustainability in the construction sector remain underdeveloped and fragmented, thereby failing to generate sufficient impetus for educational institutions and industry stakeholders to actively engage in sustainable practices.

Inadequate Awareness of Sustainability Principles: A limited level of awareness regarding sustainable development constitutes a fundamental barrier to progress. As Olsson and Gericke assert, awareness forms the cornerstone of sustainable engagement. Nonetheless, in Vietnam, many professionals within the construction industry exhibit a limited understanding of the criticality of environmental stewardship and responsible resource management [22]. Berardi further emphasises that a lack of in-depth expertise and proactive engagement with sustainability issues continues to hinder the long-term implementation of sustainable solutions [18].

Economic Pressures and Financial Constraints: Economic considerations present another significant impediment to the adoption of sustainable practices. Stern et al. identify high initial costs as a principal deterrent to the deployment of sustainable technologies and solutions [26]. Within the Vietnamese context, financial limitations frequently compel construction firms to prioritise short-term cost efficiency over long-term sustainability. Spangenberg similarly contends that restricted access to financial resources and limited institutional financial support constitute major obstacles to sustainability initiatives in the construction sector [23].

Curricular Gaps in Higher Education: The content and structure of higher education programmes often fall short of adequately addressing contemporary technological advancements and the evolving practical demands of the construction industry. Michalos et al. argue that formal education plays a pivotal role in cultivating the competencies necessary for sustainable development [23]. Nevertheless, in many Vietnamese tertiary institutions, sustainability-related content is either marginalised or insufficiently integrated, resulting in a deficiency of specialised knowledge and skills among graduates entering the labour market.

Suboptimal Learning Environments and Motivation Deficits: The quality of the learning environment, coupled with the influence of media, significantly shapes the acquisition of sustainability-related knowledge. Major et al. suggest that educational settings which do not actively foster sustainability values may inadvertently diminish students' motivation to engage with these topics [25]. Furthermore, in Vietnam, sustainable development discourses remain insufficiently represented in mass and social media, limiting students' exposure to and engagement with contemporary sustainability innovations and practices.

Time Constraints and Individual Accountability: Construction students often contend with intensive academic timetables and competing responsibilities, which constrain the time available for independent exploration of sustainability themes. Olsson and Gericke further highlight that a lack of personal initiative and accountability among students can impede meaningful learning and application of sustainability principles [25]. This underscores the necessity of developing institutional strategies aimed at enhancing student engagement in sustainability-focused educational and co-curricular activities.

3. Methodology

To conduct a comprehensive investigation into the sustainability awareness and mindsets of architecture and construction students in Vietnam, this study adopts a mixed-methods approach, integrating both qualitative and quantitative methodologies. This methodological convergence facilitates a multifaceted understanding by combining the contextual depth offered by qualitative analysis with the empirical rigour of quantitative data.

The qualitative component entails the identification of relevant aspects of sustainability awareness and mindset through a systematic review of existing literature and their contextualisation within the Vietnamese construction sector. These dimensions are further refined through consultation with domain experts and validated via a pilot study. This process ensures the conceptual relevance and cultural appropriateness of the research instruments.

Concurrently, the quantitative phase involves the collection of data through structured surveys administered to students and recent graduates from Vietnamese universities offering programmes in architecture and construction. The data are subsequently subjected to statistical analysis to derive generalisable findings and identify significant patterns and correlations.

The integration of qualitative and quantitative methods enhances the robustness and validity of the study. While the qualitative strand provides interpretive depth and contextual sensitivity, the quantitative component contributes to the objectivity and statistical reliability of the results. This methodological synthesis proves particularly effective in addressing the inherent complexity of the research topic, enabling a nuanced and holistic examination of sustainability-related knowledge and attitudes among future professionals in the built environment sector.

The research framework underpinning this study is depicted in figure 1.

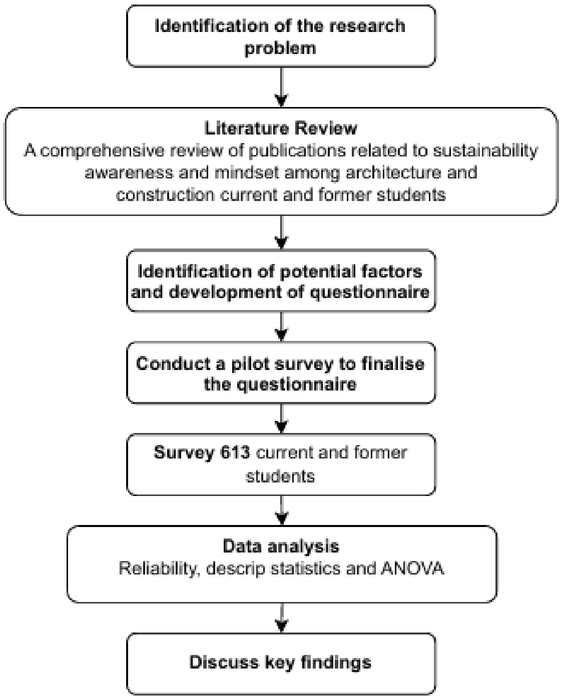

Fig. 1 *The research framework*

3.1 Identification of Relevant Factors

In order to identify the key factors underpinning sustainable awareness and mindset, an extensive and systematic review of the scholarly literature was undertaken, encompassing both international publications and studies specific to the Vietnamese context. This rigorous examination yielded a comprehensive set of factors, categorised and presented in Table 1. Specifically, six factors were identified as indicators of sustainable awareness, three were associated with perceived benefits, five related to motivation and opportunities, and ten represented perceived barriers. To ensure contextual appropriateness and theoretical robustness, the global findings were further refined through critical analysis of socio-economic and educational conditions within Vietnam. This dual-layered approach not only enhances the empirical validity of the identified factors but also ensures that the research framework is both globally informed and locally relevant.

Table 1 *Identified of relevant factors*

Code	Factor	
		Sustainable awareness
SM1	Concept of Sustainable Development	Sustainable development refers to a model of growth that seeks to protect the environment and preserve natural resources for future generations. It recognises the interdependence of ecological, economic, and social systems in achieving long-term stability and well-being.
SM2	Sustainable development contributes	Sustainable development contributes to environmental protection and the conservation of resources for future generations.
SM3	Human activities impact on the environment	Human activities, such as construction and manufacturing, can exert considerable impacts on the environment, contributing to issues such as resource depletion, pollution, and climate change.
SM4	Individual behaviours affect environmental sustainability	Individual behaviours, irrespective of scale, cumulatively affect environmental sustainability. As such, personal responsibility is fundamental to catalysing broader societal transformation.
SM5	Essential for long-term environmental preservation	While the implementation of sustainable solutions may entail significant financial costs, such measures are essential to ensuring long-term environmental protection and resilience.

SM6	Enhancing the quality of life within communities	Sustainability also has the potential to contribute positively to the enhancement of community well-being and the overall quality of life by promoting healthier environments, social equity, and responsible use of resources.
		Benefits
ST1	Future employment opportunities	It is integral to the development of competencies required for future employment opportunities.
ST2	Competencies and professional capacity	It fosters the enhancement of individual competencies and professional capacity.
ST3	Increases employability and strengthens	It significantly increases employability and strengthens one's prospects of being selected in a highly competitive job market.
		Motivation and opportunities
SD1	Integrate comprehensive knowledge	Higher education curricula in architecture and construction should systematically integrate comprehensive knowledge of sustainable development.
SD2	Seminars and symposiums	Seminars and symposiums on sustainable development in construction should be organised regularly.
SD3	Short courses and experiential internships	Short courses and experiential internships focused on sustainable development in the construction industry are necessary.
SD4	Social media and communication platforms	Social media and communication platforms should promote programmes related to sustainable development in construction.
SD5	Knowledge and understanding	Employers in the architecture and construction sectors should explicitly include requirements pertaining to knowledge and understanding of sustainable development principles.
		Barriers
SB1	Inadequate policy frameworks	Existing policy frameworks are currently inadequate to effectively support sustainable development initiatives within the construction industry.
SB2	Low level of awareness	A limited level of awareness concerning sustainable development continues to impede the successful implementation of sustainability-oriented projects in the construction sector.
SB3	Prevailing economic constraints	Prevailing economic constraints hinder the optimal realisation of sustainable development goals in construction activities.
SB4	The academic curriculum issues	The academic curriculum has not yet sufficiently aligned with contemporary technological advancements required for sustainable construction practices.
SB5	Lacks the encouragement	The current educational environment lacks the necessary encouragement to foster the development of sustainability-oriented values among students.
SB6	Limited student engagement	Instructional content often fails to adequately underscore the critical importance of sustainable development, resulting in limited student engagement with the subject matter.
SB7	Sustainable development concepts and best practices	Sustainable development concepts and best practices in construction are not widely promoted or disseminated through mainstream media and communication channels.
SB8	Lack of motivation and clearly defined objectives	There exists a notable absence of intrinsic motivation and clearly defined objectives among students for acquiring sustainability-related knowledge in the field of construction.
SB9	Time constraints	Time constraints, compounded by academic and extracurricular demands, limit opportunities for students to meaningfully engage with and develop a sustainable mindset.
SB10	A lack of personal accountability and self-directed learning	A lack of personal accountability and self-directed learning impedes the effective accumulation and application of knowledge and practices associated with sustainable construction.

3.2 Questionnaire Development

This section outlines the development of a structured questionnaire designed to investigate sustainability awareness and mindset among students and alumni in the fields of architecture and construction, with particular consideration of the Vietnamese context. The questionnaire was developed through a comprehensive review of relevant literature and consultations with domain experts. It comprised both closed-ended and Likert-scale items, allowing respondents to indicate their level of agreement with various statements.

The questionnaire was divided into two primary sections. The first section collected demographic information, including academic year, gender, and field of study. The second section focused on assessing participants' awareness and mindset regarding sustainable development, employing a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

To ensure clarity and relevance, a pilot study was conducted. Four experts in the construction industry and academia provided qualitative feedback during structured interviews. Their insights were instrumental in refining the language and content of the questionnaire, thereby enhancing its comprehensiveness and validity. Findings from the pilot phase informed the final version of the instrument used for large-scale data collection.

3.3 Data Collection

The survey was administered to a purposively selected sample of current students and alumni from Vietnamese universities that offer professional training in the built environment. This sampling approach, aligned with the recommendations of Campbell et al. in 2020, ensured representation across diverse roles within the construction sector [27] .

The survey instrument sought to capture participants' perspectives on sustainability awareness and mindset, as well as to identify perceived influencing factors. Efforts were made to reduce nonresponse bias through several strategies: the questionnaire was designed to be concise and accessible, a pilot test was conducted to refine clarity, and a multi-channel distribution method was employed, including reminder communications. Transparency regarding research objectives and the assurance of respondent anonymity further supported participation.

To assess potential nonresponse bias, an analysis comparing early and late respondents was conducted. No statistically significant differences were identified, indicating minimal bias and reinforcing the generalisability of the results. Demographic characteristics of the sample are presented in Table 2.

Table 2 *Demographic information of respondents (N = 613)*

Year	Majors	Frequency	Percentage per Major (%)	Percentage per Year (%)
First and Second year students	Architect	10	14.71%	11.09%
	Construction manager	8	11.76%	
	Construction engineer	50	73.53%	
	Total	68	100.00%	
Third-year student	Architect	15	5.70%	42.90%
	Construction manager	186	70.72%	
	Construction engineer	62	23.57%	
	Total	263	100.00%	
Fourth-year student	Architect	31	18.24%	27.73%
	Construction manager	18	10.59%	
	Construction engineer	121	71.18%	
	Total	170	100.00%	
Final year and Former students	Architect	18	16.07%	18.27%
	Construction manager	12	10.71%	
	Construction engineer	82	73.21%	
	Total	112	100.00%	
Total	Architect	*74*	*12.07%*	
	Construction manager	*224*	*36.54%*	100.00%
	Construction engineer	*315*	*51.39%*	
	Total	613	100.00%	

3.4 Data Analysis Methods

Quantitative data collected through the questionnaire were subjected to reliability testing, descriptive statistical analysis, and analysis of variance (ANOVA). Internal consistency of the questionnaire was assessed using Cronbach's alpha. The scale achieved an alpha value of 0.7, which is considered acceptable according to Hair et al [28]. Descriptive statistics, including measures of central tendency (mean, median, mode) and dispersion (range, standard deviation), were used to characterise the sample and provide an overview of the responses.

The mean ratings were employed to evaluate and rank factors related to sustainability awareness and mindset. ANOVA, Tamhane's and Bonferroni's post-hoc analysis, and ranking by mean scores were conducted to determine whether statistically significant differences existed between respondent groups (architecture students, construction management students, and construction engineering students – or First and second year students, third year students, fourth year students and Final & former students) in their perspectives on the identified factors. This analysis aimed to uncover potential variations across disciplines regarding sustainability-related attitudes and knowledge among student groups.

Firstly, to ensure the reliability and internal consistency of the questionnaire employed in this study, a reliability analysis was conducted using Cronbach's Alpha. This statistical measure assesses the degree of intercorrelation among items intended to evaluate conceptually related constructs, thereby determining the instrument's coherence and dependability. A Cronbach's Alpha coefficient exceeding the generally accepted threshold indicates satisfactory internal consistency, affirming that the questionnaire is a reliable tool for capturing students' perceptions relevant to the study's objectives [28].

Secondly, to determine whether statistically significant differences existed in students' perceptions of sustainable mindset factors across academic disciplines and levels, one-way and two-way analysis of variance (ANOVA) was employed. This statistical method is particularly appropriate for comparing mean values among multiple independent groups and is frequently utilised in research examining perceptual or attitudinal variations within diverse major or school years [29], [30]. To further investigate any significant effects identified, post-hoc analyses were carried out using Bonferroni's and Tamhane's tests, depending on the assumption of equal variances. While ANOVA indicates the presence of group-level differences, these post-hoc procedures enabled the identification of specific group pairs with statistically distinct perceptions [31].

To complement this analysis, the study also ranked the mean scores of sustainable mindset factors. These scores, derived from a five-point Likert scale, were ordered in descending fashion to highlight the factors perceived most positively by respondents. This ranking facilitated a nuanced understanding of prevailing sustainability mindsets and provided insight into which dimensions warrant prioritisation in the education and development of future construction professionals.

4. Results

4.1 Reliability Assessment

A reliability assessment was conducted to evaluate the internal consistency of the constructs associated with sustainable mindset factors. The analysis indicated that the overall scale comprising 24 items demonstrated a high level of internal consistency, with a Cronbach's alpha coefficient of 0.914. Subscale analyses further confirmed the reliability of each thematic group. Specifically, the constructs of Sustainable Awareness (SM1–SM6), Perceived Benefits (ST1–ST3), Motivation and Opportunities (SD1–SD5), and Perceived Barriers (SB1–SB10) yielded Cronbach's alpha values of 0.836, 0.804, 0.786, and 0.861, respectively. While the Motivation and Opportunities subscale exhibited a slightly lower alpha value of 0.786, it remained within acceptable bounds, closely aligning with the widely recognised threshold of 0.7 [28], thereby suggesting moderate to strong internal reliability across all dimensions. These findings confirm the robustness of the measurement instrument in capturing the underlying constructs related to sustainability awareness and mindset.

4.2 Mean and One-way Analysis of Variance (ANOVA)

Subsequently, the analysis aimed to discern variations in the prioritisation of sustainability-related attitudes and perceptions among students across different academic years and disciplinary majors. To achieve this objective, a one-way Analysis of Variance (ANOVA) was employed to examine whether statistically significant differences existed in the mean scores assigned to each sustainable mindset factor among the various student groups. This statistical method facilitated the detection of potential disparities in levels of agreement with specific factors across distinct cohorts. Furthermore, a comprehensive assessment and ranking of the 24 identified factors (as outlined in Table 1) was conducted based on the overall mean scores aggregated from all student groups. This ranking provided insight into the prevailing sustainability awareness and mindset among students, who represent the future workforce of the construction industry. The detailed outcomes of the statistical analysis, along with the corresponding rankings of sustainability-related factors across student cohorts segmented by academic year and field of study, are presented in Table 3 and Table 4, respectively.

As presented in Table 3, a comparative analysis was conducted on the mean scores (M) assigned to 24 sustainable mindset factors by student cohorts at different academic stages in Vietnam, including first- and second-year students, third-year students, fourth-year students, and final-year students, as well as former students. Among first- and second-year students, the highest-rated awareness factor was SM4, which ranked first with a mean score of 3.26. In terms of perceived benefits, ST1 held the top position (M = 3.46). Regarding motivation and opportunities, SD5 was identified as the most significant (M = 3.62), while SB3 was reported as the most prominent barrier (M = 3.28). Third-year students prioritised SM6 as the most important awareness factor (M= 3.26), while ST2 was the most highly rated benefit (M = 3.75). In this group, SD1 (M = 3.71) and SB2 (M = 3.66) emerged as the leading motivation/opportunity and barrier, respectively. For fourth-year students, SM1 received the highest mean score for awareness (M = 3.62), followed by ST1 for benefit (M = 3.84). Both SD3 and SB2 were ranked first in their respective categories—motivation/opportunities (M = 3.88) and barriers (M = 3.75). Among final-year and former students, SM3 was regarded as the most critical awareness factor (M = 3.62), ST2 was the most valued benefit (M = 3.84), SD5 was ranked highest in motivation and opportunities (M = 3.99), and SB2 was again identified as the primary barrier (M = 3.84).

Table 3 *The ranking of sustainable mindset factors among student cohorts by academic year in Vietnam*

Factor	Total (N=613)		First and Second year students (N=68)		Third year student (N=263)		Fourth year student (N=170)		Final year and Former student (N=112)		Homogeneity of Variances (Sig.)	Welch (Sig.)	ANOVA (Sig.)
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank			
Sustainable awareness													
SM1	2.98	6	2.676	6	2.848	6	3.171	6	3.188	6	.1449	0.000	
SM2	3.34	4	2.94	5	3.17	4	3.62	1	3.55	2	0.001		0.000
SM3	3.38	2	3.18	2	3.20	3	3.58	3	3.62	1	.054	0.000	
SM4	3.40	1	3.26	1	3.25	2	3.60	2	3.54	3	0.007		0.002
SM5	3.28	5	3.07	4	3.12	5	3.48	5	3.46	5	.018		0.000
SM6	3.37	3	3.09	3	3.26	1	3.56	4	3.51	4	0.011		0.002
Benefits													
ST1	3.74	1	3.46	1	3.73	3	3.84	1	3.78	2	.000		.052
ST2	3.72	2	3.25	3	3.75	1	3.77	3	3.84	1	.000		0.001
ST3	3.71	3	3.34	2	3.74	2	3.81	2	3.71	3	.000		0.011
Motivation and opportunities													
SD1	3.69	3	3.28	5	3.71	1	3.79	3	3.75	4	.000		0.001
SD2	3.69	4	3.50	4	3.67	5	3.72	4	3.80	3	.272	.298	
SD3	3.76	2	3.51	3	3.71	2	3.88	1	3.82	2	.000		0.041
SD4	3.64	5	3.51	2	3.67	4	3.63	5	3.67	5	.008		.717
SD5	3.78	1	3.62	1	3.67	3	3.86	2	3.99	1	.000		0.007
Barriers													
SB1	3.56	2	3.25	2	3.54	2	3.58	4	3.77	2	.013		0.005
SB2	3.67	1	3.24	3	3.66	1	3.75	1	3.84	1	.000		0.000
SB3	3.48	5	3.28	1	3.47	7	3.48	6	3.62	4	0.026		0.177
SB4	3.51	3	3.04	8	3.54	3	3.59	3	3.61	5	0.004		0.000
SB5	3.45	6	3.13	5	3.49	5	3.49	5	3.50	6	.075	.138	
SB6	3.36	8	3.06	7	3.36	10	3.44	7	3.45	7	.003		.059
SB7	3.51	4	3.07	6	3.52	4	3.60	2	3.62	3	.064	0.014	
SB8	3.40	7	3.21	4	3.47	6	3.39	8	3.38	10	0.344	0.362	
SB9	3.34	10	3.01	10	3.38	9	3.37	9	3.39	9	0.003		0.058
SB10	3.35	9	3.03	9	3.46	8	3.28	10	3.41	8	0.255	0.041	

To further examine the variation in perceptions of sustainability-related factors among students from different academic disciplines, the study analysed responses from three cohorts: architecture students, construction management students, and construction engineering students. Table 4 presents the mean rankings of the 24 sustainable mindset factors across the four thematic dimensions: awareness, perceived benefits, motivation and opportunities, and perceived barriers. For architecture students, *SM3* emerged as the highest-rated factor within the awareness category, achieving a mean score of 3.65. In the domain of perceived benefits, *ST3* received the top ranking (M = 3.72). With respect to motivation and opportunities, *SD3* was identified as the most influential factor (M = 3.97), while *SB1* was recognised as the most significant barrier (M = 3.77). Among students specialising in construction management, *SM4* was rated as the most prominent awareness factor (M = 3.21), whereas *ST2* attained the highest score in the benefit category (M = 3.85). In this group, *SD4* (M = 3.78) was considered the leading factor in terms of motivation and opportunities, and *SB1* (M = 3.77) remained the most critical perceived barrier. For construction engineering students, *SM4* similarly held the highest ranking in the awareness category (M = 3.54), while *ST1* was rated as the most important benefit-related factor (M = 3.76). Furthermore, *SD3* (M = 3.85) and *SB2* (M = 3.69) were identified as the most influential factors within the categories of motivation/opportunities and barriers, respectively.

Overall, when synthesising the rankings across all student cohorts, *SM4* was identified as the most prominent factor in the awareness category, with a mean score of 3.40. *ST1* received the highest rating among the perceived benefits (M = 3.74), while *SD5* emerged as the leading factor within the motivation and opportunities domain (M = 3.78). *SB2* was consistently acknowledged as the most significant barrier to sustainable mindsets (M = 3.67). These results highlight the nuanced and evolving priorities that students across various academic stages assign to sustainability-related mindset factors within the context of the construction discipline.

Table 4 *The ranking of sustainable mindset factors among student cohorts by major in Vietnam*

Major	Total (N=613)		Architect (N=74)		Construction manager (N=224)		Construction engineer (N=315)		Homogeneity of Variances (Sig.)	Welch (Sig.)	ANOVA (Sig.)
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank			
Sustainable awareness											
SM1	2.98	6	2.93	6	2.85	6	3.09	6	0.118	0.015	
SM2	3.34	4	3.49	4	3.04	5	3.51	2	0.000		0.000
SM3	3.38	2	3.65	1	3.16	3	3.47	4	0.015		0.000
SM4	3.40	1	3.41	5	3.21	1	3.54	1	0.081	0.001	
SM5	3.28	5	3.62	2	3.08	4	3.34	5	0.034		0.000
SM6	3.37	3	3.49	3	3.17	2	3.48	3	0.000		0.003
Benefits											
ST1	3.74	1	3.58	2	3.76	3	3.76	1	0.053	0.404	
ST2	3.72	2	3.22	3	3.85	1	3.74	2	0.075	0.000	
ST3	3.71	3	3.72	1	3.81	2	3.63	3	0.017		0.110
Motivation and opportunities											
SD1	3.69	3	3.74	3	3.68	4	3.69	3	0.120	0.868	
SD2	3.69	4	3.64	4	3.75	2	3.66	4	0.003		0.491
SD3	3.76	2	3.97	1	3.74	3	3.72	2	0.025		0.118
SD4	3.64	5	3.41	5	3.78	1	3.60	5	0.005		0.012
SD5	3.78	1	3.92	2	3.63	5	3.85	1	0.358	0.012	
Barriers											
SB1	3.56	2	3.77	1	3.56	5	3.51	2	0.041		0.109
SB2	3.67	1	3.74	2	3.62	1	3.69	1	0.012		0.529
SB3	3.48	5	3.32	7	3.58	3	3.44	5	0.002		0.099
SB4	3.51	3	3.38	4	3.61	2	3.48	4	0.000		0.136
SB5	3.45	6	3.46	3	3.51	8	3.41	6	0.004		0.455
SB6	3.36	8	3.30	8	3.46	10	3.31	8	0.001		0.208
SB7	3.51	4	3.36	5	3.58	4	3.50	3	0.004		0.285
SB8	3.40	7	3.30	9	3.52	6	3.34	7	0.003		0.080
SB9	3.34	10	3.34	6	3.49	9	3.23	10	0.001		0.020
SB10	3.35	9	3.08	10	3.52	7	3.30	9	0.004		0.004

Upon reviewing the ANOVA results presented in Table 3 and Table 4, a statistically significant variation was observed among student cohorts with respect to all six Sustainable Awareness factors ST1-ST6 ($p < 0.05$), both by academic year and academic major. Furthermore, the factors *ST2* (Benefits), *SD5* (Motivation and Opportunities), and *SB10* (Barriers) also demonstrated significant variation across both categorical groupings. Within the academic year-based cohorts (Table 3), additional statistically significant differences were observed for *SD4* and *SD9*. Meanwhile, among the major-based groups (Table 4), significant disparities emerged for *ST3*, *SD1*, *SD3*, *SB1*, *SB2*, *SB4*, and *SB7*. Additionally, Bonferroni's and Tamhane's post-hoc tests were employed to identify specific differences among student groups with respect to the aforementioned factors (p -value < 0.05). The comprehensive results from the post-hoc analyses are provided in Tables 5 and Table 6.

The results of the post-ANOVA analysis presented in Table 5 reveal that the level of Sustainability awareness among 1st and 2nd year students, as well as 3rd year students, is significantly lower than that observed in 4th year students and the group comprising final-year and former students across the majority of evaluated factors. However, in the dimensions related to Benefits, Motivation & Opportunities, and Barriers, this disparity is primarily evident in the 1st and 2nd year student group. Specifically, students in this cohort reported a lower perception of benefits and opportunities, while simultaneously perceiving barriers as more severe compared to their senior counterparts. These findings underscore the potential influence of academic progression on sustainability awareness, particularly with respect to students' ability to recognise opportunities and navigate challenges associated with sustainable development in the built environment.

Tab 5 *Results of Tamhane's and Bonferroni's post-hoc analysis showing differences in sustainable awareness among students' academic year groups*

Factor	Academic year	Mean Difference (Comparison within Majors)				F	p-value
		1st and 2nd year student	3rd year student	4th year student	Final year and Former student		
SM1	First and Second year students	-	-.1714	-.4941*	-.5110*	8.008	0.000
	Third-year student	.1714	-	-.3227*	-.3396*		
	Fourth-year student	.4941*	.3227*	-	-.0169		
	Final year and Former student	.5110*	.3396*	.0169	-		
SM2	First and Second year students	-	-.230	-.676*	-.612*	12.990	0.000
	Third-year student	.230	-	-.447*	-.382*		
	Fourth-year student	.676*	.447*	-	.064		
	Final year and Former student	.612*	.382*	-.064	-		
SM3	First and Second year students	-	-.021	-.406*	-.440*	8.166	0.000
	Third-year student	.021	-	-.385*	-.418*		
	Fourth-year student	.406*	.385*	-	-.034		
	Final year and Former student	.440*	.418*	.034	-		
SM4	First and Second year students	-	.014	-.335	-.280	5.185	0.002
	Third-year student	-.014	-	-.349*	-.294		
	Fourth-year student	.335	.349*	-	.055		
	Final year and Former student	.280	.294	-.055	-		
SM5	First and Second year students	-	-.048	-.403	-.391	6.553	0.000
	Third-year student	.048	-	-.355*	-.343*		
	Fourth-year student	.403	.355*	-	.012		
	Final year and Former student	.391	.343*	-.012	-		
SM6	First and Second year students	-	-.170	-.471	-.421	4.871	0.002
	Third-year student	.170	-	-.300*	-.250		
	Fourth-year student	.471	.300*	-	.050		
	Final year and Former student	.421	.250	-.050	-		
ST2	First and Second year students	-	-.503*	-.521*	-.589*	5.855	0.001
	Third-year student	.503*	-	-.018	-.086		
	Fourth-year student	.521*	.018	-	-.069		
	Final year and Former student	.589*	.086	.069	-		

ST3	First and Second year students	-	-.399	-.468	-.367	3.750	0.011
	Third-year student	.399	-	-.068	.032		
	Fourth-year student	.468	.068	-	.101		
	Final year and Former student	.367	-.032	-.101	-		
SD1	First and Second year students		-.435	-.509*	-.471*	5.226	0.001
	Third-year student	.435		-.073	-.035		
	Fourth-year student	.509*	.073		.038		
	Final year and Former student	.471*	.035	-.038			
SD3	First and Second year students		-.193	-.368	-.307	2.772	0.041
	Third-year student	.193		-.175	-.114		
	Fourth-year student	.368	.175		.061		
	Final year and Former student	.307	.114	-.061			
SD5	First and Second year students		-.055	-.247	-.373	4.058	0.007
	Third-year student	.055		-.192	-.318*		
	Fourth-year student	.247	.192		-.126		
	Final year and Former student	.373	.318*	.126			
SB1	First and Second year students		-.294	-.326	-.518*	4.388	0.005
	Third-year student	.294		-.033	-.224		
	Fourth-year student	.326	.033		-.191		
	Final year and Former student	.518*	.224	.191			
SB2	First and Second year students		-.423	-.512*	-.604*	6.447	0.000
	Third-year student	.423		-.089	-.181		
	Fourth-year student	.512*	.089		-.092		
	Final year and Former student	.604*	.181	.092			
SB4	First and Second year students		-.496*	-.550*	-.563*	6.277	0.000
	Third-year student	.496*		-.054	-.067		
	Fourth-year student	.550*	.054		-.013		
	Final year and Former student	.563*	.067	.013			
SB7	First and Second year students		-.447*	-.526*	-.543*	5.186	0.002
	Third-year student	.447*		-.079	-.095		
	Fourth-year student	.526*	.079		-.016		
	Final year and Former student	.543*	.095	.016			
SB10	First and Second year students		-.427*	-.253	-.381	3.276	0.021
	Third-year student	.427*		.174	.046		
	Fourth-year student	.253	-.174		-.128		
	Final year and Former student	.381	-.046	.128			

Table 6 shows the post-ANOVA analysis among students' major groups, indicating that the level of Sustainability awareness within the Construction Manager group is significantly lower than that of the Architect Student and Construction Engineer Student groups across the majority of evaluated factors. However, when examining dimensions related specifically to Benefits, Motivation & Opportunities, and Barriers, statistically significant differences are primarily observed in two specific factors: SD5 and SB10. In particular, the Construction Manager group reported a notably lower perception of opportunities associated with SD5 compared to the Construction Engineer Student group. Furthermore, this group also perceived the SB10 barrier to be more severe than did the Architect Student group. These findings suggest that professional orientation may influence the degree of sustainability mindset, especially in relation to sustainability awareness (SM1-SM6).

Table 6 *Results of Tamhane's and Bonferroni's post-hoc analysis showing differences in sustainable mindset among students' major groups*

Factor	Major	Mean Difference (Comparison within Majors)			F	p-value
		Architect	Construction manager	Construction engineer		
SM1	Architect	-	.0842	-.1533	4.068	0.018
	Construction manager	-.0842	-	-.2375*		
	Construction engineer	.1533	.2375*	-		
SM2	Architect	-	.442*	-.028	16.234	0.000
	Construction manager	-.442*	-	-.470*		
	Construction engineer	.028	.470*	-		
SM3	Architect	-	.492*	.176	9.470	0.000
	Construction manager	-.492*	-	-.317*		
	Construction engineer	-.176	.317*	-		
SM4	Architect	-	.191	-.131	6.499	0.002
	Construction manager	-.191	-	-.322*		
	Construction engineer	.131	.322*	-		
SM5	Architect	-	.546*	.282	9.453	0.000
	Construction manager	-.546*	-	-.264*		
	Construction engineer	-.282	.264*	-		
SM6	Architect	-	.312	.007	5.764	0.003
	Construction manager	-.312	-	-.305*		
	Construction engineer	-.007	.305*	-		
ST2	Architect	-	-.636*	-.523*	11.703	0.000
	Construction manager	.636*		.113		
	Construction engineer	.523*	-.113	-		
ST3	Architect	-	-.096	.088	2.216	0.110
	Construction manager	.096		.184		
	Construction engineer	-.088	-.184	-		
SD1	Architect	-	.054	.176	0.120	0.887
	Construction manager	-.060		-.006		
	Construction engineer	-.054	.006	-		
SD3	Architect	-	.236	.256	2.147	0.118
	Construction manager	-.236	-	.019		
	Construction engineer	-.256	-.019	-		
SD5	Architect	-	.289	.068	4.451	0.012
	Construction manager	-.289		-.221*		
	Construction engineer	-.068	.221*	-		
SB1	Architect	-	.212	.256	2.224	0.109
	Construction manager	-.212		.044		
	Construction engineer	-.256	-.044	-		
SB2	Architect	-	.127	.054	0.638	0.529
	Construction manager	-.127		-.073		
	Construction engineer	-.054	.073			
SB4	Architect	-	-.229	-.098	2.003	0.136
	Construction manager	.229		.131		
	Construction engineer	.098	-.131			
SB7	Architect	-	-.211	-.134	1.257	0.285
	Construction manager	.211	-	.077		
	Construction engineer	.134	-.077	-		
SB10	Architect	-	-.437*	-.217	5.529	0.004
	Construction manager	.437*	--	.219		
	Construction engineer	.217	-.219	-		

4.3 Two-Way Analysis of Variance (ANOVA)

To further investigate these group-level disparities, a two-way ANOVA was performed for awareness factors ST1–ST6 along with ST2, SD5, and SB10. The Levene's test results for the variables SM1, SM2, SM3, SM6, ST2, SD5, and SB10 in Table 7yielded significance values (Sig < 0.05), indicating a violation of the homogeneity of variances assumption across groups. This suggests that the variance in error terms among these groups is not equal, and as a result, the analysis lacks sufficient statistical grounds to confirm significant differences in group means for these factors.

Conversely, the variables SM4 and SM5 produced Levene's significance values of 0.096 and 0.051, respectively—both exceeding the conventional threshold of 0.05—thereby supporting the assumption of equal variances across groups. Nevertheless, the outcomes of the Tests of Between-Subjects Effects demonstrated that the F-test significance values (F-Sig) for the variables Year, Major, and their interaction term Year × Major all exceeded the 0.05 threshold for both SM4 and SM5 (as shown in Table 7). This indicates that there are no statistically significant differences in sustainable awareness related to SM4 and SM5 among students across different academic years and majors (Figure 2).

Table 7 *Results of two-way ANOVA analysis*

Factor	Levene's Test of Equality of Error Variancesa		Tests of Between-Subjects Effects (F-Sig)		
	F	Sig.	Year	Major	Year * Major
SM1	2.603	.003			
SM2	3.771	.000			
SM3	2.897	.001			
SM4	1.595	.096	.429	.717	.606
SM5	1.801	.051	.112	.105	.745
SM6	2.691	.002			
ST2	3.939	.000			
SD5	2.588	.003			
SB10	2.363	.007			

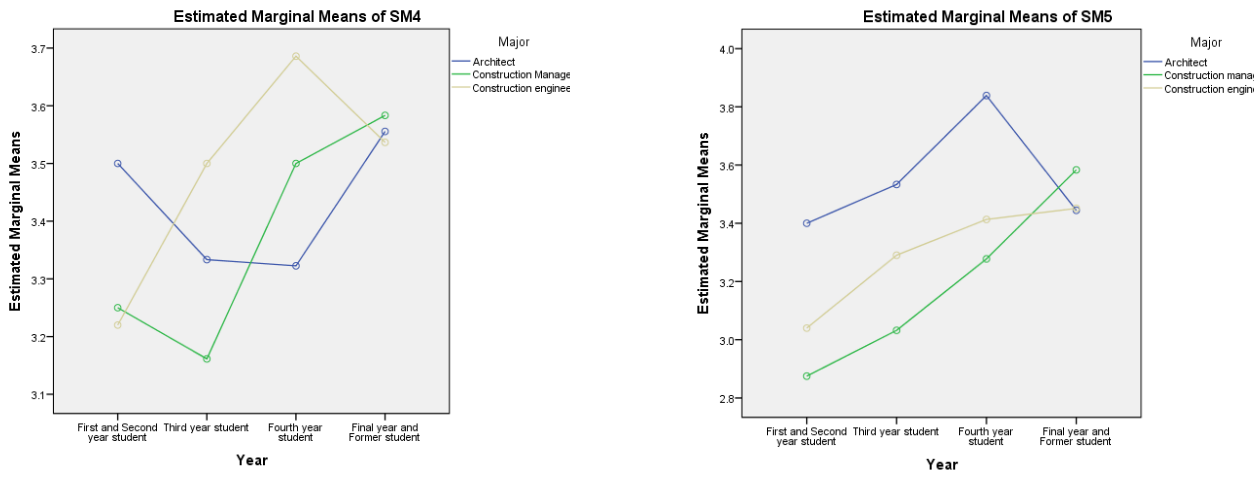

Fig 2 *Estimated marginal means of SM4 (left) and SM5 (right)*

5. Discussion and Policy Implications

The findings from this study reveal that while students and alumni in architecture and construction-related disciplines in Vietnam demonstrate a general awareness of the role of sustainable development (SD)—particularly in environmental protection, resource conservation, and quality of life improvement—their understanding of the broader conceptual framework and its multidimensional aspects remains limited. This is especially pronounced among first- and second-year students, who reported significantly lower awareness and higher perceived barriers compared to more senior cohorts.

This pattern reflects broader trends observed across many developing countries, where sustainability education often lacks institutional depth and is hindered by systemic constraints such as outdated curricula, insufficient faculty training, and weak alignment with labour market demands [32]. These limitations impede the development of critical sustainability competencies, which are essential for future professionals in the built environment sector. In contrast, developed countries have made considerable progress in embedding sustainability into higher education systems. For example, European nations such as Sweden, Germany, and the Netherlands have adopted national strategies for Education for Sustainable Development (ESD), which integrate cognitive, behavioural, and affective learning outcomes into curricula [33], [34]. Likewise, countries such as Australia and Canada have leveraged public-private partnerships and interdisciplinary approaches to enhance experiential learning and promote sustainability as a cross-cutting educational goal [35].

The Vietnamese context, as shown in this study, also highlights the growing importance of practical, career-oriented sustainability education. Students expressed strong appreciation for real-world learning formats, such as internships, short-term training, and industry-linked coursework, which were perceived as effective motivators and enablers of sustainability awareness. These findings reinforce existing research indicating that experiential and problem-based learning approaches significantly enhance student engagement with sustainability topics [36].

The present findings emphasise the necessity for fundamental reform in sustainability education within Vietnamese higher-education programmes in architecture and construction. In order to enhance sustainability awareness, especially among early-year students, Vietnam must adopt an integrated and institutionalised approach that transcends elective coursework. Central to this effort is embedding Sustainable Development (SD) principles systematically across curricula, in alignment with global frameworks such as the United Nations Sustainable Development Goals (SDGs).

Several developed countries offer instructive models. In Germany, national ESD strategies have led to wide-ranging embedding of cognitive, behavioural, and socio-emotional sustainability competencies within formal education, including higher education institutions [37]. Sweden has similarly integrated SD into its national curriculum through comparative ESD studies. Australia and Canada exemplify the effective mobilisation of public–private partnerships, enabling universities to deliver moderately robust, practice-based sustainability education, supported by experiential and interdisciplinary learning opportunities [38], [39].

The integration of sustainability principles into higher education curricula across Southeast Asia and the ASEAN region is increasingly recognised as a vital mechanism for cultivating competencies essential to sustainable development among future professionals. An expanding corpus of scholarly work advocates for systemic curriculum reform that addresses the multifaceted interconnections among environmental, social, and economic dimensions of sustainability. Banga [40] underscores the urgent need for curricular innovation in Indian higher education through interdisciplinary frameworks, experiential pedagogies, and alignment with the United Nations Sustainable Development Goals (SDGs). While situated in the Indian context, these pedagogical strategies are readily transferable to Southeast Asian settings, which often share analogous developmental trajectories and institutional challenges. Tramontin and Trois [41] highlight the significance of adopting a holistic, institution-wide approach to sustainability education, grounded in participatory governance and interdisciplinary coherence—an approach particularly pertinent for ASEAN countries characterised by diverse cultural and ecological contexts. Additionally, Iyer-Raniga and Andamon [42] provide a critical appraisal of sustainability integration in engineering and built environment curricula across the Asia-Pacific, revealing that sustainability content is frequently relegated to elective courses or treated peripherally. Together, these contributions emphasise the necessity for context-sensitive, integrated curriculum design that positions sustainability as a central pillar of higher education in the ASEAN region.

To replicate such successes, Vietnam should invest in professional development for academic staff, facilitating structured training and international partnerships. This would ensure readiness to deliver sustainability education of high academic integrity and practical relevance. Moreover, establishing tripartite collaborations among academia, industry, and government entities would foster sustainability-focused internships, capstone projects, and community engagement, enabling theory-to-practice application.

Another critical policy lever involves embedding sustainability competencies and indicators into national accreditation and quality assurance frameworks. Evidence from countries such as the Netherlands and the UK demonstrates that incorporating SD criteria into institutional performance mechanisms is a compelling motivator for curriculum alignment and longevity in educational innovation.

Beyond educational reform, enhancing sustainability mindsets also generates notable economic and commercial benefits. As the global construction industry transitions toward sustainable and low-carbon practices, employers are placing increasing value on graduates who possess sustainability competencies—enhancing employability prospects and career readiness[40]. Skills such as life-cycle thinking, resource efficiency, and familiarity with green building standards (e.g., LEED, EDGE) are increasingly regarded as prerequisites in firms seeking to meet ESG (Environmental, Social, and Governance) benchmarks. Furthermore, cultivating a sustainability mindset stimulates innovation in the construction sector, encouraging the development and application of low-carbon technologies, modular construction techniques, adaptive reuse strategies, and circular economy practices[41]. These capacities are pivotal for improving productivity and competitiveness, particularly as Vietnam integrates into global sustainable value chains. Importantly, these educational and commercial imperatives are directly aligned with Vietnam's national strategy for achieving Net Zero Carbon Buildings (NZCB) by 2050, which prioritises capacity building and institutional transformation in the construction sector [43].

In summary, addressing the observed deficits in sustainability awareness and capacity requires a robust, multi-dimensional policy strategy. Core elements include: (a) curriculum integration elevating sustainability to a central academic pillar; (b) faculty capacity-building through professional education and global engagement; (c) experiential learning fostered via collaborative partnerships with industry and communities; and (d) institutional accountability through accreditation-based sustainability standards. Drawing upon global best practices, Vietnam is positioned to transform its education system, producing graduates equipped to confront the sustainability challenges of the built environment.

In conclusion, bridging the gaps in sustainability awareness and competencies demands a comprehensive policy approach that integrates curricular reform, faculty development, experiential learning, and robust institutional governance. Drawing upon international best practices, Vietnam has a timely opportunity to reshape its educational paradigm to prepare future professionals for the multifaceted sustainability challenges facing the built environment. Such reforms will not only improve the effectiveness of sustainability education but also foster a new generation of professionals capable of driving innovation and supporting the nation's commitment to Net Zero Carbon Buildings by 2050.

6. Conclusions

This study underscores the critical importance of cultivating a sustainability-oriented mindset among future construction professionals to support Vietnam's long-term transition toward Net Zero Carbon Buildings (NZCB). The findings are directly aligned with the strategic objectives outlined in the Action Plan for Climate Change Response in the Construction Sector, issued by the Ministry of Construction, which emphasises the need to "enhance awareness and build capacity among communities and construction personnel in activities related to greenhouse gas mitigation and climate change adaptation" [43]. Realising this policy vision necessitates a robust understanding of current educational limitations and the implementation of targeted interventions to enhance sustainability competencies in higher education curricula.

By analysing 613 valid survey responses through one-way and two-way ANOVA, the research identified notable disparities in sustainability awareness across academic years and student majors. Early-year students (1st and 2nd years) exhibited significantly lower awareness compared to final-year students and recent graduates, indicating that exposure to sustainability concepts accumulates over time. Furthermore, students majoring in Construction Management demonstrated markedly lower levels of awareness than their peers in Architecture and Civil Engineering, suggesting that professional orientation can significantly influence an individual's sustainability mindset, particularly within the construction industry. Different professional roles within construction, such as architects and engineers, or contractors and project managers, may prioritise various aspects of sustainability based on their specific expertise and responsibilities. This can lead to varying perceptions of what constitutes "sustainable" construction and how to achieve it [44].

Notably, statistically significant differences in perceptions of Benefits, Motivation & Opportunities, and Barriers related to Sustainable mindsets were primarily observed between students at different academic stages rather than between different majors. These findings highlight the need for higher education institutions to embed sustainability education more systematically from the early stages of university curricula and to align learning outcomes with the specific contexts of each professional discipline.

Despite these contributions, the study is subject to certain limitations. First, the analysis was based on survey data, which may be influenced by subjective biases or social desirability effects of respondents. Second, the sample, although sizeable, was restricted to a limited institutional sample, potentially affecting the generalisability of the findings. Thirdly, the cross-sectional nature of the study limits the ability to observe how sustainability mindsets evolve longitudinally over time. Future research could address these limitations by incorporating longitudinal designs, expanding the sample across more diverse educational settings, and integrating other qualitative methods to capture deeper insights into student motivations and learning experiences. Lastly, this study acknowledges that several variables—namely SM1, SM2, SM3, SM6, ST2, SD5, and SB10—violated the homogeneity of variance assumption, as indicated by Levene's test in the two-way ANOVA ($p < 0.05$). To enhance statistical robustness and validity, future research is advised to employ more appropriate techniques, such as Welch's ANOVA or the Brown–Forsythe test, which are specifically designed to account for heteroscedasticity. Nonetheless, the findings provide a valuable empirical foundation for guiding educational reforms and policy interventions aimed at equipping the future construction workforce with the competencies needed to contribute meaningfully to national and global sustainability goals.

Acknowledgement

This research is funded by Hanoi University of Civil Engineering under grant number 24-2024/KHXD-TD. The authors express their gratitude to respondents from diverse Vietnamese universities and Hanoi University of Civil Engineering for supporting this research.

The authors gratefully acknowledge the invaluable support of the participating universities and students who generously contributed their time and insights to this research. Special appreciation is extended to the anonymous reviewers for their constructive comments and critical feedback, which have enhanced the clarity and rigour of this paper.

Declaration of Generative AI in Scientific Writing

During the preparation of this work, the authors used ChatGPT in order to assist the writing process more naturally and enhance the paper's readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Data Availability

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

Writing – review & editing, writing – original draft, methodology, questionnaire development, investigation, conceptualisation, visualisation, investigation, formal analysis, data curation: *Quynh To Thi Huong*; ***writing – review & editing, questionnaire development:*** *Bach Ta Dang*.

References

[1] N. Van Tam, T. T. H. Quynh, and N. Q. Toan, "How Vietnam can achieve net-zero carbon emissions in construction and built environment by 2050: An integrated AHP and DEMATEL approach," *Build Environ*, vol. 274, p. 112752, Apr. 2025, doi: 10.1016/j.buildenv.2025.112752.

[2] Ministry of Construction, "Thematic Seminar on Promoting the Development of Green Materials: Sustainable Solutions for a Greener Future." Accessed: May 14, 2025. [Online]. Available: https://moc.gov.vn/tl/tin-tuc/82231/hoi-thao-chuyen-de-thuc-day-phat-trien-vat-lieu-xanh--giai-phap-ben-vung-cho-mot-tuong-lai-xanh.aspx

[3] Vietnam Green Building Council (VGBC), "LOTUS New Construction – LOTUS NC V3 – Technical Manual," 2019 Accessed: May 14, 2025. [Online]. Available: https://vgbc.vn/wp-content/uploads/2019/08/LOTUS-NC-V3-H%C6%B0%E1%BB%9Bng-d%E1%BA%ABn-K%E1%BB%B9-thu%E1%BA%ADt-Y%C3%AAu-c%E1%BA%A7u-chung.pdf

[4] Prime Minister of Vietnam, "Decision 179/QĐ-TTg 'Approving the Strategy for development of the construction sector through 2030, with orientations toward 2045,'" Hanoi, 2024. Accessed: May 08, 2025. [Online]. Available: https://chinhphu.vn/?pageid=27160&docid=209726

[5] W. Pan and M. Pan, "Drivers, barriers and strategies for zero carbon buildings in high-rise high-density cities," *Energy Build*, vol. 242, p. 110970, Jul. 2021, doi: 10.1016/j.enbuild.2021.110970.

[6] N. Van Tam, N. Q. Toan, and P. H. Ngoc, "Key strategies for achieving net-zero carbon buildings and promoting carbon credits in construction markets: A case of an emerging economy," *Energy for Sustainable Development*, vol. 81, p. 101488, Aug. 2024, doi: 10.1016/j.esd.2024.101488.

[7] M. de Almeida Vittori Ferreira, C. do R. V. Morgado, and M. P. Estellita Lins, "Organizations and stakeholders' roles and influence on implementing sustainability requirements in construction projects," *Heliyon*, vol. 10, no. 1, p. e23762, Jan. 2024, doi: 10.1016/j.heliyon.2023.e23762.

[8] B. K. Ababio, W. Lu, K. Agyekum, and F. A. Ghansah, "Enhancing circular construction through procurement: A conceptual stakeholder-centric collaborative framework for sustainable outcomes," *Environ Impact Assess Rev*, vol. 112, p. 107784, Mar. 2025, doi: 10.1016/j.eiar.2024.107784.

[9] M. A. Havaei and H. Malekitabar, “Spherical sustainability in construction and demolition: How aligned are policies, goals, regulations, markets, and stakeholder mindsets?,” *Cleaner Environmental Systems*, vol. 16, p. 100256, Mar. 2025, doi: 10.1016/j.cesys.2025.100256.

[10] M. T. Tran, “Fostering sustainable mindsets: A critical exploration of educational psychology in business education,” *The International Journal of Management Education*, vol. 22, no. 3, p. 101054, Nov. 2024, doi: 10.1016/j.ijme.2024.101054.

[11] Y. Pokholkov, M. Horvat, J. C. Quadrado, M. Chervach, and K. Zaitseva, “Approaches to assessing the level of Engineering Students’ Sustainable Development Mindset,” in *2020 IEEE Global Engineering Education Conference (EDUCON)*, IEEE, Apr. 2020, pp. 1102–1109. doi: 10.1109/EDUCON45650.2020.9125292.

[12] A. T. Hoang, “Sustainability Awareness in Vietnam’s Higher Education Sector,” 2017, pp. 149–184. doi: 10.1007/978-3-319-57070-9_7.

[13] T. O. Ayodele and O. T. Ogunbayo, “Perception of sustainable construction among Nigerian university students: a case study analysis,” *International Journal of Sustainability in Higher Education*, Feb. 2025, doi: 10.1108/IJSHE-05-2024-0307.

[14] UN. Secretary-General and World Commission on Environment and Development, “Report of the World Commission on Environment and Development : note / by the Secretary-General,” 1987. Accessed: May 13, 2025. [Online]. Available: https://digitallibrary.un.org/record/139811?ln=en&v=pdf

[15] United Nations, “Transforming Our World: The 2030 Agenda for Sustainable,” New York, 2015. Accessed: May 14, 2025. [Online]. Available: https://sdgs.un.org/2030agenda

[16] P. Glavič and R. Lukman, “Review of sustainability terms and their definitions,” *J Clean Prod*, vol. 15, no. 18, pp. 1875–1885, 2007, doi: 10.1016/j.jclepro.2006.12.006.

[17] M. Munasinghe, “Environmental Economics and Sustainable Development.”

[18] U. Berardi, “Sustainability assessment of urban communities through rating systems,” *Environ Dev Sustain*, vol. 15, no. 6, pp. 1573–1591, Dec. 2013, doi: 10.1007/s10668-013-9462-0.

[19] T. Häkkinen and K. Belloni, “Barriers and drivers for sustainable building,” *Building Research and Information*, vol. 39, no. 3, pp. 239–255, May 2011, doi: 10.1080/09613218.2011.561948.

[20] José Manuel Naredo, *La economía en evolución*, Siglo XXI Editores. 2004.

[21] H. E. Daly, *Ecological Economics and Sustainable Development, Selected Essays of Herman Daly*. Edward Elgar Publishing, 2007. doi: 10.4337/9781847206947.

[22] D. Olsson, N. Gericke, and S. N. Chang Rundgren, “The effect of implementation of education for sustainable development in Swedish compulsory schools – assessing pupils’ sustainability consciousness,” *Environ Educ Res*, vol. 22, no. 2, pp. 176–202, Feb. 2016, doi: 10.1080/13504622.2015.1005057.

[23] A. C. Michalos, H. Creech, N. Swayze, P. Maurine Kahlke, C. Buckler, and K. Rempel, “Measuring Knowledge, Attitudes and Behaviours Concerning Sustainable Development among Tenth Grade Students in Manitoba,” *Soc Indic Res*, vol. 106, no. 2, pp. 213–238, Apr. 2012, doi: 10.1007/s11205-011-9809-6.

[24] J.-C. Carteron and A. Decamps, “The Sustainability Literacy Test,” *One Year Report of the Sustainability Literacy Test*, 2014.

[25] L. Major, Ž. Namestovski, R. Horák, Á. Bagány, and V. P. Krekić, “Teach it to sustain it! Environmental attitudes of Hungarian teacher training students in Serbia,” *J Clean Prod*, vol. 154, pp. 255–268, Jun. 2017, doi: 10.1016/j.jclepro.2017.03.163.

[26] D. I. Stern, M. S. Common, and E. B. Barbier, “Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development,” *World Dev*, vol. 24, no. 7, pp. 1151–1160, Jul. 1996, doi: 10.1016/0305-750X(96)00032-0.

[27] S. Campbell *et al.*, “Purposive sampling: complex or simple? Research case examples,” *Journal of Research in Nursing*, vol. 25, no. 8, pp. 652–661, Dec. 2020, doi: 10.1177/1744987120927206.

[28] J. F. Hair, W. C. Black, B. J. Babin, R. E. Anderson, and R. L. Tatham, “Multivariate data analysis,” *Prentice hall Upper Saddle River*, vol. 5, 1998.

[29] T. J. Quirk, “One-Way Analysis of Variance (ANOVA),” in *Excel 2007 for Educational and Psychological Statistics*, New York, NY: Springer New York, 2012, pp. 163–179. doi: 10.1007/978-1-4614-3725-3_8.

[30] H. I. Assaad, Y. Hou, L. Zhou, R. J. Carroll, and G. Wu, “Rapid publication-ready MS-Word tables for two-way ANOVA,” *Springerplus*, vol. 4, no. 1, p. 33, Dec. 2015, doi: 10.1186/s40064-015-0795-z.

[31] M. C. Shingala and Arti Rajyaguru, "Comparison of post hoc tests for unequal variance," *International Journal of New Technologies in Science and Engineering 2*, no. 5, pp. 22–33, 2015.

[32] J. Nyerere, F. Kapfudzaruwa, O. Fadairo, A. Odingo, J. Manchisi, and S. Kudo, "Case Study: Higher Education and the Education for Sustainable Development in Africa (ESDA) Program," 2021, pp. 179–199. doi: 10.1007/978-3-030-74693-3_11.

[33] P. Vare and W. Scott, "Learning for a Change," *J Educ Sustain Dev*, vol. 1, no. 2, pp. 191–198, Sep. 2007, doi: 10.1177/097340820700100209.

[34] U. Fredriksson, K. N. Kusanagi, P. Gougoulakis, Y. Matsuda, and Y. Kitamura, "A Comparative Study of Curriculums for Education for Sustainable Development (ESD) in Sweden and Japan," *Sustainability*, vol. 12, no. 3, p. 1123, Feb. 2020, doi: 10.3390/su12031123.

[35] D. Tilbury, "Higher education for sustainability: A global overview of commitment and progress Higher Education's Commitment to Sustainability: From Understanding to Action PART 1: THE CONTEXT Higher Education for Sustainability: A Global Overview of Commitment and Progress," 2011. [Online]. Available: https://www.researchgate.net/publication/285755127

[36] M. Rieckmann, "Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?," *Futures*, vol. 44, no. 2, pp. 127–135, Mar. 2012, doi: 10.1016/j.futures.2011.09.005.

[37] J. Grund and A. Brock, "Education for Sustainable Development in Germany: Not Just Desired but Also Effective for Transformative Action," *Sustainability*, vol. 12, no. 7, p. 2838, Apr. 2020, doi: 10.3390/su12072838.

[38] F. Douglas, K. Beasy, K. Sollis, and E. J. Flies, "Online, Experiential Sustainability Education Can Improve Students' Self-Reported Environmental Attitudes, Behaviours and Wellbeing," *Sustainability*, vol. 16, no. 6, p. 2258, Mar. 2024, doi: 10.3390/su16062258.

[39] A. Bieler and M. McKenzie, "Strategic Planning for Sustainability in Canadian Higher Education," *Sustainability*, vol. 9, no. 2, p. 161, Jan. 2017, doi: 10.3390/su9020161.

[40] K. Banga Chhokar, "Higher education and curriculum innovation for sustainable development in India," *International Journal of Sustainability in Higher Education*, vol. 11, no. 2, pp. 141–152, Apr. 2010, doi: 10.1108/14676371011031865.

[41] V. Tramontin and C. Trois, "Implementing a holistic approach to foster higher education for sustainability," in *2016 World Congress on Sustainable Technologies (WCST)*, IEEE, Dec. 2016, pp. 12–13. doi: 10.1109/WCST.2016.7886580.

[42] U. Iyer-Raniga and M. M. Andamon, "Sustainability education in the engineering and built environment curriculum: The case for Asia-Pacific," in *CERI2012 Proceedings*, IATED, 2012, pp. 5190–5200.

[43] Ministry of Construction, "Approval of the 'Action Plan of the Construction Industry to Respond to Climate Change for the 2022 - 2030 Period, with a Vision to 2050 to Implement Vietnam's Commitments at COP26,'" 2022, *Hanoi*. Accessed: Jun. 13, 2025. [Online]. Available: https://luatvietnam.vn/tai-nguyen/quyet-dinh-385-qd-bxd-bo-xay-dung-221332-d1.html

[44] J. Falana, R. Osei-Kyei, and V. W. Tam, "Towards achieving a net zero carbon building: A review of key stakeholders and their roles in net zero carbon building whole life cycle," Apr. 01, 2024, *Elsevier Ltd*. doi: 10.1016/j.jobe.2023.108223.